TAG Oil (NZ) Ltd Company Groundwater Monitoring Programme Compliance Report 2011-2012

Technical Report 2012–80

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Taranaki Regional Council
Private Bag 713
STRATFORD

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Executive summary

TAG Oil (NZ) Ltd operates two hydrocarbon wellsites and a production station, located on Mountain Road and Taylor Road at Ngaere, in the Patea and Waingongoro catchments. . This report[1] covers the results and findings of a one-off investigation implemented by the Council in respect of the activities of and consents held by TAG that relate to past discharges to land and water (including by previous site occupants). The investigation related to concerns expressed by a few members of the public, over possible effects upon shallow aquifers and surface water in the vicinity of the wellsites allegedly as a result of past hydraulic fracturing activities. The investigation was implemented by the Taranaki Regional Council during the period under review to assess the consent holders' past environmental performance, and the results and environmental effects of the relevant activities.

The wellsites and production station each have resource consents relating to the discharge of water within the catchment. There are 2 consents to discharge storm water and treated production water into tributaries of the Patea or Waingongoro rivers. Provisions within the Regional Fresh Water Plan for Taranaki (2001) also apply.

The Council's monitoring programme for the investigation under review included inspections and 8 water samples representative of groundwater quality in the locality collected for physicochemical analysis. A comprehensive suite of parameters were analysed.

The monitoring showed that there was no evidence of effects from hydraulic fracturing or other hydrocarbon exploration and extraction activities, upon shallow groundwater or surface water in the vicinity.

The investigation indicated that the Company demonstrated a high level of environmental performance and compliance with the resource consents and with the provisions of the Council's Regional Fresh Water Plan for Taranaki (2001), in respect of the matters under investigation.

This report includes recommendations concerning the nature of monitoring in the vicinity of wellsites where hydraulic fracturing is to take place or has taken place.

[1] This version of the report replaces an earlier version published on 19 March 2013. After publication of the first version, it was found that 3 results from the laboratory sheets (Appendix II) had not been transferred accurately into Table 3. The correct results had been referenced in all interpretation, discussion, and recommendations.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

This report is for the period July 2011-June 2012 by the Taranaki Regional Council describing a supplementary monitoring programme associated with activities undertaken by TAG Oil (NZ) Ltd at two of its hydrocarbon production wellsites. The Company operates wellsites situated on Taylor Road and Mountain Road, and a production station situated on Mountain Road, at Ngaere, central Taranaki, in the Patea and Waingongoro catchments. The wellsites and production station each have resource consents relating to the discharge of water within the catchment.

This report covers the results and findings of a one-off investigation implemented by the Council in respect of the activities of and consents held by TAG that relate to previous discharges to land and water. The investigation related to concerns expressed by a few members of the public, over possible effects upon shallow aquifers and surface water in the vicinity of the wellsites allegedly as a result of past hydraulic fracturing activities.

The overall record of consent compliance and environmental performance at the wellsites and the production station is set out in Council monitoring reports[2]. This report has been prepared by the Taranaki Regional Council to address a specific investigation of concerns raised over the potential effects of past activities on water resources in the area.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the Resource Management Act and the Council's obligations and general approach to monitoring sites through monitoring programmes, the resource consents held by TAG Oil in association with the Cheal field in the Ngaere sub-catchment, and the nature of the monitoring/investigation programme in place for the period under review.

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

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

Section 4 presents recommendations to be implemented in future monitoring.

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

[2] See bibliography

1.1.3 The Resource Management Act (1991) and monitoring

The Resource Management Act 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 a discharger, and may include cultural and socio-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 (eg, recreational, cultural, or aesthetic);
(e) risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Taranaki Regional Council is recognising the comprehensive meaning of `effects' inasmuch as is appropriate for each discharge source. Monitoring programmes are not only based on existing permit conditions, but also on the obligations of the Resource Management Act to assess the effects of the exercise of consents. In accordance with section 35 of the Resource Management Act 1991, the Council undertakes compliance monitoring for consents and rules in regional plans; and maintains an overview of performance of resource users against regional plans and consents. Compliance monitoring, (covering both activity and impact) monitoring, also enables the Council to continuously assess its own performance in resource management as well as that of resource users particularly consent holders. It further 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 performance

Besides discussing the various details of the performance and extent of compliance by the Company during the period under review, this report also assigns an overall rating. The categories used by the Council, and their interpretation, are as follows:

- a **high** level of environmental performance and compliance indicates that essentially there were no adverse environmental effects to be concerned about, and no, or inconsequential (such as data supplied after a deadline) non-compliance with conditions.

- a **good** level of environmental performance and compliance indicates that adverse environmental effects of activities during the monitoring period were negligible or minor at most, or, 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, or, there were perhaps some items noted on inspection notices for attention but these items were not urgent nor critical, and follow-up inspections showed they have been dealt with, and inconsequential non compliances with conditions were resolved positively, co-operatively, and quickly.

- **improvement desirable** indicates that the Council may have been obliged to record a verified unauthorised incident involving measureable environmental impacts, or, there were measureable environmental effects arising from activities and intervention by Council staff was required, and there were matters that required urgent intervention, took some time to resolve, or remained unresolved at end of the period under review, and/or abatement notices may have been issued.

- **poor performance** indicates that the Council may have been obliged to record a verified unauthorised incident involving significant environmental impacts, OR, there were adverse environmental effects arising from activities and there were grounds for prosecution or an infringement notice.

1.2 Process description

The Cheal A Wellsite was first established on Mountain Road at Ngaere by NZOG Services Ltd in 1995. The consents for the site were subsequently transferred to Indo-Pacific Energy (NZ) Ltd in 2002, then Rata Energy Ltd in 2004 and Austral Pacific Energy (NZ) Ltd in 2005. Austral Pacific developed the neighbouring Cheal B Wellsite in July 2006 and started construction of the Cheal Production Station adjacent to the Cheal A Wellsite in late 2006. The production station was commissioned in August 2007 and the tie-in to the Cheal B pipeline was completed in December 2007.

