



Ministry for the
Environment
Manatū Mō Te Taiao

Managing Environmental Effects of Onshore Petroleum Development Activities (Including Hydraulic Fracturing): Guidelines for Local Government

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This document may be cited as: Ministry for the Environment. 2014. *Managing Environmental Effects of Onshore Petroleum Development Activities (Including Hydraulic Fracturing): Guidelines for Local Government*. Wellington: Ministry for the Environment.

Published in March 2014 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington 6143, New Zealand

ISBN: 978-0-478-41240-6
Publication number: ME 1145

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This document is available on the Ministry for the Environment's website:
www.mfe.govt.nz.

Acknowledgements

These guidelines have been prepared by Rhys Armstrong and Sabrina Young of GHD Ltd, and were reviewed by Mark St Clair of Hill Young Cooper Ltd. Particular thanks is given to Fred McLay of Taranaki Regional Council who helped prepare these guidelines.

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1. Introduction

1.1 Purpose of this document

This document is a non-statutory guide which provides clarity on the roles of central and local government in managing onshore petroleum development activities (including hydraulic fracturing). The guidelines will help regional councils and territorial authorities who regulate oil and gas development activities associated with hydraulic fracturing, or who may do so in the future. The guidelines:

- clarify the regulatory roles of onshore hydraulic fracturing-related activities across central and local government
- provide guidance to local government on managing the effects of onshore oil and gas well site activities under the Resource Management Act 1991 (RMA).

1.2 Scope

These guidelines cover the *whole* life cycle of onshore oil and gas well development, not just hydraulic fracturing, because the hydraulic fracturing process cannot be usefully considered in isolation from other associated well site activities. Accordingly, the guidelines cover seismic surveying, site selection and development, drilling, hydraulic fracturing (if used), management of hazardous substances and waste, and well abandonment/decommissioning.

The guidelines also identify which regulatory agencies in New Zealand are responsible for specific parts of the onshore oil and gas life cycle and outline the legislation that regulates oil and gas development activities.

The guidelines draw on New Zealand case studies, although many have a particular Taranaki flavour because it is currently the only oil and gas producing region in New Zealand. One size does not fit all, because there are differences in the geology, plan framework and rules that will make each oil and gas activity and resource consent application unique to each region of New Zealand. Local authorities will therefore need to tailor their approach the particular circumstances of their region or district. However, some aspects of these activities will be the same or similar across different areas, as discussed in this document.

The guidelines do *not* cover:

- the regulation of oil and gas activities in New Zealand that occur beyond the well site in the oil and gas production process (aside from those that directly relate to the well life cycle, from site selection to decommissioning, such as traffic)
- offshore oil and gas activities (including in the coastal marine area), as hydraulic fracturing has so far been undertaken onshore in New Zealand – offshore hydraulic fracturing is not expected to occur in New Zealand in the foreseeable future (Power Projects Ltd, 2012), but future guidance may be developed if it becomes apparent that offshore hydraulic fracturing is likely
- management of oil and gas well sites after they have been abandoned and decommissioned
- technical guidance on hydraulic fracturing, or the oil and gas industry, that has already been published.

1.3 Structure

The document is structured in five sections.

Section 1 provides information on the purpose and scope of this guide.

Section 2 provides background information about the oil and gas industry in New Zealand.

Section 3 summarises the responsibilities for regulating oil and gas well development activities at the central and local government level.

Section 4 describes the phases of the well life cycle (from site selection to well abandonment).

Section 5 describes the key environmental effects that arise from the oil and gas production life cycle. Although these are not all specific to hydraulic fracturing, they are issues that need to be understood to ensure consistent regulation of the oil and gas industry. Some of the environmental effects described are necessary considerations regardless of whether a well is subject to hydraulic fracturing or not (including those associated with well site establishment and drilling).

Section 6 provides New Zealand examples of different planning frameworks that consider hydraulic fracturing-related matters and how some consent applications are dealt with. It also provides guidance on policy development and consenting processes to appropriately manage the effects of hydraulic fracturing and associated activities in the oil and gas industry.

Feedback

If you would like to suggest how these guidelines could be improved, please contact us by emailing info@mfe.govt.nz.

2 Background

2.1 The oil and gas industry in New Zealand

New Zealand has multiple basins with hydrocarbon potential (shown in figure 1), but only one, the Taranaki Basin, is currently producing.¹ As at May 2013, 1108 wells had been drilled in New Zealand for hydrocarbon exploration and production purposes.

The oil and gas industry makes a valuable contribution to the New Zealand economy. Information from 2012 indicates that:

- oil is New Zealand's fourth-largest export (after dairy, meat and wood), with a value of around \$2.2 billion, and the industry contributes close to \$3 billion to national Gross Domestic Product (GDP), most of which is captured in Taranaki (Petroleum Exploration and Production Association of New Zealand, 2012)
- the Government collects about \$300 million in company tax and more than \$400 million in royalties from petroleum per annum (PEPANZ, 2013).

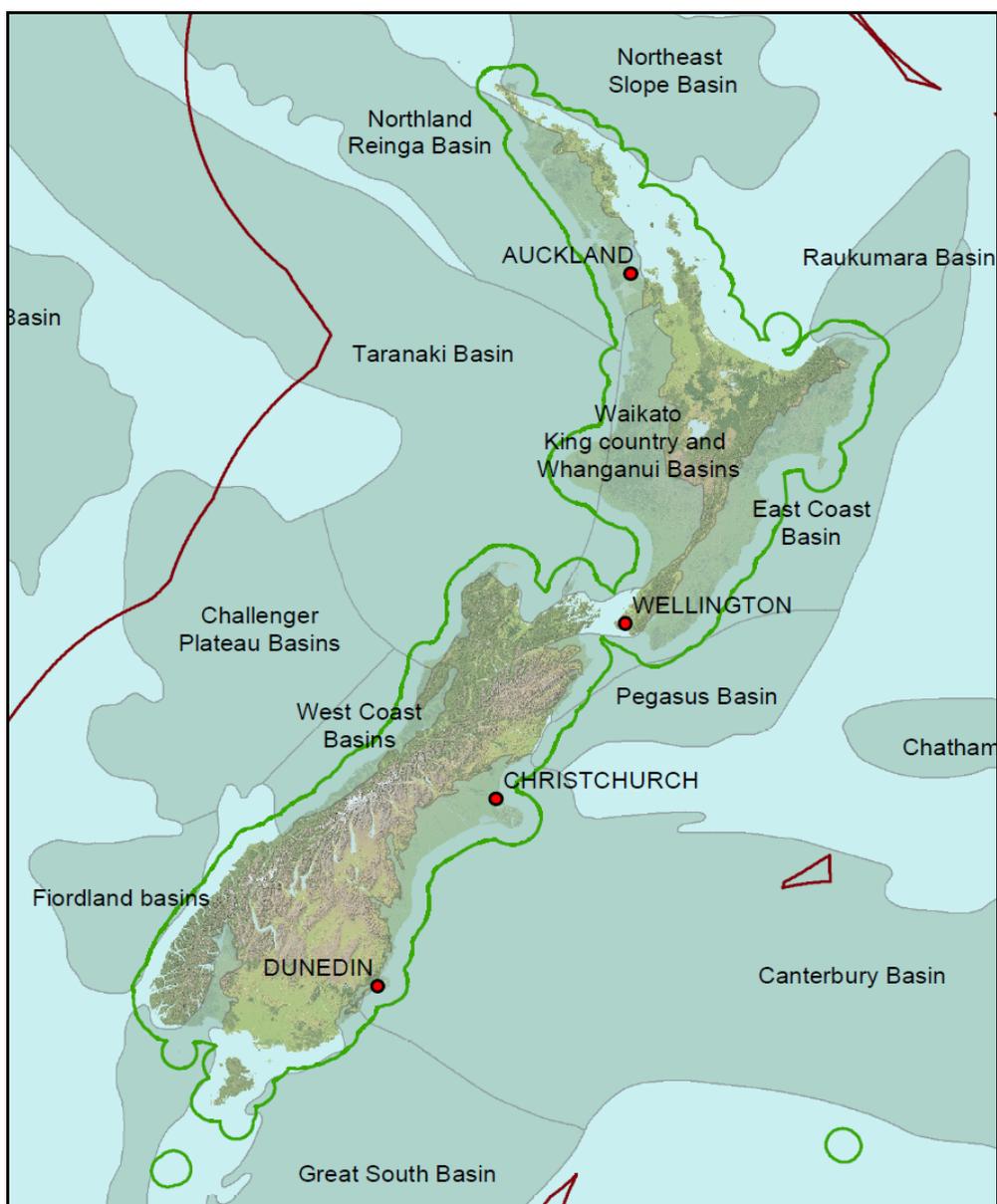
The impact of future discoveries and development may be significant. The Ministry of Business, Innovation and Employment (MBIE) has estimated that if new exploration continues at its recent rate, production from new fields could net royalties of \$5.3 billion, and could be \$9.5 billion under a higher exploration scenario. Development of a new South Island basin has the potential to increase national GDP by 1.2 per cent per year over a 30-year timeframe (through both direct and indirect economic effects) (MBIE, 2012). These projections include offshore development (which is beyond the scope of these guidelines).

Onshore oil and gas developments have environmental effects that need to be managed by district, regional and unitary councils, both in areas that already have development (such as Taranaki) and in areas where development is currently occurring or may occur in the future.

The following sections provide information about how the industry is regulated in New Zealand and detail the potential risks to the environment that need to be managed by local authorities under the RMA.

¹ More information about the basins is available in a New Zealand Petroleum and Minerals report from 2013, *New Zealand Petroleum Basins*, available at <http://www.nzpam.govt.nz/cms/pdf-library/petroleum-publications/nz-petroleum-basins-part-one/view>

Figure 1: Map of New Zealand petroleum basins



Source: Prepared by the Ministry of Business, Innovation and Employment. Note that this map includes the Exclusive Economic Zone and Continental Shelf areas, where the management of environmental effects of activities falls under the jurisdiction of the Environmental Protection Authority (EPA).

2.2 Hydraulic fracturing – what is it?

Hydraulic fracturing (also known as ‘fracking’ or ‘hydraulic stimulation’) is a well-stimulation technique which is used to increase the flow of hydrocarbon fluids to the surface from reservoirs that would not otherwise flow at commercially attractive rates, if at all.

