Greymouth Petroleum Limited
Ngatoro-E Hydraulic Fracturing Monitoring Programme Annual Report 2014-2015

Technical Report 2015-31

ISSN: 1178-1467 (Online)
Document: 1558482 (Word)
Document: 1560609 (Pdf)

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October 2015

Executive summary

Greymouth Petroleum Limited (GPL) operates the Ngatoro-E wellsite, located at 615 Dudley Road, Inglewood. The wellsite lies within the Waitara catchment and contains a hydrocarbon producing well and associated infrastructure.

GPL hold resource consent 9744-1, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,620 m TVD beneath the Ngatoro-E wellsite. The consent was issued by Taranaki Regional Council (the Council) on 11 December 2013 and contains 16 special conditions which set out the requirements that GPL must satisfy.

The following report for the period July 2014 to June 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL, within their Ngatoro-E wellsite. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

During the monitoring period being reported, GPL demonstrated a high level of environmental performance.

The programme of hydraulic fracturing undertaken by GPL at Ngatoro-E included the fracturing of one well; Ngatoro-17. The hydraulic fracturing of this well took place between 3 October 2014 and 15 April 2015.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2014-2015 monitoring period. The programme included the analysis of samples taken from a groundwater site on the wellsite. Samples of groundwater were obtained prior to hydraulic fracturing being undertaken to provide a baseline reference of groundwater composition, with a further round of sampling carried out post hydraulic fracturing for comparison with baseline results.

In addition, samples of both the hydraulic fracturing fluid and the formation fluids produced back to the wellhead immediately following the fracturing event were obtained for analysis.

The monitoring programme also incorporated a surface water component, whereby biomonitoring surveys were undertaken in surface water bodies surrounding the wellsite. In order to provide a baseline reference for stream health, surveys were undertaken prior to hydraulic fracturing. Additional surveys were then carried out post hydraulic fracturing to determine whether the activity had resulted in any adverse effects on stream health.

The monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by GPL had no adverse effects on local groundwater or surface water resources. There were no unauthorised incidents recording non-compliance in respect of the resource consent, or provisions in regional plans, during the period under review.

During the year, the Company demonstrated a high level of environmental and administrative performance with the resource consents.

For reference, in the 2014-2015 year, 75% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level o f environmental performance and compliance with their consents, while another 22% demonstrated a good level of environmental performance and compliance with their consents.

This report includes recommendations for the 2015-2016 year.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Limited (GPL) at their Ngatoro-E wellsite, 615 Dudley Road, Inglewood over the period October 2014 to April 2015. The wellsite is located in the Waitara catchment. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by GPL at the Ngatoro-E wellsite included the fracturing of one well; Ngatoro-17.

The programme of monitoring implemented by the Council in relation to this activity spanned the 2014-2015 monitoring period and included groundwater, surface water and discharge monitoring components. This is the first monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Ngatoro-E wellsite.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the *Resource Management Act 1991* and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consents held by the Company/companies in the Waitara catchment, the nature of the monitoring programme in place for the period under review, and a description of the activities and operations conducted in the Company's site/catchment.

Section 2 presents the results of monitoring during the period under review, including scientific and technical data.

Section 3 discusses the results, their interpretations, and their significance for the environment.

Section 4 presents recommendations to be implemented in the 2015-2016 monitoring year.

A glossary of common abbreviations and scientific terms, and a bibliography, are presented at the end of the report.

1.1.3 The Resource Management Act 1991 and monitoring

The RMA primarily addresses environmental 'effects' which are defined as positive or adverse, temporary or permanent, past, present or future, or cumulative. Effects may arise in relation to:

(a) the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
(b) physical effects on the locality, including landscape, amenity and visual effects;
(c) ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;
(d) natural and physical resources having special significance (for example recreational, cultural, or aesthetic);
(e) risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' inasmuch as is appropriate for each activity. Monitoring programmes are not only based on existing permit conditions, but also on the obligations of the RMA to assess the effects of the exercise of consents. In accordance with section 35 of the RMA, the Council undertakes compliance monitoring for consents and rules in regional plans, and maintains an overview of the performance of resource users and consent holders. Compliance monitoring, including both activity and impact monitoring, enables the Council to continually re-evaluate its approach and that of consent holders to resource management and, ultimately, through the refinement of methods and considered responsible resource utilisation, to move closer to achieving sustainable development of the region's resources.

1.1.4 Evaluation of environmental and administrative performance

Besides discussing the various details of the performance and extent of compliance by the consent holder/s during the period under review, this report also assigns a rating as to each Company's environmental and administrative performance.

Environmental performance is concerned with actual or likely effects on the receiving environment from the activities during the monitoring year. **Administrative performance** is concerned with the Company's approach to demonstrating consent compliance in site operations and management including the timely provision of information to Council (such as contingency plans and water take data) in accordance with consent conditions.

Events that were beyond the control of the consent holder and unforeseeable (that is a defence under the provisions of the *RMA* can be established) may be excluded with regard to the performance rating applied. For example loss of data due to a flood destroying deployed field equipment.

The categories used by the Council for this monitoring period, and their interpretation, are as follows:

Environmental Performance

- **High:** No or inconsequential (short-term duration, less than minor in severity) breaches of consent or regional plan parameters resulting from the activity; no adverse effects of significance noted or likely in the receiving environment .The Council did not record any verified unauthorised incidents involving significant environmental impacts and was not obliged to issue any abatement notices or infringement notices in relation to such impacts.

- **Good:** Likely or actual adverse effects of activities on the receiving environment were negligible or minor at most. There were some such issues noted during monitoring, from self reports, or in response to unauthorised incident reports, but these items were not critical, and follow-up inspections showed they have been dealt with. These minor issues were resolved positively, co-operatively, and quickly. The Council was not obliged to issue any abatement notices or infringement notices in relation to the minor non-compliant effects; however abatement notices may have been issued to mitigate an identified potential for an environmental effect to occur.

  For example:

  - High suspended solid values recorded in discharge samples, however the discharge was to land or to receiving waters that were in high flow at the time;
  - Strong odour beyond boundary but no residential properties or other recipient nearby.

- **Improvement required:** Likely or actual adverse effects of activities on the receiving environment were more than minor, but not substantial. There were some issues noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent minor non-compliant activity could elevate a minor issue to this level. Abatement notices and infringement notices may have been issued in respect of effects.

- **Poor:** Likely or actual adverse effects of activities on the receiving environment were significant. There were some items noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent moderate non-compliant activity could elevate an 'improvement required' issue to this level. Typically there were grounds for either a prosecution or an infringement notice in respect of effects.

Administrative performance

- **High:** The administrative requirements of the resource consents were met, or any failure to do this had trivial consequences and were addressed promptly and co-operatively.

- **Good:** Perhaps some administrative requirements of the resource consents were not met at a particular time, however this was addressed without repeated interventions from the Council staff. Alternatively adequate reason was provided for matters such as the no or late provision of information, interpretation of 'best practical option' for avoiding potential effects, etc.

- **Improvement required:** Repeated interventions to meet the administrative requirements of the resource consents were made by Council staff. These matters took some time to resolve, or remained unresolved at the end of the period under review. The Council may have issued an abatement notice to attain compliance.

- **Poor**: Material failings to meet the administrative requirements of the resource consents. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

For reference, in the 2014-2015 year, 75% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level o f environmental performance and compliance with their consents, while another 22% demonstrated a good level of environmental performance and compliance with their consents.

1.2 Process description

1.2.1 Hydraulic fracturing

Hydraulic fracturing is a reservoir stimulation technique used to increase the flow of hydrocarbons to the surface. The primary objective of hydraulic fracturing is to increase the permeability of the target reservoir by creating numerous small, interconnected fractures, thus increasing the flow of hydrocarbons from the formation to a given well. The process of hydraulic fracturing has enabled companies to produce hydrocarbons at economically viable rates from extremely low permeability reservoirs and those that have become depleted using 'traditional' production techniques.

