AGENDA

Ordinary meeting of the

Nelson Regional Sewerage Business Unit

Friday 14 March 2014
Commencing at 8.30am
Ruma Marama
Civic House
Trafalgar Street, Nelson

Membership:

D Hiser (Independent)
Councillor R Copeland and Mr D Shaw (Nelson City Council)
Councillors B Dowler and M Higgins (Tasman District Council)

In attendance:

M Hippolite (Iwi Representative)
P Wilson (Industry Customers' Representative)

A1150489

Page No.

Apologies

1. Interests

1.1 Updates to the Interests Register

1.2 Identify any conflicts of interest in the agenda

2. Confirmation of Minutes – 31 January 2014 5-12

Document number A1139620

Recommendation

> ***THAT** the minutes of the meeting of the Nelson Regional Sewerage Business Unit, held on 31 January 2014, be confirmed as a true and correct record.*

3. Status Report – 14 March 2014 13-14

Document number A452094

Recommendation

> ***THAT** the Status Report – 14 March 2014 (A452094) be received.*

4. Checklist (Board Work Plan)

Meeting Date	Activity	Papers required	Status
14 March 2014 Board meeting	Review board planning/meeting schedule. Review and update of Interest Register.	Planning meeting schedule. Interest Register.	

Meeting Date	Activity	Papers required	Status
4 April 2014 Joint Shareholders Meeting	Present Business Plan and Annual Report to Joint Shareholders Committee.	2014/15 Business Plan. 2012/13 Annual Report.	Report and documentation forwarded to NCC admin team.
June 2014 Board meeting	Consider Business Continuity Plan. Review customer satisfaction survey results. Annual Review of Strategic Plan	Draft Business Continuity Plan. Customer satisfaction report. NRSBU strategic plan.	

5. Staff Report – 14 March 2014 15-20

Document number A1145728

Recommendation

> ***<u>THAT</u> the Staff Report – 14 March 2014 (A1145728) be received.***

6. Financial Report 21-22

Document number A1111020

Recommendation

> ***<u>THAT</u> the Nelson Regional Sewerage Business Unit Financial Statement for the Period Ended 31 January 2014 (A1111020) be received.***

7. Cawthron Institute Report – Coastal Effects of the Bell Island Regional Sewerage Discharge: July 2013 Mussel Monitoring Survey 23-40

Document number A683969

Recommendation

> ***<u>THAT</u> the Cawthron Institute Report – Coastal Effects of the Bell Island Regional Sewerage Discharge: July 2013 Mussel Monitoring Survey (A683969) be received.***

8. Scion Research Report – 2013 Annual Report on the Biosolids Research Trial at Rabbit Island **41-69**

Document number A1150622

Recommendation

> ***<u>THAT</u> the Scion Research Report – 2013 Annual Report on the Biosolids Research Trial at Rabbit Island (A1150622) be received.***

Nelson City Council
te kaunihera o whakatū

Minutes of a meeting of the Nelson Regional Sewerage Business Unit

Held in the Council Chamber, Civic House, Trafalgar Street, Nelson

On Friday 31 January 2014, commencing at 1.05pm

Present:	D Hiser (Independent), Mr D Shaw (Nelson City Council), Councillors B Dowler and M Higgins (Tasman District Council)
In Attendance:	M Hippolite (Iwi Representative), P Wilson (Industry Customers' Representative, Group Manager Infrastructure (A Louverdis), Senior Asset Engineer – Solid Waste (J Thiart), Management Accountant (A Bishop), and Administration Adviser (L Canton)
Apology:	Councillor R Copeland

1. Interests

Matt Hippolite declared an interest, noting that he was a member of the Waimea Water Augmentation Committee.

Michael Higgins declared an interest, noting that he was a Rough Island Equestrian Park board member.

There were no conflicts declared with items on the agenda.

2. Election of Chairperson

The Administration Adviser called for nominations for the role of Chairperson of the Nelson Regional Sewerage Business Unit (NRSBU). Michael Higgins nominated Donna Hiser.

Resolved

***THAT** Donna Hiser be elected Chairperson of the Nelson Regional Sewerage Business Unit for the 2013-2016 triennium.*

Higgins/Hippolite — Carried

Attendance: Philip Wilson joined the meeting at 1.10pm.

3. Status Report

Document number A452094, agenda page 5 refer.

In response to a question, Mr Thiart advised that the deferment referred to in item three (Bell Island Energy Audit) was to allow the joint committee to decide how it wanted to use the building.

Resolved

<u>THAT</u> the Status Report (A452094) be received.

<u>Hiser/Shaw</u> <u>Carried</u>

4. Staff Report – 31 January 2014

Document number A681693, agenda pages 6-43 refer.

Mr Thiart presented the report.

In response to a question about the term of the biosolids spraying contract to be procured, Mr Thiart advised that it was likely to be awarded on the basis of 3+2+2 years. He explained that the two additional 2-year periods were at NRSBUs discretion, and the Resource Consent for the activity matched the initial term of 3 years.

In response to a question whether the phenomena that affect the BOD testing in the discharge sampling could not be found in the contributor sampling, Mr Thiart responded that the phenomena is linked to the extended aeration in the activated sludge area at Bell Island following the commissioning of the primary clarifier.

In response to a question about the upcoming changes to the accounting standards for public benefit entities, Management Accountant, Andrew Bishop confirmed that this would be managed by the two Councils as owners.

It was noted in regard to the peer review of the valuation that all the indexes used over time for valuations must be tracked with care.

In response to a question about the incident involving the mis-programming of the tide levels, Mr Thiart advised that this was still being investigated and he would ensure a process would be established to mitigate against such occurrence in the future.

Resolved

<u>THAT</u> the Staff Report – 31 January 2014 (A681693) be received.

<u>Dowler/Higgins</u> <u>Carried</u>

Attendance: Alec Louverdis joined the meeting.

4.1 Operations and Maintenance Contract

Mr Thiart tabled a document outlining a schedule of contract deliverables for the Operation and Maintenance Contract of the Nelson Regional Sewerage System comparing original dates for some deliverables and the extended times which had been negotiated.(A1139980).

Mr Thiart explained that there had been some issues during the transition to the new operations and maintenance contractor, but that Nelson City Council officers and the contractor had worked together to agree extended delivery timeframes that would be realistic and achievable.

Mr Louverdis added that he was comfortable that the difficulties experienced during the handover were offset by the strong relationships between all parties and he was confident the contractor would meet the newly agreed deliverables schedule.

It was confirmed that there would be no financial losses to the NRSBU as a result of these initial issues.

Resolved

> ***THAT* Nelmac be invited to report on progress at the next Board meeting.**

Shaw/Hiser — Carried

4.2 Benchmarking

Resolved

> ***THAT* a further, more comprehensive benchmark report be submitted to the Board in December 2014.**

Shaw/Hiser — Carried

4.3 Bell Island Restoration Group

It was agreed that Donna Hiser and Matt Hippolite would visit the Bell Island Restoration Group on site to view the group's progress to date and to offer their thanks for the group's efforts.

Resolved

> ***THAT* the Nelson Regional Sewerage Business Unit note that the Restoration Group has achieved the goals set for the first three years;**

<u>AND THAT</u> the budget of $6,270 be approved for the continued maintenance of the restoration area for the 2014/15 financial year;

<u>AND THAT</u> the Nelson Regional Sewerage Business Unit thank the Bell Island Restoration Group for the continued work in restoring the area.

Shaw/Dowler — Carried

4.4 Audit Management Report

Resolved

<u>THAT</u> the report be received;

<u>THAT</u> a report on the implications of the changes to the accounting standards for public benefit entities be prepared for the consideration of the Board.

Hiser/Higgins — Carried

4.5 Valuation

Resolved

<u>THAT</u> the Nelson Regional Sewerage Business Unit note that the peer review of the valuation for the period ending 30 June 2013 concluded that the valuation complies with the required standards.

Shaw/Dowler — Carried

5. Chairperson's Report

The Chairperson tabled a letter she had written to the Chief Executives of Nelson City and Tasman District Council regarding issues related to the proposed review of the governance structure of the Nelson Regional Business Unit and the need to update the Memorandum of Understanding (A1127019). She noted that it was important for the Board to have these issues resolved and anticipated that there would be further discussions.

6. Nelson Regional Sewerage Business Unit Treasury Policy 2014

Document number A1131509, agenda pages 69-76 refer.

Tasman District Council Corporate Treasury Manager, Mike Drummond, joined the meeting and explained the draft NRSBU Treasury Policy.

He said that the policy allowed a more efficient management of the treasury function between the two Councils, and provided an 'arms length' loan facility for the NRSBU that would enable it to access the same terms offered to the Councils.

Mr Bishop advised that the facility would always have three years to run, and both Councils would need to provide three years' notice if they wished to halt the facility.

Resolved

> ***THAT** the report Nelson Regional Sewerage Business Unit Treasury Policy (A1131509) and its attachment (A1131501) be received;*
>
> ***AND THAT** the NRSBU note that there is expected to be no material change to the charges as a result of the Treasury Policy;*
>
> ***AND THAT** the Draft Nelson Regional Sewerage Business Unit Treasury Policy 2014 be approved for submission to the Nelson City Council and Tasman District Council for approval;*
>
> ***AND THAT** the NRSBU approves the transfer of the responsibility for the Treasury function from Tasman District Council to Nelson City Council.*

Dowler/Shaw — Carried

Recommendation to Nelson City and Tasman District Councils

> ***THAT** the Draft Nelson Regional Sewerage Business Unit Treasury Policy 2014 be approved.*

Higgins/Shaw — Carried

7. Nelson Regional Sewerage Business Unit Business Plan 2014/15

Document number A1103900, agenda pages 44-64 refer.

7.1 Section 2. Background

It was noted that the structure diagram must be updated once the Councils have approved the treasury policy to show Nelson City Council as having the Treasury function.

7.2 Section 5. Business Objectives

The meeting discussed the timing for the development of a demand management policy. It was agreed that the date for the demand management policy and the load management policies should be moved to the end of July 2015.

In response to a question, Mr Bishop advised that the $7.6m income was derived approximately 40% from Nelson City Council, 30% from Tasman District Council, and 30% from the three non-Council industry contributors.

It was noted that there appeared to be a disconnect between the items shown in the 2013/14 and 2014/15 Business Improvement Plans. It was confirmed that Mr Thiart would prepare a schedule to show the 2013/14 and 2014/15 Business Improvement Plan items and circulate this to Board members following the meeting.

7.3 Section 7. Financial Plan

The joint committee discussed the return on investment for the NRSBU and the need to ensure charges represented fair value to contributors and to ratepayers.

In response to a question, Mr Bishop advised that the $7.6m income was derived approximately 40% from Nelson City Council, 30% from Tasman District Council and 30% from the three non-Council industry contributors.

It was agreed that any proposal to change charging levels would be best considered by the two Councils and recorded in an updated Memorandum of Understanding, as it was a political rather than a management decision. It was also noted that this would provide guidance for the review of the Trade Waste Agreement.

In response to a further question, Mr Bishop said that the figures for year one were inflation adjusted, but those for years 2 and 3 were not.

Resolved

> ***<u>THAT</u> the Nelson Regional Sewerage Business Unit Business Plan 2014/15 be adopted, subject to approval by Nelson City and Tasman District Councils and subject to minor editorial changes.***

<u>Higgins/Shaw</u> <u>Carried</u>

Attendance: The meeting adjourned for afternoon tea from 3.35pm to 3.42pm.

Recommendation to Nelson City and Tasman District Councils

> ***THAT* the Nelson Regional Sewerage Business Unit Business Plan 2014/15 be approved.**

Shaw/Higgins — Carried

8. Financial Report

Document number A1111020, agenda pages 65-66 refer.

Mr Bishop presented the report, noting that net income was slightly above budget due to a timing difference. He said that the end of year figures would result in a payment to customers.

It was noted that 'Management' was $42,000 over budget due to additional work on the renewal of the operations and maintenance contract, and a change in the two Councils' overhead allocation model. Mr Bishop said he would ensure that this had been allowed for in the 2014/15 budget.

Resolved

> ***THAT* the Nelson Regional Sewerage Business Unit Financial Statement for the Period Ended 31 December 2013 (A1111020) be received.**

Dowler/Shaw — Carried

9. Approval of Interest Rate Swaps

Document number A1129294, agenda pages 67-68 refer.

Resolved

> ***THAT* the report Approval of Interest Rate Swaps A1129294 be received;**
>
> ***AND THAT* the sixteen million dollars interest rate swaps entered into on 16th May 2012 by Nelson City Council and Tasman District Council on behalf of the Nelson Regional Sewerage Business unit is approved.**

Higgins/Shaw — Carried

10. Schedule of Meetings

The following schedule of meetings was agreed:

14 March at 8.30am (moved from 1.00pm)

20 June at 1.00pm

29 August at 1.00pm

28 November at 1.00pm (moved from 5 December)

There being no further business the meeting ended at 4.02pm.

Confirmed as a correct record of proceedings:

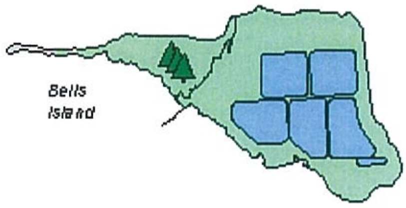
____________________________________ Chairperson ______________________ Date

NRSBU STATUS REPORT - 14 March 2014

No	Meeting Date	Document Number	Report Date	Report Title / Item Title	Officer	Resolution or Action	Status
A	31/01/14	A452094	31/01/2014	Staff report	J Thiart	Biosolids tender	
B	31/01/14	A452094	31/01/2014	Staff report	J Thiart	Arrange to meet Bell Island Restoration group on site	Restoration group confirmed that the will forward suiable dates
C	5/07/13	1552561		Minutes of meeting	J Thiart	TDC Parks and Reserves Review/Rabbit Island Management Plan. Rough Island to be considered as potential Biosolids spraying area.	
D	5/07/13	1552561		Minutes of meeting	J Thiart	Cost/Benefit of sludge disposal compared to disposal to landfill	
E	5/07/13	1552561		Minutes of meeting	J Thiart	Increase of CBOD in discharge compared to 2009	In staff report
F	5/07/13	1540469		Customer Survey 2012/13	J Thiart	Meetings with contributors between quarterly meetings	
G	5/07/13	1476829		Staff Report	J Thiart	Risk assessment if contributor exits the contributor agreement	
H	22/06/12		22/06/12	Minutes	J Thiart	Energy audit at pump stations	Programmed for 2015
I	14/12/12			Bell Island power supply	J Thiart	Improvement of power supply by Network Tasman	Network Tasman activity
J	15/03/13				J Thiart	Sludge survey 2013/14. Facultative ponds.	Next survey will be carried out in April/May 2014
1	31/01/14	A681693	31/01/14	Staff Report	J Thiart	That Nelmac be invited to report on progress at the next meeting. THAT a further benchmark report be submitted to the Board in December 2014. Bell Island restoration group: And THAT the budget of $6,720 be approved for the continued maintenance of the restoration area for the 2014/15 financial year. AND THAT the Nelson Regional Sewerage Business Unit thank the Bell Island Restoration Group for the continued work in restoring the area. AND THAT the NRSBU continue supporting the tree trials and that the monitoring continues until the trees are harvested. THAT a report on the implications of the changes to the accounting standards for public benefit entities be prepared for the consideration of the Board	The Engineer to the contract does not consider it appropriate to invite Nelmac to meet with the Board. Done. Restoration group keen to show Board members around the site. They will advise suitable dates
2	23/08/13	1582359	23/08/13	Nelson Regional Sewerage Business Unit Resopurce Consent Monitoring: Discharge Permit	J Thiart	AND THAT the increase in suspended solids and biological oxygen demand be investigated as part of the operation and maintenance contract and a further report be submitted to the Board regarding this matter in March 2014.	
3	15/03/13	682846V29	15/03/13	Major Projects Report	J Thiart	AND THAT the review of the management processes at the plant be deferred until the new Operations and Management contract has been in place for sufficient time for the new contractor to become thoroughly familiar with the plant;	
4	22/06/12	1307226	22/06/12	Bell Island Energy Audit	J Thiart	AND THAT the removal of the time of use meter at the dewatering building will be considered once the deferment of the thickening upgrade is confirmed; AND THAT the optimisation of O_2 levels in the aeration basin will be considered as part of the waste water treatment capacity review;	Deferred until we know have clarity on bringing belt thickener on line to divert secondary sludge from DAF.

						AND THAT the cost of changing the point of supply for the ponds and irrigation pump station will be investigated in order to establish the return on capital investment.	
5	9/03/12	1042662	9/03/12	Staff report	J Thiart	AND THAT the NRSBU continue supporting the tree trials and that the monitoring continues until the trees are harvested.	Ongoing
6	16/09/11	11497595	16/09/11	NRSBU BIWWTP Capacity and commissioning report	J Thiart	AND THAT an independent review be undertaken of the charging mechanism and user contracts once the capacity review in 2012/13 is complete;	Capacity review to follow the development of the Treatment Plant Model as part of O&M contract. Model expected to be completed by June 2014.
7	15/02/11	1042982	3/02/11	Bell Island Spit Restoration	J Thiart	AND THAT the project committee submit a progress report to the NRSBU on a Quarterly basis;	Next report due 30 June 2014

Nelson Regional Sewerage Business Unit



Staff Report
14 March 2014

1. Action Items

Matters arising

1.1 The Nelson Regional Sewerage Business Unit 2014/15 Business Plan was not released to Nelson City Council and Tasman District Council to allow further consideration of the distribution of surplusses. The Nelson City Council legal adviser reviewed the matter and it was determined by Nelson City Council that the distribution of surplusses as set out in the 2014/15 Business Plan is in accordance with NRSBU resolutions and compliant with the Disposal of Trade Waste Agreement. (Note that the advice was provided to Nelson City Council and the Nelson City Council legal adviser made it clear that he is not in a position to provide legal advice to the NRSBU as he sees a conflict of interest)

1.2 The Senior Asset Engineer – Solid Waste met with officers of the consenting authority on 26 February 2014 to discuss the six yearly Biosolids Discharge Permit Report and the Effluent Discharge Permit Assessment Report. A verbal report will be presented to the Board at the meeting.

1.3 The Nelson City Council Group Manager Infrastructure, who acts as the Engineer-to-the Contract for the Operation and Maintenance Contract, does not believe it is appropriate for the NRSBU Board to meet with Nelmac. Nelmac was therefore not invited to the Board as per the Board resolution taken at the Board meeting on 31 January 2014.

2. Health and Safety

2.1 There have been 11 Health and Safety inductions and 139 visitors to the Bell Island site over the past three months.

2.2 No further Health and Safety incidents are outstanding.

3. Operations and Maintenance Contract

3.1 The Engineer-to-the Contract is satisfied that Nelmac is performing as required under the contract.

4. Biosolids Contract

4.1 There is adequate capacity within the Rabbit and Bell Island pine plantations to receive biosolids.

4.2 The workability of biosolids for application is generally well within the contracted limit. The workability issues experienced in December is still being investigated by the Nelmac team.

4.3 It is projected that 27,500m^3 of biosolids will be applied during the year. (Long-term average biosolids applied = 25,000m^3)

4.4 The existing biosolids spraying contract is coming to term on 30 June 2014. The Nelson City Council projects team expect to tender the biosolids spraying contract before the end of March 2014.

