Todd Energy Ltd
Mangahewa-D Hydraulic Fracturing Monitoring Programme 2016-2019

Technical Report 2019-06

ISSN: 1178-1467 (Online)
Document: 2214140 (Word)
Document: 2237981 (Pdf)

Taranaki Regional Council
Private Bag 713
STRATFORD
June 2019

Executive summary

Todd Energy Ltd (Todd) operates the Mangahewa-D hydrocarbon exploration wellsite located on Rimutauteka Road, within the Waitara Catchment. This report for the period July 2016 to June 2019 describes the monitoring programme implemented by the Taranaki Regional Council (the Council) to assess Todd's environmental and consent compliance performance during the period under review. The report also details the results of the monitoring undertaken and assesses the environmental effects of Todd's activities.

This report outlines and discusses the results of the monitoring programme implemented by the Council in relation to the hydraulic activities conducted by Todd at the Mangahewa-D wellsite over the period 30 March 2017 to 23 March 2018.

The programme of hydraulic fracturing undertaken by Todd included the hydraulic fracturing of four wells Mangahewa-22, Mangahewa-4, Mangahewa-7 and Mangahewa-16.

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

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2016-2017, 2017-2018 and the 2018-2019 monitoring years. Monitoring 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 Manganui River. 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 Todd had no significant adverse effects on local groundwater or surface water resources. A temporary reduction in macroinvertebrate health was recorded in the unnamed tributary of the Manganui River during the hydraulic fracturing programme and additional sediment sampling was undertaken which indicated the presence of hydrocarbons in the stream. Follow-up surveys found that macroinvertebrate communities recovered to levels of health seen prior to impacts being observed and monitoring of the stream sediments indicated hydrocarbons were no longer present. There was no evidence found that indicated any connection between the activity being monitored and the observed impacts.

There were no unauthorised incidents recording non-compliance in respect of the resource consent held by Todd in relation to these activities or provisions in regional plans, during the period under review.

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

For reference, in the 2017-2018 year, consent holders were found to achieve a high level of environmental performance and compliance for 76% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 20% of the consents, a good level of environmental performance and compliance was achieved.

This is the third monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-D wellsite. In terms of overall environmental and compliance performance by the consent holder this report shows that the consent holder's performance remained at a high level.

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

Table of contents

		Page
1	Introduction	1
1.1	Compliance monitoring programme reports and the Resource Management Act 1991	1
1.1.1	Introduction	1
1.1.2	Structure of this report	1
1.1.3	The Resource Management Act 1991 and monitoring	1
1.1.4	Evaluation of environmental and administrative performance	2
1.2	Process description	3
1.2.1	Hydraulic fracturing	3
1.2.1.1	Gel fracturing	3
1.2.1.2	Slick water fracturing	4
1.2.1.3	Nitrogen gas fracturing	4
1.2.2	The Mangahewa-D wellsite and hydraulic fracturing activities	4
1.3	Resource consents	4
1.3.1	Discharges of wastes to land	4
1.4	Monitoring programme	7
1.4.1	Introduction	7
1.4.2	Programme liaison and management	7
1.4.3	Assessment of data submitted by the consent holder	7
1.4.4	Physiochemical sampling	7
1.4.4.1	Groundwater	7
1.4.4.2	Hydraulic fracturing and return fluids	8
1.4.5	Surface water quality monitoring	8
1.4.6	Biomonitoring surveys	9
1.5	External Surface water quality monitoring	9
2	Results	10
2.1	Consent holder submitted data	10
2.1.1	Mangahewa-22 post-fracturing discharge report	10
2.1.2	Mangahewa-4 post-fracturing discharge report	10
2.1.3	Mangahewa-7 post-fracturing discharge report	11
2.1.4	Mangahewa-16 post-fracturing discharge report	11
2.2	Physiochemical sampling	12
2.2.1	Groundwater	12

2.2.2 Hydraulic fracturing and return fluids 15
2.3 Biomonitoring surveys 17
2.4 Additional surface water and sediment sampling 17
2.5 Investigations, interventions, and incidents 19

3 Discussion 20
3.1 Environmental effects of exercise of consents 20
3.2 Evaluation of performance 20
3.3 Recommendations from the previous compliance report 22
3.4 Alterations to monitoring programmes of future hydraulic fracturing events 22
3.5 Exercise of optional review of consent 23

4 Recommendations 24

Glossary of common terms and abbreviations 25

Bibliography and references 27

Appendix I Resource consent held by Todd Energy Ltd

Appendix II Certificates of analysis (groundwater)

Appendix III Certificates of analysis (hydraulic fracturing fluids)

Appendix IV Biomonitoring Reports

Appendix V Todd Sediment Results Map

List of tables

Table 1 Summary of hydraulic fracturing details 6
Table 2 Details of groundwater sites included in the monitoring programme 8
Table 3 Surface water biomonitoring site details 9
Table 4 Surface water sediment sampling site details 9
Table 5 Results of groundwater sampling carried out in relation to the Mangahewa-D hydraulic fracturing events 13
Table 6 Results of hydraulic fracturing fluid sampling 15
Table 7 Results of hydraulic fracturing return fluid sampling 15
Table 8 Additional sampling undertaken by the Council 18
Table 9 Sediment sampling undertaken by BTW on behalf of Todd 18
Table 10 Shallow groundwater sampling undertaken by BTW on behalf of Todd 19
Table 11 Summary of performance for consent 7912-2.1 20
Table 12 Summary of performance for consent 7912-2.1 22

List of figures

Figure 1 Location map 5

1 Introduction

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 Todd Energy Ltd (Todd) at the Mangahewa-D wellsite, over the period 30 March 2017 to 23 March 2018. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at the Mangahewa-D wellsite included the hydraulic fracturing of four wells. The wells targeted for stimulation were the Mangahewa-22, Mangahewa-4, Mangahewa-7 and Mangahewa-16 wells.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2016-2017, 2017-2018 and 2018-2019 monitoring years. Monitoring included a mixture of groundwater, surface water, sediment and discharge monitoring components. This is the third monitoring report produced by the Council in relation to hydraulic fracturing activities at the Mangahewa-D 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 Mangahewa-D.

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 the future monitoring of any hydraulic fracturing activities at the Mangahewa-D 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 holder, this report also assigns them a rating for their 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 consent holder'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 2017-2018 year, consent holders were found to achieve a high level of environmental performance and compliance for 76% of the consents monitored through the Taranaki tailored monitoring programmes, while for another 20% 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 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 fracturing 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. [2] 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 Mangahewa-D wellsite and hydraulic fracturing activities

The Mangahewa-D wellsite is located on Rimutauteka Road within the Waitara Catchment. An unnamed tributary of the Manganui River is located 80 m to the north of the wellsite and the main channel of the Manganui River is located approximately 250 m north of the wellsite

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 Todd at the Mangahewa-D wellsite during the period being reported is provided below in Table 1.

1.3 Resource consents

1.3.1 Discharges of wastes to land

Sections 15(1)(b) and (d) of the RMA stipulate that no person may discharge any contaminant onto land if it may then enter water, or from any industrial or trade premises onto land under any circumstances, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations.

---

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

[2] *http://frackwire.com/nitrogen-gas-fracking*

Figure 1 Location map

Table 1 Summary of hydraulic fracturing details

Well	Bore id.	Fracturing date	Intervals	Formation
Mangahewa-22	GND2523	30/03/17	MaE1	Mangahewa
		31/03/17	MaE3	
Mangahewa-4	GND2494	18/06/17	MaB2u	
		20/06/17	MaD1	
		21/06/17	MaD2L	
		24/06/17	MaD2u	
		25/06/17	MaE3	
Mangahewa-7	GND2810	26/07/17	MaB3u/3L	
		27/07/17	MaC3	
		29/07/17	MaD2L	
		30/07/17	MaD2u	
		31/07/17	MaF1	
Mangahewa-16	GND2465	21/03/18	MaE2	
		22/03/18	MaE3	
		23/03/18	MaF2	

Todd was granted resource consent **7912-2.1** on 30 June 2014. The consent permits the discharge of contaminants in association with hydraulic fracturing activities at the Mangahewa-D wellsite. The consent was issued by the Council under Section 87(e) of the RMA. The consent requires the injection of fracturing fluids to occur below a depth of 3,325 m TVDss. The consent is due to expire 1 June 2024.

Consent 7912-2.1 has 17 special conditions, as summarised below:

- Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur;
- Condition 2 requires that no further hydraulic fracturing be undertaken after 1 June 2019;
- Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water);
- Conditions 4, 5, 6 and 7 relate to freshwater monitoring requirements, to allow compliance with condition 3 to be assessed;
- Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging;
- Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring;
- Condition 10 is a notification requirement;
- Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well;
- Condition 12 stipulates how the reports required by conditions 9, 11 and 12 are to be submitted;

- Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained;
- Condition 14 requires the consent holder to adopt best practicable options;
- Condition 15 relates to the composition of the fracturing fluid;
- Condition 16 is a lapse clause; and
- Condition 17 is a review provision.

This summary of consent conditions may not reflect the full requirements of each condition. The consent conditions in full can be found in the resource consent appended to this report (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 for the Mangahewa-D wellsite 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 the consent holder

As required by the conditions of consent 7912-2.1, Todd submitted pre and post-fracturing discharge reports to the Council for each well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

1.4.4 Physiochemical sampling

1.4.4.1 Groundwater

As a general accepted rule, all existing bores or wells within a 1 km radius of the proposed hydraulic fracturing activity are assessed for their suitability (or otherwise) for inclusion in the monitoring programme.

The survey of groundwater abstractions within the vicinity of the Mangahewa-D wellsite was carried out on the 31st October 2012 and a total of three groundwater sampling sites (GND2304, GND2305 and GND2306) were selected for inclusion in the original monitoring programme. These sites have all since been removed

from the programme. There are currently two sites included in the monitoring programme. The first, GND2459, was installed by Todd in 2015 specifically for monitoring groundwater at the Mangahewa-D wellsite. The second, GND2483, was added during the review period, the bore was recently installed for stock and farm supply and is located approximately 200 m down-gradient from the site.

The location of the bores included in the current monitoring programme are displayed in Figure 1 and bore details are summarised in Table 2.

A new bore GND2752, was also recently installed by Todd to monitor shallow groundwater resources in close proximity to the on-site stormwater settling ponds. This bore is not included in the current monitoring programme. The location of the bore is displayed on Figure 1 and a summary of bore details is included in Table 2.

Samples of groundwater were obtained pre-fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out during and following completion of the activities.

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Eastings	Northings	Distance from wellsite (m)	Total depth (m)	Screened/open interval (m)	Aquifer
GND2483	1710981	5673690	200	50	N/A	Volcanics
GND2459	1711180	5673585	<20	30.5	11.5-27.5	Volcanics
GND2752	1711218	5673664	<20	11	8-11	Volcanics

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 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.

Samples of hydraulic fracturing fluid were obtained by Todd during the activity and were provided to the Council for transport to RJ Hill Laboratories Ltd for analysis following standard chain of custody procedures.

1.4.5 Surface water quality monitoring

An unnamed tributary of the Manganui River is located 80 m to the north of the wellsite and the main channel of the Manganui River is located approximately 250 m north of the wellsite.

Monitoring sites have been selected to monitor upstream and downstream of the wellsite and the estimated location of groundwater/subsurface drainage from the stormwater and treated site water discharge area. Sampling is carried out at up to four sites, depending on flow conditions at the time of sampling. Details of the sites to be monitored on the tributary of the Manganui River are included in Table 3. The locations are illustrated on Figure 1.

1.4.6 Biomonitoring surveys

Biomonitoring surveys are undertaken to determine whether stormwater discharges from the wellsite have had any detrimental impacts on the macroinvertebrate communities of the unnamed tributary of the Manganui River. Samples are processed to provide number of taxa (richness), MCI and $SQMCI_S$ scores, and EPT taxa 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.

Pre-fracturing surveys were carried out prior to commencement of each fracturing event (6 March 2017, 2 June 2017 and 1 March 2018) and following the completion of each fracturing event (19 April 2017, 25 October 2017 and 23 April 2018).

Table 3 Surface water biomonitoring site details

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	1711359E 5673793N	55 m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	1711322E 5673832N	90 m downstream of Mangahewa-D wellsite discharge point and 10 m upstream of tributary confluence	60
3	MGN000492	1711376E 5673894N	60 m downstream of confluence from Mangahewa-D wellsite	60
4	MGN000493	1711392E 5673936N	100 m downstream of confluence from Mangahewa-D wellsite	60

1.5 External Surface water quality monitoring

In addition to the monitoring undertaken by the Council, further sampling was undertaken by BTW Company Ltd (BTW) on behalf of Todd. Surface water quality sampling was undertaken at three sites located along a small drainage channel less than 10 m from the wellsite and the unnamed tributary of the Manganui River it discharges in to downstream of the stormwater and treated water discharge site. All three sites were chosen in areas were sediments could be seen to be depositing along the reach of the water course. Sampling was undertaken on six occasions between June 2017 and October 2018. Details of the sites are summarised in Table 4 and approximate locations are illustrated on Figure 1.

Table 4 Surface water sediment sampling site details

Monitoring site	Eastings	Northings	Location	Altitude (masl)
Site 1	1711180	5673682	Located 100 m north of the wellsite	60
Site 2	1711335	5673845	Located 300 m downstream of site 1	60
Site 3	1711389	5673921	Located 100 m downstream of site 2	60

2 Results

2.1 Consent holder submitted data

2.1.1 Mangahewa-22 post-fracturing discharge report

The conclusions from the Mangahewa-22 post-fracturing discharge report are summarised as follows:

- One interval was fractured on 30 March 2017 at a mid-point depth of 4,089 m TVD and one interval was fractured on 31 March 2017 at a mid-point depth of 4,070 m TVD.
- A total of 3,369 bbls (536 m^3) of fluid was discharged across the two fractured zones.
- The Mangahewa-22 well zones were flowed-back together following completion and all fluid was returned from the well over the initial flow back period.
- A total of 132,173 lbs and 62,726 lbs were pumped into Interval 1 and Interval 2 respectively.
- Almost all (93%) of the 194,899 lbs of proppant injected remained within the formation. The small percentage that did not remain was returned to the surface during flow back.
- There were no screen outs reported.
- All return fluid from the Mangahewa-22 fracturing operations was transported to the Mangahewa and McKee production stations for disposal by deep well injection under consents 4182-2 (McKee-A wellsite) 5052-2 (McKee-B wellsite) and 1315-1 (Tuhua-B wellsite).
- Pressure testing was undertaken of all surface equipment prior to injection.
- Constant real-time monitoring of the operation was conducted, and all pressures remained within expected ranges.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.1.2 Mangahewa-4 post-fracturing discharge report

The conclusions from the Mangahewa-4 post-fracturing discharge report are summarised as follows:

- A total of five intervals were fractured between 18 June 2017 and 25 June 2017 at mid-point depths of 3,863, 3,714, 3,684, 3,650 and 3,538 m TVD, respectively.
- A total of 12,341 bbls (1,962 m^3) of fluid was discharged across the five fractured zones.
- The Mangahewa-4 well zones were flowed-back together following completion of the activities and all fluid injected was returned from the well over the initial flow back period.
- Almost all (99% or 361,260 lbs) of the 364,333 lbs of proppant injected remained within the formation. The small percentage that did not remain was returned to the surface during flow back.
- There were no screen outs reported.
- All return fluid from the Mangahewa-4 fracturing operations was transported to the Mangahewa and McKee production stations for disposal by deep well injection under consents 4182-2 (McKee-A wellsite) 5052-2 (McKee-B wellsite) and 1315-1 (Tuhua-B wellsite).
- Pressure testing was undertaken of all surface equipment prior to injection.
- Constant real-time monitoring of the operation was conducted, and all pressures remained within expected ranges.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.1.3 Mangahewa-7 post-fracturing discharge report

The conclusions from the Mangahewa-7 post-fracturing discharge report are summarised as follows:

- A total of five intervals were fractured between 26 July 2017 and 31 July 2017 at mid-point depths between 3,493 and 3,834 m TVD.
- A total of 12,038 bbls (1,194 m^3) of fluid was discharged across the five fractured zones.
- The Mangahewa-7 well zones were flowed-back together following completion of the activities and all fluid injected was returned from the well over the initial flow back period.
- Almost all (99% or 332,940 lbs) of the 335,764 lbs of proppant injected remained within the formation. The small percentage that did not remain was returned to the surface during flow back.
- One screen out occurred during the fracturing of MaD2L. The discharge point remained within the perforated interval and the clean-out operation returned the expected quantity of proppant. There was no indication of fluid loss to the annulus and no implications for compliance with conditions 1 and 3 of the consent.
- All return fluid from the Mangahewa-7 fracturing operations was transported to the Mangahewa and McKee production stations for disposal by deep well injection under consents 4182-2 (McKee-A wellsite) 5052-2 (McKee-B wellsite) and 1315-1 (Tuhua-B wellsite).
- Pressure testing was undertaken of all surface equipment prior to injection.
- Constant real-time monitoring of the operation was conducted, and all pressures remained within expected ranges.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.1.4 Mangahewa-16 post-fracturing discharge report

The conclusions from the Mangahewa-16 post-fracturing discharge report are summarised as follows:

- A total of three intervals were fractured between 21 March 2018 and 23 March 2018 at mid-point depths 3,557, 3,531 and 3,402 m TVD, respectively.
- A total of 4,750 bbls (755 m^3) of fluid was discharged across the three fractured zones.
- The Mangahewa-16 well zones were flowed-back together following completion of the activities and all fluid injected was returned from the well over the initial flow back period.
- Almost all (99% or 160,430 lbs) of the 161,483 lbs of proppant injected remained within the formation. The small percentage that did not remain was returned to the surface during flow back.
- One screen out occurred during the fracturing of MaF2. The discharge point remained within the perforated interval and the clean-out operation returned the expected quantity of proppant. There was no indication of fluid loss to the annulus and no implications for compliance with conditions 1 and 3 of the consent.
- All return fluid from the Mangahewa-16 fracturing operations was transported to the Mangahewa and McKee production stations for disposal by deep well injection under consents 4182-2 (McKee-A wellsite) 5052-2 (McKee-B wellsite) and 1315-1 (Tuhua-B wellsite).
- Pressure testing was undertaken of all surface equipment prior to injection.
- Constant real-time monitoring of the operation was conducted, and all pressures remained within expected ranges.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Physiochemical sampling

2.2.1 Groundwater

Hydraulic fracturing activities were undertaken at the Mangahewa-D wellsite during the period 30 March 2017 and 23 March 2018. A pre-fracturing baseline sample was collected on 26 January 2017 and due to the longevity of the programme several samples were collected during and following completion of hydraulic fracturing events.

