

Greymouth Petroleum Limited
Kowhai-C Hydraulic Fracturing
Monitoring Programme Report
2013-2015

Technical Report 2014-110

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Executive summary

Greymouth Petroleum Limited (GPL) operates the Kowhai-C wellsite, located at 492 Otaraoa Road, Tikorangi. The wellsite lies within the Waiau catchment and contains a hydrocarbon producing well and associated infrastructure.

GPL hold resource consent 9480-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,400 m TVD beneath the Kowhai-C wellsite at or about (NZTM) 1711761E-5678397N. The consent was issued by Taranaki Regional Council (the Council) on 22 February 2013 and contains a total of 16 special conditions which set out the requirements that GPL must satisfy.

The following report for the period July 2013 to October 2014 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 Kowhai-C 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 Kowhai-C included the fracturing of one well; Kowhai-3. The hydraulic fracturing of this well took place between January and July 2014.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2013-2014 and 2014-2015 monitoring periods. The programme included the analysis of samples taken from groundwater sites surrounding 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 each 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.

GPL demonstrated a high level of environmental and high level of administrative performance and compliance with the resource consent over the reporting period.

For reference, in the 2012-2013 year, 35% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

This report includes recommendations for the 2014-2015 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 GPL Petroleum Limited (GPL) at their Kowhai-C wellsite, 492 Otaraoa Road, Tikorangi over the period July 2013 to October 2014. The wellsite is located in the Waiau catchment. The report also assesses GPL's level of environmental performance and compliance with the resource consents held in relation to the activity.

The programme of hydraulic fracturing undertaken by GPL at the Kowhai-C wellsite included the fracturing of one well; Kowhai-3.

The programme of monitoring implemented by the Council in relation to this activity spanned the 2013-2014 and 2014-2015 monitoring periods 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 Kowhai-C 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* (RMA) and the Council's obligations and general approach to monitoring sites through annual programmes, the resource consents held by GPL for discharges into land associated with hydraulic fracturing in the Waiau catchment, a description of the activities undertaken under these consents, and the nature of the monitoring programme in place for the period under review.

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 2014-2015 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 consent performance

Besides discussing the various details of the performance and extent of compliance by the consent holder during the period under review, this report also assigns a rating as to GPL'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 (i.e. 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 compliance

- **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 2012-2013 year, 35% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

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 Kowhai-C wellsite history

The Kowhai-C wellsite has been in operation since 2013. The area around the wellsite and Otaraoa Road is rural with low population density. The site lies in an active petroleum exploration area, with the Kowhai-A wellsite, the Kowhai-B wellsite, the Turangi production station and the Pohukura production station within a 10 km radius of the site. These operations function alongside pastoral farming and dairy runoff operations in the area.

The Kowhai-3 well was drilled in November 2013 and hydraulic fracturing occurred during January and July 2014. The location of the wellsite is illustrated in Figure 1. Well construction schematics for the Kowhai-3 well are included in Appendix I.

A summary of all hydraulic fracturing activities carried out by GPL at the Kowhai-C wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity (2013-2014)

Well	Wellsite	Consent	Date		Injection zone (m TVDss)	Formation
			Start	End		
Kowhai-3	Kowhai-C	9480-1	17/01/14	25/01/14	3,656 to 4,004	Kapuni
			22/07/14	22/07/14	3,627 to 3,629	Kapuni

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 **9480-1**, authorising the discharge of contaminants into land at the Kowhai-C wellsite. The consent was issued by the Council on 29 March 2012, under Section 87(e) of the RMA. This is the consent under which Kowhai-3 was fractured. Consent 9480-1 contains a total of 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 2 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.

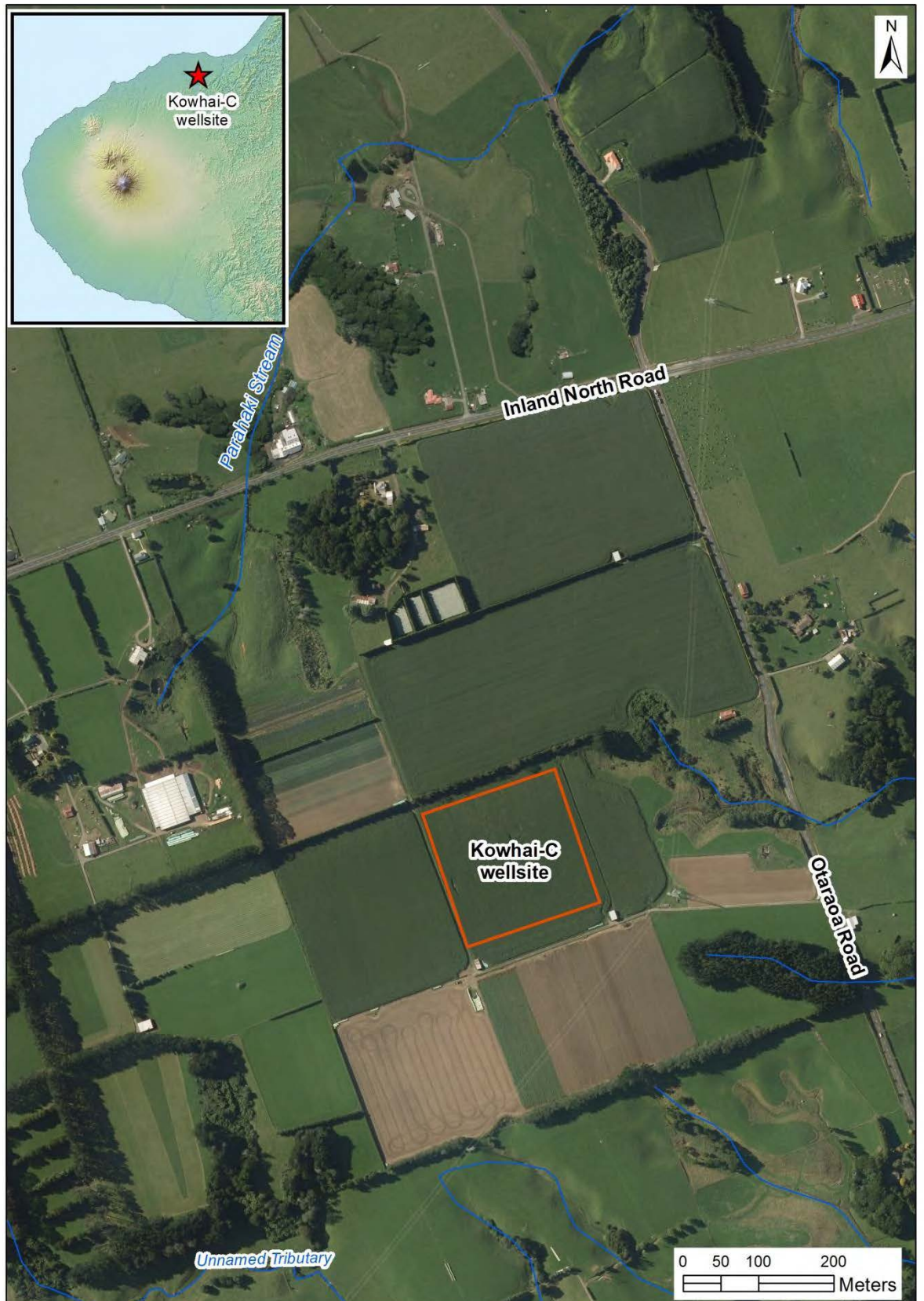


Figure 1 Location of Kowhai-C wellsite where hydraulic fracturing occurred during the period under review

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 Kowhai-3 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 consent reviews or renewals;
- 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 9480-1, 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 consents.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of existing groundwater supplies in the vicinity of the Kowhai-C 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 Kowhai-C wellsite to identify existing groundwater abstractions. The survey was undertaken within a defined 'areas of review' which extended 1 km radially from the wellsite. In total, three existing groundwater sites were identified for inclusion in the monitoring programme, GND2432, GND2433 and GND2434. The details of each site are included in Table 2 and their proximity to the wellsite is illustrated in Figure 2.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from wellsite location (m)	Total depth (m)	Screened interval (m)	Aquifer
Kowhai-3 (GND2436)	GND2432	807	180*	Unknown	Matemateaonga
	GND2433	750	2.90	Unknown	Volcanics
	GND2434	513	N/A**	N/A**	Volcanics

* Approximately

** Spring



Figure 2 Location of groundwater sampling sites in relation to Kowhai-3 well (GND2436)

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with a further round of sampling carried out post-fracturing for comparison with baseline results. Post-fracturing groundwater samples for the January fracturing events were used as pre-fracturing baseline results for the July fracturing event.