The Cheal field was previously operated by Austral Pacific Ltd, in conjunction with Rata Energy (NZ) Ltd. The owners of the Cheal facilities, including Austral Pacific Energy (NZ) Ltd, were placed in receivership in April 2009. The consents were transferred to Cheal Petroleum Limited in October 2009 and the site is now operated by TAG Oil, operating as Cheal Petroleum Ltd.

There are three wellsites for the Cheal field, denoted as Cheal A, B and C. The wellsites and the associated Cheal production station are the subject of on-going consent compliance monitoring by the Council. This work is reported separately by the Council

Two of these wellsites (A and B) have been subject to the process of hydraulic fracturing, in 2010. The fracturing at the Cheal well sites comprised[3]:

- Wells A7 and B3 were drilled vertically to 1750 mTVD. Well BH1 was deviated and had a horizontal 548m section at 1758 mTVD.
- A water based fracture fluid system was used.
- The total volume of water/fracture chemicals and sand proppant (in brackets) for A7 well included 77.2 cubic metres (17.5 tons sand proppant), for the B3 well 183 cubic metres (34.4 tons sand proppant), and for the BH1 well 511 cubic metres (115 tons sand proppant). The BH1 well comprised five fracture stages, with five zones each subject to a separate fracture treatment.
- Various additives were used as additives with the fracture fluids. MSDS sheets for these additives are available (Appendix I of reference 1).

[3] '*Hydrogeologic Risk Assessment of Hydraulic Fracturing for Gas Recovery in the Taranaki Region (2012)*' Taranaki Regional Council, updated May 2012

- The fracture chemicals comprised 0.85 % of the fracture fluid in each fracture.
- Maximum surface pressure used for the A7 well 3,700 psi, 2,200 psi for B3 well, and 2,268 psi for the BH1 well.
- Volume of return fluids for each well was difficult to determine as they flowed back to a group separator and were reused in power fluids.
- Reservoirs are in the Mt Messenger geological formation (which lies below the Matemateonga formation, the upper part of which has the freshwater/salt water interface).
- Modelling of the maximum anticipated fracture fissures extent at 1750 m indicated that fractures would extend less than 50 m within the reservoir.
- The freshwater/salt water interface for the wells is 200-500 m below the surface in the Matemateonga Formation. (Council data from an old exploration well close by Stratford notes it is at a depth of about 600 m in the Matemateonga Formation, which is consistent with the maximum depth estimate by Tag Oil Ltd).
- In view of the above data, the separation distance from the top of fracture fissures in the reservoir to the freshwater/saltwater interface is about 1100 m (1700-600=1100 m). Within this zone are numerous "geologic seals" (interbedded claystone and sandstone layers), which provide protective separation between the zone of fracturing and the zone of freshwater aquifers in the Matemateonga Formation above, and, therefore, minimize any potential for an impact from hydraulic fracturing operations.
- Return fluids were reused, or taken off site and deep well injected at depth into saline zones as provided for by resource consent. Water produced with the hydrocarbons (termed 'produced water') contains some fracture fluids that are "leached" out of the formation. It is used with other produced water from the reservoir and imported water in power fluid which is heated and circulated through the reservoir to enhance oil recovery. Any excess power fluids are deepwell injected under a resource consent.

A summary of this information is presented below in Table 1.

Table 1 TAG Oil Ltd supplied hydraulic fracturing data for Cheal well sites

Date	Well	Type fracture fluid medium	Geologic formation	Depth mTVD	Freshwater/ Saltwater Interface (m TVD)
26 April 2010	Cheal A7	Water	Mt Messenger	1750	200-500
29 September 2010	Cheal B3	Water	Mt Messenger	1750	200-500
14 November 2010	Cheal BH1	Water	Mt Messenger	1750	200-500

Note: The BH1 well contains the horizontal section referred to below and was subject to a multi stage fracture programme with five zones subject to a separate fracture treatment.

As part of well flow enhancement actions, in 2007 a process was set up by a previous consent holder to allow a flow of fluids ('power fluids') between two wells on the Cheal A wellsite (Cheal-A3X and Cheal-A4). This process was consented via Consent 4728-1. During the implementation of this process, there was leakage up the wellstem into a formation at a depth of 1400 m.

The receiving formation comprised saline formation water and hydrocarbons, and had been previously targeted as a potentially hydrocarbon producing formation (unsuccessfully). TAG undertook remedial actions to prevent further leakage.

Some time after the fracturing activities and the well flow enhancement activities described above, concerns were expressed to the Council from individuals within the local community, alleging that fracturing had caused contamination of spring and surface water in the vicinity. The Council therefore determined to investigate the situation further. This report describes the results and findings of that investigation.

1.3 Resource consents and Regional Fresh water Plan

1.3.1 Discharge permits

Section 15(1)(a) of the Resource Management Act stipulates that no person may discharge any contaminant into water, unless the activity is expressly allowed for by a resource consent or a rule in a regional plan, or by national regulations.

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

At the time, it was the Council's position that (taking all matters into account), it was not necessary for fracturing activities to be covered by a consent. However, notwithstanding this, any discharge to land that may affect water as per Section 15(1)(b) of the Resource Management Act must still satisfy the provisions of the Regional Fresh Water Plan for Taranaki (2001).

Cheal Petroleum Ltd holds water discharge permit **4727-2** to cover the discharge of up to 100 cubic metres/day [1.2 litres/second] of treated stormwater and treated production water from hydrocarbon exploration and production operations at the Cheal A wellsite and the Cheal production station onto and into land in the vicinity of an unnamed tributary of the Mangawharawhara Stream in the Waingongoro catchment. This permit was issued by the Taranaki Regional Council on 10 November 2011. It replaced an earlier one for the Cheal A wellsite issued on 2 May 1995 (change to conditions September 2005) under Section 87(e) of the Resource Management Act. The renewed consent is due to expire on 1 June 2029.

Condition 2 states the concentration limits in the receiving waters.

Condition 3 states the limit for hydrocarbons in the discharge.