Methane concentrations >1 gm^3 were reported in the majority of pre and post-fracturing samples. The presence of methane alone is of little concern when not accompanied by additional hydrocarbons and/or increased chloride concentrations. Nonetheless to determine whether the source of the methane is biogenic or thermogenic samples were sent to Geological and Nuclear Sciences (GNS) for carbon 13 isotope analysis. The presence of carbon 13 isotopes at concentrations less than-50‰ indicate the methane is from a thermogenic deep source and concentrations greater than-50‰ a shallow biogenic source. Carbon 13 concentrations in all samples analysed indicated that the source of methane in the groundwater was likely of mixed origin, with samples collected from both bores exhibiting a predominantly thermogenic signature, not uncommon in this part of the region. As no increased chlorides or additional hydrocarbons were found the gas source is likely the result of a natural gas seep.

A summary of the results for groundwater samples taken in relation to the hydraulic fracturing activities compared to baseline is included in Table 5.

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

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 Mangahewa-D hydraulic fracturing events

Parameter	Bore id	GND2459						GND2483		
Reference	Unit	Pre-frac	3 mth post-frac	3 mth post-frac	1 yr post-frac and pre-frac	3 mth post-frac	1 yr post-frac	Pre-frac	3 mth post-frac	1 yr post-frac
Sample date	-	26/01/17	16/06/17	13/09/17	20/03/18	4/07/18	20/02/19	20/03/18	3/07/18	26/02/19
Sample time	-	11:42	11:45	10:35	11:30	10:50	12:45	11:50	13:25	10:25
Lab number (TRC)	-	TRC170590	TRC172184	TRC172939	TRC181960	TRC182806	TRC190876	TRC181961	TRC182804	TRC190877
pH	pH	7.6	7.1	7.4	7.6	7.6	7.5	7.6	6.6	7.1
Total alkalinity	g/m^3 $CaCO^3$	98	93	90	89	136	107	64	48	67
Bicarbonate	g/m^3 HCO_3	118	114	109	108	165	130	78	58	82
Total hardness	g/m^3 $CaCO_3$	38	58	45	52	57	44	57	43	56
Electrical conductivity	mS/m	24.2	24.6	23.3	23.8	31.6	27	20.6	18.5	22.6
Total dissolved solids	g/m^3	194	188	176	183	220	184	161	139	169
Dissolved calcium	g/m^3	9.2	13.2	10.7	13.2	13.7	10.6	13.4	12	14
Chloride	g/m^3	15.9	15.7	16.7	17.2	17.7	17.7	12	13.7	13.7
Dissolved magnesium	g/m^3	3.7	6.1	4.5	4.6	5.4	4.3	5.7	3.1	5
Dissolved potassium	g/m^3	5	5.4	5.3	5.4	5.5	5	5.9	5.3	5.4
Dissolved sodium	g/m^3	34	26	28	19	50	40	25	14	22
Nitrite nitrogen	g/m^3 N	0.003	<0.002	<0.002	< 0.002	0.002	< 0.002	0.008	0.006	0.003
Nitrate nitrogen	g/m^3 N	0.085	0.027	0.044	0.023	< 0.002	< 0.002	0.51	1.7	0.56
Nitrate & nitrite nitrogen	g/m^3 N	0.088	0.028	0.046	0.024	0.003	< 0.002	0.52	1.71	0.56
Sulphate	g/m^3	0.7	5	0.6	3	< 0.5	0.6	12.6	11.7	15.2
Dissolved barium	mg/kg	0.0147	0.0132		0.02	0.054	0.008	0.0125	0.041	0.012
Dissolved bromine	g/m^3	0.136	0.18	0.12	-	-	-	-	-	-
Bromide	g/m^3	-	-	-	0.17	0.15	0.17	0.09	0.09	0.09
Dissolved copper	g/m^3	0.0026	<0.0005	0.001	< 0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved iron	g/m^3	1.78	0.81	1.73	1.66	8.9	4.7	1.03	1.02	0.97
Dissolved manganese	g/m^3	0.43	0.29	0.3	0.056	0.32	0.32	0.29	0.036	0.05

Parameter	Bore id	GND2459						GND2483		
Reference	Unit	Pre-frac	3 mth post-frac	3 mth post-frac	1 yr post-frac and pre-frac	3 mth post-frac	1 yr post-frac	Pre-frac	3 mth post-frac	1 yr post-frac
Sample date	-	26/01/17	16/06/17	13/09/17	20/03/18	4/07/18	20/02/19	20/03/18	3/07/18	26/02/19
Sample time	-	11:42	11:45	10:35	11:30	10:50	12:45	11:50	13:25	10:25
Lab number (TRC)	-	TRC170590	TRC172184	TRC172939	TRC181960	TRC182806	TRC190876	TRC181961	TRC182804	TRC190877
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Nickel	mg/kg	0.0044	<0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005	0.0007	< 0.0005	< 0.0005
Dissolved zinc	g/m^3	0.053	0.0058	0.049	0.0038	0.02	0.0147	0.0112	0.004	0.0053
Ethylene glycol	g/m^3	<4	<4	<4	< 4	< 4	< 4	< 4	< 4	< 4
Propylene glycol	g/m^3	<4	<4	<4	< 4	< 4	< 4	< 4	< 4	< 4
Methanol	g/m^3	<2	<2	<2	< 2	< 2	< 5	< 2	< 2	< 2
Benzene	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	0.0014	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m^3	<0.0010	<0.0010	<0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	< 0.02	0.03	< 0.02	< 0.02	< 0.02	< 0.02
Ethane	g/m^3	<0.003	<0.003	<0.003	< 0.003	0.004	0.004	< 0.003	< 0.003	< 0.003
Ethylene	g/m^3	<0.003	<0.003	<0.003	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Methane	g/m^3	0.45	1.07	2.5	1.37	14.3	9.5	8.3	2.1	3.4
C7-C9	g/m^3	<0.10	< 0.06	<0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
C10-C14	g/m^3	<0.2	<0.2	<0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15-C36	g/m^3	<0.4	<0.4	<0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons	g/m^3	<0.7	<0.7	<0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
δ13C value*	‰ (-)	-	59	50.2	50.8	52.8	46.2	37.2	39.3	38.8

*Note: *δ13C values below 50 ‰ (-) indicate a biogenic source and above 50 ‰ (-) a thermogenic source*

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 Mangahewa-22, Mangahewa-4, Mangahewa-7 and Mangahewa-16 wells are shown below in Table 6. The certificates of analysis are included in Appendix III.

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Mangahewa-22, Mangahewa-4, Mangahewa-7 and Mangahewa-16 wells are summarised below in Table 7 and certificates of analysis are included in Appendix III. Flow back was undertaken across all intervals fractured in each well, therefore samples are representative of the full range of depths targeted in each well. 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 hydraulic fracturing fluids introduced during the fracturing activities, which are comprised predominantly of freshwater.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	**Well id**	**GND2523**	**GND2494**	**GND2810**	**GND2465**
Reference	**Unit**	**MHW22-frac**	**MHW4-frac**	**MHW7-frac**	**MHW16-frac**
Fracturing event date	**-**	**Mar-17**	**Jun-17**	**Jul-17**	**Mar-18**
Ethylene glycol	g/m^3	<4	<4	<4	250
Propylene glycol	g/m^3	<4	<4	<4	<4
Methanol*	g/m^3	3	<2	<2	<20
Benzene	g/m^3	0.0024	<0.0010	<0.0010	0.0024
Toluene	g/m^3	0.0084	<0.0010	<0.0010	0.008
Ethylbenzene	g/m^3	0.0011	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	0.008	<0.002	<0.002	0.003
o-Xylene	g/m^3	0.0022	<0.0010	<0.0010	<0.0010
C7-C9	g/m^3	<0.06	<0.06	<0.06	<0.06
C10-C14	g/m^3	22	4	172	24
C15-C36	g/m^3	31	23	37	20
Total hydrocarbons	g/m^3	54	27	210	43

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	**Well id**	**GND2523***	**GND2494**	**GND2810**	**GND2465**
Reference	**Site code**	**MHW22-frac**	**MHW4-frac**	**MHW7-frac**	**MHW16-frac**
Fracturing event date	**Unit**	**Mar-17**	**Jun-17**	**Jul-17**	**Mar-18**
pH	pH	7.6	7.6	7.7	7.8
Total alkalinity	g/m^3 $CaCO^3$	3,400	4,500	2,200	2,600
Bicarbonate	g/m^3 HCO_3	23	4,870	2,430	2,360
Total hardness	g/m^3 $CaCO_3$	3,950	141	550	340
Electrical conductivity	mS/m	3,510	3,730	4,240	2,810
Total dissolved solids	g/m^3	28,000	25,000	27,000	18,500

Parameter	Well id	GND2523*	GND2494	GND2810	GND2465
Reference	Site code	MHW22-frac	MHW4-frac	MHW7-frac	MHW16-frac
Fracturing event date	Unit	Mar-17	Jun-17	Jul-17	Mar-18
Dissolved calcium	g/m^3	86	43	185	116
Chloride	g/m^3	9,400	10,700	13,400	8,100
Magnesium	g/m^3	8.9	8.0	21.0	12.9
Potassium	g/m^3	5,100	670	3,200	2,800
Sodium	g/m^3	4,600	9,900	7,800	5,000
Nitrite nitrogen	g/m^3 N	<0.2	0.004	0.106	0.0021
Nitrate nitrogen	g/m^3 N	<0.9	<0.002	0.127	0.08
Nitrate & nitrite nitrogen	g/m^3 N	<0.2	0.003	0.56	0.021
Sulphur	g/m3	85	4	63	83
Sulphate	g/m^3	167	11	190	250
Barium	mg/kg	86	176	179	84
Bromine	g/m^3	51	-	-	-
Bromide	g/m^3	-	41	33	32
Copper	g/m^3	0.0159	0.0023	0.0032	0.043
Iron	g/m^3	7.6	1.0	0.7	2.5
Manganese	g/m^3	1.68	1.45	1.28	0.40
Mercury	g/m^3	0.0056	0.00022	<0.00015	< 0.0003
Nickel	mg/kg	0.1	<0.007	<0.007	< 0.009
Zinc	g/m^3	0.155	0.112	0.107	0.096
Ethylene glycol	g/m^3	85	<20	<20	210
Propylene glycol	g/m^3	4	<20	<20	< 4
Methanol	g/m^3	2	<20	<20	< 20
Benzene	g/m^3	60	960	2	18
Toluene	g/m^3	310	8,300	4	118
Ethylbenzene	g/m^3	51	1,890	<1	22
m-Xylene	g/m^3	410	14,500	3	177
o-Xylene	g/m^3	129	4,600	1	48
Formaldehyde	g/m^3	<0.02	<1.5	<1.5	1.5
C7-C9	g/m^3	-	7	20	1,700
C10-C14	g/m^3	-	11	15	4,500
C15-C36	g/m^3	-	12	22	4,600
Total hydrocarbons	g/m^3	-	30	57	10,800

**sample was very oily so not analysed for total hydrocarbons in water*

2.3 Biomonitoring surveys

Macroinvertebrate surveys were undertaken on 6 March 2017, 19 April 2017, 2 June, 25 October 2017, 1 March 2018 and 23 April 2018 using the Council's 'kick-sampling and 'vegetation sweep' techniques to collect samples at up to four sites.

During the 6 March pre hydraulic fracturing and 19 April 2017 post-fracturing surveys sites recorded moderately low to low taxa richnesses, which were similar between the two surveys. MCI scores classified the sites as having 'fair' or 'poor' macroinvertebrate community health, and remained similar between the two surveys at sites 1, 2 and 3. Site 4 showed a significant increase between the two surveys. A significant decrease in $SQMCI_S$ scores was recorded at sites 1 and 2, and a significant increase at site 4 between the two surveys. Significant foaming was noted during processing of the post-fracturing sample taken at site 4, the furthest location from the wellsite, in addition the site exhibited a low taxa richness, with only one small individual of each taxon found, indicating that the site may have been impacted by some sort of discharge. There was no evidence of any recent detrimental impacts on the macroinvertebrate communities at the other three sites closer to the wellsite.

The 2 June and 25 October 2017 surveys recorded moderately low to moderate taxa richnesses. MCI scores classified the sites as having 'fair' or 'poor' macroinvertebrate community health, and results were similar between the two surveys at all four sites. A significant increase in $SQMCI_S$ was recorded at sites 1, 2 and 3 between the two surveys, and sites 1 and 3 recorded their highest scores to date. There was no evidence of any recent detrimental impacts on the macroinvertebrate communities at any site. Site 4 which had previously shown some detrimental effects had recovered.

Only two of the four sites could be sampled during the 1 March 2018 pre-fracturing survey, due to low water levels. All four sites were sampled during the post-fracturing survey on 23 April 2018. Taxa richnesses were low to moderate and improved between the two surveys. MCI scores categorised all sites as having 'poor' macroinvertebrate community health on both occasions, and were similar at all sites and between surveys. $SQMCI_s$ scores were generally similar between surveys, although there were some differences between sites within each survey. MCI and $SQMCI_s$ scores were for the most part similar to historic medians for each respective site. Overall, there was no evidence that discharges from the Mangahewa-D wellsite had caused any recent detrimental impacts on the macroinvertebrate communities on the tributaries of the Manganui River.

The biomonitoring full reports are appended to this report as Appendix IV.

2.4 Additional surface water and sediment sampling

Following the results of the post-fracturing biomonitoring survey undertaken in 19 April 2017 which indicated a recent detrimental impact on the macroinvertebrate communities at survey Site 4, the Council contacted Todd and two Council Officers returned to the site to investigate the anomalous results on 2 June 2018. A biomonitoring survey was carried out during the investigation and sediment and water quality samples were taken. The results of the biomonitoring survey discussed above indicated there were no longer any detectable detrimental effects and that the macroinvertebrate communities had recovered. The sediment sampling undertaken detected low levels of hydrocarbons. No hydrocarbons were detected in the water sample. Results from the sampling undertaken during the inspection are displayed in Table 8.

Following discussions with Todd regarding the hydrocarbons detected in the sediment sample, Todd contracted BTW to undertake further sediment sampling to investigate the anomalous results (Table 9). The sampling programme undertaken included sediment sampling at three sites. One site (Site 1) close to and downstream of the stormwater discharge and two sites (Site 2 and Site 3) on the unnamed tributary (Figure 1). The monitoring sites were chosen by BTW in locations where safe access was available for sampling and sediments could be seen to be depositing over time. Six rounds of sediment sampling were undertaken

between June 2017 and October 2018. The final round of sampling undertaken on 12 October 2018 indicated there were no hydrocarbons above detectable limits remaining in the sediments.

Todd also undertook an onsite investigation which included sampling the sediments accumulated in the base of the skimmer pits, where site stormwater is held prior to discharge to the tributary and remediation of the flare-pits. A shallow monitoring bore (GND2752) was also installed down-gradient of the skimmer and flare pits to enable sampling of local groundwater resources. No hydrocarbons were found in either the sediment sample or groundwater samples taken (Table 10).

In summary, there was no evidence found linking the wellsite to the anomalous results and sediment sampling continued until results had returned to acceptable levels. No further sampling or investigation was deemed necessary.

Table 8 Additional sampling undertaken by the Council

Site id.	**-**	**MGN000493**	**MGN000493**
Sample	**-**	**TRC171912**	**TRC171913**
Collected	**-**	**02/06/2017**	**02/06/2017**
Time	**-**	**13:15**	**13:15**
Type	Unit	Sediment	Water
Hydrocarbons in soil	mg/kg (calculated)	7	-
Total hydrocarbons	g/m^3	6.6	<0.5

Table 9 Sediment sampling undertaken by BTW on behalf of Todd

Site id.	**Date**	**28/06/17**	**14/07/17**	**1/08/17**	**13/10/17**	**26/01/18**	**12/10/2018**
	Parameters (mg/kg)						
Site 1 located 100 m north of wellsite	Total hydrocarbons	10	-	-	118	920	<170
	C7-C9	<0.06	-	-	<10	<20	<30
	C10-C14	<1.0	-	-	<20	<40	<50
	C15-C36	10	-	-	118	920	<100
Site 2 located 300 m downstream of site 1	Total hydrocarbons	-	172	<130	<90	230	<140
	C7-C9	-	<20	<18	<12	<8	<20
	C10-C14	-	<40	<40	<30	<20	<40
	C15-C36	-	172	<80	<40	<230	<80
Site 3 located 100 m downstream of site 2	Total hydrocarbons	-	<70	-	<70	<70	<70
	C7-C9	-	<9	-	<9	<8	<8
	C10-C14	-	<20	-	<20	<20	<20
	C15-C36	-	<40	-	<70	<40	<40

Table 10 Shallow groundwater sampling undertaken by BTW on behalf of Todd

Parameter	GND2752		Parameter	GND2752	
Sample date	**-**	**25/09/17**	**Sample date**	**-**	**25/09/17**
Sample time	**-**	**11:30**	**Sample time**	**-**	**11:30**
Lab number (Hill)	**Unit**	**1849427**	**Lab number (Hill)**	**Unit**	**1849427**
pH	pH	6.8	Ethylbenzene	g/m^3	<0.0010
Total dissolved solids	g/m^3	187	m-Xylene	g/m^3	<0.002
Chloride	g/m^3	19.3	o-Xylene	g/m^3	<0.0010
Dissolved potassium	g/m^3	6.8	C7-C9	g/m^3	<0.06
Dissolved sodium	g/m^3	24	C10-C14	g/m^3	<0.2
Benzene	g/m^3	<0.0010	C15-C36	g/m^3	<0.4
Toluene	g/m^3	<0.0010	Total hydrocarbons	g/m^3	<0.7

2.5 Investigations, interventions, and incidents

The monitoring programme for the year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the Company. 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 consent holder concerned has itself notified the Council. The register contains details of any investigation and corrective action taken.

