Greymouth Petroleum Limited
Kowhai-B Hydraulic Fracturing Monitoring Programme
Annual Report
2014-2015

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Executive summary

Greymouth Petroleum Limited (GPL) operate the Kowhai-B wellsite, located at 451 Ngatimaru Road, Tikorangi. The wellsite lies within the Waiau catchment and contains a hydrocarbon producing well and associated infrastructure.

During the 2014-2015 monitoring period, GPL exercised resource consent 9207-1. This consent authorised the discharge of water-based hydraulic fracturing fluids into land at depths greater than 3,000 m TVD beneath the Kowhai-B wellsite. The consent was issued by Taranaki Regional Council (the Council) on 29 March 2012 and contains a total of 14 special conditions which set out the requirements that GPL must satisfy. This was replaced by consent 9207-2 in July 2015.

The following report for the period July 2014 to June 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL, within their Kowhai-B 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, GPL demonstrated an overall high level of environmental performance.

The programme of hydraulic fracturing undertaken by GPL at the Kowhai-B wellsite during the monitoring period included the fracturing of one well; Kowhai-2. The hydraulic fracturing of this well took place in March 2015.

The programme of monitoring implemented by the Council in relation to fracturing activities commenced in the 2012-2013 monitoring year. The results of monitoring undertaken during the 2012-2013 and 2013-2014 monitoring periods were presented in the 2012-2014 biennial report (Taranaki Regional Council, 2015). Monitoring included groundwater sampling at three sites and processing of samples for a range of chemical and isotopic analysis. This report covers the monitoring of groundwater, surface water and hydraulic fracturing and return fluids during the 2014-2015 monitoring period.

The results of the monitoring carried out by the Council indicate that the hydraulic fracturing activities undertaken by GPL have had no adverse effects on local groundwater 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 administrative performance and compliance with the resource consent over the reporting period.

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

This report includes recommendations for the 2015-2016 year.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Limited (GPL) at their Kowhai-B wellsite, 451 Ngatimaru Road, Tikorangi over the period 12 to 18 March 2015. The wellsite is located in the Waiau 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 Kowhai-B wellsite in the 2014-2015 monitoring period included the fracturing of one well; Kowhai-2.

The programme of monitoring implemented by the Council in relation to all recent hydraulic fracturing activities at the Kowhai-B wellsite spanned the 2012-2013, 2013-2014 and 2014-2015 monitoring periods and included groundwater, surface water and discharge monitoring components.

A report was completed in April 2015 which outlined and discussed the results of the monitoring carried out in the 2012-2013 and 2013-2014 monitoring periods in relation to previous hydraulic fracturing events at the site (Taranaki Regional Council, 2015). The following report provides an update on the results of further fracturing events that occurred at the site and further monitoring carried out since the initial report was written.

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 RMA and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consents held by the GPL in the Waiau catchment, the nature of the monitoring programme in place for the period under review, and a description of the activities and operations conducted in the Company's site/catchment.

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

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

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

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

1.1.3 The Resource Management Act 1991 and monitoring

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

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

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

1.1.4 Evaluation of environmental and administrative performance

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

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

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

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

Environmental Performance

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

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

  For example:

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

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

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

Administrative performance

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

- **Good:** Perhaps some administrative requirements of the resource consents were not met at a particular time, however this was addressed without repeated interventions from the Council staff. Alternatively adequate reason was provided

for matters such as the no or late provision of information, interpretation of 'best practical option' for avoiding potential effects, etc.

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

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

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

1.2 Process description

1.2.1 Hydraulic fracturing

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

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

1.2.2 Kowhai-B wellsite history

The Kowhai-B wellsite has been in operation since 2012. The area around the wellsite and Ngatimaru Road is rural with low population density. The site lies in an active petroleum exploration area, with several production stations within a 10 km radius of

the site. These operations function alongside pastoral farming and dairy runoff operations in the area.

The Kowhai-2 well was drilled between January and March 2013 and hydraulic fracturing occurred during March and April 2013 and then in March 2015. Monitoring continued for a year beyond the end of fracturing activity. The location of the wellsite is illustrated in Figure 1. A summary of all hydraulic fracturing activities carried out by GPL at the Kowhai-B wellsite is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity (2012-2015)

Well	Wellsite	Consent	Date		Injection zone (m TVDss)	Formation
			Start	End		
Kowhai-2	Kowhai-B	9207-1	23/03/13	02/04/13	3,802 to 4,067	Kapuni
			12/03/15	18/03/15	3,360 to 3,396	Kapuni

A report was completed in April 2015 (Taranaki Regional Council, 2015) which outlined and discussed the results of the monitoring carried out during the 2012-13 and 2013-2014 monitoring periods. The following report provides an update on the results of further monitoring carried in relation to further hydraulic fracturing which occurred in the 2014-2015 monitoring period.

1.3 Resource consents

1.3.1 Discharges onto and into land

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

GPL holds resource consent 9207-2, authorising the discharge of contaminants into land at the Kowhai-B wellsite. The consent was issued on 7 July 2015. This replaced resource consent 9207-1, which also authorised the discharge of contaminants into land at the Kowhai-B wellsite. The consent was issued by the Council on 29 March 2012, under Section 87(e) of the RMA. This is the consent under which Kowhai-2 was fractured. All the monitoring referenced in this report has been carried out under consent 9207-1, so it will be against this consent that compliance is measured. Consent 9207-1 contains a total of 14 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 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 3, 4 and 5 relate to fresh water monitoring requirements, to allow compliance with condition 2 to be assessed.

Condition 6 requires the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 7 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 8 is a notification requirement.

Condition 9 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

Condition 10 stipulates how the reports required by conditions 7 and 9 are to be submitted.

Condition 11 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 12 requires the consent holder to adopt best practicable options.

Condition 13 relates to the composition of the fracturing fluid.

Consent 14 is a review provision.

1.4 Monitoring programme

1.4.1 Introduction

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

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

The monitoring programme implemented in relation to the hydraulic fracturing of the Kowhai-2 well consisted of four primary components.

1.4.2 Programme liaison and management

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

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

1.4.3 Review of consent holder submitted data

As required by the conditions of consents 9207-1, 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 existing groundwater supplies in the vicinity of the Kowhai-B wellsite and the analysis of the results.

The wells sampled were the same as those in the 2012-2014 report. The details of each site are included in Table 2 and their proximity to the wellsite is illustrated in Figure 1.

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite location (m)	Total depth (m)	Screened interval (m)	Aquifer
GND2318	854	NA*	NA*	Volcanics
GND2319	492	NA*	NA*	Volcanics
GND2324	249	NA*	NA*	Volcanics

* Spring

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.

Samples taken from springs were obtained directly from the spring discharge. 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 were carried out to assess whether any stormwater discharges from the Kowhai-B wellsite during the course of fracturing operations had resulted in any detrimental effects upon the biological communities within the receiving waters.