The process of hydraulic fracturing involves the pumping of fluids (consisting of freshwater and a small volume of chemicals) and a proppant (medium-grained sand or small ceramic pellets) down a well, through a perforated section of the well casing, and into the target reservoir. The fluid mixture is pumped at a pressure that exceeds the fracture strength of the reservoir rock in order to create fractures. Once fractures have been initiated, pumping continues in order to force the fluid and proppant into the fractures created. The proppant is designed to keep the fractures open when the pumping is stopped. The placement of proppant into the fractures is assisted by the use of cross-linked gels. These are solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become gels that transport the proppant into the formation. Once in the formation these gels 'break' back with time and temperature to a liquid state and are flowed back to surface without disturbing the proppant wedge. With continued flow, fluids pumped as part of hydraulic fracturing process, formation fluids and hydrocarbons are drawn to the surface.

1.2.2 Ngatoro-E wellsite history

The Ngatoro-E wellsite has been in operation since 1993. The land on which the wellsite is located has historically been used for dairy farming. The area around the wellsite is rural with low population density. The closest residential community is Inglewood, a small rural community which lies approximately 6 km to the northwest of the site. The site lies in an active petroleum exploration area. GPL's petroleum exploration activity dominates this area.

The Ngatoro-17 well was drilled from 22 May to 13 August 2014. The location of the wellsite is illustrated in Figure 1.

An outline of the hydraulic fracturing activities carried out by GPL at the Ngatoro-E wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity (2014-2015)

Well	Wellsite	Consent	Date	Injection zone (m TVDss)
Ngatoro-17	Ngatoro-E	9744-1	03/10/2014	5,029-5,032
			10/10/2014	4,747-4,750.2
			16/10/2014	4,218-4,221
			22/10/2014	4,110-4,113
			31/10/2014	4,000-4,002 4,005-4,006
			03/11/2014	3,381-3,383
			09/11/2014	3,314-3,317
			15/04/2015	3,297-3,299 3,307-3,309

Figure 1 Location of Ngatoro-E wellsite where hydraulic fracturing occurred during the period under review

1.3 Resource consents

1.3.1 Discharges onto and into land

Section 15(1)(b) of the RMA stipulates that no person may discharge any contaminant onto or into land, which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations.

GPL holds resource consent 9744-1, authorising the discharge of water based hydraulic fracturing fluids into land at the Ngatoro-E wellsite. The consent was issued by the Council on 11 December 2013, under Section 87(e) of the RMA. This is the consent under which Ngatoro-17 was fractured. Consent 9744-1 contains 16 special conditions which set out the requirements that GPL must satisfy.

Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur.

Condition 2 stipulates the date after which no hydraulic fracturing fluids shall be discharged into the reservoir.

Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water).

Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed.

Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 10 is a notification requirement.

Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted.

Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 14 requires the consent holder to use best practicable options.

Condition 15 relates to the composition of the fracturing fluid.

Consent 16 is a review provision.

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor, and conduct research on the exercise of resource consents, and the effects arising, within the Taranaki region and report upon these.

The Council may therefore make and record measurements of physical and chemical parameters, take samples for analysis, carry out surveys and inspections, conduct investigations, and seek information from consent holders.

The monitoring programme implemented in relation to the hydraulic fracturing of the Ngatoro-17 well consisted of four primary components.

1.4.2 Programme liaison and management

There is generally a significant investment of time and resources by the Council in:

- ongoing liaison with resource consent holders over consent conditions and their interpretation and application;
- in discussion over monitoring requirements;
- preparation for any reviews;
- renewals;
- new consents;
- advice on the Council's environmental management strategies and content of regional plans and;
- consultation on associated matters.

1.4.3 Review of consent holder submitted data

As required by the conditions of consent 9744-1, GPL submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of a groundwater monitoring bore on the Ngatoro-E wellsite, and the analysis of the results.

In order to select suitable sites for sampling, the Council carried out a well survey in the vicinity of the Ngatoro-E wellsite to identify existing groundwater abstractions. The survey was undertaken within a defined 'area of review' which extended 1 km radially from the wellsite. The survey did not result in any suitable sampling locations being identified. In the absence of any suitable existing sampling sites, condition 5 of consent 9744-1 required GPL to install a suitable monitoring bore for the purposes of obtaining groundwater samples. The design and location of the monitoring bore was discussed and agreed with Council staff prior to installation. The details of the monitoring bore

installed are included in Table 2 and its proximity to the wellsite is illustrated in Figure 1.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from wellhead(m)	Total depth (m)	Screened interval (m)	Aquifer
Ngatoro-17	GND2469	70	40.5	28.5 – 40.5	Volcanics

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out post-fracturing for comparison with baseline results.

All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

In addition to the sampling of local groundwater, samples of both the hydraulic fracturing fluid and the reservoir fluids produced back to the wellhead immediately following each fracturing event (return fluids) were obtained for analysis at Hill Laboratories Limited.

1.4.5 Biomonitoring surveys

Biomonitoring surveys are carried out to assess whether any stormwater discharges from the Ngatoro-E wellsite during the course of fracturing operations resulted in any detrimental effects upon the biological communities within the receiving waters.

Biological surveys were performed pre and post-fracturing in the vicinity of the wellsite. Surveys were carried out in the Ngaoroiti Stream as this is the nearest surface water body to the stormwater discharge location of the Ngatoro-E wellsite.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the wellsite is illustrated in Figure 1.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
NGI000174	E 1701504 N 5659247	43 m upstream of stormwater discharge point	Kick-sampling
NGI000178	E 1701595 N 5659354	100 m downstream of stormwater discharge point	Kick-sampling
NGI000180	E 1701595 N 5659354	126 m downstream of NGI000178	Kick-sampling

2. Results

2.1 Consent holder submitted data

2.1.1 Ngatoro-17 post-fracturing discharge report

The conclusions from the Ngatoro-17 post-fracturing discharge report are summarised as follows:

- A total of eight discrete zones were fractured between 3 October 2014 and 15 April 2015, at depths between 3,297 and 5,032 m TVDss.

- A total of 13,379 barrels (bbls) (2,127 m^3) of liquid was discharged across the eight fractured zones. The total proppant weight was 313 tonnes.

- By volume, 96.56% of the fluid injected was water, 0.94% was proppant and 2.5% was chemicals.

- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. The maximum pressure exerted during the fracturing programme remained below the successfully tested levels at all times.

- The Ngatoro-17 well was opened for flowback following the completion of fracturing operations. At the completion of all flow-back operations, approximately 17,853 bbls (2,838 m^3) of fracture fluids and formation fluid were returned to the surface. Due to the fact that the flowback fluid from hydraulic fracturing operations consists of a mixture of the original fluid with native reservoir fluids, it is not feasible to calculate the exact quantity remaining underground. However, it is inferred that all or most of the hydraulic fracturing fluid has been returned to surface. It is estimated that all but 9.5 tonnes of the proppant injected (313 tonnes) remains in the formation, with small volumes expected to have settled inside the casing, where they may remain, unless circulated to the surface during later well interventions.

- All fluids that returned to the surface during flowback of the Ngatoro-17 well were disposed of by deep well injection at the Kaimiro-G wellsite, as authorised by consent 9470-1.

- It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Chemical sampling

2.2.1 Ngatoro-17 groundwater sampling survey

One site was sampled to monitor the effects of the hydraulic fracturing of the Ngatoro-17 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2469 show only minor variations in analyte concentration across all sampling events. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. There were no traces of substances

associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in any of the post-fracturing samples obtained.

Dissolved methane was detected in all samples taken from GND2469. Concentrations were at trace level and within the expected ranges for shallow groundwater across Taranaki.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Ngatoro-17 well is included below in Table 4. The certificates of analysis are included in Appendix II.

