Greymouth Petroleum Limited
Kaimiro-A Hydraulic Fracturing Monitoring Programme Report
2013-2015

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Executive summary

Greymouth Petroleum Limited (GPL) operate the Kaimiro-A wellsite, located at 1180 Upland Road, Inglewood. The wellsite lies within the Waiongana catchment and contains a hydrocarbon producing well and associated infrastructure.

GPL hold resource consent 9413-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 m TVDss beneath the Kaimiro-A wellsite. The consent was issued by Taranaki Regional Council (the Council) on 25 February 2013 and contains 16 special conditions which set out the requirements that GPL must satisfy.

The following report for the period March 2014 to April 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL, within their Kaimiro-A 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 Kaimiro-A included the fracturing of one well; Kaimiro-2ST1. The hydraulic fracturing of this well took place on 29 April 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 the fracturing event were obtained for analysis.

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

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

GPL demonstrated a high level of environmental and good 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.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Limited (GPL) at their Kaimiro-A wellsite, 1180 Upland Road, Inglewood over the period March 2014 to April 2015. The wellsite is located in the Waiongana catchment. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by GPL at the Kaimiro-A wellsite included the fracturing of one well; Kaimiro-2ST1.

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 Kaimiro-A 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 though annual programmes, the resource consent held by GPL for discharges into land associated with hydraulic fracturing in the Waiau catchment, a description of the activities undertaken under this consent, 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 2015-2016 monitoring year.

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

1.1.3 The Resource Management Act 1991 and monitoring

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

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

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council recognises 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 consent were met, or any failure to do this had trivial consequences and was addressed promptly and co-operatively.

- **Good** Perhaps some administrative requirements of the resource consent were not met at a particular time, however these were 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 consent 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 consent. 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 Kaimiro-A wellsite history

The Kaimiro-A wellsite has been in operation since 2013. The land on which the wellsite is located has historically been used for dairy farming. The area around the wellsite and is rural with low population density. The closest residential community is Egmont Village, a small rural community which lies approximately 2.2 km to the north of the site and Inglewood, a rural town which lies approximately 3.6 km east of the wellsite. The site lies in an active petroleum exploration area. GPL's petroleum exploration activity dominates this area with Todd and TAG oil fields located north-east and south-east from the wellsite.

The Kaimiro-2ST1 well was sidetracked from the original Kaimiro-2 well between September 2010 and January 2011. It was later worked over between February and March 2014. Hydraulic fracturing took place on 29 April 2014. The location of the wellsite is illustrated in Figure 1. Well construction schematics for the Kaimiro-2ST1 well are included in Appendix I.

An outline of the hydraulic fracturing activities carried out by GPL at the Kaimiro-A 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
Kaimiro-2ST1	Kaimiro-A	9413-1	29/04/2014	3,328.2 to 3,330.9	McKee
				3,790 to 3,793.1	
				3,799 to 3,802.1	

1.3 Resource consent

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 **9413-1**, authorising the discharge of contaminants into land at the Kaimiro-A wellsite. The consent was issued by the Council on 25 February 2013, under Section 87(e) of the RMA. This is the consent under which Kaimiro-2ST1 was fractured. Consent 9413-1 contains 16 special conditions which set out the requirements that GPL must satisfy.

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

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

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

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

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

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

Condition 10 is a notification requirement.

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

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

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

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

Condition 15 relates to the composition of the fracturing fluid.

Consent 16 is a review provision.

Figure 1 Location of Kaimiro-A 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 Kaimiro-2ST1 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 9413-1, GPL submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of a monitoring well in the vicinity of the Kaimiro-A 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 Kaimiro-A wellsite to identify existing groundwater abstractions. The survey was undertaken within a defined ‘areas of review’ which extended 1 km radially from the wellsite. The survey did not result in any suitable sampling locations being identified. In the absence of any suitable existing sampling sites, condition 5 of consent 9413-1 required GPL to install a suitable monitoring bore for the purposes of obtaining groundwater samples. The design and location of the monitoring bore was discussed and agreed with Council staff prior to installation. The details of the monitoring bore installed are included in Table 2 and its proximity to the wellsite is illustrated in Figure 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
Kaimiro-2ST1	GND2447	31	37	25 - 37	Volcanics

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.

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 Kaimiro-A 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 two unnamed tributaries of the Mangaoraka Stream, as these are the nearest surface water bodies to the stormwater discharge locations of the Kaimiro-A 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 Figure2.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
MRK000204	E 1700054 N 5664636	150 m downstream of Upland Road	Kick-sampling
MRK000198	E 1700117 N 5664652	50 m upstream of Kaimiro-A wellsite tributary	Kick-sampling
MRK000207	E 1700171 N 5664679	50 m downstream of Kaimiro-A wellsite tributary	Kick-sampling

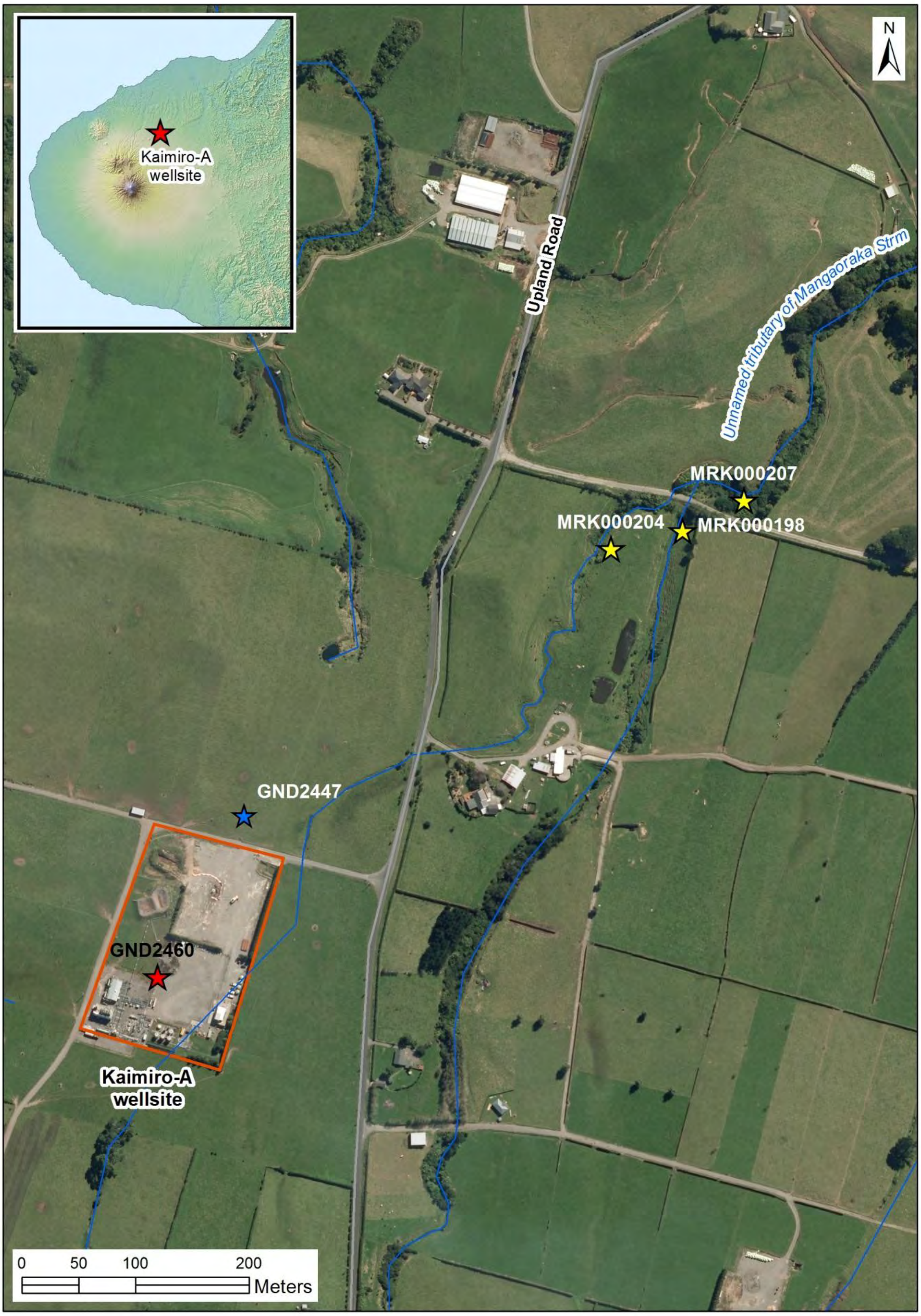


Figure 2 Location of groundwater (blue star) and surface water sampling sites (yellow stars) in relation to the Kaimiro-2ST1 well (red star)