Samples taken from springs were obtained directly from the spring discharge. Where access to the bore was not available, samples were obtained at a point in the water distribution network as close to the wellhead as practicable. Samples taken from wide diameter wells were taken directly from the well. 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 Kowhai-B wellsite during the course of fracturing operations had 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 an unnamed tributary of the Waiiau Stream and an unnamed tributary of the Parahaki Stream, as these are the nearest surface water bodies to the stormwater discharge locations of the Kowhai-C wellsite and also have high amenity and community value. The surveys were undertaken to assess whether any discharges from the site during fracturing operations had resulted in any detrimental effects upon the biological communities in these waterways.

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 3.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
WAI000070	E 1172016 N 5678534	10m downstream of discharge point	Vegetation sweep
PRH000010	E 1711471 N 5678890	20m upstream of Inland North Road	Vegetation sweep



Figure 3 Location of biomonitoring sites in relation to the Kowhai-C wellsite.

2. Results

2.1 Consent holder submitted data

2.1.1 Kowhai-3 post-fracturing discharge report

The conclusions from the Kowhai-3 post-fracturing discharge report are summarised as follows:

- A total of four discrete zones were fractured over the period 17 January to 22 July 2014, at depths between 3,627 and 4,094m TVDss.
- A total of 5,717 barrels (bbls) (909 m³) of liquid was discharged across the four fractured zones. The total proppant weight was 122 tonnes.
- By volume, 82.54% of the fluid injected was water, 15.54% was proppant and 1.92% 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 Kowhai-3 well was opened for flowback following the completion of fracturing of each individual zone. At the completion of all flow-back operations, approximately 7,523 bbls (1,196 m³) of fracture fluids and formation fluid were returned to the surface. It is estimated that approximately 98 bbls (16 m³) of the fluids injected remain in the formation. Additional fluid is likely to be returned back to the surface as the well produces.
- All fluids that returned to the surface during flowback of each hydraulic fracturing operation were disposed of by deep well injection at the Kaimiro-G wellsite as authorised by consent 9470-1.
- The Zone 10 hydraulic fracturing operation ceased pumping of fluids prematurely, due to accidental mistiming of the pump shutdown by a few seconds, resulting in approximately 3 bbls of underdisplacement, leaving 1500 pounds of proppant in the casing.
- 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 Kowhai-3 groundwater sampling survey

A total of three sites were sampled to monitor the effects of the hydraulic fracturing of the Kowhai-3 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2432 indicate a slight increase in total dissolved solids and a slight decrease in calcium concentrations and pH. The results of the laboratory analysis of samples from site GND2433 indicate a

slight increase in total hardness and potassium in the post-fracturing samples. The results of the laboratory analysis of samples from site GND2434 indicate a slight decrease in chloride and bicarbonate and a slight increase in sodium, nitrate and total hardness concentrations. 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 GND2432. The methane/ethane ratios indicate that the gas is biogenic in origin and not derived from deep gas reservoirs (Table 4). Low concentrations of dissolved methane gas were discovered in the pre-fracturing groundwater sample in GND2433 and one of the post-fracturing groundwater samples in GND2433. Concentrations were 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 Kowhai-3 well is included below in Table 4. The certificates of analysis are included in Appendix III.

Table 4 Results of groundwater sampling carried out in the vicinity of the Kowhai-3 well

Parameter	Unit	GND2432				GND2433			GND2434		
		Pre-frac	Pre/post-frac*	Post-frac		Pre-frac	Pre/post-frac*	Post-frac	Pre-frac	Pre/post-frac*	Post-frac
Sample date	-	07 Jan 2014	23 Apr 2014	23 Jun 2014	22 Oct 2014	07 Jan 2014	22 Apr 2014	22 Oct 2014	07 Jan 2014	23 Apr 2014	22 Oct 2014
Lab number	-	TRC148279	TRC149947	TRC1410441	TRC1412030	TRC148280	TRC149948	TRC1412032	TRC148281	TRC149946	TRC1412031
Total Alkalinity	g/m ³ CaCO ₃	540	580		530	24	24	24	28	19.6	27
Barium	mg/kg	0.044	0.021		0.038	0.0158	0.0162	0.0168	0.030	0.030	0.029
Benzene	g/m ³	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m ³	0.12	0.12		0.13	0.045	0.056	0.055	0.063	0.062	0.088
Calcium	g/m ³	82	50		78	9.3	9.2	9.5	10.8	-	11.7
Chloride	g/m ³	13.3	12.3		13.5	8.4	8.1	9.1	19.4	19.0	18.5
Electrical conductivity	mS/m@20°C	94.1	102.6		93.8	10.6	10.8	10.6	15.7	16.4	15.4
Dissolved copper	g/m ³	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	0.0006	0.0009	0.0029	0.0007
Dissolved oxygen	g/m ³	-	-		0.60	-	-	6.77	-	-	2.99
Ethylbenzene	g/m ³	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m ³	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m ³	<0.003	<0.003	<0.004	<0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Dissolved iron	g/m ³	14.8	4.0		11.0	<0.02	<0.02	<0.02	0.04	0.10	0.02
Formaldehyde	g/m ³	0.03	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethylene glycol	g/m ³	<4	<4		<4	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m ³	<0.7	<0.7		<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m ³ HCO ₃	650	708		640	30	29.3	29.3	34.2	23.9	32.9
Total hardness	g/m ³ CaCO ₃	350	220		360	31	32	33	40	38	44
Dissolved mercury	g/m ³	<0.00008	<0.00008		<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Potassium	g/m ³	12.9	8.5		12.9	1.08	1.29	1.22	2.6	6.5	2.7
Methanol	g/m ³	<2	<2		<2	<2	<2	<2	<2	<2	<2
Methane	g/m ³	18.2	34	40	38	0.017	<0.002	<0.002	<0.002	<0.002	0.007
δ ¹³ C Value**	%			67.7							
Magnesium	g/m ³	35	24		41	1.92	2.1	2.2	3.2	3.4	3.6
Dissolved manganese	g/m ³	0.128	0.065		0.121	0.0023	0.0033	0.0055	0.0191	0.062	0.0150
Sodium	g/m ³	49	138		61	6.8	6.9	7.0	10.2	9.3	10.4
Nickel	mg/kg	0.0051	0.0019		0.0009	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrite + nitrate nitrogen	g/m ³ N	<0.002	<0.002		<0.002	0.36	0.55	0.41	0.56	0.28	1.11
Nitrite nitrogen	g/m ³ N	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002	0.004	0.002
Nitrate nitrogen	g/m ³ N	<0.002	<0.002		<0.002	0.36	0.55	0.41	0.56	0.27	1.11
pH	pH	7.3	7.6		7.2	6.3	6.4	6.3	5.8	5.9	6.0
Propylene glycol	g/m ³	<4	<4		<4	<4	<4	<4	<4	<4	<4
Sulphate	g/m ³	<0.5	1.1		<0.5	10.3	10.1	10.9	12.4	25	12.8
Sum of Anions	meq/l	11.1	12.0		11.0	0.96	0.96	1.00	1.40	1.46	1.40
Sum of Cations	meq/l	10.0	10.9		10.6	0.94	0.97	0.99	1.31	1.33	1.40
Total dissolved solids	g/m ³	540	640		570	74	84	75	111	125	119
Toluene	g/m ³	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
o-Xylene	g/m ³	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m ³	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m ³	0.66	0.27		0.84	0.0044	0.0082	0.021	0.0151	0.0136	0.0165

*Post fracturing results for January fracturing events. Pre fracturing results for July fracturing event. ** A value <50% indicates thermogenic methane, a value >50% indicates biogenic methane.

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 Kowhai-3 well for the January and July 2014 fracturing events are summarised below in Table 5. The certificates of analysis are included in Appendix IV.

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	Kowhai-3	
Sample date	-	17 Jan 2014	22 July 2014
Lab number	-	TRC148885	TRC1410880
Benzene	g/m ³	<0.0010	0.0046
Ethylbenzene	g/m ³	0.0013	0.0015
Ethylene glycol	g/m ³	8	16
Total hydrocarbons	g/m ³	69	520
Methane	g/m ³	3	<2
Propylene glycol	g/m ³	<4	<4
Toluene	g/m ³	<0.057	0.0057
o-Xylene	g/m ³	0.0033	0.0031
m-Xylene	g/m ³	0.005	0.004

A composite sample of return fluids from Kowhai-3 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 Kowhai-3 well are summarised below in Table 6 and the certificates of analysis is included in Appendix IV. The relatively high levels of salinity (sodium and chloride) in the January 2014 sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of elevated levels of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir. In the July 2014 return fluid sample, the lower levels of sodium and chloride as well as

the elevated levels of ethylene glycol and methanol indicate that the composite samples prepared contained a greater proportion of fluids introduced during fracturing activities than saline reservoir fluids. The presence of BTEX compounds indicate that the fluids are being drawn from a hydrocarbon bearing reservoir.