Condition 4 states there shall be no change to the natural colour and clarity of the receiving water.

Cheal Petroleum Ltd holds water discharge permit **6815-1** to cover discharge of treated stormwater and treated produced water from hydrocarbon exploration and production operations at the Cheal B well site onto and into land and into the

vicinity of the Ngaere Stream in the Patea catchment at or about GR: Q20:227-026. This permit was issued by the Taranaki Regional Council on 23 March 2006 under Section 87(e) of the Resource Management Act. It is due to expire on 1 June 2022.

Condition 8 states the concentration limits of various constituents in the discharge.

Conditions 9 and 10 stipulate the acceptable degree of effects upon any receiving waters.

1.3.2 Rule in the Regional Fresh Water Plan for Taranaki (2001)

Rule 29 of the RFWP stipulates as a permitted activity, that any discharge of contaminants from industrial and trade premises onto or into land shall not result in a direct discharge into a surface water body and shall not be noxious, dangerous, offensive or objectionable to such an extent that it is or is likely to have a significant adverse effect on the environment.

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the Resource Management Act sets out obligation/s upon the Taranaki Regional Council to gather information, monitor, and conduct research on the exercise of resource consents, and the effects arising, within the Taranaki region and report upon these.

The Taranaki Regional 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 shallow groundwater/surface water in the vicinity of the Cheal well sites consisted of two primary components.

1.4.2 Programme liaison and management

There is generally a significant investment of time and resources by the Taranaki Regional Council in ongoing liaison with resource consent holders over consent conditions and their interpretation and application, in discussion over monitoring requirements, preparation for any reviews, renewals, or new consents, advice on the Council's environmental management strategies and the content of regional plans, and consultation on associated matters.

1.4.3 Chemical sampling

The Taranaki Regional Council undertook sampling of waters in the vicinity of the wellsites, from sites considered to give representative information on the quality of shallow groundwater in the locality. Water from two bores, two shallow wells, three springs and the stream was analysed, for almost 50 parameters, including a wide range of compounds commonly associated with hydraulic fracturing ("fracking") and other processes used in oil and gas exploration and well development. Sampling sites and testing parameters were carefully selected in consultation with GNS Science

(the Institute of Geological and Nuclear Science) to determine whether exploration or well development activities had indeed caused contamination.

The parameters included:

- The "BTEX" range of compounds – benzene, toluene, ethyl benzene and xylene
- Methanol
- Dissolved natural gas
- Aldehydes, which can be used as biocides (disinfectants) in fracturing
- Glycols
- Total petroleum hydrocarbons
- Trace metals
- Conventional parameters widely used to characterise fresh waters

2. Results

2.1 Water

2.1.1 Sampling

In order to select suitable sites for sampling, a survey of water abstractions sites in the vicinity of the Cheal wellsites was carried out. Initially, a desktop review of data held by the Council, including a search of the Council 'wells' database, was conducted. The desktop review indicated that the Council held records of several groundwater and surface water abstractions, in the area of investigation. Following the desktop review, a field survey was undertaken to confirm the location of known abstraction sites, and to identify any additional abstractions that may not have been registered on the Council database.

Following the desktop and field surveys, a total of 8 sites were selected for sampling. The selection of sites was designed to provide a sample set representative of water abstractions in the investigation area, including springs, groundwater wells/bores and surface water abstractions. Other criteria assessed were the distance of each site from the Cheal wellsites and whether the sample site was up-gradient or down-gradient of the Cheal wellsites, based on the inferred groundwater flow direction in the area of investigation.

A description of the various sites is as follows:

- Site 1 is a bore, which taps the unconfined volcanics aquifer. The bore is cased and screened to a total depth of 22.8 m.
- Site 2 is a large spring which provides baseflow to Te Ngaere Stream.
- Site 3 is a shallow dug well, which taps the unconfined volcanics aquifer. The well has a total depth of 2.8 m.
- Site 4 is a lined dug well, which taps the unconfined volcanics aquifer. The well has a total depth of 8 m.
- Site 5 is a bore, which taps the unconfined volcanics aquifer. The bore is cased and screened; the total depth is in excess of 10.8 m.
- Site 6 is on the in the Te Ngaere Stream upstream of the Cheal-B wellsite.
- Site 7 is on the Te Ngaere Stream downstream of the Cheal-B wellsite.
- Site 8 is a spring seepage adjacent to the Cheal-B wellsite. The spring discharges to the Te Ngaere Stream, between sites 6 and 7.

The locations of the sampling points are illustrated below in Figure 1.

Samples were collected for physicochemical analysis from sites 1 to 5 on 13 February 2012 and from sites 6 to 8 on 27 February 2012. Samples for bacteriological analysis were collected from sites 6 to 8 on 27 February 2012. The Council contacted the individual land owners associated with each site, to advise of the intention to access sites and collect samples. Results were subsequently provided to each land owner.