The biomonitoring sites sampled were the same as those in the 2012-2014 report. The details of each site are included in Table 3 and their proximity to the wellsite is illustrated in Figure 2.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
WAI000060	E 1711185 N 5677828	50m upstream of the stormwater discharge point	Vegetation sweep
WAI000062	E 1711231 N 5677797	50m downstream of the stormwater discharge point	Vegetation sweep
WAI000065	E 1711258 N 5677826	50m downstream of WAI000062	Vegetation sweep

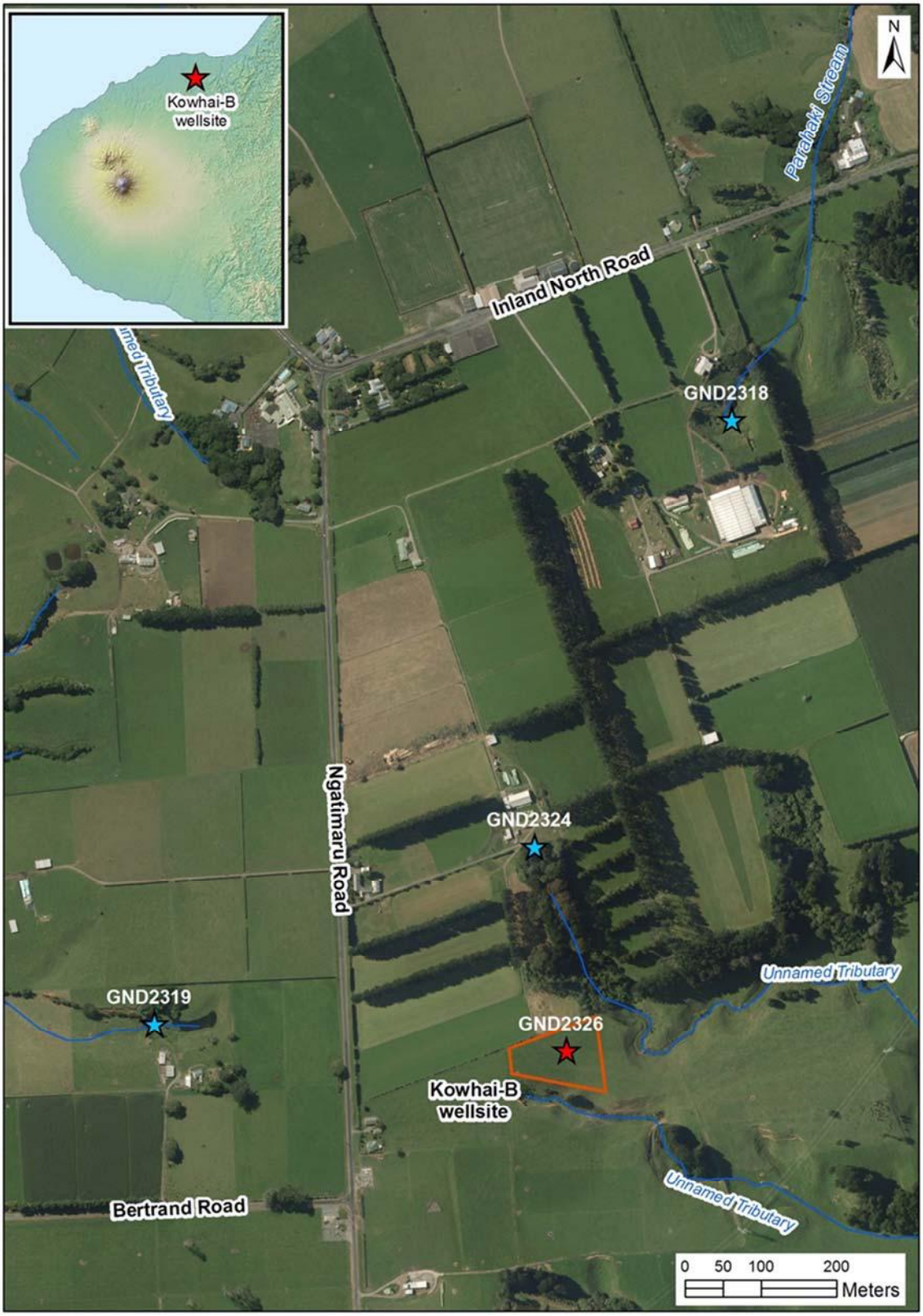

Figure 1 Location of groundwater sampling sites in relation to Kowhai-2 well (GND2326)

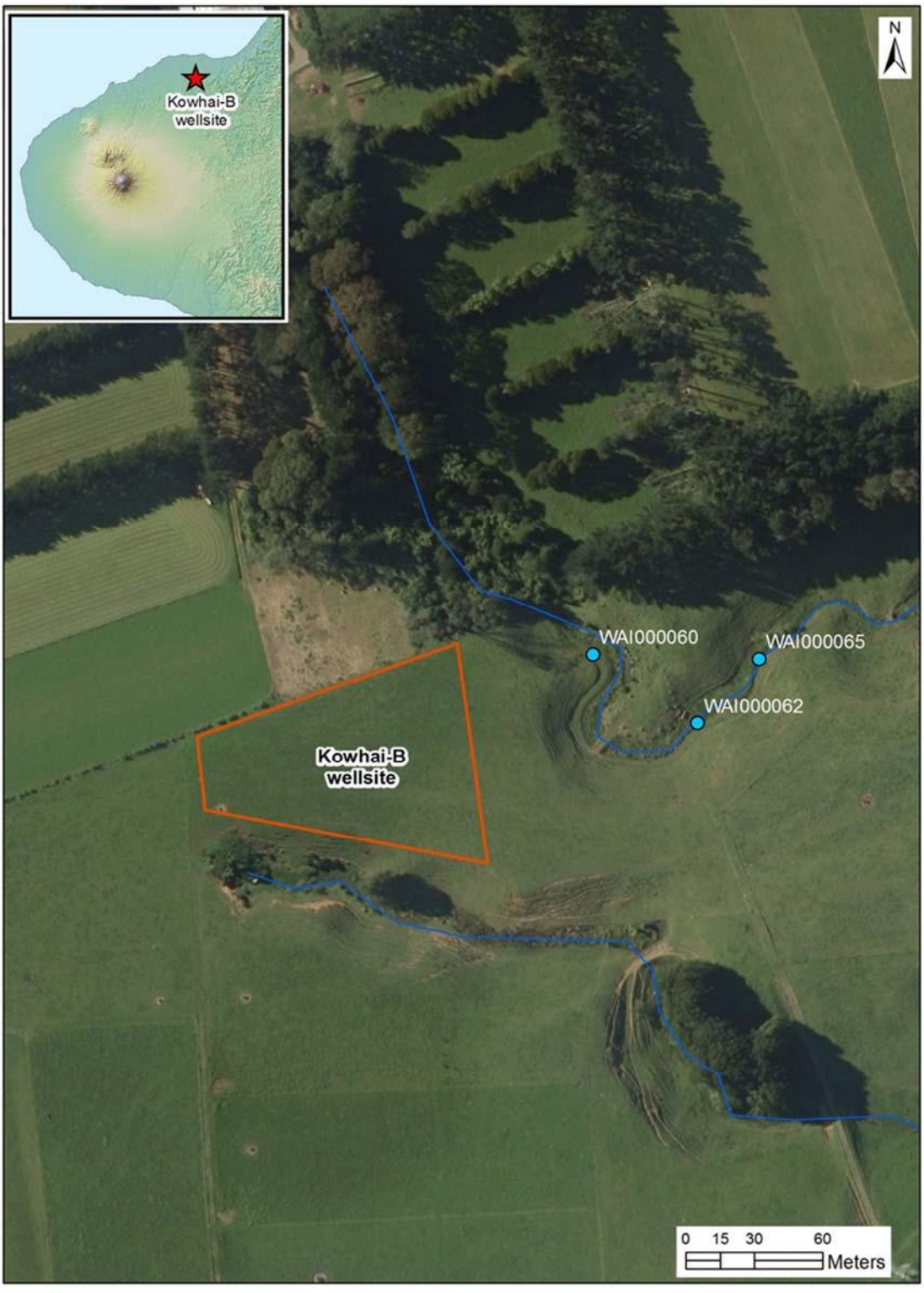

Figure 2 Location of biomonitoring sites in relation to Kowhai-B wellsite

2. Results

2.1 Consent holder submitted data

2.1.1 Kowhai-2 post-fracturing discharge report

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

- A total of three discrete zones were fractured over the period 12 March to 18 March 2015, at depths between 3,360 to 3,396 m TVDss.
- A total of 3,067 barrels (bbls) (488 m^3) of liquid was discharged across the three fractured zones. The total proppant weight was 56 tonnes.
- By volume the fluid injected was comprised of 94.58% water, 3.50% proppant and 1.92% chemicals.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. The maximum pressure exerted during the fracturing programme remained below the successfully tested levels at all times.
- The Kowhai-2 well was opened for flowback immediately after placement of the proppant. 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 clear from the composition and physical properties of the flowback fluid that it is dominantly hydraulic fracturing fluid during the initial stages of flowback, and from this a reasonable estimate of fluid remaining underground can be made. At the completion of all flow-back operations, approximately 1,642 bbls (261 m^3) of fracture fluids and formation fluid were returned to the surface, leaving 1,425 bbls (227 m^3) underground. It is estimated that all of the proppant injected (56 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.
- All fracturing treatments were placed successfully. It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Chemical sampling

2.2.1 Kowhai-2 groundwater sampling survey

In June 2015 a three month post-hydraulic fracturing groundwater sampling round was carried out at three sites. Key indicator parameters pH, electrical conductivity, chloride and total dissolved solids are plotted against time (Figures 3, 4, 5 and 6). If the concentration of these parameters changed it could indicate the migration of deep

formation water, which is highly saline in composition, via fractures or conduits created by the hydraulic fracturing process, leakage from the wellbore due to integrity issues, or the mishandling of fluids at the surface.