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

During the period under review, an investigation was initiated following the results of the biomonitoring survey undertaken in April 2017. Further monitoring indicated the presence of hydrocarbons in the stream sediments downstream of the wellsite. The investigation undertaken could not determine the original source of the hydrocarbons. Monitoring indicates that hydrocarbon concentrations in the sediments have returned to acceptable levels. No further action was deemed necessary.

3 Discussion

3.1 Environmental effects of exercise of consents

Four wells (Mangahewa-22, Mangahewa-4, Mangahewa-7 and Mangahewa-16) were stimulated by hydraulic fracturing at the Mangahewa-D wellsite during the period 30 March 2017 to 23 March 2018.

The monitoring programme carried out by the Council in relation to the fracturing events undertaken, included both groundwater and surface water monitoring components.

The groundwater monitoring component incorporated pre and post-fracturing sampling at two groundwater monitoring sites, one located on the wellsite and the other located 200 m north west of the wellsite. The results of post-fracturing groundwater sampling carried out showed only very minor variations in water composition in comparison to baseline results. Methane was reported in the majority of groundwater samples collected. Further analysis indicated the source of the methane was of mixed thermogenic/biogenic origin. 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 six biomonitoring surveys of an unnamed tributary of the Manganui River pre and post-fracturing of the Mangahewa wells. The results of the biomonitoring surveys undertaken in relation to the fracturing event indicated that the site activities had no adverse effects on local surface water resources. Some impact was seen during the April 2017 survey and additional investigations were undertaken to ensure wellsite were not the cause of the issues discovered. The investigation concluded the impacts seen in April 2017 were unlikely to have been directly related to hydraulic fracturing activities at the site. The source of the temporary impact could not be determined.

In summary, the monitoring carried out by the Council during the period being reported indicates that the hydraulic fracturing activities undertaken by Todd at the Mangahewa-D 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 year under review is set out in Table 11. A summary of Todd's compliance record for the Consent to date is set out in Table 12.

Table 11 Summary of performance for consent 7912-2.1

Purpose ***To discharge water based hydraulic fracturing fluids into land at depths greater than 3,325 mTVDss beneath the Mangahewa-D wellsite***		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,325 mTVDss	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2019	Assessment of consent holder submitted data	N/A
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater	Results of groundwater monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. Monitoring programme to include a minimum of one suitable bore	Consultation and installation of monitoring bore	Yes

Purpose *To discharge water based hydraulic fracturing fluids into land at depths greater than 3,325 mTVDss beneath the Mangahewa-D wellsite*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified Sampling and Analysis Plan	Development and certification of a Sampling and Analysis Plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 90 days of any commencement	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	NR (Todd undertake sampling)
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. Fracture fluid composition no less than 95 % water and proppant by volume	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Lapse clause	Receive notice of exercise of consent	Yes
17. 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**

N/A = not applicable; NR = not required

Table 12 Summary of performance for consent 7912-2.1

Year	Consent number	High	Good	Improvement required	Poor
2016-2019	7912-2.1	1			
2014-2016	7912-2.1	1			
2011-2014	7912-2	1			
Totals		3			

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

3.3 Recommendations from the previous compliance report

In the previous compliance report, it was recommended:

1. THAT the range of monitoring carried out during the reporting period in relation to Todd's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-D wellsite.
2. THAT the Council notes there is no requirement at this time for a consent review to be pursued or grounds to exercise the review options.

These recommendations were implemented.

3.4 Alterations to monitoring programmes 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 already made available through monitoring or other means to date;
- its relevance under the RMA;
- the Council's obligations to monitor consented activities and their effects under the RMA;
- the record of administrative and environmental performances of the consent holder; and
- reporting to the regional community.

The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki exercising resource consents.

Prior to any further activities a new consent will be required as no further discharge of hydraulic fracturing fluids can be undertaken after 1 June 2019 under the current consent. It is proposed that the range of monitoring carried out in relation to the hydraulic fracturing activities undertaken by Todd be replicated for any future fracturing events at the Mangahewa-D wellsite.

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.

3.5 Exercise of optional review of consent

Resource consent 7912-2.1 provides for an optional review of the consent in June 2019. Condition 17 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 14; and/or

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

Based on the results of monitoring in the year under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

4 Recommendations

1. THAT in the first instance, the range of monitoring carried out during the reporting period in relation to Todd's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-D 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 2019, as set out in condition 17 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).
EPT	Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) which are macroinvertebrates sensitive to pollution.
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
L/s	Litres per second.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
masl	Metres above sea level.
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).
NZTM	New Zealand Transverse Mercator coordinates.
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.

*an abbreviation for a metal or other analyte may be followed by the letters 'As', to denote the amount of metal recoverable in acidic conditions. This is taken as indicating the total amount of metal that might be solubilised under extreme environmental conditions. The abbreviation may alternatively be followed by the letter 'D', denoting the amount of the metal present in dissolved form rather than in particulate or solid form.

For further information on analytical methods, contact a Science Services Manager.

Bibliography and references

Frackwire.com at *http://frackwire.com/nitrogen-gas-fracking*

Geology.Com at http://geology.com/energy/hydraulic-fracturing-fluids/

http://blogs.bakerhughes.com/reservoir/2012/02/20/hydraulic-fracturing-an-environmentally-responsible-technology-for-ensuring-our-energy-future-part-iii-of-iii/

Todd Energy Ltd (2018) Mangahewa-16 Post-Fracturing Discharge Report May 2018 Frodo Number #2057750

Todd Energy Ltd (2018) Mangahewa-D Wellsite Water Quality Monitoring Programme February 2018 Frodo Number #2011602

Todd Energy Ltd (2017) Mangahewa-7 Post-Fracturing Discharge Report October 2017 Frodo Number #1947511

Todd Energy Ltd (2017) Mangahewa-4 Post-Fracturing Discharge Report September 2017 Frodo Number #1935370

Todd Energy Ltd (2017) Mangahewa-16 Pre-Fracturing Discharge Report July 2017 Frodo Number #1899988

Todd Energy Ltd (2017) Mangahewa-22 Post-Fracturing Discharge Report June 2017 Frodo Number #1888434

Todd Energy Ltd (2017) Mangahewa-4 Pre-Fracturing Discharge Report May 2017 Frodo Number #1857098

Todd Energy Ltd (2017) Mangahewa-7 Pre-Fracturing Discharge Report May 2017 Frodo Number #1870243

Todd Energy Ltd (2017) Mangahewa-22 Pre-Fracturing Discharge Report February 2017 Frodo Number #1839186

Todd Energy Ltd (2016) Mangahewa-D Hydraulic fracturing Monitoring Programme Report 2014-2016 Technical Report 2016-106 Frodo Number #1715561

Todd Energy Ltd (2015) Mangahewa-D Hydraulic fracturing Monitoring Programme Report 2011-2014 Technical Report 2014-107 Frodo Number #1465837

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

Appendix I

Resource consent held by Todd Energy Ltd

(For a copy of the signed resource consent please contact the TRC Consents 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:	Todd Energy Limited PO Box 802 New Plymouth 4340
Decision Date (Change):	10 November 2015
Commencement Date (Change):	10 November 2015 (Granted Date: 30 June 2014)

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3325 mTVDss beneath the Mangahewa-D wellsite
Expiry Date:	1 June 2024
Review Date(s):	June Annually
Site Location:	Mangahewa-D wellsite, Rimutauteka Road, New Plymouth (Property owner: KV & SJ Collins)
Legal Description:	Rimutauteka 1A Blk X Waitara SD (Discharge source & site)
Grid Reference (NZTM)	1711150E-5673520N
Catchment:	Waitara
Tributary:	Manganui

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 3325 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 2019.

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

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

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

5. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, 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.

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

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

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

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

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

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

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

   (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the monitoring techniques to be used to determine the fate of discharged material;
   (e) the results of the reviews required by condition 14;
   (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 3;
   (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (i) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (j) the burst pressure of the well 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 14.

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

10. The consent holder shall notify the Taranaki Regional Council of 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 9, 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.

11. Within 90 days of any commencement date as advised under condition 10, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (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 50 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 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (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 3; and
    (l) results of the monitoring referred to in condition 9 (d);
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

    Note: For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the specified 90 day deadline.

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

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

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

    (a) the discharge is contained within the fracture interval;
    (b) regular reviews 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.

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

16. This consent shall lapse on 30 June 2019, 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.

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

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

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

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

Signed at Stratford on 10 November 2015

For and on behalf of
Taranaki Regional Council

_____

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

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2128363 SPv1
Contact:	Jane Harvey	**Date Received:**	21-Feb-2019
	C/- Taranaki Regional Council	**Date Reported:**	28-Feb-2019
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	72831
		Client Reference:	#4895 - MHW D 1 Year Post Frac GW
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

Sample Name:		TRC190876 (GND2549) 20-Feb-2019 12:45 pm				
Lab Number:		2128363.1				
Individual Tests						
Sum of Anions	meq/L	2.7	-	-	-	-
Sum of Cations	meq/L	2.9	-	-	-	-
pH	pH Units	7.5	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	107	-	-	-	-
Bicarbonate	g/m³ at 25°C	130	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	44	-	-	-	-
Electrical Conductivity (EC)	mS/m	27.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	184	-	-	-	-
Sample Temperature*	°C	17.6	-	-	-	-
Dissolved Barium	g/m³	0.008	-	-	-	-
Dissolved Calcium	g/m³	10.6	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	4.7	-	-	-	-
Dissolved Magnesium	g/m³	4.3	-	-	-	-
Dissolved Manganese	g/m³	0.32	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.0	-	-	-	-
Dissolved Sodium	g/m³	40	-	-	-	-
Dissolved Zinc	g/m³	0.0147	-	-	-	-
Bromide	g/m³	0.17	-	-	-	-
Chloride	g/m³	17.7	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	0.6	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 5	-	-	-	-

Sample Type: Aqueous						
Sample Name:		TRC190876 (GND2549) 20-Feb-2019 12:45 pm				
Lab Number:		2128363.1				
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	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	0.004	-	-	-	-
Ethylene	g/m³	< 0.004	-	-	-	-
Methane	g/m³	9.5	-	-	-	-
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	-	-	-	-

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.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

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	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	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 23rd ed. 2017.	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 23rd ed. 2017.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. 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. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	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 23rd ed. 2017.	1.0 g/m³ at 25°C	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	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) 23rd ed. 2017.	10 g/m³	1
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	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 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	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 (modified) 23rd ed. 2017.	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
C7 - C9	Head Space, GCMS analysis.	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)
Client Services Manager - Environmental

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

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	1947884 SPv2
Contact:	Jane Harvey C/- Taranaki Regional Council Private Bag 713 Stratford 4352	**Date Received:**	21-Mar-2018
		Date Reported:	24-Apr-2018
		Quote No:	47915
		Order No:	70388
		Client Reference:	Todd MHWD16 Pre Frac GW March 18
		Submitted By:	Jane Harvey

Sample Type: Aqueous

Sample Name:		GND2459 20-Mar-2018 11:30 am	GND2483 20-Mar-2018 12:00 pm			
Lab Number:		1947884.1	1947884.2			
Individual Tests						
Sum of Anions	meq/L	2.3	1.91	-	-	-
Sum of Cations	meq/L	2.1	2.4	-	-	-
pH	pH Units	7.6	7.6	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	89	64	-	-	-
Bicarbonate	g/m³ at 25°C	108	78	-	-	-
Total Hardness	g/m³ as $CaCO_3$	52	57	-	-	-
Electrical Conductivity (EC)	mS/m	23.8	20.6	-	-	-
Total Dissolved Solids (TDS)	g/m³	183	161	-	-	-
Dissolved Barium	g/m³	0.020	0.0125	-	-	-
Dissolved Calcium	g/m³	13.2	13.4	-	-	-
Dissolved Copper	g/m³	< 0.0005	< 0.0005	-	-	-
Dissolved Iron	g/m³	1.66	1.03	-	-	-
Dissolved Magnesium	g/m³	4.6	5.7	-	-	-
Dissolved Manganese	g/m³	0.056	0.29	-	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m³	< 0.0005	0.0007	-	-	-
Dissolved Potassium	g/m³	5.4	5.9	-	-	-
Dissolved Sodium	g/m³	19.0	25	-	-	-
Dissolved Zinc	g/m³	0.0038	0.0112	-	-	-
Bromide	g/m³	0.17	0.09	-	-	-
Chloride	g/m³	17.2	12.0	-	-	-
Nitrite-N	g/m³	< 0.002	0.008	-	-	-
Nitrate-N	g/m³	0.023	0.51	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.024	0.52	-	-	-
Sulphate	g/m³	3.0	12.6	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	-	-	-
Toluene	g/m³	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	-	-	-
o-Xylene	g/m³	< 0.0010	< 0.0010	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2459 20-Mar-2018 11:30 am	GND2483 20-Mar-2018 12:00 pm			
Lab Number:		1947884.1	1947884.2			
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	-	-	-
Ethylene	g/m³	< 0.004	< 0.004	-	-	-
Methane	g/m³	1.37	8.3	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.06	< 0.06	-	-	-
C10 - C14	g/m³	< 0.2	< 0.2	-	-	-
C15 - C36	g/m³	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	-	-	-

Analyst's Comments

Due to instrumental breakdown, the analysis for Formaldehyde could not be carried out within the recommended holding time and therefore may be underestimated. This should be kept in mind when interpreting this result.

Summary of Methods

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-2
Total Petroleum Hydrocarbons in Water	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	0.06 - 0.7 g/m³	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1-2
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1-2
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. 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. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-2
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1-2

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	1-2
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	1-2
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.5 g/m³	1-2
C7 - C9	Head Space, GCMS analysis.	0.06 g/m³	1-2

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

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

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

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
1 Clyde Street Hamilton 3216
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:**	1714495 SPv1
Contact:	David Olson	**Date Received:**	27-Jan-2017
	C/- Taranaki Regional Council	**Date Reported:**	09-Feb-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	
		Client Reference:	MHWD 1 year Post-Frac GW
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2459 26-Jan-2017 12:30 pm				
Lab Number:		1714495.1				
Individual Tests						
Sum of Anions	meq/L	2.4	-	-	-	-
Sum of Cations	meq/L	2.5	-	-	-	-
pH	pH Units	7.6	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	98	-	-	-	-
Bicarbonate	g/m³ at 25°C	118	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	38	-	-	-	-
Electrical Conductivity (EC)	mS/m	24.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	194	-	-	-	-
Dissolved Barium	g/m³	0.0147	-	-	-	-
Dissolved Bromine*	g/m³	0.136	-	-	-	-
Dissolved Calcium	g/m³	9.2	-	-	-	-
Dissolved Copper	g/m³	0.0026	-	-	-	-
Dissolved Iron	g/m³	1.78	-	-	-	-
Dissolved Magnesium	g/m³	3.7	-	-	-	-
Dissolved Manganese	g/m³	0.43	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0044	-	-	-	-
Dissolved Potassium	g/m³	5.0	-	-	-	-
Dissolved Sodium	g/m³	34	-	-	-	-
Dissolved Zinc	g/m³	0.053	-	-	-	-
Chloride	g/m³	15.9	-	-	-	-
Nitrite-N	g/m³	0.003	-	-	-	-
Nitrate-N	g/m³	0.085	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.088	-	-	-	-
Sulphate	g/m³	0.7	-	-	-	-
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:		GND2459 26-Jan-2017 12:30 pm				
Lab Number:		1714495.1				
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	0.45	-	-	-	-
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
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1

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

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:**	1842931 SPv1
Contact:	David Olson	**Date Received:**	14-Sep-2017
	C/- Taranaki Regional Council	**Date Reported:**	20-Sep-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	66793
		Client Reference:	Todd MHWD 3 Month Post Frac GW
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2459 13-Sep-2017 10:35 am				
Lab Number:		1842931.1				
Individual Tests						
Sum of Anions	meq/L	2.3	-	-	-	-
Sum of Cations	meq/L	2.3	-	-	-	-
pH	pH Units	7.4	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	90	-	-	-	-
Bicarbonate	g/m³ at 25°C	109	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	45	-	-	-	-
Electrical Conductivity (EC)	mS/m	23.3	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	176	-	-	-	-
Dissolved Barium	g/m³	0.0108	-	-	-	-
Dissolved Calcium	g/m³	10.7	-	-	-	-
Dissolved Copper	g/m³	0.0010	-	-	-	-
Dissolved Iron	g/m³	1.73	-	-	-	-
Dissolved Magnesium	g/m³	4.5	-	-	-	-
Dissolved Manganese	g/m³	0.30	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.3	-	-	-	-
Dissolved Sodium	g/m³	28	-	-	-	-
Dissolved Zinc	g/m³	0.049	-	-	-	-
Bromide	g/m³	0.12	-	-	-	-
Chloride	g/m³	16.7	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	0.044	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.046	-	-	-	-
Sulphate	g/m³	0.6	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2459 13-Sep-2017 10:35 am				
Lab Number:		1842931.1				
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	2.5	-	-	-	-
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. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. 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. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. Analysed at 1 Clyde Street, Hamilton. 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)
Client Services Manager - Environmental

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

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2131856 SPv1
Contact:	Jane Harvey	**Date Received:**	27-Feb-2019
	C/- Taranaki Regional Council	**Date Reported:**	07-Mar-2019
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	72831
		Client Reference:	#4895 - MHW D 1 year post frac GW
		Submitted By:	Sarah Larkin