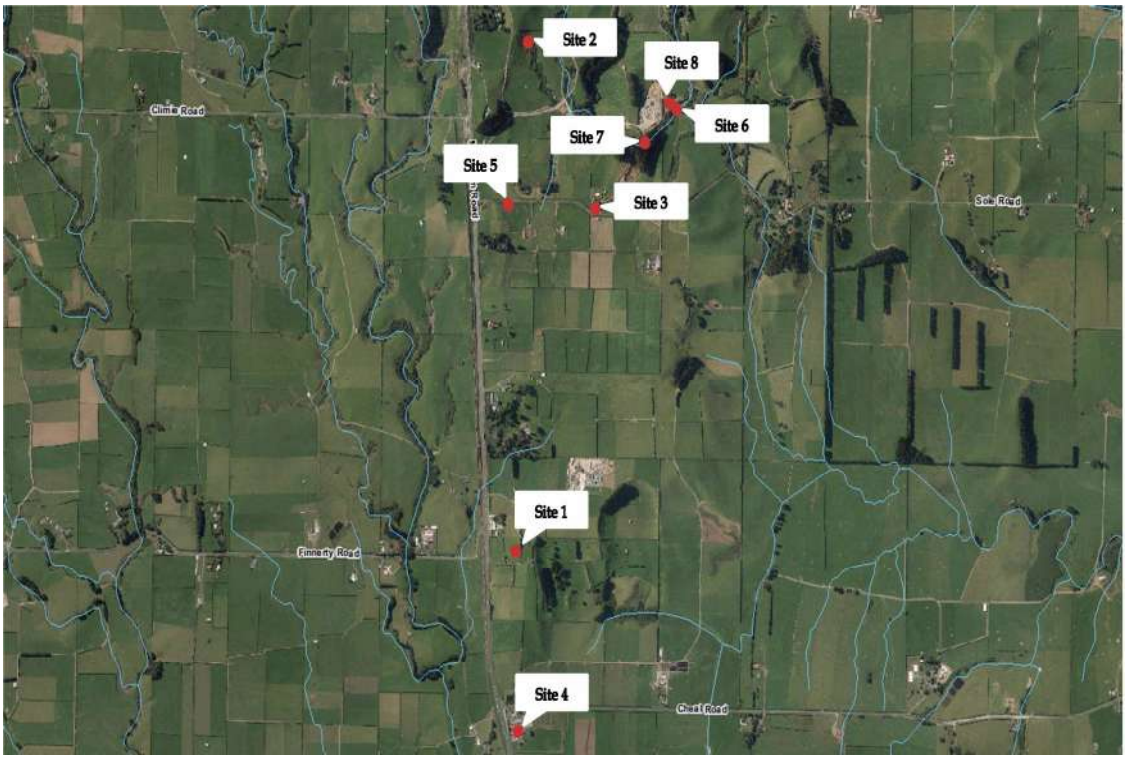

Figure 1 Sampling site locations for Cheal wellsite monitoring

2.1.2 Results of receiving environment monitoring

The results of analyses arising from the Council's investigation are set out below in Tables 1-4.

In terms of an indication of a possible effect from fracturing activities upon natural waters, the key inorganic parameters (and their changes) would be a significant increase in chloride, conductivity, total dissolved solids, bromide, and the sums of anions and cations. These changes would arise from the presence of formation water, which is highly saline. Materials used in drilling would be manifested in an increase in pH, alkalinity, total hardness, barium, sulphate, and nitrate, if they entered natural waters.

Tables 1-4 show no such increases in any key parameters for any of the samples.

The discharge of flow from return fluids or produced hydrocarbons from a hydrocarbon-bearing reservoir would manifest itself in the presence of ethylene glycol, propylene glycol, methanol, and/or formaldehyde (combinations of which are typically used in fracturing fluids); the BTEX group of chemicals (present in formation hydrocarbons, and also if a diesel-based fracturing fluid was used); and in hydrocarbon gases in groundwater. It should be noted that the gases in question (in particular methane, also known as swamp gas) are also found wherever there is decomposition of organic material within the zone of a freshwater aquifer. The locality in question is a large swamp (the Ngaere swamp), so that it is to be expected that methane might be detected within shallow groundwater samples.

No sample showed any trace of the additives typically used in fracturing fluids. No sample showed any trace of hydrocarbons (BTEX or hydrocarbons of C_7 structure or higher C_n) being present.

A trace of methane gas was found in three samples. The levels of methane found were lower than those found in many other groundwater samples that have been collected across Taranaki, specifically in localities where no fracturing has ever taken place.

Bacteriological contamination of the level to be expected in a pastoral environment was found in the Te Ngaere Stream and in the spring discharging into the stream adjacent to the Cheal –B wellsite. The highest level of bacteriological contamination was found in the spring itself. This shallow spring is fed from surrounding farmland.

Table 1 Inorganic analytes in samples

Analyte	Units	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Sum of Anions	meq/L	2.1	1.69	1.24	1.64	2.1	1.49	1.7	2.1
Sum of Cations	meq/L	2.1	1.67	1.2	1.59	2.2	1.34	1.65	1.86
pH	pH Units	6.6	6.8	6.6	6.7	7.3	7.4	7.2	7.1
Total Alkalinity	g/m3 as $CaCO_3$	40	42	33	44	71	45	48	40
Bicarbonate	g/m^3 at 25°C	49	51	40	54	86	55	58	49
Total Hardness	g/m3 as $CaCO_3$	62	50	39	45	70	39	47	51
Conductivity (EC)	mS/m	21.5	17.6	12.9	17	20.7	15	17.4	21.3
Total Dissolved Solids (TDS)	g/m^3	199	153	95	139	163	110	127	167
Dissolved Barium	g/m^3	0.0103	0.021	0.041	0.0107	0.007	0.023	0.034	0.0132
Dissolved Calcium	g/m^3	15.9	12.4	11.3	10.6	16.4	10.1	11.7	12.6
Dissolved Copper	g/m^3	0.0105	< 0.0005	0.0005	< 0.0005	0.0031	< 0.0005	0.0006	0.0005
Dissolved Iron	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	0.02	0.35	0.56	0.85
Dissolved Magnesium	g/m^3	5.4	4.7	2.5	4.5	7.1	3.3	4.3	4.8
Dissolved Manganese	g/m^3	0.0022	0.0017	0.0012	< 0.0005	0.0023	0.057	0.197	0.077
Dissolved Nickel	g/m^3	0.0048	< 0.0005	< 0.0005	< 0.0005	0.001	< 0.0005	< 0.0005	< 0.0005
Dissolved Potassium	g/m^3	3.9	2.9	4.7	3.1	3.2	3.5	4.8	2.1
Dissolved Sodium	g/m^3	17.3	13.5	7	14.2	15.1	10.7	12.9	17.4
Dissolved Zinc	g/m^3	0.042	0.0031	0.0049	0.0018	0.3	< 0.0010	0.0027	< 0.0010
Bromide	g/m^3	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.07	0.08	0.08
Chloride	g/m^3	21	16.9	9.3	15.5	13.7	16.7	20	28
Nitrite-N	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.008	0.004