5. Level of Service

5.1 Level of Service performance for the previous <u>three months</u> is as follows:

Environmental: Treatment and Disposal			
RMA consent - wastewater Discharge to Coastal Marine Area	RMA Consent - Discharge of Contaminants to Air (Odour complaints)	RMA Consent - Discharge of Contaminants to Land	Equipment failure of critical components within treatment and disposal system
1			
Environmental: Pump Stations			
Odour complaints from pump stations	Pump station wet weather overflows	Pump station overflows resulting from power failure	Pump station overflows resulting from mechanical failure

Environmental: Pipeline	
Reticulation breaks	Air valve malfunction
Capacity: Overloading system capacity	
Treatment & Disposal	Pump Stations

Reliability: Equipment failure of critical components		
Treatment & Disposal	Pump Stations	Pipelines
Responsiveness: Speed of response for emergency and urgent maintenance works		
Treatment & Disposal	Pump Stations	Pipelines
Responsiveness: Speed of response for routine and programmable maintenance works		
Treatment & Disposal	Pump Stations	Pipelines
Key customer relationships: Overall satisfaction		
Treatment & Disposal	Pump Stations	Pipelines

Note 1: A discharge occurred at low tide on 20 January 2014. Investigations into the incident could not confirm any control issues. Discharge procedures were reviewed and a sign-off procedure implemented by Nelmac to manage this activity.

5.2 Level of Service performance for the previous 12 months is as follows:

i)	**Resource Consent Compliance (rolling 12 month record)**	
	➢ Discharge to Estuary Permit	Not achieved. A discharge occurred on 20 January 2014 that was outside consented discharge times.
	➢ Discharge to Air Permit	100% Compliance
	➢ Biosolids Disposal	100% Compliance
	➢ Discharge treated waste water to land	100% Compliance
ii)	**Odour Notifications**	
	➢ Past three months	Nil.
	➢ Last 12 months	Nil.
iii)	**Overflows**	
	➢ Past three months	Nil
	➢ Last 12 months	Three overflows. All overflows were associated with the heavy rainfall event on 21 April 3013. Performance of the pump stations following the completion of the pipeline upgrade suggest that all three overflow events would not have occurred had the pump station worked as designed. These pump stations are now operating as designed.
iv)	**Speed of response for maintenance works**	
	Six call-outs were recorded over the past three months	
	➢ Response within 30 minute response requirement. Achieved.	

5.3 The Total Biological Oxygen Demand (TBOD) levels in effluent discharged from Bell Island have returned to levels recorded prior to the commissioning of the primary clarifier.

6. 2012 Action Plan Implementation

6.1 The following table indicates the draft time lines for the individual action items.

AP	Action	Target Date	Completion Date	Comments
Levels of Service				
1.1	Annual customer survey.	March 2014		
Demand Management				
2.1	Extending/renewing the Memorandum of Understanding that expires in 2010.	2014/15		Await action by shareholders (Nelson City Council and Tasman District Council)
2.2	Review Improvement Plan, consider and if appropriate prioritise and move to action.		Ongoing	Continuing.
2.3	Flow and load analyses.	July 2013	25 July 2013	Completed. Included in Annual Report.
Risk Management				
3.1	Carry out a risk assessment at component level and maintain risk schedules.	December 2013		Operational risk review completed in September 2013. This will be reviewed as part of the Operation and Maintenance contract by May 2014
3.2	Annual calibration.	June 2014		
3.3	Emergency spillage contingency plans and alarms procedures reviewed.	March 2014		
Financial				
4.1	Valuation.	August 2013	September 2013	Internal valuation completed.
4.2	Business Continuity Plan updated.	June 2014		
4.3	Internal review of customer charging model.	June 2014		

AP	Action	Target Date	Completion Date	Comments
Asset Management				
5.1	Review Asset Management Plan.	June 2014		
5.2	Renewal programme review.	October 2013	October 2013	
5.3	Treatment Plant Capacity Review.	June 2014		Included in operation and maintenance contract procurement process.
5.5	Review flow meter and sampling.	30 August 2013	September 2013	
5.6	Benchmarking.	December 2013	January 2014	
General				
6.1	Board Workshop.	August 2013	9 August 2013	

7. Financial

Operations and Maintenance

7.1 The operation and maintenance costs are projected to be significantly lower than budget.

7.2 The cost of power used is lower than budget and result mainly from lower power consumption at pump stations and the fact that A-train was not operated for an extended period to allow programmed maintenance and remedial work.

8. General

8.1 A request was received from the Rabbit Island Forest Manager, Peter Wilks, for a contribution from the Board towards his costs to attend a biosolids conference in April. Peter will present a paper on the application of biosolids at Rabbit Island. The forest manager is part of the team that manage the application of biosolids at Rabbit Island. It is considered that his presentation at the conference will increase the awareness of the sustainable practices employed by the NRSBU, and by extension TDC and NCC, in disposing of what is generally considered a waste product. The total cost to attend the conference is estimated at $3,160.

For consideration.

J K Thiart
Senior Asset Engineer - Solid Waste

Nelson Regional Sewerage Business Unit

Financial Report

Income Account for the period to 31st January 2014

	Actual Month	Budget Month	Actual YTD	% YTD	% Year	2013/14 Budget YTD	2013/14 Budget Annual	YTD Variation
Income								
Contributions Fixed	359,559	389,200	2,516,914	92	54	2,724,200	4,670,000	207,286
Contributions Variable	267,691	295,200	2,024,002	98	57	2,066,200	3,542,000	42,198
Other Recoveries	17,040	14,700	107,846	104	61	103,300	177,000	(4,546)
Interest	26	80	130	22	13	600	1,000	470
Forestry Income	-	830	-			5,800	10,000	
Revaluation Derivative Instruments	-		-					
Total Income	**644,316**	**700,010**	**4,648,892**	95	55	**4,900,100**	**8,400,000**	**245,408**
Less Expenses								
Management	820	13,500	124,280	132	77	94,500	162,000	(29,780)
Electricity	64,240	62,850	400,177	91	53	439,800	754,000	39,623
Contract Maintenance	53,612	125,000	546,703	63	36	874,600	1,499,300	327,897
General Maintenance	41,705	11,000	310,859	398	232	78,200	134,000	(232,659)
Project Maintenance	-	11,350	0	0	0	79,200	135,700	79,200
Monitoring	10,000	14,000	71,912	74	43	97,400	167,000	25,488
Consultancy	-	6,300	12,053	28	16	43,800	75,000	31,747
Insurance	4,943	5,000	34,602	99	58	35,000	60,000	398
Sundry	2,635	5,950	46,193	110	64	42,000	72,000	(4,193)
Biosolids Disposal	41,746	43,250	297,407	98	57	303,300	520,000	5,893
Operating & Maintenance Expenses	**219,703**	**298,200**	**1,844,184**	**88**	**52**	**2,087,800**	**3,579,000**	**243,616**
Financial	71,964	75,650	483,017	91	53	529,700	908,000	46,683
Depreciation	145,778	167,000	1,020,448	87	51	1,169,000	2,004,000	148,552
Total Expenses	**437,445**	**540,850**	**3,347,649**	88	52	**3,786,500**	**6,491,000**	**438,851**
Net Income before Rebate	**206,872**	**159,160**	**1,301,243**	117	68	**1,113,600**	**1,909,000**	**(193,443)**
Owners rebate	**0**		**0**					
Net Income after rebate	**206,872**	**159,160**	**1,301,243**			**1,113,600**	**1,909,000**	**(193,443)**
Capital Expenditure								
Renewals	200,926	48,800	200,926			341,250	585,000	
New Capital Expenditure	12	-	777,828			-	-	
Total Capital Expenditure	**200,938**	**48,800**	**978,754**			**341,250**	**585,000**	

Nelson Regional Sewerage Business Unit

Balance Sheet as at 31st January 2014

	Current	Last Month	June 2013
Equity			
Opening Equity (July)	36,229,451	36,229,451	35,587,766
Plus Net Income YTD	1,301,243	1,094,371	317,653
Plus Revaluation	0	0	324,032
Closing Equity	37,530,694	37,323,823	36,229,451
Contingency Reserve	100,000	100,000	100,000
	37,630,694	**37,423,823**	**36,329,451**
Which was Invested as follows -			
Current Assets			
Bank	161,735	91,656	52,516
Debtors	37,837	42,844	185,914
NCC Current account	200,583	268,539	0
Total Current Assets	**400,154**	**403,039**	**238,431**
Fixed Assets	**54,751,774**	**54,696,614**	**54,793,469**
Current Liabilities			
Creditors	(181,086)	(135,683)	(123,873)
TDC Current Account	0	0	(613,214)
NCC Current account	0	0	(1,825,214)
Total Current Liabilities	**(181,086)**	**(135,683)**	**(2,562,301)**
Term Liabilities	**(17,600,000)**	**(17,800,000)**	**(16,400,000)**
Derivative Financial Instruments	**259,852**	**259,852**	**259,852**
	37,630,694	**37,423,823**	**36,329,451**

NRSBU Ledger and Financial Report 2013 14 (A1111020).xls

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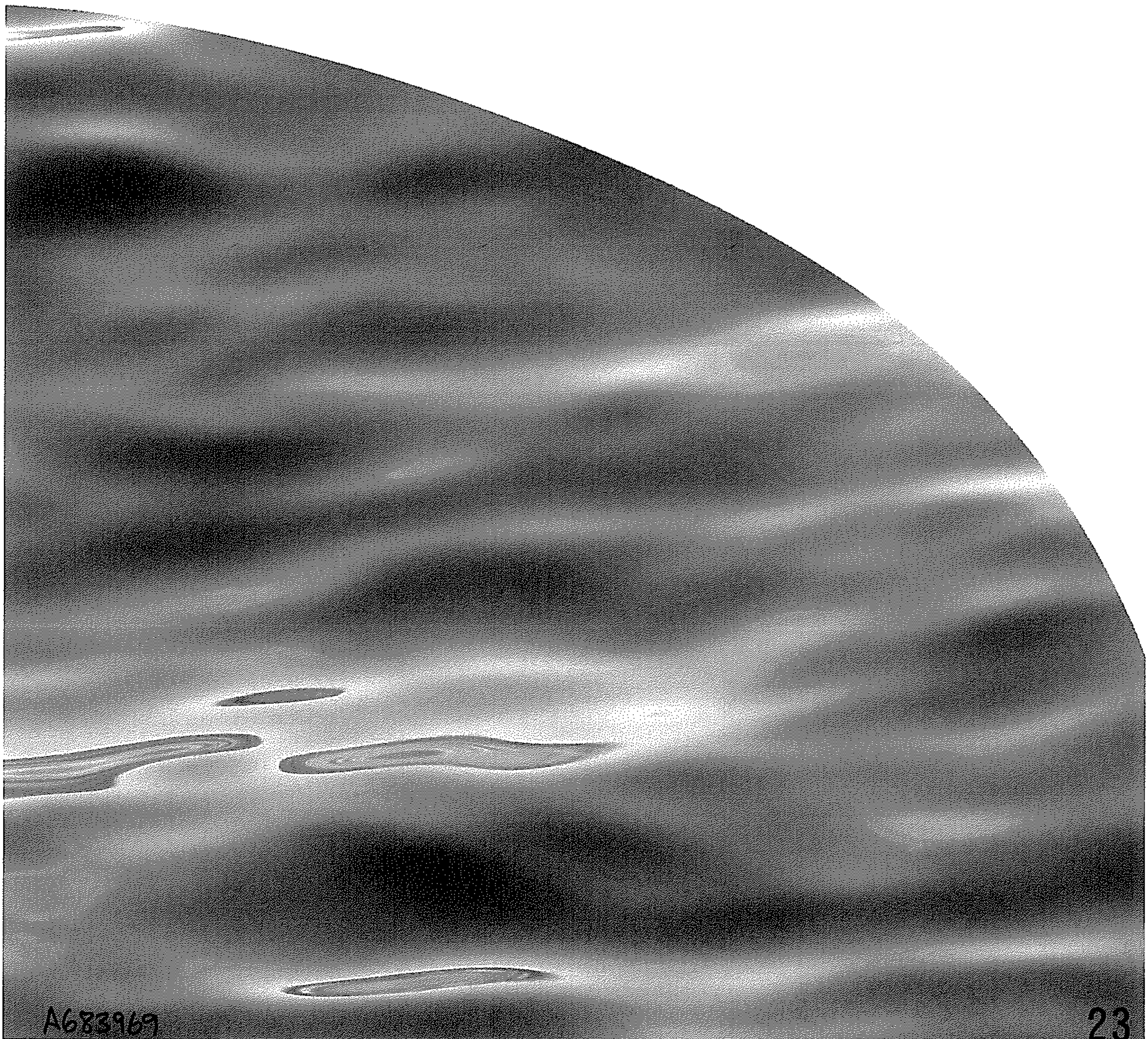
REPORT NO. 2404

COASTAL EFFECTS OF THE BELL ISLAND REGIONAL SEWERAGE DISCHARGE: JULY 2013 MUSSEL MONITORING SURVEY



A683969

COASTAL EFFECTS OF THE BELL ISLAND REGIONAL SEWERAGE DISCHARGE: JULY 2013 MUSSEL MONITORING SURVEY

PAUL GILLESPIE, REID FORREST

Prepared for Nelson Regional Sewerage Business Unit.

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Chris Cornelisen

APPROVED FOR RELEASE BY:
Rowan Strickland

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1. BACKGROUND

Cawthron Institute (Cawthron) has been commissioned by the Nelson Regional Sewerage Business Unit (NRSBU) to undertake twice yearly (summer and winter) shellfish monitoring surveys to identify any potential bacteriological water quality issues at inner Tasman Bay sites in the vicinity of the Bell Island regional sewerage outfall. The surveys, first implemented in April 2008, are carried out in accordance with conditions of consent for Coastal Permit NN925584 (Annex 2, Part B, revised July 2007). The present report describes the results of the July 2013 survey.

2. METHODS

2.1. Mussel deployment and analyses

Farmed green-lipped mussels (*Perna canaliculus*) were sourced from Aquaculture Management Area 3B, ~7 km offshore in Tasman Bay on 16 July 2013. The mussels were sub-sampled for analysis of faecal indicator bacteria (FIB; enterococci, faecal coliforms, and *E. coli*) concentrations in the mussel flesh, and the remaining mussels were distributed into plastic, open-mesh baskets for experimental deployment at approximately 11:00 on the same day.

The baskets were suspended from a surface float at approximately midwater depths above an anchor point at Sites 18, 19, 21 and 22 (Figure 1). The mussels were retrieved on 19 July 2013 (~ 09:00) after a 3-day deployment period with no significant rainfall in the Waimea River catchment. Water depths at the time of deployment were approximately 3.5 m, 6.8 m, 6.0 m and 7.3 m at Sites 18, 19, 21 and 22, respectively. Depths were approximately 0.5 m deeper at retrieval due to the different tidal state. Predicted tide heights are shown in Appendix 1.

Pre- and post-deployment mussel samples were put into plastic bags, chilled and returned to the laboratory for analyses of FIB concentrations. Analyses were carried out within 24 hours of collection according to procedures defined in Appendix 2.

2.2. Seawater sampling and analyses

During retrieval of mussels, seawater samples were hand collected near the surface at each site, sub-sampled and distributed into sterile containers for FIB analyses. Samples were stored on ice, refrigerated and analysed for FIB concentrations within 24 hours of collection. Two additional post-deployment sub-samples (one preserved with Lugol's iodine and one unpreserved) were collected for determination of phytoplankton species and abundance. Analytical procedures are provided in Appendix 2.

Vertical water column profiles of salinity, temperature, light, turbidity, chlorophyll-*a* and dissolved oxygen concentration were measured *in situ* at each site on pre- and post-deployment sampling occasions using a Seabird Electronics (Seacat SBE-19 Plus) profiler.

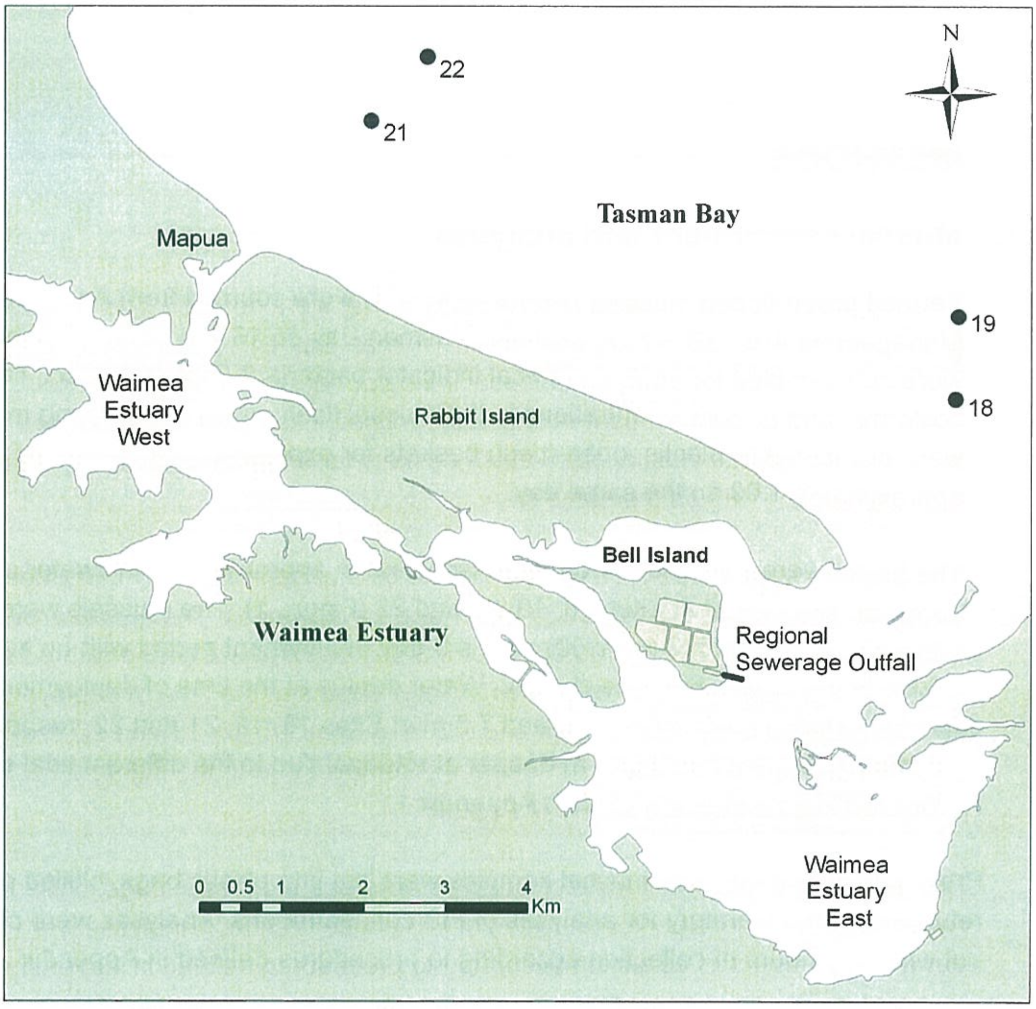

Figure 1. Inner Tasman Bay mussel monitoring sites.

3. RESULTS

3.1. Faecal indicator bacteria

Table 1. Pre-deployment faecal indicator bacteria concentrations in mussel flesh (16 July 2013).