Table 6 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Kowhai-3	
		22 Jan 2014	22 July 2014
Sample date	-	22 Jan 2014	22 July 2014
Lab number	-	TRC148886	TRC1410881
Total alkalinity	g/m ³ CaCO ₃	49	1,650
Barium	mg/kg	17.1	21
Benzene	g/m ³	137	14.4
Bromide	g/m ³	16.5	8.3
Calcium	g/m ³	68	39
Chloride	g/m ³	5,000	2,800
Conductivity	mS/m@20°C	1,951	1,097
Dissolved copper	g/m ³	0.028	0.065
Ethylbenzene	g/m ³	89	1.25
Ethane	g/m ³	2.3	1.11
Ethylene	g/m ³	<0.005	<0.003
Dissolved iron	g/m ³	3.4	0.81
Formaldehyde	g/m ³	0.39	7.7
Ethylene glycol	g/m ³	<20	890
Bicarbonate	g/m ³ HCO ₃	2,530	1,865
Total hardness	g/m ³ CaCO ₃	250	122
Potassium	g/m ³	990	400
Methanol	g/m ³	<20	28,000
Methane	g/m ³	0.85	4.2
Magnesium	g/m ³	20	6
Dissolved manganese	g/m ³	2.8	1.32
Sodium	g/m ³	4,000	2,600
Nickel	mg/kg	0.26	0.08
Nitrate & nitrite nitrogen	g/m ³ N	<0.002	<0.2
Nitrite	g/m ³ N	<0.002	<0.2
Nitrate	g/m ³ N	<0.002	<0.2
pH	pH	7.3	7.1
Propylene glycol	g/m ³	<20	<4
Dissolved sulphur	g/m ³	23	6
Sulphate	g/m ³	68	19
Total dissolved solids	g/m ³	17,000	8,600
Toluene	g/m ³	570	21
o-Xylene	g/m ³	185	2.7
m-Xylene	g/m ³	600	8.3
Total hydrocarbons	g/m ³	-	119
Dissolved zinc	g/m ³	0.13	3.3

2.3 Biomonitoring survey

The Council's standard 'vegetation sweep' sampling techniques were used to collect streambed macroinvertebrates from the unnamed tributary of the Waiau Stream and of the Parahaki Stream in relation to fracturing at the Kowhai-C 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. Samples were processed to provide number of taxa (richness), MCI and SQMCI_s 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 SQMCI_s 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 SQMCI_s between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Taxa richnesses were moderate and similar to the median richness recorded by 'control' sites in similar streams elsewhere in the region. The macroinvertebrate communities of both streams contained more 'tolerant' than 'sensitive' taxa. A comparison of the surveys carried out prior to and after hydraulic fracturing showed no significant differences in MCI score at either site. The SQMCI_s score of 3.2 units recorded at site 1 (upstream) in the Waiau Stream was significantly (Stark, 1998) higher than that recorded in the post-fracturing survey. This was the only significant difference in SQMCI_s score recorded in the surveys and may be attributed to the reduction of both iron oxide sediment and long green filamentous algae recorded at this site.

The MCI scores recorded in this survey indicated that the stream communities were of poor 'health' (TRC, 2014), and similar to the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region. There was no indication from the results of the two surveys that the discharge from the Kowhai-C wellsite has impacted on the biological communities of the unnamed tributary of the Waiau Stream or Parahaki Stream.

A full report on the biomonitoring carried out in the vicinity of the wellsite is included in Appendix V.

2.4 Investigations, interventions, and incidents

The monitoring programme for the year was period 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 consents 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 selected sites in the vicinity of the Kowhai-C 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 Kowhai-3 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 in GND2433 and GND2434. Concentrations were within the expected range for shallow groundwater in Taranaki. Higher methane concentrations were found in GND2432, but the methane/ethane ratios for this well indicate that the methane gas is biogenic in origin and not derived from deep gas reservoirs. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater.

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 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 9480-1: To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3,000 mTVD beneath the Kowhai-C wellsite.

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,400 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2015	Assessment of consent holder submitted data and site inspections	N/A
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. If no suitable groundwater monitoring bore within 500 m of the wellsite, a monitoring well will need to be installed	Development and certification of a monitoring programme	N/A
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

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 environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

During the 2013-2014 and 2014-2015 monitoring periods, GPL demonstrated a high level of environmental and administrative performance and compliance with its resource consent as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2014-2015

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 the obligations of the RMA in terms of monitoring emissions/discharges and effects, and subsequently reporting 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 further round of groundwater sampling be carried out across all sites previously surveyed to assess for any delayed effects on local groundwater resources.

3.4 Exercise of optional review of consent

Resource consent 9480-1 provides for an optional review of the consent on an annual basis, with the next optional review date being June 2015. 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 during the 2015-2016 monitoring year, a further round of groundwater sampling be carried out across all sites previously surveyed to assess for any delayed effects on local groundwater resources as a result of fracturing events at the Kowhai-C wellsite.
2. THAT following the assessment of the results of the groundwater sampling recommended above, a review be undertaken to determine if any further monitoring is warranted, or whether the programmes can be discontinued, provided no further fracturing occurs at the Kowhai-C wellsite.
3. THAT the option for a review of resource consents in June 2015, as set out in condition 16 of consent 9480-1, 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	<i>Resource Management Act 1991</i> and including all subsequent amendments.
SQMCI	Semi quantitative macroinvertebrate community index.

Bibliography and references

GPL Petroleum Limited (2013) Technical Proposal- Kowhai 3

GPL Petroleum Limited (2014) Kowhai-3 Post-Fracturing Discharge Report

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 (2014) Biomonitoring of an unnamed tributary of the Waiau Stream and of the Parahaki Stream following hydraulic fracturing at the Kowhai-C wellsite, August 2014. Report BT039

Taranaki Regional Council (2013) GPL Petroleum Limited Hydraulic Fracturing - Kowhai-C Wellsite Water Quality Monitoring Programme

Appendix II

Resource consents 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: 22 February 2013

Commencement Date: 22 February 2013

Conditions of Consent

Consent Granted: To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3400 mTVD beneath the Kowhai-C wellsite

Expiry Date: 1 June 2020

Review Date(s): June annually

Site Location: Kowhai-C wellsite, 492 Otaraoa Road, Tikorangi
[Property owner: K & L Hunter]

Legal Description: Lot 2 DP 6166 Blk VI Waitara SD

Grid Reference (NZTM) 1711761E-5678397N

Catchment: Waiau

*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 to section 36 of the Resource Management Act 1991.

Special conditions

1. The discharge point shall be deeper than 3400 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 2015.
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). Useable 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 dedicated 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 ($^{13}\text{C-CH}_4$).

Note: The samples required, under conditions 4 and 6 could be taken and analysed by the 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 and 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 and its 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 2;
- (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;
 - (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 bottomhole 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 2; 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.

Consent 9480-1

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 95% 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 22 February 2013

For and on behalf of
Taranaki Regional Council

Chief Executive

Appendix III

Certificates of analysis (Groundwater)

ANALYSIS REPORT

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	1220958	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	08-Jan-2014	
		Date Reported:	15-Jan-2014	
		Quote No:	47915	
		Order No:		
		Client Reference:	Kowhai C Pre Frac Sample	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:	GND2432 07-Jan-2014 1:00 pm	GND2433 07-Jan-2014 1:50 pm	GND2434 07-Jan-2014 2:30 pm		
Lab Number:	1220958.1	1220958.2	1220958.3		
Individual Tests					
Sum of Anions	meq/L	11.1	0.96	1.40	-
Sum of Cations	meq/L	10.0	0.94	1.31	-
pH	pH Units	7.3	6.3	5.8	-
Total Alkalinity	g/m ³ as CaCO ₃	540	24	28	-
Bicarbonate	g/m ³ at 25°C	650 #1	30	34	-
Total Hardness	g/m ³ as CaCO ₃	350	31	40	-
Electrical Conductivity (EC)	mS/m	94.1	10.6	15.7	-
Total Dissolved Solids (TDS)	g/m ³	540	74	111	-
Dissolved Barium	g/m ³	0.044	0.0158	0.030	-
Dissolved Bromine*	g/m ³	0.12	0.045	0.063	-
Dissolved Calcium	g/m ³	82	9.3	10.8	-
Dissolved Copper	g/m ³	< 0.0005	< 0.0005	0.0009	-
Dissolved Iron	g/m ³	14.8	< 0.02	0.04	-
Dissolved Magnesium	g/m ³	35	1.92	3.2	-
Dissolved Manganese	g/m ³	0.128	0.0023	0.0191	-
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m ³	0.0051	< 0.0005	< 0.0005	-
Dissolved Potassium	g/m ³	12.9	1.08	2.6	-
Dissolved Sodium	g/m ³	49	6.8	10.2	-
Dissolved Zinc	g/m ³	0.66	0.0044	0.0151	-
Chloride	g/m ³	13.3	8.4	19.4	-
Nitrite-N	g/m ³	< 0.002	< 0.002	< 0.002	-
Nitrate-N	g/m ³	< 0.002	0.36	0.56	-
Nitrate-N + Nitrite-N	g/m ³	< 0.002	0.36	0.56	-
Sulphate	g/m ³	< 0.5	10.3	12.4	-
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 4	< 4	< 4	-
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 2	< 2	< 2	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
m&p-Xylene	g/m ³	< 0.002	< 0.002	< 0.002	-

Sample Type: Aqueous						
Sample Name:	GND2432 07-Jan-2014 1:00 pm	GND2433 07-Jan-2014 1:50 pm	GND2434 07-Jan-2014 2:30 pm			
Lab Number:	1220958.1	1220958.2	1220958.3			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	0.03	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m ³	< 0.003	< 0.003	< 0.003	-	-
Methane	g/m ³	18.2	0.017	< 0.002	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m ³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m ³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

#1 Please note that the calculation used to determine the carbonate and bicarbonate content is only valid when the total dissolved solids (TDS) content is <500mg/L. It was observed that the TDS content of this sample is >500mg/L, therefore these results should be treated as indicative only.