Sample Type: Aqueous

		Sample Name:	TRC190877 (GND2483) 26-Feb-2019 10:25 am				
		Lab Number:	2131856.1				
Individual Tests							
Sum of Anions	meq/L		2.1	-	-	-	-
Sum of Cations	meq/L		2.2	-	-	-	-
pH	pH Units		7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$		67	-	-	-	-
Bicarbonate	g/m³ at 25°C		82	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$		56	-	-	-	-
Electrical Conductivity (EC)	mS/m		22.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m³		169	-	-	-	-
Sample Temperature*	°C		15.9	-	-	-	-
Dissolved Barium	g/m³		0.012	-	-	-	-
Dissolved Calcium	g/m³		14.0	-	-	-	-
Dissolved Copper	g/m³		< 0.0005	-	-	-	-
Dissolved Iron	g/m³		0.97	-	-	-	-
Dissolved Magnesium	g/m³		5.0	-	-	-	-
Dissolved Manganese	g/m³		0.050	-	-	-	-
Dissolved Mercury	g/m³		< 0.00008	-	-	-	-
Dissolved Nickel	g/m³		< 0.0005	-	-	-	-
Dissolved Potassium	g/m³		5.4	-	-	-	-
Dissolved Sodium	g/m³		22	-	-	-	-
Dissolved Zinc	g/m³		0.0053	-	-	-	-
Bromide	g/m³		0.09	-	-	-	-
Chloride	g/m³		13.7	-	-	-	-
Nitrite-N	g/m³		0.003	-	-	-	-
Nitrate-N	g/m³		0.56	-	-	-	-
Nitrate-N + Nitrite-N	g/m³		0.56	-	-	-	-
Sulphate	g/m³		15.2	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
Sample Name:		TRC190877 (GND2483) 26-Feb-2019 10:25 am				
Lab Number:		2131856.1				
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	-	-	-	-
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	3.4	-	-	-	-
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	-	-	-	-

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.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

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	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	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 23rd ed. 2017.	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 23rd ed. 2017.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. 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. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	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 23rd ed. 2017.	1.0 g/m³ at 25°C	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	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) 23rd ed. 2017.	10 g/m³	1
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	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 23rd ed. 2017.	0.0005 g/m³	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.05 g/m³	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.02 g/m³	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	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 (modified) 23rd ed. 2017.	0.002 g/m³	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1
C7 - C9	Head Space, GCMS analysis.	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)
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
1 Clyde Street Hamilton 3216
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:**	1794030 SPv1
Contact:	David Olson	**Date Received:**	17-Jun-2017
	C/- Taranaki Regional Council	**Date Reported:**	27-Jun-2017
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	64993
		Client Reference:	MHW D 4+7 Pre Frac GW June 2017
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2459 16-Jun-2017 11:45 am				
Lab Number:		1794030.1				
Individual Tests						
Sum of Anions	meq/L	2.4	-	-	-	-
Sum of Cations	meq/L	2.5	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	93	-	-	-	-
Bicarbonate	g/m³ at 25°C	114	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	58	-	-	-	-
Electrical Conductivity (EC)	mS/m	24.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	188	-	-	-	-
Dissolved Barium	g/m³	0.0132	-	-	-	-
Dissolved Calcium	g/m³	13.2	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	0.81	-	-	-	-
Dissolved Magnesium	g/m³	6.1	-	-	-	-
Dissolved Manganese	g/m³	0.29	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.4	-	-	-	-
Dissolved Sodium	g/m³	26	-	-	-	-
Dissolved Zinc	g/m³	0.0058	-	-	-	-
Bromide	g/m³	0.18	-	-	-	-
Chloride	g/m³	15.7	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	0.027	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.028	-	-	-	-
Sulphate	g/m³	5.0	-	-	-	-
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:		GND2459 16-Jun-2017 11:45 am				
Lab Number:		1794030.1				
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	1.07	-	-	-	-
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	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	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	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
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 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.	0.06 g/m³	1
C10 - C14	Solvent extraction, GC-FID analysis. US EPA 8015B/NZ OIEWG.	0.2 g/m³	1
C15 - C36	Solvent extraction, GC-FID analysis. US EPA 8015B/NZ OIEWG.	0.4 g/m³	1
Total hydrocarbons (C7 - C36)	Solvent extraction, GC-FID analysis and Headspace, GC-MS FS analysis for C7-C9 carbon band.	0.7 g/m³	1

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

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

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

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

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2009941	SPv1
Contact:	Jane Harvey	**Date Received:**	04-Jul-2018	
	C/- Taranaki Regional Council	**Date Reported:**	11-Jul-2018	
	Private Bag 713	**Quote No:**	47915	
	Stratford 4352	**Order No:**	72792	
		Client Reference:	PKW 3 Month GW	
		Submitted By:	Sarah Larkin	

Sample Type: Aqueous

Sample Name:		GND 2483 182804 03-Jul-2018 1:25 pm				
Lab Number:		2009941.1				
Individual Tests						
Sum of Anions	meq/L	1.70	-	-	-	-
Sum of Cations	meq/L	1.63	-	-	-	-
pH	pH Units	6.6	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	48	-	-	-	-
Bicarbonate	g/m³ at 25°C	58	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	43	-	-	-	-
Electrical Conductivity (EC)	mS/m	18.5	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	139	-	-	-	-
Sample Temperature*	°C	15.2	-	-	-	-
Dissolved Barium	g/m³	0.041	-	-	-	-
Dissolved Calcium	g/m³	12.0	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	1.02	-	-	-	-
Dissolved Magnesium	g/m³	3.1	-	-	-	-
Dissolved Manganese	g/m³	0.036	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.3	-	-	-	-
Dissolved Sodium	g/m³	14.0	-	-	-	-
Dissolved Zinc	g/m³	0.0040	-	-	-	-
Bromide	g/m³	0.09	-	-	-	-
Chloride	g/m³	13.7	-	-	-	-
Nitrite-N	g/m³	0.006	-	-	-	-
Nitrate-N	g/m³	1.70	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	1.71	-	-	-	-
Sulphate	g/m³	11.7	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND 2483 182804 03-Jul-2018 1:25 pm				
Lab Number:		2009941.1				
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	-	-	-	-
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	2.1	-	-	-	-
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	-	-	-	-

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	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	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. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
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 Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1
Dissolved Barium	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
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 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 (modified) 22nd ed. 2012.	0.5 g/m³	1
C7 - C9	Head Space, GCMS analysis.	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)
Client Services Manager - Environmental

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

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2010684	SPv1
Contact:	Jane Harvey	**Date Received:**	05-Jul-2018	
	C/- Taranaki Regional Council	**Date Reported:**	13-Jul-2018	
	Private Bag 713	**Quote No:**	47915	
	Stratford 4352	**Order No:**	72831	
		Client Reference:	MHWD 3 Month GW	
		Submitted By:	Sarah Larkin	

Sample Type: Aqueous

Sample Name:		182806 GND 2459 [Client Temp: 14.3] 04-Jul-2018 10:50 am				
Lab Number:		2010684.1				
Individual Tests						
Sum of Anions	meq/L	3.2	-	-	-	-
Sum of Cations	meq/L	3.8	-	-	-	-
pH	pH Units	7.6	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	136	-	-	-	-
Bicarbonate	g/m³ at 25°C	165	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	57	-	-	-	-
Electrical Conductivity (EC)	mS/m	31.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	220	-	-	-	-
Sample Temperature*	°C	14.3	-	-	-	-
Dissolved Barium	g/m³	0.054	-	-	-	-
Dissolved Calcium	g/m³	13.7	-	-	-	-
Dissolved Copper	g/m³	0.0005	-	-	-	-
Dissolved Iron	g/m³	8.9	-	-	-	-
Dissolved Magnesium	g/m³	5.4	-	-	-	-
Dissolved Manganese	g/m³	0.32	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.5	-	-	-	-
Dissolved Sodium	g/m³	50	-	-	-	-
Dissolved Zinc	g/m³	0.020	-	-	-	-
Bromide	g/m³	0.15	-	-	-	-
Chloride	g/m³	17.7	-	-	-	-
Nitrite-N	g/m³	0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.003	-	-	-	-
Sulphate	g/m³	< 0.5	-	-	-	-
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	-	-	-	-

Sample Type: Aqueous						
Sample Name:		182806 GND 2459 [Client Temp: 14.3] 04-Jul-2018 10:50 am				
Lab Number:		2010684.1				
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	0.0014	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	0.03	-	-	-	-
Gases in groundwater						
Ethane	g/m³	0.004	-	-	-	-
Ethylene	g/m³	< 0.004	-	-	-	-
Methane	g/m³	14.3	-	-	-	-
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	-	-	-	-

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	Solvent Hexane extraction, GC-FID analysis, Headspace GC-MS FS analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734;26687,3629]	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. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
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 Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1
Dissolved Barium	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
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 22nd ed. 2012.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 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 (modified) 22nd ed. 2012.	0.5 g/m³	1
C7 - C9	Head Space, GCMS analysis.	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)
Client Services Manager - Environmental

Appendix III

Certificates of analysis (hydraulic fracturing fluids)

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
1 Clyde Street Hamilton 3216
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

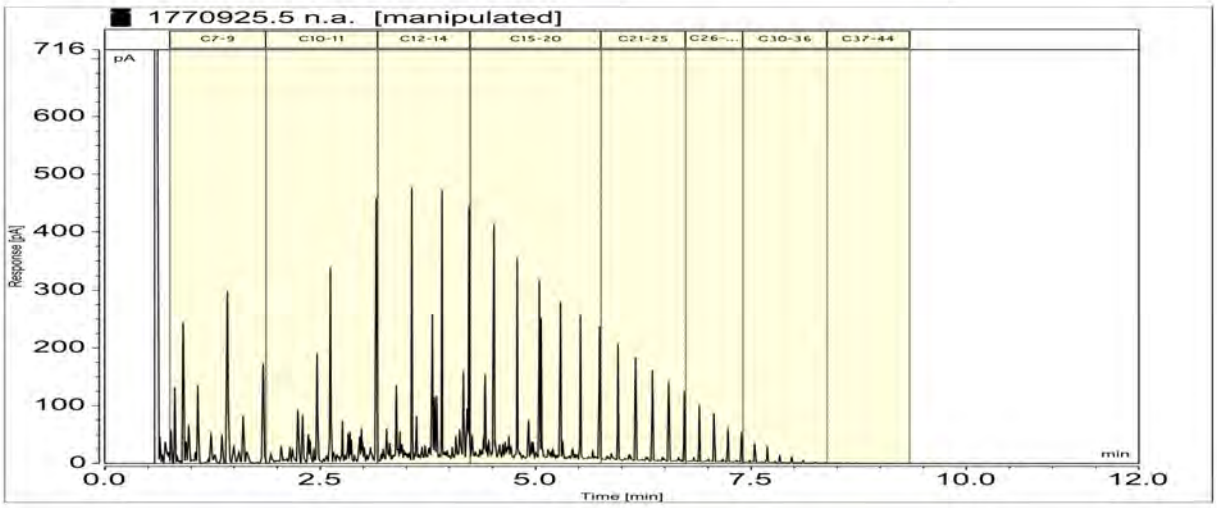
Client:	Taranaki Regional Council	**Lab No:**	1770925 SPv1
Contact:	David Olson	**Date Received:**	06-May-2017
	C/- Taranaki Regional Council	**Date Reported:**	22-May-2017
	Private Bag 713	**Quote No:**	71307
	Stratford 4352	**Order No:**	
		Client Reference:	TODD MHW 22 Return Fluid Composite
		Submitted By:	David Olson

Sample Type: Saline

Sample Name:		GND 2523 RF Composite of GND 2523 RFD A, GND 2523 RFD B, GND 2523 RFD C + GND 2523 RFD D				
Lab Number:		1770925.5				
Individual Tests						
pH*	pH Units	7.6	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$	3,400	-	-	-	-
Analysis Temperature for Bicarbonate	°C	23	-	-	-	-
Bicarbonate	g/m³ at Analysis Temperature	3,950	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$	128	-	-	-	-
Electrical Conductivity (EC)*	mS/m	3,510	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	28,000	-	-	-	-
Total Barium*	g/m³	86	-	-	-	-
Total Bromine*	g/m³	51	-	-	-	-
Total Calcium*	g/m³	36	-	-	-	-
Total Copper*	g/m³	0.0159 #1	-	-	-	-
Total Iron*	g/m³	7.6 #1	-	-	-	-
Total Magnesium*	g/m³	8.9	-	-	-	-
Total Manganese*	g/m³	1.68	-	-	-	-
Total Mercury*	g/m³	0.0056	-	-	-	-
Total Nickel*	g/m³	0.10 #2	-	-	-	-
Total Potassium*	g/m³	5,100	-	-	-	-
Total Sodium*	g/m³	4,600	-	-	-	-
Total Sulphur*	g/m³	56	-	-	-	-
Total Zinc*	g/m³	0.155 #1	-	-	-	-
Chloride*	g/m³	9,400	-	-	-	-
Nitrite-N	g/m³	< 0.2 #3	-	-	-	-
Nitrate-N	g/m³	< 0.2	-	-	-	-
Nitrate*	g/m³	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.2 #3	-	-	-	-
Sulphate*	g/m³	167	-	-	-	-
Free Product GC Scan by FID						
Free Product*	mL/100mL	4.1	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	85	-	-	-	-

Sample Type: Saline						
Sample Name:	GND 2523 RF Composite of GND 2523 RFD A, GND 2523 RFD B, GND 2523 RFD C + GND 2523 RFD D					
Lab Number:	1770925.5					
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	60	-	-	-	-	
Toluene* g/m³	310	-	-	-	-	
Ethylbenzene* g/m³	51	-	-	-	-	
m&p-Xylene* g/m³	410	-	-	-	-	
o-Xylene* g/m³	129	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde* g/m³	< 0.02	-	-	-	-	

1770925.5
GND 2523 RF Composite of GND 2523 RFD A, GND 2523 RFD B, GND 2523 RFD C + GND 2523 RFD D
Client Chromatogram for GC Scan



Analyst's Comments

#1 It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample. The average of the results of the replicate analyses has been reported.

#2 It should be noted that the replicate analyses performed on this sample as part of our in-house Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample. The average of the results of the replicate analyses has been reported. Replicate 1: 0.10 mg/L, replicate 2: 0.09 mg/L.

#3 Due to the nature of this sample a dilution was performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

SUMMARY OF METHODS

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

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Client Chromatogram for GC Scan*	.	-	5
Free Product GC Scan by FID*	Dilution of free product in organic solvent	1.0 mL/100mL	5
Volume of Free Product present in TPH Water samples*	Volumes estimated using Measuring Cylinder.	1.0 mL/100mL	5

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	5
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	5
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	5
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	5
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	5
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	5
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	5
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m³ as $CaCO_3$	5
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	5
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m³ at Analysis Temperature	5
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	5
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	5
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	5
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m³	5
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m³	5
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	5
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	5
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	5
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	5
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m³	5
Total Mercury*	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	5
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.007 g/m³	5
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m³	5
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m³	5
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	5
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m³	5
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	5
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m³	5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	5
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	5
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	5
Total Sulphate*	Calculation: from total sulphur.	2 g/m³	5

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.

This report must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix IV

Biomonitoring Reports

To	Job Manager, Jane Harvey
From	Environmental Scientist, Katie Blakemore
Report No	KB062
Document	2093132
Date	23 Jul 2018

Biomonitoring of unnamed tributaries of the Manganui River in relation to hydraulic fracturing at the Mangahewa-D wellsite, March and April 2018

Introduction

Macroinvertebrate surveys were carried out in two unnamed tributaries of the Manganui River in the vicinity of the Mangahewa-D wellsite prior to the commencement of hydraulic fracturing (HF) activities, and following the completion of HF. This provided data to determine whether discharges relating to the HF activities had caused a detrimental effect upon the macroinvertebrate communities of these unnamed tributaries. At the wellsite, treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River (Figure 1). Nine previous surveys had been completed in relation to wellsite activities at the site, with the most recent survey undertaken on 25 October 2017. The results of these surveys are discussed in the reports listed in the references.

Methods

A pre-HF survey was undertaken on 1 March 2018 at two previously established sites (sites 1 and 4). Two further sites were not sampled on this occasion due to low flow conditions prohibiting sampling (site 2) and unsafe access (site 3). A post-HF survey was undertaken at all four sites on 23 April 2018 (Table 1, Figure 1).

Table 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	E1711359 N5673793	55m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	E1711322 N5673832	90m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence	60
3	MGN000492	E1711376 N5673894	60m downstream of confluence from Mangahewa-D wellsite discharge	60
4	MGN000493	E1711392 N5673936	100m downstream of confluence from Mangahewa-D wellsite discharge	60

The standard '400mL kick-sampling' technique was used to collect streambed macroinvertebrates at site 4 in the pre-HF survey and sites 3 and 4 in the post-HF survey. The 'vegetation sweep' technique was used to collect streambed macroinvertebrates at site 1 in the pre-HF survey and sites 1 and 2 in the post-HF survey. The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocols C1 (hard-bottomed,

semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate sampling in wadeable streams (Stark et al. 2001).