2. Results

2.1 Consent holder submitted data

2.1.1 Kaimiro-2ST1 post-fracturing discharge report

The conclusions from the Kaimiro-2ST1 post-fracturing discharge report are summarised as follows:

- A total of three discrete zones were fractured on 29 April 2014, at depths between 3,328.2 and 3,350.8 m TVDss.
- A total of 1,326 barrels (bbls) (211 m^3) of liquid was discharged across the three fractured zones. The total proppant weight was 31 tonnes.
- By volume, 80.77% of the fluid injected was water, 17.32% was proppant and 1.91% 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 Kaimiro-2ST1 well was opened for flowback following the completion of fracturing operations. At the completion of all flow-back operations, approximately 3,659 bbls (582 m^3) of fracture fluids and formation fluid were returned to the surface. Due to the fact that the flowback fluid from hydraulic fracturing operations consists of a mixture of the original fluid with native reservoir fluids, it is not feasible to calculate the exact quantity remaining underground. However, it is inferred that all or most of the hydraulic fracturing fluid has been returned to surface. It is estimated that all the proppant injected (31 tonnes) remains in the formation, with small volumes expected to have settled inside the casing, where they may remain, unless circulated to the surface during later well interventions.
- All fluids that returned to the surface during flowback of each hydraulic fracturing operation were disposed of by deep well injection at the Kaimiro-G wellsite as authorised by consent 9470-1.
- It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Chemical sampling

2.2.1 Kaimiro-2ST1 groundwater sampling survey

One site was sampled to monitor the effects of the hydraulic fracturing of the Kaimiro-2ST1 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2447 indicate a slight decrease in electrical conductivity, total dissolved solids and pH . There was a slight increase in dissolved iron and manganese 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 GND2447. The methane/ethane ratios indicate that the gas is biogenic in origin and not derived from deep gas reservoirs (See section 2.2.2). 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 Kaimiro-2ST1 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 Kaimiro-2ST1 well

Parameter	**Unit**	**GND2447**		
		Pre-frac	**Post-frac**	
Sample date	-	25 Mar 2014	04 Aug 2014	23 Apr 2015
Lab number	-	TRC149606	TRC1410739	TRC151704
Total alkalinity	g/m^3 $CaCO_3$	82	89	74
Barium	mg/kg	0.0129	0.021	0.0176
Benzene	g/m^3	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m^3	0.079	0.051	0.041
Calcium	g/m^3	9.7	13.8	10.1
Chloride	g/m^3	12.5	8.8	8.0
Electrical conductivity	$mS/m@20^0C$	21.2	20.0	16.9
Dissolved copper	g/m^3	0.0086	<0.0005	<0.0005
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.003	<0.003	<0.004
Dissolved iron	g/m^3	0.19	5.1	7.7
Formaldehyde	g/m^3	<0.02	<0.02	<0.02
Ethylene glycol	g/m^3	<4	<4	<4
Total hydrocarbons	g/m^3	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 HCO_3	100.0	108.6	91
Total hardness	g/m^3 $CaCO_3$	40	53	44
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008
Potassium	g/m^3	8.5	5.9	6.1
Methanol	g/m^3	<2	<2	<2
Methane	g/m^3	3.7	3.6	5.7
Magnesium	g/m^3	3.9	4.6	4.6
Dissolved manganese	g/m^3	0.22	0.39	0.29
Sodium	g/m^3	21	16.6	16.4
Nickel	mg/kg	0.0008	0.0009	<0.0005
Nitrate + nitrite nitrogen	g/m^3 N	0.007	<0.02	<0.2
Nitrite	g/m^3 N	<0.002	<0.02	<0.2

Parameter	Unit	GND2447		
		Pre-frac	Post-frac	
Nitrate	g/m^3 N	0.005	<0.02	<0.2
pH	pH	7.1	7.0	6.6
Propylene glycol	g/m^3	<4	<4	<4
Sulphate	g/m^3	5.6	<0.5	<0.5
Sum of Anions	meq/l	2.1	2.0	1.72
Sum of Cations	meq/l	1.94	2.1	2.0
Total dissolved solids	g/m^3	194	163	159
Toluene	g/m^3	<0.0010	<0.0010	<0.0010
o-Xylene	g/m^3	0.0013	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002
Dissolved zinc	g/m^3	0.0040	0.0135	0.0099

2.2.2 Carbon isotope snalysis

During the period being reported, one groundwater sample was sent to GNS Science for carbon isotope analysis in their National Isotope Centre. The isotopic analysis is used to calculate a delta carbon13 (δ13C) value for a given sample, which is then used to determine the origin of the gas. Generally, a δ13C value that exceeds -50‰ indicates biogenic methane, and a δ13C value less than -50‰ indicates thermogenic methane. The higher or lower the δ13C values, the stronger the isotopic signature. A δ13C value in the vicinity of -50‰ can indicate a mixture of both biogenic and thermogenic methane. Results of analyses undertaken in the period being reported are compared with previous results in Table 5 below.

Table 5 Results of carbon isotope analysis at GND2447

	GND2447
Date	4/08/2014
δ13C value	-89‰

Table 5 shows that the methane gas present in GND2447 is strongly biogenic.

It is important to note that the results were issued from the analysing laboratory with an uncertainty of measurement of ±10‰

2.2.3 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 Kaimiro-2ST1 well for the April 2014 fracturing events are summarised below in Table 6. 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 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Kaimiro-2ST1
Sample date	-	29 April 2014
Lab number	-	TRC149920
Benzene	g/m^3	<0.0010
Ethylbenzene	g/m^3	0.0014
Ethylene glycol	g/m^3	16
Total hydrocarbons	g/m^3	720
Methane	g/m^3	<2
Propylene glycol	g/m^3	<4
Toluene	g/m^3	0.0027
o-Xylene	g/m^3	0.0031
m-Xylene	g/m^3	0.004

A composite sample of return fluids from Kaimiro-2ST1 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 Kaimiro-2ST1 well are summarised below in Table 7 and the certificates of analysis is included in Appendix IV. The relatively high levels of salinity (sodium and chloride) in the sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Kaimiro-2ST1
Sample date	-	29 April 2014
Lab number	-	TRC1410024
Total alkalinity	g/m^3 $CaCO_3$	2400
Barium	mg/kg	9.4
Benzene	g/m^3	6.2
Bromide	g/m^3	6.5
Calcium	g/m^3	250
Chloride	g/m^3	3,000
Conductivity	mS/m@20°C	1,338

Dissolved copper	g/m^3	0.035
Ethylbenzene	g/m^3	0.72
Ethane	g/m^3	0.72
Ethylene	g/m^3	<0.03
Dissolved iron	g/m^3	7.1
Formaldehyde	g/m^3	1.8
Ethylene glycol	g/m^3	<4
Bicarbonate	g/m^3 HCO_3	2,770
Total hardness	g/m^3 $CaCO_3$	670
Potassium	g/m^3	1,040
Methanol	g/m^3	3
Methane	g/m^3	4.7
Magnesium	g/m^3	9
Dissolved manganese	g/m^3	1.92
Sodium	g/m^3	2,100
Nickel	mg/kg	0.16
Nitrate & nitrite nitrogen	g/m^3 N	0.013
Nitrite	g/m^3 N	0.003
Nitrate	g/m^3 N	0.009
pH	pH	7.2
Dissolved sulphur	g/m^3	21
Sulphate	g/m^3	62
Total dissolved solids	g/m^3	12,500
Toluene	g/m^3	7.8
o-Xylene	g/m^3	1.46
m-Xylene	g/m^3	4.0
Total hydrocarbons	g/m^3	1,660
Dissolved zinc	g/m^3	0.19

2.3 Biomonitoring survey

The Council's standard 'kick-sampling' techniques were used to collect streambed macroinvertebrates from two unnamed tributaries of the Mangaoraka Stream in relation to fracturing at the Kaimiro-A 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.