Analyte	Units	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Nitrate-N	g/m³	6.2	4.1	2.4	2.9	2.7	0.98	1.41	5.1
Nitrate-N + Nitrite-N	g/m³	6.2	4.1	2.4	2.9	2.7	0.98	1.42	5.1
Sulphate	g/m³	10.8	3.9	7	5.2	6	2.6	3.8	5.7

Table 2 Organic analytes in samples

Analyte	Units	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Ethylene glycol	g/m³	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Propylene glycol	g/m³	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Methanol	g/m³	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

Table 3 Hydrocarbon gases in samples

Analyte	Units	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Methane	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.009	0.028	0.149

Table 4 Bacteriological quality of samples

Location:	Surface Water Upstream of Cheal-B Site	Surface Water Downstream of Cheal-B Site	Spring Cheal-B Site
Date:	27 Feb 2012	27 Feb 2012	27 Feb 2012
Time (NZST):	12:45	13:10	13:30
Faecal Coliforms (per 100ml)	110	68	150
E.Coli (per 100ml)	88	68	96

3. Discussion

3.1 Environmental effects of fracturing and other well flow enhancement activities on shallow groundwater/surface water

Samples were collected across a wide area, from pre-determined points, in order to determine whether any evidence could be found to support concerns that hydraulic fracturing or other exploration activities had led to contamination of surface waters or shallow freshwater aquifers.

Analysis of samples collected from a number of bores, springs, and wells tapping into shallow groundwater in the vicinity of the Cheal wellsites showed no trace of any contamination that can be associated with either drilling or fracturing activities. The only contamination of natural water quality that could be detected was due to bacteriological contamination. While microbial source testing was not applied to this contamination, it is most likely that it reflects runoff from grazing animals.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record as demonstrated in the investigation under review is set out in Table 5.

Table 5 Summary of performance for consents and by comparison with the RFWP (relevant provisions)

Condition requirement	Means of monitoring during period under review	Compliance achieved?
Consent 4727-2 To discharge treated stormwater and produced water from hydrocarbon exploration and production operations at the Cheal-A wellsite and Cheal Production Station, onto and into land in circumstances where it may enter an unnamed tributary of the Mangawharawhara Stream (a tributary of the Waingongoro River)		
8. Discharge limits pH 6-9; suspended solids less than 100 gm^{-3}; total recoverable hydrocarbons less than 15 gm^{-3}; chloride less than 50 gm^{-3}	Inspection and sampling	Yes
10. After mixing, limits to be applied to films and scums; changes in colour or clarity; odour; suitability for farm animal consumption; and in-stream ecology	Inspection and sampling	Yes
Consent 6815-1 To discharge treated stormwater and treated produced water from hydrocarbon exploration and production operations at the Cheal-B wellsite onto and into land in the vicinity of the Ngaere Stream in the Patea catchment		
7. Discharge limits pH 6.5-8.5; suspended solids less than 100 gm^{-3}; total recoverable hydrocarbons less than 15 gm^{-3}; chloride less than 50 gm^{-3}	Inspection and sampling	Yes
9. After mixing, limits to be applied to films and scums; changes in colour or clarity; odour; suitability for farm animal consumption; and in-stream ecology	Inspection and sampling	Yes
Rule 29 RFWP Discharges to land from industrial and trade premises as a permitted activity		

Condition requirement	Means of monitoring during period under review	Compliance achieved?
Discharge shall not result in …runoff of any contaminant into a surface water body	Inspection and sampling	Yes
No direct discharge of any contaminant into a surface water body	Inspection and sampling	Yes
Discharge not to cause adverse effects as detailed	Inspection and sampling	Yes
Overall assessment of consent compliance, RFWP compliance, and environmental performance in respect of this issue		**High**

Based on the investigation under review, the consent holders demonstrated a high level of environmental performance and compliance with the resource consents and the Council's Regional Fresh Water Plan for Taranaki, in respect of effects upon shallow groundwater and surface water. A comprehensive sampling and testing regime at multiple points in the vicinity of the drilling and fracturing activities showed no evidence of effects from fracturing or other exploration and flow development activities, on shallow water aquifers and surface waters.

3.3 Alterations to monitoring programmes for future fracturing activities

In designing and implementing the monitoring programmes for discharges to land and water in the region, the Taranaki Regional Council has taken into account the extent of information made available by previous authorities, its relevance under the Resource Management Act, the obligations of the Act in terms of monitoring discharges and effects, and subsequently reporting to the regional community, 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 discharging to the environment.

It is proposed that in the case of future hydraulic fracturing activities in the region, the basic monitoring requirement will be that there is baseline (pre-fracturing) sampling of shallow groundwater and/or surface water at representative sites within the vicinity of the proposed location, for a comprehensive suite of parameters to characterise water quality and as background for detecting any subsequent contamination by fluids used in fracturing and/or present in return flows from hydrocarbon formations, together with subsequent sampling and analysis at intervals up to one year after the conclusion of any fracturing programme. Such a programme will provide the greatest likelihood of detecting any unauthorised discharges arising from fracturing activities (or any other down-well activity), whether via leakage back up the well or via induced fracturing of overlying formations in the vicinity, over the period of greatest likelihood (ie while formation pressure is still at its highest).

A recommendation to this effect is attached to this report.

4. Recommendations

1. THAT this report be forwarded to the Company, and to any interested parties upon request; and

2. THAT monitoring for effects of hydraulic fracturing activities at any wellsite shall in general consist of baseline and post-event sampling of groundwater and/or surface water at appropriately representative locations, taking into account the fracturing activity and the nature of local geology and water uses, for parameters characterising water quality and related to the fracturing fluid and formation characteristics in question.