Test	MPN/100 g
Faecal coliforms	< 20
E. coli	< 20
Presumptive enterococci*	20

* Confirmed enterococci can be considered to be ≤ presumptive enterococci.

Table 2. Post-deployment faecal indicator bacteria concentrations in mussel flesh (19 July 2013).

	MPN/100 g			
	Site 18	Site 19	Site 21	Site 22
Faecal coliforms	20	< 20	20	< 20
E. coli	20	< 20	20	< 20
Presumptive enterococci*	140	< 20	< 20	< 20

* Confirmed enterococci can be considered to be ≤ presumptive enterococci.

Table 3. Post-deployment faecal indicator bacteria concentrations in seawater (19 July 2013).

	(cfu/100 ml)			
Test	Site 18	Site 19	Site 21	Site 22
Enterococci	< 5	< 5	< 5	< 5
Faecal coliforms	15	< 5	< 5	< 5
E. coli	15	< 5	< 5	< 5

3.2. Phytoplankton

Results of post-deployment phytoplankton analyses are provided in Appendix 2.

3.3. Water column characteristics

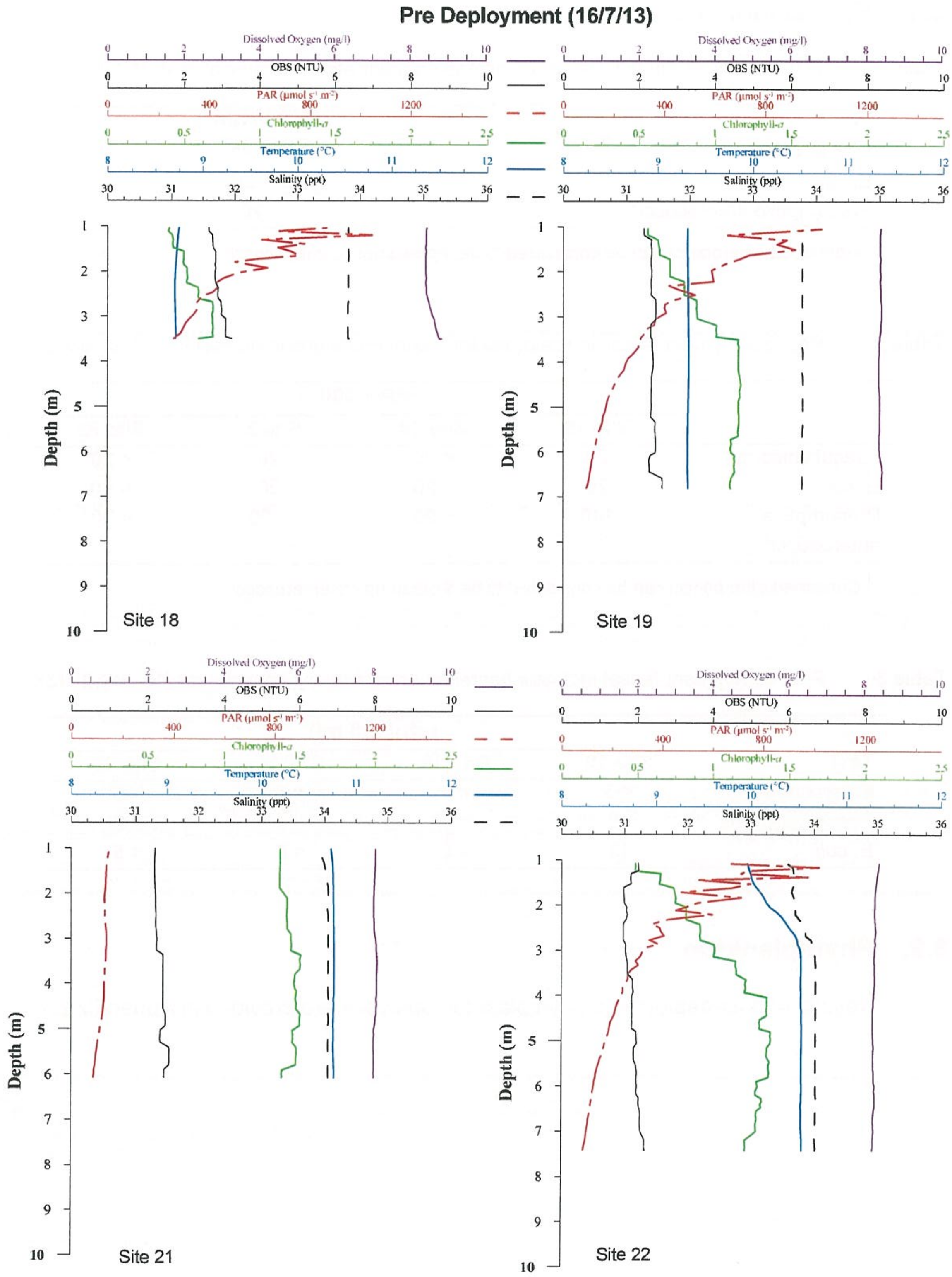

Figure 2. Pre-deployment water column profiling results (16 July 2013).

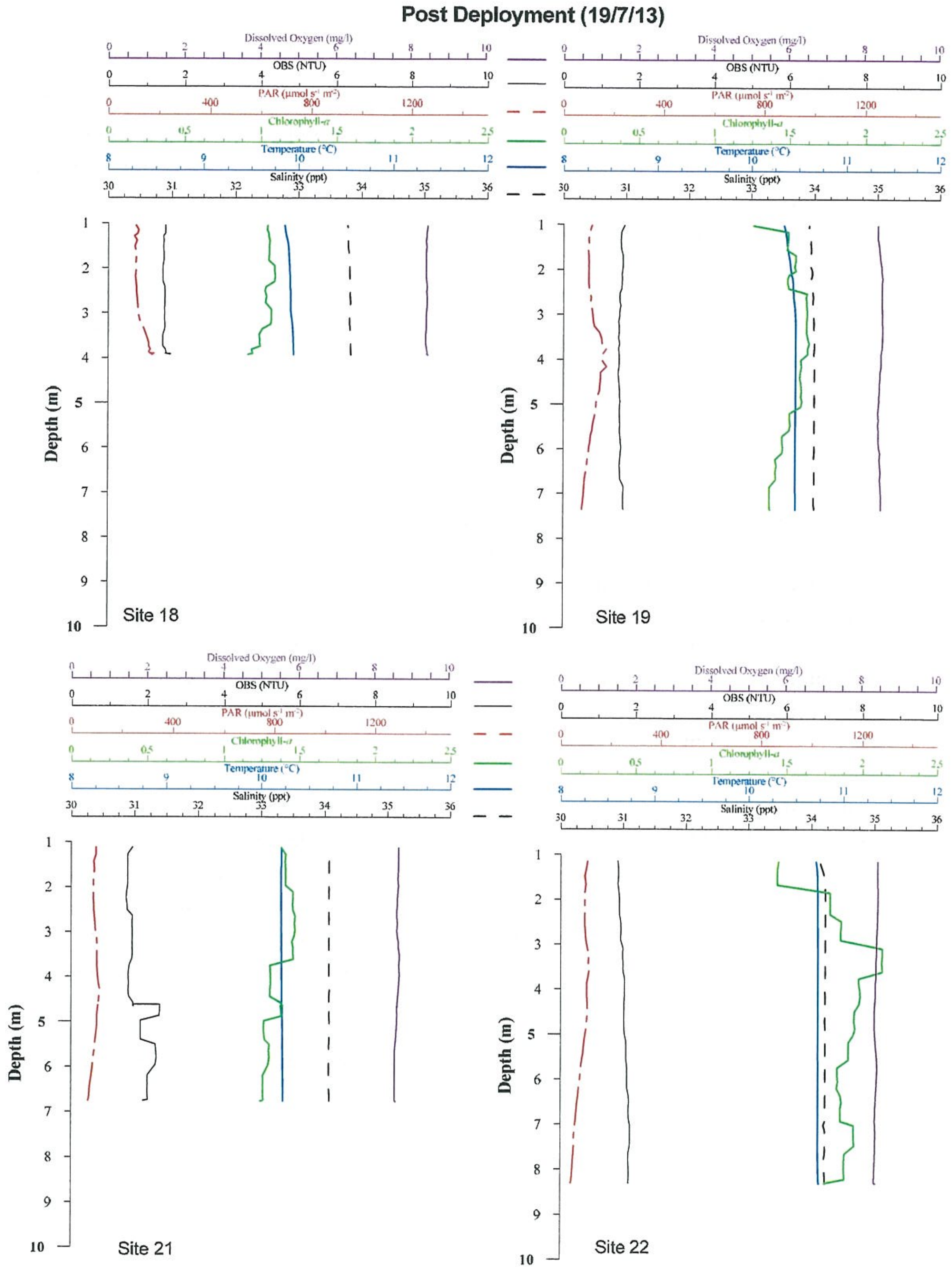

Figure 3. Post-deployment water column profiling results (19 July 2013).

4. BRIEF COMMENT

Faecal coliform and *E. coli* concentrations in the pre-deployment mussel flesh composite (Table 1) were below analytical detection limits (*i.e.* < 20 MPN/100 g). This most likely reflects the relatively low (< 40 m^3/s) and stable flow of the Motueka River during the survey period. In the post-deployment mussel flesh samples from Sites 18 and 21, faecal coliform and *E. coli* concentrations (Table 2) were low but detectable whereas those for Sites 19 and 22 were below detection limit. Slightly elevated concentrations of 'presumptive' enterococci were recorded at Site 18.

Post-deployment seawater faecal coliform and *E. coli* concentrations (Table 3) at Site 18 nearest the Bell Island wastewater discharge channel were slightly elevated (15 cfu/100 ml) however enterococci concentrations at the same site were below the detection limit of 5 cfu/100 ml. FIB concentrations at Sites 19, 21 and 22 were all below detection limits of 5 cfu/100 ml. Flow records for the Waimea River were moderate; *i.e.* declining from ~11 m^3/s on 16 July to ~9 m^3/s on 19 July.

Phytoplankton analyses of post-deployment seawater samples (Appendix 2) revealed low biomass of a relatively diverse mixture of ciliates, cryptomonads, diatoms, and dinoflagellates. The photosynthetic protozoan, *Mesodinium rubrum* (= *Myrionecta rubra*) was present in low but significant numbers in all samples. This species is often associated with non-toxic blooms causing bright red colouration of coastal waters. No potentially toxic microalgal species were observed and, with the exception of a low number of euglenoids at Site 18, there were no taxa observed that are normally associated with oxidation pond flora.

Seawater profile characteristics (Figures 2 and 3) were indicative of a well-mixed water column at all sites with low freshwater influence. Deployment and retrieval measurements were carried out under calm conditions, such that physical disturbance of the seabed, resulting in sediment (turbidity) and microalgal (chlorophyll-*a*) re-suspension was less obvious compared to most previous surveys. Dissolved oxygen concentrations were at near-saturation levels and chlorophyll-*a* concentrations were within a range considered typical for inner Tasman Bay locations.

The above survey results show no obvious evidence consistent with adverse effects related to the Bell Island wastewater discharge.

5. APPENDICES

Appendix 1. Land Information New Zealand tide predictions (July 2013).

Land Information New Zealand
Toitū te whenua

Sourced from http://www.linz.govt.nz/
E-mail address customersupport@linz.govt.nz

NEW ZEALAND HYDROGRAPHIC AUTHORITY TIDE PREDICTIONS

NELSON

Lat. 41° 16' S., Long. 173° 16' E.

JULY 2013

TIME ZONE: -1200 TIMES AND HEIGHTS OF HIGH AND LOW WATERS

	Time	m		Time	m		Time	m		Time	m
1 Mo	0326	3.6	9 Tu	0404	0.8	17 We	0332	3.5	25 Th	0504	0.3
	0941	1.1		1018	3.7		0940	1.1		1132	4.3
	1605	3.4		1622	0.8		1600	3.5		1733	0.3
	2217	1.3		2246	4.0		2210	1.3		2345	4.5
2 Tu	0425	3.5	10 We	0439	0.7	18 Th	0438	3.5	26 Fr	0549	0.4
	1040	1.3		1057	3.8		1046	1.1		1217	4.2
	1708	3.3		1655	0.8		1712	3.5		1815	0.4
	2326	1.3		2319	4.0		2329	1.2			
3 We	0525	3.4	11 Th	0514	0.7	19 Fr	0547	3.5	27 Sa	0029	4.3
	1141	1.3		1135	3.8		1157	1.0		0633	0.5
	1816	3.3		1729	0.7		1828	3.6		1301	4.0
				2353	4.0					1857	0.6
4 Th	0029	1.3	12 Fr	0550	0.7	20 Sa	0042	1.0	28 Su	0112	4.1
	0624	3.4		1212	3.8		0655	3.6		0718	0.7
	1241	1.3		1803	0.8		1308	0.9		1344	3.8
	1920	3.4					1938	3.8		1941	0.9
5 Fr	0122	1.2	13 Sa	0028	3.9	21 Su	0144	0.8	29 Mo	0158	3.9
	0718	3.4		0628	0.8		0759	3.8		0803	0.9
	1336	1.2		1250	3.8		1413	0.7		1429	3.6
	2013	3.5		1838	0.8		2037	4.1		2030	1.1
6 Sa	0209	1.1	14 Su	0105	3.8	22 Mo	0239	0.6	30 Tu	0247	3.6
	0809	3.5		0708	0.8		0858	4.0		0851	1.2
	1425	1.1		1329	3.7		1510	0.5		1519	3.4
	2057	3.7		1918	0.9		2129	4.3		2129	1.3
7 Su	0250	1.0	15 Mo	0146	3.7	23 Tu	0329	0.4	31 We	0341	3.4
	0855	3.6		0753	0.9		0953	4.2		0947	1.3
	1508	1.0		1411	3.6		1601	0.3		1619	3.2
	2136	3.8		2004	1.0		2217	4.5		2242	1.5
8 Mo	0328	0.9	16 Tu	0235	3.6	24 We	0417	0.3			
	0938	3.7		0843	1.0		1044	4.3			
	1547	0.9		1500	3.6		1648	0.3			
	2211	3.9		2100	1.2		2302	4.6			

TIMES LISTED ARE NZ STANDARD TIME

Appendix 2. Laboratory analytical reports.

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Ensuring Integrity Through Analytical Excellence.

Certificate of Analysis: Final

Cawthron Contract Number: 10210

Project Number: T21336

Cawthron Institute
Private Bag 2
NELSON

Attention: Paul Gillespie

Customer Ref: Bell Island Baseline
Email Recipients: Paul Gillespie
Date Project Started: 16/07/2013 13:12

Sample Details

Laboratory ID: T21336-1 **Sample Type:** Wholeshell Mussels **Date Sampled:** 16/07/2013 09:00
Description: Bells Island Baseline **Date Received:** 16/07/2013 11:30

Analysis	Result	Units	Method
Presumptive coliforms	230	MPN/100g	Compendium 4th Edn 2001
Faecal coliforms	<20	MPN/100g	Compendium 4th Edn 2001
E.coli	<20	MPN/100g	Compendium 4th Edn 2001
Presumptive *Enterococci*	20	MPN/100g	Compendium 4th Edn 2001

Results apply to samples as received

Our routine detection limits for chemical testing relate to samples with a clean matrix.
Reported detection limits may be higher for individual samples if there is insufficient sample or the matrix is complex.

< means less than, > means greater than

Date Generated: 19/7/13

Authorised by: Mark Englefield (LAS)

Position: Senior Technician, Microbiology Laboratory

Signature:

107
40
laboratory

This laboratory is accredited by IANZ. Unless specified all tests reported herein have been performed in accordance with the laboratory's scope of registration.

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Cawthron Analytical Services:
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Certificate of Analysis: Final

Cawthron Contract Number: 10210

Project Number: T21472

Cawthron Institute
Private Bag 2
NELSON

Attention: Paul Gillespie

Customer Order No: Bells Island
Customer Ref: BST: 1374809
Email Recipients: Reid Forrest, Paul Gillespie
Date Project Started: 19/07/2013 12:13

Sample Details

Laboratory ID: T21472-1 **Sample Type:** Water **Date Sampled:** 19/07/2013 09:25
Date Received: 19/07/2013 10:45
Customer ID: Site 18

Analysis	Result	Units	Method
Enterococci	<5	cfu/100mL	APHA (online) 9230C
Faecal coliforms	15	cfu/100mL	APHA (online) 9222D
E.coli	15	cfu/100mL	APHA (online) 9222G

Sample Details

Laboratory ID: T21472-2 **Sample Type:** Water **Date Sampled:** 19/07/2013
Date Received: 19/07/2013 10:45
Customer ID: Site 19

Analysis	Result	Units	Method
Enterococci	<5	cfu/100mL	APHA (online) 9230C
Faecal coliforms	<5	cfu/100mL	APHA (online) 9222D
E.coli	<5	cfu/100mL	APHA (online) 9222G

Sample Details

Laboratory ID: T21472-3 **Sample Type:** Water **Date Sampled:** 19/07/2013 09:00
Date Received: 19/07/2013 10:45
Customer ID: Site 21

Analysis	Result	Units	Method
Enterococci	<5	cfu/100mL	APHA (online) 9230C
Faecal coliforms	<5	cfu/100mL	APHA (online) 9222D
E.coli	<5	cfu/100mL	APHA (online) 9222G

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Sample Details

Laboratory ID: T21472-4 **Sample Type:** Water **Date Sampled:** 19/07/2013 08:50
Date Received: 19/07/2013 10:45
Customer ID: Site 22

Analysis	Result	Units	Method
Enterococci	<5	cfu/100mL	APHA (online) 9230C
Faecal coliforms	<5	cfu/100mL	APHA (online) 9222D
E.coli	<5	cfu/100mL	APHA (online) 9222G

Sample Details

Laboratory ID: T21472-5 **Sample Type:** Wholeshell Mussels **Date Sampled:** 19/07/2013 08:50
Description: Bells Island **Date Received:** 19/07/2013 10:45
Customer ID: Site 18

Analysis	Result	Units	Method
Presumptive coliforms	230	MPN/100g	Compendium 4th Edn 2001
Faecal coliforms	20	MPN/100g	Compendium 4th Edn 2001
E.coli	20	MPN/100g	Compendium 4th Edn 2001
Presumptive *Enterococci*	140	MPN/100g	Compendium 4th Edn 2001

Sample Details

Laboratory ID: T21472-6 **Sample Type:** Wholeshell Mussels **Date Sampled:** 19/07/2013 09:00
Description: Bells Island **Date Received:** 19/07/2013 10:45
Customer ID: Site 19

Analysis	Result	Units	Method
Presumptive coliforms	330	MPN/100g	Compendium 4th Edn 2001
Faecal coliforms	<20	MPN/100g	Compendium 4th Edn 2001
E.coli	<20	MPN/100g	Compendium 4th Edn 2001
Presumptive *Enterococci*	<20	MPN/100g	Compendium 4th Edn 2001

Sample Details

Laboratory ID: T21472-7 **Sample Type:** Wholeshell Mussels **Date Sampled:** 19/07/2013 09:15
Description: Bells Island **Date Received:** 19/07/2013 10:45
Customer ID: Site 21

Analysis	Result	Units	Method
Presumptive coliforms	490	MPN/100g	Compendium 4th Edn 2001
Faecal coliforms	20	MPN/100g	Compendium 4th Edn 2001
E.coli	20	MPN/100g	Compendium 4th Edn 2001
Presumptive *Enterococci*	<20	MPN/100g	Compendium 4th Edn 2001

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Sample Details

Laboratory ID: T21472-8	**Sample Type:** Wholeshell Mussels		**Date Sampled:** 19/07/2013 09:25
Description: Bells Island			**Date Received:** 19/07/2013 10:45
Customer ID: Site 22			

Analysis	Result	Units	Method
Presumptive coliforms	230	MPN/100g	Compendium 4th Edn 2001
Faecal coliforms	<20	MPN/100g	Compendium 4th Edn 2001
E.coli	<20	MPN/100g	Compendium 4th Edn 2001
Presumptive *Enterococci*	<20	MPN/100g	Compendium 4th Edn 2001

Results apply to samples as received

Our routine detection limits for chemical testing relate to samples with a clean matrix.
Reported detection limits may be higher for individual samples if there is insufficient sample or the matrix is complex.