The richness and $SQMCI_s$ score recorded at MRK000204 in the small unnamed tributary downstream of the production station discharge typically were dissimilar to those recorded at the two sites in the larger tributary. At the time of this survey, the availability of instream habitat at this site was limited due to iron-oxide deposition on the streambed which is restrictive to the establishment of a macroinvertebrate community comprising certain 'sensitive' taxa. In contrast, MRK000198 and MRK000207 in the major tributary supported more diverse communities which included abundances of several 'sensitive' taxa. It was considered most likely that the difference in taxa richness and $SQMCI_s$ score at site 2 compared to the two sites in the larger tributary, resulted from differences in physical habitat rather than as a result of the Kaimiro-A wellsite drilling stormwater and production wastewater discharges.

$SQMCI_s$ and MCI scores recorded at each of the two sites in the main tributary in this survey were within one to two units respectively of the median scores for each site upon post-fracturing sampling; an indication of relatively good preceding water quality under moderate flow conditions following a recent wet autumn period. They were also within an insignificant 6 MCI units and 0.2 $SQMCI_s$ unit of pre-drill late summer scores.

In summary the results of this May 2014 survey indicated that discharges from the Kaimiro-A wellsite had not had any recent detrimental effects on the macroinvertebrate communities of the main tributary of the Mangaoraka Stream and that the poorer community found in the (minor) receiving tributary was coincident with streambed iron-oxide deposition and typical of communities recorded at this site to date.

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

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

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

Condition 11 of consent 9413-1 requires that a post-fracturing discharge report be provided within 60 days after the programme is complete. As the programme was completed on 29 April 2014, the report was due by 28 June 2014. On 13 August 2014 it was determined that no post-fracturing discharge report had been submitted. Contact was made with GPL on this date. It was determined that the report had been compiled, but not sent to the Council due to human error. It was sent to the Council on 13 August 2014. The Council decided that it was unnecessary to take any further enforcement action, as the mistake resulted from a genuine administrative oversight. Apart from this, 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 a selected site in the vicinity of the Kaimiro-A 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 Kaimiro-2ST1 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities. Methane was detected in low concentrations. Concentrations were within the expected range for shallow groundwater in Taranaki. 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 during any of the post-fracturing sampling events.

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

In summary, the monitoring carried out by the Council during the 2013-2014 and 2014-2015 monitoring periods 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 8.

Table 8 Summary of performance for Consent 9413-1: To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 mTVD beneath the Kaimiro-A wellsite.

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,140 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. A dedicated groundwater 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	No*
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		Good

* A post-fracturing discharge report was received by the Council outside the allotted 60 days

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

3.3 Alterations to monitoring programmes for 2015-2016

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account the extent of information made available by previous authorities, its relevance under the RMA 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, no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kaimiro-A wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 9413-1 provides for an optional review of the consent 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 no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kaimiro-A wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

2. THAT the option for a review of resource consents in June 2015, as set out in condition 16 of consent 9413-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

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

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

Bibliography and references

Greymouth Petroleum Limited (2014) Technical Proposal – Kaimiro 2

Greymouth Petroleum Limited (2014) Kaimiro-2ST1 Post-Fracturing Discharge Report

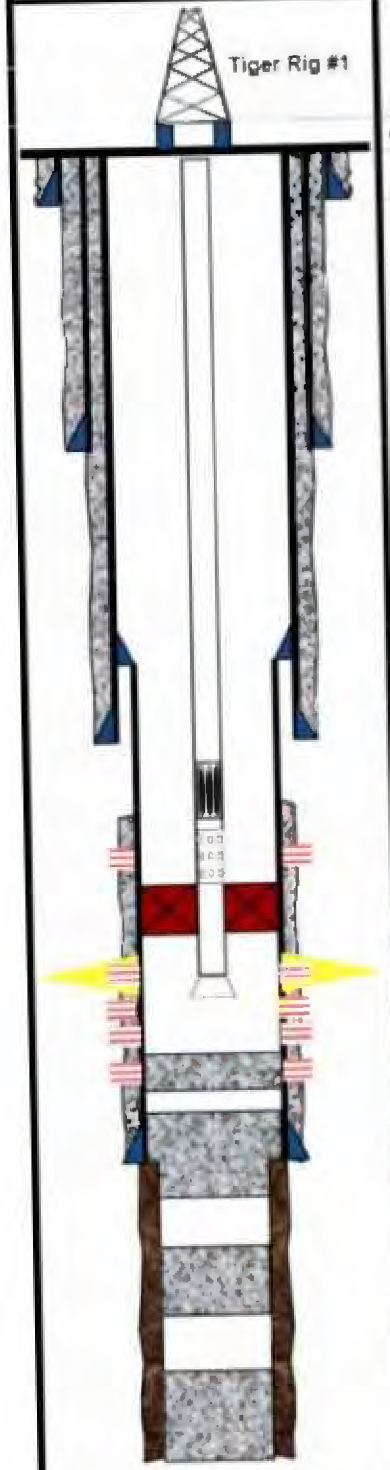
Stark JD, (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66

Taranaki Regional Council (2014) Post-well drilling biomonitoring of two unnamed tributaries of the Mangaoraka Stream in relation to the Kaimiro-A wellsite, May 2014. Report CF617

Taranaki Regional Council (2014) Greymouth Petroleum Limited Hydraulic Fracturing - Kaimiro-A Wellsite Water Quality Monitoring Programme

Appendix I

Well construction schematic

SCHEMATIC	DESCRIPTION	DEPTH	
		m AHBKB	m SSTVD
	Kelly Bushing (KB) 260.45m AMSL		
	Ground Level (GL) 253.75 AMSL	6.7	253.8
	30" Conductor	32	228.45
	13 3/8" Casing Shoe, 17 1/2" hole	588	-327.51
	7" Liner Hangar at 2330m, 197jts of N80 grade 29ppf to 4609m	2348	-2087.4
	9 5/8" Casing shoe, 12 ¼" Hole to 2450m	2447	-2186.4
	Perforations #2 for Remedial Cement Job	3620	-3197.9
	7" Production packer	3689	-3253.8
	SSD Jar down to open	3708.1	
	2 7/8" Completion Tubing	3712.6	-3273.4
	Perforated Joint 2 7/8" FOX 6.4ppf 13Cr85 tubing	3733.9	-3291.9
	Wireline Re-enrty Guide	3734.5	-3291.9
	Perforations: Mangahewa K1 36.1, from: Hydraulic Fracture performed with approximately 6000lbs of sand within the formation	3776 to 3779.3	-3327.4 to -3330.3
	Perforations: K1 36.2 (Top Mangahewa) 2.125" OwenOilTools Shotgun, 6spf, 40deg phasing SDP charge	3790 to 3793.1	-3339.6 to -3342.3
	Perforations: K1 36.3 (Top Mangahewa) 2.125" OwenOilTools Shotgun, 6spf, 40deg phasing SDP charge	3799 to 3802.1	-3347.5 to -3350.0
	Cement Plug from	3976 to 3889	-3507.7 to -3427.0
	Perforations #1 for Remedial Cement Job	3960	-3493.4
	Cement Plug from 4624m to 4435m		
	7" Liner Shoe, 8 ½" Hole to 4610m	4609	-4138.2
	Cement Plug from 4804m to 4760m		
	Cement Plug from 5114m to 4936m		
	TD 6" Hole @ 5114m	5114	-4895

Appendix II

Resource consent held by GPL

Discharge Permit

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

Name of Consent Holder:	Greymouth Petroleum Limited P O Box 3394 NEW PLYMOUTH 4341
Decision Date:	25 February 2013
Commencement Date:	25 February 2013

Conditions of Consent

Consent Granted:	To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3140 mTVDss beneath the Kaimiro-A wellsite
Expiry Date:	1 June 2020
Review Date(s):	June annually
Site Location:	Kaimiro-A wellsite, 1180 Upland Road, Inglewood
Legal Description:	Lot 4 DP 436344 (Discharge source & site)
Grid Reference (NZTM)	1699694E-5664338N
Catchment:	Waiongana
Tributary:	Mangaoraka

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 [the Council] all the administration, monitoring and supervision costs of this consent, fixed in accordance to section 36 of the Resource Management Act.

Special conditions

1. The discharge point shall be deeper than 3140 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e. the true vertical depth in metres below mean sea 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. The Monitoring Programme shall include sampling of groundwater from a dedicated monitoring bore established for the purpose. The bore shall be between 20 metres and 50 metres deep, installed in accordance with NZS 4411:2001 and at a location established after consultation with the Chief Executive, Taranaki Regional Council.