As Figures 3 to 6 show, groundwater parameters remained relatively consistent from samples taken before the March 2015 hydraulic fracturing event to samples taken after. The results of the laboratory analysis show only minor variations in analyte concentration across all sampling events. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in the post-fracturing sample obtained were detected. Trace levels of methane were found in GND2318 and GND2319. These levels are consistent with natural methane levels in groundwater in Taranaki. The levels were considered too low for carbon isotope analysis to be carried out on the samples.

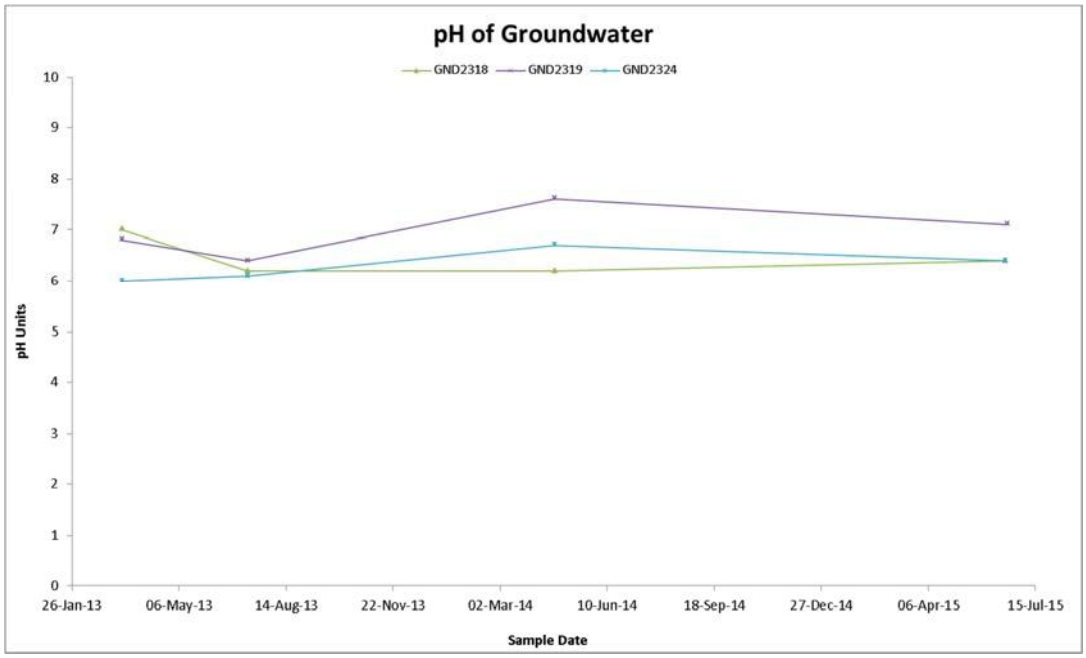

Figure 3 Results of pH analysis in local groundwater

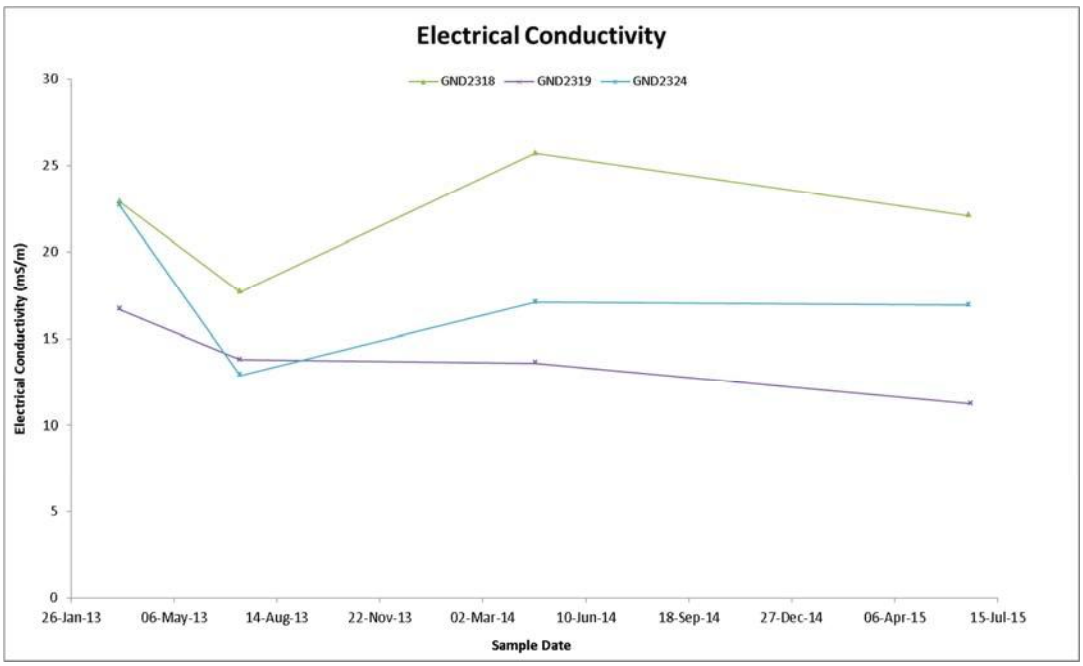

Figure 4 Results of electrical conductivity analysis in local groundwater

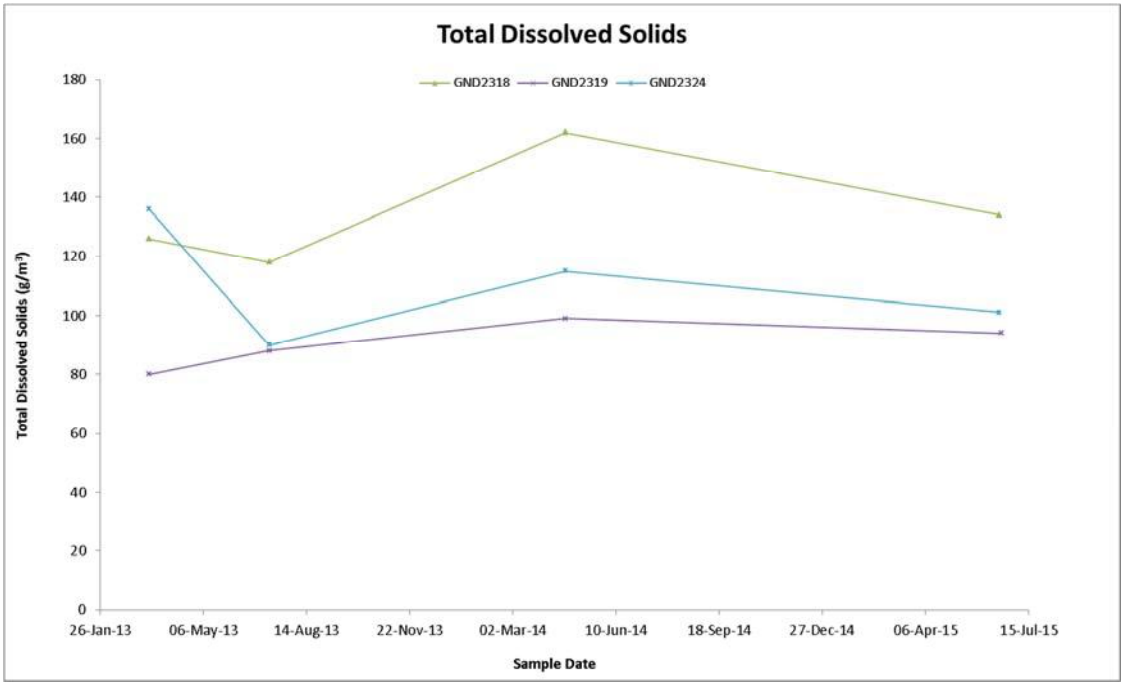

Figure 6 Results of total dissolved solids analysis in local groundwater

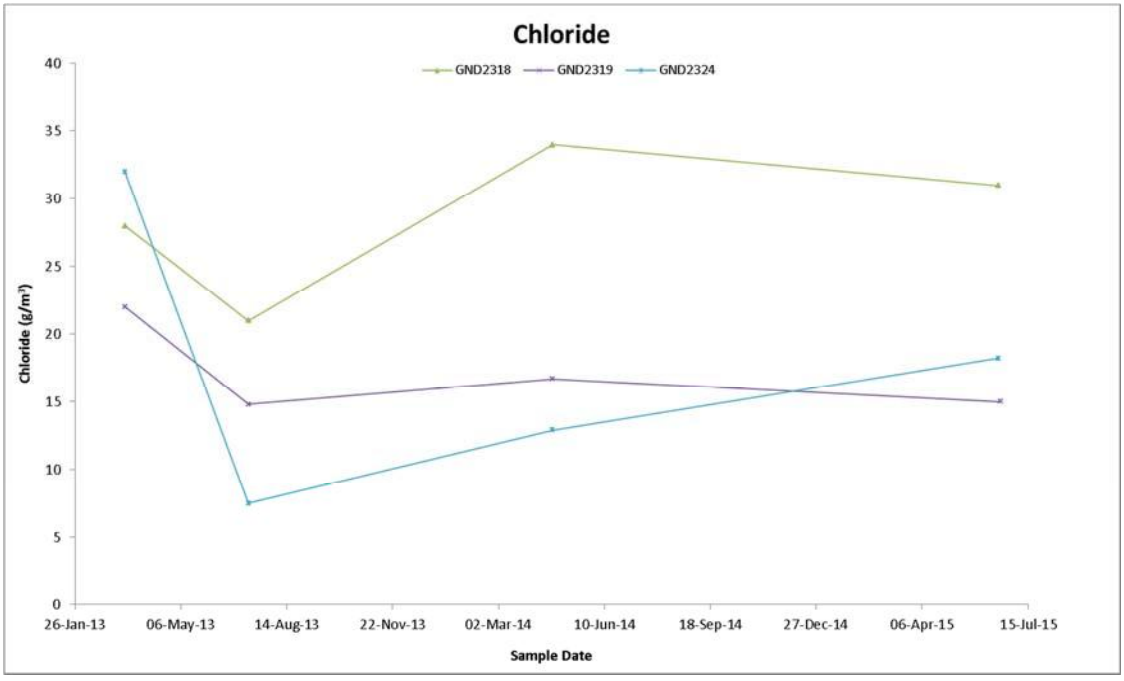

Figure 5 Results of chloride analysis in local groundwater

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Kowhai-2 well is included in Appendix II. The certificates of analysis are included in Appendix III.

2.2.2 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Kowhai-2 well are summarised below in Table 4. 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 4 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Kowhai-2
Sample date	-	12 March 2015
Lab number	-	TRC152895
Benzene	g/m^3	<0.010
Ethylbenzene	g/m^3	<0.0010
Ethylene glycol	g/m^3	61
Total hydrocarbons	g/m^3	680
Methanol	g/m^3	<2
Propylene glycol	g/m^3	<4
Toluene	g/m^3	<0.0010
o-Xylene	g/m^3	<0.010
m-Xylene	g/m^3	<0.02

Composite samples of return fluids from Kowhai-2 were submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Kowhai-2 well are summarised below in Table 5 and the certificates of analysis are included in Appendix IV. The relatively high levels of salinity (sodium and chloride) and total hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities (comprised predominantly of freshwater). The presence of elevated levels of hydrocarbon and BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 5 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Kowhai-2
Sample Date	-	12 March 2015
Lab number	-	TRC153007
Total alkalinity	g/m^3 CaCO3	1,300
Barium	mg/kg	3.0
Benzene	g/m^3	3.4
Total bromine	g/m^3	2.7
Calcium	g/m^3	24
Chloride	g/m^3	1,050
Electrical conductivity	mS/m@20^oC	517
Total copper	g/m^3	0.039
Ethylbenzene	g/m^3	4.1
Ethane	g/m^3	-
Ethylene	g/m^3	-
Total iron	g/m^3	3.3
Formaldehyde	g/m^3	<0.15
Ethylene glycol	g/m^3	<400
Total hydrocarbons	g/m^3	9,000
Bicarbonate	g/m^3 HCO3	939
Total hardness	g/m^3 CaCO3	95
Total mercury	g/m^3	<0.011
Potassium	g/m^3	168
Methanol	g/m^3	<20
Methane	g/m^3	-
Magnesium	g/m^3	8.8
Total manganese	g/m^3	0.72
Sodium	g/m^3	900
Nickel	mg/kg	0.07
Nitrate + nitrite nitrogen	g/m^3 N	<0.02
Nitrite	g/m^3 N	<0.02
Nitrate	g/m^3 N	<0.02
pH	pH	7.6
Propylene glycol	g/m^3	<400
Total sulphur	g/m^3	21
Sulphate	g/m^3	62
Total dissolved solids	g/m^3	5,100
Toluene	g/m^3	18.1
o-Xylene	g/m^3	15.4
m-Xylene	g/m^3	37.0