< means less than, > means greater than

Date Generated: 22/7/13

Authorised by: Ryan Hunter (LAS)

Position: Technician, Microbiology Laboratory

Signature:

Authorised by: Mark Englefield (LAS)

Position: Senior Technician, Microbiology Laboratory

Signature:

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Certificate of Analysis: Final

Cawthron Contract Number: 10210

Project Number: T21471

Cawthron Institute
Private Bag 2
NELSON

Attention: Paul Gillespie

Customer Ref: Bells Island
Email Recipients: Paul Gillespie, Reid Forrest

Sample Details

Laboratory ID: T21471-1 **Sample Type:** Grab **Date Sampled:** 19/07/2013
Description: 18 **Date Received:** 19/07/2013 10:45
Site Description PU01 - Phyto Site Unspecified

Species	Description	Count (cells/L)	Trigger (cells/L)	Risk	Action
Biomass : Low					
Rhizosolenia spp.	Potential Problem Species	200			
Ciliate (unidentified)	Other Dominant Species	3600			
Cryptomonads	Other Dominant Species	4000			
Euglenoid spp.	Other Dominant Species	200			
Gymnodinium spp.	Other Dominant Species	400			
Katodinium spp.	Other Dominant Species	200			
Navicula spp.	Other Dominant Species	200			
Nitzschia spp.	Other Dominant Species	600			
Protoperidinium sp.	Other Dominant Species	200			
Skeletonema spp.	Other Dominant Species	2800			
Small Flagellates	Other Dominant Species	600			
Thalassiosira spp.	Other Dominant Species	400			
Mesodinium rubrum	**Non-toxic bloom forming spp.**	**1200**		Low	

Method: In-house, based on UNESCO 1978 and IOC Manual and Guides 55 2010

Sample Details

Laboratory ID: T21471-2 **Sample Type:** Grab **Date Sampled:** 19/07/2013
Description: 19 **Date Received:** 19/07/2013 10:45
Site Description PU01 - Phyto Site Unspecified

Species	Description	Count (cells/L)	Trigger (cells/L)	Risk	Action
Biomass : Low					
Ceratium tripos	Other Dominant Species	200			
Ciliate (unidentified)	Other Dominant Species	2800			
Cryptomonads	Other Dominant Species	2800			
Ebria sp.	Other Dominant Species	200			
Gymnodinium spp.	Other Dominant Species	200			
Gyrodinium sp.	Other Dominant Species	200			
Heterocapsa spp.	Other Dominant Species	200			
Katodinium spp.	Other Dominant Species	600			
Nitzschia spp.	Other Dominant Species	1200			
Noctiluca spp.	Other Dominant Species	200			
Prorocentrum spp.	Other Dominant Species	200			
Skeletonema spp.	Other Dominant Species	600			
Small Flagellates	Other Dominant Species	200			
Thalassiosira spp.	Other Dominant Species	800			
Mesodinium rubrum	**Non-toxic bloom forming spp.**	**800**		Low	

Method: In-house, based on UNESCO 1978 and IOC Manual and Guides 55 2010

Sample Details

Laboratory ID: T21471-3 **Sample Type:** Grab **Date Sampled:** 19/07/2013
Description: 21 **Date Received:** 19/07/2013 10:45
Site Description PU01 - Phyto Site Unspecified

Species	Description	Count (cells/L)	Trigger (cells/L)	Risk	Action
Biomass : Low					
Ceratium fusus	Other Dominant Species	600			
Ciliate (unidentified)	Other Dominant Species	5200			
Coscinodiscus spp.	Other Dominant Species	200			
Cryptomonads	Other Dominant Species	3000			
Gymnodinium spp.	Other Dominant Species	800			
Gyrodinium sp.	Other Dominant Species	400			
Heterocapsa spp.	Other Dominant Species	800			
Katodinium spp.	Other Dominant Species	400			
Nitzschia spp.	Other Dominant Species	600			
Small Flagellates	Other Dominant Species	800			
Torodinium spp.	Other Dominant Species	200			
Alexandrium margalefi	Non-toxic Alexandrium Species	200			
Mesodinium rubrum	**Non-toxic bloom forming spp.**	**3600**		Moderate	

Method: In-house, based on UNESCO 1978 and IOC Manual and Guides 55 2010

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Sample Details

Laboratory ID: T21471-4 **Sample Type:** Grab **Date Sampled:** 19/07/2013

Description: 22 **Date Received:** 19/07/2013 10:45

Site Description PU01 - Phyto Site Unspecified

Species	Description	Count (cells/L)	Trigger (cells/L)	Risk	Action
Biomass : Low					
Ceratium furca	Other Dominant Species	200			
Ceratium fusus	Other Dominant Species	200			
Ceratium tripos	Other Dominant Species	400			
Ciliate (unidentified)	Other Dominant Species	2200			
Cryptomonads	Other Dominant Species	2000			
Ebria sp.	Other Dominant Species	200			
Gymnodinium spp.	Other Dominant Species	400			
Heterocapsa spp.	Other Dominant Species	1000			
Katodinium spp.	Other Dominant Species	200			
Pyramimonas sp.	Other Dominant Species	200			
Small Flagellates	Other Dominant Species	1000			
Surirella spp.	Other Dominant Species	200			
Mesodinium rubrum	**Non-toxic bloom forming spp.**	**1200**		Low	

Method: In-house, based on UNESCO 1978 and IOC Manual and Guides 55 2010

Results apply to samples as received

Our routine detection limits for chemical testing relate to samples with a clean matrix.
Reported detection limits may be higher for individual samples if there is insufficient sample or the matrix is complex.

< means less than, > means greater than

Date Generated: 19/7/13

Authorised by: Jennifer Robinson

Position: Technician, Microalgae Laboratory

Signature:

2013 Annual Report on the Biosolids Research Trial at Rabbit Island

Jianming Xue and Mark Kimberley

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REPORT INFORMATION SHEET

REPORT TITLE	2013 ANNUAL REPORT ON THE BIOSOLIDS RESEARCH TRIAL AT RABBIT ISLAND
AUTHORS	JIANMING XUE, MARK KIMBERLEY
CLIENT	PF OLSEN LIMITED
CLIENT CONTRACT NO:	75704
FRST CONTRACT NO:	CO3X0902
SIDNEY OUTPUT NUMBER	52289
SIGNED OFF BY	LISA (E.R.) LANGER
DATE	DECEMBER 2013
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EXECUTIVE SUMMARY

Introduction

Biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha radiata pine (*Pinus radiata*) plantation at Rabbit Island since 1996. An experimental research trial was established within the plantation in 1997 to investigate the effects of biosolids applications on tree growth, nutrition and the ecosystem. Biosolids were applied to the trial site in 1997, 2000, 2003, 2006, 2009, and most recently in 2012, at three application rates: 0 (Control), 300 (Standard) and 600 kg N ha^{-1} (High). Three stocking density treatments, i.e., subplots of 300, 450 and 600 stems ha^{-1}, were included within each biosolids treatment main plot. This report provides updated information on tree growth and nutrition responses of radiata pine to biosolids application up to age 22, focusing on data collected in 2013.

Key Results

This report summarises the 16-year long (i.e. 1997-2013) series of growth measurements and foliar nutrient concentrations from the radiata pine biosolids research trial.

There has been a considerable increase in accumulated volume in biosolids treated trees over the 16 years that biosolids have been applied at the site. In July 2013 when the trees were aged 22 years, stem volume in the Standard treatment was 21% greater than the Control treatment, while stem volume in the High treatment was 27% greater than the Control treatment. The relative improvement in stem volume increment in biosolids treatments over the Control has been decreasing in recent years, but the increased stem volume achieved especially from early to mid-rotation in trees treated with biosolids is strongly maintained.

At higher stocking rates, competition has led to significantly smaller diameter trees. However, the higher stocked plots have significantly greater per hectare basal area and volume than the lower stocked plots. Tree stocking rates have had no significant effect on mean top height.

Foliage nitrogen (N) concentration in the biosolids treated plots has been consistently elevated compared with the Control plots. Foliar N concentrations in 2013 were 0.21 and 0.26 percentage points greater than the Control in the Standard and High treatments respectively.

In general, the application of biosolids has been beneficial to trees growing on this site. Biosolids applications have transformed the site from a relative low productivity to a moderately high productivity forest site.

Recommendations

To evaluate the sustainability and economic benefit of the biosolids application to Rabbit Island forests, we recommend maintaining regular monitoring of tree growth and nutrition, groundwater and soil quality until the end of rotation, and reassessing wood properties in the near future.

2013 Annual report on the biosolids research trial at Rabbit Island

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December 2013

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1. Introduction

Using biosolids (i.e., treated sewage sludge) as a fertiliser and soil amendment is one of the common options for biosolids management in many parts of the world (UN-HABITAT 2008; Wang et al. 2008). Forest land application, rather than applying biosolids to agricultural land, can reduce the risk of contaminants entering the human food chain (Magesan and Wang 2003), and also can increase tree growth and subsequent economic returns (Kimberley et al. 2004; Prescott and Blevins 2005; Wang et al. 2006).

Treated biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha radiata pine forest plantation at Rabbit Island near Nelson City since 1996, with repeated applications to individual forest stands made approximately every three years. To investigate whether this practice would be sustainable long-term, a research trial was established in 1997 (age 6). Since then tree growth responses have been measured regularly with a number of other environmental variables, such as soil and groundwater quality. A number of reports have been prepared to collate and interpret the monitoring data from the research trial site. This report updates results documented in 2012 (Xue and Kimberley 2012).

2. Objectives

The objective of this report is to summarise the effects of the biosolids applications on tree growth and nutrition, focusing on new data obtained in 2013.

3. Materials and Methods

3.1 Trial design and establishment

The trial was established in October 1997 in a stand of radiata pine planted in 1991. The soil at the trial site consists of coarse coastal dune sands, classified as a sandy raw soil (Hewitt 1998), which provides free rooting access to the shallow groundwater 2.0 - 4.2 m below the surface. The stand was established at a stocking rate of 1000 stems ha^{-1}, and all trees in the trial were pruned in up to four lifts to 6 m height during the period November 1996 - August 2001. Three treatments have been used in a split-plot, randomised complete block design with four replicates. Treated biosolids from the Nelson regional wastewater treatment plant were applied in 1997, 2000, 2003, 2006, 2009, and most recently in November 2012 at three application rates: 0 (Control), 300 (Standard) and 600 kg N ha^{-1} (High). To determine the effect of each treatment on the growth of the pine plantation, three stocking density treatments (i.e., 300, 450 and 600 stems ha^{-1}) were established as subplot within each biosolids treatment of the main-plot (Figure 1).

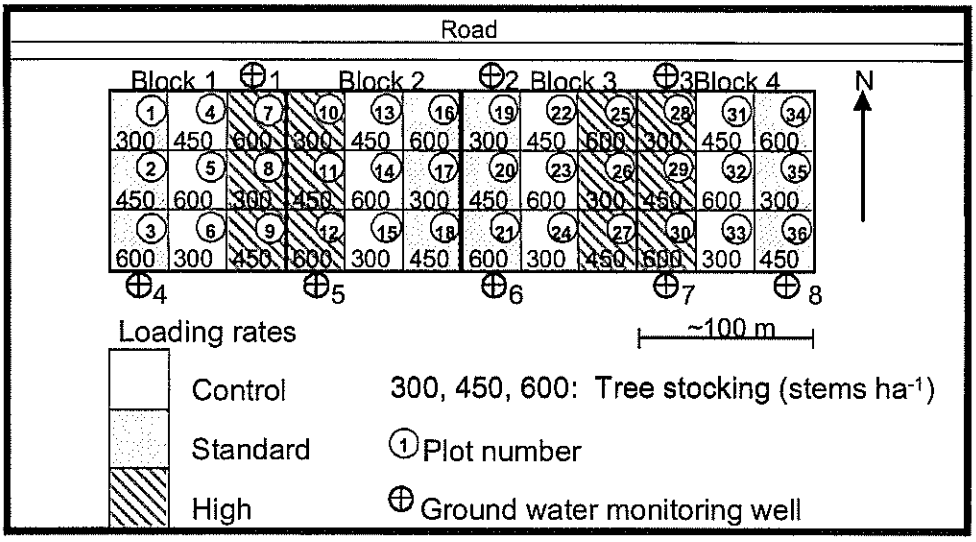

Figure 1: Biosolids trial plot layout at Rabbit Island.

3.2 Trial monitoring

3.2.1 Tree growth measurement

Height and diameter at breast height (DBH) of all trees in each plot were measured annually in winter from 1997 to 2013. Visual observations of each tree were recorded (e.g., stem form, health). All data were entered into the Scion's Permanent Sample Plot System. Stocking, mean top height (MTH, mean height of the largest 100 trees per hectare), basal area (BA) and stem volume were estimated for each plot (Wang and Kimberley, 2003).

3.2.2 Tree nutrition

To assess changes in tree nutrition due to biosolids application, the current-year needles were sampled annually from the youngest second-order branches in the top third of crown of selected trees in each plot in March of 1998-2011 and 2013. The samples were bulked between stocking density treatments within the same biosolids loading rates and analysed for a range of nutrients, including N, P, K, Ca, Mg, Na, Mn, Zn, Cu, B and Fe.

3.3 Statistical analysis

In this report, two-way mixed model (split-plot design) analysis of variance (ANOVA) and least significant difference (LSD) tests were used to determine the statistical significance of the biosolids loading rate (main plot) and tree stocking rate (subplot) effects on tree growth. The biosolids loading rate and tree stocking rate were treated as fixed effects and block effect were treated as a random effect. The growth data were analysed using the MIXED Procedure (SAS/STAT Version 9.3), with the following model:

[1] $y_{ijk} = \mu + \alpha z_{ijk} + \beta_j + \gamma n_{ijk} + \delta_k n_{ijk} + b_i + p_{ij} + e_{ijk}$

where,

y_{ijk} is any observation of a dependent variable (e.g., BA) for which
i = 1, 2, 3, 4 is the blocking factor
j = 1, 2, 3 is the biosolids loading factor
k = 1, 2, 3 is the tree stocking factor

μ is the overall mean
α is the coefficient for the initial size covariate
z_{ijk} is the initial size covariate (e.g., mean DBH at age 6 years)
β_j is the effect of biosolids loading j
γ is the coefficient for the stocking term
n_{ijk} is the stocking density
δ_k is the coefficient for the interaction between stocking and biosolids loading
b_i is the replication (i.e. block) effect (normally distributed with zero mean)
p_{ij} denotes the main-plot error (normally distributed with zero mean)
e_{ijk} denotes the subplot error (normally distributed with zero mean).

One-way mixed model (randomised complete block design) ANOVA and least significant difference (LSD) tests were used to determine the statistical significance of the biosolids loading rate effect on tree nutrition.

4. Results and Discussion

4.1 Effects of biosolids application rate on tree growth

4.1.1 Stem diameter, basal area and height

In treatments with biosolids applied, diameter at breast height (DBH) and basal area (BA) remained significantly greater than the untreated Control in 2013 (Figures 2 & 3). At age 22 years, the Standard and High treatments increased mean DBH by 10% and 11% respectively, when compared to the Control (Figure 2). The mean BA of the High treatment was 26% greater than the Control while the mean BA of the Standard treatment was 22% greater than the Control (Figure 3).

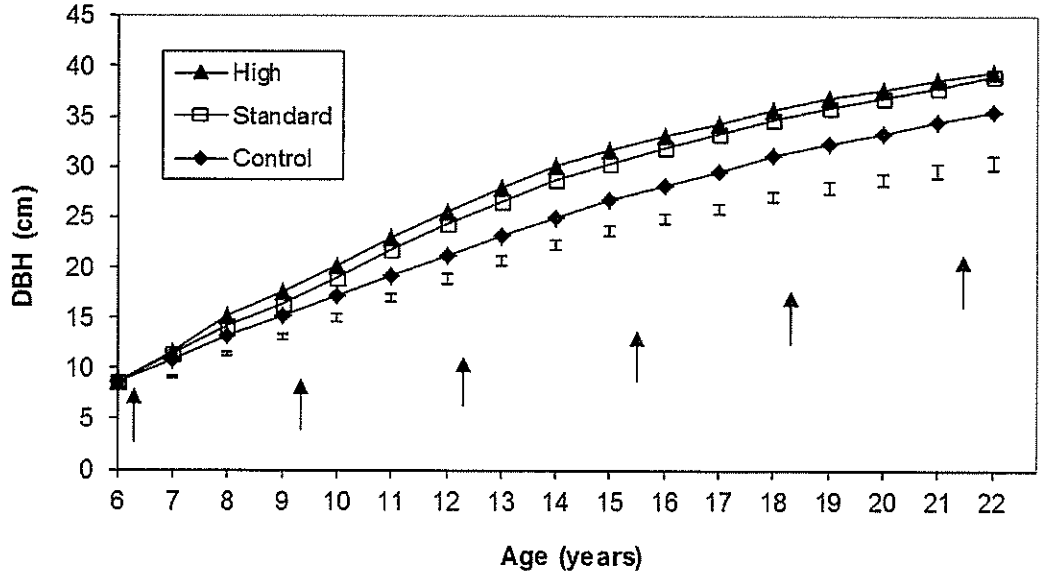

Figure 2: Effect of biosolids application on diameter at breast height (DBH) since the initial biosolids application at age 6 years. The bars show least significant differences (LSDs) calculated for each age. Treatment differences greater than the LSD are statistically significant (P = 0.05). The arrows show when biosolids treatments were applied.