Hydraulic fracturing is only used in rocks with low to extremely low permeability and porosity (ie, ‘tight gas’ and ‘unconventional’ types of oil and gas reservoirs) through which oil and gas cannot easily flow. It involves injecting water, sand and chemicals down a well at high pressure

to fracture rock. These fractures overcome the lack of permeability and porosity and provide paths for the oil or gas to flow through.

Hydraulic fracturing may be used to access petroleum from ‘tight’ sandstone and shale formations, as well as coal-bed methane (also known as coal seam gas). A more detailed description of the process of hydraulic fracturing is provided in section 4.3, and in a report produced for MBIE, *Hydraulic Fracturing in New Zealand* (Power Projects Ltd, 2012).

Hydraulic fracturing is not a new technology. It has been used commercially around the world for more than 60 years and in New Zealand for around 25 years. Similar techniques that fracture rock are also used for some geothermal developments and water-well stimulations, as well as measurement of in situ rock stress for the design of underground structures.

Hydraulic fracturing has occurred in Taranaki (predominantly ‘tight’ sandstone), and in the Waikato and Southland regions (for coal seam gas). Significant shale resource potential has been identified in the East Coast of the North Island, and this is likely to require hydraulic fracturing to access (Power Projects Ltd, 2012). Solid Energy has also expressed renewed interest in focusing coal seam gas operations in Taranaki (Solid Energy New Zealand Ltd, 2012).

3 The regulatory regime for oil and gas in New Zealand

3.1 Overview

Five key statutes regulate the oil and gas industry in New Zealand. These are the Crown Minerals Act 1991, the Health and Safety in Employment Act 1992 (HSE Act) and the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (HSE Regulations), the Hazardous Substances and New Organisms Act 1996 (HSNO), the Resource Management Act 1991 (RMA) and the Historic Places Act 1993 (HPA).

The purpose of each of these statutes is distinct.

- The Crown Minerals Act is essentially a resource allocation statute.
- The HSE Act deals with the management of risks to the health and safety of people (including employees and non-employees) on a particular work site, and the HSE Regulations have particular provisions to manage these risks at petroleum exploration and production facilities.
- HSNO manages the risk associated with the manufacture/importation, storage, use and disposal of hazardous substances.
- The RMA addresses the sustainable management of natural and physical resources, including the potential effects of activities (positive and adverse) on the natural and physical environment.
- The HPA protects archaeological sites, whether recorded or unknown, from destruction, damage, or modification.

Responsibility for regulation under these statutes falls with various central and local government agencies, as shown in table 1.

Table 1: Agencies involved in regulating the New Zealand oil and gas industry

Agency	Role
Ministry for the Environment	RMA policy advice Hazardous substances policy advice
Ministry of Business, Innovation and Employment	New Zealand Petroleum and Minerals (Crown minerals permits) Energy and resources policy Health and safety policy Approval of access to Crown-owned land
WorkSafe New Zealand	Health and safety regulation (including the High Hazards Unit) Hazardous substance enforcement
Department of Conservation	New Zealand Coastal Policy Statement Approval of access to public conservation land
Regional/district councils	Regional policy statement, regional and district plans Resource consents
Environmental Protection Authority	Hazardous substances administration
New Zealand Historic Places Trust	Archaeological authorities

An overview of each statute, and linkages, are described below, and further information is provided in Appendix F.

3.2 Crown Minerals Act 1991

The Crown Minerals Act sets out how the Crown will allocate the right to explore, prospect or mine Crown-owned minerals, which includes petroleum.² The Minister of Energy and Resources allocates prospecting, exploration or mining permits for particular areas. The prospecting, exploration and mining of petroleum in New Zealand basins is managed and regulated by New Zealand Petroleum and Minerals (NZP&M), which is part of MBIE. The permitting regime is described further in Appendix F.

The Crown Minerals Act also sets the regime for accessing land to undertake petroleum prospecting, exploration or mining. Access arrangements will be required between operators and the relevant Minister if activities are on Crown-owned land, unless the activity complies with minimum impact activity standards set out in the Crown Minerals Act. Regulations set out rates and provisions for royalty payments, specify information that permit holders must supply to the government, and set out fees payable.

In addition to the Crown Minerals Act, the *Minerals Programme for Petroleum 2013* (the ‘Petroleum Programme’, (MBIE, 2013b)) provides guidance on how the government will interpret the Act and exercise specific powers and discretions.

Section 2 of that document sets out how the Minister of Energy and Resources and the Chief Executive of MBIE will have regard to the principles of the Treaty of Waitangi.³ This section provides for:

- the exclusion of land identified as being particularly important to the mana of iwi/hapū from petroleum permits
- consultation by the Minister or NZP&M with iwi/hapū on specific matters
- principles and procedures for consultation with iwi/hapū
- notification of matters to iwi/hapū by NZP&M
- annual reporting by permit holders to NZP&M on their engagement with iwi/hapū whose rohe includes some or all of the permit area, or who are otherwise affected by the permit.

3.3 Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013

The Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013, known as the HSE(PEE) Regulations, are made under the HSE Act 1992 and are a key component of the overall process of regulating the safety of oil and gas operations, including hydraulic fracturing. The Regulations provide for the management of hazards associated with

² ‘Petroleum’ has a specific legislative definition in section 2 of the Crown Minerals Act 1991. Also see the glossary.

³ See: <http://www.nzpam.govt.nz/cms/pdf-library/petroleum-legislation-1/petroleum-programme-2013.pdf>.

petroleum exploration and production activities in relation to their potential health and safety impacts. It is important to note that, under section 15 of the HSE Act, employers must take all practicable steps to ensure that no action or inaction of any employee while at work harms any other person.

Under the HSE(PEE) Regulations, the safety of wells and well operations is managed by:

- requiring an operator to prepare an installation safety case, which must be accepted by WorkSafe New Zealand⁴ before work can commence
- the issuing of a well operations notice, requiring an operator to notify WorkSafe New Zealand before well operations commence
- the preparation and implementation of a well examination scheme, requiring operators to arrange for all wells to be examined by an independent and competent person.

Further detail of these Regulations is provided in section 3.8.3 and Appendix F. This approach is consistent with the regulation of the petroleum sector in the United Kingdom.

3.4 Hazardous Substances and New Organisms Act 1996

The Hazardous Substances and New Organisms Act 1996 (HSNO) protects the environment and the health and safety of communities by preventing or managing the adverse effects of hazardous substances⁵ and new organisms. Chemicals used in the fracture fluid and for other applications onsite are subject to HSNO if they are considered a hazardous substance.

HSNO, and regulations developed under that Act, are administered by the Ministry for the Environment but implemented by the Environmental Protection Authority (EPA).⁶ The Ministry provides policy advice to the government on the regulation of hazardous substances, including the effectiveness of HSNO. The EPA decides what controls are placed on hazardous substances, including their approval if the hazardous substance is new. (Further information is available at <http://www.epa.govt.nz/hazardous-substances/Pages/default.aspx>.)

More information about the HSNO regime is provided in Appendix F. Detail about fracturing fluids management is also provided below in section 5.4.

3.5 Resource Management Act 1991

The RMA is New Zealand's principal environmental management statute. It applies to activities on land and in New Zealand's territorial sea – out to 12 nautical miles offshore.⁷ The RMA provides the framework for managing the environmental effects of activities.

⁴ WorkSafe New Zealand is a Crown entity set up as New Zealand's health and safety regulator under the WorkSafe New Zealand Act 2013.

⁵ Hazardous substances are those compounds that can readily explode, burn or oxidise, or that are corrosive, or that are toxic to people and ecosystems. There are more than 100,000 hazardous substances in common use in New Zealand.

⁶ However, they are not enforced by the EPA because it is not a designated enforcement agency.

⁷ The Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 applies beyond 12 nautical miles, out to 200 nautical miles offshore. Note that these guidelines do not address offshore oil and gas development.

Under the RMA, consideration of the environmental effects of oil and gas exploration and extraction activities is the responsibility of regional and territorial authorities. Regional policy statements, and regional and district plans, set out the detail of how environmental effects will be managed. The diversity of activities associated with oil and gas operations requires a broad consideration of RMA provisions.

The type of resource consents that are required for hydraulic fracturing and related activities (such as drilling and waste disposal) will ultimately depend on the nature and scale of the operation, its effects on the environment, and what is permitted in the relevant regional, district or unitary plan. Generally, but limited to the list below, consents could be required from the relevant regional council or territorial authority for the:

- system/programme for installing the well (or ‘well delivery system’), including the construction and drilling of a well or bore⁸ (under RMA section 9 – land use)
- taking and use of water for hydraulic fracturing activities (under section 14 – water permit)
- discharge of contaminants to air (eg, for flaring or venting) (under RMA section 15, particularly section 15(1)(c) – discharge permit)
- subsurface discharge of fluids as part of the hydraulic fracturing operation (under section 15, particularly 15(1)(d) – discharge permit)
- discharge of contaminants associated with the drilling process to land (including circumstances where it may enter water), such as drilling muds (under section 15, particularly 15(1)(d) – discharge permit).
- discharge or disposal of waste fluids (under section 15 – discharge permit).

Territorial authorities have other land-use issues to consider in assessing applications for land-use consent under section 9 of the RMA, including the design of buildings and structures (eg, height, surface area), traffic, vibration and noise, vegetation clearance, cultural considerations (eg, proximity to culturally significant sites), managing hazardous substances, the effects of construction earthworks, and light overspill.

Schedule 4 of the RMA sets out the type of matters that should be considered in an assessment of environmental effects (AEE) for a resource consent application. Taranaki Regional Council has produced guidelines for applicants on the matters that it considers necessary for an AEE for hydraulic fracturing activities (Taranaki Regional Council, 2013d). Local circumstances will also influence the specific information required. More detailed information on the scope of an AEE is contained in section 6.4 and Appendix D, including examples from Taranaki Regional Council.

