Greymouth Petroleum Limited
Turangi-C Hydraulic Fracturing
Monitoring Programme Report
2016-2017

Technical Report 2018-3

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Executive summary

This report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to hydraulic fracturing activities conducted by Greymouth Petroleum Limited (GPL) at their Turangi-C wellsite over the period September to October 2016. The wellsite is located on Turangi Road Upper, Motunui and lies within the Parahaki Catchment. This report also assesses GPL's level of environmental performance and compliance with the resource consents held in relation to the activity.

GPL hold resource consent 9418-2, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,390 metres true vertical depth subsea (TVDss) beneath the Turangi-C wellsite. This consent was issued by the Council on 14 January 2016 replacing consent 9418-1 which was issued on 25 February 2013. Consent 9418-2 contains a total of 20 special conditions which set out the requirements that GPL must satisfy.

The programme of hydraulic fracturing undertaken by GPL at Turangi-C discussed in this report included the fracturing of one well. The well targeted for stimulation was Turangi-6. The hydraulic fracturing of the well took place between September and October 2016.

During the monitoring period, the Company demonstrated an overall high level of environmental performance.

The programme of monitoring implemented by the Council in relation to hydraulic fracturing activities at the Turangi-C wellsite was initiated in 2016. This report details the results of monitoring conducted in relation to the activities undertaken during the 2016-2017 monitoring year.

The programme of monitoring implemented by the Council during the period being reported included pre and post discharge groundwater sampling. Biomonitoring surveys were also carried out to assess the impact of any site discharges during the fracturing programme on an unnamed tributary of the Parahaki Stream. Samples of hydraulic fracturing fluids, and fluids returning to the wellhead post-fracturing, were also obtained for physicochemical analysis in order to characterise the discharges and to determine compliance with consent conditions.

The monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by GPL had no significant adverse effects on local groundwater or surface water resources. There were no unauthorised incidents recording non-compliance in respect of the resource consents held by GPL in relation to these activities, 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 2016-2017 year, consent holders were found to achieve a high level of environmental performance and compliance for 74% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 21% of the consents, a good level of environmental performance and compliance was achieved.

This report includes recommendations for the future monitoring of any hydraulic fracturing activities at the Turangi-C wellsite.

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1.1. Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1. Introduction

This 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 Turangi-C wellsite, over the period September to October 2016. 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 their Turangi-C wellsite included the hydraulic fracturing of one well. The well targeted for stimulation was the Turangi-6 well.

The programme of monitoring implemented by the Council in relation to the hydraulic fracturing activities included a mixture of groundwater, surface water and discharge monitoring components. This is the first monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Turangi-C wellsite.

1.1.2. Structure of this report

Section 1 of this report is a background section. It sets out general information about:

- the nature of the monitoring programme in place for the period under review; and
- a description of the activities and operations conducted at Turangi-C.

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 for any future monitoring of any hydraulic fracturing activities at the Turangi-C wellsite.

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 *Resource Management Act 1991* (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); and
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 holders, this report also assigns a rating as to each Company's environmental and administrative performance during the period under review.

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 2016-2017 year, consent holders were found to achieve a high level of environmental performance and compliance for 74% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 21% of the consents, a good level of environmental performance and compliance was achieved.

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 conventional production techniques.

The process of hydraulic fracturing involves the pumping of fluids 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 can be assisted by the use of cross-linked gels (gel fracking) or turbulent flow (slick-water fracking).

1.2.1.1. Gel fracturing

Gel fracturing utilises cross-linked gel solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become viscous gels. These gels are used to transport the proppant into the

formation. Once in the formation they 'break' back with time, temperature and the aid of gel breaking chemicals into a liquid state and are flowed back to surface, without disturbing the proppant which remains in place and enhances the flow of hydrocarbons back to the surface.

1.2.1.2. Slick water fracturing

Slick water fracturing utilises water based fracturing fluids with friction-reducing additives. The addition of the friction reducers allows the fracturing fluids and proppant to be pumped to the target zone at higher rates and reduced pressures, than when using water alone. The higher rate creates turbulence within the fluid column holding the proppant and enabling its placement into the open fractures and enhancing the flow of hydrocarbons back to the surface. [1]

1.2.1.3. Nitrogen gas assisted fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N^2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracking is extremely beneficial from a production standpoint as inevitably during the fracturing process some of the water pumped down the well remains underground in the rock formation, which can block some of the small pores inhibiting hydrocarbon recovery. Nitrogen gas achieves the same purpose as water but returns more easily to the surface. More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal[2].

1.2.2. The Turangi-C wellsite and hydraulic fracturing activities

The Turangi-C wellsite is located on Turangi Road Upper, Motunui and lies within the Parahaki catchment. The area surrounding the site is rural in nature and farming and forestry activities co-exist with active petroleum exploration and production operations. The location of the wellsite is illustrated in Figure 1.

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

Table 1 Summary of hydraulic fracturing activity during the reporting period

Well	TRC bore name	Fracturing date		Range mid-point injection zones (m TVDss)	Formation
		Start	End		
Turangi-6	GND2598	01/09/2016	20/10/2016	3,498-3,566	Kaimiro and Mangahewa

[1] *http://geology.com/energy/hydraulic-fracturing-fluids/*

Figure 1 Location map

1.3. Resource consents

1.3.1. Discharges onto and into land

Sections 15(1)(b) of the RMA stipulate 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.

The current consent 9418-2 has 20 special conditions, as summarised below:

- Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur;
- Condition 2 stipulates the date before which discharge of hydraulic fracturing fluids must occur;
- Condition 3 stipulates actions to be taken if a nearby seismic event higher than a magnitude 3.0 occurs;
- Condition 4 stipulates the investigation and reporting requirements if a nearby seismic event higher than magnitude 3.0 occurs;
- Condition 5 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 6, 7, 8 and 9 relate to fresh water monitoring requirements, to allow compliance with condition 5 to be assessed;
- Condition 10 requires the consent holder to carry out pressure testing of equipment prior to discharging;
- Condition 11 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring;
- Condition 12 is a notification requirement;
- Condition 13 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well;
- Condition 14 relates to the submittal of interim post fracturing reports which may be required in order to meet the 90-day submittal deadline;
- Condition 15 stipulates how the reports required by conditions 11, 13 and 14 are to be submitted;
- Condition 16 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained;
- Condition 17 requires the consent holder to adopt best practicable options;
- Condition 18 relates to the composition of the fracturing fluid;
- Condition 19 is a lapse clause; and
- Condition 20 is a review provision.

A Copy of the consent valid during the reporting period is included in Appendix I.

1.4. Monitoring programme

1.4.1. Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor and conduct research on the exercise of resource consents within the Taranaki region. The Council is also required to assess the effects arising from the exercising of these consents and report upon them.

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 Turangi-6 well consisted of four primary components.

1.4.2. Programme liaison and management

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

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

1.4.3. Assessment of data submitted by consent holder

As required by the conditions of consent 9418-2, 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, 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 consent.

1.4.4. Physicochemical sampling

1.4.4.1. Groundwater

In order to select suitable sites for sampling, a well survey was carried out in the vicinity of the Turangi-C wellsite to identify any existing groundwater abstractions in the area. The survey was undertaken in 2012 within a defined area which extended 1 km radially from the wellsite. Only one groundwater abstraction site was identified. This bore (GND0177) was determined to be unsuitable for monitoring purposes due to both distance (900 m) and position (up gradient of the inferred shallow groundwater flow direction in relation to the wellsite). As no suitable existing monitoring bores could be identified, a purpose built monitoring bore was drilled and constructed by GPL, in order to comply with condition 7 of consent 9418-2, prior to any hydraulic fracturing activities at the wellsite. The site selection is designed to provide a samples representative of groundwater abstractions in the area surrounding the site.

The details of the monitoring site sampled over the course of the reporting period are included in Table 2. The location and proximity to the Turangi-C wellsite is illustrated in Figure 2.

Figure 2 Monitoring sites at the Turangi-C wellsite

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite (m)	Total depth (m)	Screened interval (m)
GND2567	55	40	28-40

Samples of groundwater were obtained pre-fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out three months and one year after the cessation of activities.

1.4.4.2. Hydraulic fracturing and return fluids

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

Samples of hydraulic fracturing fluid were obtained from storage tanks on-site. While the fracturing fluid is predominantly comprised of water, specialised additives are used to either increase the viscosity (gel fracking) or turbulence (slick-water fracking) of the fluid in order to suspend the proppant prior to injection.

Samples of return fluids for each well were collected at regular intervals during the flow-back period. 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 fluid 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 individual samples of return fluid are generally combined in a composite sample for laboratory analysis. Composites are designed to provide a representative sample of fluids returning to the wellhead over the entire flow-back period.

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

1.4.5. Surface water quality monitoring

1.4.5.1. Biomonitoring surveys

Macroinvertebrate surveys were carried out on 9 August 2016 and 23 November 2016 at the Turangi-C wellsite to determine whether discharges relating to hydraulic fracturing undertaken during the reporting period at the wellsite had caused a detrimental effect upon the macroinvertebrate communities of an unnamed tributary of the Parahaki Stream. The wellsite treated stormwater and uncontaminated site water were discharged from a skimmer pit into an unnamed tributary of the Parahaki Stream (Figure 2).

Taxa richness is the most robust index when determining whether a macroinvertebrate community has been exposed to toxic discharges. When exposed to toxic discharges, macroinvertebrates may die and be swept downstream or may deliberately drift downstream as an avoidance mechanism (catastrophic drift). The Macroinvertebrate Index (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 Semi-quantitative Macroinvertebrate Index (SQMCI) 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 MCI or SQMCI between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

The details of each biomonitoring site included in the surveys are presented in Table 3. Their location and proximity to the Turangi-C wellsite is illustrated in Figure 2.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	PRH000035	E1712866 N5681040	20m upstream of Turangi-C wellsite discharge	60
2	PRH000037	E1712905 N5681107	20m downstream of Turangi-C wellsite discharge	60
3	PRH000040	E1712931 N5681171	85m downstream of Turangi-C wellsite discharge	60

2. Results

2.1. Consent holder submitted data

2.1.1. Turangi-6 post-fracturing discharge report

The conclusions from the Turangi-6 (GND2598) post-fracturing discharge report are summarised as follows:

- A total of three discrete zones were fractured over the period 2 September to 20 October 2016 at depths between 3,458 to 3,989 m TVD.
- A total of 4,518 bbls (718 m^3) of liquid was discharged across the three fractured zones. The total proppant weight was 112 tonnes (246,920 lbs).
- The Turangi-6 well was opened for flow-back following the completion of fracturing operations. In total, 8,934 bbls (1,420 m^3) of fluid was returned from the well over the initial flow-back period.
- The volume of fluid returned during the flow-back was 4,416 bbls (702 m^3) greater than the volume of fluid injected.
- Approximately 93.8 tonnes (206,687 lbs) or 83.7% of proppant remained within the formation after the completion of flow back.
- One screen out occurred during the hydraulic fracturing of Interval 3. The screen out occurred near the end of the operation and resulted in the under-placement of some proppant. All proppant was recovered during flow-back.
- All return fluid from the Turangi-6 fracturing operations was disposed of by deep well injection, at the Turangi Production Station and the Kaimiro-G wellsite.
- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. When threshold pressures were imminent, measures were taken to reduce the pressure and when threshold pressures were reached, pumping ceased.
- 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. Physicochemical sampling

2.2.1. Groundwater

The hydraulic fracturing activities commenced at Turangi-C (well Turangi-6) in September 2016. Pre-fracturing sampling was undertaken on 15 August 2016 at GND2567. Hydraulic fracturing continued over several weeks until 30 October 2016. A three month post-fracturing sample was obtained 9 December 2016 and a one year post-fracturing sampling on 5 October 2017 (Table 4).