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

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and

(l) carbon-13 composition of any dissolved methane gas discovered ($^{13}C-CH_4$).

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

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

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

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

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

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

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

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

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

15. The fracture fluid shall be comprised of no less than 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 25 February 2013

For and on behalf of
Taranaki Regional Council

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Director-Resource Management

Appendix III

Certificates of analysis (Groundwater)

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1253338 SPv1
Contact:	Regan Phipps	**Date Registered:**	26-Mar-2014
	C/- Taranaki Regional Council	**Date Reported:**	04-Apr-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	GPL Kaimiro A Pre HF GW
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2447 25-Mar-2014 11:47 am				
Lab Number:		1253338.1				
Individual Tests						
Sum of Anions	meq/L	2.1	-	-	-	-
Sum of Cations	meq/L	1.94	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	82	-	-	-	-
Bicarbonate	g/m³ at 25°C	100	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	40	-	-	-	-
Electrical Conductivity (EC)	mS/m	21.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	194	-	-	-	-
Dissolved Barium	g/m³	0.0129	-	-	-	-
Dissolved Bromine*	g/m³	0.079	-	-	-	-
Dissolved Calcium	g/m³	9.7	-	-	-	-
Dissolved Copper	g/m³	0.0086	-	-	-	-
Dissolved Iron	g/m³	0.19	-	-	-	-
Dissolved Magnesium	g/m³	3.9	-	-	-	-
Dissolved Manganese	g/m³	0.22	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0008	-	-	-	-
Dissolved Potassium	g/m³	8.5	-	-	-	-
Dissolved Sodium	g/m³	21	-	-	-	-
Dissolved Zinc	g/m³	0.0040	-	-	-	-
Chloride	g/m³	12.5	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	0.005	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.007	-	-	-	-
Sulphate	g/m³	5.6	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous

Sample Name:		GND2447 25-Mar-2014 11:47 am				
Lab Number:		1253338.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	0.0013	-	-	-	-
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	3.7	-	-	-	-
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	-	-	-	-

Analyst's Comments

As we were unable to use the filtered nitric container because it contained particulate, the dissolved metals were analysed from the UP1L supplied.

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 mEquiv/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/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 22nd ed. 2012.	1.0 g/m^3 at 25°C	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.	10 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, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd 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 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd 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

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ANALYSIS REPORT

Client: Taranaki Regional Council
Contact: Regan Phipps
C/- Taranaki Regional Council
Private Bag 713
STRATFORD 4352

Lab No: 1307333 SPv1
Date Registered: 05-Aug-2014
Date Reported: 08-Aug-2014
Quote No: 47915
Order No:
Client Reference: Kaimiro A Post HF GW
Submitted By: Regan Phipps

Sample Type: Aqueous

	Sample Name:	GND2447 04-Aug-2014 10:45 am				
	Lab Number:	1307333.1				
Individual Tests						
Sum of Anions	meq/L	2.0	-	-	-	-
Sum of Cations	meq/L	2.1	-	-	-	-
pH	pH Units	7.0	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	89	-	-	-	-
Bicarbonate	g/m^3 at 25°C	108	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	53	-	-	-	-
Electrical Conductivity (EC)	mS/m	20.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	163	-	-	-	-
Dissolved Barium	g/m^3	0.021	-	-	-	-
Dissolved Bromine*	g/m^3	0.051	-	-	-	-
Dissolved Calcium	g/m^3	13.8	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Iron	g/m^3	5.1	-	-	-	-
Dissolved Magnesium	g/m^3	4.6	-	-	-	-
Dissolved Manganese	g/m^3	0.39	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	0.0009	-	-	-	-
Dissolved Potassium	g/m^3	5.9	-	-	-	-
Dissolved Sodium	g/m^3	16.6	-	-	-	-
Dissolved Zinc	g/m^3	0.0135	-	-	-	-
Chloride	g/m^3	8.8	-	-	-	-
Nitrite-N	g/m^3	< 0.02	-	-	-	-
Nitrate-N	g/m^3	< 0.02	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.02 #1	-	-	-	-
Sulphate	g/m^3	< 0.5	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous

Sample Name:		GND2447 04-Aug-2014 10:45 am				
Lab Number:		1307333.1				
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	3.6	-	-	-	-
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	-	-	-	-

Analyst's Comments

[#1] Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2Nanalysis.

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 mEquiv/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H$^+$ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/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 22nd ed. 2012.	1.0 g/m^3 at 25°C	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.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd 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 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd 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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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1416942 SPv2
Contact:	Regan Phipps	**Date Registered:**	24-Apr-2015
	C/- Taranaki Regional Council	**Date Reported:**	07-May-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A 1 Yr Post HF
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2447 23-Apr-2015 12:20 pm				
Lab Number:		1416942.1				
Individual Tests						
Sum of Anions	meq/L	1.72	-	-	-	-
Sum of Cations	meq/L	2.0	-	-	-	-
pH	pH Units	6.6	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	74	-	-	-	-
Bicarbonate	g/m^3 at 25°C	91	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	44	-	-	-	-
Electrical Conductivity (EC)	mS/m	16.9	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	159	-	-	-	-
Dissolved Barium	g/m^3	0.0176	-	-	-	-
Dissolved Bromine*	g/m^3	0.041	-	-	-	-
Dissolved Calcium	g/m^3	10.1	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Iron	g/m^3	7.7	-	-	-	-
Dissolved Magnesium	g/m^3	4.6	-	-	-	-
Dissolved Manganese	g/m^3	0.29	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Potassium	g/m^3	6.1	-	-	-	-
Dissolved Sodium	g/m^3	16.4	-	-	-	-
Dissolved Zinc	g/m^3	0.0099	-	-	-	-
Chloride	g/m^3	8.0	-	-	-	-
Nitrite-N	g/m^3	< 0.2	-	-	-	-
Nitrate-N	g/m^3	< 0.2	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.2 [#1]	-	-	-	-
Sulphate	g/m^3	< 0.5	-	-	-	-
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	-	-	-	-

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:		GND2447 23-Apr-2015 12:20 pm				
Lab Number:		1416942.1				
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	< 0.004	-	-	-	-
Methane	g/m^3	5.7	-	-	-	-
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	-	-	-	-

Analyst's Comments

[#1] Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N analysis.

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 mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H$^+$) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H$^+$ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/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 22nd ed. 2012.	1.0 g/m^3 at 25°C	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.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd 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 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

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

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Date Measured:
Approved By:
Date Reported: 22/08/2014

Invoice **Taranaki Regional Council**
Attn: **Rachel**
Private Bag 713
Stratford
4352
New Zealand

Sample Type: **other C-bearing material**

SIL ID	**External ID**	**δ13C Value**	**Analysis Type**	**State or Province**	Country Code	Latitude	Longitude	Collection Date/Time (Start)	Other Info
G-1402625	GND2447	-89.0	C13	Taranaki	NZ	-39.16388889	174.1543889	04/08/2014 10:45	Water

Appendix IV

Certificates of analysis (Hydraulic fracturing and return fluid)

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1269954 SPv1
Contact:	Regan Phipps	**Date Registered:**	02-May-2014
	C/- Taranaki Regional Council	**Date Reported:**	13-May-2014
	Private Bag 713	**Quote No:**	50522
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A - HF Fluro
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND 2460 29-Apr-2014 12:00 pm				
Lab Number:		1269954.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	16	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	0.0027	-	-	-	-
Ethylbenzene	g/m³	0.0014	-	-	-	-
m&p-Xylene	g/m³	0.004	-	-	-	-
o-Xylene	g/m³	0.0031	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	3.5	-	-	-	-
C10 - C14	g/m³	260	-	-	-	-
C15 - C36	g/m³	460	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	720	-	-	-	-