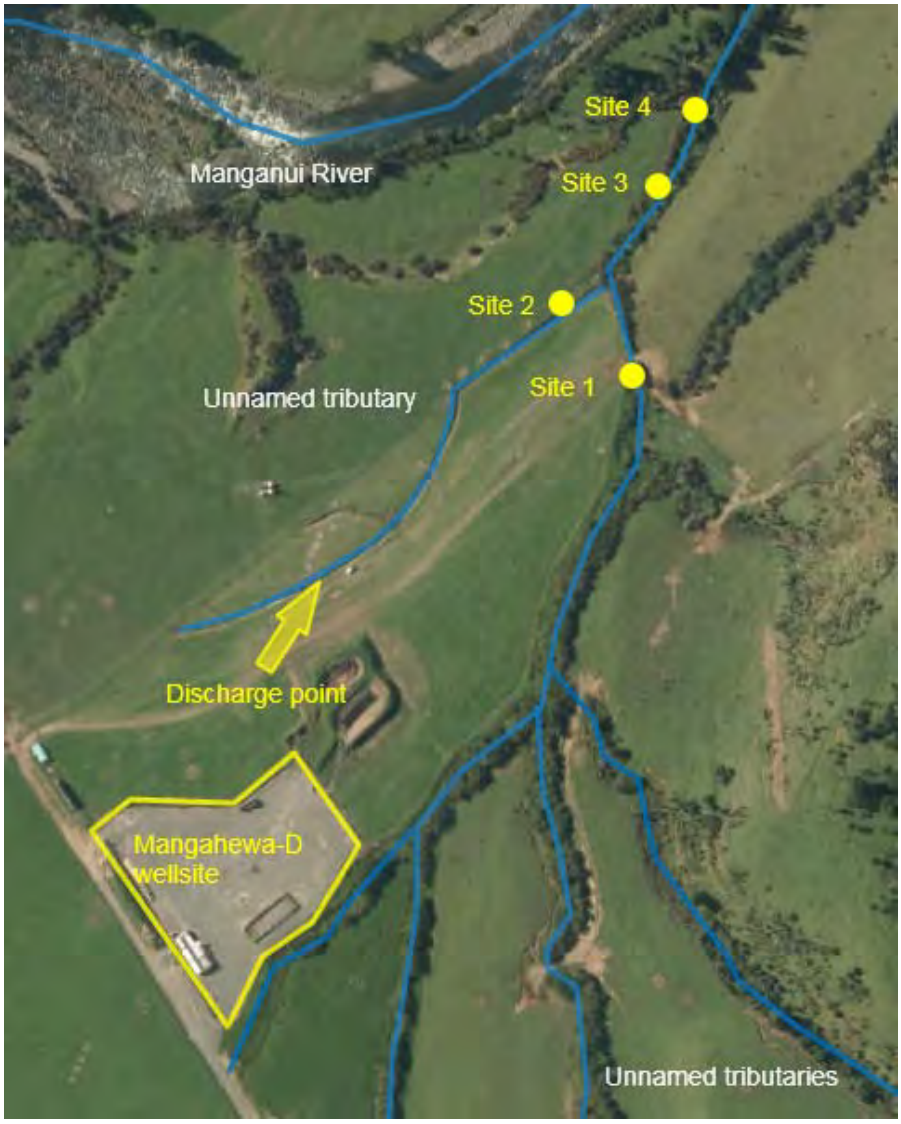


Figure 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

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 in each sample were recorded based on the abundance 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 scores 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. However, other physical variables such as sedimentation, temperatures, water velocity and dissolved oxygen levels may also affect the MCI scores because the taxa that are able to tolerate extremes in these variables generally have lower sensitivity scores. More 'sensitive' communities inhabit less polluted waterways. A gradation of biological water quality conditions based upon MCI ranges has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark 1985; Boothroyd & Stark 2001) is shown in Table 3. A difference of eleven or more MCI units is considered statistically significant (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985; 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.

Results

The pre-HF survey was carried out nine days after a fresh of 3x median flow and 102 days after a fresh of 7x median flow. Flows were very low, and were slow and cloudy but uncoloured at site 1, while the flow at site 4 was steady, clear and uncoloured. Water temperatures ranged between 17.8 – 18.6 °C. Substrate at site 1 was dominated by silt, sand and hard clay, with some gravel and boulder present. Site 4 had substrate dominated by cobble and gravel, with some silt, sand and boulder present.

Periphyton was absent at site 1, while mats and filaments were patchy at site 4. Leaves were patchy on the streambed at both sites, while moss was patchy at site 4 only. Macrophytes were present on the streambed at site 1 and absent at site 4. Site 4 had complete shading from overhanging vegetation and undercut banks, while site 1 was unshaded.

Site 2 could not be sampled during the pre-HF survey, due to the low flows at the time of the survey which had caused this smaller tributary to dry out completely. Site 3 was not sampled due to significant erosion causing the site access to be unsafe.

The post-HF survey was carried out 7 days after a fresh of 3x median flow and 29 days after a fresh of 7x median flow. Flows were moderate and steady in the larger tributary, but low and slow in the smaller

receiving tributary. All sites had clear and uncoloured flows. Water temperatures ranged from 13.1- 15.2 °C. Substrate at site1 comprised silt and hard clay, while site 2 had similar substrate with the addition of some wood/root. Site 3 had substrate dominated by hard clay and wood/root, with some silt, sand and fine gravel present. Site 4 was dominated by sand and gravels, with some silt, cobble and boulder present.

Periphyton was absent at all site except site 4, which had a thin periphyton film. Moss was patchy on the streambed at site 3 and widespread at site 4, while leaves were widespread at sties 3 and 4. Macrophytes were present on the streambed at sites 1 and 2, and on the stream margins at site 4. The streambed was completely shaded by overhanging vegetation at sites 2, 3 and 4 but was unshaded at site 1.

Macroinvertebrate communities

Comparative data from control sites in Taranaki lowland coastal streams at similar altitude is provided in Table 4, while results from previous surveys are summarised in Table 6. Full results of the current surveys are provided in Table 5 for the pre-HF survey and Table 7 for the post-HF survey.

Table 4 Summary of taxa richness, MCI and $SQMCI_s$ values for 'control' sites in Taranaki lowland coastal streams at altitudes between 50 and 79 masl (TRC 2016)

Metric	Number of samples	Range	Median
Taxa richness	128	0-30	20
MCI	128	60-109	79
$SQMCI_s$	99	1.2-6.7	4.2

Table 5 Range and medians of previously recorded taxa richness, MCI and $SQMCI_s$ scores for the survey sites, together with the results of the current surveys

Site	N	Taxa richness				MCI				$SQMCI_s$			
		Range	Median	Pre-HF	Post-HF	Range	Median	Pre-HF	Post-HF	Range	Median	Pre-HF	Post-HF
1	9	13-21	20	14	24	66-84	74	77	73	1.3-4.2	3.3	2.0	2.7
2	5	8-20	11	-	9	71-78	76	-	69	1.4-3.4	2.2	-	2.1
3	9	4-16	13	-	13	55-88	80	-	69	2.5-5.0	3.7	-	3.1
4	9	6-27	13	9	15	68-89	80	71	72	2.6-4.5	3.7	3.8	3.0

Table 6 Macroinvertebrate fauna of an unnamed tributary of the Manganui River sampled in relation to the Mangahewa-D wellsite on 1 March 2018

Taxa List	Site Number	MCI score	1	4
	Site Code		MGN000489	MGN000493
	Sample Number		FWB18107	FWB18108
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-
ANNELIDA (WORMS)	Oligochaeta	1	C	C
MOLLUSCA	*Potamopyrgus*	4	R	VA
CRUSTACEA	Ostracoda	1	VA	R
	Paracalliope	5	-	R
	Paratya	3	-	R
ODONATA (DRAGONFLIES)	*Austrolestes*	4	R	-
	Xanthocnemis	4	A	-
	Aeshna	5	R	-
	Procordulia	5	C	-
COLEOPTERA (BEETLES)	Hydrophilidae	5	R	-
	Scirtidae	8	R	-
TRICHOPTERA (CADDISFLIES)	*Oxyethira*	2	C	C
	Triplectides	5	C	C
DIPTERA (TRUE FLIES)	*Aphrophila*	5	-	R
	Limonia	6	-	R
	Orthocladiinae	2	R	-
	Tanypodinae	5	C	-
		No of taxa	14	9
		MCI	77	71
		SQMCIs	2.0	3.8
		EPT (taxa)	1	1
		%EPT (taxa)	7	11

'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 two unnamed tributaries of the Manganui River sampled in relation to the Mangahewa-D wellsite on 23 April 2018

Taxa List	Site Number	MCI score	1	2	3	4
	Site Code		MGN000489	MGN000491	MGN000492	MGN000493
	Sample Number		FWB18219	FWB18220	FWB18221	FWB18222
COELENTERATA	Coelenterata	3	R	-	-	R
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	C	C	R	R
NEMERTEA	Nemertea	3	-	-	-	C
ANNELIDA (WORMS)	Oligochaeta	1	A	A	C	A
	Lumbricidae	5	R	C	-	-
HIRUDINEA (LEECHES)	Hirudinea	3	C	-	R	R
MOLLUSCA	*Physa*	3	A	-	-	-
	Potamopyrgus	4	C	R	C	A
CRUSTACEA	Copepoda	5	-	R	-	-
	Ostracoda	1	A	A	R	C
	Paracalliope	5	R	-	R	-
	Paratya	3	-	-	-	C
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	R	-	R	R
	Hemicordulia	5	R	-	-	-
	Procordulia	5	-	-	R	-
COLEOPTERA (BEETLES)	Dytiscidae	5	-	R	-	-
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	R	-	-	-
	Hydrobiosis	5	R	-	R	-
	Polyplectropus	6	R	-	R	-
	Psilochorema	6	R	-	-	-
	Oxyethira	2	C	-	-	-
	Triplectides	5	-	-	-	C
LEPIDOPTERA (MOTHS)	*Hygraula*	4	R	-	-	-
DIPTERA (TRUE FLIES)	Eriopterini	5	-	-	-	R
	Hexatomini	5	R	-	-	-
	Chironomus	1	R	-	-	-
	Corynoneura	3	R	-	-	-
	Harrisius	6	-	-	-	R
	Orthocladiinae	2	-	R	R	-
	Tanypodinae	5	C	-	-	R
	Tanytarsini	3	R	-	R	-
	Ceratopogonidae	3	R	-	-	-
	Austrosimulium	3	VA	-	A	R
ACARINA (MITES)	Acarina	5	-	C	-	C
		No of taxa	24	9	13	15
		MCI	73	69	69	72
		SQMCIs	2.7	2.1	3.1	3.0
		EPT (taxa)	4	0	2	1
		%EPT (taxa)	17	0	15	7

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

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

Site 1

A moderately low taxa richness of 14 taxa was found in the pre-HF survey, while a moderate richness of 24 taxa was recorded in the post-HF survey. This is a substantial increase in richness between the two surveys, and the post-HF survey result is the highest richness recorded at this site to date (Table 5). The macroinvertebrate community in the pre-HF survey was characterised by two 'tolerant' taxa [seed shrimp (Ostracoda) and red damselfly (*Xanthocnemis*)] (Table 6). The post-HF survey community was characterised by four 'tolerant' taxa [oligochaete worm, snail (*Physa*), seed shrimp (Ostracoda) and sandfly larvae (*Austrosimulium*)] (Table 7).

Similar MCI scores of 77 and 73 were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'poor' macroinvertebrate community health on both occasions. Both scores are similar to the median score for this site (Table 5).

$SQMCI_s$ scores of 2.0 and 2.7 were recorded in the pre-HF and post-HF surveys respectively. These scores are not significantly different from one another, while the pre-HF result is significantly lower than the median for this site and the post-HF survey is similar to the median score (Table 5).

Site 2

This site was not sampled in the pre-HF survey due to no water being present in this tributary.

A low taxa richness of nine taxa was recorded in the post-HF survey, two taxa less than the median for this site (Table 5). The macroinvertebrate community was characterised by only two 'tolerant' taxa [seed shrimp (Ostracoda) and midge larvae (Orthocladiinae)].

The macroinvertebrate community was represented only by a few taxa, which are those typically able to tolerate the dry periods that may be experienced in ephemeral streams. Some taxa, such as worms, may be able to survive in muddy substrate for a period. Other taxa may have adapted to allow a life stage such as eggs, which are resilient to drying out, to survive such periods.

A MCI score of 69 units was recorded, categorising the site as having the 'poor' macroinvertebrate community health. This score is not significantly different from the median MCI score for this site (76 units; Table 5).

A $SQMCI_s$ score of 2.1 units was recorded, not significantly different from the median score for this site (2.2 units; Table 5).

Site 3

This site was not surveyed in the pre-HF survey.

The post-HF survey recorded a moderately low taxa richness of 13 taxa, equal to the median richness for this site. The macroinvertebrate community was characterised by only one 'tolerant' taxon [sandfly larvae (*Austrosimulium*)] (Table 7).

A MCI score of 69 was recorded, which is a significant 11 units lower than the median score for this site but an insignificant 10 units lower than the median score for lowland coastal streams at similar altitude (Table 4, Table 5). This score categorises the site as having 'poor' macroinvertebrate community health (Table 3).

A $SQMCI_s$ score of 3.1 was recorded, which is similar to the median score for this site (Table 5).

Site 4

Low and moderate taxa richnesses of nine and 15 taxa were recorded in the pre-HF and post-HF surveys respectively. These scores are similar to the median richness of 13 taxa for this site. The macroinvertebrate community in the pre-HF survey was characterised by only one 'tolerant' taxon [snail (*Potamopyrgus*)] (Table 6). The community in the post-HF survey was characterised by two 'tolerant' taxa [oligochaete worms and snail (*Potamopyrgus*)] (Table 7).

Similar MCI scores of 71 and 72 were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'poor' macroinvertebrate community health on both occasions. These scores are non-significantly lower than the median MCI score for this site (79 units; Table 5).

$SQMCI_s$ scores of 3.8 and 3.0 were recorded in the pre-HF and post-HF surveys. These scores are not significantly different from one another, or from the median $SQMCI_s$ score for the site (3.7 units; Table 5).

Discussion and conclusions

The Councils 'kick-sampling' and 'vegetation sweep' techniques were used at four sites to collect macroinvertebrates from two unnamed tributaries of the Manganui River in the vicinity of the Mangahewa-D wellsite. This has provided data to assess whether discharges to one of these tributaries had any affect on the macroinvertebrate communities of the unnamed tributary. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when 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 MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. However, it is also influenced by the 'patchiness' of macroinvertebrates on the streambed, and as such must be considered in the context of all three metrics. Significant differences in either the MCI or the $SQMCI_S$ scores between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

Taxa richnesses in these two surveys were low to moderate, with an increase observed between the two surveys at the two sites which were sampled on both occasions. The post-HF survey richness at site 1 was the highest recorded at this site to date. Richnesses generally similar to those recorded by previous surveys at these sites. It is of note that the highest taxa richness on both occasions was at site 1, upstream of the wellsite. This is typical of these sites, and is likely a result of greater habitat diversity and less scouring at this site.

Site 2 was not sampled in the pre-HF survey due to having no water in this tributary with only some muddy substrate, indicating that no recent discharges had occurred from the wellsite. In the post-HF survey, this site recorded a low richness of nine taxa. This is within the range previously recorded at this site. As might be expected, the macroinvertebrate community comprised taxa that are somewhat resilient to dry periods. These taxa include some (such as the three types of worms) which are able to live in the substrate and therefore avoid desiccation. Other taxa (such as ostracods and copepods) have eggs that are able to withstand desiccation, allowing them to quickly recolonise after dry periods.

All MCI scores in these two surveys categorised the sites as having 'poor' macroinvertebrate community health. These scores did not differ significantly between sites or surveys. Further, the scores were similar to

the medians for each respective site, with the exception of site 3 which in the post-HF survey recorded a score 11 units lower than its historic median.

$SQMCI_s$ scores in the two surveys ranged from 2.0 to 3.8. All scores, with the exception of site 1 in the pre-HF survey, recorded scores similar to their respective historic medians. Further, there were no significant differences in scores at any site between the two surveys. In the pre-HF survey, site 1 recorded a significantly lower score than site 4 and in the post-HF survey, site 2 recorded a significantly lower score than sites 3 and 4.

Overall, the results of these two surveys indicate low to moderate taxa richness and 'poor' macroinvertebrate community health. Taxa richness increased between the two surveys, while MCI and $SQMCI_s$ scores remained similar. The community at site 2 (in the smaller receiving tributary) had no water present in the pre-HF survey, and, as expected, in the post-HF survey was characterised by taxa that can withstand dry periods. Overall, there was no evidence that discharges from the Mangahewa-D wellsite had caused any recent detrimental effects on these two unnamed tributaries of the Manganui River.

Summary

Macroinvertebrate surveys were undertaken on 1 March and 23 April 2018, using the Council's 'kick-sampling' and 'vegetation sweep' techniques to collect samples at four sites. On the first occasion, only two of the four sites could be sampled. Taxa richnesses were low to moderate and improved between the two surveys. MCI scores categorised all sites as having 'poor' macroinvertebrate community health on both occasions, and were similar at all sites and between surveys. $SQMCI_s$ scores also were generally similar between surveys, although there were some differences between sites within surveys. MCI and $SQMCI_s$ scores were for the most part similar to historic medians for each respective site.

Overall, there was no evidence that discharges from the Mangahewa-D wellsite had caused any recent detrimental impacts on the macroinvertebrate communities on these two unnamed tributaries of the Manganui River.

References

Blakemore KS, 2016. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, April 2016. TRC report KB010.

Blakemore KS, 2018a. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, March and April 2017. TRC report KB040.

Blakemore KS, 2018b. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, June and October 2017. TRC Report KB041.

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

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

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

Stark JD, Boothroyd IKG, Harding JS, Maxted JR, Scarsbrook MR, 2001: Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report

No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

Stark JD and Fowles CR, 2009: Relationships between MCI, site altitude, and distance from source for Taranaki ring plain stream. Prepared for Taranaki Regional Council. Stark Environmental Report No. 2009-01. 47p.

Sutherland DL, 2015. Biomonitoring of two unnamed tributaries of the Manganui River in relation to drilling by Todd Energy Ltd at the Mangahewa-D wellsite, May 2015. TRC report DS011.

Thomas BT, 2014. Biomonitoring of an unnamed tributary of the Manganui River before and after hydraulic fracturing at Mangahewa-D wellsite by Todd Energy Ltd, April 2014 and August 2014. TRC report BT037.

TRC, 2017: Some statistics from the Taranaki Regional Council database (Esam) of freshwater macroinvertebrate surveys performed during the period from January 1980 to 30 September 2017.

Winterbourn MJ, Gregson KLD, Dolphin CH, 2006. Guide to the aquatic insects of New Zealand. [4th edition]. Bulletin of the Entomological Society of New Zealand 14, 108p.

To	Job Manager, Jane Harvey
From	Environmental Scientist, Katie Blakemore
Report No	KB041
Document	2039173
Date	16 Apr 2018

Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, June and October 2017

Introduction

Macroinvertebrate surveys were carried out in the vicinity of the Mangahewa-D wellsite prior to the commencement of hydraulic fracturing (HF) activities, and following the completion of HF, to determine whether discharges relating to the HF activities had caused a detrimental effect upon macroinvertebrate communities of two unnamed tributaries of the Manganui River. At the wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River (Figure 1). Previous surveys had been completed in relation to wellsite activities at the site on 15 April 2014, 28 August 2014, 18 May 2015, 26 May 2015 and 18 April 2016, 6 March and 19 April 2017. The results of these surveys are discussed in the reports listed in the references.