Table 4 Groundwater sampling undertaken over the reporting period

Bore	Fracturing date		Pre-fracturing sample date	3 month post-fracturing sample date	One year post-fracturing sample date
	Start	End			
GND2567	21/02/2016	01/04/2016	15/08/2016	9/12/2016	5/10/2017

The results of the laboratory analysis of samples from GND2567 indicate there have been no significant changes in groundwater composition over the monitored period.

Trace toluene was recorded in the baseline sample taken at GND2567, which is located on the Turangi-C wellsite. The sample was re-tested and the results were inconclusive. Trace values can sometimes be attributable to lab margins of error and subsequent samples reported concentrations within expected ranges.

All samples demonstrate relatively narrow ranges between analyte concentrations over time. The subtle variation in analyte concentrations at each site are a result of natural seasonal fluctuation and sampling variability.

Low concentrations of methane were detected in all samples and therefore samples were sent to GNS for further analysis. Isotopic analysis of the dissolved methane within the samples analysed by GNS indicates the methane gas is biogenic in origin and concentrations from all samples were all within the expected ranges for shallow groundwater across Taranaki.

Biogenic methane is produced by the biological breakdown of organic matter in shallow formations and is distinct from thermogenic methane which is produced under high pressures and temperatures in deep hydrocarbon bearing formations.

A summary of results for groundwater samples taken in relation to the hydraulic fracturing activities during the reporting period compared to baseline is included in Table 5. The certificates of analysis for the review period are included in Appendix II.

Table 5 Results of groundwater sampling carried out in relation to the Turangi-C fracturing event compared to baseline

Parameter	Unit	GND2567		
		Baseline (pre-frac)	3 mth post-frac	1 year post-frac
Sample date		**15/08/2016**	**09/12/2016**	**05/10/2017**
Lab number	**TRC**	**TRC162699**	**TRC170020**	**TRC173701**
pH	pH	7.3	7.2	7.0
Total alkalinity	g/m^3 $CaCO_3$	117	114	66
Bicarbonate	g/m^3 HCO_3	142	138	80
Total hardness	g/m^3 $CaCO_3$	85	88	57
Conductivity	mS/m	31	30	21
Total dissolved solids	g/m^3	187	166	126
Dissolved barium	g/m^3	0.033	0.029	0.020
Dissolved bromine	g/m^3	0.077	0.087	0.130
Dissolved calcium	g/m^3	18	21	13
Dissolved copper	g/m^3	< 0.0005	< 0.0005	< 0.0005
Dissolved iron	g/m^3	1.12	1.75	2.70
Dissolved mercury	g/m^3	< 0.00008	< 0.00008	< 0.00008

Parameter	Unit	GND2567		
		Baseline (pre-frac)	3 mth post-frac	1 year post-frac
Sample date		**15/08/2016**	**09/12/2016**	**05/10/2017**
Lab number	**TRC**	**TRC162699**	**TRC170020**	**TRC173701**
Dissolved nickel	g/m^3	0.0007	< 0.0005	< 0.0005
Dissolved potassium	g/m^3	8.7	7.2	5.1
Dissolved sodium	g/m^3	19.2	15.6	12.9
Dissolved magnesium	g/m^3	9.7	8.6	6.0
Dissolved manganese	g/m^3	0.21	0.28	0.46
Dissolved zinc	g/m^3	0.0011	0.0017	< 0.0010
Chloride	g/m^3	20	20	22
Nitrite nitrogen	g/m^3 N	< 0.02	< 0.002	< 0.002
Nitrate nitrogen	g/m^3 N	< 0.02	< 0.002	0.003
Nitrate & nitrite	g/m^3 N	< 0.020	< 0.002	0.004
Sulphate	g/m^3	7.7	4.8	3.7
Ethylene glycol	g/m^3	< 4	< 4	< 4
Propylene glycol	g/m^3	< 4	< 4	< 4
Methanol	g/m^3	< 2	< 2	< 2
Benzene	g/m^3	< 0.001	< 0.001	< 0.001
Toluene	g/m^3	0.007	< 0.001	< 0.001
Ethylbenzene	g/m^3	< 0.001	< 0.001	< 0.001
o-Xylene	g/m^3	< 0.001	< 0.001	< 0.002
m-Xylene	g/m^3	< 0.002	< 0.002	< 0.001
Formaldehyde	g/m^3	< 0.02	< 0.02	< 0.02
Ethane	g/m^3	< 0.003	< 0.003	< 0.003
Ethylene	g/m^3	< 0.004	< 0.004	< 0.003
Methane	g/m^3	2.90	7.50	1.66
Hydrocarbons	g/m^3	< 0.7	< 0.7	< 0.7
δ13C value*	‰	-77.4	-77.5	-71.7

* A value >-50‰ indicates thermogenic methane, a value <-50‰ indicates biogenic methane.

2.2.2. Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Turangi-6 well are shown below in Table 6. The certificates of analysis are included in Appendix III.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Turangi-6		
		GND2598		
Sample date	-	25/08/2016	02/09/2016	26/11/2016
Lab number	-	TRC170032	TRC170033	TRC170036
Benzene	g/m^3	0.002	0.002	< 0.001
Ethylbenzene	g/m^3	< 0.0010	0.0012	< 0.0010
Ethylene glycol	g/m^3	< 2,000	< 2,000	< 20
Total hydrocarbons	g/m^3	43	4,000	1,060
Methanol	g/m^3	< 200	< 200	< 20
Propylene glycol	g/m^3	< 2,000	< 2,000	< 20
Toluene	g/m^3	0.0048	0.0041	< 0.0010
o-Xylene	g/m^3	0.0015	0.0025	< 0.0010
m-Xylene	g/m^3	0.002	0.005	< 0.002

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Turangi-6 well are summarised below in Table 7 and certificates of analysis are included in Appendix III. Return fluid samples generally contain a composite of samples collected at different intervals during the flow back period. The relatively high levels of chloride, sodium and hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of reservoir fluids than fluids introduced during fracturing activities (comprised predominantly of freshwater).

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Turangi-6		
		GND2598		
Sample date		10/09/2016	10/09/2016	12/11/2016
Lab number		TRC170034	TRC170035	TRC170037
Total alkalinity	g/m^3 $CaCO_3$	690	3,100	2,200
Total barium	g/m^3	68	50	6
Benzene	g/m^3	4.3	14.6	8.9
Total bromine	g/m^3	20.0	13.7	18.0
Total calcium	g/m^3	103	37	58
Dissolved calcium	g/m^3	103	40	53
Chloride	g/m^3	6,500	3,900	2,600
Conductivity	mS/m	1,986	1,680	1,237
Total copper	g/m^3	0.480	0.164	0.054
Ethylbenzene	g/m^3	0.23	1.93	0.55
Dissolved iron	g/m^3	3.40	1.22	12.80
Formaldehyde	g/m^3	0.24	0.39	0.10
Ethylene glycol	g/m^3	< 2,000	< 2,000	< 4
Hydrocarbons	g/m^3	360	2,300	240
Bicarbonate	g/m^3 HCO_3	909	3,240	2,440
Total hardness	g/m^3 $CaCO_3$	300	119	152
Total mercury	g/m^3	< 0.0021	< 0.0021	0.00015
Potassium	g/m^3	148	470	320
Methanol	g/m^3	< 2,000	< 2,000	24
Total magnesium	g/m^3	11.2	4.9	5.1
Dissolved magnesium	g/m^3	10.5	4.9	4.0
Total manganese	g/m^3	2.3	2.4	7.4
Sodium	g/m^3	4,200	3,700	2,800
Total nickel	g/m^3	0.083	0.104	0.350
Nitrate & nitrite nitrogen	g/m^3 N	< 0.02	0.13	< 0.20
Nitrite nitrogen	g/m^3 N	< 0.02	0.12	< 0.20
Nitrate	g/m^3 N	< 0.09	< 0.09	< 0.90
Nitrate nitrogen	g/m^3 N	< 0.02	< 0.02	< 0.20
pH	pH	6.9	7.2	7.1
Propylene glycol	g/m^3	< 2,000	< 2,000	< 4

Parameter	Unit	Turangi-6		
		GND2598		
Total sulphur	g/m^3	6	57	70
Sulphate	g/m^3	18	172	210
Total dissolved solids	g/m^3	12,400	12,700	10,100
Toluene	g/m^3	3.5	21.0	7.7
o-Xylene	g/m^3	0.51	4.00	1.29
m-Xylene	g/m^3	1.3	12.3	3.2
Dissolved zinc	g/m^3	1.13	1.40	0.18

2.3. Biomonitoring surveys

The Council's standard 'kick-sampling' technique was used at three established sites to collect streambed macroinvertebrates from an unnamed tributary of the Parahaki Stream. 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 abundance as well as sensitivity to pollution, and may reveal more subtle changes in communities. It may be the more appropriate 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.

Macroinvertebrate surveys were carried out at three sites near the Turangi-C wellsite prior to and following hydraulic fracturing activities to determine if discharges from the wellsite had had detrimental effects on the stream macroinvertebrate communities.

MCI scores post-fracturing did not change significantly (Stark 1998) for any of the three sites compared to the pre-fracturing survey, although site 3 recorded a significantly lower MCI score than either site 1 or site 2 on both occasions. MCI scores at sites 1 and 2 were similar to the median scores for Taranaki lowland coastal streams at similar altitude, while the score for site 3 was significantly lower than this median on both occasions.

$SQMCI_s$ scores were significantly higher at sites 1 and 2 than site 3, and sites 1 and 2 recorded a significant increase in $SQMCI_s$ score, related to changes in the abundance of particular taxa, when compared with the pre-fracturing survey, while the score for site 3 did not change significantly.

Overall, the results of both surveys indicated there was no evidence that the stormwater discharges from the Turangi-C wellsite have caused any recent significant adverse effects on the macroinvertebrate communities of the unnamed tributary of the Parahaki Stream.