Total zinc	g/m^3	0.37

2.3 Biomonitoring survey

The Council's 'vegetation-sweep' technique was used to collect streambed macroinvertebrates from the unnamed tributary of the Waiau Stream in relation to fracturing at the Kowhai-B wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. Post-fracturing surveys were carried out in April 2015. Samples were processed to provide number of taxa (richness), MCI and $SQMCI_S$ scores for each site.

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

Taxa richnesses at all three sites were lower than what had been found at the first survey and this is most likely due to a seasonal effect, probably as a result of the long hot dry summer preceding the last survey in combination with the unnamed tributary being very small in size and containing extensive macrophytes beds. For the first post-frac survey there had been only 12 days since a fresh of 7 x median flow or more had occurred while for the second post-frac survey there had been 112 days since flow had exceeded the 7 x median flow. It was likely that freshwater macroinvertebrates in the unnamed tributary were impacted by high water temperatures and low dissolved oxygen levels. The 'primary' impacted site had particularly low taxa richness but this is likely to have been due to physical variability as the 'secondary' impacted site had a higher taxa richness than the 'control' site indicating that wellsite discharges were not the cause of the unusually low taxa richness. MCI and $SQMCI_S$ scores for the two 'impacted' sites were also either not significantly different or significantly higher (Stark, 1998) than the 'control' site providing further evidence that wellsite discharges had not had a significant negative effect on the macroinvertebrate communities in the unnamed tributary of the Waiau Stream.

2.4 Investigations, interventions, and incidents

The monitoring programme for the year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During the year 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 (IR) 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).

In the 2014-2015 period, the Council was not required to undertake significant additional investigations and interventions, or record incidents, in association with GPL's conditions in resource consents or provisions in Regional Plans.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

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

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

The results of post-fracturing groundwater sampling carried out in the vicinity of the Kowhai-2 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. Trace levels of methane were detected. Concentrations were within the expected range for shallow groundwater in Taranaki. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during the post-fracturing sampling event.

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

In summary, the monitoring carried out by the Council during the 2014-2015 monitoring period indicates that the hydraulic fracturing activities undertaken by GPL at the Kowhai-B wellsite 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 6.