District or regional plan provisions, formulated through engagement with iwi, the sector, land owners and the broader community, may also restrict or prohibit particular activities (such as drilling, hydraulic fracturing or waste disposal) in specified locations, and also address the cumulative effects of ‘scale up’ in regions and districts where there is interest in future development. This may be appropriate to avoid adverse environmental effects in areas identified as being particularly sensitive or significant (eg, areas with known active faults). Plan provisions made to address this would need to be formulated through the plan development

⁸ The terms ‘well’, ‘bore’ or ‘well bore’ may be used interchangeably, but relevant definitions will typically be provided in regional resource management plans, as discussed further in sections 5.2 and 5.3. ‘Well’ has a specific legislative definition for the purpose of the HSE(PEE) Regulations 2013.

process specified in Schedule 1 of the RMA. Further discussion is provided below in section 6.1.

3.6 Health Act 1956

Part 2A of the Health Act 1956 contains provisions for protecting drinking water supplies as they relate to public health. Drinking water suppliers are required to register their supply, and suppliers of more than 500 people are required to prepare and implement a water safety plan for their drinking water supply (under section 69Z of the Health Act 1956).⁹ These plans may also be required of suppliers to smaller populations if this is deemed necessary by a medical officer of health. Oil and gas development activities may present a risk to drinking water supplies, which needs to be identified at the time these plans are developed.

Note that potential effects on drinking water supplies need to be managed in accordance with the National Environmental Standard for Sources of Human Drinking Water (discussed below in section 5.6.2). Potential risks to drinking water sources are discussed further in section 3.8.4.

Other aspects of the Health Act of note are:

- section 66: a medical officer of health can certify that a polluted water course may not be used for domestic water supply purposes until that certificate is revoked
- sections 29–35 (nuisances) – while issues relating to air quality are normally dealt with under the RMA, an environmental health officer employed by a territorial authority may be asked to investigate if a neighbour feels their health is not being protected adequately by regional plan provisions / consent conditions for air discharges.

3.7 Historic Places Act 1993

The Historic Places Act is an important component in the management of land-based resources, particularly in relation to archaeological sites¹⁰ for which a separate consent regime exists in the form of the archaeological authority process. It is an offence to destroy, damage or modify a site, knowing or having reasonable cause to suspect that a site is an archaeological site, without having first obtained an archaeological authority from the New Zealand Historic Places Trust¹¹ (NZHPT). Companies may be required to obtain an archaeological authority for land use activities associated with petroleum exploration and development (eg, seismic surveying (including drilling shot holes), well site development (including earthworks), well construction, construction and/or upgrading of access roads and tracks).

Further information about the archaeological authority process is available at <http://www.historic.org.nz/protectingourheritage/archaeology/legalauthorities.aspx>.

⁹ A detailed guide to writing a water safety plan, which should list the risk factors to a drinking water supply, is contained on the Ministry of Health website at <http://www.health.govt.nz/publication/public-health-risk-management-plan-guides-drinking-water-supplies>.

¹⁰ “Archaeological site” has a specific legislative meaning in the Historic Places Act 1993 – see glossary.

¹¹ Note, the Heritage New Zealand Pouhere Taonga Bill proposes to rename NZHPT as Heritage New Zealand Pouhere Taonga, and reform the archaeological authority process under the HPA, however the definition of archaeological site and requirements for obtaining an archaeological authority are substantially the same.

3.8 Linkages

3.8.1 Block offers and other processes

The Crown Minerals Act now requires an initial high-level assessment of a company's health, safety and environmental capability for Tier 1 activities¹² (which include petroleum prospecting, exploration or mining). Applications for Tier 1 permits require statements of company capabilities on health, safety and environmental matters, or evidence of how the bidder will obtain this expertise. This assessment is for the Minister of Energy to be satisfied that the applicant will have the capability and systems required to meet its health and safety and environmental requirements. This assessment does not duplicate processes already in the RMA and the HSE Act.¹³ It is possible that an applicant may be awarded a permit but will not be able to obtain a resource consent under the RMA or an access arrangement under the Crown Minerals Act.

Section 4 of the Crown Minerals Act requires persons exercising functions and powers under the Act to have regard to the principles of the Treaty of Waitangi. To meet the Crown's responsibility in this regard, section 2 of the *Minerals Programme for Petroleum 2013* (the 'Petroleum Programme') sets various provisions to be carried out during the block offer by NZP&M with affected iwi and hapū. This process enables issues to be raised by iwi that contribute to the expectations of bidders (eg, the exclusion of certain land of particular importance to the mana of iwi or hapū from permit areas) and potential conditions to be placed on permits.

Section 33C of the Crown Minerals Act requires that petroleum permit holders submit an annual report to the Minister on their engagement with iwi and hapū whose rohe is covered by the permit area or who may otherwise be affected by the permit. More information about iwi engagement report requirements is provided in section 2.11 of the Petroleum Programme.

Timeframes involved with block offers under the Crown Minerals Act (discussed above in section 3.2) provide a significant lead-in time to develop an awareness of the potential effects of oil and gas exploration and mining activity and to engage with appropriate parties. Given permit holders are directed by NZP&M to regularly engage iwi under the Petroleum Programme, there is potential for councils to gain insight into upcoming proposals by working directly with iwi when seeking to engage early with permit holders. A typical work programme for an exploration permit covers five years, as summarised in Appendix A.

The permit holder typically has three years to appraise the permit area and make what is known as the 'drill or drop' decision. There are benefits for the permit holder to engage with iwi and hapū within this period regarding the seismic acquisition activities and potential locations for well sites, to assist in identifying any issues to be addressed through the resource consent process (eg, sensitive sites to be avoided).

However, experience suggests that engagement may be lacking between permit holders and councils after completion of the block offer process and before the lodgement of the relevant resource consents. Where little engagement occurs, this can result in a missed opportunity for

¹² The Crown Minerals Amendment Act 2013 introduced a two-tier system to categorise minerals permits. Tier 1 permits are generally more complex and have a higher risk and return than Tier 2 permits. Tier 1 and 2 permits are defined in section 2B of the Crown Minerals Act. Prospecting, exploration and mining permits that relate to petroleum are all Tier 1 permits.

¹³ Section 5.4 of the Petroleum Programme sets out what is required in this initial assessment (MBIE, 2013b).

the project proponent, in consultation with the consent authority, to develop engagement strategies with affected communities, stakeholders and iwi for use as the project matures through to consent lodgement.

The lead time offered by the work programme conditions of a minerals permit potentially provides the following benefits.

- The permit holder has the opportunity to develop an engagement process with land owners and neighbours, iwi, any other potentially affected parties and the wider community, which can be focused as greater certainty is achieved over time in relation to drilling opportunities and potential drill site locations.
- Councils can engage with the permit holder to better understand the nature of the drilling prospect, the degree to which the drilling programme may involve hydraulic fracturing, and the broad resource management issues they are likely to face; and to influence the location of the drill site to avoid or minimise adverse effects. Details of minerals permit holders, and the acreages that minerals permits apply to, are available on the NZP&M website.
- Councils can engage with the community (including iwi) to identify any issues relating to potential oil and gas development within particular permit areas.

Within this timeframe the permit holder will also be making decisions about the scope of any wider engagement process they may wish to undertake with the community.

Note that, as Treaty partners with the Crown, iwi have particular recognition under the Crown Minerals Act, Conservation Act, HSNO Act, Environmental Protection Authority Act, Local Government Act, and RMA. This means that iwi are uniquely placed to contribute to all stages of the statutory framework for petroleum development activities. Iwi are likely to have valuable insights that can help councils undertake their functions under the RMA before any resource consent applications are lodged for proposed work programmes provided for by the conditions of a minerals permit.

The University of Otago publication *Māori and Mining* (Ruckstuhl et al. 2013) provides detailed information about the relationships with and values of Māori regarding minerals development (including oil and gas).

3.8.2 Hazardous substances

The placement of any additional controls on hazardous substances under the RMA should only be considered if there are particular environmental effects that cannot be managed through existing HSNO controls. Councils should be aware of the effect of existing HSNO controls regarding particular substances to avoid any duplication under the RMA.

More general information about hazardous substance management, and the RMA/HSNO interface, is provided in the Quality Planning Guidance note *Managing Hazardous Substances* (<http://www.qualityplanning.org.nz/index.php/related-laws/hazardous-substances>).

3.8.3 Well design and examination

Well design and integrity are important matters to consider for managing risk to both health and safety and the environment. The regulation of well design and integrity to manage risk to health

and safety is the responsibility of the High Hazards Unit (part of WorkSafe New Zealand) under the HSE(PEE) Regulations.

- The Regulations place a general duty on well operators to ensure that a well is designed, constructed, operated, maintained, suspended and abandoned so that risks from it are reduced to a level that is as low as is reasonably practicable. This is supplemented by obligations that set goals for identifying and assessing hazards and establish principles for the safe design, construction, maintenance, and abandonment of wells.
- The Regulations also require well operators to implement arrangements for independent and competent persons to examine all wells within their inventory.¹⁴ This provides an independent quality control check for the design, construction, operation, maintenance, modification, suspension, and abandonment of new and existing wells.
- There is no formal well certification or approval process, as such, whereby a regulatory agency certifies the design of the relevant well.

In its review of shale gas extraction in the United Kingdom, the Royal Society and Royal Academy of Engineering found that well designs should be reviewed by the well examiner from both a health and safety perspective and an environmental perspective to ensure well integrity (Royal Society and Royal Academy of Engineering, 2012, p 27).

Well examinations under the HSE(PEE) Regulations 2013 are not required to examine potential environmental effects arising from defective well design (only risks to health and safety). The Regulations ensure that the risk of an unplanned escape of fluids from a well are reduced to “as low as reasonably practicable”, from drilling to abandonment of the well. Territorial or regional authorities need to be satisfied that the well design, and the subsequent integrity of the well throughout its life cycle, is sufficient to reduce the environmental risks associated with oil and gas operations (eg, groundwater contamination) to an acceptable level.

This matter has been approached differently in different regions. For example:

- Horizons and Hawke’s Bay Regional Councils require resource consents for the purposes of well drilling to be applied for, at which point environmental assessments are made
- Taranaki Regional Council provides for drilling a bore as a permitted activity, provided it is cased and sealed (along with other criteria discussed further in section 6).

It is likely that many of the management plans an operator prepares for well integrity for health and safety purposes will also be appropriate for the resource consent process under the RMA.¹⁵ Where appropriate, the information in these plans should contribute to the assessment of environmental effects (AEE) submitted with a resource consent application to enable local authorities to assess the potential effects on the environment.