Glossary of common terms and abbreviations

The following abbreviations and terms are commonly used within Council reports:

Al*	aluminium
As*	arsenic
Biomonitoring	assessing the health of the environment using aquatic organisms
BOD	biochemical oxygen demand. A measure of the presence of degradable organic matter, taking into account the biological conversion of ammonia to nitrate
BODF	biochemical oxygen demand of a filtered sample
bund	a wall around a tank to contain its contents in the case of a leak
CBOD	carbonaceous biochemical oxygen demand. A measure of the presence of degradable organic matter, excluding the biological conversion of ammonia to nitrate
cfu	colony forming units. A measure of the concentration of bacteria usually expressed as per 100 millilitre sample
COD	chemical oxygen demand. A measure of the oxygen required to oxidise all matter in a sample by chemical reaction
Condy	conductivity, an indication of the level of dissolved salts in a sample, usually measured at 20°C and expressed in mS/m
Cu*	copper
Cumec	A volumetric measure of flow- 1 cubic metre per second (1 m^3s^{-1})
DO	dissolved oxygen
DRP	dissolved reactive phosphorus
E.coli	*escherichia coli,* an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample
Ent	enterococci, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre of sample
F	fluoride
FC	faecal coliforms, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample
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 what were the circumstances/events surrounding an incident including any allegations of an incident
l/s	litres per second

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
mixing zone	the zone below a discharge point where the discharge is not fully mixed with the receiving environment. For a stream, conventionally taken as a length equivalent to 7 times the width of the stream at the discharge point
NH_4	ammonium, normally expressed in terms of the mass of nitrogen (N)
NH_3	unionised ammonia, normally expressed in terms of the mass of nitrogen (N)
NO_3	nitrate, normally expressed in terms of the mass of nitrogen (N)
NTU	Nephelometric Turbidity Unit, a measure of the turbidity of water
O&G	oil and grease, defined as anything that will dissolve into a particular organic solvent (e.g. hexane). May include both animal material (fats) and mineral matter (hydrocarbons)
Pb*	lead
pH	a numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5
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
PM_{10}	relatively fine airborne particles (less than 10 micrometre diameter)
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
SS	suspended solids
SQMCI	semi quantitative macroinvertebrate community index;
Temp	temperature, measured in °C (degrees Celsius)
Turb	turbidity, expressed in NTU
UI	Unauthorised Incident
UIR	Unauthorised Incident Register – contains a list of events recorded by the Council on the basis that they may have the potential or actual environmental consequences that may represent a breach of a consent or provision in a Regional Plan
Zn*	zinc

*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 the Council's laboratory.

Bibliography and references

Austral Pacific Energy (NZ) Limited Cheal A 6 & 7 Wellsite Monitoring Programme Annual Report 2007-2008 Technical Report 2008–49, Taranaki Regional Council July 2009

Austral Pacific Energy Limited Cheal B Well site Monitoring Programme Annual Report2006-2007Technical Report 2007–07, Taranaki Regional Council February 2007

Austral Pacific Energy (NZ) Limited Cheal Production Station Monitoring Programme Biennial Report 2007-2009 Technical Report 2009–78, Taranaki Regional Council March 2010

Cheal Petroleum Limited Cheal Production Station Monitoring Programme Annual Report 2009-2010 Technical Report 2010–88, Taranaki Regional Council August 2011

Hydrogeologic Risk Assessment of Hydraulic Fracturing for Gas Recovery in the Taranaki Region (2012) Taranaki Regional Council (updated May 2012)

Rata Energy NZ Limited & Austral Pacific Energy (NZ) Limited Cheal Production Wells Monitoring Programme Annual Report 2005-2006 Technical Report 2006–29, Taranaki Regional Council August 2006

Appendix I

Resource consents held by TAG Oil (NZ) Ltd

TARANAKI REGIONAL COUNCIL
CHIEF EXECUTIVE
PRIVATE BAG 713
47 CLOTEN ROAD
STRATFORD
NEW ZEALAND
PHONE: 06-765 7127
FAX: 06-765 5097
www.trc.govt.nz
Please quote our file number on all correspondence

Discharge Permit

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

Name of Consent Holder:	Cheal Petroleum Limited P O Box 402 NEW PLYMOUTH 4340
Decision Date:	10 November 2011
Commencement Date:	10 November 2011

Conditions of Consent

Consent Granted:	To discharge treated stormwater and produced water from hydrocarbon exploration and production operations at the Cheal-A wellsite and Cheal Production Station, onto and into land in circumstances where it may enter an unnamed tributary of the Mangawharawhara Stream at or about (NZTM) 1712310E-5639497N
Expiry Date:	1 June 2029
Review Date(s):	June 2017, June 2023
Site Location:	Cheal-A wellsite and Cheal Production Station, Mountain Road, Ngaere [Property owners: JR & RP Lightoller]
Legal Description:	Pt Sec 24 Blk VI Ngaere SD [Site of discharge]
Catchment:	Waingongoro
Tributary:	Mangawharawhara

For General, Standard and Special conditions pertaining to this consent please see reverse side of this document
www.trc.govt.nz

General condition

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

Special conditions

1. The 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 minimise any actual or likely adverse effect on the environment associated with the discharge of contaminants from the site.

2. Stormwater discharged shall be collected from a catchment area of no more than 1.3 hectares.

3. At least 7 working days prior the consent holder shall advise the Chief Executive, Taranaki Regional Council of the date of each of the following events:
   a) commencement of any site works, and
   b) commencement of any well drilling operation.

   If either of these events is rescheduled or delayed after advice is given, the consent holder shall immediately provide further notice advising of the new date.

   Any advice given in accordance with this condition shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

4. The consent holder shall maintain a contingency plan that, to the satisfaction of the Chief Executive, Taranaki Regional Council, details measures and procedures to be undertaken to prevent spillage or accidental discharge of contaminants not authorised by this consent and measures to avoid, remedy or mitigate the environmental effects of such a spillage or discharge. The contingency plan shall be provided to the Council prior to discharging from the site.

5. The design, management and maintenance of the stormwater system shall be undertaken in accordance with the information submitted in support of the consent application 5603 in particular sections 7.2 and 8.1.

6. All stormwater and produced water [with a maximum chloride concentration of 50 ppm] shall be directed for treatment through the stormwater treatment system before being discharged.