Methods

A pre-HF survey was undertaken on 2 June 2017 at four previously established sites (Figure 1, Table 1). A post-HF survey was undertaken at the same four sites on 25 October 2017.

Table 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	E1711359 N5673793	55m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	E1711322 N5673832	90m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence	60
3	MGN000492	E1711376 N5673894	60m downstream of confluence from Mangahewa-D wellsite discharge	60
4	MGN000493	E1711392 N5673936	100m downstream of confluence from Mangahewa-D wellsite discharge	60

The standard '400 mL kick sampling' technique was used to collect streambed macroinvertebrates at sites 3 and 4 in both the pre-HF and post-HF surveys, and site 1 in the pre-HF survey. The 'vegetation sweep' technique was used to collect streambed macroinvertebrates at sites 1 and 2 in the post-HF survey, while a combination of 'kick sampling' and 'vegetation sweep' techniques were used at site 2 in the pre-HF survey. The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocols C1 (hard-bottomed,

semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZWMG) protocols for macroinvertebrate samples in wadeable streams (Stark et al. 2001).

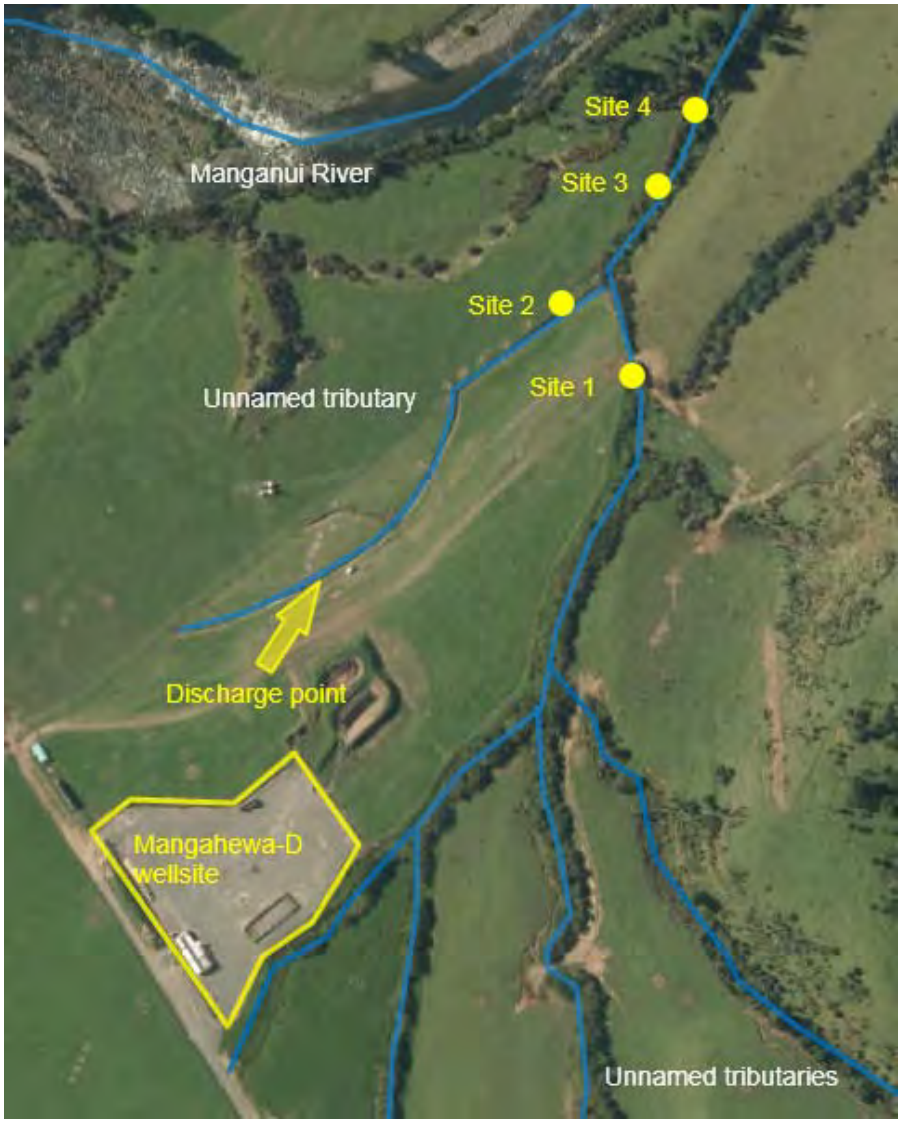


Figure 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

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 found in each sample were recorded based on the abundance 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. However, other physical variables such as sedimentation, temperatures, water velocity, and dissolved oxygen levels may also affect the MCI scores because the taxa that are able to tolerate extremes in these variables generally have lower sensitivity scores. More 'sensitive' communities inhabit less polluted waterways. A gradation of biological water quality conditions based upon MCI ranges has been adapted for Taranaki Streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985; Boothroyd and Stark 2000) is shown in Table 3. A difference of eleven or more MCI units is considered statistically significant (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985; 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.

Results

The pre-HF survey was carried out nine days after a fresh of 3x median flow and 15 days after a fresh of 7x median flow. Flows were moderate, steady, clear and uncoloured at sites 1, 3 and 4, while site 2 had a very low, very slow/still, uncoloured and cloudy flow. Substrate at sites 1, 3 and 4 was dominated by cobbles and gravels, with small amounts of silt, sand and boulder present. Sites 3 and 4 also had a small amount of wood/root present. Site 2 had substrate comprised entirely of silt. A silt coating was present at sites 1, 3 and 4.

Periphyton mats were absent at sites 1, 2 and 3, and patchy at site 4, while filamentous periphyton was absent from all sites. Moss was patchy on the streambed at site 3 and absent from sites 1, 2 and 4. Leaves and wood were patchy on the streambed at sites 3 and 4 and absent at sites 1 and 2. Macrophytes were present on the stream margins at site 2, on the streambed at sites 2 and 3 and absent at site 4. Overhanging vegetation and/or steep banks provided complete shading at site 2 and partial shading at sites 1, 3 and 4.

The post-HF survey was carried out 11 days after a fresh of 3x median flow and 12 days after a fresh of 7x median flow. Flows were moderate, steady, clear and uncoloured at sites 1, 3 and 4, while site 2 had a very

low, very slow/still, cloudy brown flow. Substrate at site 1 was dominated by silt and wood/root, with some sand, gravels and cobbles present also. Site 2 had substrate comprised entirely of silts. Sites 3 and 4 had cobble and gravels as the dominant substrate, with some sand, silt and boulder also present. A silt coating was present on the streambed at all four sites.

Periphyton mats were absent at sites 1 and 2 and slippery at sites 3 and 4, while filamentous periphyton was absent at all sites. Moss was widespread on the streambed at site 3, patchy at site 4 and absent at sites 1 and 2. Leaves and wood were patchy on the streambed at sites 3 and 4, and absent at site 1 and 2. Macrophytes were present on the streambed at sites 1 and 2 and absent at sites 3 and 4. Overhanging vegetation and /or steep banks provided partial shading at site 1 and complete shading at sites 2, 3 and 4.

Macroinvertebrate communities

Comparative data from control sites in Taranaki lowland coastal stream at similar altitude is provided in Table 4, while results from previous surveys are summarised in Table 5. Full results of the current surveys are provided in Table 6 for the pre-HF survey and Table 7 for the post-HF survey.

Table 4 Summary of taxa richness, MCI values and $SQMCI_S$ values for 'control' sites in Taranaki lowland coastal streams at altitudes between 50 and 79 m asl (TRC 2016)

Metric	Number of samples	Range	Median
Taxa richness	124	0-30	20
MCI	124	60-109	79
$SQMCI_S$	95	1.2-6.7	4.0

Table 5 Range of previously recorded taxa richness, MCI and $SQMCI_S$ scores for the survey sites, together with the results of the current surveys

Site	Number of previous surveys	Taxa richness			MCI			$SQMCI_S$		
		Range	Pre-HF	Post-HF	Range	Pre-HF	Post-HF	Range	Pre-HF	Post-HF
1	7	13-21	20	15	66-83	76	84	1.3-3.8	2.5	4.2
2	3	8-20	11	18	71-78	78	72	1.4-3.4	2.2	3.3
3	7	4-16	13	12	55-88	85	85	2.5-4.0	3.8	5.0
4	7	6-27	19	13	68-89	87	86	2.6-4.5	3.4	3.7

Table 6 Macroinvertebrate fauna of two unnamed tributaries of the Manganui River sampled in relation to the Mangahewa-D wellsite on 2 June 2017

Taxa List	Site Number	MCI score	1	2	3	4
	Site Code		MGN000489	MGN000491	MGN000492	MGN000493
	Sample Number		FWB17267	FWB17268	FWB17269	FWB17270
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	-	-	R
NEMERTEA	Nemertea	3	A	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	R	C	A
	Lumbricidae	5	R	C	R	-
HIRUDINEA (LEECHES)	Hirudinea	3	C	-	-	R
MOLLUSCA	*Physa*	3	-	C	-	-
	Potamopyrgus	4	R	A	A	A
	Sphaeriidae	3	R	-	-	-
CRUSTACEA	Ostracoda	1	VA	VA	-	-
	Paracalliope	5	VA	-	R	C
	Paratya	3	-	-	-	R
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	-	-	R	R
	Neozephlebia	7	R	-	-	-
	Zephlebia group	7	-	-	-	R
PLECOPTERA (STONEFLIES)	*Acroperla*	5	-	-	R	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	R	-	-	R
COLEOPTERA (BEETLES)	Elmidae	6	-	-	R	-
TRICHOPTERA (CADDISFLIES)	Ecnomidae/Psychomyiidae	6	-	-	-	R
	Hydrobiosis	5	R	-	R	-
	Polyplectropus	6	-	-	-	R
	Psilochorema	6	R	R	-	R
	Oxyethira	2	R	-	R	R
	Triplectides	5	-	-	-	C
DIPTERA (TRUE FLIES)	*Aphrophila*	5	-	-	-	R
	Eriopterini	5	-	-	R	R
	Hexatomini	5	-	R	-	-
	Paralimnophila	6	R	-	-	-
	Zelandotipula	6	-	R	-	-
	Orthocladiinae	2	C	R	R	R
	Tanypodinae	5	C	R	R	C
	Ceratopogonidae	3	R	-	-	-
	Austrosimulium	3	C	-	-	-
	Tanyderidae	4	-	-	-	R
ACARINA (MITES)	Acarina	5	R	A	-	-
		No of taxa	20	11	13	19
		MCI	76	78	85	87
		SQMCIs	2.5	2.2	3.8	3.4
		EPT (taxa)	3	1	3	6
		%EPT (taxa)	15	9	23	32

'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 two unnamed tributaries of the Manganui River sampled in relation to the Mangahewa-D wellsite on 25 October 2017

Taxa List	Site Number	MCI score	1	2	3	4
	Site Code		MGN000489	MGN000491	MGN000492	MGN000493
	Sample Number		FWB17326	FWB17327	FWB17328	FWB17329
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	-	A	-	-
ANNELIDA (WORMS)	Oligochaeta	1	A	A	R	C
	Lumbricidae	5	-	C	-	-
MOLLUSCA	*Physa*	3	-	A	-	-
	Potamopyrgus	4	A	A	R	C
CRUSTACEA	Copepoda	5	-	A	-	-
	Ostracoda	1	R	A	-	-
	Paracalliope	5	VA	-	C	C
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	A	-	C	C
	Zephlebia group	7	R	-	-	R
PLECOPTERA (STONEFLIES)	*Acroperla*	5	R	-	-	-
	Zelandobius	5	-	-	R	R
COLEOPTERA (BEETLES)	Elmidae	6	-	-	R	-
	Dytiscidae	5	-	C	-	-
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	R	-	-	-
	Hydrobiosis	5	R	-	R	C
	Psilochorema	6	R	-	R	-
	Oxyethira	2	-	-	-	R
DIPTERA (TRUE FLIES)	*Aphrophila*	5	-	R	-	C
	Eriopterini	5	-	-	-	R
	Paralimnophila	6	-	R	-	-
	Chironomus	1	-	R	-	-
	Orthocladiinae	2	A	-	R	A
	Polypedilum	3	C	C	R	-
	Tanypodinae	5	R	R	-	-
	Tanytarsini	3	-	C	-	-
	Culicidae	3	-	R	-	-
	Paradixa	4	-	R	-	-
	Empididae	3	-	R	-	-
	Austrosimulium	3	A	-	R	R
	Tanyderidae	4	-	-	R	-
ACARINA (MITES)	Acarina	5	R	A	-	C
		No of taxa	15	18	12	13
		MCI	84	72	85	86
		SQMCIs	4.2	3.3	5.0	3.7
		EPT (taxa)	6	0	4	4
		%EPT (taxa)	40	0	33	31

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

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

Site 1

Moderate taxa richnesses of 20 and 15 taxa were recorded in the pre-HF and post-HF surveys respectively. These richnesses are within the range previously recorded at this site (Table 5) and are similar to the median richness for Taranaki lowland coastal streams at similar altitude (Table 4). Two taxa characterised the macroinvertebrate community in both the pre-HF surveys, the 'tolerant' taxon [oligochaete worms] and the 'moderately sensitive' taxon [amphipod (*Paracalliope*)]. Two additional 'tolerant' taxa were characteristic in the pre-HF survey [proboscis worm (Nemertea) and seed shrimp (Ostracoda)]. Four additional taxa were characteristic in the post-HF survey, three 'tolerant' taxa [mud snail (*Potamopyrgus*), midge larvae (Orthocladiinae) and sandfly larvae (*Austrosimulium*)] and one 'moderately sensitive' taxon [mayfly (*Austroclima*].

MCI scores of 76 and 84 were recorded in the pre-HF and post-HF surveys respectively, a slight but non-significant (Stark 1998) increase. These scores categorise the macroinvertebrate communities as having 'poor' and 'fair' health respectively. The score of 84 units recorded in the post-HF survey is the highest recorded MCI score at this site to date (Table 5). Both scores are similar to the median MCI score for Taranaki lowland coastal streams at similar altitude (Table 4).

$SQMCI_S$ scores of 2.5 and 4.2 were recorded in the pre-HF and post-HF surveys respectively, a statistically significant increase between the two surveys. The score of 4.2 units recorded in the post-HF survey is the highest recorded $SQMCI_S$ score at this site to date (Table 5) and is similar to the median $SQMCI_S$ score for Taranaki lowland coastal streams at similar altitude (Table 4). The score recorded in the pre-HF survey is within the range previously recorded at this site (Table 5) but is significantly lower (Stark 1998) than the median score for Taranaki lowland coastal streams at similar altitude (Table 4).

Site 2

A low taxa richness of 11 taxa was recorded in the pre-HF survey, while a moderate richness of 18 taxa was recorded in the post-HF survey. Both scores are within the range of previously recorded scores at this site (Table 5). Three taxa characterised the macroinvertebrate community in both surveys, the two 'tolerant' taxa [mud snail (*Potamopyrgus*) and seed shrimp (Ostracoda)] and the 'moderately sensitive' taxon [mite (Acarina)]. Four additional taxa characterised the community in the post-HF survey, three 'tolerant' taxa [flatworm (*Cura*), worm (Oligochaeta) and snail (*Physa*)] and one 'moderately sensitive' taxon [crustacean (Copepoda)].

Similar MCI scores of 78 and 72 units were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'poor' macroinvertebrate community health on both occasions. These scores are within the range of previously recorded scores at this site (Table 5) and are not significantly different (Stark 1998) from the median MCI score for Taranaki lowland coastal streams at similar altitude (Table 4).

$SQMCI_S$ scores of 2.2 and 3.3 were recorded in the pre-HF and post-HF surveys respectively, a significant increase (Stark 1998) between the two surveys. Both scores are within the range of previously recorded $SQMCI_S$ scores at this site (Table 5). The post-HF score is similar to the median score for Taranaki lowland coastal streams at similar altitude, while the pre-HF score is significantly lower (Stark 1998) than this median (Table 4).

Site 3

Moderately low taxa richnesses of 12 and 13 taxa were recorded in the pre-HF and post-HF surveys respectively, both of which are within the previously recorded range of taxa richnesses for this site (Table 5). Both scores are substantially lower than the median richness for Taranaki lowland coastal streams at similar

altitude (Table 4). One 'tolerant' taxon [snail (*Potamopyrgus*)] characterised the macroinvertebrate community in the pre-HF survey. No macroinvertebrate taxa were characteristic in the post-HF survey.

MCI scores of 85 units were recorded in both the pre-HF and pot-HF surveys, categorising the macroinvertebrate community as being in 'fair' health. This score is within the range of previously recorded richnesses for this site (Table 5) and is not significantly different (Stark 1998) from the median score for Taranaki lowland coastal streams at similar altitude (Table 4).

$SQMCI_S$ scores of 3.8 and 5.0 were recorded in the pre-HF and post-HF surveys, a significant increase (Stark 1998) between the two surveys. The score recorded in the post-HF survey is the highest $SQMCI_S$ score recorded to date at this site (Table 5) and is a significant 1.0 unit higher than the median $SQMCI_S$ score for lowland coastal streams at similar altitude (Table 4). The pre-HF score is similar to this median score (Table 4).

Site 4

A moderate taxa richness of 19 taxa was recorded in the pre-HF survey, while a moderately low taxa richness of 13 taxa was recorded in the post-HF survey. Both richnesses are within the range previously recorded at this site (Table 5). The pre-HF richness is similar to the median richness for Taranaki lowland coastal streams at similar altitude, while the post-HF richness is substantially lower (Table 4). Two 'tolerant' taxa [oligochaete worms and snail (*Potamopyrgus*)] characterised the macroinvertebrate community in the pre-HF survey, while one 'tolerant' taxon [midge larvae (Orthocladiinae)] characterised the community in the post-HF survey.

Similar MCI scores of 87 and 86 were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'fair' macroinvertebrate community health on both occasions. These scores are within the previously recorded range at this site (Table 5) and are not significantly different from the median MCI score for Taranaki lowland coastal streams at similar altitude (Table 4).