Table 4 Results of groundwater sampling carried out in GND2469

Parameter	Unit	GND2469		
		Pre-frac	Post-frac/Pre-frac	Post-frac
Sample date	-	09 Sep 2014	19 Jan 2015	14 Jul 2015
Lab number	-	TRC1412052	TRC150297	TRC152330
Total alkalinity	g/m^3 $CaCO_3$	160	153	149
Barium	mg/kg	0.0072	0.0135	0.0116
Benzene	g/m^3	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m^3	0.017	0.018	0.017
Calcium	g/m^3	14.3	14.4	13.4
Chloride	g/m^3	5.9	4.9	5.1
Electrical conductivity	mS/m@20°C	37.0	36.0	34.9
Dissolved copper	g/m^3	0.0012	<0.0005	<0.0005
Dissolved oxygen	g/m^3	2.43	0.39	0.46
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.003	<0.003	<0.003
Dissolved iron	g/m^3	0.48	0.46	0.38
Formaldehyde	g/m^3	<0.02	<0.02	<0.02
Ethylene glycol	g/m^3	<11	<4	<4
Total hydrocarbons	g/m^3	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 HCO_3	195.2	186	182
Total hardness	g/m^3 $CaCO_3$	96	97	91
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008
Potassium	g/m^3	5.6	6.0	5.1
Groundwater level	m	2.54	2.59	2.08
Methanol	g/m^3	<2	<2	<2
Methane	g/m^3	0.008	0.61	0.24
Magnesium	g/m^3	14.8	14.7	14.0
Dissolved manganese	g/m^3	0.40	0.38	0.38
Sodium	g/m^3	40	42	35
Nickel	mg/kg	<0.0005	<0.0005	<0.0005
Nitrate + nitrite nitrogen	g/m^3 N	0.002	<0.002	<0.002
Nitrite	g/m^3 N	<0.002	<0.002	<0.002
Nitrate	g/m^3 N	<0.002	<0.002	<0.002
pH	pH	7.40	7.61	7.29

Parameter	Unit	GND2469		
		Pre-frac	Post-frac/Pre-frac	Post-frac
Propylene glycol	g/m^3	<11	<4	<4
Sulphate	g/m^3	26	28	25
Sum of Anions	meq/l	3.9	3.8	3.6
Sum of Cations	meq/l	3.8	4.0	3.5
Total dissolved solids	g/m^3	260	250	230
Temperature	^oC	14.0	16.0	13.2
Toluene	g/m^3	<0.0010	<0.0010	<0.0010
o-Xylene	g/m^3	<0.002	<0.002	<0.002
m-Xylene	g/m^3	<0.0010	<0.0010	<0.0010
Dissolved zinc	g/m^3	0.0033	0.0023	<0.0010

2.2.2 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Ngatoro-17 well are summarised below in Table 5. The certificates of analysis are included in Appendix III.

Due to the viscosity of the sample of the fluid samples obtained, the range of analyses that were able to be performed on each sample were limited. The samples taken were gel like in composition, as opposed to a liquid. While the fracturing fluid is predominantly comprised of water, specialised additives are used to increase the viscosity of the fluid in order to suspend the proppant prior to injection.

Due to the volume of water used in the fracturing fluid mixture, all additives included in the mixture are highly dilute.

Table 5 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Ngatoro-17
Sample date	-	10 Oct 2014
Lab number	-	TRC1412298
Benzene	g/m^3	0.0039
Ethylbenzene	g/m^3	<0.0010
Ethylene glycol	g/m^3	23
Total hydrocarbons	g/m^3	1,110
Methane	g/m^3	<2
Propylene glycol	g/m^3	<20
Toluene	g/m^3	0.0018
o-Xylene	g/m^3	0.0012
m-Xylene	g/m^3	<0.003

A composite sample of return fluids from Ngatoro-17 was submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the

wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Ngatoro-17 well are summarised below in Table 6 and the certificates of analysis is included in Appendix III. The relatively high levels of salinity (sodium and chloride) in the sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 6 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Ngatoro-17
Sample Date	-	11 Nov 2014
Lab number	-	TRC1412295
Total alkalinity	g/m3 $CaCO_3$	2,500
Barium	mg/kg	27
Benzene	g/m^3	7.4
Dissolved bromine	g/m^3	14.6
Calcium	g/m^3	103
Chloride	g/m^3	5,700
Electrical conductivity	mS/m@20°C	2,150
Dissolved copper	g/m^3	0.007
Ethylbenzene	g/m^3	0.158
Ethane	g/m^3	0.170
Ethylene	g/m^3	0.003
Dissolved iron	g/m^3	1.37
Formaldehyde	g/m^3	<1.5
Ethylene glycol	g/m^3	<20
Total hydrocarbons	g/m^3	660
Bicarbonate	g/m^3 HCO3	2,680
Total hardness	g/m^3 CaCO3	310
Dissolved mercury	g/m^3	<0.011
Potassium	g/m^3	750
Methanol	g/m^3	<20
Methane	g/m^3	1.74
Magnesium	g/m^3	14
Dissolved manganese	g/m^3	4.6
Sodium	g/m^3	4,500
Nickel	mg/kg	0.12
Nitrate + nitrite nitrogen	g/m^3 N	<0.2
Nitrite	g/m^3 N	<0.2
Nitrate	g/m^3 N	<0.2
pH	pH	7.0
Propylene glycol	g/m^3	<20

Parameter	Unit	Ngatoro-17
Dissolved sulphur	g/m^3	5
Sulphate	g/m^3	15
Total dissolved solids	g/m^3	15100
Toluene	g/m^3	9.1
o-Xylene	g/m^3	1.00
m-Xylene	g/m^3	0.38
Dissolved zinc	g/m^3	0.08

2.3 Biomonitoring survey

The Council's standard 'kick-sampling' techniques were used to collect streambed macroinvertebrates from the Ngaoroiti Stream in relation to fracturing at the Ngatoro-E wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. Post-fracturing surveys were carried out in January and May 2015, Samples were processed to provide number of taxa (richness), MCI and SQMCIS scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The SQMCIS takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant differences in either the MCI or the SQMCIS between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Taxa richnesses were moderate to moderately high for all three sites during both post-fracturing surveys and were similar to numbers found in the previous surveys except for the NGI000174 second post-fracturing survey. There was a substantial decrease in taxa richness at the 'control' site between the first and second post-fracturing surveys which would be unrelated to any wellsite discharges and probably due to a combination of high flows and stream typology. There had been significant amounts of rain prior to sampling and river flows had exceeded 50 x median base flow on three separate occasions in the ten days prior to sampling. The 'control' site is situated in a confined section of the stream with steep sided undercut banks on the true left side and high flows would likely cause significant scouring of the streambed.

MCI scores were not significantly different from the pre-fracturing survey to the first post-fracturing survey and NGI000174 and NGI000178 had a significant improvement in score from the first post-fracturing survey to the second post-fracturing survey. SQMCIS scores remained relatively constant at all three sites during both surveys with no significant differences found among sites and surveys.

There were no significant decreases in health of the macroinvertebrate communities in the Ngatoroiti Stream shown by the two post-fracturing surveys and therefore there was no evidence that Ngatoro-E wellsite discharges to the Ngatoriti Stream had had any significant effects on macroinvertebrate communities in the stream.

2.4 Investigations, interventions, and incidents

The monitoring programme for the year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During each period matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual courses of non-compliance or failure to maintain good practices. A pro-active approach that in the first instance avoids issues occurring is favoured.

The Council operates and maintains a register of all complaints or reported and discovered excursions from acceptable limits and practices, including non-compliance with consents, which may damage the environment. The Incident Register includes events where the company concerned has itself notified the Council. The register contains details of any investigation and corrective action taken.

Complaints may be alleged to be associated with a particular site. If there is potentially an issue of legal liability, the Council must be able to prove by investigation that the identified company is indeed the source of the incident (or that the allegation cannot be proven).

During the period under review, there was no requirement for the Council to undertake any significant additional investigations and/or interventions, or record incidents, in association with the conditions in GPL's resource consent or provisions in Regional Plans relating to this site.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

The primary objective of the monitoring programme implemented by the Council was to assess whether the hydraulic fracturing activities undertaken by GPL during the period being reported had resulted in any adverse effects on useable freshwater resources. As defined in the conditions of the relevant resource consent, useable freshwater includes both groundwater and surface water systems.