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: Aqueous

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

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

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

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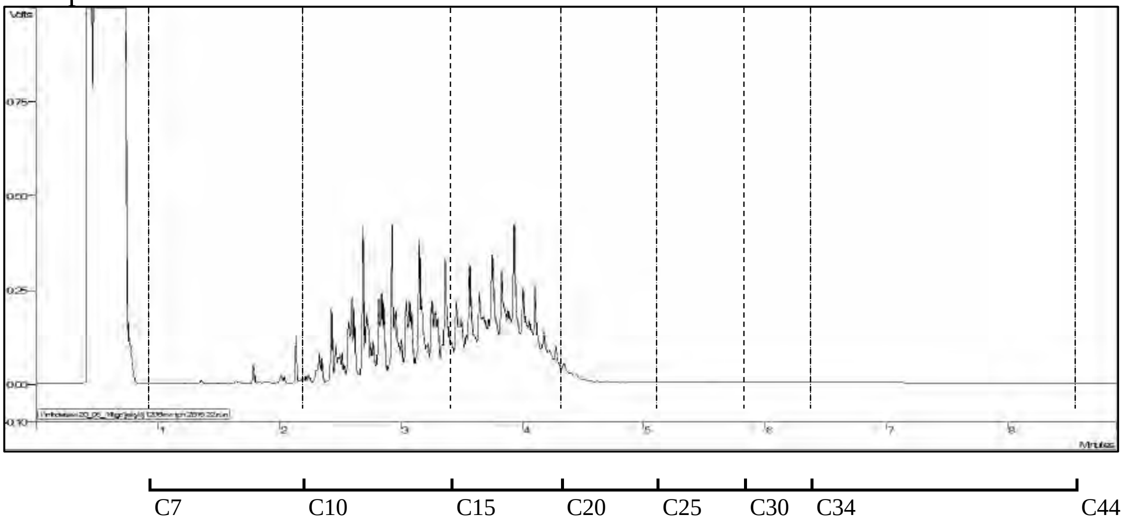
Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental Division

Sample : 1269954.1



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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1278331 SPv1
Contact:	Regan Phipps	**Date Registered:**	22-May-2014
	C/- Taranaki Regional Council	**Date Reported:**	06-Jun-2014
	Private Bag 713	**Quote No:**	49265
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A - Return Fluid
		Submitted By:	Regan Phipps

Sample Type: Saline

Sample Name:		GND2460 29-Apr-2014 4:00 pm				
Lab Number:		1278331.1				
Individual Tests						
pH*	pH Units	7.2	-	-	-	-
Total Alkalinity*	g/m^3 as $CaCO_3$	2,400	-	-	-	-
Analysis Temperature for Bicarbonate	°C	21	-	-	-	-
Bicarbonate	g/m^3 at Analysis Temperature	2,770	-	-	-	-
Total Hardness*	g/m^3 as $CaCO_3$	670	-	-	-	-
Electrical Conductivity (EC)*	mS/m	1,338	-	-	-	-
Total Dissolved Solids (TDS)*	g/m^3	12,500 [#1]	-	-	-	-
Dissolved Barium*	g/m^3	9.4	-	-	-	-
Dissolved Bromine*	g/m^3	6.5	-	-	-	-
Dissolved Calcium*	g/m^3	250	-	-	-	-
Dissolved Copper*	g/m^3	0.035	-	-	-	-
Dissolved Iron*	g/m^3	7.1	-	-	-	-
Dissolved Magnesium*	g/m^3	9	-	-	-	-
Dissolved Manganese*	g/m^3	1.92	-	-	-	-
Total Mercury*	g/m^3	< 0.011	-	-	-	-
Dissolved Nickel*	g/m^3	0.16	-	-	-	-
Dissolved Potassium*	g/m^3	1,040	-	-	-	-
Dissolved Sodium*	g/m^3	2,100	-	-	-	-
Dissolved Sulphur*	g/m^3	21	-	-	-	-
Dissolved Zinc*	g/m^3	0.19	-	-	-	-
Chloride*	g/m^3	3,000	-	-	-	-
Nitrite-N	g/m^3	0.003	-	-	-	-
Nitrate-N	g/m^3	0.009	-	-	-	-
Nitrate*	g/m^3	0.041	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	0.013	-	-	-	-
Sulphate*	g/m^3	62	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	8	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	3	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m^3	6.2	-	-	-	-
Toluene*	g/m^3	7.8	-	-	-	-
Ethylbenzene*	g/m^3	0.72	-	-	-	-

Sample Type: Saline

Sample Name:		GND2460 29-Apr-2014 4:00 pm				
Lab Number:		1278331.1				
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m³	4.0	-	-	-	-
o-Xylene*	g/m³	1.46	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	1.8	-	-	-	-
Gases in groundwater						
Ethane*	g/m³	0.72	-	-	-	-
Ethylene*	g/m³	< 0.003	-	-	-	-
Methane*	g/m³	4.7	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	91	-	-	-	-
C10 - C14*	g/m³	560	-	-	-	-
C15 - C36*	g/m³	1,020	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	1,660	-	-	-	-

Analyst's Comments

[#1] It should be noted that the sample contained an oil-like substance which has contributed to the TDS result. This should be kept in mind when interpreting this result.

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/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
pH*	Saline water, 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/m³ 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 (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m³ at Analysis Temperature	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 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/m³	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/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m³	1

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
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
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.006 g/m^3	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd 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 22nd 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) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO$_3^-$ I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. 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 22nd ed. 2012.	0.002 g/m^3	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m^3	1

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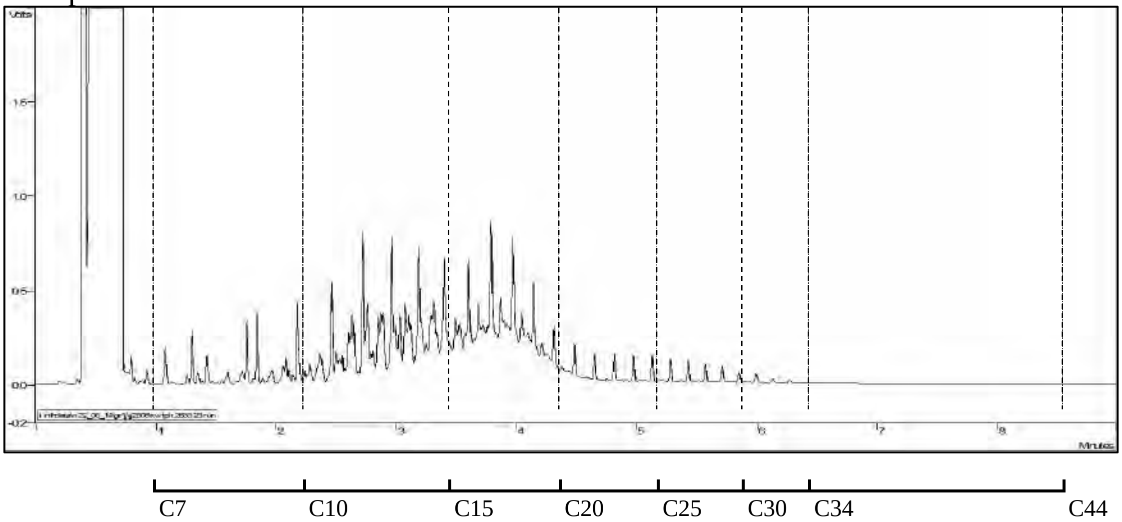
Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Sample : 1278331.1



Appendix V

Biomonitoring report

To	Job Manager, Callum MacKenzie
From	Freshwater Biologists, B Jansma and CR Fowles
Report No	CF617
Doc No	1401365
Date	September 2014

Post-well drilling biomonitoring of two unnamed tributaries of the Mangaoraka Stream in relation to the Kaimiro-A wellsite, May 2014

Introduction

This was a survey performed following drilling and hydraulic fracturing activities at the Kaimiro-A wellsite in early May, 2014. Survey results may be compared with those of the two biomonitoring surveys undertaken in the 2013-2014 monitoring year for the Kaimiro Production Station of Greymouth Petroleum; particularly that undertaken in February, 2014 (CF615) which can be considered as the pre-drilling survey. The Taranaki Regional Council has undertaken surveys since January 1985 in the tributaries of the Mangaoraka Stream that receive stormwater and wastewater from the production station area. The results of surveys performed since the 1998-99 monitoring year are discussed in the references at the end of this report.

Methods

This survey was undertaken on 5 May 2014 at three sites in two unnamed tributaries of the Mangaoraka Stream. Figure 1 shows the location of these sampling sites. Site 1 is the 'control' site which is located in a major tributary of the Mangaoraka Stream, upstream of the confluence with a more minor tributary. Site 2 is situated in the minor tributary which receives the stormwater discharge from the production station and site 3 is approximately 50 metres downstream of the confluence of this tributary (Table 1).