Similar $SQMCI_S$ scores of 3.4 and 3.7 units were recorded in the pre-HF and post-HF surveys respectively. These scores are within the previously recorded range at this site (Table 5) and are not significantly different from the median $SQMCI_S$ score for Taranaki lowland coastal streams at similar altitude (Table 4).

Discussion and conclusions

The Councils 'kick-sampling' and 'vegetation sweep' techniques were used at four sites to collect macroinvertebrates from two unnamed tributaries of the Manganui River in the vicinity of the Mangahewa-D wellsite. This has provided data to assess whether discharges to one of these tributaries had any affect on the macroinvertebrate communities of the unnamed tributary. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when 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 MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. However, it is also influenced by the 'patchiness' of macroinvertebrates on the streambed, and as such must be considered in the context of all three metrics. Significant differences in either the MCI or the $SQMCI_S$ scores between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

Moderate to moderately low taxa richnesses were recorded in these surveys, although all richnesses were within the range previously recorded for each respective site. The richnesses at sites 1 and 4 decreased between the two surveys, while site 2 showed an increase and site 3 remained similar. All richnesses were similar to or lower than the median richness for Taranaki lowland coastal streams at similar altitude.

MCI scores of 76, 78, 85 and 87 were recorded at sites 1-4 respectively in the pre-HF survey. The score recorded at site 1 was significantly lower than the score at site 4, while there were no other significant differences between sites. The post-HF survey recorded scores of 84, 72, 85 and 86 at the four sites respectively. In this survey, the score at site 2 was significantly lower compared to all other sites, while sites 1, 3 and 4 had similar scores. The scores did not changes significantly at any site between the two surveys.

$SQMCI_S$ scores of 2.5, 2.2, 3.8 and 3.4 were recorded at sites 1-4 respectively in the pre-HF survey. The scores at sites 1 and 2 are similar, and are significantly lower than those at sites 3 and 4 (which are also similar to each other). The post-HF survey recorded scores of 4.2, 3.3, 5.0 and 3.7 at the four sites respectively. In this survey, site 3 had the highest score, which was significantly higher than sites 2 and 4 but similar to site 1. Site 2 had the lowest score which was significantly lower than sites 1 and 3 but similar to site 4. Site 4 had a score significantly lower than site 3 but similar to sites 1 and 2, while site 1 was significantly higher than site 2 but similar to sites 3 and 4. The scores at sites 1, 2 and 3 increased significantly between the two surveys, while site 4 showed a non-significant decrease.

The results at site 4 show some improvement in taxa richness and abundance when compared with the previous survey, which recorded decreased taxa richness and only a single, small individual of each taxon. This sample also had significant foaming noted during processing and a lack of organic detritus in the sample. No such observations were made in the current two surveys. A streambed sediment sample was taken at this site at the time of the pre-HF survey, which found low levels of hydrocarbons. Further investigations are being undertaken by the Company.

Overall, the results of these two surveys indicate moderate to moderately low taxa richnesses, 'poor' to 'fair' MCI scores and moderate to low $SQMCI_S$ scores. The impact noted at site 4 during the previous survey was not apparent in the current survey and there appears to have been some recovery of the macroinvertebrate community since this survey. The results of these two surveys provides no evidence of any further impacts on these two unnamed tributaries of the Manganui River.

Summary

Macroinvertebrate surveys were undertaken on 2 June and 25 October 2017, using the Council's 'kick-sampling and 'vegetation sweep' techniques to collect samples at four sites. Moderately low to moderate taxa richnesses were recorded, which were similar between the two surveys. MCI scores classified the sites as having 'fair' or 'poor' macroinvertebrate community health, and remained similar between the two surveys at all four sites. $SQMCI_S$ scores ranged between 2.2 and 3.8 in the pre-HF survey and between 3.3 and 5.0 in the post-HF survey. A significant increase was recorded at sites 1, 2 and 3 between the two surveys, and sites 1 and 3 recorded their highest scores to date in the post-HF survey.

The previous post-HF survey noted reduced taxa richness and abundances at site 4, along with foaming evident during sample processing. There were no such observations made in the current two surveys, and the results of all three invertebrate metrics indicated that the macroinvertebrate communities at this site had recovered since this time.

Overall, there is no evidence that the Mangahewa-D wellsite has caused any recent significant detrimental impacts on the macroinvertebrate communities of these two unnamed tributaries of the Manganui River.

References

Blakemore KS, 2016. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, April 2016. TRC report KB010.

Blakemore KS, 2018. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, March and April 2017. TRC report KB040.

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

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

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

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

Stark JD and Fowles CR, 2009: Relationships between MCI, site altitude, and distance from source for Taranaki ring plain stream. Prepared for Taranaki Regional Council. Stark Environmental Report No. 2009-01. 47p.

Sutherland DL, 2015. Biomonitoring of two unnamed tributaries of the Manganui River in relation to drilling by Todd Energy Ltd at the Mangahewa-D wellsite, May 2015. TRC report DS011.

Thomas BT, 2014. Biomonitoring of an unnamed tributary of the Manganui River before and after hydraulic fracturing at Mangahewa-D wellsite by Todd Energy Ltd, April 2014 and August 2014. TRC report BT037.

TRC, 2016: Some statistics from the Taranaki Regional Council database (Esam) of freshwater macroinvertebrate surveys performed during the period from January 1980 to 30 September 2016.

Winterbourn MJ, Gregson KLD, Dolphin CH, 2006. Guide to the aquatic insects of New Zealand. [4th edition]. Bulletin of the Entomological Society of New Zealand 14, 108p.

To	Job Manager, Jane Harvey
From	Environmental Scientist, Katie Blakemore
Report No	KB040
Document	2038157
Date	13 Apr 2018

Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, March and April 2017

Introduction

Macroinvertebrate surveys were carried out in the vicinity of the Mangahewa-D wellsite prior to the commencement of hydraulic fracturing (HF) activities, and following the completion of HF, to determine whether discharges relating to the HF activities had caused a detrimental effect upon macroinvertebrate communities of two unnamed tributaries of the Manganui River. At the wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River (Figure 1). Previous surveys had been completed in relation to wellsite activities at the site on 15 April 2014, 28 August 2014, 18 May 2015, 26 May 2015 and 18 April 2016. The results of these surveys are discussed in the reports listed in the references.

Methods

A pre-HF survey was undertaken on 6 March 2017 at four previously established sites (Figure 1, Table 1). A post-HF survey was undertaken at the same four sites on 19 April 2017.

Table 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	E1711359 N5673793	55m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	E1711322 N5673832	90m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence	60
3	MGN000492	E1711376 N5673894	60m downstream of confluence from Mangahewa-D wellsite discharge	60
4	MGN000493	E1711392 N5673936	100m downstream of confluence from Mangahewa-D wellsite discharge	60

The standard '400 mL kick sampling' technique was used to collect streambed macroinvertebrates at sites 3 and 4 in both the pre-HF and post-Hf surveys. The 'vegetation sweep' technique was used to collect streambed macroinvertebrates at site 2 in the pre-HF survey, while a combination of 'kick sampling' and 'vegetation sweep' techniques were used at site 2 in the post-HF survey and at site 1 in both the pre-HF and post-HF surveys. The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocols C1 (hard-bottomed, semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand.

Macroinvertebrate Working Group (NZWMG) protocols for macroinvertebrate samples in wadeable streams (Stark et al. 2001).

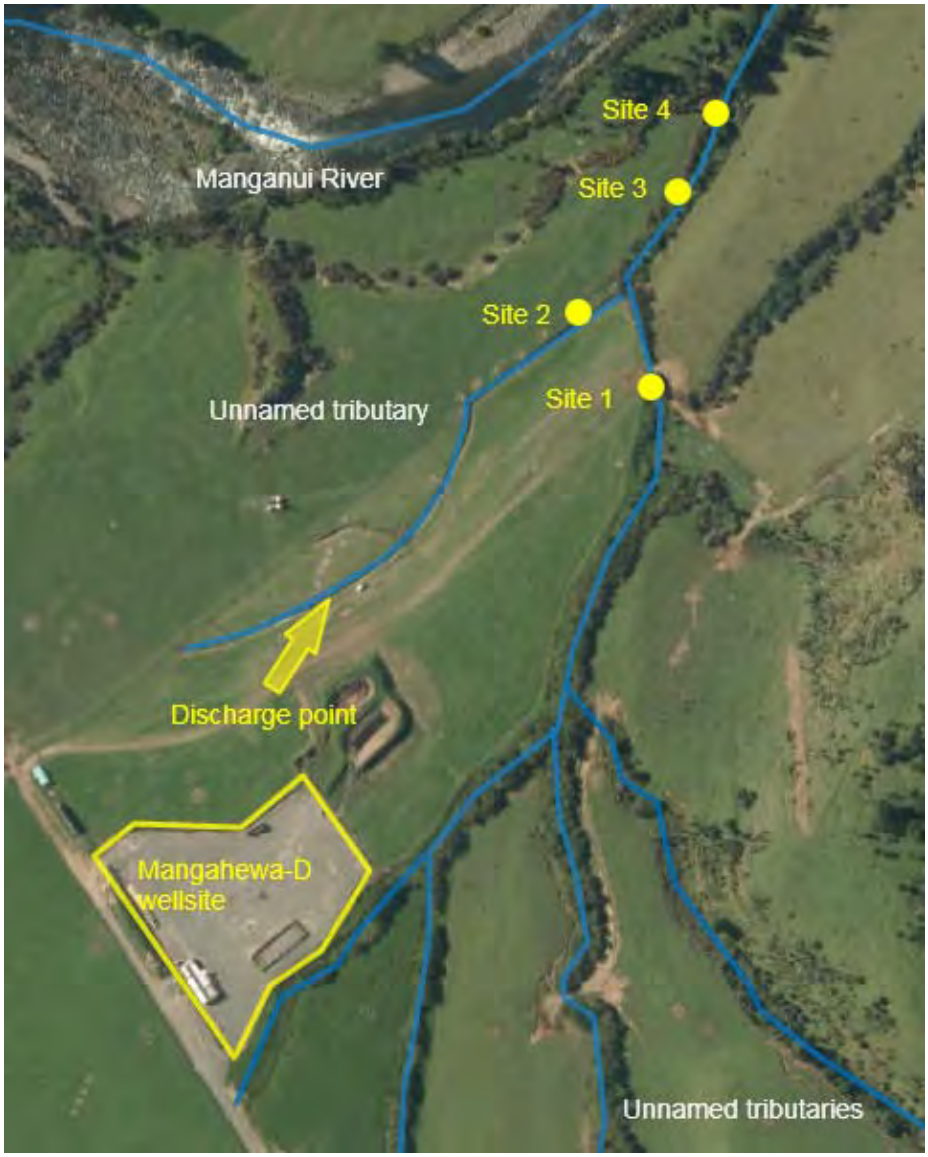


Figure 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

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 found in each sample were recorded based on the abundance 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. However, other physical variables such as sedimentation, temperatures, water velocity, and dissolved oxygen levels may also affect the MCI scores because the taxa that are able to tolerate extremes in these variables generally have lower sensitivity scores. More 'sensitive' communities inhabit less polluted waterways. A gradation of biological water quality conditions based upon MCI ranges has been adapted for Taranaki Streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985; Boothroyd and Stark 2000) is shown in Table 3. A difference of eleven or more MCI units is considered statistically significant (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges adapted for Taranaki streams nd rivers (TRC, 2013) from Stark's classification (Stark, 1985; 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.

Results

The pre-HF survey was carried out 30 days after a fresh in excess of 3x median flow and 31 days after a fresh in excess of 7x median flow (based on the Manganui River at Everett Park). Flows were low and steady at sites 1, 3 and 4, and very low and very slow/still at site 2. The water was cloudy but uncoloured at site 1, dirty brown at site 2 and cloudy grey at sites 3 and 4. Water temperatures ranged from 16.9 °C – 18.1 °C. Substrate at sites 1 and 2 was dominated by silt, with gravels and wood/root present in small amounts at site 1, and wood/root at site 2. Substrate at site 3 was dominated by cobble and boulder, with silt, sand, gravels and wood/root also present, while at site 4 cobble, gravels and sand were dominant with small amounts of silt, boulder and wood/root also present. A silt coating was present at all four sites.

Periphyton was absent at sites 1 and 2, while site 3 had slippery mats and no filaments and site 4 had patchy mats and patchy filaments. Moss and leaves were absent from the streambed at sites 1 and 2 and patchy at sites 3 and 4. Wood was patchy on the streambed at sites 1, 3 and 4 and absent at site 2. Macrophytes were present on the streambed at sites 1 and 2 and absent at sites 3 and 4. Overhanging vegetation provided partial shading at sites 1 and 4 and complete shading at sites 2 and 3.

The post-HF survey was undertaken 4 days after a fresh in excess of both 3x and 7x median flow. Moderate flows were recorded which were steady at site 1, slow at site 2 and swift at sites 3 and 4. The water was clear an uncoloured at all sites. Water temperatures ranged from 13.8 °C – 16.8 °C. Substrate at site 1 was dominated by gravel, cobble and hard clay, with some silt, sand and wood/root also present. At site 2 the substrate was dominated by hard clay, with some silt, sand and fine gravel present. Sites 3 and 4 had mainly cobble, boulder and gravels, with some sand, silt and wood/root also present. There was a silt coating on the streambed at sites 1 and 2 only.

Periphyton was absent at all four sites. Moss was absent from the streambed at sites 1 and 2, patchy at site 3 and widespread at site 4, while leaves were patchy at site 3 and absent at sites 1, 2 and 4. Wood was patchy at sites 3 and 4 and absent at sites 1 and 2. Macrophytes were present on the streambed at sites 1 and 2, on the edges only at site 3 and absent at site 4. There was overhanging vegetation providing partial shading at sites 3 and 4, while sites 1 and 2 were unshaded.

Macroinvertebrate communities

Comparative data from control sites in Taranaki lowland coastal stream at similar altitude is provided in Table 4, while results from previous surveys are summarised in Table 5. Full results of the current surveys are provided in Table 6 for the pre-HF survey and Table 7 for the post-HF survey.

Table 4 Summary of taxa richness, MCI values and $SQMCI_S$ values for 'control' sites in Taranaki lowland coastal streams at altitudes between 50 and 79 m asl (TRC 2016)

Metric	Number of samples	Range	Median
Taxa richness	124	0-30	20
MCI	124	60-109	79
$SQMCI_S$	95	1.2-6.7	4.0

Table 5 Range of previously recorded taxa richness, MCI and $SQMCI_S$ scores for the survey sites, together with the results of the current surveys

Site	Number of previous surveys	Taxa richness			MCI			$SQMCI_S$		
		Range	Pre-HF	Post-HF	Range	Pre-HF	Post-HF	Range	Pre-HF	Post-HF
1	5	19-21	13	16	66-83	75	74	2.5-3.8	2.8	1.3
2	1	20	8	11	76	78	71	1.4	3.4	2.1
3	5	4-16	15	12	55-80	88	80	2.5-4.0	3.8	3.7
4	5	6-27	12	11	68-85	73	89	2.6-3.9	3.9	4.5

Table 6 Macroinvertebrate fauna of two unnamed tributaries of the Manganui River sampled in relation to the Mangahewa-D wellsite on 6 March 2017

Taxa List	Site Number	MCI score	1	2	3	4
	Site Code		MGN000489	MGN000491	MGN000492	MGN000493
	Sample Number		FWB17179	FWB17180	FWB17181	FWB17182
COELENTERATA	Coelenterata	3	R	-	-	-
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	C	-	-	-
NEMERTEA	Nemertea	3	R	-	R	-
NEMATODA	Nematoda	3	-	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	-	C	C
	Lumbricidae	5	-	C	-	-
MOLLUSCA	*Physa*	3	R	C	-	R
	Potamopyrgus	4	A	-	A	VA
CRUSTACEA	Ostracoda	1	A	C	-	C
	Paracalliope	5	A	-	-	R
	Paratya	3	-	-	-	C
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	-	-	R	-
	Neozephlebia	7	R	-	-	-
	Zephlebia group	7	-	-	R	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	-	-	R
COLEOPTERA (BEETLES)	Elmidae	6	-	-	R	-
	Hydrophilidae	5	-	-	R	-
TRICHOPTERA (CADDISFLIES)	*Hydrobiosis*	5	R	-	-	-
	Polyplectropus	6	-	-	-	R
	Psilochorema	6	A	R	R	-
	Oxyethira	2	-	-	R	-
	Pycnocentria	7	-	-	R	-
	Triplectides	5	-	-	-	A
DIPTERA (TRUE FLIES)	*Limonia*	6	-	-	R	-
	Orthocladiinae	2	-	-	R	R
	Polypedilum	3	-	R	-	-
	Tanypodinae	5	A	R	-	R
	Paradixa	4	-	-	R	-
	Austrosimulium	3	VA	R	R	-
ACARINA (MITES)	Acarina	5	-	R	-	R
	No of taxa		13	8	15	12
	MCI		75	78	88	73
	SQMCIs		2.8	3.4	3.8	3.9
	EPT (taxa)		3	1	4	2
	%EPT (taxa)		23	13	27	17
'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 two unnamed tributaries of the Manganui River sampled in relation to the Mangahewa-D wellsite on 19 April 2017

Taxa List	Site Number	MCI score	1	2	3	4
	Site Code		MGN000489	MGN000491	MGN000492	MGN000493
	Sample Number		FWB17212	FWB17213	FWB17214	FWB17215
COELENTERATA	Coelenterata	3	R	-	-	-
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	C	R	-	-
NEMERTEA	Nemertea	3	C	-	-	-
ANNELIDA (WORMS)	Oligochaeta	1	XA	-	C	-
	Lumbricidae	5	-	C	R	R
HIRUDINEA (LEECHES)	Hirudinea	3	C	-	-	-
MOLLUSCA	*Physa*	3	R	A	-	-
	Potamopyrgus	4	A	C	A	R
CRUSTACEA	Copepoda	5	R	-	-	-
	Ostracoda	1	VA	VA	R	-
	Isopoda	5	-	-	R	-
	Paracalliope	5	A	-	C	R
	Paranephrops	5	-	-	-	R
HEMIPTERA (BUGS)	*Microvelia*	3	-	R	-	-
COLEOPTERA (BEETLES)	Elmidae	6	-	-	R	R
	Dytiscidae	5	-	C	-	-
TRICHOPTERA (CADDISFLIES)	Ecnomidae/Psychomyiidae	6	-	-	-	R
	Hydrobiosis	5	-	-	R	-
	Polyplectropus	6	R	-	-	-
	Psilochorema	6	R	-	-	-
	Oxyethira	2	-	-	-	R
	Triplectides	5	-	-	-	R
DIPTERA (TRUE FLIES)	*Aphrophila*	5	-	-	R	-
	Limonia	6	-	-	R	R
	Orthocladiinae	2	-	R	R	R
	Polypedilum	3	R	A	-	-
	Tanypodinae	5	C	C	-	-
	Ceratopogonidae	3	R	-	-	-
	Austrosimulium	3	-	-	C	R
ACARINA (MITES)	Acarina	5	R	C	-	-
	No of taxa		16	11	12	11
	MCI		74	71	80	89
	SQMCIs		1.3	2.1	3.7	4.5
	EPT (taxa)		2	0	1	2
	%EPT (taxa)		13	0	8	18

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

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

Site 1

In the pre-HF survey this site recorded a low taxa richness of 13, while in the post-HF survey a moderate taxa richness of 16 taxa was recorded. Both results are lower than have previously been recorded at this site, although both results are within the range recorded in lowland coastal streams at similar altitude. The macroinvertebrate community was characterised by seven taxa in the pre-HF survey and four taxa in the post-HF survey. The 'moderately sensitive' taxon [amphipod (*Paracalliope*)] and the three 'tolerant' taxa [oligochaete worms, mud snail (*Potamopyrgus*) and seed shrimp (Ostracoda)] were characteristic in both surveys. The two 'moderately sensitive' taxa [caddisfly (*Psilochorema*) and midge (Tanypodinae)] and the 'tolerant' taxon [sandfly (*Austrosimulium*)] were also characteristic in the pre-HF survey (Table 6, Table 7).