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	-	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-3
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H+ B 22 nd ed. 2012.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-3
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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd ed. 2012.	0.1 mS/m	1-3
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) 22 nd ed. 2012.	10 g/m ³	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-3
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-3

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NQ ₃ I 22 nd ed. 2012.	0.002 g/m ³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	1-3

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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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental Division



ANALYSIS REPORT

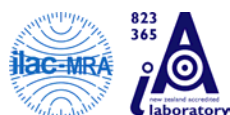
Client:	Taranaki Regional Council	Lab No:	1265755	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	23-Apr-2014	
		Date Reported:	02-May-2014	
		Quote No:	47915	
		Order No:		
		Client Reference:	Kowhai C - Post HF GW	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:	GND2433 22-Apr-2014 3:15 pm				
Lab Number:	1265755.1				

Individual Tests

Sum of Anions	meq/L	0.96	-	-	-	-
Sum of Cations	meq/L	0.97	-	-	-	-
pH	pH Units	6.4	-	-	-	-
Total Alkalinity	g/m ³ as CaCO ₃	24	-	-	-	-
Bicarbonate	g/m ³ at 25°C	29	-	-	-	-
Total Hardness	g/m ³ as CaCO ₃	32	-	-	-	-
Electrical Conductivity (EC)	mS/m	10.8	-	-	-	-
Total Dissolved Solids (TDS)	g/m ³	84	-	-	-	-
Dissolved Barium	g/m ³	0.0162	-	-	-	-
Dissolved Bromine*	g/m ³	0.056	-	-	-	-
Dissolved Calcium	g/m ³	9.2	-	-	-	-
Dissolved Copper	g/m ³	< 0.0005	-	-	-	-
Dissolved Iron	g/m ³	< 0.02	-	-	-	-
Dissolved Magnesium	g/m ³	2.1	-	-	-	-
Dissolved Manganese	g/m ³	0.0033	-	-	-	-
Dissolved Mercury	g/m ³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m ³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m ³	1.29	-	-	-	-
Dissolved Sodium	g/m ³	6.9	-	-	-	-
Dissolved Zinc	g/m ³	0.0082	-	-	-	-
Chloride	g/m ³	8.1	-	-	-	-
Nitrite-N	g/m ³	< 0.002	-	-	-	-
Nitrate-N	g/m ³	0.55	-	-	-	-
Nitrate-N + Nitrite-N	g/m ³	0.55	-	-	-	-
Sulphate	g/m ³	10.1	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	-	-	-	-
Toluene	g/m ³	< 0.0010	-	-	-	-
Ethylbenzene	g/m ³	< 0.0010	-	-	-	-
m&p-Xylene	g/m ³	< 0.002	-	-	-	-



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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous						
Sample Name:	GND2433 22-Apr-2014 3:15 pm					
Lab Number:	1265755.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	-	-	-	-
Ethylene	g/m ³	< 0.003	-	-	-	-
Methane	g/m ³	< 0.002	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	-	-	-	-
C10 - C14	g/m ³	< 0.2	-	-	-	-
C15 - C36	g/m ³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 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/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	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/m ³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H+ B 22 nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 nd ed. 2012.	1.0 g/m ³ 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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd 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) 22 nd ed. 2012.	10 g/m ³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cf E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NQ ₃ I 22 nd ed. 2012.	0.002 g/m ³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	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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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division



ANALYSIS REPORT

Client:	Taranaki Regional Council	Lab No:	1266272	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	24-Apr-2014	
		Date Reported:	09-May-2014	
		Quote No:	47915	
		Order No:		
		Client Reference:	Kowhai C - Post HF GW	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2434	GND2432			
		23-Apr-2014 8:50 am	23-Apr-2014 9:15 am			
Lab Number:		1266272.1	1266272.2			
Individual Tests						
Sum of Anions	meq/L	1.46	12.0	-	-	-
Sum of Cations	meq/L	1.33	10.9	-	-	-
pH	pH Units	5.9	7.6	-	-	-
Total Alkalinity	g/m ³ as CaCO ₃	19.6	580	-	-	-
Bicarbonate	g/m ³ at 25°C	24	710 #1	-	-	-
Total Hardness	g/m ³ as CaCO ₃	38	220	-	-	-
Electrical Conductivity (EC)	mS/m	16.4	102.6	-	-	-
Total Dissolved Solids (TDS)	g/m ³	125	640	-	-	-
Dissolved Barium	g/m ³	0.030	0.021	-	-	-
Dissolved Bromine*	g/m ³	0.062	0.12	-	-	-
Dissolved Calcium	g/m ³	9.6	50	-	-	-
Dissolved Copper	g/m ³	0.0029	< 0.0005	-	-	-
Dissolved Iron	g/m ³	0.10	4.0	-	-	-
Dissolved Magnesium	g/m ³	3.4	24	-	-	-
Dissolved Manganese	g/m ³	0.062	0.065	-	-	-
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m ³	< 0.0005	0.0019	-	-	-
Dissolved Potassium	g/m ³	6.5	8.5	-	-	-
Dissolved Sodium	g/m ³	9.3	138	-	-	-
Dissolved Zinc	g/m ³	0.0136	0.27	-	-	-
Chloride	g/m ³	19.0	12.3	-	-	-
Nitrite-N	g/m ³	0.004	< 0.002	-	-	-
Nitrate-N	g/m ³	0.27	< 0.002	-	-	-
Nitrate-N + Nitrite-N	g/m ³	0.28	< 0.002	-	-	-
Sulphate	g/m ³	25	1.1	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m ³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m ³	< 0.002	< 0.002	-	-	-



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Sample Type: Aqueous						
Sample Name:	GND2434 23-Apr-2014 8:50 am	GND2432 23-Apr-2014 9:15 am				
Lab Number:	1266272.1	1266272.2				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	-	-	-
Ethylene	g/m ³	< 0.003	< 0.003	-	-	-
Methane	g/m ³	< 0.002	34	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	-	-	-
C10 - C14	g/m ³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m ³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	< 0.7	-	-	-

Analyst's Comments

#1 Please note that the calculation used to determine the carbonate and bicarbonate content is only valid when the total dissolved solids (TDS) content is <500mg/L. It was observed that the TDS content of this sample is >500mg/L, therefore these results should be treated as indicative only.