The full biomonitoring reports are included as Appendix IV.

2.4. Investigations, interventions, and incidents

The monitoring programme for the reporting period 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 causes of non-compliance or failure to maintain good practices. A pro-active approach that in the first instance avoids issues occurring is favoured.

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

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

During the reporting period, the Council was not required to undertake significant additional investigations and interventions, or record incidents, in association with the conditions in GPL's resource consent or provisions in regional plans.

3. Discussion

3.1. Environmental effects of hydraulic fracturing on useable freshwater resources

The Turangi-6 well was stimulated by hydraulic fracturing between September and October 2016. The well is located at the Turangi-C wellsite

Monitoring carried out by the Council in relation to these activities included both groundwater and surface water monitoring components. The groundwater monitoring component incorporated pre and post-fracturing sampling at one groundwater monitoring site in the local vicinity of the Turangi-C wellsite.

The results of post-fracturing groundwater sampling carried out showed only very minor variations in water composition in comparison to baseline results. The minor variations in most analytes are a result of natural variations in water composition.

The surface water monitoring component of the programme comprised of two biomonitoring surveys of an unnamed tributary of the Parahaki Stream, pre and post-fracturing of the well.

The results of the biomonitoring surveys undertaken in relation to the Turangi-C fracturing event indicate that site activities had no adverse effects on local surface water resources.

In summary, the monitoring carried out by the Council during the period being reported indicates that the hydraulic fracturing activities undertaken by GPL at the Turangi-C wellsite has had no significant 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 period under review is set out in Tables 8.

Table 8 Summary of performance for Consent 9418-2

Purpose: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,390 metres true vertical depth subsea (TVDss) beneath the Turangi-C wellsite		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,390 mTVDss	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2025	Assessment of consent holder submitted data	N/A
3. Hydraulic activities to cease if a nearby seismic event of Magnitude 3.0 or above is recorded	Assessment of consent holder submitted data	No events recorded
4. Consent holder shall investigate and report on any recorded seismic events of magnitude 3.0 or higher occur nearby during hydraulic fracturing activities	Assessment of consent holder submitted data	No events recorded

Purpose: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,390 metres true vertical depth subsea (TVDss) beneath the Turangi-C wellsite		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
5. Exercise of consent shall not result in any contaminants reaching any useable freshwater	Results of groundwater monitoring	Yes
6. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
7. If no suitable bores exist within 500 m of the wellsite, a monitoring bore may need to be installed	Inspection of bores and construction of GND2567	Yes
8. 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
9. 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
10. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
11. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
12. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
13. A post-fracturing discharge report is to be provided to the Council within 90 days of any commencement	Post-fracturing discharge report received	Yes
14. Interim post fracturing reports are to be provided if necessary to meet the 90 day deadline	Interim post-fracturing discharge report received	Yes
15. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
16. 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
17. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes

Purpose: To discharge water based hydraulic fracturing fluids into land at depths greater than 3,390 metres true vertical depth subsea (TVDss) beneath the Turangi-C wellsite		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
18. Composition of fluids to be no less than 95% water and proppant by volume	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
19. Lapse clause	Receive notice of exercise of consent	Yes
20. 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 reporting period, GPL demonstrated a high level of environmental and high level of administrative performance with the resource consents as defined in Section 1.1.4.

3.3. Alterations to monitoring of future hydraulic fracturing events

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 the range of monitoring carried out in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Turangi-C wellsite. No further monitoring is proposed at this point.

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

It should be noted that the proposed programme represents a reasonable and risk-based level of monitoring for the site in question. The Council reserves the right to subsequently adjust the programme from that initially prepared, should the need arise if potential or actual non-compliance is determined at any time during future monitoring periods.

3.4. Exercise of optional review of consent

Resource consent 9418-2 provides for an optional review of the consent in June 2018. Condition 20 allows the Council to review the consent, for the purpose 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.

Based on the results of monitoring carried out in the period under review, it is considered that there are no grounds to require a consent review to be pursued or grounds to exercise the review options.

A recommendation to this effect is presented in Section 4 of this report.

4. Recommendations

1. THAT in the first instance, the range of monitoring carried out during the reporting period in relation to GPL's hydraulic fracturing activities be replicated for any future fracturing events at the Turangi-C wellsite.
2. THAT should there be issues with environmental or administrative performance in future periods, monitoring may be adjusted to reflect any additional investigation or intervention as found necessary.
3. THAT the option for a review of resource consents in June 2018, as set out in condition 20 of the consent not be exercised

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/m3	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.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
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.
Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

Bibliography and references

Greymouth Petroleum Limited (2016) Hydraulic Fracturing Turangi-6 Post-Fracturing Discharge Report. December 2016. Doc id. 1797635

Greymouth Petroleum Limited (2016) Hydraulic Fracturing Turangi-6 Interim Post-Fracturing Discharge Report. November 2016.

Greymouth Petroleum Limited (2016) Hydraulic Fracturing Turangi-6 Wellsite Pre-Fracturing Discharge Report. July 2016. Doc id. 1713190

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

Taranaki Regional Council (2016) Sampling and Analysis Plan Turangi-C Groundwater Monitoring Programme. Doc id. 1787925.

Taranaki Regional Council, (2016). Biomonitoring of an unnamed tributary of the Parahaki Stream in relation to hydraulic fracturing by Greymouth Petroleum Ltd at the Turangi-C wellsite, August 2016. Report KB011. Doc id. 1738160.

Taranaki Regional Council, (2017). Biomonitoring of an unnamed tributary of the Parahaki Stream in relation to hydraulic fracturing at the Turangi-C wellsite, August 2016. Report KB013. Doc id. 1803800.

Appendix I
Resource consents held by Greymouth Petroleum Limited

(For a copy of the signed resource consent
please contact the TRC consent department)

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 Turangi Limited PO Box 3394 Fitzroy New Plymouth 4341
Decision Date:	14 January 2016
Commencement Date:	14 January 2016

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,390 mTVDss beneath the Turangi-C wellsite
Expiry Date:	1 June 2030
Review Date(s):	June Annually
Site Location:	Turangi-C wellsite, 162-174 Turangi Road Upper, Motunui (Property owner: Ducal Products Limited)
Legal Description:	Lot 1 DP 19476 Blk VI Waitara SD (Discharge source & site)
Grid Reference (NZTM)	1712975E-5680993N
Catchment:	Parahaki

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

General condition

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

Special conditions

1. The discharge point shall be deeper than 3,390 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level

2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2025.

3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3.0 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, 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 the conditions of this consent could be taken and analysed by the Taranaki Regional 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, Taranaki Regional Council 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, Taranaki Regional Council 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, Taranaki Regional Council. 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 0, 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, Taranaki Regional Council. 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, Taranaki Regional Council 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 31 March 2021, 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 14 January 2016

For and on behalf of
Taranaki Regional Council

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A D McLay
Director - Resource Management

Appendix II
Certificates of analysis (groundwater)

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1856043 SPv1
Contact:	David Olson	**Date Received:**	06-Oct-2017
	C/- Taranaki Regional Council	**Date Reported:**	19-Oct-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	67234
		Client Reference:	GPL Turangi C 1 Year Post Frac
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2567 05-Oct-2017 10:30-12:00				
Lab Number:		1856043.1				
Individual Tests						
Sum of Anions	meq/L	2.0	-	-	-	-
Sum of Cations	meq/L	1.95	-	-	-	-
pH	pH Units	7.0	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	66	-	-	-	-
Bicarbonate	g/m³ at 25°C	80	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	57	-	-	-	-
Electrical Conductivity (EC)	mS/m	21.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	126	-	-	-	-
Dissolved Barium	g/m³	0.020	-	-	-	-
Dissolved Calcium	g/m³	13.0	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	2.7	-	-	-	-
Dissolved Magnesium	g/m³	6.0	-	-	-	-
Dissolved Manganese	g/m³	0.46	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.1	-	-	-	-
Dissolved Sodium	g/m³	12.9	-	-	-	-
Dissolved Zinc	g/m³	< 0.0010	-	-	-	-
Bromide	g/m³	0.13	-	-	-	-
Chloride	g/m³	22	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	0.003	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.004	-	-	-	-
Sulphate	g/m³	3.7	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2567 05-Oct-2017 10:30-12:00				
Lab Number:		1856043.1				
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	1.66	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

Analyst's Comments

Sample 1 Comment:
Please note that the TPH C7 - C9 band was analysed by the head space/GCMS method, with all other TPH bands analysed by hexane solvent extraction/GC/FID.

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 Analysis performed at 25 Te Aroha Street, Hamilton	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID Analysis performed at 25 Te Aroha Street, Hamilton	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID Analysis performed at 25 Te Aroha Street, Hamilton	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629] Analysis performed at 1 Clyde Street, Hamilton	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS Analysis performed at 1 Clyde Street, Hamilton	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis. Analysis performed at 1 Clyde Street, Hamilton	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629] Analysis performed at 1 Clyde Street, Hamilton	0.06 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved 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
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.05 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
C7 - C9	Head Space, GCMS analysis. Analysis performed at 1 Clyde Street, Hamilton.	0.06 g/m³	1

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

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

Ara Heron BSc (Tech)
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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1695159 SPv1
Contact:	Regan Phipps	**Date Received:**	12-Dec-2016
	C/- Taranaki Regional Council	**Date Reported:**	19-Dec-2016
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	
		Client Reference:	GPC Turangi - C 3 Month Frac
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2567 09-Dec-2016 2:23 pm				
Lab Number:		1695159.1				
Individual Tests						
Sum of Anions	meq/L	2.9	-	-	-	-
Sum of Cations	meq/L	2.7	-	-	-	-
pH	pH Units	7.2	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	114	-	-	-	-
Bicarbonate	g/m³ at 25°C	138	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	88	-	-	-	-
Electrical Conductivity (EC)	mS/m	30.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	166	-	-	-	-
Dissolved Barium	g/m³	0.029	-	-	-	-
Dissolved Bromine*	g/m³	0.087	-	-	-	-
Dissolved Calcium	g/m³	21	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	1.75	-	-	-	-
Dissolved Magnesium	g/m³	8.6	-	-	-	-
Dissolved Manganese	g/m³	0.28	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	7.2	-	-	-	-
Dissolved Sodium	g/m³	15.6	-	-	-	-
Dissolved Zinc	g/m³	0.0017	-	-	-	-
Chloride	g/m³	19.9	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	4.8	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:	GND2567 09-Dec-2016 2:23 pm					
Lab Number:	1695159.1					
BTEX in Water by Headspace GC-MS						
o-Xylene g/m³	< 0.0010	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde g/m³	< 0.02	-	-	-	-	
Gases in groundwater						
Ethane g/m³	< 0.003	-	-	-	-	
Ethylene g/m³	< 0.004	-	-	-	-	
Methane g/m³	7.5	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9 g/m³	< 0.10	-	-	-	-	
C10 - C14 g/m³	< 0.2	-	-	-	-	
C15 - C36 g/m³	< 0.4	-	-	-	-	
Total hydrocarbons (C7 - C36) g/m³	< 0.7	-	-	-	-	