Table 6 Summary of performance of consent 9207-1

Purpose: *To discharge water-based hydraulic fracturing fluids into land at depths greater than 3,000 m TVD beneath the Kowhai-B wellsite*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,000 mTVD	Assessment of consent holder submitted data	Yes
2. 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
3. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
4. 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
5. 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
6. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
7. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
8. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
9. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
10. The reports outlined in conditions 7 and 9 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
11. 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
12. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
13. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes

Purpose: *To discharge water-based hydraulic fracturing fluids into land at depths greater than 3,000 m TVD beneath the Kowhai-B wellsite*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
14. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

During the year, GPL demonstrated a high level of environmental and high level of administrative performance with the resource consent as defined in Section 1.1.4.

3.3 Recommendations from the 2012-2014 Biennial Report

In the 2013-2014 Biennial Report, it was recommended:

1. THAT no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kowhai-B wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

   Hydraulic fracturing re-occurred at the site in March 2015 so the monitoring programme recommenced.

2. THAT the option for a review of resource consent in June 2015, as set out in condition 14 of consent 9207-1, is not exercised, on the grounds that the current conditions of the consents are adequate to ensure that any significant adverse effects on the environment are avoided.

   As resource consent 9207-1 expired in June 2015, a new consent, 9207-2, was granted to GPL in July 2015 under which discharge of water-based hydraulic fracturing fluids into land is allowed at Kowhai-B wellsite at depths greater than 3,000 m TVD.

3.4 Alterations to monitoring programmes for 2015-2016

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

It is proposed that for the 2015-2016 monitoring period, a one-year post-fracturing groundwater sampling round be carried out in March 2016. After this, no further monitoring should be carried out unless any further hydraulic fracturing is undertaken at the site.

Recommendations to this effect are included in Section 4 of this report.

3.5 Exercise of optional review of consent

Resource consent 9207-2 provides for an optional review of the consent on an annual basis, with the next optional review date being June 2016. Condition 20 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 one year post-fracturing groundwater sampling be carried out in March 2016. After that, the monitoring programme will be discontinued, providing no further fracturing occurs at the Kowhai-B wellsite.

2. THAT the option for a review of resource consent(s) in June 2016, as set out in condition 20 of consent 9207-2, not be exercised, on the grounds that there is no requirement at this time for a consent review.

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.

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Taranaki Regional Council (2015) Biomonitoring of an unnamed tributary of the Waiau Stream following hydraulic fracturing by Greymouth Petroleum Ltd at the Kowhai B wellsite, April 2015. Report DS012.

Taranaki Regional Council (2015) Greymouth Petroleum Limited Kowhai-B Hydraulic Fracturing Monitoring Programme Report 2012-2014. Report 2014-108.

Taranaki Regional Council (2013) Greymouth Petroleum Kowhai-B Hydraulic Fracturing Groundwater Monitoring Programme.

Appendix I

Resource consents held by GPL

Taranaki Regional Council

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:	29 March 2012
Commencement Date:	29 March 2012

Conditions of Consent

Consent Granted:	To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3000 mTVD beneath the Kowhai-B wellsite at or about (NZTM) 1711087E-5677788N
Expiry Date:	1 June 2015
Review Date(s):	June 2012, June 2013, June 2014
Site Location:	Kowhai-B wellsite, 451 Ngatimaru Road, Tikorangi (Property owner: R & B Jupp)
Legal Description:	Lot 4 DP 378739 Blk VI Waitara SD (Discharge source & site)
Catchment:	Waiau

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

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General condition

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

Special conditions

1. The discharge point shall be deeper than 3000 mTVD.

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

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

3. 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 2 (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.

4. 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 3 and 4, could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

5. 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 2.

   Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 2.*

6. 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.

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

   (a) the specific well in which each discharge is to occur and the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment);
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well and its intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the results of the reviews required by condition 12;
   (e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 2;
   (g) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

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

8. 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 7, 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.

9. 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 4(a) to 4(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
   (e) an estimate of the volume of fluids (and proppant) remaining underground;
   (f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed;
   (g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
   (h) the results of pressure testing required by condition 6, and the well and discharge pressure durations and the maximum pressure reached during the hydraulic fracture discharge;
   (i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
   (j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 2; and
   (k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

10. The reports described in conditions 7 and 9 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

11. 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.

12. 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.

13. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

14. 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 12; 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 29 March 2012

For and on behalf of
Taranaki Regional Council

Director-Resource Management

Taranaki Regional Council

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 PO Box 3394 New Plymouth 4341
Decision Date:	7 July 2015
Commencement Date:	7 July 2015

Conditions of Consent

Consent Granted:	To discharge water-based hydraulic fracturing fluids into land at depths greater than 3,000 mTVD beneath the Kowhai-B wellsite
Expiry Date:	1 June 2027
Review Date(s):	June Annually
Site Location:	Kowhai-B wellsite, 451 Ngatimaru Road, Tikorangi (Property owner: Hurstpierpoint Trust Limited)
Legal Description:	Lot 4 DP 378739 Lot 1 DP 7887 Blk VI Waitara SD
Grid Reference (NZTM)	1711087E-5677788N
Catchment:	Waiau

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

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Please quote our document number in your reply

General condition

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

Special conditions

1. The discharge point shall be deeper than 3,000 mTVD.

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

2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2022.

3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3 within 5 km of the geographical position (in 3 dimensions) of any hydraulic fracturing discharge, then:

   (a) if a hydraulic fracturing discharge is currently being undertaken it shall cease immediately and not recommence; or
   (b) if a hydraulic fracturing discharge has occurred within the previous 72 hours no further hydraulic fracturing discharges shall occur.

4. Following the occurrence of any seismic event described in special condition 3 the consent holder shall investigate and report to the Chief Executive, Taranaki Regional Council on the likelihood of the seismic event being induced by the exercise of this consent. Hydraulic fracturing discharges may only then continue once the Chief Executive, Taranaki Regional Council has considered the report and concluded that the environmental risk of recommencing hydraulic fracturing is acceptable and has advised the consent holder accordingly.

5. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1,000 mg/l.

6. 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 5 (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.

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

8. 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 7 and 9 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

9. 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. The 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 5.

   Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by* condition 6.

10. 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.

11. 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 monitoring techniques to be used to determine the fate of discharged material;
    (e) the results of the reviews required by condition 17;
    (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
    (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 5;
    (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
    (i) any identified faults within the modelled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
    (j) the burst pressure of the well casing and the anticipated maximum well and discharge pressures and the duration of the pressures; and
    (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
    (l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 17.

    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.*

12. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 11, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

13. Subject to condition 14, within 90 days of any commencement date as advised under condition 12, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) 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;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 8(a) to 8(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;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
    (h) 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;
    (i) the results of pressure testing required by condition 10 and the top-hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) 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 5; and
    (l) results of the monitoring referred to in condition 11 (d); and
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

14. On occasions, including for programs involving multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the 90-day deadline from commencement required by condition 13. In these situations the consent holder shall submit an 'Interim Post-fracturing Discharge Report', which includes all the information that is available, to the Chief Executive within 90 days and a final Post-fracturing report as soon as practicable but within 90 days of the interim report.

15. The reports described in conditions 11 and 13 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

16. 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.