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/m ³	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	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/m ³	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-2
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-2
pH	pH meter. APHA 4500-H+ B 22 nd ed. 2012.	0.1 pH Units	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-2
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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd 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) 22 nd ed. 2012.	10 g/m ³	1-2
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-2
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-2

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NQ ₃ I 22 nd ed. 2012.	0.002 g/m ³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	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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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division



ANALYSIS REPORT

Client:	Taranaki Regional Council	Lab No:	1342437	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	23-Oct-2014	
		Date Reported:	07-Nov-2014	
		Quote No:	47915	
		Order No:		
		Client Reference:	Kowhai C - Post HF	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:	GND2432 22-Oct-2014 8:23 am	GND2434 22-Oct-2014 9:05 am	GND2433 22-Oct-2014 9:10 am		
Lab Number:	1342437.1	1342437.2	1342437.3		
Individual Tests					
Sum of Anions	meq/L	11.0	1.40	1.00	-
Sum of Cations	meq/L	10.6	1.40	0.99	-
pH	pH Units	7.2	6.0	6.3	-
Total Alkalinity	g/m ³ as CaCO ₃	530	27	24	-
Bicarbonate	g/m ³ at 25°C	640 #1	33	29	-
Total Hardness	g/m ³ as CaCO ₃	360	44	33	-
Electrical Conductivity (EC)	mS/m	93.8	15.4	10.6	-
Total Dissolved Solids (TDS)	g/m ³	570 #1	119	75	-
Dissolved Barium	g/m ³	0.038	0.029	0.0168	-
Dissolved Bromine*	g/m ³	0.13	0.088	0.055	-
Dissolved Calcium	g/m ³	78	11.7	9.5	-
Dissolved Copper	g/m ³	< 0.0005	0.0007	0.0006	-
Dissolved Iron	g/m ³	11.0	0.02	< 0.02	-
Dissolved Magnesium	g/m ³	41	3.6	2.2	-
Dissolved Manganese	g/m ³	0.121	0.0150	0.0055	-
Dissolved Mercury	g/m ³	< 0.00008	< 0.00008	< 0.00008	-
Dissolved Nickel	g/m ³	0.0009	< 0.0005	< 0.0005	-
Dissolved Potassium	g/m ³	12.9	2.7	1.22	-
Dissolved Sodium	g/m ³	61	10.4	7.0	-
Dissolved Zinc	g/m ³	0.84	0.0165	0.021	-
Chloride	g/m ³	13.5	18.5	9.1	-
Nitrite-N	g/m ³	< 0.002	0.002	< 0.002	-
Nitrate-N	g/m ³	< 0.002	1.11	0.41	-
Nitrate-N + Nitrite-N	g/m ³	< 0.002	1.11	0.41	-
Sulphate	g/m ³	< 0.5	12.8	10.9	-
Ethylene Glycol in Water					
Ethylene glycol*	g/m ³	< 4	< 4	< 4	-
Propylene Glycol in Water					
Propylene glycol*	g/m ³	< 4	< 4	< 4	-
Methanol in Water - Aqueous Solvents					
Methanol*	g/m ³	< 2	< 2	< 2	-
BTEX in Water by Headspace GC-MS					
Benzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
Toluene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
Ethylbenzene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-
m&p-Xylene	g/m ³	< 0.002	< 0.002	< 0.002	-



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous						
Sample Name:	GND2432 22-Oct-2014 8:23 am	GND2434 22-Oct-2014 9:05 am	GND2433 22-Oct-2014 9:10 am			
Lab Number:	1342437.1	1342437.2	1342437.3			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m ³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m ³	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m ³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m ³	< 0.004	< 0.003	< 0.003	-	-
Methane	g/m ³	38	0.007	< 0.002	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m ³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m ³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m ³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

#1 Please note that the calculation used to determine the carbonate and bicarbonate content is only valid when the total dissolved solids (TDS) content is <500mg/L. It was observed that the TDS content of this sample is >500mg/L, therefore these results should be treated as indicative only.

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/m ³	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	1-3
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/m ³	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H+ B 22 nd ed. 2012.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-3
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 22 nd ed. 2012.	1.0 g/m ³ at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 nd ed. 2012.	1.0 g/m ³ as CaCO ₃	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22 nd ed. 2012.	0.1 mS/m	1-3
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) 22 nd ed. 2012.	10 g/m ³	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.00010 g/m ³	1-3
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.005 g/m ³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-3

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0005 g/m ³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.05 g/m ³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.02 g/m ³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NQ ₃ I 22 nd ed. 2012.	0.002 g/m ³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 nd ed. 2012.	0.5 g/m ³	1-3

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

All results are reported with respect to VPDB, normalized to our internal standards RM8560 (-44.8‰ for $\delta^{13}\text{C}$). The analytical precision for these measurements are 0.3‰ for $\delta^{13}\text{C}$. Samples were run through a GC column and combusted at 900°C for ^{13}C and analysed on an IsoPrime mass spectrometer.

Samples will be kept for 3 months from the date of the report and discarded unless otherwise notified.

Appendix IV

Certificates of analysis (Hydraulic fracturing and return fluid)

ANALYSIS REPORT

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	1230665	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	01-Feb-2014	
		Date Reported:	17-Feb-2014	
		Quote No:	49265	
		Order No:		
		Client Reference:	Kowhai C - Return Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Saline

Sample Name:	GND2436 22-Jan-2014 2:30 pm				
Lab Number:	1230665.1				

Individual Tests

pH*	pH Units	7.3	-	-	-	-
Total Alkalinity*	g/m ³ as CaCO ₃	49	-	-	-	-
Analysis Temperature for Bicarbonate	°C	22	-	-	-	-
Bicarbonate	g/m ³ at Analysis Temperature	2,530	-	-	-	-
Total Hardness*	g/m ³ as CaCO ₃	250	-	-	-	-
Electrical Conductivity (EC)*	mS/m	1,951	-	-	-	-
Total Dissolved Solids (TDS)*	g/m ³	17,000	-	-	-	-
Dissolved Barium*	g/m ³	17.1	-	-	-	-
Dissolved Bromine*	g/m ³	16.5	-	-	-	-
Dissolved Calcium*	g/m ³	68	-	-	-	-
Dissolved Copper*	g/m ³	0.028	-	-	-	-
Dissolved Iron*	g/m ³	3.4	-	-	-	-
Dissolved Magnesium*	g/m ³	20	-	-	-	-
Dissolved Manganese*	g/m ³	2.8	-	-	-	-
Total Mercury*	g/m ³	0.084	-	-	-	-
Dissolved Nickel*	g/m ³	0.26	-	-	-	-
Dissolved Potassium*	g/m ³	990	-	-	-	-
Dissolved Sodium*	g/m ³	4,000	-	-	-	-
Dissolved Sulphur*	g/m ³	23	-	-	-	-
Dissolved Zinc*	g/m ³	0.13	-	-	-	-
Chloride*	g/m ³	5,000	-	-	-	-
Nitrite-N	g/m ³	< 0.002	-	-	-	-
Nitrate-N	g/m ³	< 0.002	-	-	-	-
Nitrate*	g/m ³	< 0.010	-	-	-	-
Nitrate-N + Nitrite-N	g/m ³	< 0.002	-	-	-	-
Sulphate*	g/m ³	68	-	-	-	-

Free Product GC Scan by FID

Free Product*	mL/100mL	7.1	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	< 20	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 20	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 20	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m ³	137	-	-	-	-

Sample Type: Saline

Sample Name:	GND2436 22-Jan-2014 2:30 pm				
Lab Number:	1230665.1				
BTEX in Water by Headspace GC-MS					
Toluene*	g/m ³	570	-	-	-
Ethylbenzene*	g/m ³	89	-	-	-
m&p-Xylene*	g/m ³	600	-	-	-
o-Xylene*	g/m ³	185	-	-	-
Formaldehyde in Water by DNPH & LCMSMS					
Formaldehyde*	g/m ³	0.39	-	-	-
Gases in groundwater					
Ethane*	g/m ³	2.3	-	-	-
Ethylene*	g/m ³	< 0.005	-	-	-
Methane*	g/m ³	0.85	-	-	-

Analyst's Comments

Due to the type of matrix found in sample 1230665.1, a dilution was required for Methanol analysis. Hence the higher detection limit reported.

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

Appendix No.2 - Bicarbonate Report - GND2436 - 1230665.1

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
Free Product GC Scan by FID*	Dilution of free product in organic solvent	1.0 mL/100mL	1
Volume of Free Product present in TPH Water samples*	Volumes estimated using Measuring Cylinder.	1.0 mL/100mL	1
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	1
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
pH*	pH meter. APHA 4500-H+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	1
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	1
Bicarbonate	Bicarbonate (HCO ₃) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m ³ at Analysis Temperature	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m ³ 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.	50 g/m ³	1
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	1
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m ³	1
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m ³	1
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m ³	1

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.004 g/m ³	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 nd ed. 2012.	0.0021 g/m ³	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.006 g/m ³	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.0 g/m ³	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	1
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m ³	1
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.004 g/m ³	1
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl ⁻ E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
Nitrate*	Calculation from Nitrate-N.	0.010 g/m ³	1
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m ³	1