SUMMARY OF METHODS

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

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

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

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

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

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1631463	SPv2
Contact:	Regan Phipps	**Date Received:**	16-Aug-2016	
	C/- Taranaki Regional Council	**Date Reported:**	30-Aug-2016	
	Private Bag 713	**Quote No:**	47915	
	Stratford 4352	**Order No:**		
		Client Reference:	Turangi-C Pre Frac	
		Submitted By:	David Olson	

Sample Type: Aqueous

Sample Name:		GND2567 15-Aug-2016 12:18 pm				
Lab Number:		1631463.1				
Individual Tests						
Sum of Anions	meq/L	3.1	-	-	-	-
Sum of Cations	meq/L	2.8	-	-	-	-
pH	pH Units	7.3	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	117	-	-	-	-
Bicarbonate	g/m³ at 25°C	142	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	85	-	-	-	-
Electrical Conductivity (EC)	mS/m	31.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	187	-	-	-	-
Dissolved Barium	g/m³	0.033	-	-	-	-
Dissolved Bromine*	g/m³	0.077	-	-	-	-
Dissolved Calcium	g/m³	18.0	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	1.12	-	-	-	-
Dissolved Magnesium	g/m³	9.7	-	-	-	-
Dissolved Manganese	g/m³	0.21	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0007	-	-	-	-
Dissolved Potassium	g/m³	8.7	-	-	-	-
Dissolved Sodium	g/m³	19.2	-	-	-	-
Dissolved Zinc	g/m³	0.0011	-	-	-	-
Chloride	g/m³	20	-	-	-	-
Nitrite-N	g/m³	< 0.02	-	-	-	-
Nitrate-N	g/m³	< 0.02	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.02	-	-	-	-
Sulphate	g/m³	7.7	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	0.0070	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2567 15-Aug-2016 12:18 pm				
Lab Number:		1631463.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.004	-	-	-	-
Methane	g/m³	2.9	-	-	-	-
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	-	-	-	-

Analyst's Comments

Amended Report: This report which replaces an earlier report issued on the 24/8/16. Following a client query [QOWQ62755], the BTEX analysis was repeated. The toluene result was confirmed in one 40mL vial, but not the other.

SUMMARY OF METHODS

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

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1

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

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix III
Certificates of analysis
(hydraulic fracturing fluids and return flow fluids)

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

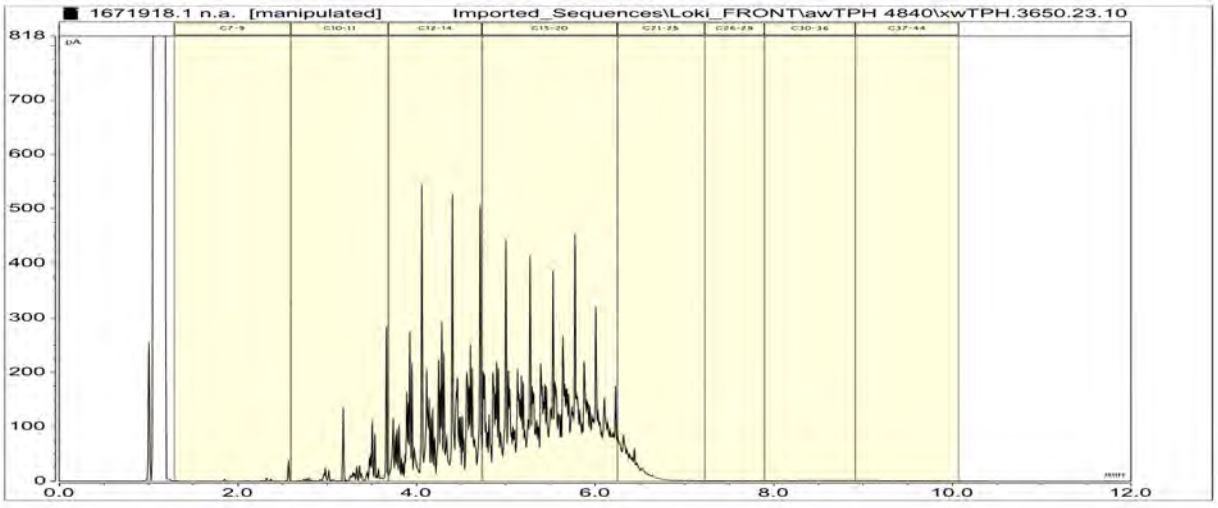
ANALYSIS REPORT

Client:	BTW Company Limited	**Lab No:**	1671918 SPv1
Contact:	Sheridan Standen	**Date Received:**	29-Oct-2016
	C/- BTW Company Limited	**Date Reported:**	15-Nov-2016
	PO Box 551	**Quote No:**	80359
	New Plymouth 4340	**Order No:**	
		Client Reference:	Hydraulic fracturing fluid testing
		Submitted By:	Sheridan Standen

Sample Type: Aqueous

Sample Name:		Turangi-6 HF Fluid 20-Oct-2016				
Lab Number:		1671918.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 200	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 200	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.152	-	-	-	-
Toluene	g/m³	0.124	-	-	-	-
Ethylbenzene	g/m³	0.0014	-	-	-	-
m&p-Xylene	g/m³	0.025	-	-	-	-
o-Xylene	g/m³	0.0101	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	40	-	-	-	-
C10 - C14	g/m³	4,000	-	-	-	-
C15 - C36	g/m³	7,500	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	11,500	-	-	-	-

1671918.1
Turangi-6 HF Fluid 20-Oct-2016
Client Chromatogram for TPH by FID



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

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

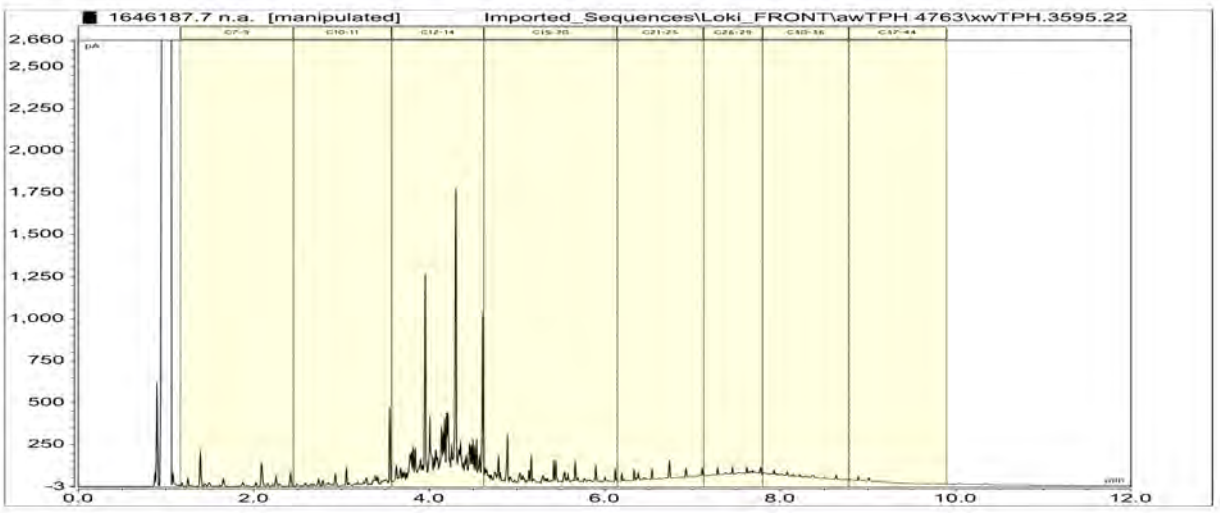
Client:	BTW Company Limited	**Lab No:**	1646187 SPv1
Contact:	Sheridan Standen	**Date Received:**	10-Sep-2016
	C/- BTW Company Limited	**Date Reported:**	28-Sep-2016
	PO Box 551	**Quote No:**	80356
	New Plymouth 4340	**Order No:**	14101.33
		Client Reference:	Return Fluid Composite (Tur-6)
		Submitted By:	Sheridan Standen

Sample Type: Saline

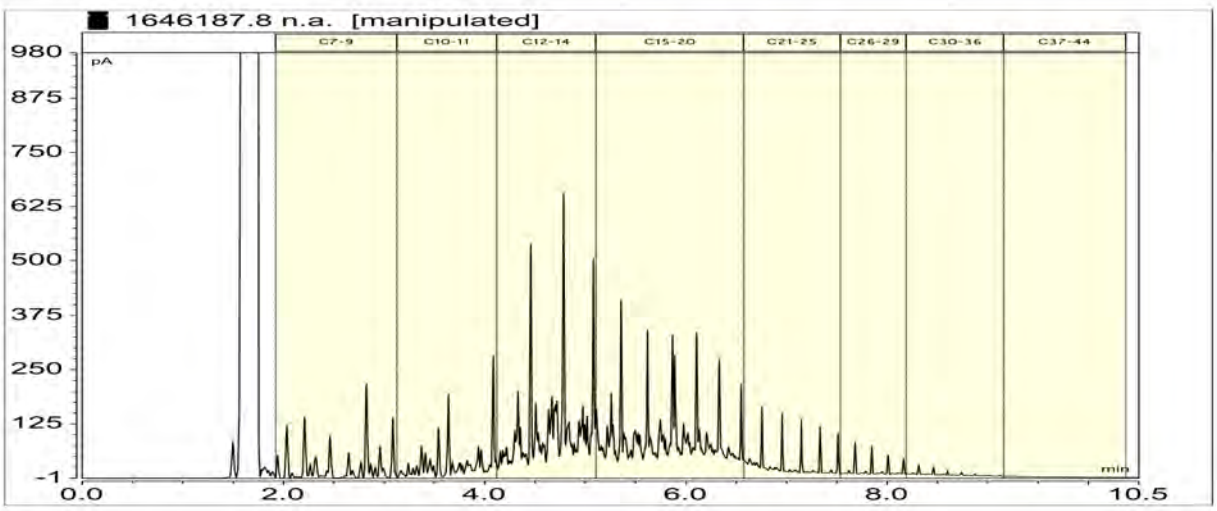
Sample Name:	Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete	Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete			
Lab Number:	1646187.7	1646187.8			
Individual Tests					
pH* pH Units	6.9	7.2	-	-	-
Total Alkalinity* g/m³ as $CaCO_3$	690	3,100	-	-	-
Analysis Temperature for Bicarbonate °C	23	23	-	-	-
Bicarbonate g/m³ at Analysis Temperature	909	3,240	-	-	-
Total Hardness* g/m³ as $CaCO_3$	300	119	-	-	-
Electrical Conductivity (EC)* mS/m	1,986	1,680	-	-	-
Total Dissolved Solids (TDS)* g/m³	12,400	12,700	-	-	-
Total Barium* g/m³	68	50	-	-	-
Total Bromine* g/m³	20	13.7	-	-	-
Dissolved Calcium* g/m³	103	40 #2	-	-	-
Total Calcium* g/m³	103	37 #2	-	-	-
Total Copper* g/m³	0.48	0.164	-	-	-
Total Iron* g/m³	3.4	1.22	-	-	-
Dissolved Magnesium* g/m³	10.5	4.9	-	-	-
Total Magnesium* g/m³	11.2	4.9	-	-	-
Total Manganese* g/m³	2.3	2.4	-	-	-
Total Mercury* g/m³	< 0.0021	< 0.0021	-	-	-
Total Nickel* g/m³	0.083	0.104	-	-	-
Total Potassium* g/m³	148	470	-	-	-
Total Sodium* g/m³	4,200	3,700	-	-	-
Total Sulphur* g/m³	6	57	-	-	-
Total Zinc* g/m³	1.13	1.40	-	-	-
Chloride* g/m³	6,500	3,900	-	-	-
Nitrite-N g/m³	< 0.02 #1	0.12 #1	-	-	-
Nitrate-N g/m³	< 0.02	< 0.02	-	-	-
Nitrate* g/m³	< 0.09	< 0.09	-	-	-
Nitrate-N + Nitrite-N g/m³	< 0.02 #1	0.13 #1	-	-	-
Sulphate* g/m³	18	172	-	-	-
Ethylene Glycol in Water					
Ethylene glycol* g/m³	< 2,000	< 2,000	-	-	-