To assess the level of environmental performance and compliance by GPL during the period being reported, the monitoring programme implemented by the Council included both groundwater and surface water monitoring components. The groundwater monitoring component of the programme included the sampling of groundwater at a selected site on the Ngatoro-E wellsite. The surface water monitoring component of the programme comprised biomonitoring surveys being carried out in surface water systems adjacent to the wellsite. Both groundwater and surface water systems were surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Ngatoro-17 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities. Methane was detected in low concentrations. Concentrations were within the expected range for shallow groundwater in Taranaki. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during any of the post-fracturing sampling events.

The result of the biomonitoring survey undertaken suggests that hydraulic fracturing operations did not result in adverse effects on local surface water resources, with community indices in line with reference sites of similar altitude.

In summary, the monitoring carried out by the Council during the 2014-2015 monitoring period indicates that the hydraulic fracturing activities undertaken by GPL over the period being reported had no adverse effects on local groundwater or surface water resources.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the year under review is set out in Table 7.

Table 7 Summary of performance for Consent 9744-1

Purpose: *To discharge water based hydraulic fracturing fluids into land at depths greater than 3,620 mTVD beneath the Ngatoro-E wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,620 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2017	Assessment of consent holder submitted data and site inspections	Yes
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. A dedicated groundwater monitoring well will need to be installed	Development and certification of a monitoring programme	Yes
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified sampling and analysis plan	Development and certification of a sampling and analysis plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes

Purpose: *To discharge water based hydraulic fracturing fluids into land at depths greater than 3,620 mTVD beneath the Ngatoro-E wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of consent compliance and environmental performance in respect of this consent		High
Overall assessment of administrative performance in respect of this consent		High

During the 2014-2015 monitoring periods, GPL demonstrated a high level of environmental performance and a high level of administrative performance and compliance with its resource consent as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2015-2016

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account the extent of information made available by previous authorities, its relevance under the RMA, its obligations to monitor emissions/discharges and effects under the RMA, and report to the regional community. The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

It is proposed that for 2015-2016 year, a one year post-fracturing groundwater sample is collected in April 2016. Following this, no further monitoring should be carried out in relation to the previous fracturing events at Ngatoro-E. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 9744-1 provides for an optional review of the consent an annual basis, with the next optional review date being June 2016. Condition 16 of this consent allows the Council to review consent conditions to ensure they are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time. The Council can also review the consent in order to further specify the best practicable option and/or to ensure that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Following an assessment of the current consent conditions and the results of monitoring undertaken over the period under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

4. Recommendations

1. THAT a one year post-fracturing groundwater sample is collected from GND2469 in April 2016.

2. Following the post-fracturing sampling event in April 2016, the monitoring programme should be discontinued, unless further fracturing is undertaken at the site.

3. THAT the option for a review of resource consents in June 2016, as set out in condition 16 of consent 9744-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000 litres).
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	*Resource Management Act 1991* and including all subsequent amendments.
SQMCI	Semi quantitative macroinvertebrate community index.

Bibliography and references

Greymouth Petroleum Limited (2014) Ngatoro-17 Post-Fracturing Discharge Report

Greymouth Petroleum Limited (2015) Ngatoro-17 Post-Fracturing Discharge Report (Rev.1)

Greymouth Petroleum Limited (2014) Technical Proposal – Ngatoro-17

Stark JD, (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66

Taranaki Regional Council (20145) Biomonitoring of the Ngatoroiti Stream in relation to hydraulic fracturing at the Ngatoro-E wellsite, January and May 2015. Document # 1522214.

Taranaki Regional Council (2014) Greymouth Petroleum Limited Hydraulic Fracturing - Ngatoro-E Wellsite Water Quality Monitoring Programm

Appendix II

Resource consent held by GPL

Discharge Permit

Pursuant to the Resource Management Act 1991
a resource consent is hereby granted by the
Taranaki Regional Council

Name of Consent Holder:	Greymouth Petroleum Limited P O Box 3394 NEW PLYMOUTH 4341
Decision Date:	11 December 2013
Commencement Date:	11 December 2013

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,620 mTVD beneath the Ngatoro-E wellsite
Expiry Date:	1 June 2022
Review Date(s):	June annually
Site Location:	Ngatoro-E wellsite, 615 Dudley Road, Inglewood
Legal Description:	Sec 12 Blk VIII Egmont SD (Discharge source & site)
Grid Reference (NZTM)	1701339E-5659246N
Catchment:	Waitara
Tributary:	Manganui Ngatoro Ngatoro-iti

For General, Standard and Special conditions
pertaining to this consent please see reverse side of this document

General condition

a. The consent holder shall pay to the Taranaki Regional Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the Resource Management Act 1991.

Special conditions

1. The discharge point shall be deeper than 3,620 mTVD.

   Note: mTVD = metres true vertical depth, i.e. the true vertical depth in metres below ground level.

2. There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2017.

3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.

4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:

   (a) the location of the discharge point(s);
   (b) the location of sampling sites; and
   (c) sampling frequency with reference to a hydraulic fracturing programme.

5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a monitoring bore. The bore would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.

6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
   (l) carbon-13 composition of any dissolved methane gas discovered ($^{13}C\text{-}CH_4$).

Note: The samples required, under conditions 4 and 6 could be taken and analysed by the Taranaki Regional Council or other contracted party on behalf of the consent holder.

7. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

   Note: The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 4.

8. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.

9. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing discharge report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:

   (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the results of the reviews required by condition 14;
   (e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
   (g) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

   Note: For the avoidance of doubt, the information provided with a resource consent application would usually be sufficient to constitute a 'Pre-fracturing discharge report' for any imminent hydraulic fracturing discharge. The Pre-fracturing discharge report provided for any later discharge may refer to the resource consent application or earlier Pre-fracturing discharge reports noting any differences.

10. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.

11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:

    (a) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
    (b) the contaminant volumes and compositions discharged into each fracture interval;
    (c) the volume of return fluids from each fracture interval;
    (d) an analysis for the constituents set out in conditions 6(a)to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (e) an estimate of the volume of fluids (and proppant) remaining underground;
    (f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
    (g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (h) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
    (k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

12. The reports described in conditions 9 and 11 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

13. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:

    (a) the discharge is contained within the fracture interval;
    (b) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (c) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

15. The fracture fluid shall be comprised of no less than 91% water and proppant by volume.

16. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:

    (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

    (b) further specifying the best practicable option as required by condition 14; and/or

    (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 11 December 2013

For and on behalf of
Taranaki Regional Council

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Director-Resource Management

Appendix III

Certificates of analysis (Groundwater)