17. 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 of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
    (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

18. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

19. This consent shall lapse on 1 June 2022, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

20. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review:

    a) during the month of June each year, and/or
    b) within 30 days of receiving any investigation and report in accordance with special condition 4 above;

    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 17; 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 7 July 2015

For and on behalf of
Taranaki Regional Council

A D McLay
Director - Resource Management

Appendix II

Groundwater Chemistry Table

Parameter	unit	GND2318				GND2319				GND2324			
		Pre-frac	Post-frac			Pre-frac	Post-frac			Pre-frac	Post-frac		
Sample date		14 Mar 2013	09 Jul 2013	22 Apr 2014	17 Jun 2015	14 Mar 2013	09 Jul 2013	22 Apr 2014	19 Jun 2015	14 Mar 2013	09 Jul 2013	22 Apr 2014	17 Jun 2015
Lab number		TRC135329	TRC136535	TRC149955	TRC152064	TRC135326	TRC136537	TRC149953	TRC152062	TRC135328	TRC136536	TRC149954	TRC152063
Alkalinity	g/m3 CaCO3	55	29	34	27	46	29	34	26	44	32	39	27
Barium	mg/kg	0.069	0.053	0.069	0.044	0.0071	0.029	0.0196	0.027	0.079	0.043	0.051	0.048
Benzene	g/m3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bromine	g/m3	-	0.115	0.188	0.158	0.35	0.076	0.093	0.061	<0.05	0.074	0.127	0.086
Calcium	g/m3	11.5	12.3	13.5	12.9	12.1	11.6	9.3	11.7	13.2	11.2	12.6	11.5
Chloride	g/m3	28	21	34	31	22	14.8	16.7	15.0	32	7.5	12.9	18.2
Conductivity	mS/m@20C	22.9	17.7	25.7	22.1	16.7	13.8	13.6	13.0	22.7	12.9	17.1	15.7
Dissolved copper	g/m3	0.0010	0.0005	0.0011	0.0006	<0.0005	<0.0005	<0.0005	0.0005	0.0008	<0.0005	<0.0005	0.0013
Ethylbenzene	g/m3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m3	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m3	<0.003	<0.004	<0.003	<0.003	<0.003	<0.004	<0.003	<0.003	<0.003	<0.004	<0.003	<0.003
Dissolved iron	g/m3	2.0	<0.02	0.21	0.03	0.83	0.35	1.33	0.13	1.79	0.72	5.3	0.16
Formaldehyde	g/m3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethylene glycol	g/m3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m3	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m3 HCO3	67	35	41.5	33	56	35	41.5	32	54	39	47.6	33
Total hardness	g/m3 CaCO3	44	41	47	43	45	39	33	39	47	37	45	39
Dissolved mercury	g/m3	-	<0.00008	<0.00008	<0.00008	-	<0.00008	<0.00008	<0.00008	-	<0.00008	<0.00008	<0.00008
Potassium	g/m3	15	10.4	17.7	13.7	5.7	3.0	5.2	2.8	12.4	6.2	7.1	8.1
Methanol	g/m3	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Methane	g/m3	0.090	<0.002	0.031	0.004	0.33	0.013	0.38	0.014	0.039	0.065	0.44	<0.002
Magnesium	g/m3	3.7	2.6	3.2	2.6	3.5	2.4	2.4	2.4	3.4	2.2	3.3	2.5
Manganese	g/m3	0.147	0.0088	0.052	0.0086	0.78	0.041	0.106	0.0099	0.26	0.27	0.26	0.025
Sodium	g/m3	14.1	11.5	17.2	16.7	12.3	8.3	9.7	8.5	15.8	6.1	9.1	10.6
Nickel	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0006
Nitrate & nitrite nitrogen	g/m3 N	0.078	1.88	4.2	2.5	<0.002	0.36	<0.002	0.24	<0.002	0.194	0.047	0.54
Nitrite nitrogen	g/m3 N	0.014	<0.002	0.012	<0.002	<0.002	0.013	0.003	0.003	<0.002	0.003	0.002	<0.002
Nitrate nitrogen	g/m3 N	0.065	1.88	4.2	2.5	<0.002	0.35	<0.002	0.24	<0.002	0.192	0.044	0.54
PH	pH	7	6.2	6.2	6.4	6.8	6.4	7.6	7.1	6.0	6.1	6.7	6.4
Propylene	g/m3	-	<4	<4	<4	-	<4	<4	<4	-	<4	<4	<4
Sulphate	g/m3	7.8	13.4	12.2	14.2	<0.5	13.3	3.0	12.4	12.3	14.6	17.7	13.3
Sum of anions	meq/l	-	1.59	2.2	1.88	-	1.30	1.22	1.22	-	1.17	1.52	1.37
Sum of cations	meq/l	-	1.60	2.1	1.93	-	1.23	1.27	1.23	-	1.21	1.68	1.46
Total dissolved solids	g/m3	126	118	162	134	80	88	99	94	136	90	115	101
Toluene	g/m3	<0.0010	<0.0010	<0.0010	<0.0010	0.0066	<0.0010	<0.0010	<0.0010	<0.0063	<0.0010	<0.0010	<0.0010
o-Xylene	g/m3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m3	0.0045	0.0132	0.0179	0.0140	0.0021	0.0048	0.0032	0.0042	0.026	0.067	0.0122	0.107

Appendix III

Groundwater Certificates of Analysis

Hill Laboratories
BETTER TESTING BETTER RESULTS

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Hamilton 3240, New Zealand

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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:**	1440085 SPv1
Contact:	Regan Phipps	**Date Registered:**	18-Jun-2015
	C/- Taranaki Regional Council	**Date Reported:**	25-Jun-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kowhai B- 3 Month Post MF
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2324 17-Jun-2015 9:30 am	GND2318 17-Jun-2015 10:00 am			
Lab Number:		1440085.1	1440085.2			
Individual Tests						
Sum of Anions	meq/L	1.37	1.88	-	-	-
Sum of Cations	meq/L	1.46	1.93	-	-	-
pH	pH Units	6.4	6.4	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	27	27	-	-	-
Bicarbonate	g/m³ at 25°C	33	33	-	-	-
Total Hardness	g/m³ as $CaCO_3$	39	43	-	-	-
Electrical Conductivity (EC)	mS/m	15.7	22.1	-	-	-
Total Dissolved Solids (TDS)	g/m³	101	134	-	-	-
Dissolved Barium	g/m³	0.048	0.044	-	-	-
Dissolved Bromine*	g/m³	0.086	0.158	-	-	-
Dissolved Calcium	g/m³	11.5	12.9	-	-	-
Dissolved Copper	g/m³	0.0013	0.0006	-	-	-
Dissolved Iron	g/m³	0.16	0.03	-	-	-
Dissolved Magnesium	g/m³	2.5	2.6	-	-	-
Dissolved Manganese	g/m³	0.025	0.0086	-	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m³	0.0006	< 0.0005	-	-	-
Dissolved Potassium	g/m³	8.1	13.7	-	-	-
Dissolved Sodium	g/m³	10.6	16.7	-	-	-
Dissolved Zinc	g/m³	0.107	0.0140	-	-	-
Chloride	g/m³	18.2	31	-	-	-
Nitrite-N	g/m³	< 0.002	< 0.002	-	-	-
Nitrate-N	g/m³	0.54	2.5	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.54	2.5	-	-	-
Sulphate	g/m³	13.3	14.2	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2324 17-Jun-2015 9:30 am	GND2318 17-Jun-2015 10:00 am			
Lab Number:		1440085.1	1440085.2			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	-	-	-
Ethylene	g/m³	< 0.003	< 0.003	-	-	-
Methane	g/m³	< 0.002	0.004	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	-	-	-
C10 - C14	g/m³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	-	-	-

SUMMARY OF METHODS

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

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-2

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

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

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

Hill Laboratories
BETTER TESTING BETTER RESULTS

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1441188 SPv2
Contact:	Regan Phipps	**Date Registered:**	20-Jun-2015
	C/- Taranaki Regional Council	**Date Reported:**	02-Jul-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kowhai B GW sample
		Submitted By:	Regan Phipps

Amended Report

This report replaces an earlier report issued on the 29 Jun 2015 at 1:03 pm
Following a query by the client, the BTEX result for sample 1441188.1 was reanalysed and found not to confirm that originally reported due to spot contamination [QOWQ 58129].