Sample Type: Saline						
Sample Name:		Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete	Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete			
Lab Number:		1646187.7	1646187.8			
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 2,000	< 2,000	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2,000	< 2,000	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m³	4.3	14.6	-	-	-
Toluene*	g/m³	3.5	21	-	-	-
Ethylbenzene*	g/m³	0.23	1.93	-	-	-
m&p-Xylene*	g/m³	1.31	12.3	-	-	-
o-Xylene*	g/m³	0.51	4.0	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	0.24	0.39	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	12.8	240	-	-	-
C10 - C14*	g/m³	179	1,000	-	-	-
C15 - C36*	g/m³	166	1,090	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	360	2,300	-	-	-

1646187.7
Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete
Client Chromatogram for TPH by FID



1646187.8
Composite of Turangi-6 Flow Back Initial, Turangi-6 Flow Back Mid and Turangi-6 Flow Back Complete
Client Chromatogram for TPH by FID



Analyst's Comments

Due to the type of matrix found in samples 1646187.7 and .8, a dilution was required for the Methanol analysis. Hence the higher detection limit reported.

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

#2 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

SUMMARY OF METHODS

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

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	7-8
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	7-8
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	7-8
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	7-8
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	7-8
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	7-8
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	7-8
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	7-8
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	7-8
pH*	Saline water, pH meter. APHA 4500-H$^+$ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	7-8
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	7-8
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	7-8
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m^3 at Analysis Temperature	7-8
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	7-8
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	7-8

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m³	7-8
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	7-8
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m³	7-8
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m³	7-8
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m³	7-8
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	7-8
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	7-8
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	7-8
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m³	7-8
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	7-8
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	7-8
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m³	7-8
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	7-8
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	7-8
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	7-8
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m³	7-8
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	7-8
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	7-8
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	7-8
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	7-8
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	7-8
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	7-8
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	7-8

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

Appendix IV
Biomonitoring report

To Job Manager**,** Jane Harvey

From Technical Officer, Katie Blakemore

Document 1803800

Report No. KB013

Date 13 January 2017

Biomonitoring of an unnamed tributary of the Parahaki Stream in relation to hydraulic fracturing at the Turangi-C wellsite

Introduction

A post- hydraulic fracturing (HF) survey was carried out at the Turangi-C wellsite, following completion of the HF activity, to determine whether stormwater discharges onto land near this unnamed tributary of the Parahaki Stream had a significant adverse impact on the stream macroinvertebrate community. A post-drill survey previously carried out at the same sites, and reported (in report KB011), also serves to provide pre-HF data for these sites.

Methods

The post-HF survey was completed on 23 November 2016 at three previously established sites (Table 1, Figure 1). These sites were situated in an unnamed tributary of the Parahaki Stream, with a 'control' site approximately 20m upstream of the discharge point (Site 1), a 'primary impact' site 20m downstream of this discharge point (Site 2) and a 'secondary impact' site 85m downstream of this discharge point (Site 3).

The Council's standard 'vegetation sweep' technique was used to collect streambed macroinvertebrates in the unnamed tributary of the Parahaki Stream. 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 the unnamed tributary of the Parahaki Stream in relation to discharges from the Turangi-C wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	PRH000035	E1712866 N5681040	20m upstream of Turangi-C wellsite discharge	60
2	PRH000037	E1712905 N5681107	20m downstream of Turangi-C wellsite discharge	60
3	PRH000040	E1712931 N5681171	85m downstream of Turangi-C wellsite discharge	60

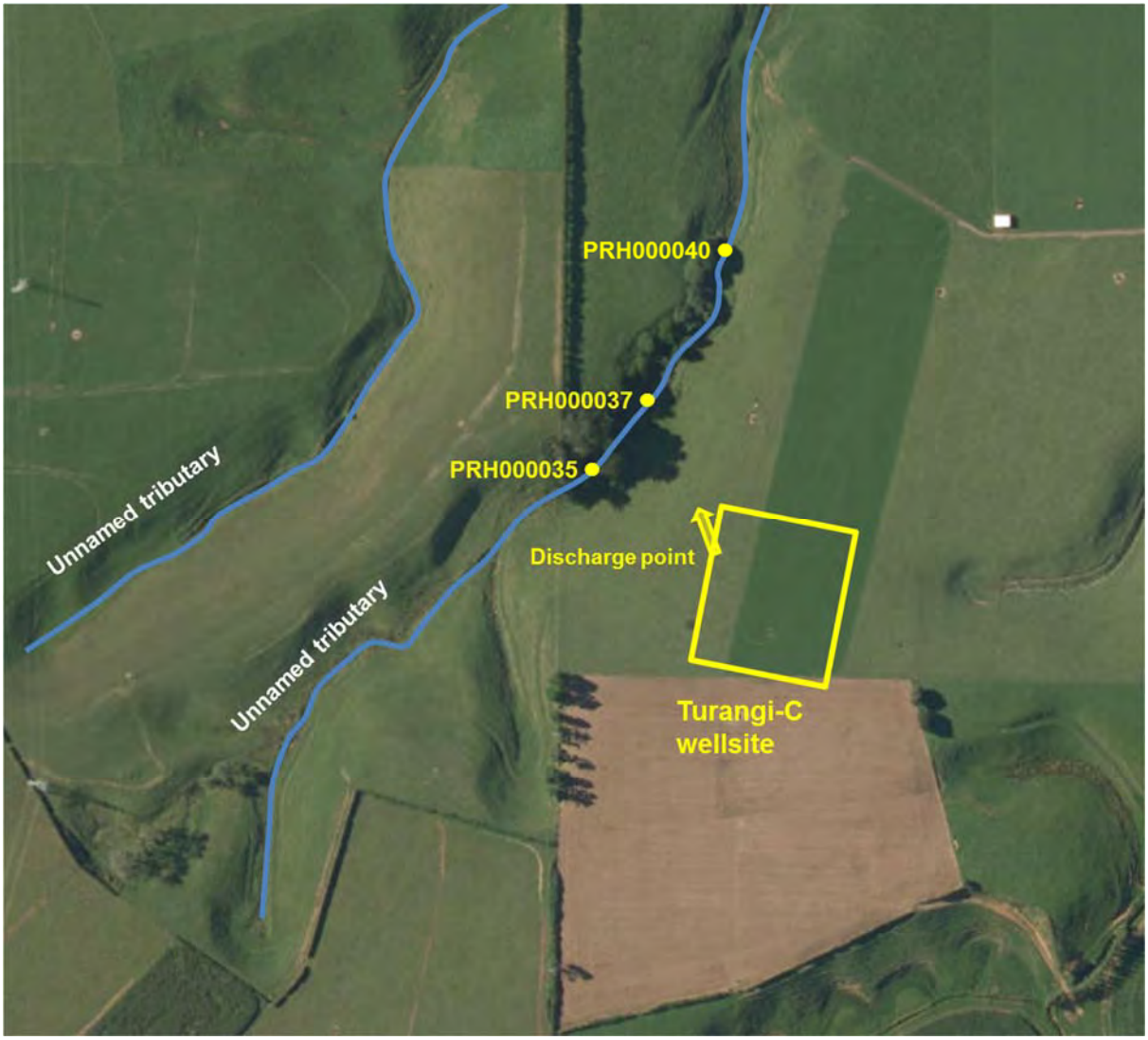

Figure 1 Biomonitoring sites in an unnamed tributary of the Parahaki Stream in relation to the Turangi-C wellsite.

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Macroinvertebrate taxa abundances found in each sample were recorded based on the categories in Table 2.

Table 2 Macroinvertebrate abundance categories

Abundance category	Number of individuals
R (rare)	1-4
C (common)	5-19
A (abundant)	20-99
VA (very abundant)	100-499
XA (extremely abundant)	>499

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. A gradation of biological water quality conditions based upon MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000) (Table 3). More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000)

Grading	MCI
Excellent	>140
Very Good	120-140
Good	100-119
Fair	80-99
Poor	60-79
Very Poor	<60

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. Macroinvertebrate community health grades can also be assigned from the $SQMCI_S$, although these have not been modified for Taranaki. The grades based on the $SQMCI_s$ are given in Table 4.

Table 4 Macroinvertebrate community health based on SQMCIs ranges from Stark and Maxted's classification (Stark and Maxted 2007)

Grading	SQMCIs
Excellent	>5.99
Good	5.00-5.99
Fair	4.00-4.99
Poor	<4.00

Results

The post HF survey was carried out approximately one month following the completion of HF activities. At the time of the post-HF survey being carried out, there was a slow, clear and uncoloured flow with a moderate water level at all three sites. The substrate at all three sites was predominantly silt, with small quantities of fine and coarse gravels and wood or root mats present variously at the three sites. Water temperatures at the three sites ranged between 15.4 – 15.7°C. The survey was carried out 5 days following a fresh of 3x median flow and 8 days following a fresh of 7x median flow (based on the nearby Mangaoraka Stream).

All three sites had extensive macrophytes throughout the streambed, while moss, leaves and woody debris were absent. Periphyton mats were absent at all three sites, while filamentous periphyton was absent at site 1, patchy at site 2 and widespread at site 3. Sites 1 and 2 had partial shading from overhanging vegetation, whereas site 3 was not shaded.