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1374734 SPv1
Contact:	Regan Phipps	**Date Registered:**	20-Jan-2015
	C/- Taranaki Regional Council	**Date Reported:**	28-Jan-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ngatoro E Post HF GW
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2469 19-Jan-2015 11:24 am				
Lab Number:		1374734.1				
Individual Tests						
Sum of Anions	meq/L	3.8	-	-	-	-
Sum of Cations	meq/L	4.0	-	-	-	-
pH	pH Units	7.4	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	153	-	-	-	-
Bicarbonate	g/m³ at 25°C	186	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	97	-	-	-	-
Electrical Conductivity (EC)	mS/m	36.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	250	-	-	-	-
Dissolved Barium	g/m³	0.0135	-	-	-	-
Dissolved Bromine*	g/m³	0.018	-	-	-	-
Dissolved Calcium	g/m³	14.4	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	0.46	-	-	-	-
Dissolved Magnesium	g/m³	14.7	-	-	-	-
Dissolved Manganese	g/m³	0.38	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	6.0	-	-	-	-
Dissolved Sodium	g/m³	42	-	-	-	-
Dissolved Zinc	g/m³	0.0023	-	-	-	-
Chloride	g/m³	4.9	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	28	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2469 19-Jan-2015 11:24 am				
Lab Number:		1374734.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.003	-	-	-	-
Methane	g/m³	0.61	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Hill Laboratories
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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1450294 SPv1
Contact:	Regan Phipps	**Date Registered:**	15-Jul-2015
	C/- Taranaki Regional Council	**Date Reported:**	22-Jul-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ngatoro E 3 Month Post HF
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND 2469 14-Jul-2015 10:00 am				
Lab Number:		1450294.1				
Individual Tests						
Sum of Anions	meq/L	3.6	-	-	-	-
Sum of Cations	meq/L	3.5	-	-	-	-
pH	pH Units	7.4	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	149	-	-	-	-
Bicarbonate	g/m³ at 25°C	182	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	91	-	-	-	-
Electrical Conductivity (EC)	mS/m	34.9	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	230	-	-	-	-
Dissolved Barium	g/m³	0.0116	-	-	-	-
Dissolved Bromine*	g/m³	0.017	-	-	-	-
Dissolved Calcium	g/m³	13.4	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	0.38	-	-	-	-
Dissolved Magnesium	g/m³	14.0	-	-	-	-
Dissolved Manganese	g/m³	0.38	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.1	-	-	-	-
Dissolved Sodium	g/m³	35	-	-	-	-
Dissolved Zinc	g/m³	< 0.0010	-	-	-	-
Chloride	g/m³	5.1	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	25	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:	GND 2469 14-Jul-2015 10:00 am					
Lab Number:	1450294.1					
BTEX in Water by Headspace GC-MS						
o-Xylene g/m³	< 0.0010	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde g/m³	< 0.02	-	-	-	-	
Gases in groundwater						
Ethane g/m³	< 0.003	-	-	-	-	
Ethylene g/m³	< 0.003	-	-	-	-	
Methane g/m³	0.24	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9 g/m³	< 0.10	-	-	-	-	
C10 - C14 g/m³	< 0.2	-	-	-	-	
C15 - C36 g/m³	< 0.4	-	-	-	-	
Total hydrocarbons (C7 - C36) g/m³	< 0.7	-	-	-	-	

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Appendix IV

Certificates of analysis
(Hydraulic fracturing and return fluid)

Hill Laboratories
BETTER TESTING BETTER RESULTS

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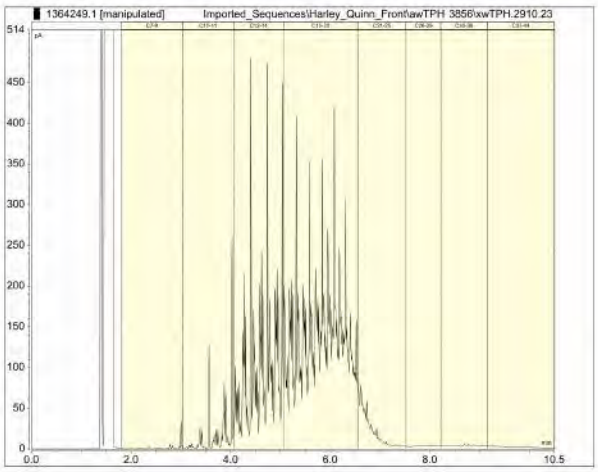
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1364249	SPv1
Contact:	Regan Phipps	**Date Registered:**	13-Dec-2014	
	C/- Taranaki Regional Council	**Date Reported:**	29-Dec-2014	
	Private Bag 713	**Quote No:**	50522	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Ngatoro E - HF Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2470 03-Dec-2014 12:00 pm				
Lab Number:		1364249.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	23	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 20 #1	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0039	-	-	-	-
Toluene	g/m³	0.0018	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	0.003	-	-	-	-
o-Xylene	g/m³	0.0012	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	4.2	-	-	-	-
C10 - C14	g/m³	390	-	-	-	-
C15 - C36	g/m³	710	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	1,110	-	-	-	-

1364249.1
GND2470 03-Dec-2014 12:00 pm
Client Chromatogram for TPH by FID



Analyst's Comments

#1 Due to the nature of the sample a dilution was required prior to analysis for propylene glycol, resulting in a detection limit higher than that normally achieved.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Client Services Manager - Environmental Division

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ANALYSIS REPORT

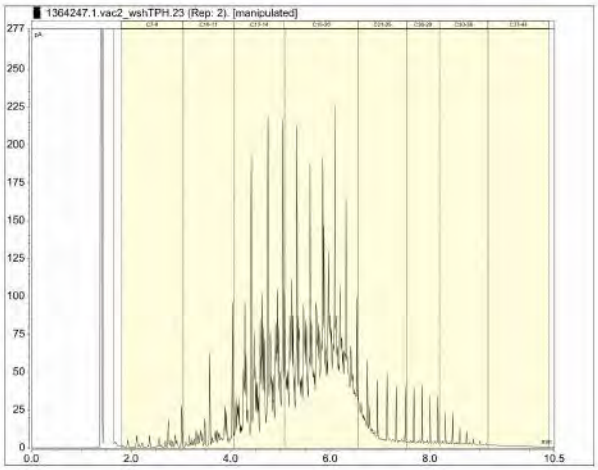
Client:	Taranaki Regional Council	**Lab No:**	1364247 SPv1
Contact:	Regan Phipps	**Date Registered:**	13-Dec-2014
	C/- Taranaki Regional Council	**Date Reported:**	05-Jan-2015
	Private Bag 713	**Quote No:**	49265
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ngatoro E- Return Fluid
		Submitted By:	Regan Phipps

Sample Type: Saline

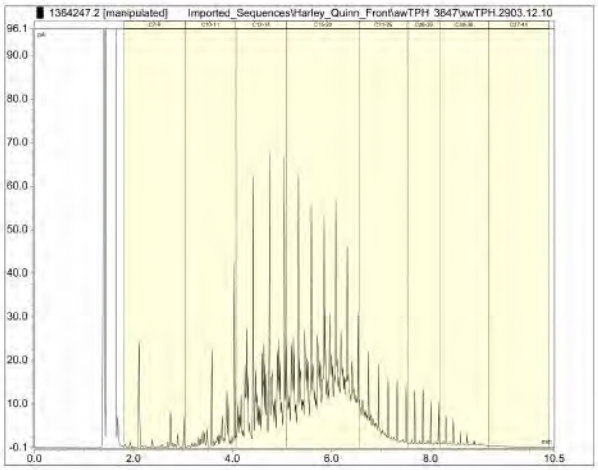
Sample Name:	GND2470 10/10/14 11:30	GND2470 11/11/14/ 13:00			
Lab Number:	1364247.1	1364247.2			
Individual Tests					
pH* pH Units	6.8	7.0	-	-	-
Total Alkalinity* g/m³ as $CaCO_3$	1,470	2,500	-	-	-
Analysis Temperature for Bicarbonate °C	23	23	-	-	-
Bicarbonate g/m³ at Analysis Temperature	1,385	2,680	-	-	-
Total Hardness* g/m³ as $CaCO_3$	1,220	310	-	-	-
Electrical Conductivity (EC)* mS/m	2,320	2,150	-	-	-
Total Dissolved Solids (TDS)* g/m³	15,600	15,100	-	-	-
Dissolved Barium* g/m³	36	27	-	-	-
Dissolved Bromine* g/m³	15.1	14.6	-	-	-
Dissolved Calcium* g/m³	470	103	-	-	-
Dissolved Copper* g/m³	0.007	0.007	-	-	-
Dissolved Iron* g/m³	1.62	1.37	-	-	-
Dissolved Magnesium* g/m³	11	14	-	-	-
Dissolved Manganese* g/m³	8.4	4.6	-	-	-
Total Mercury* g/m³	< 0.011	< 0.011	-	-	-
Dissolved Nickel* g/m³	0.06	0.12	-	-	-
Dissolved Potassium* g/m³	1,280	750	-	-	-
Dissolved Sodium* g/m³	3,800	4,500	-	-	-
Dissolved Sulphur* g/m³	19	5	-	-	-
Dissolved Zinc* g/m³	0.24	0.08	-	-	-
Chloride* g/m³	6,500	5,700	-	-	-
Nitrite-N g/m³	0.006	< 0.2	-	-	-
Nitrate-N g/m³	0.014	< 0.2	-	-	-
Nitrate* g/m³	0.063	< 0.9	-	-	-
Nitrate-N + Nitrite-N g/m³	0.021	< 0.2 #1	-	-	-
Sulphate* g/m³	56	15	-	-	-
Ethylene Glycol in Water					
Ethylene glycol* g/m³	< 20	< 20	-	-	-
Propylene Glycol in Water					
Propylene glycol* g/m³	< 20	< 20	-	-	-
Methanol in Water - Aqueous Solvents					
Methanol* g/m³	< 20	< 20	-	-	-
BTEX in Water by Headspace GC-MS					
Benzene* g/m³	2.0	7.4	-	-	-
Toluene* g/m³	1.90	9.1	-	-	-
Ethylbenzene* g/m³	0.23	0.158	-	-	-
m&p-Xylene* g/m³	1.37	1.00	-	-	-