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

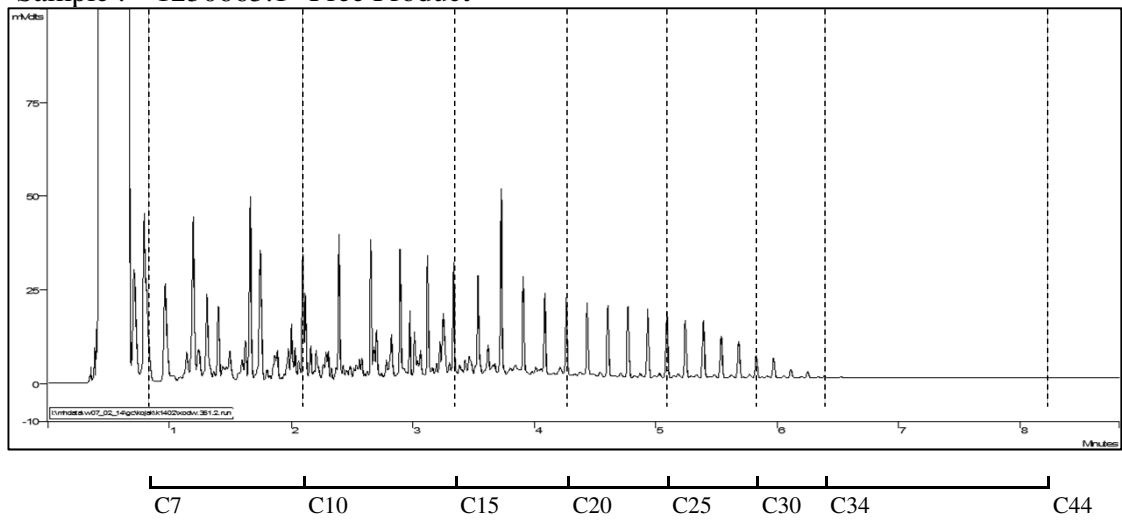
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Sample : 1230665.1 Free Product



**CERTIFICATE OF ANALYSIS****BICARBONATE ANALYSIS**

Report No: 2014020404

Customer Ref:136972

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

GNS Sample No. 2014000723
Collection Date: 22/01/2014
Site ID: 1230665/1
Field ID GND2436

pH		7.13	-	-	-
Bicarbonate (Total)	mg/l	2534	-	-	-
HCO ₃ Analysis Temperature	°C	22	-	-	-
HCO ₃ Analysis Date		5/02/2014	-	-	-

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.

Bruce Mountain, Ph.D.
 Geochemist

ANALYSIS REPORT

Page 1 of 3

Client:	Taranaki Regional Council	Lab No:	1306682	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	02-Aug-2014	
		Date Reported:	18-Aug-2014	
		Quote No:	49265	
		Order No:		
		Client Reference:	Kowhai C Return Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Saline

Sample Name:	GND2436 22-Jul-2014 4:35 pm				
Lab Number:	1306682.1				

Individual Tests

pH*	pH Units	7.1	-	-	-	-
Total Alkalinity*	g/m ³ as CaCO ₃	1,650	-	-	-	-
Analysis Temperature for Bicarbonate	°C	21	-	-	-	-
Bicarbonate	g/m ³ at Analysis Temperature	1,865	-	-	-	-
Total Hardness*	g/m ³ as CaCO ₃	122	-	-	-	-
Electrical Conductivity (EC)*	mS/m	1,097	-	-	-	-
Total Dissolved Solids (TDS)*	g/m ³	8,600	-	-	-	-
Dissolved Barium*	g/m ³	21	-	-	-	-
Dissolved Bromine*	g/m ³	8.3	-	-	-	-
Dissolved Calcium*	g/m ³	39	-	-	-	-
Dissolved Copper*	g/m ³	0.065	-	-	-	-
Dissolved Iron*	g/m ³	0.81	-	-	-	-
Dissolved Magnesium*	g/m ³	6	-	-	-	-
Dissolved Manganese*	g/m ³	1.32	-	-	-	-
Total Mercury*	g/m ³	< 0.011	-	-	-	-
Dissolved Nickel*	g/m ³	0.08	-	-	-	-
Dissolved Potassium*	g/m ³	400	-	-	-	-
Dissolved Sodium*	g/m ³	2,600	-	-	-	-
Dissolved Sulphur*	g/m ³	6	-	-	-	-
Dissolved Zinc*	g/m ³	3.3	-	-	-	-
Chloride*	g/m ³	2,800	-	-	-	-
Nitrite-N	g/m ³	< 0.2	-	-	-	-
Nitrate-N	g/m ³	< 0.2	-	-	-	-
Nitrate*	g/m ³	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m ³	< 0.2	-	-	-	-
Sulphate*	g/m ³	19	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	890	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	28,000	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m ³	14.4	-	-	-	-
Toluene*	g/m ³	21	-	-	-	-
Ethylbenzene*	g/m ³	1.25	-	-	-	-

Sample Type: Saline						
Sample Name:	GND2436 22-Jul-2014 4:35 pm					
Lab Number:	1306682.1					
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m ³	8.3	-	-	-	-
o-Xylene*	g/m ³	2.7	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m ³	7.7	-	-	-	-
Gases in groundwater						
Ethane*	g/m ³	1.11	-	-	-	-
Ethylene*	g/m ³	< 0.003	-	-	-	-
Methane*	g/m ³	4.2	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m ³	34	-	-	-	-
C10 - C14*	g/m ³	39	-	-	-	-
C15 - C36*	g/m ³	47	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m ³	119	-	-	-	-

Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

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/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m ³	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m ³	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/m ³	1
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
pH*	pH meter. APHA 4500-H+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m ³ as CaCO ₃	1
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	1
Bicarbonate	Bicarbonate (HCO ₃) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m ³ at Analysis Temperature	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m ³ 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.	50 g/m ³	1
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	1
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m ³	1
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m ³	1
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m ³	1
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m ³	1

Sample Type: Saline			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.004 g/m ³	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.0010 g/m ³	1
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22 nd ed. 2012.	0.0021 g/m ³	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.006 g/m ³	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	1.0 g/m ³	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22 nd ed. 2012.	0.4 g/m ³	1
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m ³	1
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22 nd ed. 2012.	0.004 g/m ³	1
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl E (modified from continuous flow analysis) 22 nd ed. 2012.	0.5 g/m ³	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₂ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO ₂ N. In-House.	0.0010 g/m ³	1
Nitrate*	Calculation from Nitrate-N.	0.010 g/m ³	1
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ ⁻ I 22 nd ed. 2012.	0.002 g/m ³	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m ³	1

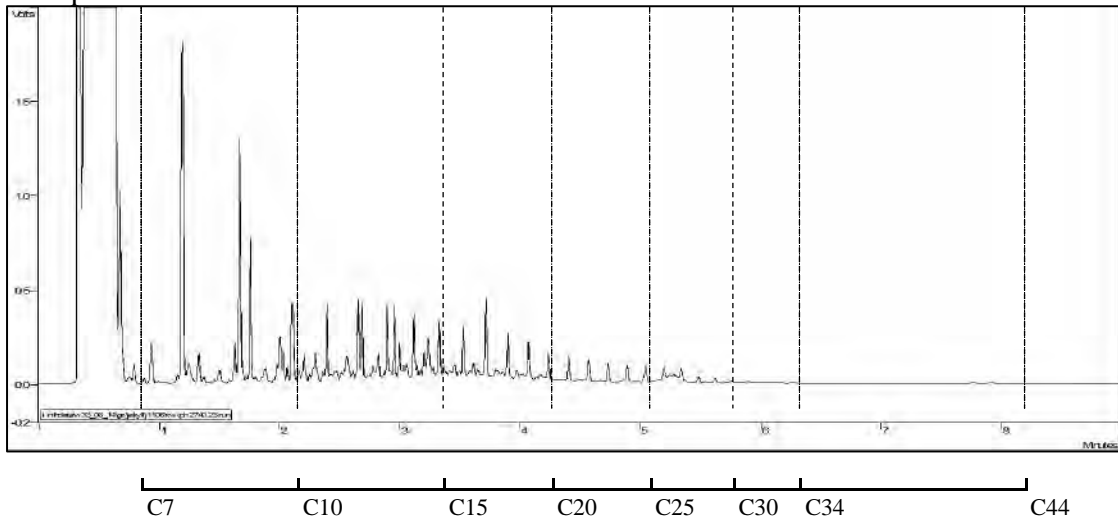
These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

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

Sample : 1306682.1



ANALYSIS REPORT

Page 1 of 2

Client:	Taranaki Regional Council	Lab No:	1306683	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	02-Aug-2014	
		Date Reported:	15-Aug-2014	
		Quote No:	50522	
		Order No:		
		Client Reference:	Kowhai C HF Fluid	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:	GND2436 22-Jul-2014 12:00 pm					
Lab Number:	1306683.1					
Ethylene Glycol in Water						
Ethylene glycol*	g/m ³	16	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m ³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	0.0046	-	-	-	-
Toluene	g/m ³	0.0057	-	-	-	-
Ethylbenzene	g/m ³	0.0015	-	-	-	-
m&p-Xylene	g/m ³	0.004	-	-	-	-
o-Xylene	g/m ³	0.0031	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	1.80	-	-	-	-
C10 - C14	g/m ³	138	-	-	-	-
C15 - C36	g/m ³	380	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	520	-	-	-	-

Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

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.