There is no requirement for integration between the health and safety responsibilities at the central government level and environmental responsibilities at the local government level. However, central and local government regulators are looking at ways in which working more closely may lead to further efficiency in the regulation of well design and integrity, from both the environmental and the health and safety perspectives.

¹⁴ MBIE is preparing guidance on independence of well examiners.

¹⁵ Management plans include contingency and emergency management plans, spill response plans, and operational management plans (eg, for the deep well injection of produced water).

In some overseas jurisdictions, memoranda of understanding have been used as an approach for coordinating some of the issues under the jurisdiction of health and safety and environmental regulatory agencies.¹⁶ In New Zealand, councils are encouraged to establish and maintain working arrangements (such as memoranda of understanding) with the High Hazards Unit (HHU) to promote efficiency in regulation and avoid unnecessary duplication or regulatory gaps under the existing framework (eg, for well integrity).

For example, the HHU has a working relationship with Taranaki Regional Council and is able to provide useful information and services to help other councils assess well designs from an environmental viewpoint. The HHU is currently developing guidelines that may form the basis of an approved code of practice on well integrity issues, which will provide useful guidance to environmental regulators. Coordination of monitoring activities between councils and the HHU is also encouraged to promote efficiency in regulation.

Additional controls through resource consent conditions or plan provisions should not duplicate what is already required of operators under the HSE(PEE) Regulations. Councils should work closely with the HHU to determine whether there are any aspects of a well design that could result in adverse environmental effects. Such risks include potential groundwater contamination via a well leak deep below the surface, or where non-aqueous drilling fluid is used at shallow depths (but poses no risk to human health and safety).

This is consistent with the approach used in the United Kingdom, where the Health and Safety Executive manages well integrity under their health and safety in employment regime, while the Environment Agency manages well design and places controls if needed in terms of potential risks to the environment.

3.8.4 Drinking water supplies

Local authorities may consult with any person about a resource consent application (under section 36A(1)(c) of the RMA). In situations where an oil or gas development could result in contamination of a drinking water supply, councils are recommended to consult with a medical officer of health from the local district health board (DHB), as medical officers of health can provide public health advice on these types of provisions. Councils should also consult with DHBs when preparing regional plan provisions for discharges of contaminants to water and air where they may enter drinking water supplies, in accordance with the requirements of the National Environment Standard for Sources of Human Drinking Water Regulations 2007 (as detailed in section 5.6). Drinking water suppliers should also be notified of any resource consent applications that pose a potential source contamination risk so they can meet their obligations under the Health Act 1956.

Councils and DHBs may also wish to establish and maintain working relationships for managing oil and gas development activities in their area. In the United Kingdom, for example, the Environment Agency and Health Protection Agency have a 'working together agreement' to coordinate operations, including consultation provisions, which councils and DHBs may wish to refer to (Environment Agency and Health Protection Agency, 2012).

¹⁶ For example, in the United Kingdom, the Health and Safety Executive currently has MOU with the Environment Agency (Environment Agency and Health and Safety Executive, 2012) and the Department of Energy and Climate Change (Department of Energy and Climate Change and Health and Safety Executive, 2011).

4 Well life-cycle phases

There are a variety of potential environmental effects and management issues at each stage of the oil and gas process, of which hydraulic fracturing can be one component. Not all oil and gas processes involve hydraulic fracturing. The key phases of the well life cycle are:

- site selection and development
- well design, drilling, casing and cementing
- well completion
- hydraulic fracturing (where required)
- production¹⁷
- well decommissioning and abandonment.

These phases are discussed below. The management of various environmental issues associated with each of these phases is discussed in section 5 (with the exception of seismic survey assessment, which is discussed separately below as the effects are more concise).

Coal seam gas well developments have an additional ‘dewatering’ process, which is discussed below in section 4.4.2.

4.1 Site selection and development

The selection of an onshore well site typically takes 18 months to two years. The well site selection process starts by assessing pre-existing geological and geophysical data. Once an exploration permit is obtained, an operator would typically undertake seismic survey assessments to identify potential target formations (ie, rock/geological formations that are most likely to contain oil or gas accumulations).

Once the target formation(s) are identified, the operator will identify the most appropriate location for the drill pad and associated infrastructure. The optimal position for conventional oil and gas is usually directly over the drilling prospect (where economic quantities of hydrocarbons are predicted to be located) so that the well is drilled vertically, but wells can be deviated if necessary. For unconventional oil and gas (where hydraulic fracturing is used) wells may be deviated so that a greater volume of the resource is accessed with the same surface footprint. A deviated well (which involves controlled drilling away from the vertical in particular places) may minimise off-site effects, but it increases the complexity of the well design and therefore the cost.

Assessing the appropriateness of a well site should involve consideration of adjacent land uses, the location of sensitive receptors (particularly for noise and glare), access to the local roading network, and the location of other sensitive sites such as wāhi tapu. While there is no obligation for the operator to consult with anyone about a resource consent, early engagement

¹⁷ For coal seam gas (coal-bed methane) development, an additional stage of ‘dewatering’ using mechanical pumping equipment is usually required to allow gas to flow through to the well before production can occur. Coal-bed methane development is described in pages 28–30 of International Energy Agency, 2012.

with the relevant council(s) (with jurisdiction in the area), neighbours and local iwi/hapū can ensure potential constraints are identified early and are appropriately managed.

Effective site selection should also consider the potential for related ancillary activities to be located beyond the well site (eg, pipelines, earthworks), and the effects these may have on the surrounding environment.

As with any activity, councils must undertake a notification assessment upon receipt of an application for resource consent for the location it has been applied for (if a resource consent is required). This is discussed further in section 6.6.

4.1.1 Pre-existing geological and geophysical data evaluation

The first phase of any exploration programme is the gathering and evaluation of as much pre-existing geological and geophysical data as is available for the areas in which hydrocarbon prospecting is proposed to occur (eg, a basin, ‘fairway’ or play, within which particular geological features are likely). This can be a lengthy process but is more economical than seismic data acquisition or exploratory well drilling.

The usual outcomes of this desktop exercise are either to acquire further information (seismic or well drilling) at the explorer’s cost, or to abandon the particular area as not prospective. Explorers aim to make basin, fairway or play maps, which help to define areas for two-dimensional (2D) seismic surveying or even exploratory well drilling.

4.1.2 Seismic survey assessment

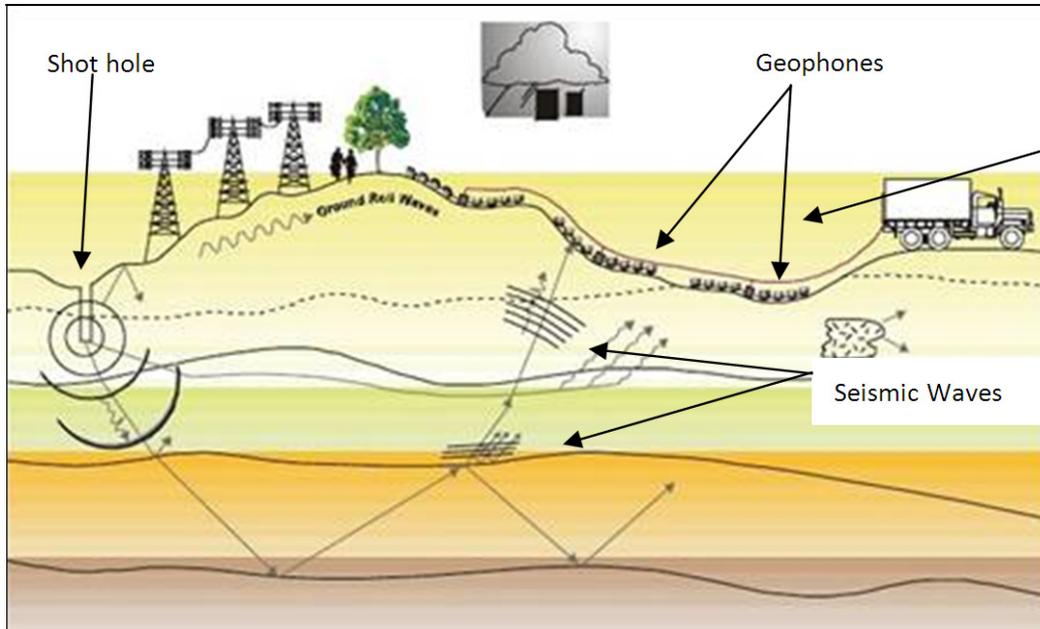
Seismic surveying is used to map the structure of subsurface formations to identify possible petroleum reservoirs. Formations with different mechanical properties (rock types) will reflect back seismic waves at their boundaries. This means that seismic surveys can be used to map the boundaries of geological units. Interpretations of 2D and 3D seismic data results in a subsurface geological model (geo-model, or geological framework model), which can be used to establish an estimate of the thickness, dip and character of the rock units and the way in which they have been deformed by faults and folds.

As well as providing a 3D map of the main subsurface units, seismic surveys can also provide useful subsurface information for designing hydraulic fracturing, deep-well injection of waste and other subsurface activities. Seismic investigations can also be used to identify lithology (rock type), fluid content (oil, gas, or water) within formations – all indicators of the potential presence and volume of oil and/or gas reserves in an area of interest. Data obtained by seismic surveying is typically correlated with petrophysical and geophysical logs from boreholes in the locality of the survey area, and/or existing information on the stratigraphy of the area.

The surveying of underground formations using seismic methods is based on the principles of seismic reflection and refraction. Seismic waves are generated by artificial methods, typically by small explosive charges lowered into shallow bores known as ‘shot holes’. Alternatively, purpose-built vehicles with a ram-driven shock pad may be used, which strike the surface of the ground to create the shock wave.

When detonated, the energy released by the charge is transmitted through the geological strata and reflected back to the surface. The arrival of a seismic wave at the surface is detected by geophones spaced across the survey area (figure 2).

Figure 2: Schematic of the seismic survey process



Source: Adapted from Taranaki Regional Council, 2013b.

Note: This is not to scale (the geological formations will be much larger than they appear in this figure)

The time it takes for the seismic wave to reach one or more of the geophones, placed at known distances from the shot hole, is recorded during a survey. By plotting the distance-time relationship, the properties of geological units can be assessed. Each geological formation has a characteristic seismic velocity that dictates the speed with which a seismic wave reaches the geophones.