Sample Type: Saline						
Sample Name:		GND2470 10/10/14 11:30	GND2470 11/11/14/ 13:00			
Lab Number:		1364247.1	1364247.2			
BTEX in Water by Headspace GC-MS						
o-Xylene*	g/m³	0.65	0.38	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	< 1.5	< 1.5	-	-	-
Gases in groundwater						
Ethane*	g/m³	0.091	0.170	-	-	-
Ethylene*	g/m³	< 0.003	< 0.003	-	-	-
Methane*	g/m³	0.81	1.74	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	41	19.5	-	-	-
C10 - C14*	g/m³	820	220	-	-	-
C15 - C36*	g/m³	1,570	420	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	2,400	660	-	-	-

1364247.1
GND2470 10/10/14 11:30
Client Chromatogram for TPH by FID



1364247.2
GND2470 11/11/14/ 13:00
Client Chromatogram for TPH by FID



Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN sal / NO2Nsal analysis.

Appendix No.1 - GNS report

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-2
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-2
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-2
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-2
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1-2
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-2

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1-2
pH*	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1-2
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m³ as $CaCO_3$	1-2
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	1-2
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m³ at Analysis Temperature	1-2
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-2
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m³	1-2
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	1-2
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m³	1-2
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m³	1-2
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m³	1-2
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m³	1-2
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m³	1-2
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.006 g/m³	1-2
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m³	1-2
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m³	1-2
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m³	1-2
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m³	1-2
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	1-2
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-2
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m³	1-2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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CERTIFICATE OF ANALYSIS

SALINE FOR BICARBONATE ANALYSES

Report No: 2014121603

Customer Ref:141570

Ara Heron
RJ Hill Laboratories (Hamilton)
Environmental Reports Officers
Private Bag 3205
Hamilton

GNS Sample No.		2014009053	2014009054		
Collection Date:		10/10/2014	11/11/2014		
Site ID:		1364247	1364247		
Field ID		1	2		
pH		7.40	6.95	-	-
Bicarbonate (Total)	mg/l	1385	2683	-	-
HCO_3Analysis Temperature	°C	23	23	-	-
HCO_3Analysis Date		18/12/2014	19/12/2014	-	-

SUMMARY OF METHODS AND DETECTION LIMITS

The following table gives a brief description of the methods used to conduct the analyses on this report.
The detection limits given below are those attainable in a relatively clean matrix.

Parameter	Method	*Detection Limit	
Bicarbonate (total)	HCO_3 Titration Method ASTM Standards D513-82 Vol.11.01 1988	20	mg/l
pH	Electrometric Method - APHA 4500-H+ B 22nd Edition 2012	-	-

*Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Notes: These samples were collected by yourselves (or your agent) and analysed as received at the laboratory. This report must not be reproduced, except in full, without the written consent of the signatory. Samples are held at the laboratory after reporting for a period of 2 to 6 months, dependent on sample type.

Appendix V

Biomonitoring report

To Job Manager; Callum MacKenzie
From Freshwater Biologist; Darin Sutherland
Report No DS013
Document 1522214
Date 12 June 2015

Biomonitoring of the Ngatoroiti Stream in relation to hydraulic fracturing at the Ngatoro-E wellsite, January and May 2015

Introduction

Macroinvertebrate surveys were performed at the Ngatoro-E wellsite to determine whether hydraulic fracturing (fracking) had a detrimental effect upon macroinvertebrate communities present in the Ngatoroiti Stream. The wellsite stormwater and site production water were discharged from a skimmer pit into an unnamed tributary approximately 20 m upstream of its confluence with the Ngatoroiti Stream (Figure 1). Two separate surveys were completed (January and May) to capture two separate fracking operations.

Pre-drill and post-drill surveys had been performed at the site in May and November 2014 respectively which showed no evidence of wellsite discharges having a detrimental impact on macroinvertebrate communities present in the Ngatoroiti Stream (Sutherland, 2015). Physiochemical compliance monitoring to date found no wastewater samples that were non-compliant with their consent conditions (consent 4067-2).

Methods

The first post-frac survey was undertaken on 27 January 2015 and the second post-frac survey was undertaken on 18 May 2015 at three sites (Table 1). Site 1 was the 'control' site while site 2 was the 'primary impacted' site and site 3 was the 'secondary impacted' site. The altitude of the three sites was approximately 330 m asl.

The Council's standard 'kick-sampling' technique was used to collect macroinvertebrates in the Ngatoroiti Stream (Table 1). The 'kick-sampling' technique is very similar to Protocol C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark et al, 2001).

Table 1 Biomonitoring sites in the Ngatoroiti Stream in relation to the Ngatoro-E wellsite.

Site No.	Site code	Grid reference (NZTM)	Location
1	NGI000174	1701506E-5659250N	Approx 30m upstream of the discharge tributary confluence
2	NGI000178	1701596E-5659355N	110m downstream of the discharge tributary confluence
3	NGI000180	1701631E-5659464N	220m downstream of the discharge tributary confluence