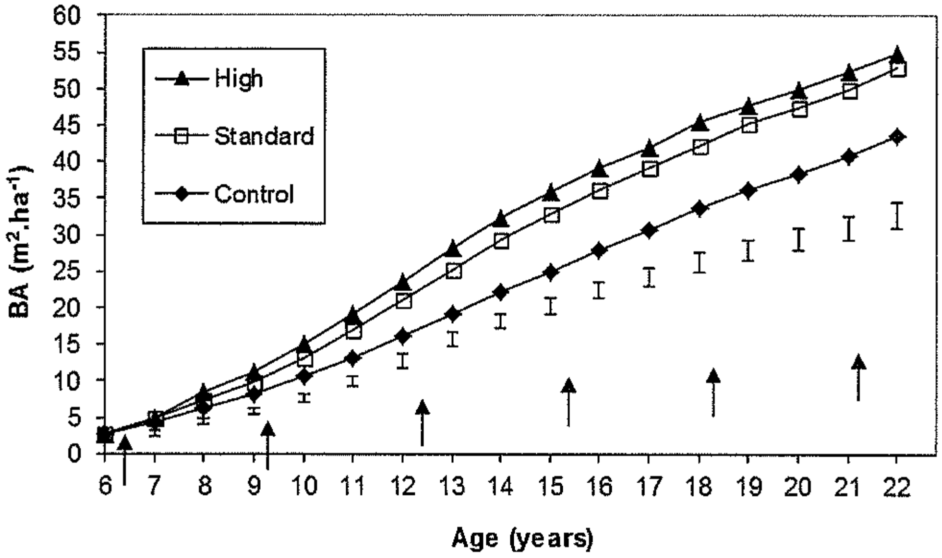

Figure 3: Effect of biosolids application on basal area (BA) since the initial biosolids application at age 6 years. The bars show LSDs calculated for each age. Treatment differences greater than the LSD are statistically significant (P = 0.05). The arrows show when biosolids treatments were applied.

Up to age 14 years, BA current annual increment (BACAI) was significantly greater in the biosolids treatments than the Control plots (Figure 4). However, this trend has narrowed in the last few years. In the current year, there were no significant differences between biosolids treatments in BACAI, except for the plots with the lowest stocking (300 stems ha $^{-1}$) where BACAI was significantly higher in the Standard treatment compared with the Control treatment (Table 1).

However, this apparent reduction in the growth response to biosolids has to be interpreted carefully. Because of the natural sigmoidal shape of the BA growth curve, some apparent narrowing in the rate of growth between treated and untreated treatments was expected, simply because the treated trees are ahead of the Control trees in development. It is more revealing to plot the increment against the mean BA (Figure 5). This shows that the BA growth rate of treated trees was much greater than Control trees until the BA reached around 30 m^2 ha^{-1}. Although it has since narrowed considerably, the growth rate of treated trees remains ahead of Control trees at a comparable BA.

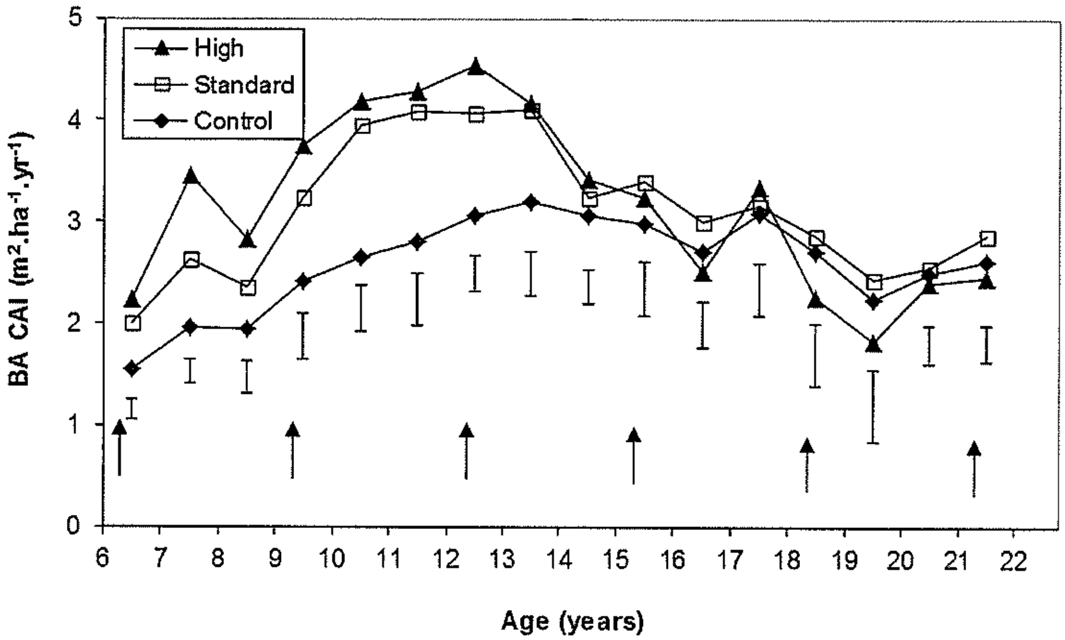

Figure 4: Effect of biosolids application on basal area current annual increments (BACAI) since the initial biosolids application at age 6 years. The bars show LSDs calculated for each age. Treatment differences greater than the LSD are statistically significant (*P* = 0.05). The arrows show when biosolids treatments were applied.

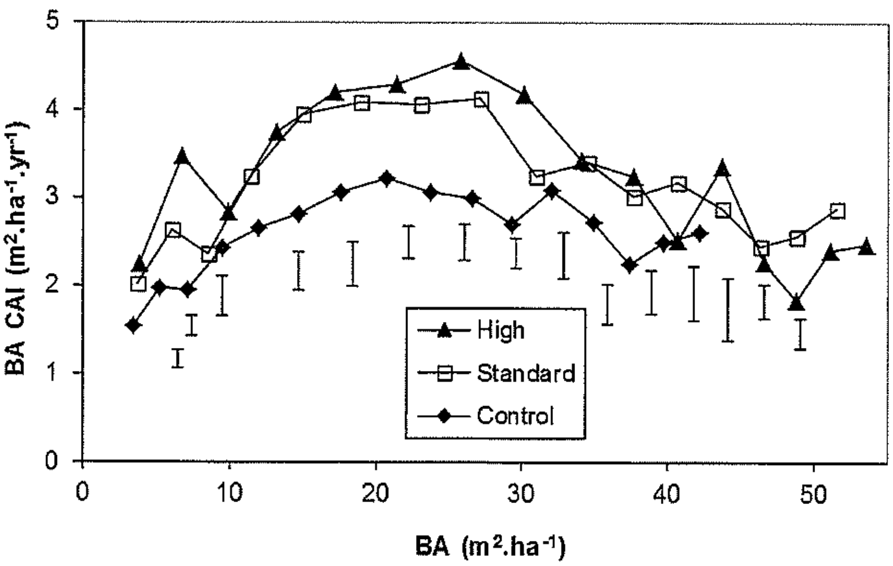

Figure 5: Basal area current annual increments (BACAI) plotted against mean basal area (BA) for each treatment. The bars show LSDs. Treatment differences greater than the LSD are statistically significant (*P* = 0.05).

Mean top height (MTH) in both Standard and High biosolids treatments has shown a slight but statistically significant divergence from the Control treatment since 2001 (age 10 years) (Figure 6).

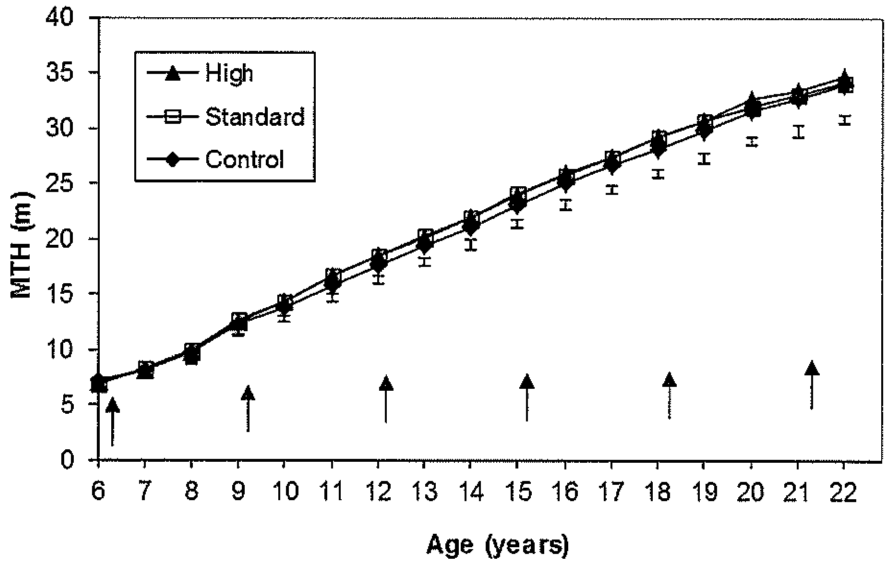

Figure 6: Effect of biosolids application on mean top height (MTH) since the initial biosolids application at age 6 years. The bars show LSDs calculated for each age. Treatment differences greater than the LSD are statistically significant (P = 0.05). The arrows show when biosolids treatments were applied.

4.1.2 Stem volume

Stem volume remained significantly greater in plots with biosolids applied than those with no biosolids application (Figure 7). In 2013 at age 22 years, the stem volume of the High treatment (607 m^3 ha^{-1}) was 27% greater than the Control (477 m^3 ha^{-1}). The stem volume of the Standard treatment (579 m^3 ha^{-1}) was 21% greater than the Control, indicating a substantial gain in productivity. Current stem volume increments in both the Standard and the High rate treatments were significantly greater than in the Control (Figure 8) until about age 17 years. However, since 2009 growth year there has been no significant difference in volume growth between the Control and treated trees. As discussed above for basal area, this partly reflects the natural trend driven by the sigmoidal nature of the growth curve. When the volume increment is plotted against the total volume (Figure 9), the growth rate of treated trees is still slightly greater than Control trees at a comparable stand volume, although there is now some evidence that this gap is narrowing.

Figure 8 shows that the maximum growth differential between treated and untreated trees occurred between ages 10-14 years. Importantly, the increased stem volume achieved over these years appears to be strongly maintained. Although the difference in growth rate is now narrowing, there is no sign that the difference in total volume is closing.

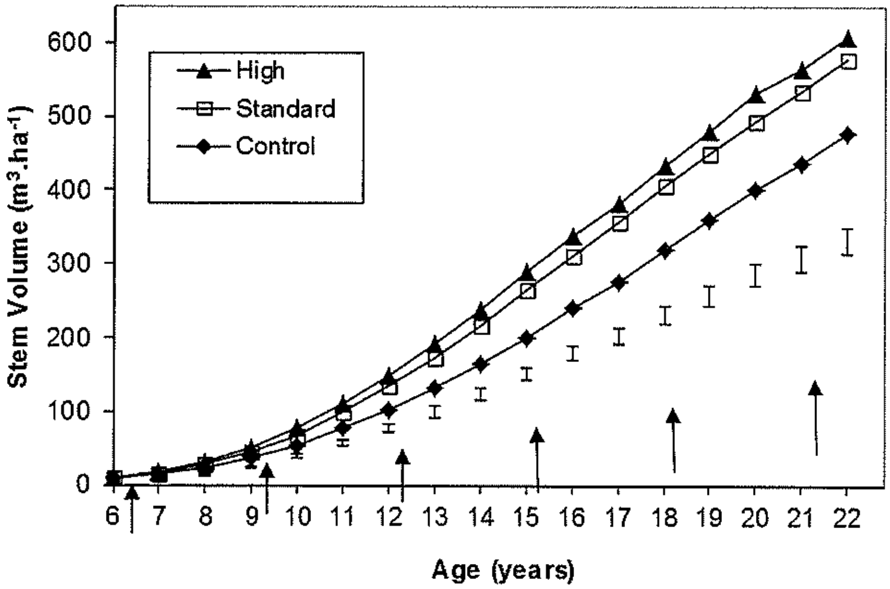

Figure 7: Effect of biosolids application on stem volume since the initial biosolids application at age 6 years. The bars show LSDs calculated for each age. Treatment differences greater than the LSD are statistically significant (*P* = 0.05). The arrows show when biosolids treatments were applied.

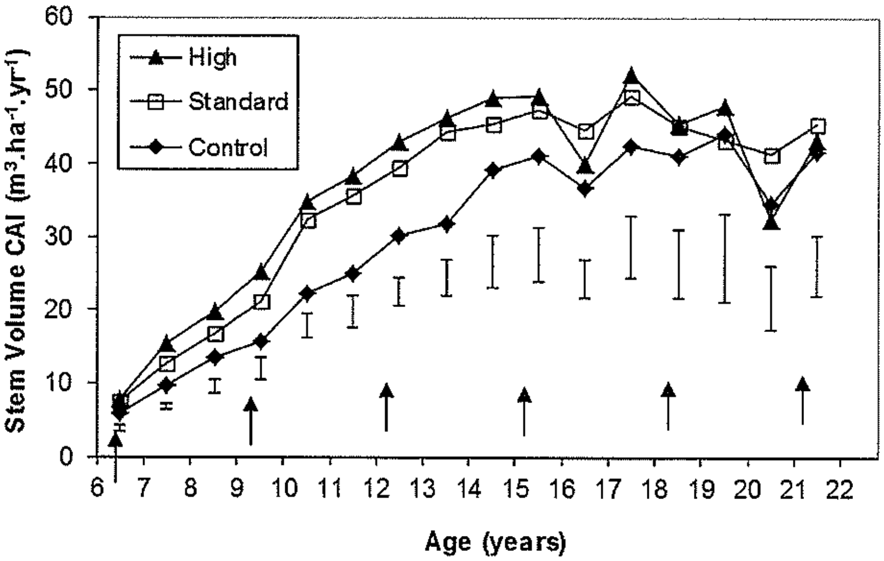

Figure 8: Effect of biosolids loading on stem volume current annual increments (CAI) since the initial biosolids application at age 6 years. The bars show LSDs calculated for each age. Treatment differences greater than the LSD are statistically significant (*P* = 0.05). The arrows show when biosolids treatments were applied.

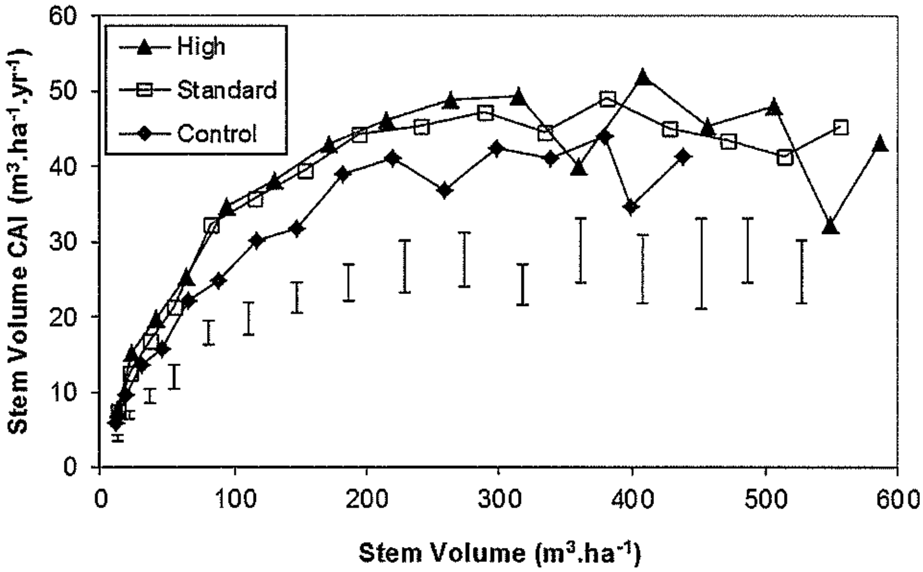

Figure 9: Stem volume current annual increments plotted against mean stem volume for each treatment. The bars show LSDs. Treatment differences greater than the LSD are statistically significant (P = 0.05).

4.1.3 300 Index

The best measure of volume productivity for radiata pine used in New Zealand is the 300 Index (Kimberley et al. 2005), which is defined as the volume mean annual increment (i.e., the stem volume per hectare divided by the age) at age 30 years. Because volume growth is strongly influenced by management regime especially stocking, the 300 Index is defined for a 'standard' regime of 300 stems ha^{-1}. However, it is possible to estimate the 300 Index using a plot measurement even when the stocking differs from 300 stems ha^{-1} using an adjustment algorithm based on the 300 Index Growth Model. This procedure was applied to each plot measurement in the trial to obtain estimates of the 300 Index, and the resultant indices were analysed to determine the effect of biosolids loading.

The results show that biosolids have elevated the 300 Index significantly (Figure 10). At the latest measurement, the 300 Index of the Control treatment averaged 21.2 $m^3\ ha^{-1}\ yr^{-1}$ while the 300 Index for the Standard and High treatments were 24.8 and 25.7 $m^3\ ha^{-1}\ yr^{-1}$ respectively. Nationally, the 300 Index for radiata pine averages about 25 and ranges between about 15 and 35. Therefore, these results indicate that biosolids have elevated the site from a low to a medium level of fertility.

One noticeable feature of Figure 10 is that the Control treatment shows a steady increase in 300 Index over time, from 18.0 at age 6 years to 21.2 at age 22 years. It is not clear why this has occurred, but it is not unusual for sites to show some level of 300 Index 'drift' either positive or negative. This occurs when the 300 Index growth model does not accurately reflect the underlying growth trend at the site. For example a site that has poor early growth but above average growth later in the rotation will tend to show a positive drift in the 300 Index.

However, another possibility is that trees in the Control plots have received some nutritional benefit from the application of biosolids to neighbouring plots, leading to a gradual improvement in fertility. This could have occurred, for example, as a result of over-spray during the application of biosolids; through leaching; or because roots of trees in Control plots are able to access nitrogen from neighbouring fertilised plots. In any of these cases, the trial measurements will tend to overstate the growth of trees in Control plots. This would imply that, if anything, the trial may underestimate the growth benefit of biosolids. One way of testing for this would be to test whether Control trees closer to plot boundaries adjacent to treated trees have superior growth to those near the plot centre.

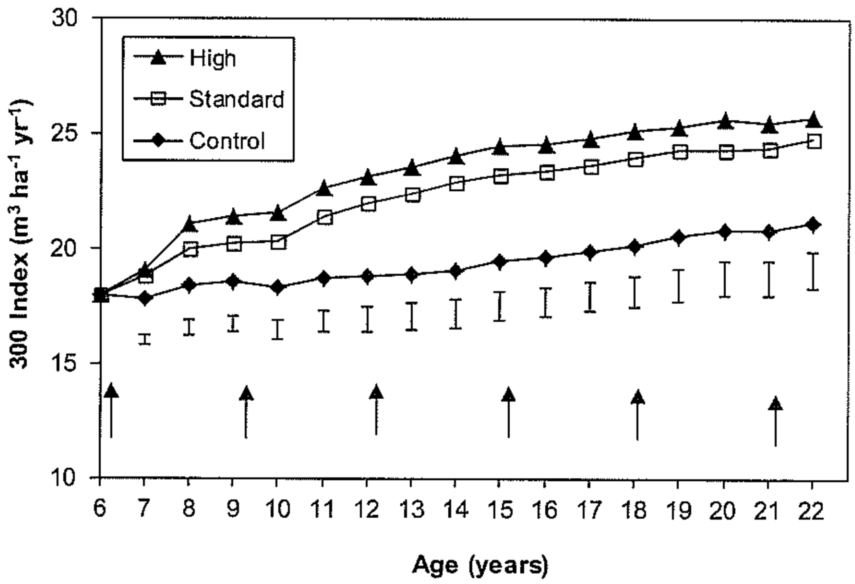

Figure 10: 300 Index estimated for each measurement year and treatment. The bars show LSDs. Treatment differences greater than the LSD are statistically significant (P = 0.05).

4.2 Effects of stocking rate on tree growth

At higher stocking rates, inter-tree competition has led to significantly (P<0.05) smaller diameter trees (Figure 11). However, the higher stocked plots have significantly greater per hectare BA and volume than the lower stocked plots (Figures 12 & 13).