Sample Type: Aqueous

Sample Name:		GND2319 19-Jun-2015 10:15 am				
Lab Number:		1441188.1				
Individual Tests						
Sum of Anions	meq/L	1.22	-	-	-	-
Sum of Cations	meq/L	1.23	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	26	-	-	-	-
Bicarbonate	g/m³ at 25°C	32	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	39	-	-	-	-
Electrical Conductivity (EC)	mS/m	13.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	94	-	-	-	-
Dissolved Barium	g/m³	0.027	-	-	-	-
Dissolved Bromine*	g/m³	0.061	-	-	-	-
Dissolved Calcium	g/m³	11.7	-	-	-	-
Dissolved Copper	g/m³	0.0005	-	-	-	-
Dissolved Iron	g/m³	0.13	-	-	-	-
Dissolved Magnesium	g/m³	2.4	-	-	-	-
Dissolved Manganese	g/m³	0.0099	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	2.8	-	-	-	-
Dissolved Sodium	g/m³	8.5	-	-	-	-
Dissolved Zinc	g/m³	0.0042	-	-	-	-
Chloride	g/m³	15.0	-	-	-	-
Nitrite-N	g/m³	0.003	-	-	-	-
Nitrate-N	g/m³	0.24	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.24	-	-	-	-
Sulphate	g/m³	12.4	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2319 19-Jun-2015 10:15 am				
Lab Number:		1441188.1				
BTEX in Water by Headspace GC-MS						
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.003	-	-	-	-
Methane	g/m³	0.014	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
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/m³	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/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1

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

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

Martin Cowell - BSc
Client Services Manager - Environmental Division

Appendix IV

Hydraulic Fracturing and Return Fluid Certificates of Analysis

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

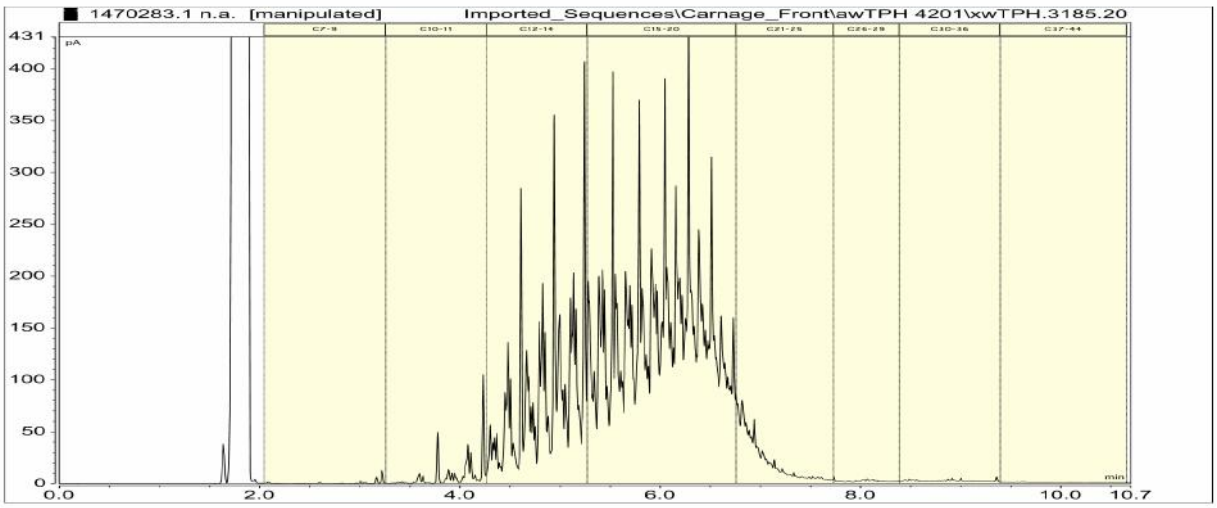
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1470283	SPv1
Contact:	Regan Phipps	**Date Registered:**	02-Sep-2015	
	C/- Taranaki Regional Council	**Date Reported:**	17-Sep-2015	
	Private Bag 713	**Quote No:**	50522	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Kowhai B - HF Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND 2326 12-Mar-2015 12:00 pm				
Lab Number:		1470283.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	61	-	-	-	-
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	< 0.010	-	-	-	-
Toluene	g/m³	< 0.010	-	-	-	-
Ethylbenzene	g/m³	< 0.010	-	-	-	-
m&p-Xylene	g/m³	< 0.02	-	-	-	-
o-Xylene	g/m³	< 0.010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	1.44	-	-	-	-
C10 - C14	g/m³	192	-	-	-	-
C15 - C36	g/m³	490	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	680	-	-	-	-

1470283.1
GND 2326 12-Mar-2015 12:00 pm
Client Chromatogram for TPH by FID



Analyst's Comments

The sample was received in a plastic bottle that wasn't completely filled. Please note that glass bottles should be used (and completely filled) for hydrocarbon analysis to avoid loss of volatile compounds and possible plastic contamination.

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
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1

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

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

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

Appendix V

Biomonitoring Report

To Job Manager; Callum MacKenzie
From Freshwater Biologist; Darin Sutherland
Report No DS012
Document 1521383
Date 9 June 2015

Biomonitoring of an unnamed tributary of the Waiau Stream following hydraulic fracturing by Greymouth Petroleum Ltd at the Kowhai-B wellsite, January 2015

Introduction

Macroinvertebrate surveys were performed at the Kowhai-B wellsite to determine whether hydraulic fracturing (fracking) had had a detrimental effect upon macroinvertebrate communities of an unnamed tributary of the Waiau Stream. The wellsite treated stormwater, uncontaminated site water, and production water was discharged from a skimmer pit to land near the unnamed tributary (Figure 1). No pre-drill survey had been performed at the site but there was a post drilling and hydraulic fracturing survey completed on 17 December 2013 (Thomas, 2014).

Methods

The post-frac survey was undertaken on 30 January 2015 at three sites (Table 1). Site 1 was the control site while site 2 was the primary impacted site and site 3 was the secondary impacted site. The altitude of the three sites was approximately 80 m asl.

The Council's standard 'vegetation sweep' technique was used to collect streambed macroinvertebrates in the unnamed tributary of the Waiau Stream Stream (Table 1; Figure 1). The 'vegetation sweep' technique is very similar to C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

Table 1 Biomonitoring sites in an unnamed tributary of the Waiau Stream in relation to the Kowhai-B wellsite.

Site No.	Site code	Grid reference (NZTM)	Location
1	WAI000060	1711185E-5677828N	50m u/s of Kowhai B wellsite discharge
2	WAI000062	1711231E-5677797N	50m d/s of Kowhai B wellsite discharge
3	WAI000065	1711258E-5677826N	100m d/s of Kowhai B wellsite discharge

Figure 1 Biomonitoring sites in an unnamed tributary of the Waiau Stream in relation to the Kowhai-B wellsite

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

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

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

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

A semi-quantitative MCI value ($SQMCI_s$) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the $SQMCI_s$ is not

multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower. A difference of 0.9 units or more in $SQMCI_s$ is considered significantly different (Stark, 1998).

Results

Site habitat characteristics

The water temperatures during the survey were moderate (range 14.1-18.8 °C). Water levels were very low and water speed was very slow. The water was uncoloured and clear. The substrate for all three sites was comprised entirely of silt (Table 2).

No algal mats were present but filamentous algae were widespread at sites 1 and 2 but not site 3. Moss, leaves and wood were absent from all sites and macrophytes were present on the stream edges at site 1 and on the bed at sites 2 and 3. Site 1 had partial shading from overhanging vegetation but sites 2 and 3 had no shading.

Table 2 Summary of time of sampling and some water variables collected on 17 December, 2013 (first post-frac) and 30 January, 2015 (second post-frac) at each site.

	Time (NZST)		Temperature (°C)		Water Colour		Water Clarity		Flow Conditions		Water Speed	
	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac	First post-frac	Second post-frac
WAI000060	1140	1245	17.3	18.8	Uncoloured	Uncoloured	Clear	Clear	V. Low	V. Low	V. Slow	V. Slow
WAI000062	1120	1235	16.6	14.8	Uncoloured	Uncoloured	Clear	Clear	V. Low	V. Low	V. Slow	V. Slow
WAI000065	1105	1230	16.5	14.1	Uncoloured	Uncoloured	Clear	Clear	V. Low	V. Low	V. Slow	V. Slow

Macroinvertebrate communities

Results of the first post-frac and second post-frac survey macroinvertebrate faunal data are summarised in (Table 3).