The data obtained using seismic investigation techniques, and the subsequent modelling of this data, allows exploration companies and regulators to characterise geological formations and their stratigraphy within the survey area. The results of the survey can indicate the presence of potential oil- and gas-bearing structures. Almost all petroleum exploration involves seismic investigation methods. Geological investigations and models have a degree of uncertainty. However, compared to other investigative methods, seismic methods give by far the best subsurface structural and lithological image.

New acquisition techniques such as 'passive seismic' have the potential to image individual flowing features. This is different to traditional seismic surveying in that it does not use refraction, but rather detects natural low-frequency seismicity in the subsurface. This is a currently emerging technology which may become more prevalent in lieu of more traditional seismic surveying techniques in the future.

The seismic data acquisition phase has the potential to identify formations where hydraulic fracturing may be a useful technique. This will then flow through into well design, and well integrity and geological integrity considerations.

4.2 Well design, drilling, cementing and casing

Following seismic and other geological data acquisition, drilling an exploration well is the next step to determine whether a potential hydrocarbon reservoir is present in economic quantities. Drilling can take a few weeks to a few months, and is typically a 24/7 operation.

As mentioned above, many conventional wells are drilled vertically to minimise costs, although there may be instances where unconventional sources or the geology of overlying formations justify deviated drilling (which is becoming increasingly common). Deviated drilling may also be used to avoid particularly sensitive sites, reduce the total number of well sites (as multiple deviated wells can be drilled at a single site), reduce surface infrastructure, or optimise the way the reservoir is produced.

Well casing, drilling muds and well-logging techniques are important aspects of the drilling phase and are discussed in further detail below.

4.2.1 Well casing and cementing

A well contains multiple steel casings inside each other and cemented in place (see figure 3). These casings isolate the well from surrounding rock formations and aquifers and provide a conduit for oil and gas to flow to the surface. They also control subsurface pressure.

Drilling occurs in sections. After each section is complete, casings of decreasing diameter are put in place within the well, which is then cemented and pressure tested. An ultrasonic cement bond log may be run to verify that the cement is of high quality (Power Projects Ltd, 2012). Well logging is discussed further in section 4.2.3 below.

The first casing to be run is the conductor casing (approximately 75 centimetres in diameter), which typically extends 20 to 50 metres below the surface (see figure 3). The primary purpose is to provide an adequate foundation for the well, prevent the hole collapsing while drilling through soft shallow sediments, and isolate shallow groundwater aquifers from the well.

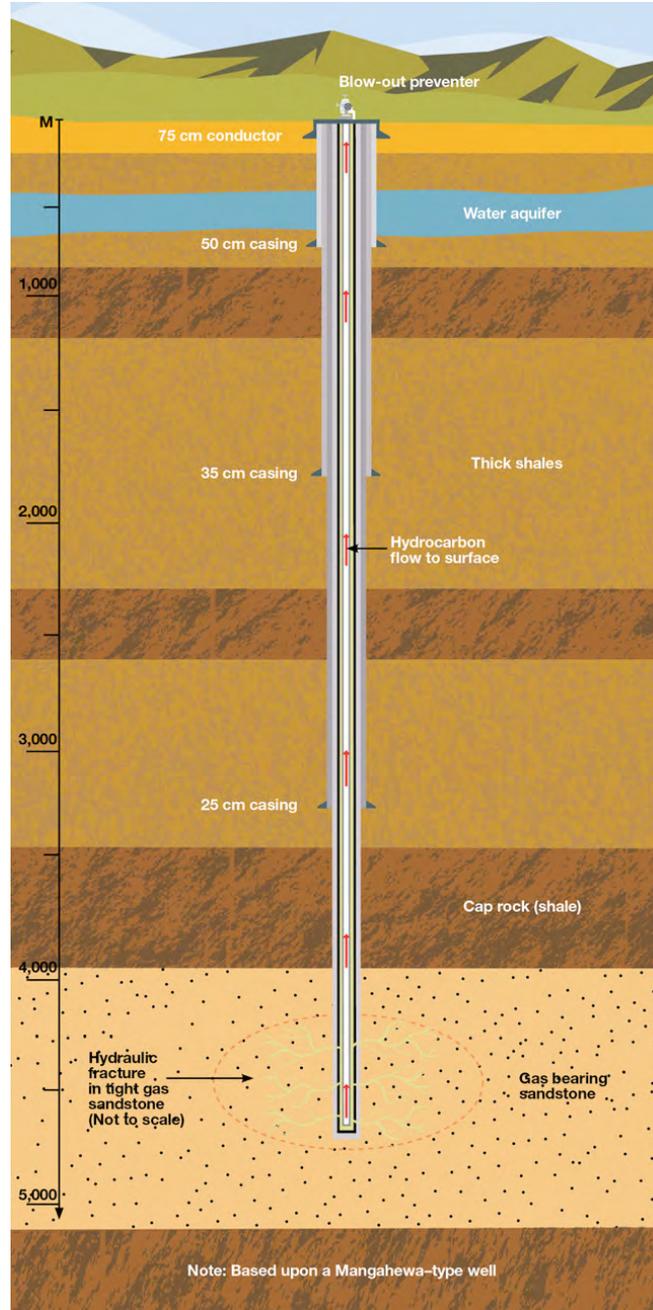
This is followed by the surface casing (approximately 50 centimetres in diameter), whose primary function is to contain any fluids under pressure in the well and to isolate the well from any freshwater zones, typically to a depth of between 400 and 1000 metres. The pipe string is cemented back to the surface by pumping cement down the borehole and then up the annulus (ring-shaped space) between the casing and the rock wall of the well.

An intermediate casing (approximately 35 centimetres in diameter) may be run if it is necessary to isolate deep productive zones from shallower zones where a significant change in formation pressure could cause a cross flow to occur within the bore. This casing is cemented in the same way as the previously installed casings. Intermediate casing is not always cemented back to the previous casing (this would depend on the design and objectives of the cement job).

The final casing (approximately 25 centimetres in diameter) is the production casing, which typically runs all the way to the surface and in some cases may be cemented all the way to the surface. The purpose of this casing is to isolate the producing zone from other subsurface formations (Power Projects Ltd, 2012).

Each casing and cementing operation forms an individual but interconnected system of pressure barriers, designed to keep fluids (including hydrocarbons) inside the casing and separate from fresh or saltwater sources outside the casing (American Petroleum Institute, 2009a).

Figure 3: Well schematic of a Taranaki tight gas well, showing four levels of casing



Source: Power Projects Ltd, 2012. Note that measurements are metric, whereas the industry usually uses imperial. Note also that the smaller individual casings do not necessarily require cementing along the full length of the well to achieve adequate isolation and structural strength – this will depend on the geology at the particular well location.

4.2.2 Drilling muds

Drilling muds are used to provide hydrostatic pressure to keep formation fluids (fluids contained naturally within the geological formations) out of the borehole, and to control formation pressure, provide cooling to the drill bit, and carry cuttings away from the drill bit and up the borehole. There are three types of muds that have been commonly used in the petroleum hydrocarbon industry: water-based mud, oil-based mud and synthetic oil-based mud.

Water-based muds may range in formulation from fresh water, to water with viscosifiers, weighting agents and various additives to control formation properties (eg, swelling clays). Barite (BaSO_4) is a commonly used weighting agent to control formation pressures. Well pressures are kept in check so long as the mud weight is sufficient to balance the reservoir pressure. Mud tank levels are also monitored, and regular flow checks are performed to make sure the mud weight is sufficient to prevent flows from the formations being drilled.

Oil-based and synthetic-oil-based muds (non-aqueous drilling fluids)¹⁸ have been formulated and used in Taranaki to control ‘swelling clays’ and to improve drilling performance in deeper sections. Swelling clays are particular types of naturally occurring clay minerals that swell in the presence of water. Drilling muds contain a variety of substances, which may include BTEX (although water-based muds do not generally contain BTEX).¹⁹

The use of synthetic-based muds over oil-based muds is encouraged to reduce risk to groundwater, and the use of water-based muds to drill through any potable aquifer zones is highly recommended. Detailed information about the common constituents of drilling muds and their purposes is available in Appendix 6 of the document *Drilling Fluids and Health Risk Management* (International Petroleum Industry Environmental Conservation Association and International Association of Oil & Gas Producers, 2009).

In New South Wales and Queensland, the use of BTEX additives in coal seam gas drilling mud (and hydraulic fracturing fluid) is prohibited, and any drilling and fracturing additives used must be tested and comply with guideline values (see section 4.5.2 below).

At the surface, the blowout preventer is a specialised piece of equipment through which the mud is channelled into and out of the borehole. The blowout preventer is essentially a series of emergency valves, which can be used to shut in or control well pressures in the event of unexpected pressure changes, such as a ‘gas kick’, caused by pockets of over-pressured gas. Blowout preventers allow the well to be closed and are regularly pressure tested and function tested as part of company safety procedures, based on good oilfield practice and standards, such as the American Petroleum Institute standards. As higher pressures are encountered in deeper formations, mud density is increased during drilling by the addition of barite to offset the pressure, and additives may also be necessary to prevent clay swelling.

On a drilling rig, mud is pumped from a mud storage tank down the drill string to the bit, where it exits through nozzles, cleaning and cooling the bit before lifting the cuttings to the surface. Lifting the cuttings up in the space between the outside of the drill string and the drilled hole requires both sufficient flow velocity and a viscous mud.

¹⁸ Note that these could be hazardous substances under the HSNO Act, depending on their composition.

¹⁹ A combination of benzene, toluene, ethylbenzene and xylenes. Note that substances containing BTEX compounds would likely be hazardous substances requiring approval and control under the HSNO Act (depending on their composition).

The returning mud may contain hydrocarbons and gases, which are then separated from the mud, and these are either vented or flared during drilling. Rock cuttings are separated or filtered out of the mud and the mud returns to the mud tank (a specific container onsite used for the storage of drilling muds). The cuttings provide the primary evidence of the lithologies being penetrated and of potential fluids, so regular and frequent samples are taken for immediate and later analysis and archiving. Eventually, excess rock cuttings will be disposed of. This will generally require a resource consent, because, although generally inert, the cuttings may have mud additives adhering to them and trace levels of hydrocarbons.