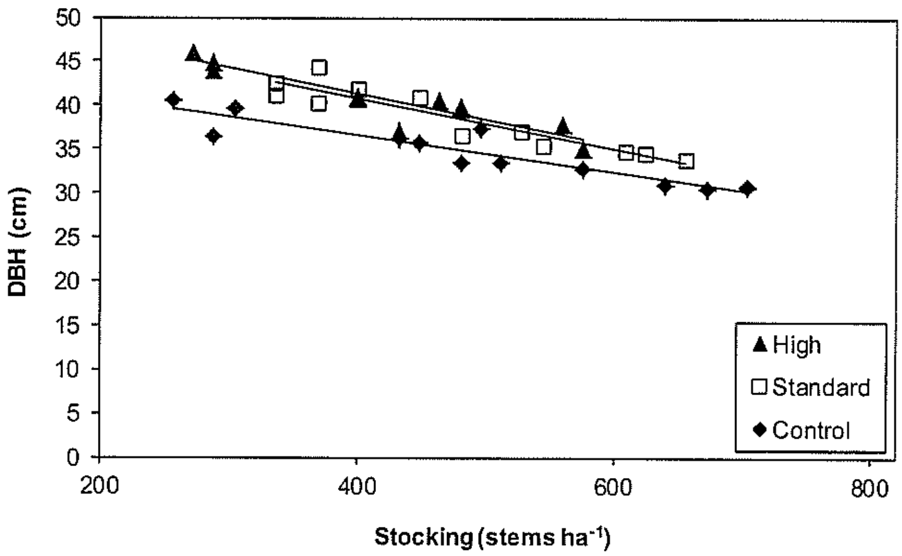

Figure 11: Effect of tree stocking rate and biosolids loading on mean DBH at age 22 years.

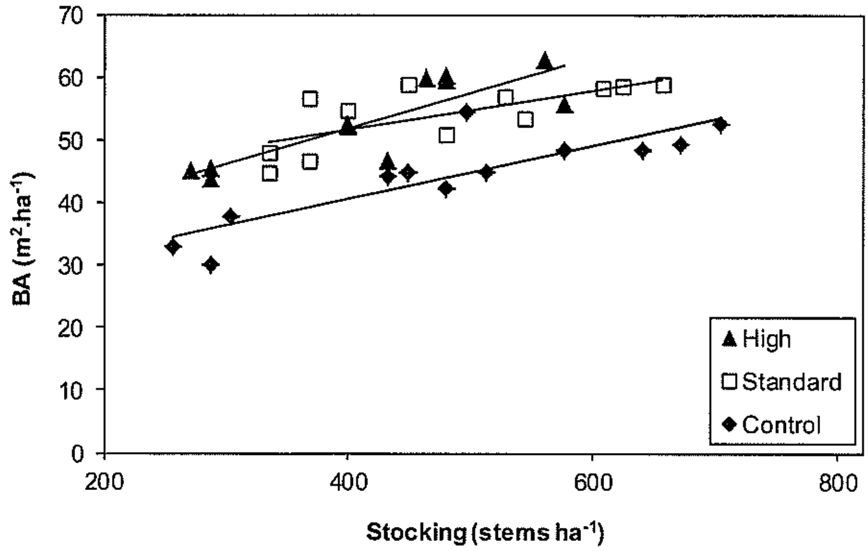

Figure 12: Effect of tree stocking rate and biosolids loading on basal area (BA) at age 22 years.

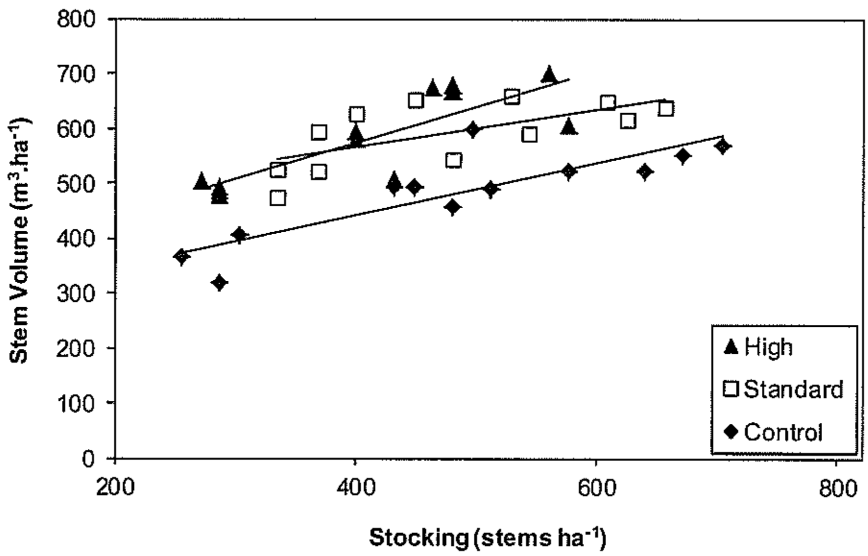

Figure 13: Effect of tree stocking rate and biosolids loading on stem volume at age 22 years.

Tabulated values of important growth parameters at three representative stockings for each loading rate at age 22 years have been produced from the fitted model (equation [1]) and are shown in Table 1.

Table 1: Effect of biosolids loading rates on tree growth within each stocking*.

Stocking (stems ha^{-1})	Loading	BA (m^2 ha^{-1}) 2012/13 CAI	BA (m^2 ha^{-1}) 2013 total	DBH (cm) 2013 total	MTH (m) 2013 total	Volume (m^3 ha^{-1}) 2012/13 CAI	Volume (m^3 ha^{-1}) 2013 total
300	Control	2.21 a	34.8 a	38.2 a	33.6 a	34.7 a	374 a
	Standard	2.84 b	48.3 b	43.6 b	34.5 a	41.8 a	528 b
	High	2.31 a	45.0 b	43.8 b	34.4 a	38.9 a	492 b
450	Control	2.60 ab	43.1 a	35.7 a	33.8 a	41.2 a	472 a
	Standard	2.87 a	52.7 b	39.2 b	34.1 ab	45.2 a	577 b
	High	2.46 b	54.3 b	39.7 b	34.6 b	42.9 a	602 b
600	Control	2.99 a	51.5 a	33.1 a	34.0 a	47.6 a	570 a
	Standard	2.89 a	57.2 b	34.8 b	33.8 a	48.5 a	625 b
	High	2.61 a	63.6 c	35.5 b	34.8 a	47.0 a	713 c

*For each stocking, values within a column followed by the same letter do not differ significantly (*P*=0.05).

4.3 Effects of biosolids application rate on tree nutrition

Treatment means of foliar nutrient concentrations in 2013 are shown in Table 2. Biosolids application significantly increased foliar N and B concentrations, but the High treatment reduced foliar Ca concentration, which might be caused by growth dilution. In the Control treatment, foliar concentrations of all nutrients except N and Cu were in the "satisfactory" range of tree nutrition (Will 1985), indicating N was the main limiting nutrient for tree growth.

Table 2: Effect of biosolids application on foliar nutrient concentrations in March 2013*.

Treatment	N		P		K		Ca		Mg		Zn		Cu		B		Fe		Mn	
	%										mg kg^{-1}									
Control	1.22	a	0.15	a	0.79	a	0.14	a	0.16	a	30	a	3.1	a	20	a	40	a	196	a
Standard	1.42	b	0.14	a	0.78	a	0.15	a	0.17	a	31	a	5.3	a	25	b	41	a	187	a
High	1.48	b	0.13	a	0.75	a	0.11	b	0.16	a	29	a	2.8	a	26	b	41	a	175	a

*Values within a column followed by the same letter do not differ significantly (*P* = 0.05).

Foliar analysis has consistently shown that natural soil N supply in the Rabbit Island radiata pine forest is not satisfactory, with foliar N concentration of the Control treatment remaining consistently well below 1.5% N (Figure 14), a threshold value below which radiata pine may benefit from N fertiliser (Will 1985).

Successive applications of biosolids have produced a consistently positive response in foliar N concentration in the subsequent assessment when compared with Control trees (Figure 14). The boost in foliar N generally declined over a period of several years following an application. However, this pattern was not so obvious during the period of last two applications. This could imply that the biosolids-derived residual N in the soil might become more influential than the freshly applied biosolids N on foliar N concentration. Following the 2012 application, foliar N concentrations in the Standard and High treatments were 0.21 and 0.26 percentage points respectively greater than the Control.

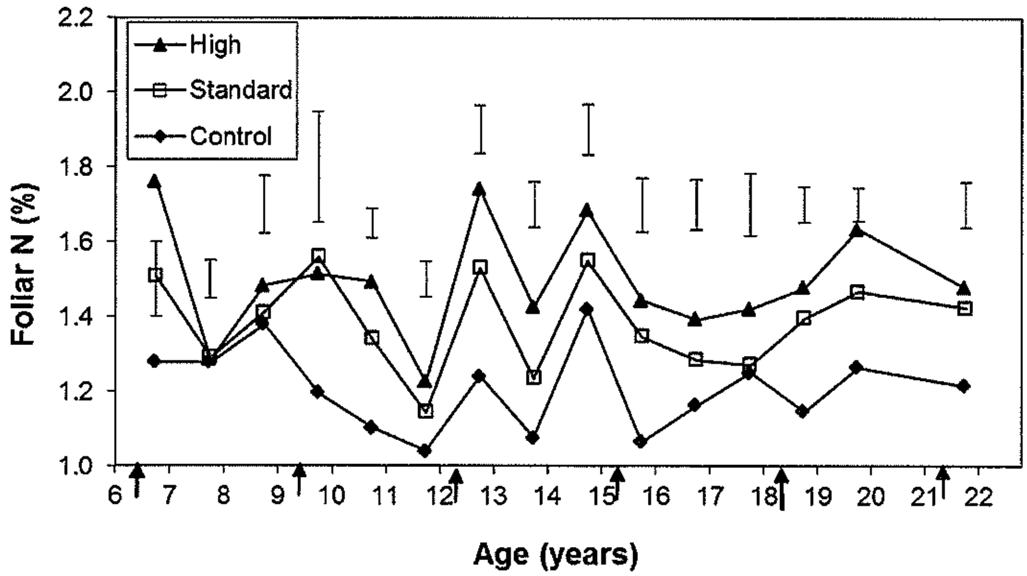

Figure 14: Effect of biosolids application on foliar nitrogen (N) concentration. Arrows indicate time of biosolids application. Error bars show least significant differences (P = 0.05) and can be used to determine the significance of treatment differences.

5. Conclusions

This report provides a summary of growth measurements and foliar nutrient concentrations from the biosolids research trial site at Rabbit Island during the period of 1997 to 2013. The accumulated volume increase in biosolids treated trees over the 16 years is considerable when compared to the untreated trees.

In July 2013 at age 22 years, stem volume of the Standard and High treatments were 21% and 27% respectively greater than the Control treatment. The relative improvement in stem volume increment in biosolids treatments over the Control has been decreasing in recent years, which is partly due to the natural sigmoidal pattern of growth. However, the increased stem volume achieved especially from early to mid-rotation in trees treated with biosolids is strongly maintained.

Foliage N concentration in the biosolids treated plots has been significantly elevated compared with the Control plots following the application of biosolids. Foliar N concentrations in the Standard and High treatments were 0.21 and 0.26 percentage points respectively greater than the Control in 2013.

In general, applications of biosolids have proved to be very beneficial to trees growing on this site. Effectively they have transformed the forest site from one of relative low productivity to moderately high productivity.

6. Recommendation

To evaluate the sustainability and economic benefit of the biosolids application to Rabbit Island forests, we recommend maintaining regular monitoring forest nutrition and growth, and the environmental (groundwater and soil) qualities until the end of rotation. It will be necessary to reassess wood properties of biosolids-treated radiata pine from pith to bark in the near future. Results from the long-term monitoring of this research trial will support and inform management practices for sustainable land application of biosolids, and provide direct evidence for regional councils to make informed decisions during the resource consent application process.

7. Acknowledgements

The authors wish to thank PF Olsen Limited, Tasman District Council, Nelson City Council, the Nelson Regional Sewerage Business Unit, NZ Ministry of Business, Innovation and Employment for funding or in-kind support, J.D. Graham for foliage sampling, and E.R. Langer for reviewing the report, and all those who have contributed to the project over the years.

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Long-term effect of biosolids land application on the groundwater quality at Rabbit Island

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ABSTRACT

Biosolids, rich in organic carbon and nutrients, are commonly used as supplemental fertilisers and soil amendments on crop land, and preferably on forest land in New Zealand. Biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha *Pinus radiata* plantation growing on a sandy, low fertility soil at Rabbit Island since 1996, at the rate of 300 or 450 kg ha^{-1} of nitrogen (N) every 3 years depending on the stand age. To meet the compliance reporting, 11 piezometers (monitoring wells) were installed around the Island to intensively monitor the groundwater quality change in addition to tree health and soil quality since biosolids application commenced in 1996. In addition, a research trial with three biosolids application rates (0, 300 and 600 kg N ha^{-1}) and 3 stocking rates (300, 450 and 600 stems ha^{-1}) was also established on the site in 1997 to investigate the long-term effects of biosolids application on tree nutrition, growth, soil and groundwater quality. To monitor groundwater quality change 8 piezometers were installed up- and down-gradient of the research trial.

Groundwater levels at Rabbit Island showed a seasonal as well as a tidal influence. The impact of biosolids application on groundwater levels was negligible. The EC values and concentrations of Cl, Ca, Mg and Na increased over the years, and were greater in the downgradient wells than in the upgradient wells of the research trial. This indicates some effect of biosolids application on the groundwater salt content.

The mean NO_3-N concentrations in groundwater were overall below the drinking water maximum acceptable value (MAV) of 11.3 g NO_3-N m^{-3} over the years. However, some peak concentrations of NO_3-N in certain years and wells were much greater than the MAV during the Rabbit Island compliance monitoring. This indicates that some biosolids-derived N accumulated in the soil was finally leached into the groundwater when not taken up by the trees.

Except for As, Cd, Pb and Ni, the concentrations of all other heavy metals were below the MAVs set by the Drinking Water Standards for New Zealand. We conclude that the increases of heavy metal concentrations in groundwater due to biosolids application were not large enough to be important at this stage. However, further monitoring is warranted to assess the long-term fate of biosolids-derived heavy metals in the receiving environment.

INTRODUCTION

Land application of biosolids as a supplemental fertiliser and soil amendment is one of the most common options for biosolids management (Magesan and Wang 2003). Optimum use of biosolids requires knowledge of their composition not only in relation to beneficial uses but also to environmental implications. Thus, maintaining the quality of the environment is a major consideration when developing management practices to effectively use biosolids as a nutrient and C resource and soil conditioner in agricultural or forestry production system (Bolan *et al.* 2012). In New Zealand, application of biosoilds on forest land is preferred than on agricultural land because it can reduce the risk of contaminants entering the human food chain and can also increase tree growth and subsequent economic returns (Kimberley *et al.* 2004; Wang *et al.* 2006). Treated biosolids from the Nelson Regional Sewage Treatment Plant has been applied to a 1000-ha *Pinus radiata* (radiata pine) forest plantation at Rabbit Island near Nelson City since 1996. For a requirement of the resource compliance, intensive monitoring of soil and groundwater as well as tree growth and health has been carried out since biosolids spraying commenced in 1996. An ecological assessment of the Waimea estuary is also carried out every five years. In addition, a long-term research trial was established on the site in 1997 to monitor the environmental effects of the repeated application of biosolids on the plantation, and to determine sustainable application rates. Since then tree nutrition, growth and wood properties have been assessed along with a number of environmental variables, such as soil quality (Xue *et al.* 2012). The objective of this study was to investigate the long-term effects of repeated applications of biosolids on the groundwater quality at Rabbit Island over a period of 17 years.

MATERIALS AND METHODS

Site conditions and biosolids application at Rabbit Island

Rabbit Island (41°16′15″S 173°08′51″E) lies across the southernmost part of Tasman Bay, at the top of South Island. The long narrow island runs east-west for 8 kilometres and covers 15 km^2. It lies opposite the mouth of the Waimea River, 7 kilometres to the west of Richmond, Nelson. The Island is very flat (maximum altitude 10m), and the soil is classified as a sandy raw soil (Hewitt 1998) with naturally low nutrient and organic levels. The lack of nitrogen (N) in particular, greatly limits radiata pine growth. Organic material is almost absent from soil profiles due to previous burning practices for re-establishment. The soil is permeable and provides free root access to the shallow ground water levels which are between 2 and 4 meters below the surface. Annual rainfall is around 900mm.

In 1994, when the wastewater treatment plant on Bells Island was upgraded, a sludge treatment facility was build. The biosolids produced after treatment are suitable for land application onto forest plantations. Subsequently, a 25 year discharge permit for the land application of biosolids at Rabbit Island was granted to the Nelson Regional Sewerage Unit. Application of biosolids on approximately 1000 ha of radiata pine at Rabbit Island commenced in March 1996. The application of biosolids is strictly controlled as the composition of the biosolids varies with the season and N concentrations can range from 6% to 15% of the dry solids. Applications of either 300 or 450 kg ha^{-1} of N every 3 years are permitted depending on the stand age.

Rabbit Island compliance monitoring wells

In addition to tree growth and health, intensive monitoring of soil and groundwater has been carried out since biosolids application commenced in 1996. The discharge permit requires that 11 groundwater piezometers (monitoring wells) at Rabbit Island (Fig. 1) be sampled quarterly (February, May, August, November) for water level, pH, electrical conductivity (EC), nitratenitrogen (NO_3-N), ammonium-nitrogen (NH_4-N) and chloride (Cl) and annually for heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn).

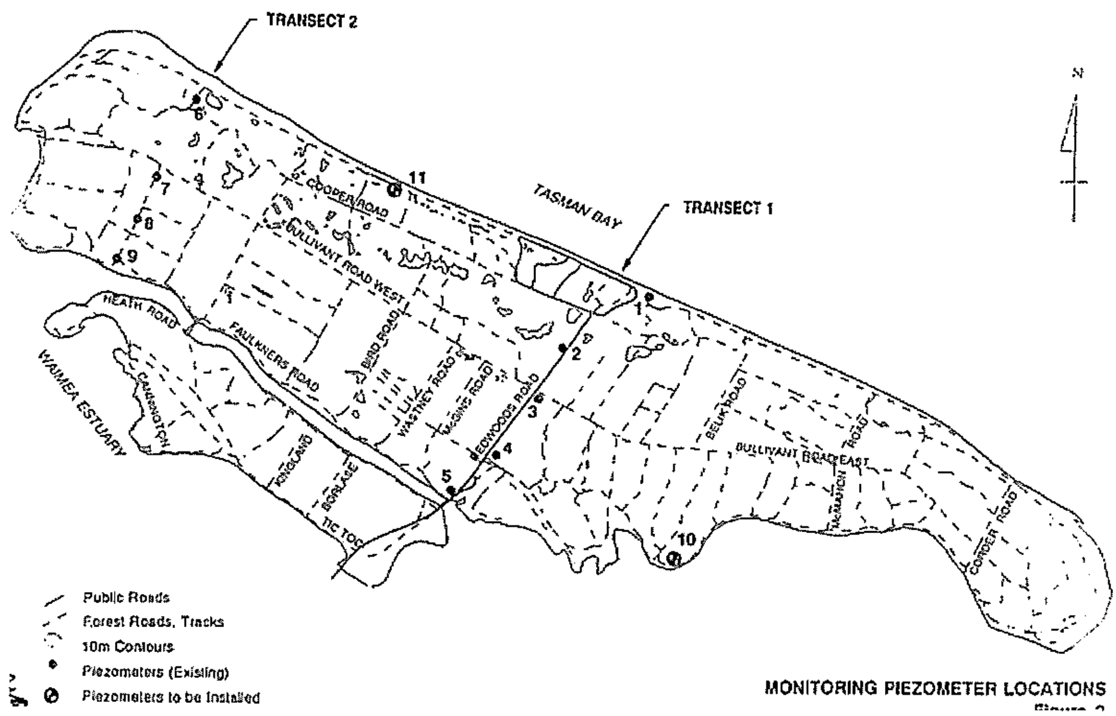


Fig. 1. Location of 11 monitoring piezometers at Rabbit Island, Nelson.