7. There shall be no discharge of produced water with a chloride concentration greater than 50 ppm.

8. Constituents in the discharge shall meet the standards shown in the following table.

Constituent	Standard
pH	Within the range 6.0 to 9.0
suspended solids	Concentration not greater than 100 gm^{-3}
total recoverable hydrocarbons	Concentration not greater than 15 gm^{-3} [as determined by infrared spectroscopic technique]
chloride	Concentration not greater than 50 gm^{-3}

9. After allowing for a mixing zone of 25 metres, the discharge shall not give rise to an increase in temperature of more than 2 degrees Celsius.

10. After allowing for a mixing zone of 25 metres, the discharge shall not give rise to any of the following effects in the receiving water:

a) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;
b) any conspicuous change in the colour or visual clarity;
c) any emission of objectionable odour;
d) the rendering of fresh water unsuitable for consumption by farm animals;
e) any significant adverse effects on aquatic life.

11. The consent holder shall advise the Chief Executive, Taranaki Regional Council, in writing at least 48 hours prior to the reinstatement of the site and the reinstatement shall be carried out so as to minimise adverse effects on stormwater quality. Notification shall include the consent number and a brief description of the activity consented and be emailed to worknotification@trc.govt.nz.

12. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2017 and/or June 2023, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource 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.

Signed at Stratford on 10 November 2011

For and on behalf of
Taranaki Regional Council

Director-Resource Management

TARANAKI REGIONAL COUNCIL
CHIEF EXECUTIVE
PRIVATE BAG 713
47 CLOTEN ROAD
STRATFORD
NEW ZEALAND
PHONE: 06-765 7127
FAX: 06-765 5097
www.trc.govt.nz
Please quote our file number on all correspondence

Discharge Permit

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

Name of Consent Holder:	Cheal Petroleum Limited P O Box 402 NEW PLYMOUTH 4340
Decision Date [Change]:	24 August 2011
Commencement Date [Change]:	24 August 2011 [Granted: 23 March 2006]

Conditions of Consent

Consent Granted:	To discharge treated stormwater and treated produced water from hydrocarbon exploration and production operations at the Cheal-B wellsite onto and into land in the vicinity of the Ngaere Stream in the Patea catchment at or about (NZTM) 1712659E-5640761N
Expiry Date:	1 June 2022
Review Date(s):	June 2016
Site Location:	Cheal-B wellsite, 2 Taylor Road, Stratford [Property owner: RC & CA Taylor]
Legal Description:	Lot 1 DP 18576 Lots 1& 2 DP 20526 Blk VI Ngaere SD [Discharge source & site]
Catchment:	Patea
Tributary:	Ngaere

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

General condition

a) On receipt of a requirement from the Chief Executive, Taranaki Regional Council the consent holder shall, within the time specified in the requirement, supply the information required relating to the exercise of this consent.

b) Unless it is otherwise specified in the conditions of this consent, compliance with any monitoring requirement imposed by this consent must be at the consent holder's own expense.

c) The consent holder shall pay to the Council all required administrative charges fixed by the Council pursuant to section 36 in relation to:

i) the administration, monitoring and supervision of this consent; and
ii) charges authorised by regulations.

Special conditions

1. 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 minimise any adverse effects of the discharge.

2. The maximum stormwater catchment area shall be no more than 10,470 m^2.

3. The Chief Executive, Taranaki Regional Council, shall be advised in writing at least 7 days prior to any site works commencing, and again in writing at least 7 days prior to any well drilling operation commencing.

4. Prior to the exercise of this consent, the consent holder shall provide for the written approval of the Chief Executive, Taranaki Regional Council, site specific details relating to contingency planning for the wellsite.

5. All stormwater and produced water to be discharged under this permit shall be directed for treatment through the stormwater treatment system for discharge in accordance with the special conditions of this consent.

6. Any above ground hazardous substances storage areas shall be bunded with drainage to sumps, or other appropriate recovery systems, and not to the stormwater catchment.

7. The following concentrations shall not be exceeded in the discharge:

Component	Concentration
pH (range)	6.5 - 8.5
suspended solids	100 gm^{-3}
total recoverable hydrocarbons [infrared spectroscopic technique]	15 gm^{-3}
chloride	50 gm^{-3}

This condition shall apply prior to the entry of the treated stormwater and produced water either onto and into land, or into surface water, at a designated sampling point approved by the Chief Executive, Taranaki Regional Council.

8. After allowing for reasonable mixing, within a mixing zone extending seven times the width of the water body downstream of a designated discharge point, the discharge shall not give rise to an increase in temperature of more than 2 degrees Celsius.

9. After allowing for reasonable mixing, within a mixing zone extending seven times the width of the water body downstream of a designated discharge point, the discharge shall not give rise to any of the following effects in the receiving waters:

   a) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;
   b) any conspicuous change in the colour or visual clarity;
   c) any emission of objectionable odour;
   d) the rendering of fresh water unsuitable for consumption by farm animals;
   e) any significant adverse effects on aquatic life.

10. The discharge onto and into land shall occur a minimum of 30 metres from any surface water body. Discharge shall be onto and into land and there shall be no direct discharge to surface water.

11. The Chief Executive, Taranaki Regional Council, shall be advised in writing at least 48 hours prior to the reinstatement of the site and the reinstatement shall be carried out so as to minimise effects on stormwater quality.

12. This consent shall lapse on the expiry of five years after the date of issue of this consent, 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.

13. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2010 and/or June 2016, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource 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.