4.2.3 Well logging and evaluation

Well logging is the process of recording the properties of geological formations penetrated by a well (including physical, chemical and structural properties of those formations). Well logging is an important tool that enables the exploration company to assess the potential for hydrocarbon recovery, identify target zones, provide information on the freshwater/saline water interface, and assess well construction requirements. It is also an important analytical tool throughout the whole life cycle of the well (Hetrick, 2011).

Wireline logging is a logging technique that involves the use of an electrically powered logging tool, which is lowered into the well by a wireline cable. Once the logging tool has been lowered to the lowest area of interest, the logging tool is raised out of the well, and measurement of formation properties (including pressure, dimensions, fluid and electrical properties, such as resistivity, of formations) are recorded. Measurements are made as the cable is raised to improve the accuracy (as tension is maintained) (Schlumberger Ltd, 2013e).

Wireline logs can also provide information on the integrity of the well (ie, the physical integrity of the casing, the bond between the casing and the cement, and the bond between the cement and the formation). Taken together, this data can be used to determine (identify and characterise) intervals for hydraulic fracturing.

A summary of the different types of wireline logging techniques is provided in table 2.

Table 2: Summary of wireline logging tools

Log Type	Specific Log	Borehole Conditions	Information
Electrical	Potential, resistivity, focused resistivity	Open or screened holes with fluid	Lithology, formation water composition analysis (salinity), calibration of surface geophysics
Radioactivity	Gamma-ray, gamma-gamma (density), neutron (porosity), spectral gamma-ray	Open or cased holes with or without fluid	Lithology, density, porosity, calibration of surface geophysics
Electromagnetic	Induction, susceptibility	Open and PVC-cased holes with or without fluid	Lithology, porosity, salinity
Acoustic	Sonic	Open holes with fluids	Lithology, porosity, cement bond, rock strength
Physical	Calliper	Open or cased holes with or without fluids	Borehole diameter
Fluid	Water quality	Open or cased holes with fluids	Conductivity, temperature, pH

Source: Taranaki Regional Council, 2013b.

Well logging can be used to assess the properties of both the rock and the fluids within underlying geological formations, and the depth and extent of potential hydrocarbon-bearing zones. Typically a combination of geological and geophysical logging techniques will be used to assess various parameters of interest, with the data used to build a conceptual model of the penetrated formations. The data is also used to finalise the well completion details, including the depth of surface casing, cementing and perforation zones for production.

The logging methods available and the range of obtainable data will vary based on the operational phase and condition of the well, and (particularly) whether the borehole is an open hole or cased with a steel casing that is secured to the formation with cement. Common practice is to run open-hole logs while drilling, or as each well section is completed before the casing is run. Cased-hole sonic logs may be run to confirm the cement bond or during work-over procedures in cased and cemented production wells.

Logging data can also provide information on the vertical extent of freshwater aquifers and the depths at which formation waters become increasingly saline. Following well completion, geophysical logging methods allow operators to confirm that construction of a well meets specification with regard to its structural integrity and isolation from surrounding formations. Logging can also occur while drilling, which has become more common in recent years (and in some cases has been used instead of wireline logging).

However, logging results are sensitive to when the log was run, any movement of casing while the cement was setting, or small changes in pressure conditions in the well during setting or while the log is being recorded. Well logging therefore does not provide a definitive measure of cement bond quality, and ultimately the assessment of cement quality is a matter of engineering judgement. Regulators should therefore be satisfied that cementing is assessed in accordance with currently accepted best practice.²⁰

4.3 Well completion

If hydrocarbons are found, the next stage is to run a well completion and well testing (which can occur before and after hydraulic fracturing, if this occurs, and at other times throughout the life of the production well). This usually involves installing production tubing and packers to isolate production from the well annulus.

Packers are generally used where hydraulic fracturing is planned, but they are not used in all well completions. A concise overview of the well completion process has been published by Schlumberger Limited (von Flatern, 2012).

This stage will also typically involve the development of pipelines and processing facilities if hydrocarbons are recovered from the well(s) in volumes that make production commercially viable. When the final casing strings of the well are set and cemented and the completion is run, the blowout preventer is replaced with a well head, complete with valves and connections to the production facilities (sometimes called a ‘Christmas tree’), which is generally about 1 metre high.

²⁰ See American Petroleum Institute Standard 65 for currently accepted best practice in cementing (as at 2013) (American Petroleum Institute, 2010b).

Surface facilities include vessels to separate gas, oil and water phases without losing fluid (including gas). Methane may be flared from the first wells to determine well production rates (Power Projects Ltd, 2012).

4.4 Additional matters for coal seam gas

Coal seam gas extraction has similarities with and differences from conventional and unconventional tight sandstone and shale gas wells. Surface well site operations for coal seam gas are similar to those for other types (in terms of the need for a well pad, drilling rig and ancillary infrastructure). The coal itself has very low porosity and permeability, but significant amounts of gas and water can be stored in cleats (natural fractures) throughout the coal bed.

The key differences to consider for coal seam gas developments compared with shale and tight resources relate to formation depths, and the need to undertake dewatering of coal seams (as an additional stage after drilling).

4.4.1 Depth

Coal seams are generally located at shallower depths than petroleum-bearing tight sandstone or shale formations. Coal seams are typically found at less than 1000 metres in New Zealand (Power Projects Ltd, 2012) and can be located in shallow formations as little as 100 metres below the surface (International Energy Agency, 2012).

A conventional drilling rig (as used for tight gas and shale) is used for deep coal seam gas deposits. However, shallow coal seam gas wells can be drilled using water-well-drilling equipment at considerably lower cost (up to around 400 metres depth) (International Energy Agency, 2012).

The depth of the formation has implications for the number of wells an operator may wish to drill for an overall development project. In the case of shallow coal seams, it is generally more cost effective to drill a larger number of vertical wells to access the coal seam. For deeper coal seams, it is more economical to drill fewer wells, but to drill horizontally along the coal seam. Generally, the thinner the coal seam and the deeper the location, the greater the likelihood that horizontal drilling will be used (International Energy Agency, 2012).

The number of wells an operator wishes to drill will be a business decision (depending on the nature of the resource and their minerals permit allocation). However, this can have implications for the scale and extent of development activities at the surface, and associated cumulative effects resulting from development and production infrastructure across an area. This is not unique to coal seam gas operations, but drilling multiple vertical wells over a more widespread area (rather than multiple horizontal wells from the same well site) is likely to be less expensive for accessing shallow coal seams than for deep shale gas or sandstone deposits.

4.4.2 Dewatering

Coal seams often contain water, which is usually brackish. This water needs to be removed to facilitate production of the gas, because water will flow in preference to the gas, which is more tightly bound to the coal (Power Projects Ltd, 2012). Water can be extracted under natural pressure or by using mechanical pumping equipment (dewatering), which may need to continue

for some time before gas will flow, and may therefore produce large volumes of waste fluid. As dewatering continues, pressure drops in the coal seam, enabling gas to flow. Gas and water are separated at the surface, and the gas is compressed and injected into a pipeline to be transported off the well site.

The flow rate of gas generally peaks quickly as water is extracted and then slowly declines over time (with the lifespan of a well typically ranging between 5 and 15 years) (International Energy Agency, 2012).

4.5 Hydraulic fracturing

4.5.1 The hydraulic fracturing process

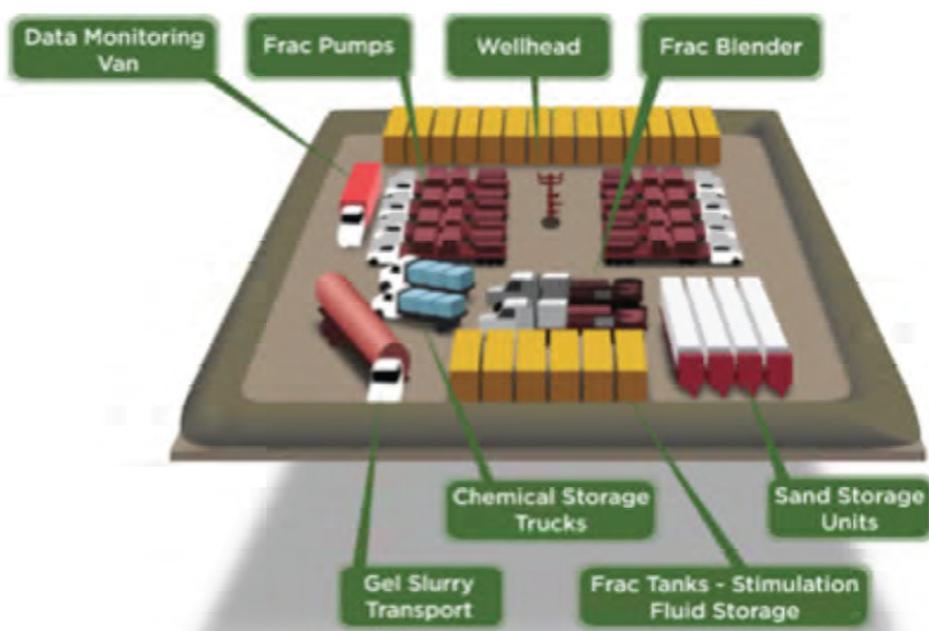
The MBIE report *Hydraulic Fracturing in New Zealand* (Power Projects Ltd, 2012) describes the hydraulic fracturing process in detail. Whether fracturing is required will be a business decision by the operator, and operators will only undertake fracturing if it is economic to do so for a particular formation. Hydraulic fracturing is required to facilitate production from shale (which has extremely low permeability and porosity) (Power Projects Ltd, 2012).

Before hydraulic fracturing can occur, a perforating gun is used to blast small holes with explosives in the well casing at the target depth²¹ to access the reservoir formation. Fracturing can occur at multiple sections within the same well, so multiple fracturing operations may be required. This generally occurs for horizontal wells (see figure 5 below), but may also be used for vertical wells. Hydraulic fracturing for coal seam gas is usually a single-stage process (ie, a single fracturing job per well), and is usually only used for deeper wells (typically several hundred metres deep) (International Energy Agency, 2012), as it may be more economic to drill multiple wells and not undertake fracturing in shallower formations.

Well sites that are subject to hydraulic fracturing will have equipment that is not found on conventional well sites – collectively called a ‘frack spread’ (see figure 4). This equipment includes storage units for sand, water and chemicals, truck-mounted pumping units, a blender (to mix the hydraulic fracturing fluid), a manifold that connects the storage units to the blender and well head, and a data monitoring van (also known as the ‘frack van’).