Macroinvertebrate communities

A summary of previously recorded median scores and ranges for macroinvertebrate indices in Taranaki lowland coastal streams between 50 and 79 metres above sea level, together with results recorded in the current surveys are provided in Table 5.

Table 5 Summary of medians and ranges based on previously recorded data (111 surveys) from Taranaki lowland coastal streams between 50-79m above sea level (TRC 2016), together with results recorded in the current surveys and the range of previously recorded results at these sites

	Lowland Coastal Streams		Post-HF Survey (previously recorded range)		
	Median	Range	PRH000035	PRH000037	PRH000040
Number of taxa	20	0-30	18 (10-20)	17 (11-13)	8 (11-18)
MCI	79	60-109	77 (76-83)	71 (75-80)	53 (58-74)
SQMCIs	4.0	1.2-6.7	3.7 (1.2-4.8)	4.6 (1.4-4.1)	1.2 (1.6-3.8)

The results of the post-HF survey are provided in Table 6.

Table 6 Macroinvertebrate fauna of the unnamed tributary of Parahaki Stream in relation to Turangi-C wellsite stormwater discharge sampled on 23 November 2016

Taxa List	Site Number	MCI score	1	2	3
	Site Code		PRH000035	PRH000037	PRH000040
	Sample Number		FWB16266	FWB16267	FWB16268
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	A	A
MOLLUSCA	Lymnaeidae	3	-	R	-
	Potamopyrgus	4	A	VA	-
	Sphaeriidae	3	C	-	-
CRUSTACEA	Ostracoda	1	C	A	R
	Paracalliope	5	VA	XA	R
	Paraleptamphopidae	5	VA	C	-
EPHEMEROPTERA (MAYFLIES)	*Zephlebia group*	7	C	-	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	C	A	C
TRICHOPTERA (CADDISFLIES)	*Polyplectropus*	6	C	A	-
	Psilochorema	6	R	R	-
	Oxyethira	2	R	R	R
	Triplectides	5	-	C	-
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	-	-
	Chironomus	1	R	R	VA
	Orthocladiinae	2	-	C	R
	Polypedilum	3	C	C	-
	Tanypodinae	5	C	R	R
	Paradixa	4	R	C	-
	Austrosimulium	3	C	C	-
	No of taxa		18	17	8
	MCI		77	71	53
	SQMCIs		3.7	4.6	1.2
	EPT (taxa)		3	3	0
	%EPT (taxa)		17	18	0

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

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

Site 1 (Upstream of wellsite discharge)

Moderate taxa richness of 18 taxa was recorded at this upstream 'control' site at the time of the post-HF survey. This value is higher than that recorded in the post-drill survey. This result falls below the median taxa richness of 20 taxa, but within the previously recorded range of taxa richnesses for lowland coastal streams at similar altitude in Taranaki (Table 5).

The pre-drill survey recorded a MCI score of 77 at this site, categorising the site as having 'poor' macroinvertebrate community health. This score was not significantly different (Stark 1998) from either the post-drill survey score of 80 units or the median MCI score of 79 for lowland coastal streams at similar altitude in Taranaki (Table 5). A $SQMCI_s$ score of 3.7 was recorded, a significant increase (Stark 1998) from the score of 1.2 recorded in the post-drill survey, but not significantly different from the median $SQMCI_s$ score for lowland coastal streams at similar altitude in Taranaki.

The invertebrate community was characterised by four taxa at the time of the post-HF survey, two 'moderately sensitive' taxa [amphipods (*Paracalliope* and Paraleptamphopidae)] and two 'tolerant' taxa [the snail (*Potamopyrgus*) and oligochaete worms].

Site 2 (20m downstream of wellsite discharge)

Moderate taxa richness of 17 taxa was recorded at this 'primary impact' site at the time of the post-HF survey, higher than the richness of 12 taxa recorded in the post-drill survey. This result is within the previously recorded range of taxa richnesses, but is lower than the median richness for lowland coastal streams in Taranaki (Table 5).

The post-HF survey recorded an MCI score of 71, not significantly different (Stark 1998) from either the post-drill survey MCI score of 80 or the median score for similar sites in this altitudinal range (Table 5). This score categorised the site as having 'poor' macroinvertebrate community health. The recorded $SQMCI_s$ score of 4.6 was a significant improvement (Stark 1998) from the score of 1.4 recorded in the post-drill survey.

The macroinvertebrate community at this site was characterised by six taxa at the time of this survey. Characteristic taxa included two 'moderately sensitive' taxa [amphipod (*Paracalliope*) and uncased caddis (*Polyplectropus*)], and four 'tolerant' taxa [snail (*Potampopyrgus*), damselfly (*Xanthocnemis*), ostracod seed shrimps and oligochaete worms].

Site 3 (85m downstream of wellsite discharge)

Low taxa richness of eight taxa was recorded at this 'primary impact' site at the time of this post-HF survey, slightly lower than the richness of 12 taxa recorded in the post-drill survey. These values are below the median taxa richness of 20 taxa, but within the previously recorded range of taxa richnesses for lowland coastal streams at similar altitude in Taranaki (Table 5).

This post-HF survey recorded an MCI score of 53 at this site, insignificantly lower (Stark 1998) than the score of 58 recorded in the post-drill survey and classifying the stream as having 'very poor' ecological health. These scores are significantly lower than the median MCI score of 79 for similar sites in this altitudinal range (Table 5) (Stark 1998). The $SQMCI_s$ score was 1.2 units for this survey, insignificantly lower than the post-drill survey's recorded score of 1.7 units. These scores are not significantly different from each other, but are significantly lower than the median $SQMCI_s$ score of 4.0 units for lowland coastal streams at similar altitude in Taranaki (Table 5). The current score is equal to the lowest previously recorded $SQMCI_s$ score for similar streams within a similar altitudinal range.

This macroinvertebrate community at this site was characterised by two 'tolerant' taxa [oligochaete worms and midge larvae (*Chironomus*)].

Discussion and conclusions

The Council's 'vegetation sweep' technique was used to collect samples from three sites in this unnamed tributary. This has provided data to assess the impact of the stormwater discharge to land from the Turangi-C wellsite on the macroinvertebrate communities of the stream. Samples were processed to provide taxa richness, MCI and $SQMCI_s$ scores for each site.

Taxa richness is a valuable macroinvertebrate community metric when determining whether a community has been exposed to a toxic discharge, as macroinvertebrates will either drift downstream to avoid the discharge or may be killed. This would result in a reduced taxa richness at the downstream sites. In contrast, the MCI and $SQMCI_s$ scores are a measure of community tolerance to organic pollution, although they can also provide an indication of more subtle influences caused by a poor quality discharge. As the $SQMCI_s$ score takes into account relative abundances of the taxa found in the sample, it provides additional insight to that provided by the MCI score. However, it is also easily influenced by the 'patchiness' of invertebrates on the stream bed, and as such must be considered in the context of all three metrics.

Taxa richnesses were found to be moderate to low in all instances. Site 3 had a significantly lower taxa richness compared to sites 1 and 2, although the score was similar to that recorded at site 3 in the post-drill survey. Further, sites 1 and 2 both recorded an increase in taxa richness when compared to the post-drill survey. All taxa richnesses were lower than the median taxa richness for Taranaki lowland coastal stream sites between 50 and 79m above sea level (Table 5). The low taxa richnesses are most likely a result of poor quality habitat, with the streambed made up primarily of fine sediment which does not support high quality freshwater macroinvertebrate communities. Furthermore, the taxa found in the current surveys are generally associated with macrophytes, which were extensive at all sites.

MCI scores did not change significantly (Stark 1998) for any of the three sites compared to the post-drill survey, although site 3 recorded a significantly lower MCI score than either site 1 or site 2 on both occasions. MCI scores at sites 1 and 2 were similar to the median scores for Taranaki lowland coastal streams at similar altitude, while the score for site 3 was significantly lower than this median on both occasions.

$SQMCI_s$ scores were 3.7, 4.6 and 1.2 for sites 1-3 respectively. This was a significant increase from the post-drill survey scores for both sites 1 and 2 (Stark 1998), caused primarily by an increased abundance of the 'moderately sensitive' crustaceans *Paracalliope* and Paraleptamphopidae at site 1, and the 'moderately sensitive taxa *Paracalliope* and *Polyplectropus* at site 2. Site 3 showed an insignificant decrease from the previous $SQMCI_s$ score, caused by an increase in the abundance of oligochaete worms (MCI score 1) together with a decrease in the abundance of the 'moderately sensitive' taxa *Paracalliope*, *Triplectides* and Tanypodinae. The scores for sites 1 and 2 were not significantly different (Stark 1998) from the median $SQMCI_s$ score for Taranaki lowland coastal streams at similar altitude, while the score for site 3 was significantly lower (Stark 1998) than this median and was equal to the lowest previously recorded $SQMCI_s$ score for streams of this type at similar altitude.

All scores except for site 2 during the pre-drill survey were significantly below the median $SQMCI_s$ score for Taranaki lowland coastal streams at similar altitude.

The lower invertebrate community metrics at site 3 compared to sites 1 and 2 is likely to be a reflection of habitat differences, with site 3 having less shading (due to only minor overhanging vegetation at site 3), less woody debris in the stream channel (which provides important invertebrate habitat in soft-bottomed streams) and an increased cover of filamentous algae at this site, further reducing the available habitat for benthic

macroinvertebrates. Further, there is a culvert approximately five metres downstream of this site, which may have contributed to increased deposited sediment on the streambed at this site compared to sites 1 and 2.

Overall the invertebrate metrics recorded in these surveys provided no evidence that discharges from the Turangi-C wellsite have had any impact on the macroinvertebrate communities of this unnamed tributary of the Parahaki Stream. The low taxa richnesses observed are a result of poor quality habitat, and did not change significantly when compared with the post-drill survey. The MCI scores did not change significantly at any site when compared with those recorded in the post-drill survey, indicating that that any discharges from the Turangi-C wellsite have not had a significant impact on the macroinvertebrate communities. The significantly lower invertebrate community metrics recorded at site 3 compared to sites 1 and 2 is likely to be a reflection of habitat differences and is unlikely to be related to the wellsite discharges. This is evidenced by the scores being similar to those recorded at this site in previous surveys. Further, any discharges would be expected to have the largest impact on macroinvertebrate communities at site 2, the 'primary impact' site and these were not observed. Differences in $SQMCI_s$ scores are the result of changes in abundance of particular taxa, and are considered to reflect the patchy nature of stream macroinvertebrate communities rather than the effects of any discharges that may have occurred.