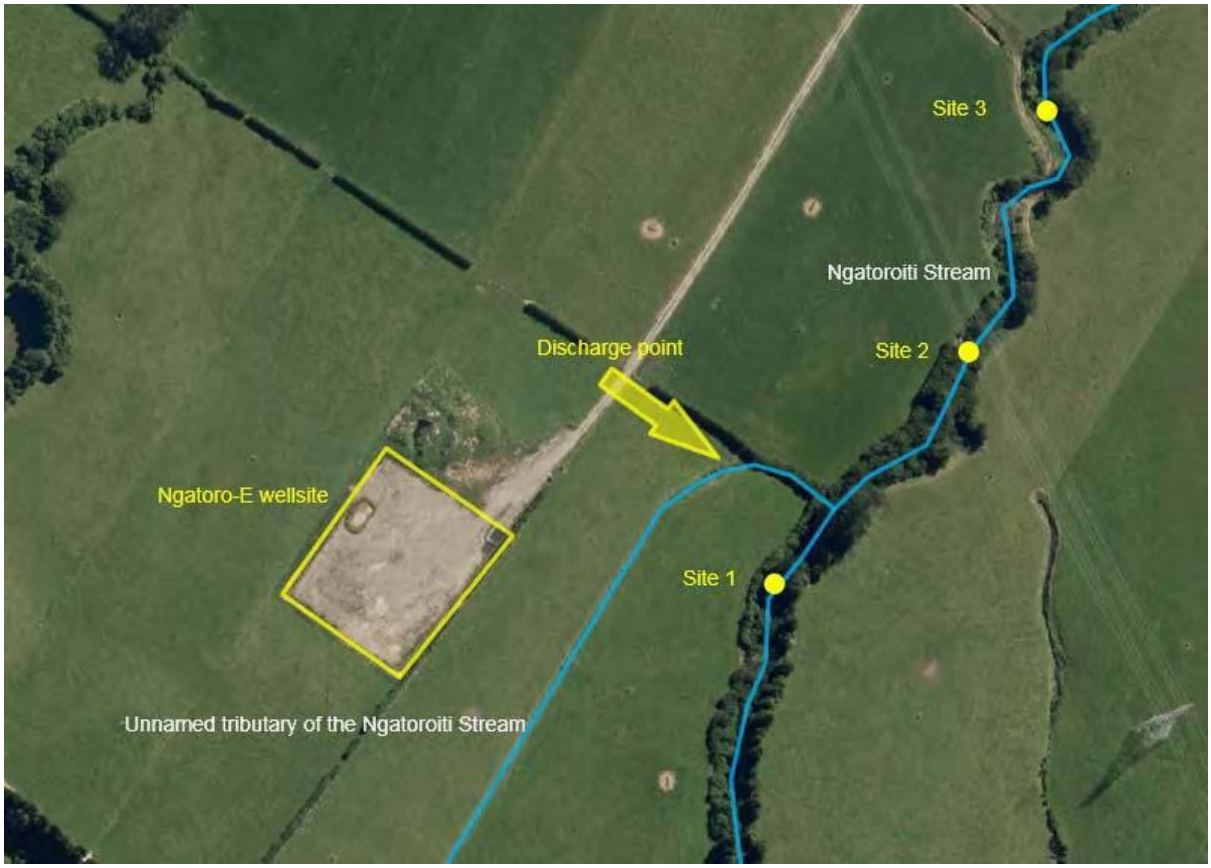

Figure 1 Biomonitoring sites in the Ngatoroiti Stream in relation to the Ngatoro-E wellsite

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology which uses Protocol P1 of NZMWG protocols of sampling macroinvertebrates in wadeable streams (Stark et al, 2001). Macroinvertebrate taxa found in each sample were recorded as:

R (rare)	= less than 5 individuals;
C (common)	= 5-19 individuals;
A (abundant)	= estimated 20-99 individuals;
VA (very abundant)	= estimated 100-499 individuals;
XA (extremely abundant)	= estimated 500 individuals or more.

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience.

By averaging the scores obtained from a list of taxa taken from one site and multiplying by a scaling factor of 20, a Macroinvertebrate Community Index (MCI) value was obtained. The MCI is a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

A semi-quantitative MCI value ($SQMCI_s$) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very

abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the $SQMCI_s$ is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower. A difference of 0.9 units or more in $SQMCI_s$ is considered significantly different (Stark, 1998).

Results

Site habitat characteristics

The water temperatures during the first post-frac survey (range 15.2-15.5 °C) were substantially warmer than for the second post-frac survey (10.5-11.3 °C). Water levels were low and water speed steady for the first post-frac survey but were substantially higher for the second post-frac survey with moderate water levels and swift flows. Water was uncoloured and clear for all sites during both surveys (Table 2). Substrate compositions during the post-drill and post-frac surveys for all three sites were comprised mainly of course gravel, cobbles and boulders.

There were slippery periphyton mats at all sites during the first post-frac survey with only site 3 having patchy filamentous algae. At the time of the second post-frac survey there were no mats or filamentous algae at any of the three sites. Moss and leaves were patchy while macrophytes were absent for all sites during both surveys while wood was patchy at site 1 for both surveys but was absent for sites 2 and 3 for both surveys. Sites 1 and 2 had complete shading from overhanging vegetation while site 3 had partial shading from overhanging vegetation.

Table 2 Summary of time of sampling and some water variables collected at three sites in the Ngatoroiti Stream sampled at 27/01/15 and 18/05/15.

	Time (NZST)		Temperature (°C)		Water Colour		Water Clarity		Flow Conditions		Water Speed	
Survey	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac
NGI000174	1315	1455	15.5	10.5	Uncoloured	Uncoloured	Clear	Clear	Low	Moderate	Steady	Swift
NGI000178	1245	1440	15.4	10.8	Uncoloured	Uncoloured	Clear	Clear	Low	Moderate	Steady	Swift
NGI000180	1215	1425	15.2	11.3	Uncoloured	Uncoloured	Clear	Clear	Low	Moderate	Steady	Swift

Macroinvertebrate communities

Data for the previous two surveys are summarised in Table 3. Results of the pre-drill and post-drill survey macroinvertebrate faunal data are summarised in (Table 4).

Table 3 Number of taxa, MCI and SQMCIs scores for two previous macorinvertebrate surveys conducted to investigate wellsite discharges at Ngatoro-E wellsite 16 May 2014 (pre-drill) and 14 November, 2014 (post-drill).

Survey	Pre-drill			Post-drill		
Site Code	NGI000174	NGI000178	NGI000180	NGI000174	NGI000178	NGI000180
No. of taxa	21	28	24	25	26	25
MCI	111	124	128	126	125	122
$SQMCI_s$	6.9	7.4	7.0	7.9	7.7	7.4

Table 4 Macroinvertebrate fauna of the Ngatoroiti Stream in relation to the Ngatoro-E wellsite surveys sampled 27 January 2015 (first post-frac) and 18 May, 2015 (second post-drill).

Taxa List	Survey	MCI	First post-drill			Second post-drill		
	Site Code	score	NGI000174	NGI000178	NGI000180	NGI000174	NGI000178	NGI000180
PLATYHELMINTHES (FLATWORMS)	*Neppia*	6	R	-	-	R	-	R
ANNELIDA (WORMS)	Oligochaeta	1	C	C	-	-	-	C
	Lumbricidae	5	-	-	-	R	-	C
MOLLUSCA	*Potamopyrgus*	4	-	-	R	R	-	R
CRUSTACEA	*Paranephrops*	5	R	-	-	-	-	-
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	A	C	C	R	C	R
	Coloburiscus	7	XA	VA	VA	A	VA	VA
	Deleatidium	8	VA	VA	VA	A	VA	VA
	Ichthybotus	8	R	-	-	-	-	R
	Nesameletus	9	C	C	VA	R	A	A
	Zephlebia group	7	C	C	A	-	R	C
PLECOPTERA (STONEFLIES)	*Acroperla*	5	-	-	R	-	-	-
	Austroperla	9	R	C	-	-	R	-
	Megaleptoperla	9	-	R	R	-	R	R
	Spaniocerca	8	-	R	-	-	-	-
	Zelandoperla	8	C	R	C	C	C	C
COLEOPTERA (BEETLES)	Elmidae	6	C	C	A	R	C	C
	Hydraenidae	8	C	R	R	R	-	R
	Hydrophilidae	5	R	-	-	-	-	-
	Ptilodactylidae	8	R	-	-	-	-	-
	Scirtidae	8	-	-	-	-	R	-
MEGALOPTERA (DOBSONFLIES)	*Archichauliodes*	7	A	C	C	-	C	C
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	C	R	C	C	C	A
	Costachorema	7	R	R	R	R	R	R
	Hydrobiosis	5	R	C	C	-	R	R
	Hydropsyche (Orthopsyche)	9	R	-	-	-	-	-
	Plectrocnemia	8	-	-	R	-	-	-
	Psilochorema	6	-	-	R	-	-	-
	Beraeoptera	8	C	C	A	A	A	A
	Confluens	5	-	-	-	-	-	R
	Helicopsyche	10	-	-	-	R	R	-
	Oeconesidae	5	-	-	-	-	-	R
	Oxyethira	2	-	-	R	-	-	-
	Pycnocentria	7	-	-	-	-	R	R
	Pycnocentrodes	5	-	-	R	-	R	-
	Triplectides	5	R	-	-	-	-	-
	Zelolessica	7	-	-	-	-	R	-
DIPTERA (TRUE FLIES)	*Aphrophila*	5	A	C	A	R	C	C
	Eriopterini	5	-	-	-	-	-	R
	Hexatomini	5	-	R	-	-	-	-
	Chironomus	1	-	-	R	-	-	-
	Orthocladiinae	2	C	C	C	-	-	R
	Polypedilum	3	C	C	R	-	-	R
	Tanypodinae	5	R	R	-	-	-	C
	Dolichopodidae	3	-	-	-	-	-	R
	Empididae	3	-	-	R	-	R	-
	Austrosimulium	3	A	C	C	-	-	-
	Tabanidae	3	-	-	-	-	-	R
	Tanyderidae	4	R	-	R	-	-	R
		No of taxa	28	23	27	15	21	30
		MCI	121	123	112	136	139	114
		SQMCIs	6.9	7.0	7.4	7.3	7.5	7.0
		EPT (taxa)	14	13	15	9	16	15
		%EPT (taxa)	50	57	56	60	76	50

'Tolerant' taxa | 'Moderately sensitive' taxa | 'Highly sensitive' taxa

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

Site 1: Approximately 30m upstream of discharge tributary confluence

A moderately high macroinvertebrate community richness of 28 taxa was found at site 1 ('control' site) at the time of the first post-frac survey. A much lower taxa richness of 15 taxa was found at the second post-frac survey. Moderate taxa richnesses had been found previously for the site (taxa richness 21 and 25; Table 3).