²¹ Note that these explosives and their use are regulated under the HSNO Act.

Figure 4: Hydraulic fracturing equipment layout



Source: Power Projects Ltd, 2012.

Note that this figure uses the spelling 'frac' (rather than 'frack', which is used elsewhere in these guidelines).

Hydraulic fracturing operation typically lasts approximately 1 hour, and involves perforating the well casing at the desired depth with explosives and then forcing the hydraulic fracturing fluid into the rock at high pressure (typically 2000–10,000 psi at the surface). The pressure is calculated to exceed the strength of the rocks but not the well casing.

A 'mini-frac' is undertaken to test rock properties, reservoir tensile strength, and fluid leak-off. This is a short pumping job (Power Projects Ltd, 2012).

The main pump job involves the following actions:

- **pre-pad volume:** injection of water, and a low- to mid-strength acid (optional), to initiate the fracture
- **pad²² volume:** injection of water, viscosifier and friction reducer to grow the fracture (an emulsion, or gel, breaker is added towards the end of the pad)
- **slurry:** injection of the pad fluid plus proppant²³ to fill the fracture and prop it open
- **displacement or flush:** injection of water to force the remaining slurry from the well into the fracture
- **flow-back (or return fluids):** reduction of pressure at the surface to encourage spent fracturing fluids and formation fluids (including produced water) to flow into the fracture and, via the perforations, up the well to the surface for collection and licensed disposal (Power Projects Ltd, 2012).

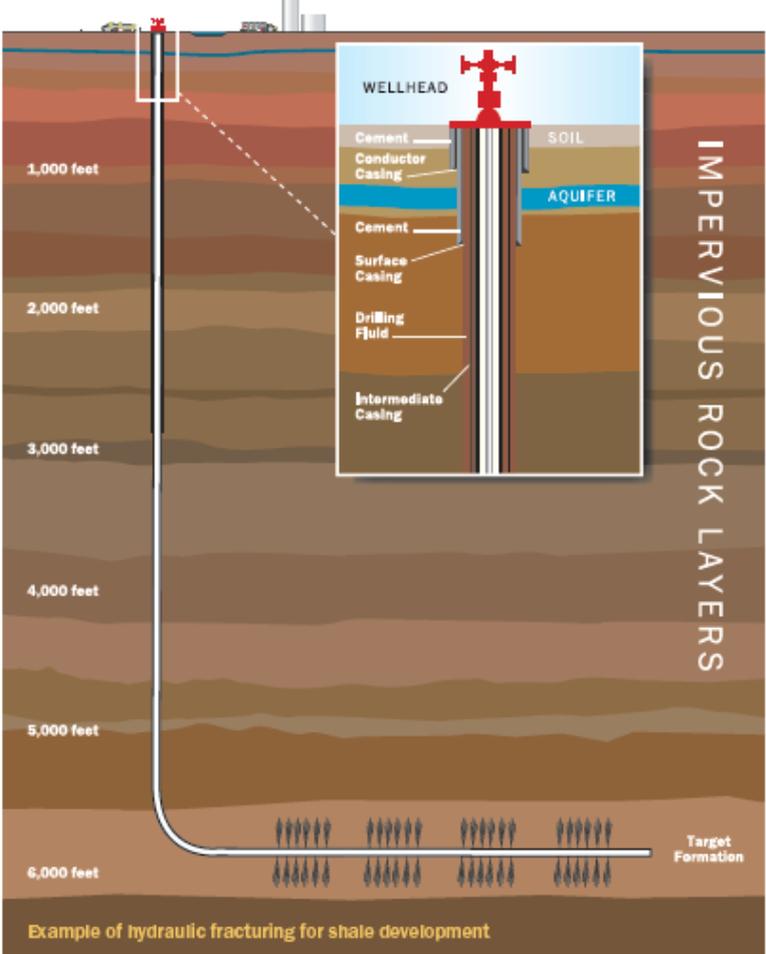
²² 'Pad' in the context of a hydraulic fracturing operation refers to fluid used to initiate hydraulic fracturing that does not contain proppant (Schlumberger Limited, 2013b).

²³ Proppant is a granular material such as sand or artificial sand (see figure 6) used to 'prop' fractures open, to retain their permeability by reducing the tendency of fractures to close after pumping stops (Power Projects Limited, 2012).

The pressure of the fluid induces fractures in the hydrocarbon reservoir. The pressure at the surface will be highest on formation breakdown at the end of the job, when the fluid is lighter and the hydrostatic head is reduced, or during screen-out. Once fractures are open, a proppant (sand or ceramic beads) is added to keep the fractures open once the pressure reduces. These fractures are naturally self-limiting, and can extend up to 100 metres long by 20 metres high, but are very narrow (2 to 3 millimetres), due to the stress caused by the weight of rocks above. Fluid tracers, micro-seismic analysis or tilt meters can be used to undertake real-time monitoring of pumping operations.

Once the hydraulic fracturing operation is complete, pressure at the surface is reduced to enable fluids to return to the surface (referred to as ‘flow back’), leaving the proppant in the fractures. This fluid will be a mixture of hydraulic fracturing fluids and other fluids from the reservoir, including saline produced water (ie, subsurface water) and hydrocarbons, which will emerge within a few hours. The separation and treatment of produced waters is discussed further in section 5.6. Produced water also occurs in conventional wells. Figure 5 provides an example of a well that has been subject to hydraulic fracturing.

Figure 5: Example of hydraulic fracturing for shale development



Source: American Petroleum Institute, 2010a, p 7. Reproduced courtesy of the American Petroleum Institute. Note that groundwater zones can also be located at deeper locations than is shown by this diagram.

The discharge of contaminants through the hydraulic fracturing activity (energy,²⁴ chemicals, water, and sand/small ceramic pellets) occurs into ‘land’ at a considerable depth. It produces relatively minor and short-term changes to the physical and chemical condition of the land (ie, the reservoir).

The principal considerations of environmental effects associated with the hydraulic fracturing process are discussed in section 5 below, and are:

- potential contamination of freshwater aquifers through leakage caused by defective well installation or operation, leakage through the geological media, well blowouts (section 5.3), or leakage or improper handling of chemicals or wastewater (sections 5.5 and 5.6)
- potential seismic effects, including low-level induced seismicity (section 5.11)
- managing hydraulic fracturing fluids on the well site before the hydraulic fracturing operation is undertaken (section 5.5)
- managing the recovery of produced water after the completion of the hydraulic fracturing operation (see section 5.6)
- the treatment and disposal of the recovered hydraulic fracturing fluids (section 5.6)
- use of water, and the effects associated with the take of the proposed volume of water required for the fracturing operation, and any measures adopted to minimise water use (section 5.4).

4.5.2 Fracturing fluids composition

Hydraulic fracturing fluid predominantly consists of water and a proppant (sand or ceramic beads, see figure 6), which together generally comprise between 98 and 99.5 per cent of the fluid. The remainder is made up of chemical additives to ensure the fracturing job is effective and efficient. These additives perform a range of functions, such as controlling friction,²⁵ and protecting the well casing from corrosion and bacterial contamination.

Figure 6: Example of proppant used in Taranaki fracture operations



Source: Taranaki Regional Council, 2013b.

²⁴ ‘Energy’ is covered by the definition of ‘contaminant’ in Section 2 of the RMA.

²⁵ A drag-reducing polymer is used to reduce wall friction in flow down the well, but can also increase wall friction in flow along the fracture (both of which are desirable features).

In the past, diesel-based hydraulic fracturing fluids were used in Taranaki (from 2001 to 2005). These fluids are controversial because they contain low levels of BTEX compounds, which, in sufficient quantities, can have harmful effects on the central nervous system in humans if introduced to water or soil. BTEX compounds are present in produced hydrocarbons, as well as in manufactured products such as petrol (much higher levels), diesels and oils, and may also be contained in drilling muds (Broni-Bediako and Amorin, 2010). These fluids also contain other hydrocarbons that have harmful properties, such as polyaromatic hydrocarbons (PAHs). Diesel itself is classified as a suspected human carcinogen under HSNO. Benzene is classified as a known human carcinogen. Because of the risks associated diesel-based hydraulic fracturing fluids, water-based fluids should be strongly preferred.

Queensland prohibits the adding of BTEX to hydraulic fracturing fluid. To ensure that the BTEX in fracturing fluids will not contaminate drinking water, or have an impact on groundwater-dependent flora and fauna, the individual compounds used in fluid should meet the levels shown in table 3.

Table 3: Environmental and health standards for BTEX in fracking fluids

Substance name	Standard (parts per billion)	Guideline
Benzene	1	Australian Drinking Water Guidelines
Toluene	180	ANZECC ²⁶
Ethylbenzene	80	ANZECC
m-Xylene	75	ANZECC
o-Xylene	350	ANZECC
p-Xylene	200	ANZECC

Source: Figures taken from State of Queensland (Department of Environment and Heritage Protection), 2012.

Table 4 is an example of the composition of hydraulic fracturing fluid. Further detail of particular chemicals an operator may wish to use in fracturing fluid is provided in Appendix I (Taranaki Regional Council, 2013b).

²⁶ *Australia and New Zealand Environment Conservation Council Guidelines for Fresh and Marine Water Quality*

Table 4: Hydraulic fracturing components and purposes

Material/compound	Fracturing use
Water	Municipal supply (96% of total)
Proppant (ceramic beads or sand)	Props fractures open to create a permeable pathway for reservoir fluids
Additives	
Acids	Dissolves minerals and promotes fracturing
Sodium chloride	Delays breakdown of gel polymer chains
Potassium chloride	Suppresses clay mineral hydration
Ammonium bisulphate	Protects steel pipes from corrosion
Sodium or potassium carbonate	Maintains the effectiveness of compounds
Borate salts	Maintains fluid viscosity as temperatures rise
Guar gum	Thickens water
Citric acid	Prevents precipitation of metal oxides
Ethylene glycol	Prevents scale deposits in pipe
Glutaraldehyde	Removes water bacteria to prevent contamination
Polyacrylamide	Minimises friction between fluid and pipe
N, n-Dimethyl formamide	Stops pipe corrosion

Source: Adapted from Power Projects Ltd, 2012. See section 5.4.2 for information about substance approvals.