The standard '400 ml kick-sampling' technique was used to collect streambed macroinvertebrates from these sites in this survey. This 'kick-sampling' technique is very similar to Protocol C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

Table 1 Biomonitoring sites in two tributaries of the Mangaoraka Stream in relation to discharges from the Kaimiro Production Station

Site	Site code	GPS reference (NZTM)	Location
1	MRK 000198	E1700117 N5664652	Major tributary approx. 50m u/s of confluence with minor tributary
2	MRK 000204	E1700054 N5664636	Minor tributary (receives discharge) 150m d/s of Upland Road
3	MRK 000207	E1700171 N5665679	Major tributary approx. 50m d/s of confluence with minor tributary

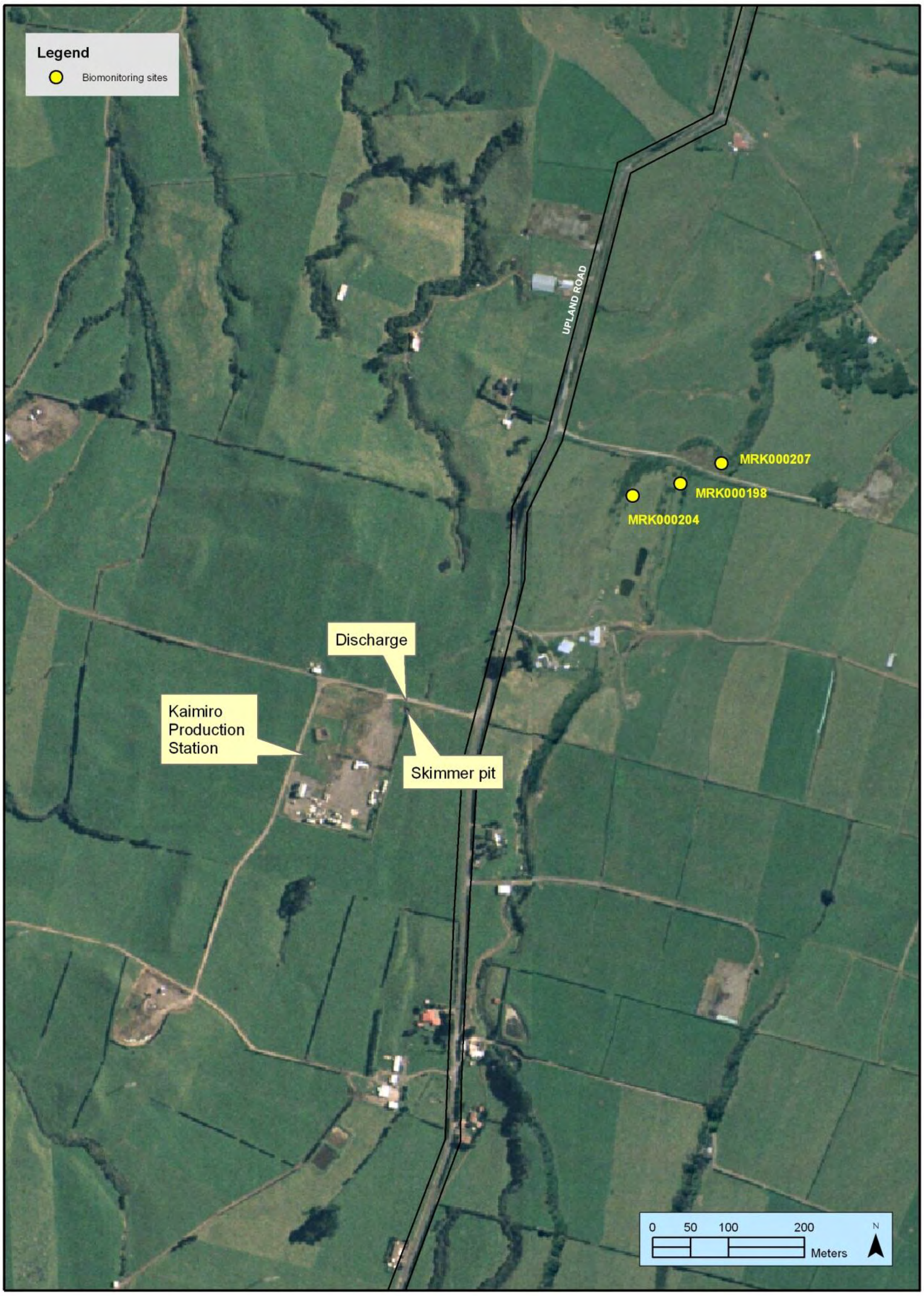


Figure 1 Biomonitoring sites in two unnamed tributaries of the Mangaoraka Stream related to the Kaimiro Production Station (and Kaimiro-A drilling site)

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for 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. Averaging the scores from a list of taxa taken from one site and multiplying by a scaling factor of 20 produces a Macroinvertebrate Community Index (MCI) value.

The MCI was designed for use in stony streams, and all sites sampled in this survey provided stony substrate. The MCI was designed as a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution, though sedimentation, temperatures, current speed, dissolved oxygen levels and some toxins can also affect the index values, because the taxa capable of tolerating extremes in these variables generally have low sensitivity scores. Usually 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, therefore SQMCI$_s$ values range from 1 to 10, while MCI values range from 20 to 200.

Results and discussion

This May 2014 survey was performed 6 days after a fresh in excess of three times median flow and 90 days after a fresh in excess of seven times median flow. However, in the month prior to this survey, there had been several fresh events which exceeded three times median flow. During this early morning survey, water temperature in the main tributary was 14.2°C (at site 3) and in the minor tributary water temperature was 15.0°C.

The substrate at all sites consisted predominantly of boulders, gravels and cobbles, with smaller proportions of silt and sand substrate present also. A moderate, steady to swift flow of clear, uncoloured water was recorded at all three sites.

In the major tributary, there was no evidence of extensive slumping of the banks upstream and downstream of site 1 compared with that noted by the May 2012 survey, which most likely had been caused by stock accessing the stream. The stream bed at this open site had patchy periphyton mats and filamentous algal cover. At the completely shaded site 3, thin periphyton mats were observed on the bed of the stream along with patchy moss but no filamentous algae were present. Thin algal mats and patchy filamentous algae and moss were recorded at the partially shaded site 2 in the minor tributary of the Mangaoraka Stream. Some iron oxide deposits were found on the stream bed at this site similar to previous occurrences in this and many small seepage streams in Taranaki. (Typically such deposits result from the oxidation of dissolved ferrous iron in groundwater seepage, upon contact with atmospheric oxygen. Small streams may often have insufficient flow to flush these deposits away.) No iron oxide deposits were recorded at sites 1 or 3 at the time of this survey. There was minimal evidence of sediments deposited on parts of the tributary stream bed at the time of this survey unlike on recent occasions where silt was the dominant component of the substrate.

Macroinvertebrate communities

Most past surveys have shown that the larger tributary supports richer macroinvertebrate communities, including abundances of 'sensitive' mayflies. These results reflect the good habitat conditions normally provided by faster-flowing, stony-bedded streams on the upper to mid reaches of the ring plain. The smaller tributary has tended to support communities with lower numbers of taxa and smaller proportions of 'sensitive' taxa. This in part has been due to the slower flow and/or iron oxide deposition on the more sedimented stream bed of this tributary.

Table 2 provides a summary of the results from the sites sampled in this survey together with historical results (including the previous (pre-drill) survey in February 2014). The full results of the current survey are presented in Table 3.

Table 2 Results of previous surveys performed between January 1985 and February 2014 in two unnamed tributaries of the Mangaoraka Stream, together with current (post-drill) survey results

Site No	Numbers of taxa					MCI values					SQMCI$_s$ values				
	No. samples	Range	Median	Feb 2014	May 2014	No. Samples	Range	Median	Feb 2014	May 2014	No. samples	Range	Median	Feb 2014	May 2014
1	54	18-37	27	26	21	54	83-110	97	92	98	29	1.9-5.1	3.4	4.4	4.4
2	50	3-26	15	12	15	50	55-103	81	95	101	28	1.2-4.1	2.2	2.7	3.5
3	54	14-33	24	18	23	54	71-111	99	101	97	29	1.7-6.2	4.0	4.4	4.2

Major tributary
Upstream of discharge tributary (site 1)

Survey results to date are illustrated in Figure 2.