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	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/m ³	1

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

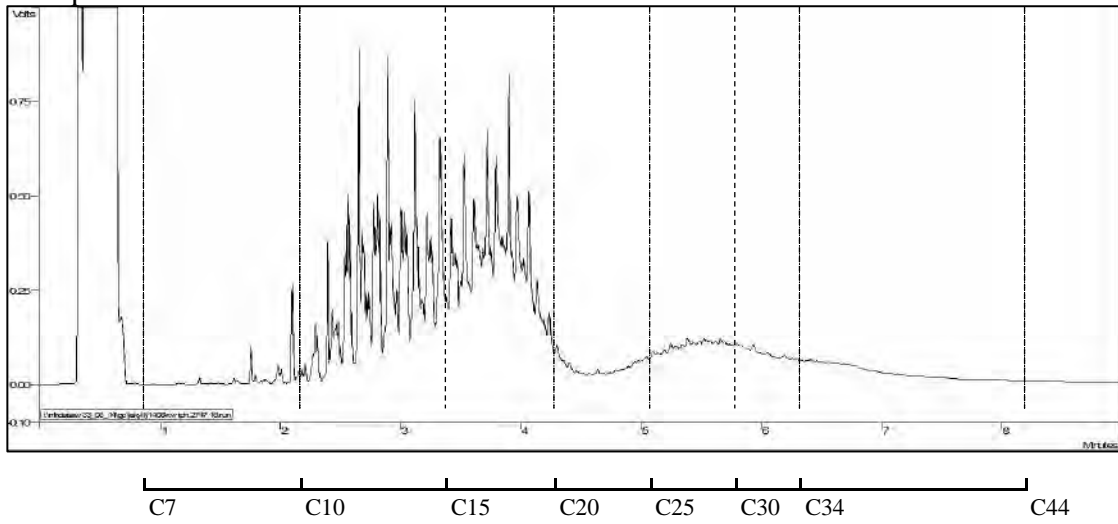
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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A handwritten signature in blue ink, consisting of several overlapping, stylized lines.

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

Sample : 1306683.1





ANALYSIS REPORT

Client:	Taranaki Regional Council	Lab No:	1230666	SPV1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	Date Registered:	01-Feb-2014	
		Date Reported:	24-Feb-2014	
		Quote No:	50522	
		Order No:		
		Client Reference:	Kowhai C HF Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Saline

Sample Name:	GND2436 17-Jan-2014 12:00 pm					
Lab Number:	1230666.1					
Ethylene Glycol in Water						
Ethylene glycol	g/m ³	8	-	-	-	-
Propylene Glycol in Water						
Propylene glycol	g/m ³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol	g/m ³	3	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m ³	< 0.0010	-	-	-	-
Toluene	g/m ³	0.0057	-	-	-	-
Ethylbenzene	g/m ³	0.0013	-	-	-	-
m&p-Xylene	g/m ³	0.005	-	-	-	-
o-Xylene	g/m ³	0.0033	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m ³	0.38	-	-	-	-
C10 - C14	g/m ³	23	-	-	-	-
C15 - C36	g/m ³	46	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m ³	69	-	-	-	-

Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

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/m ³	1
Propylene Glycol in Water	Direct injection, dual column GC-FID	4 g/m ³	1
Methanol in Water - Aqueous Solvents	Direct injection, dual column GC-FID	1.0 g/m ³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m ³	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/m ³	1

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

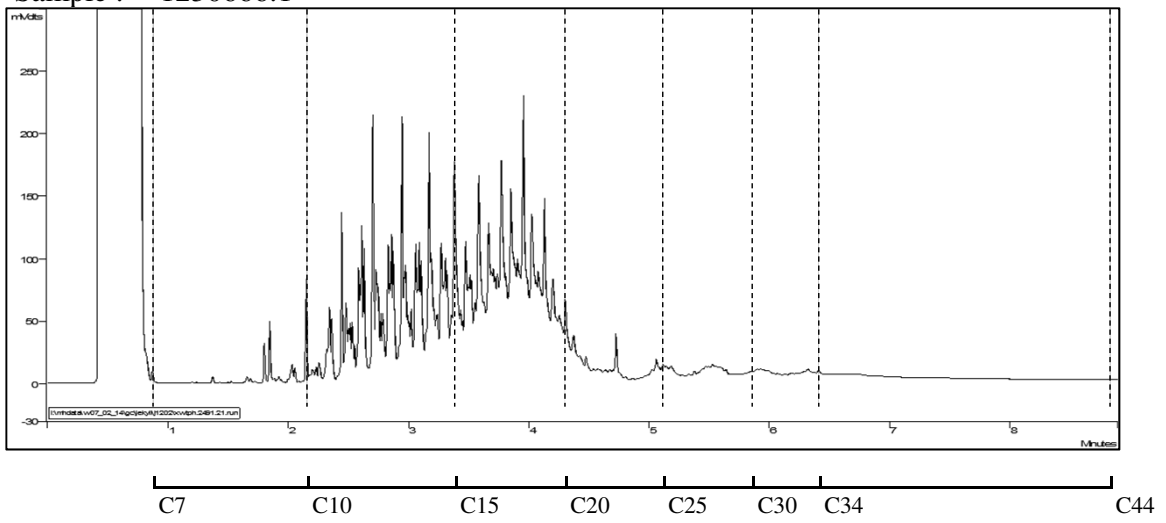
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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A handwritten signature in blue ink, appearing to read 'Peter Robinson', with a long horizontal flourish extending to the right.

Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Sample : 1230666.1



Appendix V
Biomonitoring report

To Job Manager: Callum MacKenzie
From Freshwater Biologist: Brooke Thomas
Report No BT039
Document 1425230
Date October 2014

Biomonitoring of an unnamed tributary of the Waiau Stream and of the Parahaki Stream following hydraulic fracturing at the Kowhai-C wellsite, August 2014

Introduction

These two biological surveys were performed following hydraulic fracturing (HF) at the Kowhai-C well, to determine whether or not treated stormwater and uncontaminated site and production water discharges, in the vicinity of the Waiau Stream and Parahaki Stream had any effects upon the macroinvertebrate communities of these streams. A biological survey of the Waiau Stream was conducted prior to drilling and hydraulic fracturing activities at the Kowhai-C well, to provide baseline data on the macroinvertebrate community of the stream (Thomas, 2014). A biological survey of the Parahaki Stream was carried out after drilling activities of the Kowhai-C wellsite but prior to hydraulic fracturing; also to provide baseline data on the macroinvertebrate community of the stream (Thomas, 2014). A biological survey of the Waiau Stream and Parahaki Stream was also undertaken following production at the Kowhai-C wellsite in February 2014; again to determine whether or not treated stormwater and uncontaminated site and production water discharges, in the vicinity of the Waiau Stream and Parahaki Stream had any effects upon the macroinvertebrate communities of these streams (Thomas, 2014a).

Methods

Kowhai-C wellsite treated stormwater and site production water was discharged on to land within the vicinity of the unnamed tributary of the Waiau Stream (Figure 1). This survey of the unnamed tributary of the Waiau Stream was undertaken on 5 August 2014 at one established site (Table 1); 10 metres downstream of an access culvert and pond (site 1). No upstream site was established as the position of the Kowhai-C discharge was directly above the headwaters of the unnamed tributary of the Waiau Stream. Only one site was sampled below the discharge point due to limited accessibility.

A survey of the Parahaki Stream was also carried out on 5 August 2014 at one established site (Table 1); 20 metres upstream of Inland North Road (site 2). The Parahaki Stream is valued by the local community for its watercress. Although not in the direct vicinity of the Kowhai-C discharge, this biological survey was deemed necessary to determine whether or not hydraulic fracturing activities of the Kowhai-C wellsite had any detrimental effect upon macroinvertebrate communities of this valued stream.

The council's 'vegetation sweep' technique was used to collect streambed macroinvertebrates in both the unnamed tributary of the Waiau Stream, and in the Parahaki Stream. The 'vegetation sweep' technique is very similar to Protocol C2 (soft-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 site details of sites monitored in relation to the Kowhai C wellsite including the unnamed tributary of the Waiau Stream and the Parahaki Stream

Site No.	Site code	Grid reference (NZTM)	Location	Altitude (m asl)
1	WAI000070	1172016E-5678534N	10m d/s of pond	79
2	PRH000010	1711471E-5678890N	20m u/s Inland North Road	79



Figure 1 Biomonitoring sites in the unnamed tributary of the Waiau Stream and the Parahaki Stream in relation to the Kowhai-C 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 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.

Results and discussion

At the time of the mid-afternoon survey of the unnamed tributary of the Waiau Stream an uncoloured, clear, low and slow flow was recorded. The stream temperature was 13.7 °C at this partially shaded site. Macrophytes were recorded growing on both the stream bed and at the edges of the stream. Substrate comprised predominantly of silt, with minor proportions of wood and root. Unlike the previous survey, no iron oxide sediment or filamentous algae was recorded and the stream was newly fenced.