Table 3 Macroinvertebrate fauna of an unnamed tributary of the Waiau Stream in relation to the Kowhai-B wellsite surveys sampled December 17 2013 (first post-frac)and 30 January 2015 (second post-frac).

Taxa List	Survey	MCI score	first Post-frac			second Post-frac		
	Site Code		WAI000060	WAI000062	WAI000065	WAI000060	WAI000062	WAI000065
	Site Number		Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	R	R	R	-	-
NEMERTEA	Nemertea	3	C	-	R	-	-	-
NEMATODA	Nematoda	3	-	R	-	-	-	-
ANNELIDA (WORMS)	Oligochaeta	1	-	C	A	XA	R	A
	Lumbricidae	5	-	-	-	-	-	R
MOLLUSCA	Lymnaeidae	3	-	R	-	-	-	-
	Potamopyrgus	4	XA	XA	XA	XA	C	A
CRUSTACEA	Ostracoda	1	XA	XA	XA	XA	A	A
	Paracalliope	5	R	VA	XA	R	-	-
	Paraleptamphopidae	5	R	XA	VA	R	A	XA
EPHEMEROPTERA (MAYFLIES)	*Zephlebia group*	7	A	A	C	-	-	R
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	R	-	-	-	-
HEMIPTERA (BUGS)	*Microvelia*	3	-	-	R	R	-	R
	Saldula	5	R	-	R	-	-	-
COLEOPTERA (BEETLES)	Scirtidae	8	-	-	-	-	-	R
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	-	-	-	R	-	-
	Polyplectropus	6	R	C	-	R	-	C
	Psilochorema	6	-	-	R	-	-	-
	Oeconesidae	5	-	-	-	-	-	R
	Oxyethira	2	XA	-	-	-	-	-
	Triplectides	5	-	-	R	-	-	-
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	-	R	-	-	-	C
	Zelandotipula	6	R	R	C	-	-	C
	Orthocladiinae	2	C	A	A	-	-	-
	Polypedilum	3	-	-	R	-	-	-
	Tanypodinae	5	C	A	A	C	R	A
	Culicidae	3	-	-	-	R	-	-
	Dolichopodidae	3	-	-	R	-	-	-
	Paradixa	4	-	-	A	-	-	-
	Empididae	3	A	A	C	-	-	C
	Ephydridae	4	R	C	R	R	-	-
	Sciomyzidae	3	-	R	R	-	-	-
	Austrosimulium	3	R	R	C	-	-	-
	Stratiomyidae	5	R	R	-	-	-	-
ACARINA (MITES)	Acarina	5	R	C	A	R	C	C
	No of taxa		18	21	23	13	6	15
	MCI		82	80	77	75	70	93
	SQMCIs		2.4	3.5	3.5	2.0	3.3	4.7
	EPT (taxa)		2	2	3	2	0	3
	%EPT (taxa)		11	10	13	15	0	20

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

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

Site 1- 50m upstream of Kowhai-B wellsite discharge

A moderately low macroinvertebrate community richness of 13 taxa was found at site 1 ('control' site) at the time of the second post-frac survey which was 5 taxa lower than that found at the time of the first post-frac survey (Table 3).

The MCI score of 75 units indicated a community of 'poor' biological health and was not significantly different (Stark, 1998) to the MCI score of 82 units found at the time of the first post-frac survey. The $SQMCI_S$ score of 2.0 units was not significantly different (Stark, 1998) to the $SQMCI_S$ score of 2.4 units found at the time of the first post-frac survey Table 3).

The community was characterised by three 'tolerant' taxa [oligochaete worms, snail (*Potamopygus*), and ostracod seed shrimps] (Table 3).

Site 2- 50m downstream of Kowhai-B wellsite discharge

A low macroinvertebrate community richness of only six taxa was found at site 2 ('primary impacted' site) at the time of the second post-frac survey which was 15 taxa lower than that found at the time of the first post-frac survey (Table 3).

The MCI score of 70 units indicated a community of 'poor' biological health and was not significantly different (Stark, 1998) to the MCI score of 80 units found at the time of the first post-frac survey. The $SQMCI_S$ score of 3.3 units was not significantly different (Stark, 1999) to the $SQMCI_S$ score of 3.5 units found at the time of the first post-frac survey Table 3).

The community was characterised by one 'tolerant' taxon (ostracod seed shrimps) and one 'moderately sensitive' taxon [amphipod (Paraleptamphopidae)] (Table 3).

Site 3- 100m downstream of Kowhai-B wellsite discharge

A moderately low macroinvertebrate community richness of 15 taxa was found at site 3 ('secondary impacted' site) at the time of the second post-frac survey which was eight taxa lower than that found at the time of the first post-frac survey (Table 3).

The MCI score of 93 units indicated a community of 'fair' biological health and was significantly better (Stark, 1998) than the MCI score of 77 units found at the time of the first post-frac survey. The $SQMCI_S$ score of 4.7 units was significantly higher (Stark, 1998) than the $SQMCI_S$ score of 3.5 units found at the time of the first post-frac survey (Table 3).

The community was characterised by three 'tolerant' taxa [oligochaete worms, snail (*Potamopygus*), and ostracod seed shrimps] and two 'moderately sensitive' taxa [amphipod, (Paraleptamphopidae) and midge (Tanypodinae)] (Table 3).

Discussion and Conclusions

The Councils 'vegetation sweep' technique was used at three sites to collect macroinvertebrates from an unnamed tributary of the Waiau Stream post hydraulic fracturing at the Kowhai-B wellsite. This has provided data to assess impacts of skimmer pit discharge effects from the Kowhai-B wellsite to nearby land on the macroinvertebrate communities of this stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

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

Taxa richnesses at all three sites were lower than what had been found at the first survey and this is most likely due to a seasonal effect, probably as a result of the long hot dry summer preceding the last survey in combination with the unnamed tributary being very small in size and containing extensive macrophytes beds. For the first post-frac survey there had been only 12 days since a fresh of 7 x median flow or more had occurred while for the second post-frac survey there had been 112 days since flow had exceeded the 7 x median flow. It was likely that freshwater macroinvertebrates in the unnamed tributary were impacted by high water temperatures and low dissolved oxygen levels. The 'primary' impacted site had particularly low taxa richness but this is likely to have been due to physical variability as the 'secondary' impacted site had a higher taxa richness than the 'control' site indicating that wellsite discharges were not the cause of the unusually low taxa richness. MCI and $SQMCI_S$ scores for the two 'impacted' sites were also either not significantly different or significantly higher (Stark, 1998) than the 'control' site providing further evidence that wellsite discharges had not had a significant negative effect on the macroinvertebrate communities in the unnamed tributary of the Waiau Stream.

Summary

- A macroinvertebrate survey was completed at three sites near the Kowhai-B wellsite to determine if any wellsite discharges to nearby land following hydraulic fracturing had impacted on the health of macroinvertebrate communities in the adjacent unnamed tributary of the Waiau Stream.

- Taxa richnesses were moderate to low at the three sites surveyed and were lower than taxa numbers previously recorded at the sites, probably as a result of the long dry summer period, small size of the unnamed tributary and extensive macrophyte beds.

- MCI and SQMCIs scores for the two 'impacted' sites were either not significantly different or significantly higher than those at the 'control' site.

- There was no indication from any of the macroinvertebrate indices examined that Kowhai-B wellsite discharges to adjacent land had had any adverse effects on the health of the macroinvertebrate communities present at sites downstream of the discharge area.

References

Stark JD, 1985: A macroinvertebrate community index of water quality for stony streams. *Water and Soil* Miscellaneous Publication No. 87.

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.

Stark JD, 1999: An evaluation of Taranaki Regional Council's SQMCI biomonitoring index. Cawthron Institute, Nelson. Cawthron Report No. 472.

Stark JD, Boothroyd IKG, Harding JS, Maxted JR, Scarsbrook MR, 2001: Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

Thomas BT, 2014: Biomonitoring of an unnamed tributary of the Waiau Stream following drilling and hydraulic fracturing by Greymouth Petroleum Ltd at the Kowhai B wellsite, December 2013. (BT013).