Research trial monitoring wells

The research trial was established in a 6-year-old radiata pine stand in the Rabbit Island plantation in 1997. The trial was a split-plot, randomised block design with four replicates. Three biosolids treatments, applied in main-plots, were (1) Control (no biosolids), (2) Standard treatment (300 kg N ha^{-1}), and (3) High treatment (600 kg N ha^{-1}). Each main-plot contained three tree stocking rates (subplots) at 300, 450 and 600 stems/ha. There were 36 subplots in total. Each subplot measured 25 m × 25 m, plus 5 m buffer zones. Treated biosolids from the Nelson regional wastewater treatment plant were applied in 1997, 2000, 2003, 2006, 2009 and 2012 at the same rates to the same plots. Details about properties of the biosolids applied and method of application were given by Wang *et al.* (2004).

To assess the change in groundwater levels and quality due to biosolids application, eight monitoring wells were installed around the research trial (Fig. 2). The wells were positioned along the expected southwestern groundwater flow direction towards the estuary. Three upgradient wells were installed to provide control data, five wells were installed downgradient of the trial site. Groundwater levels were measured quarterly (February, May, August and November). Groundwater samples were collected quarterly too for analysis of pH, EC, NO_3-N, NH_4-N, Cl, Ca, Mg, K and Na, and collected annually for analysis of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn).

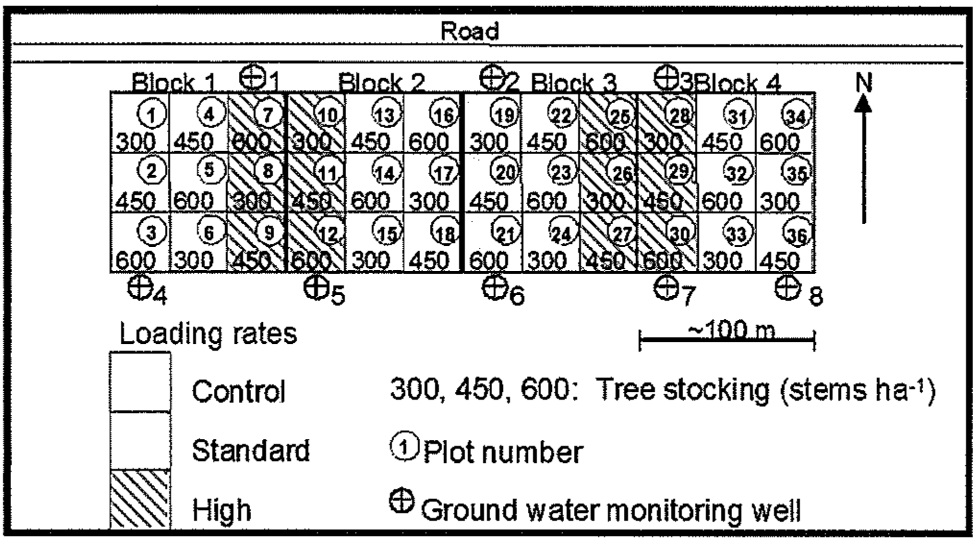


Fig. 2. Location of 8 monitoring wells around the research trial at Rabbit Island, Nelson.

Statistical analysis

In this study, only groundwater data was collected and analysed. Analysis of variance (ANOVA) and Duncan's multiple range tests were conducted to determine the statistical significance of year, season or well/piezometer location effects on groundwater level, pH, EC and concentrations of nutrients and heavy metals by using the SAS/STAT Version 9 GLM procedure.

RESULTS AND DISCUSSION

Groundwater levels

In the research trial monitoring, groundwater levels (expressed as below ground levels) showed significant variations (Fig.3a) among the years (Fig.3b), seasons (Fig. 3c) and wells (Fig. 3d). From 2007 to 2013, groundwater levels generally increased over the years with the highest groundwater levels in 2012 (Fig.3b). Groundwater levels showed a seasonal pattern with higher groundwater levels in winter and spring and lower groundwater levels in summer and autumn (Fig 3c). The highest groundwater levels were found at Well 7 while lowest level at Well 3 and 4 (Fig. 3d). From our previous study (Gielen 1999), it was found that the groundwater gradient and direction changed over time, with an overall southwestern groundwater flow direction.

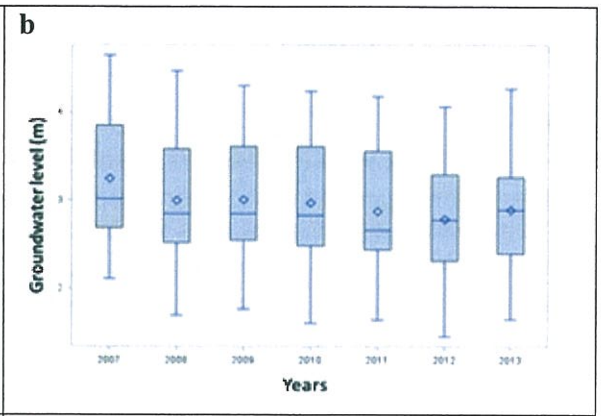
In the compliance monitoring, groundwater level was significantly different between years, seasons and locations (Fig 4) too. Groundwater levels were higher by 17-56 mm in 2010-13 and lower by 18-294 mm for other years when compared to that before biosolids spaying in 1996 (Fig. 4b). Groundwater level also showed a seasonal pattern with the decreasing order of winter (highest) > spring > autumn > summer (lowest) (Fig. 4c). The highest groundwater levels were found at Well 11 while lowest level at Well 9 and 10 (Fig. 4d).

Groundwater levels at Rabbit Island show a seasonal as well as a tidal influence (Gielen 1999). We assumed that the groundwater level variation with years and seasons was more related to the rainfall recharge or deficit. It is not expected that there was any effect of biosolids on groundwater levels due to the low frequency (once every three years) and hydraulic loading rates of biosolids application.

ANOVA results

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	6	2.60955153	0.43492526	10.29	<.0001
Season	3	2.64448106	0.88149369	20.85	<.0001
WellNo	7	95.97075943	13.71010849	324.35	<.0001
Year*WellNo	42	1.47986991	0.03523500	0.83	0.7489
Season*WellNo	21	1.17164165	0.05579246	1.32	0.1729

a



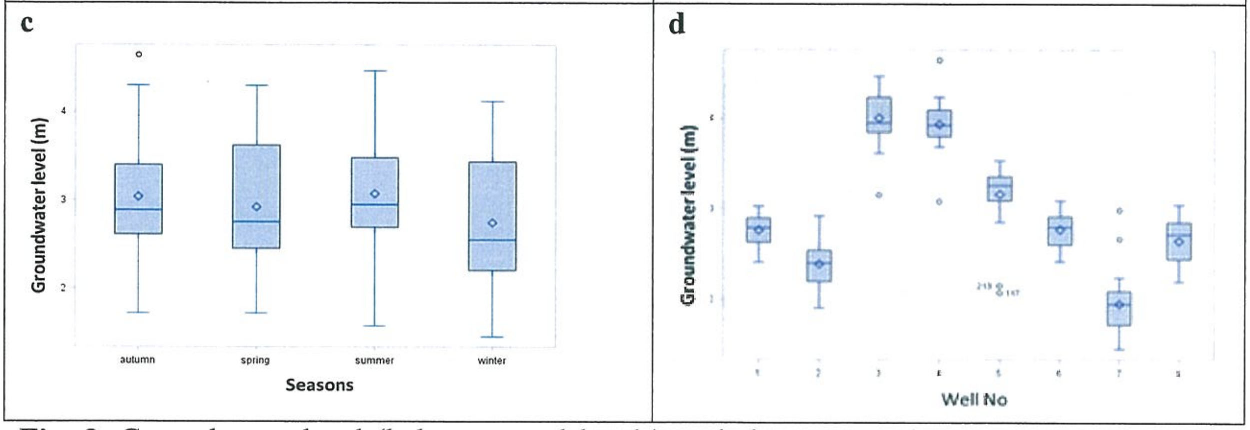


Fig. 3. Groundwater level (below ground levels) variation among the years (b), seasons (c) and wells (d) in the research trial monitoring.

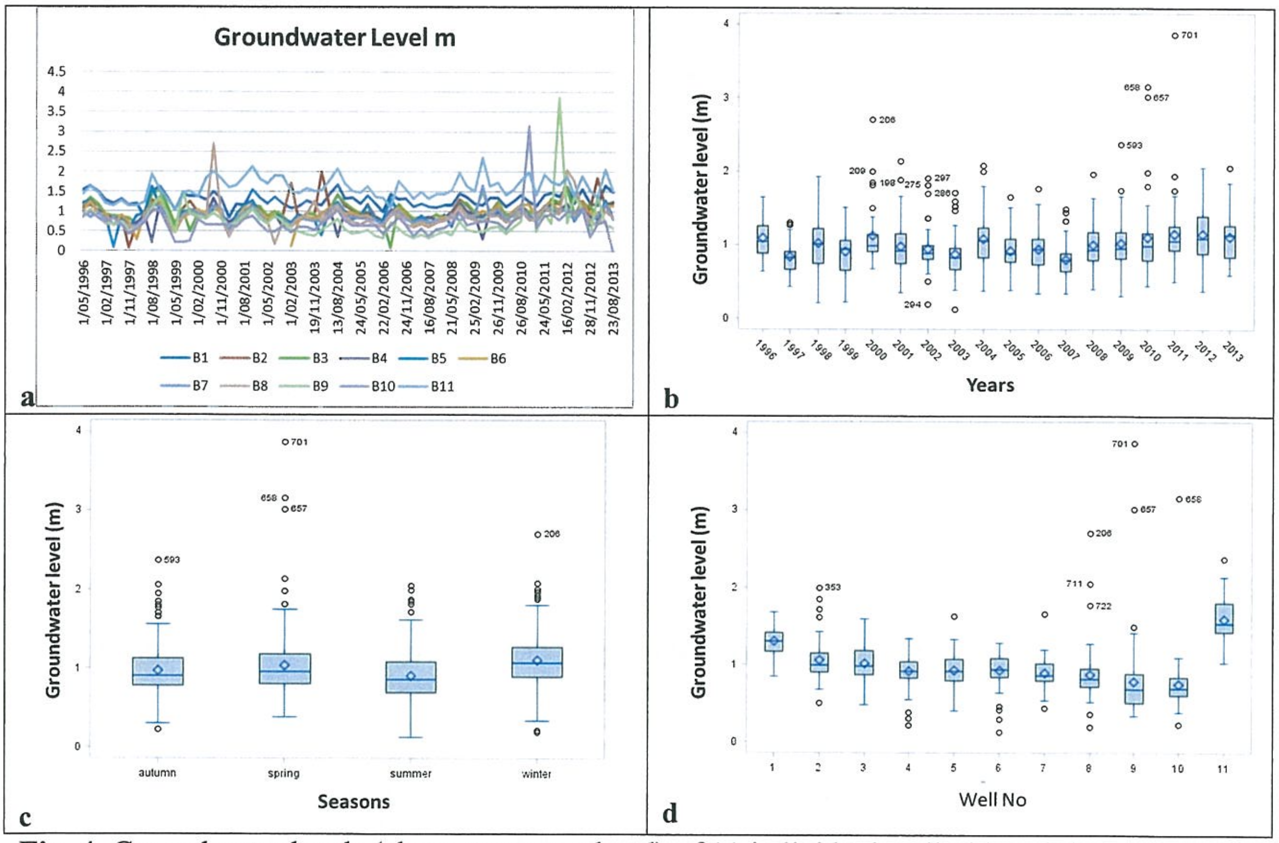


Fig. 4. Groundwater levels (above mean sea level) of 11 individual wells (a) and their variation among the years (b), seasons (c) and wells (d) in the compliance monitoring.

Groundwater quality

pH and EC

For both the compliance and research trial monitoring, there were significant differences in pH between years (Fig 5A, a) and well locations (Fig 5C, c). Significant pH differences were also found between seasons in the research trial monitoring wells (Fig 5b). The pH levels were initially high before biosolids application and generally decreased over the years closer to neutral (Fig 5A, a), implying some effect of biosolids application.

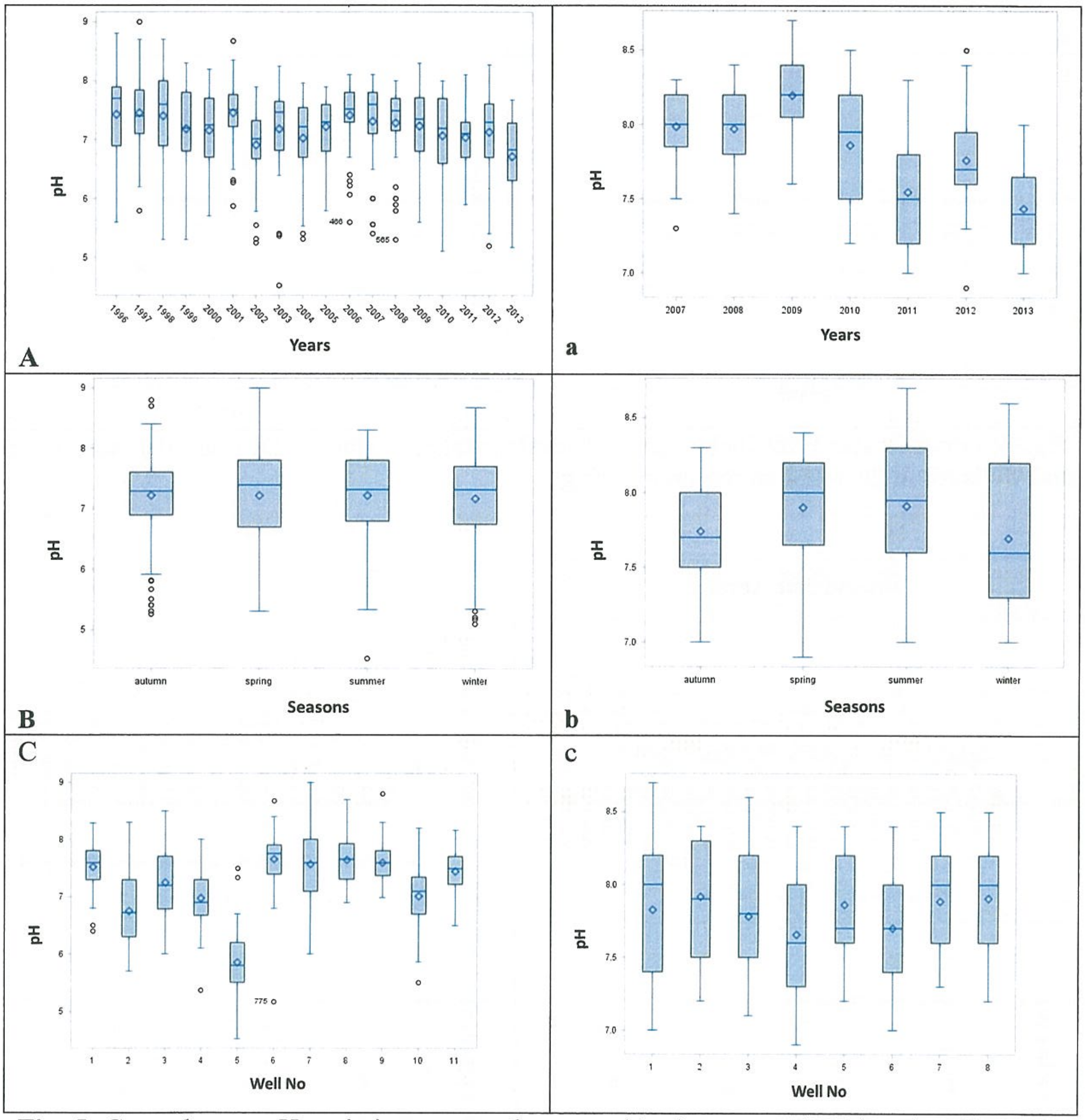


Fig. 5. Groundwater pH variation among the years (A, a), seasons (B, b) and wells (C, c) in the compliance monitoring (A, B, C) and research trial monitoring (a, b, c).

Electrical conductivity (EC) is an indicator of salt content. Similar to pH, significant differences in EC were found between years, seasons and well locations for the research trial monitoring (Fig 6a, b, c) and between years and well locations for the compliance monitoring

(Fig 6A, C). The EC averaged across the compliance monitoring wells slightly increased over the years after biosolids application (Fig. 6A). The yearly increase pattern in EC was more obvious in the research trial (Fig. 6a). This could be related to the higher loading rate of biosolids onto the plots. In the research trial monitoring, the groundwater EC was generally higher in the upgradient wells of 4, 5, 6, and 8 (except 7) than the downgradient wells of 1, 2 and 3. The results indicate there was a small but significant effect of biosolids application on the groundwater salt content.