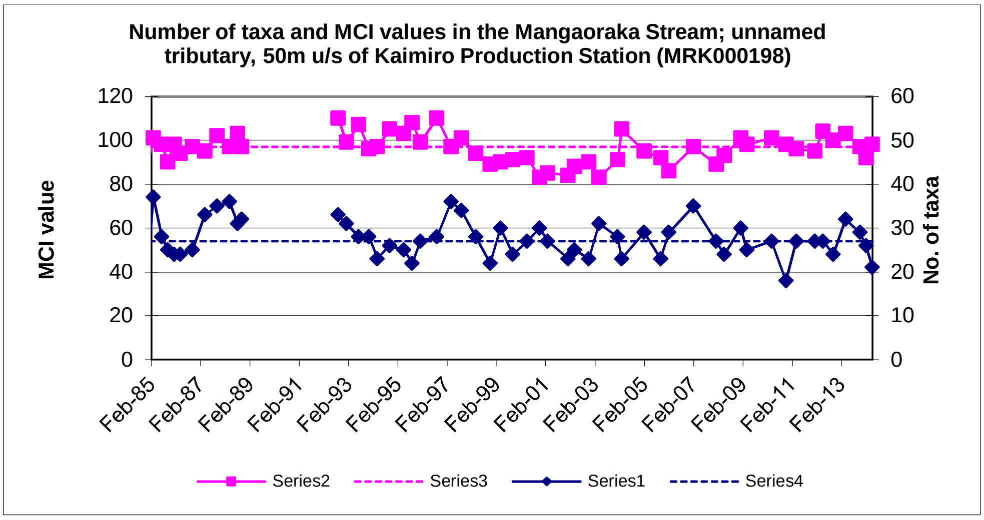


Figure 2 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 50 m upstream of Kaimiro Production Station (MRK000198)

Table 3 Macroinvertebrate fauna of two unnamed tributaries of the Mangaoraka Stream in relation to Kaimiro-A wellsite post-drill, sampled on 5 May 2014

Taxa List	Site Number	MCI score	1	3	2
	Site Code		MRK000198	MRK000207	MRK000204
	Sample Number		FWB14202	FWB14204	FWB14203
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	-	C	-
NEMERTEA	Nemertea	3	R	R	-
NEMATODA	Nematoda	3	-	-	R
ANNELIDA (WORMS)	Oligochaeta	1	C	XA	A
	Lumbricidae	5	-	R	-
MOLLUSCA	*Potamopyrgus*	4	VA	VA	R
CRUSTACEA	Isopoda	5	-	R	R
	Paraleptamphopidae	5	R	R	-
	Talitridae	5	R	-	-
	Paranephrops	5	-	-	R
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	C	-	-
	Coloburiscus	7	C	A	-
	Zephlebia group	7	VA	XA	-
PLECOPTERA (STONEFLIES)	*Acroperla*	5	-	-	R
HEMIPTERA (BUGS)	*Sigara*	3	R	-	-
COLEOPTERA (BEETLES)	Elmidae	6	C	R	R
	Ptilodactylidae	8	R	C	-
MEGALOPTERA (DOBSONFLIES)	*Archichauliodes*	7	R	A	R
TRICHOPTERA (CADDISFLIES)	*Aoteapsyche*	4	A	A	-
	Hydrobiosis	5	C	-	-
	Orthopsyche	9	-	A	C
	Oxyethira	2	A	-	-
	Pycnocentria	7	R	R	-
	Triplectides	5	R	-	-
	Zelolessica	7	C	-	R
DIPTERA (TRUE FLIES)	*Aphrophila*	5	R	-	R
	Eriopterini	5	-	R	C
	Hexatomini	5	-	R	-
	Limonia	6	-	-	R
	Zelandotipula	6	-	-	R
	Orthocladiinae	2	A	R	C
	Polypedilum	3	-	R	-
	Empididae	3	-	R	-
	Austrosimulium	3	VA	C	-
	Tanyderidae	4	-	R	-
ACARINA (MITES)	Acarina	5	-	R	-
		No of taxa	21	23	15
		MCI	98	97	101
		SQMCIs	4.4	4.2	3.5
		EPT (taxa)	8	5	3
		%EPT (taxa)	38	22	20
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa			

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

A richness of twenty-one taxa was recorded at this site by the current survey, which was six taxa fewer than the historical median taxa number (Table 2). The macroinvertebrate community at this site was characterised by no 'highly sensitive' taxa; one 'moderately sensitive' taxon [mayfly (*Zephlebia* group)]; and five 'tolerant' taxa [snail (*Potamopyrgus*), net-building caddisfly (*Aoteapsyche*), algal-piercing caddisfly (*Oxyethira*), orthoclad midges, and sandfly (*Austrosimulium*)] (Table 3).

The moderately high proportion of 'sensitive taxa' (62%) recorded at this site was reflected in the MCI score of 98 units, one unit higher than the median score recorded at the site previously (Figure 2 and Table 2) and six units higher than the MCI score recorded by the previous late summer (pre-drill) survey (92 units).

A moderate $SQMCI_s$ score of 4.4 units was recorded at this site by the current survey which reflected the numerical dominance by two very abundant 'tolerant' taxa (snail and sandfly) and one 'moderately sensitive' mayfly taxon. This score was 1.0 $SQMCI_s$ unit higher than the historical median score and identical with the pre-drill, late summer $SQMCI_s$ score.

Downstream of discharge tributary (site 3)

Results to date for this site, downstream of the confluence with the Production Station discharges receiving waters tributary, are illustrated in Figure 3.

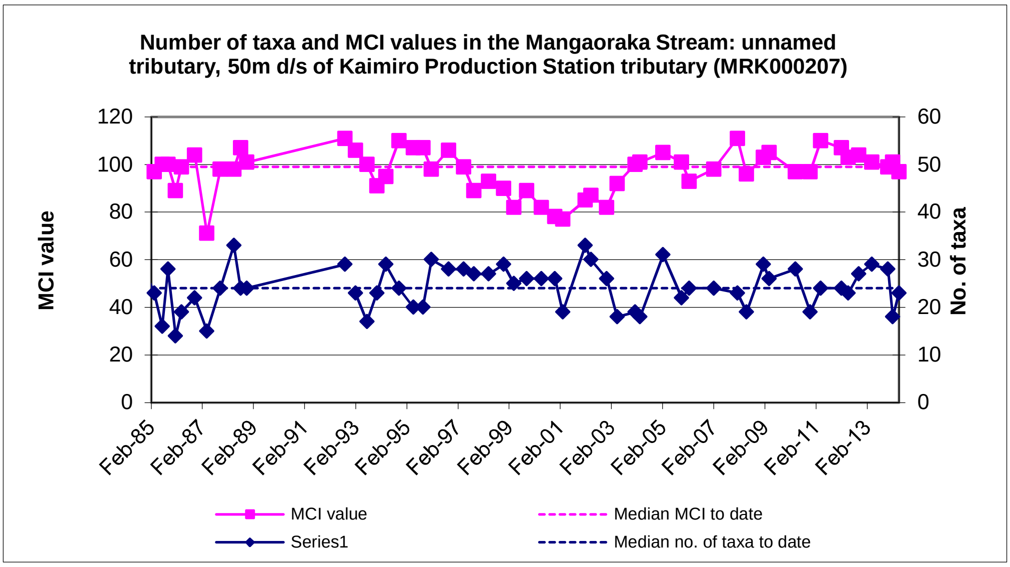


Figure 3 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 50 m d/s of Kaimiro Production Station tributary (MRK000207)

A slightly higher richness of 23 taxa was found at this site, two taxa more than at the upstream 'control' site, and one taxon fewer than the median recorded by all previous surveys (Figure 3 and Table 2). The community was characterised by one 'highly sensitive' taxon [net-building caddisfly (*Orthopsyche*)]; three 'moderately sensitive' taxa [mayflies (*Zephlebia* group and *Coloburiscus*) and dobsonfly (*Archichauliodes*)]; and three 'tolerant' taxa [oligochaete worms, snail (*Potamopyrgus*), and net-building caddisfly (*Aoteapsyche*)]; several more dominant taxa than found at this site by the pre-drill survey and found by the current survey at the upstream 'control' site.