Summary

A macroinvertebrate survey was carried out at three sites near the Turangi-C wellsite following hydraulic fracturing activities, to determine if discharges from the wellsite had had detrimental effects on the stream macroinvertebrate communities. The survey, undertaken in November 2016, recorded taxa richnesses that were moderate to low at all three sites. MCI scores ranged from 77-53 across the three sites. No site recorded a significant change in MCI score when compared with the post-drill survey, although site 3 recorded significantly lower scores than sites 1 and 2 in both surveys. This is likely to be a result of habitat differences between the sites. $SQMCI_s$ scores were significantly higher at sites 1 and 2 than site 3, and sites 1 and 2 recorded a significant increase in $SQMCI_s$ score when compared with the post-drill survey, while the score for site 3 did not change significantly from the post-drill survey's result. These differences in $SQMCI_s$ scores reflected the changes in abundance of particular taxa. Overall, there is no evidence that discharges from the Turangi-C wellsite have impacted on the macroinvertebrate communities of this unnamed tributary of the Parahaki Stream.

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Biomonitoring of an unnamed tributary of the Parahaki Stream in relation to drilling at the Turangi-C wellsite, Winter 2016

Introduction

A pre-drill biological survey was carried out at the Turangi-C wellsite, to provide baseline data on the health of the macroinvertebrate community in this unnamed tributary of the Parahaki Stream prior to the commencement of drilling activities. A follow-up survey was undertaken upon completion of the drilling to determine whether stormwater discharges onto land near this unnamed tributary of the Parahaki Stream had impacted on the stream macroinvertebrate community.

Methods

The pre-drill survey was completed on 3 June 2016 at three previously established sites (Table 1, Figure 1). These sites were situated in an unnamed tributary of the Parahaki Stream, with a 'control' site approximately 20m upstream of the discharge point (Site 1), a 'primary impact' site 20m downstream of this discharge point (Site 2) and a 'secondary impact' site 85m downstream of this discharge point (Site 3). A post-drill survey at these same sites was carried out on 9 August 2016.

The Council's standard 'vegetation sweep' technique was used to collect streambed macroinvertebrates in the unnamed tributary of the Parahaki Stream. 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 the unnamed tributary of the Parahaki Stream in relation to discharges from the Turangi-C wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	PRH000035	E1712866 N5681040	20m upstream of Turangi-C wellsite discharge	60
2	PRH000037	E1712905 N5681107	20m downstream of Turangi-C wellsite discharge	60
3	PRH000040	E1712931 N5681171	85m downstream of Turangi-C wellsite discharge	60

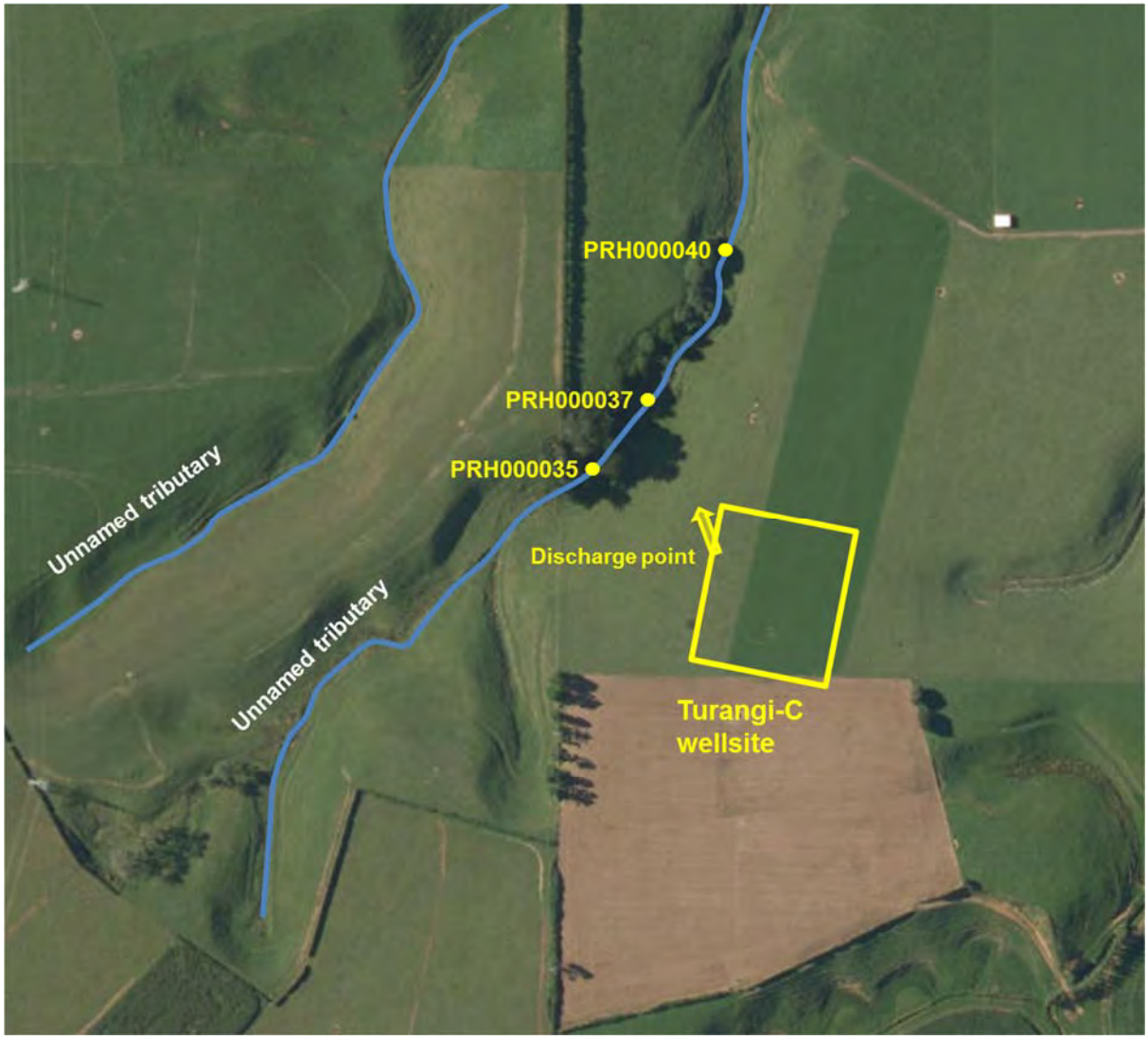

Figure 1 Biomonitoring sites in an unnamed tributary of the Parahaki Stream in relation to the Turangi-C wellsite.

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Macroinvertebrate taxa abundances found in each sample were recorded based on the categories in Table 2.

Table 2 Macroinvertebrate abundance categories

Abundance category	Number of individuals
R (rare)	1-4
C (common)	5-19
A (abundant)	20-99
VA (very abundant)	100-499
XA (extremely abundant)	>499

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. A gradation of biological water quality conditions based upon MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000) (Table 3). More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000)

Grading	MCI
Excellent	>140
Very Good	120-140
Good	100-119
Fair	80-99
Poor	60-79
Very Poor	<60

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. Macroinvertebrate community health grades can also be assigned from the $SQMCI_S$, although these have not been modified for Taranaki. The grades based on the $SQMCI_s$ are given in Table 4.

Table 4 Macroinvertebrate community health based on SQMCIs ranges from Stark and Maxted's classification (Stark and Maxted 2007)

Grading	$SQMCI_s$
Excellent	>5.99
Good	5.00-5.99
Fair	4.00-4.99
Poor	<4.00

Results

At the time of the pre-drill survey being carried out, there was a slow or very slow/still clear, uncoloured flow with a low water level at all three sites. The substrate at all sites was predominantly silt and sand. Sites 2 and 3 also had small amounts of fine and coarse gravel. Water temperatures ranged between 12.7- 13.6°C at the three sites. The survey was carried out 3 days since a fresh of 3x median flow and 6 days since a fresh of 7x median flow (based on the nearby Mangaoraka Stream).

All three sites had no periphyton, moss or wood present. Patchy leaves were present on the streambed at sites 1 and 2 but absent at site 3. Macrophytes were present throughout the streambed at all three sites.

The post-drill survey was carried out 1 day after a fresh of 3x median flow and 4 days after a fresh of 7x median flow. There was a moderate to high flow which was clear and uncoloured. The flow was steady at site 1 and slow at sites 2 and 3. Water temperatures ranged from 13.9 – 14.5 °C at the three sites. The substrate at all sites was predominantly silt and sand, with small amounts of fine and coarse gravel. Wood and root were also present at sites 1 and 2.

All three sites had no periphyton or moss present. Leaves were widespread on the streambed at site 1 and patchy at sites 2 and 3, while wood was patchy at sites 1 and 2 but absent at site 3. Macrophytes were present on the streambed at all three sites.

Macroinvertebrate communities

A summary of previously recorded median scores and ranges for macroinvertebrate indices in Taranaki lowland coastal streams between 50 and 79 metres above sea level, together with results recorded in the current surveys are provided in Table 5.

Table 5 Summary of medians and ranges based on previously recorded data from Taranaki lowland coastal streams between 50-79m above sea level (TRC 2015), together with results recorded in the current surveys

	Lowland Coastal		Pre-drill survey			Post-drill survey		
	Median	Range	PRH000035	PRH000037	PRH000040	PRH000035	PRH000037	PRH000040
Number of taxa	20	0-30	12	11	11	10	12	12
MCI	79	60-109	83	80	58	76	80	58
$SQMCI_s$	4.0	1.4-6.7	2.2	4.1	1.6	1.2	1.4	1.7

The results of the pre-drill survey are provided in Table 6, and the results of the post-drill survey are provided in Table 7.