Similar MCI scores of 75 and 74 were recorded in the pre-HF and post-HF surveys respectively, characterising the site as having 'poor' macroinvertebrate community health on both occasions. These

scores are within the range previously recorded at this site (Table 5) and are not significantly different (Stark 1998) to the median score for Taranaki lowland coastal streams at similar altitude (median MCI score 79 units; Table 4). $SQMCI_S$ scores of 2.8 and 1.3 units were recorded in the pre-HF and post-HF surveys, a statistically significant (Stark 1998) decrease. The score of 1.3 units was the lowest score recorded at this site to date, by a significant 1.2 units (Table 5).

Site 2

Low taxa richnesses of eight and 11 taxa were recorded at this site in the pre-HF and post-HF surveys respectively. These scores are substantially lower than the previously recorded score of 20 taxa (which is the only previously recorded score at this site. Both scores are within the previously recorded range of scores for lowland coastal streams at similar altitude. There were no characteristic taxa present in the pre-HF survey (Table 6). Three 'tolerant' taxa characterised the community in the post-HF survey [snail (*Physa*), seed shrimp (Ostracoda) and midge larvae (*Polypedilum*)] (Table 7).

Similar MCI scores of 78 and 71 were recorded in the pre-HF and post-HF surveys respectively, both of which categorise the site as having 'poor' macroinvertebrate community health. These scores are not significantly different to the previously recorded score at this site (Table 5) and to the median score for Taranaki lowland coastal streams at similar altitude (Table 4). $SQMCI_S$ scores of 3.4 and 2.1 were recorded in the pre-HF and post-HF surveys respectively, a significant (Stark 1998) decrease. This decrease is a result of the increased abundance of 'tolerant' taxa in the post-HF survey. Both scores are higher than the previously recorded score for this site (Table 5), although this difference is significant (Stark 1998) only for the pre-HF survey. Both scores are lower than the median $SQMCI_S$ score for Taranaki lowland coastal streams at similar altitude (Table 4) although this difference is significant (Stark 1998) only for the post-HF survey.

Site 3

A moderately low taxa richness of 15 taxa was recorded in the pre-HF survey, while a low richness of 12 taxa was recorded in the post-HF survey. These scores are towards the upper end of the previously recorded range of scores at this site (Table 5), and are a substantial 5 and 8 taxa below the median richness for Taranaki lowland coastal streams at similar altitude respectively (Table 4). In both surveys the macroinvertebrate community was characterised by only one taxon, the 'tolerant' snail (*Potamopyrgus*) (Table 6, Table 7).

Similar MCI scores of 80 and 88 were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'fair' macroinvertebrate community health. These scores are equal to and eight units higher than the highest previously recorded score at this site (Table 5). Both scores are higher than the median score for Taranaki lowland coastal streams at similar altitude (Table 4). Similar $SQMCI_S$ scores of 3.8 and 3.7 were recorded in the pre-HF and post-HF surveys respectively. These scores are within the previously recorded range at this site (Table 5) and are not significantly different to the median score for Taranaki lowland coastal streams at similar altitude (Table 4).

Site 4

Low taxa richnesses of 12 and 11 taxa were recorded in the pre-HF and post-HF surveys respectively. These scores are within the range of previously recorded richnesses at this site, and are substantially lower than the median richness for Taranaki lowland coastal streams at similar altitude. The macroinvertebrate community in the pre-HF survey was characterised by one tolerant taxon [snail (*Potamopyrgus*)] and one 'moderately sensitive' taxon [caddisfly (*Triplectides*)] (Table 6).

In the post- HF survey, there were no characteristic taxa found. This sample recorded eleven 'rare' taxon, each with only one small individual found. This sample also contained very little organic matter, and considerable foaming was noted during the processing of the sample.

MCI scores of 73 and 89 were recorded in the pre-HF and post-HF surveys respectively, categorising the site as having 'poor' and 'fair' macroinvertebrate community health on the two occasions. This is a statistically significant (Stark 1998) increase between the two surveys. The result recorded in the post-HF survey was the highest score recorded at this site to date by three units (Table 5). Similar $SQMCI_S$ scores of 3.9 and 4.5 were recorded in the pre-HF and post-HF surveys respectively. These scores are respectively equal to and 0.6 unit higher than the highest previously recorded score at this site (Table 5). Both scores are similar to the median $SQMCI_S$ score for Taranaki lowland coastal streams at similar altitude (Table 4).

Discussion and conclusions

The Councils 'kick-sampling' and 'vegetation sweep' techniques were used at four sites to collect macroinvertebrates from two unnamed tributaries of the Manganui River in the vicinity of the Mangahewa-D wellsite. This has provided data to assess whether discharges to one of these tributaries had any affect on the macroinvertebrate communities of the unnamed tributary. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when 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 MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. However, it is also influenced by the 'patchiness' of macroinvertebrates on the streambed, and as such must be considered in the context of all three metrics. Significant differences in either the MCI or the $SQMCI_S$ scores between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

The pre-HF survey recorded low or moderately low taxa richnesses at the four sites. Sites 1 and 2 recorded the lowest taxa richnesses to date, although as there is only limited previous data (five previous surveys at site 1 and one previous survey at site 2), this may be of little significance. The post-HF survey recorded similar richnesses to the pre-HF survey. In general, taxa richnesses were relatively low for Taranaki lowland coastal streams at similar altitude.

MCI scores of 75, 78, 88 and 73 were recorded at sites 1-4 respectively in the pre-HF survey. The score recorded at site 3 was significantly higher compared to site 1 and site 4, while there were no other significant differences between sites. The post-HF survey recorded scores of 74, 71, 80 and 89 at the four sites respectively. On this occasion, the score at site 4 was significantly higher when compared to site 1 and site 2, while there were no other significant differences between sites. The scores at sites 1, 2 and 3 remained similar between the two surveys while at site 4 a significant increase was recorded.

$SQMCI_S$ scores of 2.8, 3.4, 3.8 and 3.9 were recorded in the pre-HF survey at sites 1-4 respectively. The score at site 1 was significantly lower compared to the score at site 3 and at site 4, while there were no other significant differences between sites. The post-HF survey recorded 1.3, 2.1, 3.7 and 4.5 at the four sites respectively. The score at site 1 was significantly lower compared with site 3 and site 4, but was similar to the score at site 2. Site 2 also recorded a score significantly lower than at site 3 and at site 4, while sites 3 and 4 had similar scores. Between surveys, the scores at site 1 and site 2 decreased significantly, while site 3 remained similar and site 4 showed a non-significant increase.

The results recorded at site 4 in the post-HF survey raise some concerns, especially with the low taxa richness and low abundances (only a single small individual) of each taxa found. Although the MCI and $SQMCI_S$ scores are higher than have been previously recorded, this is likely to be caused by the lowered taxa richness and abundance. When all three metrics are considered together, and when the exceptionally low abundance of each taxon and small size of each taxon are considered, this indicates that the macroinvertebrate community is likely to have been exposed to some sort of event (such as a toxic discharge) and the re-colonisation process was starting to occur. This may have been related to the fresh only four days prior to sampling. However, the notably small amount of other organic matter in the sample and foaming noted during sample processing leads further credence to the likelihood of the poor results being caused by a discharge of some type. Because these observations were made only at site 4 (the furthest downstream site) and not at site 2 (in the receiving tributary) or site 3 (downstream of the receiving tributary confluence) there is uncertainty as to whether any discharge may have come from the Mangahewa-D wellsite, as surface run-off from the surrounding area or from some natural event. Follow-up streambed sediment sampling has proven inconclusive, however the company has undertaken further investigation.

Overall, the results of these two surveys indicate moderately low and low taxa richnesses, 'poor' to 'fair' MCI scores and moderate to low $SQMCI_S$ scores. The results at site 4 in the post-HF survey indicate some event has caused detrimental effects, but given that sites 2 and 3 which are also downstream of the wellsite discharges show no such effects, it is uncertain as to whether this is a result of any wellsite discharges. Follow-up sampling has proven inconclusive and the Company has undertaken further investigation.

Summary

Macroinvertebrate surveys were undertaken on 6 March and 19 April 2017, using the Council's 'kick-sampling and 'vegetation sweep' techniques to collect samples at four sites. Moderately low to low taxa richnesses were recorded, which were similar between the two surveys. MCI scores classified the sites as having 'fair' or 'poor' macroinvertebrate community health, and remained similar between the two surveys at sites 1, 2 and 3, while site 4 showed a significant increase between the two surveys. $SQMCI_S$ scores ranged between 2.8 and 3.9 in the pre-HF survey, and between 1.3 and 4.5 in the post-HF survey. A significant decrease was recorded at sites 1 and 2, and a significant increase at site 4.

During processing of the samples, it was noted that the sample taken from the post-HF survey had significant foaming, and that in addition to a low taxa richness, only one small individual of each taxon was found. This indicates that this site may have been impacted by some sort of discharge, although as the other sites downstream of the Mangahewa-D wellsite did not show the same impacts it is uncertain as to whether this discharge is in fact from the Mangahewa-D wellsite.

Overall, the results of these surveys indicate that there has been some recent detrimental impact on the macroinvertebrate communities at site 4, although no other sites show the same impact. As such, it is uncertain as to whether this discharge is a result of activities at the Mangahewa-D wellsite.

References

Blakemore KS, 2016. Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, April 2016. TRC report KB010.

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

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

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

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

Stark JD and Fowles CR, 2009: Relationships between MCI, site altitude, and distance from source for Taranaki ring plain stream. Prepared for Taranaki Regional Council. Stark Environmental Report No. 2009-01. 47p.

Sutherland DL, 2015. Biomonitoring of two unnamed tributaries of the Manganui River in relation to drilling by Todd Energy Ltd at the Mangahewa-D wellsite, May 2015. TRC report DS011.

Thomas BT, 2014. Biomonitoring of an unnamed tributary of the Manganui River before and after hydraulic fracturing at Mangahewa-D wellsite by Todd Energy Ltd, April 2014 and August 2014. TRC report BT037.

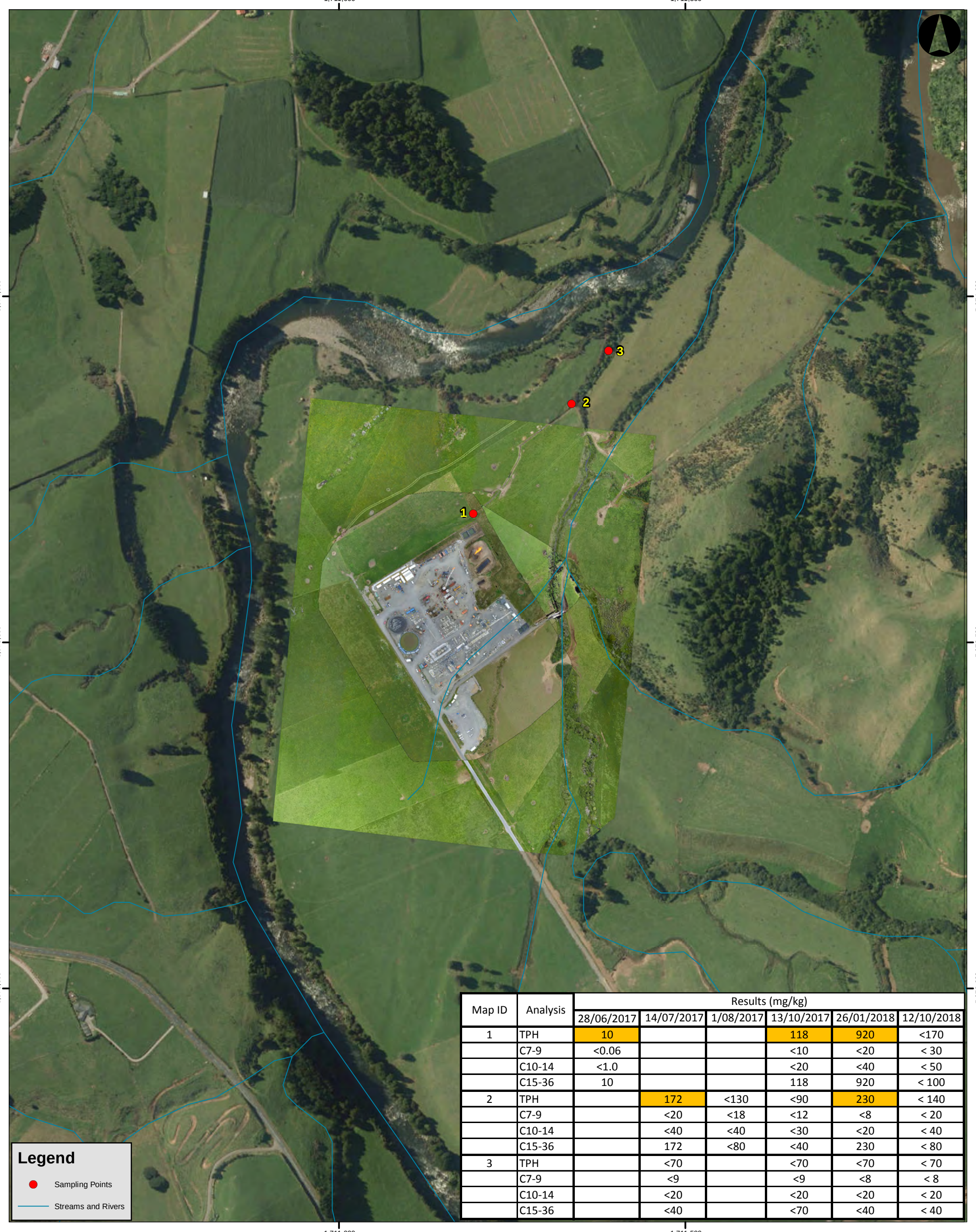
TRC, 2016: Some statistics from the Taranaki Regional Council database (Esam) of freshwater macroinvertebrate surveys performed during the period from January 1980 to 30 September 2016.

Winterbourn MJ, Gregson KLD, Dolphin CH, 2006. Guide to the aquatic insects of New Zealand. [4th edition]. Bulletin of the Entomological Society of New Zealand 14, 108p.

Appendix V

Todd Sediment Results Map

1,711,000
1,711,500
5,674,000
5,673,500
5,673,000



Map ID	Analysis	Results (mg/kg)					
		28/06/2017	14/07/2017	1/08/2017	13/10/2017	26/01/2018	12/10/2018
1	TPH	10			118	920	<170
	C7-9	<0.06			<10	<20	< 30
	C10-14	<1.0			<20	<40	< 50
	C15-36	10			118	920	< 100
2	TPH		172	<130	<90	230	< 140
	C7-9		<20	<18	<12	<8	< 20
	C10-14		<40	<40	<30	<20	< 40
	C15-36		172	<80	<40	230	< 80
3	TPH		<70		<70	<70	< 70
	C7-9		<9		<9	<8	< 8
	C10-14		<20		<20	<20	< 20
	C15-36		<40		<70	<40	< 40

GENERAL NOTES
1. Coordinates are in terms of New Zealand Transverse Mercator

DISCLAIMER
GIS data and imagery are for indicative purposes only.

No works may be undertaken in the vicinity of pipelines without a work permit and 2 days' notice.
Contact Details: First Gas: (06) 755-0861 Core Group: (06) 769-9391, (0800) 267-347

TITLE

TODD INTERNAL STREAM SEDIMENT SAMPLE RESULTS: MANGAHEWA D

DRAWN	P. STREET	17.11.17
CHECKED	S. STANDEN	17.11.17
PROJECT No	05131	
LOCATION	TARANAKI	
SCALE	1:5,000	
ORIGINAL SIZE	A3	

TODD ENERGY

BTW COMPANY
SURVEYING | ENGINEERING | PLANNING & ENVIRONMENT

NO	DATE	BY	CHKD.	
2	19.10.18	TS	GL	Results table updated,
1	08.02.18	TS	SS	Results table updated,

REVISIONS

0 50 100 200 300 Meters

1:5,000

DRAWING No 05131-138-GIS

SHEET 1

REVISION 2