At the time of the mid-afternoon survey of the Parahaki Stream, the water temperature was 14.7°C. An uncoloured, clear, moderate and steady flow was recorded at this partially shaded site. Substrate was comprised of silt only. Macrophytes (mainly watercress) were recorded growing on both the stream bed and at the edges of the stream bank. No periphyton or iron oxide sediment was recorded.

Macroinvertebrate communities

Table 2 summarises the results of the current macroinvertebrate surveys following hydraulic fracturing activities at the Kowhai-C wellsite, along with results following production activities at the Kowhai-C wellsite (carried out February 2014), and results prior to drilling and hydraulic fracturing activities (carried out September 2013 and December 2013). Comparative data for sites in similar streams are presented in Table 3. The macroinvertebrate fauna recorded by the current surveys are presented in Table 4 (site 1) and

Table 5 (site 2).

Table 2 Number of taxa, MCI and SQMCI_s in the unnamed tributary of the Waiau Stream (site 1) and Parahaki Stream (site 2) prior to and after production and hydraulic fracturing at the Kowhai-C wellsite.

Site No.	Site Code	No of taxa			MCI value			SQMCI _s value		
		Pre-production (06 Sept & 17 Dec 2013)	Post-production (20 Feb 2014)	Post-HF (05 Aug 2014)	Pre-production (06 Sept & 17 Dec 2013)	Post-production (20 Feb 2014)	Post-HF (05 Aug 2014)	Pre-production (06 Sept & 17 Dec 2013)	Post-production (20 Feb 2014)	Post-HF (05 Aug 2014)
1	WAI000070	25	10	18	83	70	74	2.7	1.7	3.2
2	PRH000010	22	15	15	76	72	73	4.1	3.2	4.0

Table 3 Range and median number of taxa, MCI values and SQMCI_s scores for control sites at altitudes between 50 and 79 m asl ((TRC, 1999 (updated 2013)).

	No. of taxa	MCI value	SQMCI _s value
No. Samples	61	61	33
Range	0-27	60-90	1.4-5.0
Median	17	73	4

Table 4 Macroinvertebrate fauna of the unnamed tributary of the Waiau Stream in relation to the Kowhai-C wellsite sampled 05 August 2014.

Taxa List	Site Number	MCI score	1
	Site Code		WAI000070
	Sample Number		FWB14219
PLATYHELMINTHES (FLATWORMS)	<i>Cura</i>	3	R
NEMERTEA	Nemertea	3	C
ANNELIDA (WORMS)	Oligochaeta	1	VA
HIRUDINEA (LEECHES)	Hirudinea	3	R
MOLLUSCA	<i>Potamopyrgus</i>	4	XA
	Sphaeriidae	3	C
CRUSTACEA	Copepoda	5	R
	Ostracoda	1	VA
ODONATA (DRAGONFLIES)	<i>Ischnura</i>	4	R
	<i>Xanthocnemis</i>	4	R
COLEOPTERA (BEETLES)	Dytiscidae	5	R
TRICHOPTERA (CADDISFLIES)	<i>Polypsectropus</i>	6	R
DIPTERA (TRUE FLIES)	<i>Zelandotipula</i>	6	R
	<i>Polypedilum</i>	3	R
ACARINA (MITES)	Tanypodinae	5	R
	Tanytarsini	3	R
	<i>Austrosimulium</i>	3	C
	Acarina	5	C
No of taxa			18
MCI			74
SQMCI _s			3.2
EPT (taxa)			1
%EPT (taxa)			6
'Tolerant' taxa	'Moderately sensitive' taxa		'Highly sensitive' taxa

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

Table 5 Macroinvertebrate fauna of the Parahaki Stream in relation to the Kowhai-C wellsite 05 August 2014.

Taxa List	Site Number	MCI score	2
	Site Code		PRH000010
	Sample Number		FWB14220
COELENTERATA	Coelenterata	3	C
ANNELIDA (WORMS)	Oligochaeta	1	C
	Lumbricidae	5	R
MOLLUSCA	Lymnaeidae	3	C
	<i>Potamopyrgus</i>	4	VA
CRUSTACEA	Ostracoda	1	A
	<i>Paracalliope</i>	5	VA
EPHEMEROPTERA (MAYFLIES)	<i>Zephlebia group</i>	7	R
TRICHOPTERA (CADDISFLIES)	<i>Polyplectropus</i>	6	C
	<i>Oxyethira</i>	2	A
DIPTERA (TRUE FLIES)	Orthoclaadiinae	2	R
	Tanypodinae	5	R
	Tanytarsini	3	R
ACARINA (MITES)	<i>Austrosimulium</i>	3	C
	Acarina	5	C
No of taxa			15
MCI			73
SQMCI _s			4.0
EPT (taxa)			2
%EPT (taxa)			13
'Tolerant' taxa		'Moderately sensitive' taxa	'Highly sensitive' taxa

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

Site 1- 10 metres downstream of pond (Waiiau Stream)

A moderate community richness of 18 taxa was found at site 1 (Table 2 and Table 4), seven taxa fewer than what was recorded in the pre-drill survey, although eight taxa more than recorded in post-production survey and one taxon more than the median richness found at similar sites elsewhere in the region (Table 3). The macroinvertebrate community contained a significant proportion of 'tolerant' taxa (67 %), which was reflected in the MCI score of 74 units. This result represented a decrease from that recorded in the pre-drill survey (of 9 MCI units) but an increase (of 4 MCI units) from the post-production survey. This MCI score was similar to the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

The community was characterised by three 'tolerant' taxa; (oligochaete worms, snails (*Potamopyrgus*), and seed shrimp (Ostracoda)).

The numerical dominance of a higher-scoring 'tolerant' taxon (snail (*Potamopyrgus*)) resulted in a SQMCI_s score of 3.2 units, which was higher (by 0.5 unit) than what was recorded in the pre-drill survey, and was significantly (Stark, 1998) higher (by 1.5 units) than that recorded in the post-production survey. This SQMCI_s score was slightly lower (by 0.8 unit) than the median score for 'control' sites in similar streams at this altitude (Table 3).

Site 2- 20 metres upstream of Inland North Road (Parahaki Stream)

A moderate community richness of fifteen taxa was found at site 2 (Table 2 and Table 5), seven taxa less than what was recorded in the pre-HF survey, two taxa less than the median richness found at similar sites and the same as that recorded in the post-production survey (Table 3). The macroinvertebrate community contained a large proportion of 'tolerant' taxa (60%), which was reflected in the MCI score of 73 units; three units less than what was recorded during the pre-HF survey, one unit more than recorded in the post-production survey and the same as the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

This community was characterised by three 'tolerant' taxa; (snail (*Potamopyrgus*), seed shrimp (Ostracoda) and axehead caddisfly (*Oxyethira*)); and one 'moderately sensitive' taxon, (amphipod (*Paracalliope*)).

The numerical dominance of 'tolerant' taxa was tempered by one very abundant 'sensitive' taxon (amphipod (*Paracalliope*)), which resulted in a SQMCI₅ score of 4.0 units, which was similar to that recorded in the pre-HF survey, slightly higher than that recorded in the post-production survey (by 0.8 unit) and the same as the median score for 'control' sites in similar streams at this altitude (Table 3).

Summary and Conclusions

The Councils 'vegetation sweep' technique was used to collect streambed macroinvertebrates from an unnamed tributary of the Waiau Stream and from the Parahaki Stream. This has provided data to compare with baseline data for the assessment of hydraulic fracturing and skimmer pit discharge effects from the Kowhai-C wellsite on the macroinvertebrate communities of these streams. Samples were processed to provide number of taxa (richness), MCI, and SQMCI₅ 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 SQMCI₅ 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 SQMCI₅ scores between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

This August 2014 survey of the unnamed tributary of the Waiau Stream and of the Parahaki Stream was undertaken following drilling and hydraulic fracturing at the Kowhai C wellsite. Taxa richness's were moderate and similar to the median richness recorded by 'control' sites in similar streams elsewhere in the region. The macroinvertebrate communities of both streams contained more 'tolerant' than 'sensitive' taxa. A comparison of the surveys carried out prior to and after hydraulic fracturing showed no significant differences in MCI score at either site. The SQMCI₅ score of 3.2 units recorded at site 1 in the Waiau Stream was significantly (Stark, 1998) higher than that recorded in the post-production survey. This was the only significant difference in SQMCI₅ score recorded in the current surveys and may be attributed to the reduction of both iron oxide sediment and long green filamentous algae recorded at this site.

The MCI scores recorded in this survey indicated that the stream communities were of poor 'health' (TRC, 2014), and similar to the biological health recorded at 'control' sites in similar streams at a comparative altitude elsewhere in the region. There was no indication from the results of the two surveys that the discharge from the Kowhai-C wellsite has impacted on the biological communities of the unnamed tributary of the Waiau Stream or Parahaki Stream.

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