Table 6 Macroinvertebrate fauna of the unnamed tributary of Parahaki Stream in relation to Turangi-C wellsite stormwater discharge sampled on 3 June 2016

Taxa List	Site Number	MCI score	1	2	3
	Site Code		PRH000035	PRH000037	PRH000040
	Sample Number		FWB16210	FWB16211	FWB16212
NEMERTEA	Nemertea	3	R	-	-
NEMATODA	Nematoda	3	-	-	R
ANNELIDA (WORMS)	Oligochaeta	1	VA	A	A
HIRUDINEA (LEECHES)	Hirudinea	3	-	-	A
MOLLUSCA	*Potamopyrgus*	4	R	A	-
	Sphaeriidae	3	C	C	-
CRUSTACEA	Ostracoda	1	A	A	VA
	Isopoda	5	-	R	-
	Paracalliope	5	A	VA	C
	Paraleptamphopidae	5	A	C	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	R	C
TRICHOPTERA (CADDISFLIES)	*Polyplectropus*	6	R	-	-
	Oxyethira	2	-	-	R
	Triplectides	5	-	-	R
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	-	-
	Zelandotipula	6	R	C	-
	Chironomus	1	-	-	A
	Orthocladiinae	2	-	-	R
	Tanypodinae	5	R	A	C
ACARINA (MITES)	Acarina	5	C	R	-
No of taxa			12	11	11
MCI			83	80	58
SQMCIs			2.2	4.1	1.6
EPT (taxa)			1	0	1
%EPT (taxa)			8	0	9
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa			
R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant					

Table 7 Macroinvertebrate fauna of the unnamed tributary of Parahaki Stream in relation to Turangi-C wellsite stormwater discharge sampled on 9 August 2016

Taxa List	Site Number	MCI score	1	2	3
	Site Code		PRH000035	PRH000037	PRH000040
	Sample Number		FWB16213	FWB16214	FWB16215
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-	R
ANNELIDA (WORMS)	Oligochaeta	1	XA	XA	XA
HIRUDINEA (LEECHES)	Hirudinea	3	-	-	C
MOLLUSCA	Lymnaeidae	3	-	R	R
	Potamopyrgus	4	C	A	-
	Sphaeriidae	3	A	A	-
CRUSTACEA	Copepoda	5	R	-	-
	Ostracoda	1	C	A	VA
	Paracalliope	5	C	A	VA
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	C	A
TRICHOPTERA (CADDISFLIES)	*Polyplectropus*	6	-	C	-
	Oxyethira	2	-	-	R
	Triplectides	5	-	R	C
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	R	-
	Chironomus	1	-	-	C
	Orthocladiinae	2	-	-	R
	Tanypodinae	5	C	C	C
ACARINA (MITES)	Acarina	5	C	R	-
		No of taxa	10	12	12
		MCI	76	80	58
		SQMCIs	1.2	1.4	1.7
		EPT (taxa)	0	2	1
		%EPT (taxa)	0	17	8
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa			

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

Site 1 (Upstream of wellsite discharge)

Low taxa richness of 12 taxa was recorded at this upstream 'control' site at the time of the pre-drill survey, while 10 taxa were recorded in the post-drill survey. These values are below the median taxa richness of 20 taxa, but within the previously recorded range of taxa richnesses for lowland coastal streams at similar altitude in Taranaki (Table 5).

The pre-drill survey recorded a MCI score of 83 at this site, while the post-drill survey recorded a MCI score of 76.These scores categorised the site as having 'fair' and 'poor' macroinvertebrate community health respectively. The difference between these scores is not statistically significant (Stark 1998), and neither score is significantly different from the median MCI score of 79 for lowland coastal streams at similar altitude in Taranaki (Table 5). In contrast, the $SQMCI_s$ score decreased from 2.2 to 1.2 between the pre-drill and post-drill surveys, a statistically significant difference (Stark 1998).

The invertebrate community was characterised by four taxa at the time of the pre-drill survey, two 'moderately sensitive' amphipods (*Paracalliope* and Paraleptamphopidae) and two 'tolerant' taxa (ostracod seed shrimps and oligochaete worms). Two 'tolerant' taxa (oligochaete worms and sphaerid pea clams) characterised the community at the time of the post-drill survey.

Site 2 (20m downstream of wellsite discharge)

Low taxa richness of 11 taxa was recorded at this 'primary impact' site at the time of the pre-drill survey, while 12 taxa were recorded in the post-drill survey. These values are below the median taxa richness of 20 taxa, but within the previously recorded range of taxa richnesses for lowland coastal streams at similar altitude in Taranaki (Table 5).

Both the pre-drill and post-drill surveys recorded a MCI score of 80, classifying the stream as having 'fair' ecological health. Both scores are similar to the median score of 79 for similar sites in this altitudinal range (Table 5). There is no statistically significant difference between these scores (Stark 1998). The $SQMCI_s$ scores at this site were 4.1 and 1.4 in the pre-drill and post-drill surveys respectively. This indicates a statistically significant decrease in stream health (Stark 1998).

The macroinvertebrate community at this site was characterised by five taxa at the time of the pre-drill survey and by five taxa at the time of the post-drill survey. Characteristic taxa in both surveys included one 'moderately sensitive' amphipod (*Paracalliope*), and three 'tolerant' taxa [snail (*Potamopyrgus*), ostracod seed shrimps and oligochaete worms]. The pre-drill community was characterised further by a 'moderately sensitive' fly larvae (Tanypodinae); while the post-drill invertebrate community was characterised by an additional 'tolerant' taxon (sphaerid seed shrimps).

Site 3 (85m downstream of wellsite discharge)

Low taxa richness of 11 taxa was recorded at this 'primary impact' site at the time of the pre-drill survey, while 12 taxa were recorded in the post-drill survey. These values are below the median taxa richness of 20 taxa, but within the previously recorded range of taxa richnesses for lowland coastal streams at similar altitude in Taranaki (Table 5).

Both the pre-drill and post-drill surveys recorded a MCI score of 58, classifying the stream as having 'very poor' ecological health. These scores are significantly lower than the median MCI score of 79 for similar sites in this altitudinal range (Table 5) (Stark 1998). The $SQMCI_s$ scores were recorded as 1.6 units for the pre-drill survey and a similar 1.7 units for the post-drill survey. These scores are not significantly different from each other, but are significantly lower than the median $SQMCI_s$ score of 4.0 units for lowland coastal streams at similar altitude in Taranaki (Table 5).

The macroinvertebrate community at this site was characterised by four numerically dominant taxa at the time of the pre-drill survey and four taxa at the time of the post-drill survey. Characteristic taxa in both surveys were the two 'tolerant' taxa [oligochaete worms and ostracod seed shrimps]. The pre-drill survey found two additional 'tolerant' characteristic taxa [leeches and midge larvae (*Chironomus*)], while the post-drill survey also found two additional characteristic taxa, the 'moderately sensitive' amphipod (*Paracalliope*) and the 'tolerant' damselfly (*Xanthocnemis*).

Discussion and conclusions

The Council's 'vegetation sweep' technique was used to collect samples from three sites in this unnamed tributary on two occasions. This has provided data to assess the impact of the stormwater discharge to land from the Turangi-C wellsite on the macroinvertebrate communities of the stream. Samples were processed to provide taxa richness, MCI and $SQMCI_s$ scores for each site.

Taxa richness is a valuable macroinvertebrate community metric when determining whether a community has been exposed to a toxic discharge, as macroinvertebrates will either drift downstream to avoid the discharge or may be killed. This would result in a reduced taxa richness at the downstream sites. In contrast, the MCI and $SQMCI_s$ scores are a measure of community tolerance to organic pollution, although they can also provide an indication of more subtle influences caused by a poor quality discharge. As the $SQMCI_s$ score takes into account relative abundances of the taxa found in the sample, it provides additional insight to that provided by the MCI score. However, it is also easily influenced by the 'patchiness' of invertebrates on the stream bed, and as such must be considered in the context of all three metrics.

Taxa richnesses were found to be low in all instances. There no significant differences in taxa richnesses between any of the three sites or between surveys. All taxa richnesses were lower than the median taxa richness for Taranaki lowland coastal stream sites between 50 and 79m above sea level (Table 5). The low taxa richnesses are most likely a result of poor quality habitat, with the streambed made up primarily of fine sediment which does not support high quality freshwater macroinvertebrate communities. Furthermore, the taxa found in the current surveys are generally associated with macrophytes, which were extensive at all sites.

MCI scores did not change significantly for any of the three sites between survey occasions, although site 3 recorded a significantly lower MCI score than either site 1 or site 2 on both occasions. MCI scores at sites 1 and 2 were similar to the median scores for Taranaki lowland coastal streams at similar altitude, while the score for site 3 was significantly lower than this median on both occasions. This is likely a reflection of habitat differences, with site 3 having less shading (due to only minor overhanging vegetation at site 3), and less woody debris in the stream channel (which provides important invertebrate habitat in soft-bottomed streams).

$SQMCI_s$ scores were 2.2, 4.1 and 1.6 for sites 1-3 respectively in the pre-drill survey. Sites 1 and 3 recorded scores that are insignificantly different from each other, while site 2 had a significantly higher score than either site 1 or site 3 (Stark 1998). The scores recorded in the post-drill survey were 1.2, 1.4 and 1.7 for these sites respectively. There is no significant difference between in $SQMCI_s$ scores between sites in this survey (Stark 1998). Both site 1 and site 2 showed a significant decrease in $SQMCI_s$ score between the pre-drill and post-drill surveys (Stark 1998), while scores for site 3 were similar on both occasions. The decrease observed at site 1 was primarily due to the increase of oligochaete worms (MCI score 1) from 'very abundant' to 'extremely abundant', while at site 2 it was primarily due to the decrease of tanypod larvae from 'abundant' to 'common and *Paracalliope* amphipods from 'very abundant' to 'abundant'.

All scores except for site 2 during the pre-drill survey were significantly below the median $SQMCI_s$ score for Taranaki lowland coastal streams at similar altitude.

A previous survey has been carried out at these sites (TRC, unpublished data). The results of this survey found similar results at sites 1 and 2, with no decline in MCI score observed at site 3. It is possible that there has been

a change in habitat at site 3, with increased sedimentation on the streambed since the previous survey. A culvert approximately 5m downstream of site 3 would contribute to a buildup of deposited sediment on the streambed at this site. Furthermore, the construction of the wellsite pad occurred during this interval, which could have resulted in an increased fine sediment supply to the stream. However, there is insufficient evidence to attribute this change at site 3 to the Turangi-C wellsite.

Overall the invertebrate metrics recorded in these surveys provided no evidence that discharges from the Turangi-C wellsite have had any impact on the macroinvertebrate communities of this unnamed tributary of the Parahaki Stream. The low taxa richnesses observed are a result of poor quality habitat, and did not change significantly between surveys. The MCI scores did not change significantly at any site between the two surveys, indicating that that any discharges from the Turangi-C wellsite have not had a significant impact on the macroinvertebrate communities. The significantly lower score recorded at site 3 compared to sites 1 and 2 is likely to be a reflection of habitat differences and is unlikely to be related to the wellsite discharges. This is evidenced by the score being similar in both the pre-drill and post-drill surveys. Further, any discharges would be expected to have the largest impact on macroinvertebrate communities at site 2, the 'primary impact' site and these were not observed. Differences in $SQMCI_s$ scores are the result of changes in abundance of particular taxa, and are considered to reflect the patchy nature of stream macroinvertebrate communities rather than the effects of any discharges that may have occurred.

Summary

Two macroinvertebrate surveys were carried out at three sites near the Turangi-C wellsite prior to and following drilling activities, to determine if discharges from the wellsite had had detrimental effects on the stream macroinvertebrate communities. These surveys, undertaken in June 2016 and August 2016, both recorded taxa richnesses that were low at all three sites. MCI scores ranged from 83 – 58 across the two surveys. No site recorded a significant change in MCI score between the two surveys, although site 3 recorded significantly lower scores than sites 1 and 2 in both surveys. This is likely to be a result of habitat differences between the sites. $SQMCI_s$ scores ranged widely between sites and surveys, and reflected the changes in abundance of particular taxa. Overall, there is no evidence that discharges from the Turangi-C wellsite have impacted on the macroinvertebrate communities of this unnamed tributary of the Parahaki Stream.

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