Signed at Stratford on 24 August 2011

For and on behalf of
Taranaki Regional Council

Director-Resource Management

Appendix II

Chemical analyses reports

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	977191	SPv2
Contact:	Regan Phipps	**Date Registered:**	14-Feb-2012	
	C/- Taranaki Regional Council	**Date Reported:**	07-Feb-2013	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Groundwater	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		Site 1 13-Feb-2012 9:30 am	Site 2 13-Feb-2012 11:15 am	Site 3 13-Feb-2012 11:38 am	Site 4 13-Feb-2012 12:10 pm	Site 5 13-Feb-2012 12:50 pm
Lab Number:		977191.1	977191.2	977191.3	977191.4	977191.5
Individual Tests						
Sum of Anions	meq/L	2.1	1.69	1.24	1.64	2.1
Sum of Cations	meq/L	2.1	1.67	1.20	1.59	2.2
pH	pH Units	6.6	6.8	6.6	6.7	7.3
Total Alkalinity	g/m³ as $CaCO_3$	40	42	33	44	71
Bicarbonate	g/m³ at 25°C	49	51	40	54	86
Total Hardness	g/m³ as $CaCO_3$	62	50	39	45	70
Electrical Conductivity (EC)	mS/m	21.5	17.6	12.9	17.0	20.7
Total Dissolved Solids (TDS)	g/m³	199	153	95	139	163
Dissolved Barium	g/m³	0.0103	0.021	0.041	0.0107	0.0070
Dissolved Calcium	g/m³	15.9	12.4	11.3	10.6	16.4
Dissolved Copper	g/m³	0.0105	< 0.0005	0.0005	< 0.0005	0.0031
Dissolved Iron	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	0.02
Dissolved Magnesium	g/m³	5.4	4.7	2.5	4.5	7.1
Dissolved Manganese	g/m³	0.0022	0.0017	0.0012	< 0.0005	0.0023
Dissolved Nickel	g/m³	0.0048	< 0.0005	< 0.0005	< 0.0005	0.0010
Dissolved Potassium	g/m³	3.9	2.9	4.7	3.1	3.2
Dissolved Sodium	g/m³	17.3	13.5	7.0	14.2	15.1
Dissolved Zinc	g/m³	0.042	0.0031	0.0049	0.0018	0.30
Bromide	g/m³	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Chloride	g/m³	21	16.9	9.3	15.5	13.7
Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m³	6.2	4.1	2.4	2.9	2.7
Nitrate-N + Nitrite-N	g/m³	6.2	4.1	2.4	2.9	2.7
Sulphate	g/m³	10.8	3.9	7.0	5.2	6.0
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	< 4	< 4
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	< 2	< 2
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010

Sample Type: Aqueous						
Sample Name:		Site 1 13-Feb-2012 9:30 am	Site 2 13-Feb-2012 11:15 am	Site 3 13-Feb-2012 11:38 am	Site 4 13-Feb-2012 12:10 pm	Site 5 13-Feb-2012 12:50 pm
Lab Number:		977191.1	977191.2	977191.3	977191.4	977191.5
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Methane	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7

Analyst's Comments

Supplement to test report issued on the 23/2/12.

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**	**Samples**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-5
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-5
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-5
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	1-5
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-5
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-5
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-5
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-5
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	1-5
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-5
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 21st ed. 2005.	1.0 g/m³ at 25°C	1-5
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-5
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.1 mS/m	1-5
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) 21st ed. 2005.	10 g/m³	1-5
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00010 g/m³	1-5
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-5
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-5
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-5
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-5
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-5

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-5
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-5
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-5
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1-5
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 g/m³	1-5
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3- I (Modified) 21st ed. 2005.	0.002 g/m³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m³	1-5
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 g/m³	1-5

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.

Martin Cowell - BSc (Chem)
Client Services Manager - Environmental Division

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	981830	SPv4
Contact:	Regan Phipps	**Date Registered:**	28-Feb-2012	
	C/- Taranaki Regional Council	**Date Reported:**	07-Feb-2013	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:		
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		Site 6 27-Feb-2012 1:45 pm	Site 7 27-Feb-2012 2:10 pm	Site 8 27-Feb-2012 2:30 pm		
Lab Number:		981830.1	981830.2	981830.3		
Individual Tests						
Sum of Anions	meq/L	1.49	1.70	2.1	-	-
Sum of Cations	meq/L	1.34	1.65	1.86	-	-
pH	pH Units	7.4	7.2	7.1	-	-
Total Alkalinity	g/m³ as $CaCO_3$	45	48	40	-	-
Bicarbonate	g/m³ at 25°C	55	58	49	-	-
Total Hardness	g/m³ as $CaCO_3$	39	47	51	-	-
Electrical Conductivity (EC)	mS/m	15.0	17.4	21.3	-	-
Total Dissolved Solids (TDS)	g/m³	110	127	167	-	-
Dissolved Barium	g/m³	0.023	0.034	0.0132	-	-
Dissolved Calcium	g/m³	10.1	11.7	12.6	-	-
Dissolved Copper	g/m³	< 0.0005	0.0006	0.0005	-	-
Dissolved Iron	g/m³	0.35	0.56	0.85	-	-
Dissolved Magnesium	g/m³	3.3	4.3	4.8	-	-
Dissolved Manganese	g/m³	0.057	0.197	0.077	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m³	3.5	4.8	2.1	-	-
Dissolved Sodium	g/m³	10.7	12.9	17.4	-	-
Dissolved Zinc	g/m³	< 0.0010	0.0027	< 0.0010	-	-
Bromide	g/m³	0.07	0.08	0.08	-	-
Chloride	g/m³	16.7	20	28	-	-
Nitrite-N	g/m³	< 0.002	0.008	0.004	-	-
Nitrate-N	g/m³	0.98	1.41	5.1	-	-
Nitrate-N + Nitrite-N	g/m³	0.98	1.42	5.1	-	-
Sulphate	g/m³	2.6	3.8	5.7	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-

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Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane*	g/m³	< 0.003	< 0.003	< 0.003	-	-
Ethylene*	g/m³	< 0.004	< 0.004	< 0.004	-	-
Methane*	g/m³	0.009	0.028	0.149	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

Supplement to test report issued 9/3/12.

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**	**Samples**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-3
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-3
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H+ B 21st ed. 2005.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-3
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 21st ed. 2005.	1.0 g/m³ at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.1 mS/m	1-3
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 21st ed. 2005.	10 g/m³	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00010 g/m³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-3
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1-3
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 g/m³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3- I (Modified) 21st ed. 2005.	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 g/m³	1-3

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

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

Martin Cowell - BSc (Chem)
Client Services Manager - Environmental Division