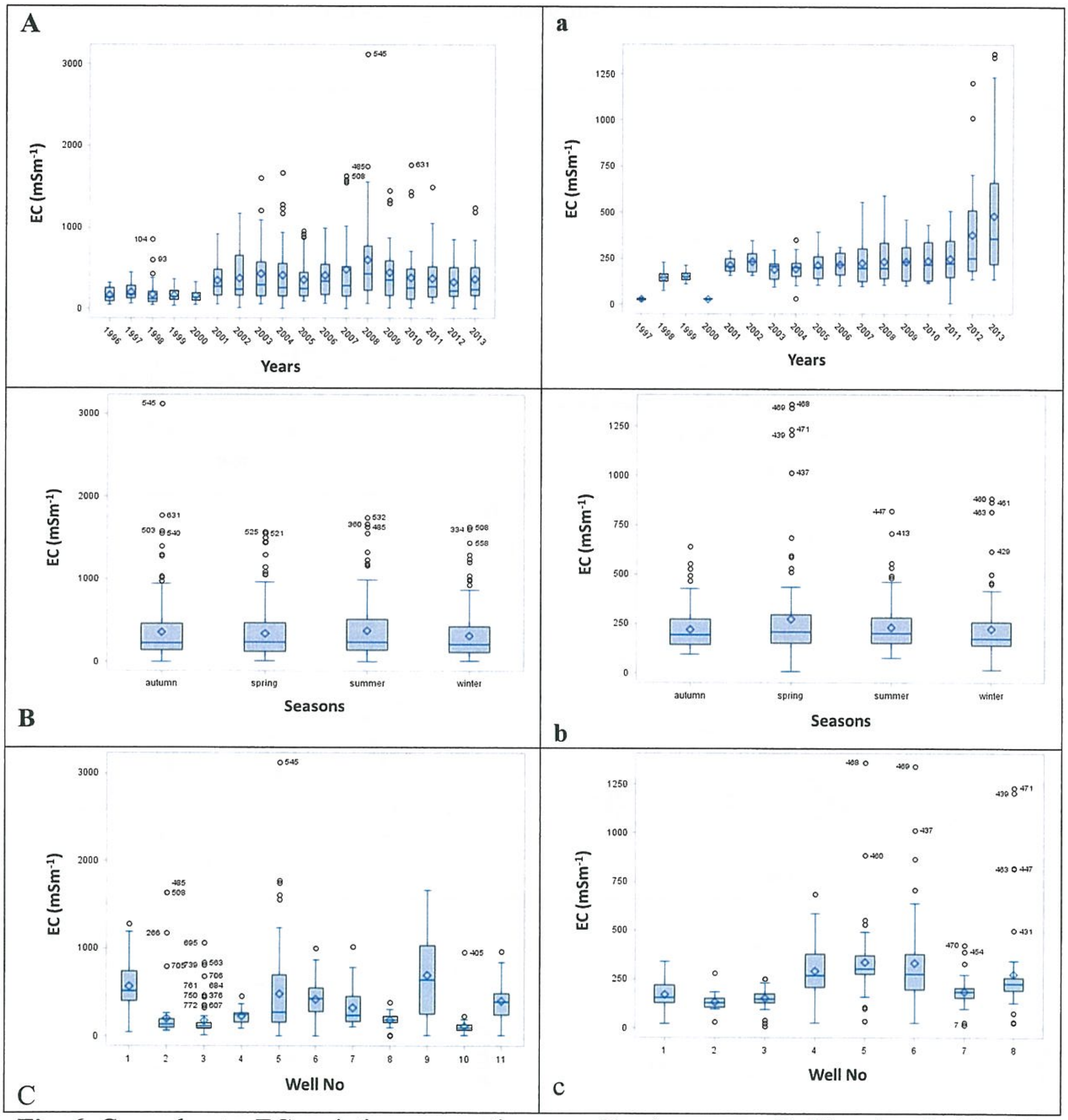


Fig. 6. Groundwater EC variation among the years (A, a), seasons (B, b) and wells (C, c) in the compliance monitoring (A, B, C) and research trial monitoring (a, b, c).

Concentrations of nutrients

In the research trial monitoring, the concentrations of Cl, Ca, Mg and Na in groundwater significantly increased over the years after application of biosolids (data not shown). It was found that the increased EC was significantly correlated to the increased concentration of Cl, Ca, Mg and Na in groundwater (Table 1). The concentrations of Cl, Ca, Mg and Na in groundwater also significantly varied with the location of wells (data not shown). The concentrations of these nutrients were generally higher in upgradient wells of 4, 5, 6, and 8 (except 7) than downgradient wells of 1, 2 and 3, further indicating a small effect of biosolids application on the groundwater nutrient concentrations.

Table 1. Pearson correlation coefficients between the groundwater EC and nutrient concentrations in 8 monitoring wells of the research trial

	Cl	Ca	Mg	K	Na	Total
EC	0.64***	0.70***	0.58***	n.s	0.54***	0.73***

Total = Cl + Ca + Mg + K + Na; n.s – not significant, *** - significant at P<0.0001.

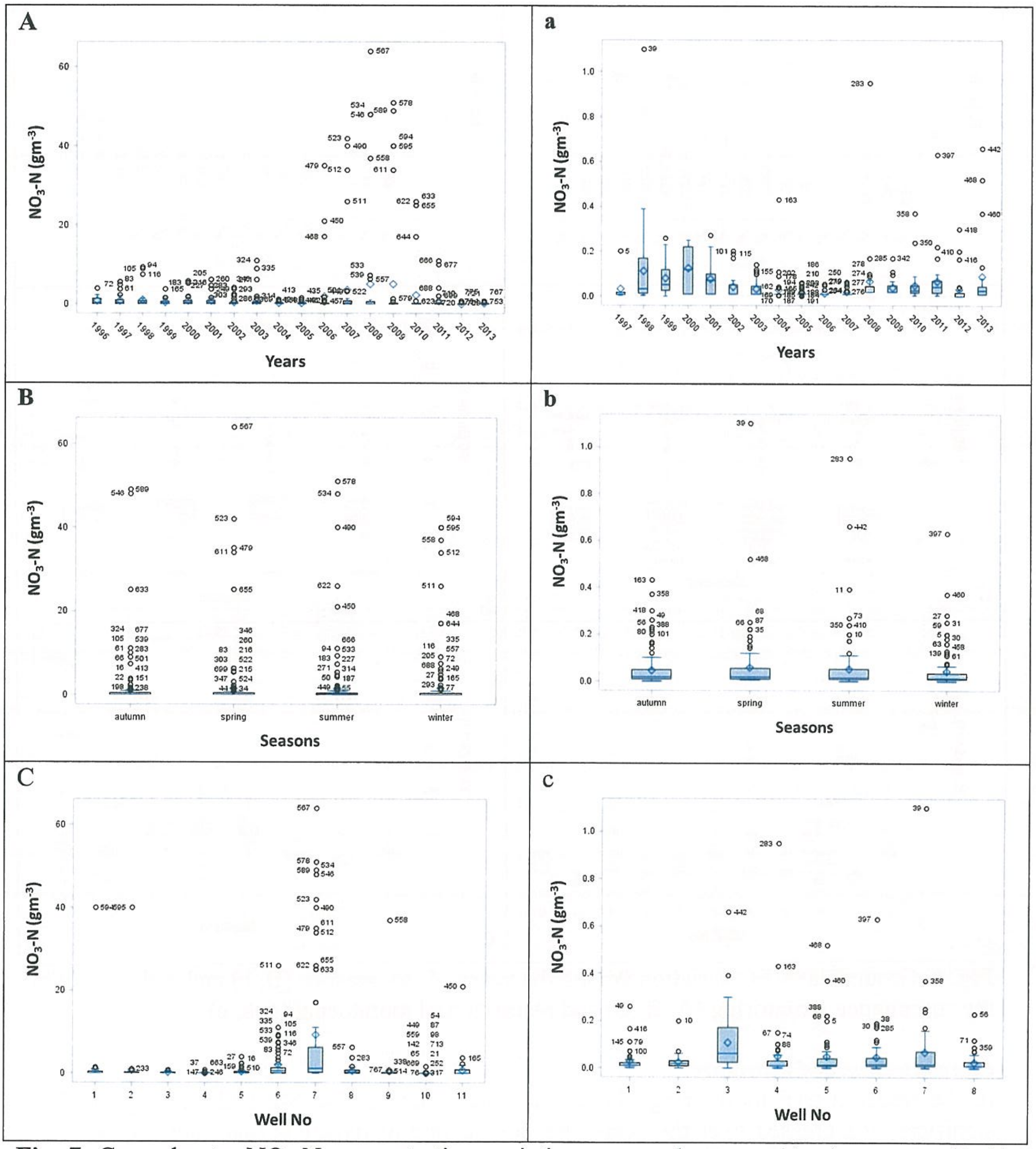


Fig. 7. Groundwater NO_3-N concentration variation among the years (A, a), seasons (B, b) and wells (C, c) in the compliance monitoring (A, B, C) and research trial monitoring (a, b, c).

In the research trial and compliance monitoring wells, the concentration of NH_4-N in groundwater was overall similar before and after biosolids application except for the occasional small peak, indicating no significant impact of biosolids application. However, there were significant differences between years and well locations (but not seasonally) in the concentration of NO_3-N in groundwater (Fig. 7). For the research trial monitoring, despite some peak concentrations of NO_3-N in certain wells (e.g. 4, 5, 6, 7) and in several different years (Fig. 7a, c), they were considerably lower than the maximum acceptable value (MAV) of 11.3 g NO_3-N m^{-3} set by the Drinking Water Standards for New Zealand (2008). For the compliance monitoring, the groundwater NO_3-N concentrations averaged across seasons and well locations exhibited a 64-fold variation (0.08-5.08 g m^{-3}) among the years of 1996-2013 (Fig. 7A). In contrast, the groundwater NO_3-N concentrations averaged across years and seasons exhibited a 231-fold variation (0.04-9.24 g m^{-3}) among the locations of 11 wells (Fig. 7C). It was found that some peak concentrations of NO_3-N especially in 2006-10 (Fig. 7A) and at Well 7 (Fig. 7B) were much greater than the MAV. This implies that the biosolids-derived organic N was finally mineralised into NO_3-N, which was then leached into the groundwater if not taken up by the trees. In the future, it will be useful to use some process-based models to predict the N mineralisation of biosolids, the movement of biosolids-derived NO_3-N along the soil profile and the NO_3-N outbreak in groundwater based on the forest stand and site conditions.

Concentrations of heavy metals

In the research trial monitoring, the concentrations of heavy metals in groundwater were significantly different among the years but not among the wells (except for As). In the compliance monitoring, the concentrations of heavy metals in groundwater were significantly different among the years and wells (except for Hg and Cd). However, the Duncan's multiple range tests showed that the concentrations of most heavy metals were generally higher before 2002 than after 2002 (data not shown). This was related to the lower detection limits of heavy metals applied by the new service provider after 2002.

The As concentrations (averaged across wells) varied significantly over the years, with some individual peaks greater than the drinking water MAV of 0.01 g m^{-3} (Fig 8A, a). The yearly change pattern showed that the average As concentrations were at the level of 0.01 g m^{-3} for many years before 2012. This could be affected by the detection limit of 0.01 g m^{-3} applied over an extended period for analysis of groundwater samples. The analyses carried out by the new service provider have a detection limit of 0.0005 g m^{-3} and it is believed that the lower average concentrations of As better represent the quality of the groundwater at Rabbit Island.

The As concentrations (averaged across years) also varied significantly among the well locations, with some individual peaks greater than the drinking water MAV of 0.01 g m^{-3} (Fig 8B, b). In the compliance monitoring, the As concentration was significantly higher in Well 3 than other wells (Fig 8B). For the research trial monitoring, the As concentration was significantly higher in Well 7 but lower in Well 6 than other wells (Fig 8b).

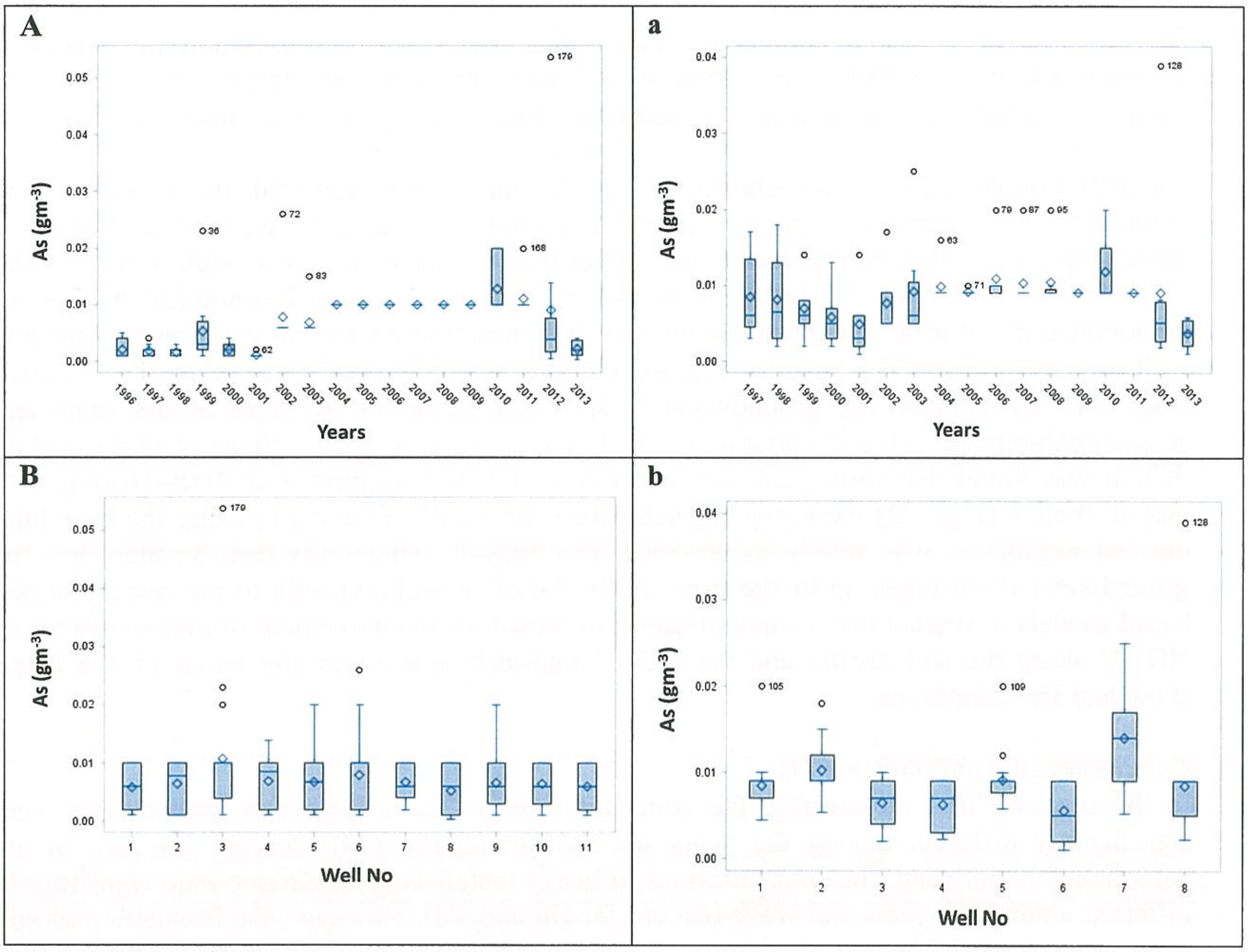


Fig. 8. Groundwater As concentration variation among the years (A, a), seasons (B, b) and wells (C, c) in the compliance monitoring (A, B, C) and research trial monitoring (a, b, c).

In the compliance monitoring, the mean and maximum concentrations of heavy metals in groundwater for each of 11 wells are listed in Table 2. Except for As, Cd, Pb and Ni, the concentrations of all other heavy metals were below the maximum acceptable values (MAVs) set by the Drinking Water Standards for New Zealand (2008). Occasionally, the As concentrations were greater than the drinking water MAV of 0.01 g m^{-3} at Well 3, 4, 5 and 9 (Table 2). In contrast, the Pb concentrations were greater than the drinking water MAV 0.01 g m^{-3} at Well 4, 7, 10 and 11 (Table 2). The maximum concentration values were found for Cd at Well 1, for Hg at Well 10 and for Ni at Well 5, which are all greater than the drinking water MAVs for these heavy metals (Table 2). Although the overall increases in the concentrations of heavy metal in groundwater were not large enough to be important, the long-term effect of biosolids application on the groundwater needs to be further monitored in relation to spatial (different wells) and temporal (different years) changes.

Table 2. Mean and maximum concentrations of heavy metals in groundwater for each of 11 wells (averaged across years).

Well No		As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
						$g\ m^{-3}$			
1	Mean	0.0051	0.0013	0.0010	0.0013	0.0042	0.0001	0.0017	0.0081
	Maximum	0.0100	**0.0060**	0.0020	0.0030	0.0080	0.0002	0.0033	0.0250
2	Mean	0.0060	0.0005	0.0035	0.0013	0.0037	0.0001	0.0118	0.0111
	Maximum	0.0100	0.0005	0.0060	0.0020	0.0080	0.0001	0.0390	0.0230
3	Mean	**0.0119**	0.0005	0.0100	0.0026	0.0090	0.0001	0.0096	0.0175
	Maximum	**0.0537**	0.0005	0.0440	0.0080	0.0330	0.0001	0.0320	0.0600
4	Mean	0.0075	0.0001	0.0025	0.0020	0.0088	0.0001	0.0121	0.0158
	Maximum	**0.0139**	0.0001	0.0070	0.0080	**0.0480**	0.0001	0.0550	0.0500
5	Mean	0.0072	0.0006	0.0071	0.0144	0.0039	0.0001	0.0345	0.0405
	Maximum	**0.0200**	0.0013	0.0312	0.1200	0.0060	0.0001	**0.1100**	0.2200
6	Mean	0.0076	0.0004	0.0009	0.0011	0.0045	0.0001	0.0095	0.0095
	Maximum	0.0260	0.0005	0.0020	0.0030	0.0100	0.0002	0.0300	0.0300
7	Mean	0.0052	0.0004	0.0019	0.0019	0.0055	0.0004	0.0007	0.0184
	Maximum	0.0100	0.0005	0.0040	0.0050	**0.0110**	0.0020	0.0013	0.0700
8	Mean	0.0069	0.0004	0.0014	0.0015	0.0035	0.0001	0.0006	0.0097
	Maximum	0.0100	0.0005	0.0030	0.0030	0.0090	0.0001	0.0008	0.0400
9	Mean	0.0049	0.0004	0.0010	0.0011	0.0032	0.0001	0.0006	0.0112
	Maximum	**0.0200**	0.0005	0.0020	0.0020	0.0070	0.0002	0.0008	0.0400
10	Mean	0.0052	0.0004	0.0022	0.0033	**0.0138**	0.0042	0.0112	0.0145
	Maximum	0.0100	0.0005	0.0070	0.0130	**0.0590**	**0.0249**	0.0320	0.0460
11	Mean	0.0044	0.0004	0.0011	0.0015	0.0058	0.0001	0.0052	0.0176
	Maximum	0.0100	0.0005	0.0020	0.0030	**0.0120**	0.0002	0.0120	0.0770
Before spraying		0.002	<0.005	<0.04	<0.01	<0.05	<0.001	<0.05	0.06
Drinking water MAV*		0.01	0.004	0.05	2	0.01	0.007	0.08	N/A

*MAV – maximum acceptable value

CONCLUSIONS

Groundwater levels showed a seasonal as well as a tidal influence. There was no biosolids application effect on groundwater levels in consideration of the low frequency and hydraulic loading rates of biosolids application. However, the EC values and concentrations of Cl, Ca, Mg and Na increased over the years, and were greater in the downgradient wells than in the upgradient wells (in the research trial monitoring). This indicates some effect of biosolids application on groundwater quality.

Although the mean NO_3-N concentrations in groundwater were overall below the drinking water MAV of 11.3 g NO_3-N m^{-3} over the years, some peak concentrations of NO_3-N were much greater than the MAV in certain years and wells (in the compliance monitoring). This indicates that some biosolids-derived N was finally leached into the groundwater when not taken up by the trees.

The concentrations of As, Cd, Pb and Ni were occasionally greater than the drinking water MAVs at certain years and wells. However, concentrations of all other heavy metals were below the drinking water MAVs during the whole monitoring period and at different locations. We conclude that at this stage the increases in groundwater heavy metal concentrations possibly due to biosolids application were not large enough to be important. However, further monitoring is warranted to assess the long-term fate of biosolids-derived heavy metals in the receiving environment. It may be necessary to adopt the lower rate of biosolids application or even some remediation solutions if the frequencies of the NO_3-N and heavy metal concentration outbreaks (greater than the MAVs) increase significantly in the future.

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