The first post-frac survey MCI score of 121 units indicated a community of 'very good' biological health and this score had increased significantly (Stark, 1998) to 136 units at the time of the second post-frac survey which also indicated a community of 'very good' biological health. The first post-frac survey score was not significantly different to the previous surveys but the second post-frac survey score was significantly higher (Stark, 1998) than the pre-drill survey scores (MCI scores 111 and 126; Table 3).

The first post-frac $SQMCI_S$ score of 6.9 units and the second post-frac score of 7.3 units were not significantly different (Stark, 1998) to each other or these of the previous surveys ($SQMCI_S$ score of 6.9 and 7.3 units; Table 3).

The first post-frac survey community was characterised by one 'tolerant' taxon [sandfly (*Austrosimilium*)], four 'moderately sensitive' taxa [mayflies (*Austrolima* and *Coloburiscus*), dobsonfly (*Archichauliodes*), and cranefly (*Aphrophila*)] and one 'highly sensitive' taxon [mayfly (*Deleatidium*)]. The second post-drill survey community was characterised by one 'moderately sensitive' taxon [mayfly (*Coloburiscus*)] and two 'highly sensitive' taxa [mayfly (*Deleatidium*) and caddisfly (*Beraeoptera*)] (Table 4).

Site 2. 110m d/s of discharge tributary, under power lines

A moderate macroinvertebrate community richness of 23 taxa was found at site 2 ('primary impacted' site) at the time of the first post-frac survey. A similar taxa richness of 21 taxa was found at the second post-frac survey. Slightly higher taxa richnesses had been found previously for the site (taxa richness 28 and 26; Table 3).

The first post-frac MCI score of 123 units indicated a community of 'very good' biological health and this had increased significantly (Stark, 1998) to 139 units at the time of the second post-frac survey which also indicated a community of 'very good' biological health. The first post-frac survey score was not significantly different to the previous survey's scores but the second post-frac survey was significantly higher (Stark, 1998) than the previous surveys scores (MCI scores 124 and 125; Table 3).

The first post-frac survey $SQMCI_S$ score of 7.0 units and the second post-frac survey score of 7.5 units were not significantly different (Stark, 1998) to each other or that of the previous surveys ($SQMCI_S$ score of 7.4 and 7.7 units; Table 3).

The first post-frac survey community was characterised by one 'moderately sensitive' taxon [mayfly (*Coloburiscus*)] and one 'highly sensitive' taxon [mayfly (*Deleatidium*)]. The post-drill survey community was characterised by one 'moderately sensitive' taxon [mayfly (*Coloburiscus*)] and three 'highly sensitive' taxa [mayflies (*Deleatidium* and *Nesameletus*) and caddisfly (*Beraeoptera*)] (Table 4).

Site 3. 220m downstream of the discharge tributary confluence

A moderately high macroinvertebrate community richness of 27 taxa was found at site 2 ('secondary impacted' site) at the time of the first post-frac survey. A similar taxa richness of 30 taxa was found at the second post-frac survey. Slightly lower taxa richnesses had been found previously for the site (taxa richness 24 and 25; Table 3).

The first post-frac survey MCI score of 112 units and the second post-frac survey MCI score of 114 units indicated communities of 'good' biological health. Both survey scores were significantly lower than the pre-drill survey MCI score but not significantly different (Stark, 1998) to the post-drill survey MCI score (MCI scores 128 and 122; Table 3).

The first post-frac $SQMCI_S$ score of 7.4 units and the second post-frac score of 7.0 units were not significantly different to each other (Stark, 1998) or that of the previous surveys ($SQMCI_S$ score of 7.0 and 7.4 units; Table 3).

The first post-frac survey community was characterised by three 'moderately sensitive' taxon [mayfly (*Coloburiscus*)], elimid beetles, and tipulid (*Aphrophila*)], and three 'highly sensitive' taxa [mayflies (*Deleatidium* and *Nesameletus*) and caddisfly (*Beraeoptera*)]. The second post-frac survey community was characterised by one 'tolerant' taxon [caddisfly (*Hydropsyche/ Aoteapsyche*)], one 'moderately sensitive' taxon [mayfly (*Coloburiscus*)], and three 'highly sensitive' taxa [mayflies (*Deleatidium* and *Nesameletus*) and caddisfly (*Beraeoptera*)] (Table 4).

Discussion and Conclusions

The Council's 'kick-sampling' technique was used at three sites to collect streambed macroinvertebrates from the Ngatoroiti Stream after two separate hydraulic fracturing operations at the Ngatoro-E wellsite. This has provided data to assess the impacts of discharges from the Ngatoro-E wellsite on the macroinvertebrate communities of the Ngatoroiti stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when ascertaining whether a macroinvertebrate community has been exposed to acutely toxic discharges. Macroinvertebrates when exposed to toxic chemicals may die and be swept downstream or deliberately drift downstream as an avoidance mechanism (catastrophic drift). The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. Significant differences in either the taxa richness, MCI or the $SQMCI_S$ between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

Taxa richnesses were moderate to moderately high for all three sites during both post-frac surveys and were similar to numbers found in the previous surveys except for the site 1 second post-frac survey. There was a substantial decrease in taxa richness at the 'control' site between the first and second post-frac surveys which would be unrelated to any wellsite discharges and probably due to a combination of high flows and stream typology. There had been significant amounts of rain prior to sampling and river flows had exceeded 50 x median base flow on three separate occasions in the ten days prior to sampling. The 'control' site is situated in a confined section of the stream with steep sided undercut banks on the true left side and high flows would likely cause significant scouring of the streambed.

MCI scores were not significantly different from the post-drill survey to the first post-frac survey and sites 1 and 2 had a significant improvement in score from the first post-frac survey to the second post-frac survey. $SQMCI_S$ scores remained relatively constant at all three sites during both surveys with no significant differences found among sites and surveys.

There were no significant decreases in health of the macroinvertebrate communities in the Ngatoroiti Stream shown by the two post-frac surveys and therefore there was no evidence that Ngatoro-E wellsite discharges to the Ngatoriti Stream had had any significant effects on macroinvertebrate communities in the stream.

Summary

- Macroinvertebrate surveys were completed at three sites near the Ngatoro-E wellsite to determine if any wellsite discharges to the Ngatoriti Stream following hydraulic fracturing had impacted on the health of macroinvertebrate communities in the Ngatoriti Stream.

- Taxa richnesses were moderate to moderately high for all three sites except for the 'control' site which had a substantial decrease in taxa richness, probably as a result of heavy rain and stream typology, at the second post-frac survey.

- MCI scores for the two post-frac surveys were relatively similar to each other and indicated that the macorinvertebrate communities surveyed were mostly of 'very good' health at sites 1 and 2 and 'good' health at site 3.

- There was no indication from any of the macroinvertebrate indices examined that Ngatoro-E wellsite discharges to the Ngatoriti Stream had had any significant effects on the health of the macroinvertebrate communities in the Ngatoroiti Stream.

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