There were several significant differences within individual taxon abundances found between sites 1 and 3, two of which were increases in abundances of 'sensitive' taxa and three decreases within 'tolerant' taxa in a downstream direction (Table 3). These differences were tempered by decreases within three other 'sensitive' taxa and increases in two 'tolerant' taxa (particularly oligochaete worms), which resulted in a small decrease of 0.2 unit in $SQMCI_s$ value (Table 2). This $SQMCI_s$ was slightly higher than the historical median for this site and indicative of a macroinvertebrate community in relatively good health, coincidental with a small increase in taxa richness.

As a result of a small decrease in the proportion of 'sensitive' taxa in the community (57%) compared with site 1, the MCI score (97 units) decreased insignificantly (by one unit) which was two units below the median MCI score recorded to date at this site and an insignificant four units less than the MCI score found by the pre-drill late summer survey. The $SQMCI_s$ and MCI scores were both indicative of minimal recent impacts on the macroinvertebrate community below the inflowing tributary which receives the Kaimiro Production Station and Kaimiro-A drilling phase discharges of stormwater and production wastewater.

Minor tributary which receives Kaimiro Production Station discharges (site 2)

The results of surveys performed to date at this site, in the tributary which receives the Production Station's discharges, are illustrated in Figure 4.

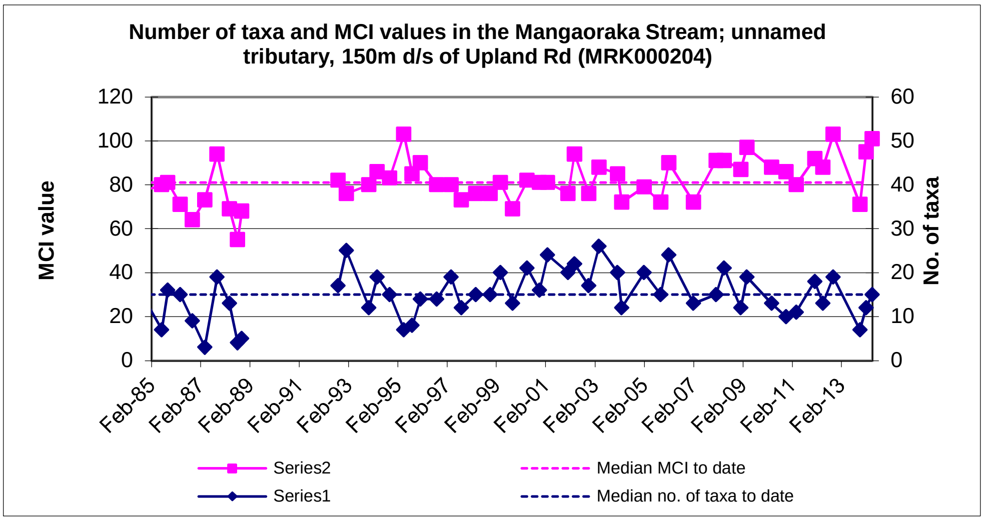


Figure 4 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 150 m d/s of Upland Road (MRK000204)

A relatively poor but typical richness of 15 taxa was found at this site where there was iron oxide deposition on the substrate. This was equivalent with the median richness of previous surveys (Figure 4, Table 2) and was considered to be related in part to the reduced invertebrate habitat available due to iron-oxide sedimentation of the streambed. The community was characterised by only one 'tolerant' taxon [oligochaete worms] (Table 3). However, the relatively high proportion of 'moderately sensitive' taxa (73%) in this community resulted in the MCI score of 101 units, a significant 20 units higher than the historical median for this site and only two units below the historical maximum (Figure 4), and six units above the MCI score found by the pre-drill survey. However, the presence of only one 'highly sensitive' taxon and scarcity of abundant taxa recorded in the community were indicative of poorer habitat quality. This was reflected in the lower $SQMCI_s$ score (3.5 units) which was due mainly to the abundance of just the one 'tolerant taxon.
This site's taxa richness was up to eight taxa fewer than those found at the two sites in the main tributary. The $SQMCI_s$ score was below the scores found at these two sites, although the MCI score was higher than scores found at both sites. These dissimilarities were typical of the differences in communities found by past surveys under low, spring and/or summer-autumn warmer flow conditions when the habitat differences between tributaries often have been pronounced.

The current survey results were more indicative of recent impacts of streambed iron-oxide sedimentation upon the macroinvertebrate community of the receiving tributary rather than attributable to the Kaimiro Production Station discharges and were indicative of no detrimental impacts of recent re-drilling activities at the Kaimiro-A site. This was also reinforced by an absence of 'sewage fungus' on the stream bed.

Discussion

Most of the previous surveys undertaken in relation to the Kaimiro Production Station stormwater discharge have shown that the larger tributary of the Mangaoraka Stream supports richer macroinvertebrate communities, including greater abundances of 'sensitive' mayflies. The results of this late autumn post-Kaimiro-A drilling survey were consistent with these trends. Taxa richnesses recorded at sites 1 and 3 were higher than that recorded at site 2 in the unnamed tributary which receives the production station and drilling site stormwater and production wastewater discharges and had been affected to some extent by and iron-oxide streambed deposits under moderate flow conditions. The $SQMCI_s$ score recorded at site 2 was lower than those recorded at sites 1 and 3 in the larger tributary but not to the extent found by the previous late-summer pre-drill survey. At the time of this survey, the availability of habitat in the smaller tributary was more limited than in the major tributary with moderate flows recorded at all three sites after a wet autumn period. The condition of the habitat at site 2 was compromised to some extent by the presence of naturally occurring iron oxide sediment. Such habitat conditions are unlikely to support more 'sensitive' taxa, several of which were recorded in abundance at one or both of the two sites in the major tributary. In this survey, no iron oxide sedimentation was recorded at site 1 or at site 3. It is considered that the differences in richness and $SQMCI_s$ recorded between site 2 and the two sites in the larger tributary in this post-drill survey and the previous pre-drill survey related to differences in habitat (mainly sedimentation) rather than due to the effects of the stormwater and production wastewater discharges from the production station or the drilling activities at the Kaimiro-A wellsite.

The richness and SQMCI results recorded at the site in the minor (receiving) tributary were indicative of poorer habitat quality in this tributary at the time of this post-drill survey.

Overall, the results of this survey under autumn, moderate flow conditions indicated that the discharge of stormwater and production wastewater from the Kaimiro Production station and recent Kaimiro-A drilling activities had not resulted in any recent significant adverse effects on the macroinvertebrate communities in the main tributary of the Mangaoraka Stream.

Summary

A three site biomonitoring survey was undertaken in May 2014 in two tributaries of the Mangaoraka Stream, to monitor the health of the macroinvertebrate communities of these tributaries, in relation to the discharges of treated stormwater and production wastewater from the Kaimiro Production Station but more particularly following the re-drilling activities of the Kaimiro-A wellsite (at the same location). The Council's standard 'kick' sampling technique was used to collect the stream bed macroinvertebrate samples from each site. 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 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.
The richness and $SQMCI_s$ score recorded at site 2 in the small unnamed tributary downstream of the production station discharge typically were dissimilar to those recorded at the two sites in the larger tributary. At the time of this survey, the availability of instream habitat at this site was limited due to iron-oxide deposition on the streambed which is restrictive to the establishment of a macroinvertebrate community comprising certain 'sensitive' taxa. In contrast, sites 1 and 3 in the major tributary supported more diverse communities which included abundances of several 'sensitive' taxa. It was considered most likely that the difference in taxa richness and $SQMCI_s$ score at site 2 compared to the two sites in the larger tributary, resulted from differences in physical habitat rather than as a result of the Production Station or Kaimiro-A wellsite drilling stormwater and production wastewater discharges.

$SQMCI_s$ and MCI scores recorded at each of the two sites in the main tributary in this survey were within one to two units respectively of the median scores for each site on this autumn occasion; an indication of relatively good preceding water quality under moderate flow conditions following a recent wet autumn period. They were also within an insignificant 6 MCI units and 0.2 $SQMCI_s$ unit of pre-drill late summer scores.

In summary the results of this May 2014 survey indicated that discharges from the Kaimiro Production Station and post-Kaimiro-A wellsite drilling site had not had any recent detrimental effects on the macroinvertebrate communities of the main tributary of the Mangaoraka Stream and that the poorer community found in the (minor) receiving tributary was coincident with streambed iron-oxide deposition and typical of communities recorded at this site to date.

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