The choice of hydraulic fracturing fluid composition by an operator will vary from one geological basin or formation to another. Even within the basin, a different mixture of hydraulic fracturing fluid might be used for different hydraulic fracturing jobs on the same well.

During the process of fracturing, some of the chemicals are absorbed by the natural geological media (eg, clay stabilisers). Process design provides for some chemical degradation due to pressure, temperature and physico-chemical reactions (eg, due to biocides and gel breakers). A proportion of the fracturing fluid remains behind in the formation after the initial clean-up period due to gas breakthrough (ie, enough fracture fluid has been produced that gas production commences). Additional fracturing fluid may be removed over time as part of the production process.

Over the lifetime of a well, the chemical composition of the produced fluid slowly changes from predominantly fracturing fluid to primarily *in situ* formation fluid (eg, hydrocarbons and some salty water). How long it takes to recover the fracture fluids depends on several factors, primarily the overall production flow rate (higher is better), the producing gas:fluid ratio, and the nature of the target reservoir rock.

The volume of fracture fluid recovered in the initial return flow, and then subsequently over time in the well bore flow, depends on the fracture operation itself and the properties of the formation being fractured. Between 25 and 75 per cent of fracture fluids injected should generally return to the surface after fracturing (King, 2010). For example, in the Mangahewa-6 well hydraulic fracturing job, an estimated 40 per cent of the fracturing fluids were recovered initially, in the return flow. It is expected that most of the remainder of the fracturing fluid will be recovered over time in the well bore flow during production, so that only a relatively minor fraction will be unrecoverable – mainly that which is retained on the proppant and reservoir due to capillary action (Taranaki Regional Council, 2012a).

Fracturing fluids that are returned to the surface in return flow may contain naturally occurring hydrocarbons (including BTEX). BTEX is usually present in low concentrations (measurements showed less than 8 ppm for Waitui-1 well flow-back fluids) but still require careful management to avoid potential adverse environmental effects (Taranaki Regional Council, 2012b). Management of return fluids is discussed in section 5.66.

4.6 Initial production

The production phase can occur after a well has been connected to ‘downstream’ processing facilities. This is the longest phase of the well lifecycle, and can last upwards of 30 years (depending on the nature of the resource). Aside from the ‘Christmas tree’ (or trees if there are multiple wells at one well site), and infrastructure (pipelines), which connect the site to production facilities, infrastructure can be removed from the well site.

If an exploration phase is successful (ie, hydrocarbons are found in commercial quantities), development drilling of additional wells may occur at a single well site. This would result in additional drilling operations, and additional hydraulic fracturing operations if required.

In some cases a well may be subject to additional hydraulic fracturing procedures at later dates throughout the production phase (ie, re-fracturing) (International Energy Agency, 2012).

4.7 Well abandonment and decommissioning

Well ‘suspension’ means to render a well temporarily inoperative, and ‘abandonment’ means to seal the well to render it permanently inoperative. The purpose of decommissioning is generally to revert the land to its original condition and use permanently, unless otherwise agreed with a land owner and consented under the RMA (eg, a concrete production pad being left and used as the floor of a shed or feed pad).

In the petroleum industry, a well is abandoned if a potential hydrocarbon reservoir is dry or it is no longer economic to continue to exploit it. This includes where the exploration phase has been unsuccessful (ie, exploratory and appraisal wells have shown that hydrocarbons are not available in commercially viable quantities). Wells have been drilled and abandoned in New Zealand for around 150 years.

If an exploration well is unsuccessful, it will typically be decommissioned after the initial one to three months of activity. Decommissioning of onshore production installations occurs at the end of their commercial life, typically 20–40 years, and involves removing buildings and equipment, and restoring the site closure (MBIE, 2013a).

In practice, abandoning a well typically involves plugging sections of the well with cement to prevent migrating between zones, or leaking into groundwater or to the surface. The area around the well head is then excavated, the well head is removed and a cap is sealed in the well, which is then buried below the surface. This enables the land surface to be restored to the state it was in before drilling.

Environmental effects to be addressed, and the regulation of well abandonment and decommissioning, are discussed below in section 5.3

5 Key environmental issues and effects management

5.1 Overview

These guidelines identify the resource management issues associated with each stage of the well life cycle so the effects of hydraulic fracturing can be seen in context. A number of environmental effects will occur to different extents, at different stages of the well life cycle, as summarised in Appendix G. Detail of issues and the management of environmental effects are discussed in the following sections.

5.2 Seismic surveying

5.2.1 Issues

There are a number of potential environmental issues associated with seismic surveying operations including:

- vegetation and soil disturbance for the development of areas for shot-hole drilling and geophone placement
- vibration associated with the detonation of charges
- vehicle movements (generally minor)
- potential upwelling and discharge to the environment of groundwater fluid (and subsequent drawdown of groundwater), or upwelling of shallow gas through shot holes.

5.2.2 Effects management

Permitted activity standards or conditions on resource consents for seismic surveying can be used to manage the potential environmental effects of these operations.

Vegetation clearance should be minimised, and councils may wish to provide for replanting to offset any considerable vegetation clearance, if needed. Shot holes should be back filled with soil and tamped after the seismic survey operations have been completed.

The effects of vibration on the surrounding environment can be managed by setting appropriate setback distances from structures, which is affected by the charge weight of the explosive used. For example, in Manitoba, different setback distances are set for explosive and non-explosive operations, as described in the following table.

Table 5: Minimum distances for seismic surveying operations in Manitoba

Type of surface improvement	Non-explosive	Explosive	
	Minimum distance (metres)	Charge weight (kilograms)	Minimum distance (metres)
A structure with a concrete base	50	Not more than 10	180
A water well	100	Not more than 10	180
A water pipeline, low-pressure gas distribution pipeline, ²⁷ measured from the centre line of the pipeline, or an irrigation canal that is more than 4 metres wide	10	Not more than 10	20
A residential driveway, gateway, survey monument, buried telephone or telecommunication line, or underground electrical facility	3	Not more than 10	3
A high-pressure pipeline, measured from the centre line of the pipeline, or an oil or gas well	15	Not more than 2	32
		More than 2, not more than 4	45
		More than 4, not more than 6	55
		More than 6, not more than 8	64
		More than 8, not more than 10	72

Source: Adapted from Manitoba Government, 1994.

Another example is Arkansas, where permitted setback distances are the same for any residence, water well, oil well, gas well, brine well, injection well or other structure, as shown in table 6. However, for any exceedance to the permitted setbacks or charge weight based on those setbacks, written approval must be obtained from the owners of those structures, and permission from the regulator must be obtained for any charge greater than 25 pounds.

Table 6: Minimum 'permitted' setback distances from structures, by charge weight for seismic surveying in Arkansas

Distance to structure (feet)	Maximum allowable charge weight (pounds)
50	0.5
100	2.0
150	4.5
200	8.0
250	12.0
300	18.0
350	25.0

Source: Arkansas Oil and Gas Commission, 2013, p 113.

Upwelling and discharge of fluid or gas is a potential effect of seismic surveying if these subsurface substances are encountered during or after drilling. This risk can be mitigated by:

- ensuring drilling is discontinued immediately (if substances are encountered), and notifying the regional council if this occurs

²⁷ For the purpose of this regulation, high-pressure pipelines are designed or intended to be operated at pressure greater than 700 kPa, and low-pressure gas distribution pipelines are up to 700 kPa.

- placement of movable bunds (eg, hay bales) around shot holes
- ensuring shot holes are not located close to surface freshwater bodies
- using only fresh water or water-based drilling fluid
- placement of a maximum permitted depth for drilling shot holes in particular areas with known shallow aquifers (eg, in Manitoba, approval must be obtained to drill a shot hole deeper than 30 metres (Manitoba Government, 1994)
- appropriate abandonment and remediation of shot holes to prevent any fluid discharging into or out of the holes (eg, using cement or gravel).

5.3 Well development and decommissioning

5.3.1 Issues

Well design and the integrity of the well throughout its design life are the key factors in managing the environmental risk associated with oil and gas exploration, development and production. Poor well integrity is a significant risk to people's health and safety, and to the environment. The most likely source of contamination into an aquifer is from a well with poor integrity.

The well design and well integrity examination process is the most important factor in protecting groundwater quality throughout the life cycle of a well (which is the main risk associated with the well development process). According to the UK Royal Society and the Royal Academy of Engineering (2012, p 4.), "ensuring well integrity must remain the highest priority to prevent contamination. The probability of well failure is low for a single well if it is designed, constructed and abandoned according to best practice."

Well failure that causes a leak can result from a number of situations.

- **Blowout** – a sudden and uncontrolled escape of fluids from a well to the surface, caused by a build-up of pressure. A blowout is very rare, but can have major and long-lasting effects, including the loss of human life, adverse environmental effects, and substantial commercial losses to the companies directly involved and any affected third parties.²⁸
- **Annular leak** – inadequate cementing between the steel casing allows contaminants to move vertically through the well.
- **Radial leak** – casing failure allows fluid to move horizontally out of the well and into the surrounding rock formations or aquifers (Royal Society and Royal Academy of Engineering, 2012, p 24).

There is risk of groundwater contamination through defective well installation or operation, leakage through geological media or well blowouts (as well as improper handling of chemicals or wastewater, discussed below in 5.3 and 5.4). Risk of aquifer contamination is linked to radial leaks as it is unlikely to result from a blowout or annular leak to the surface (though there are other surface contamination and health and safety risks associated with these situations).

²⁸ In 1995 a blowout occurred at the McKee-13 well in Taranaki. Gas, oil and drilling mud erupted around the base of the rig and spouted up to 30 metres into the air. The operator was prosecuted under the HSE Act and the RMA.

It is critical that wells are designed so they have a sufficient number of casings for the conditions, the cementing is sound, and the well is pressure tested to ensure it is able to withstand the pressure it is likely to be exposed to.

5.3.2 Effects management

Because well integrity is important for health and safety in employment, this is regulated by the HSE(PEE) Regulations. Through the Regulations, WorkSafe New Zealand's High Hazards Unit has oversight of the well design process and the health and safety regime by assessing and approving the safety case that applies to a particular well-drilling operation, but it does not formally certify a well.

It is important to note that this process is undertaken from a health and safety perspective, not an environmental perspective, and that regional councils and territorial authorities are responsible for managing well integrity in relation to potential environmental effects.

Additional regulation under the RMA should not duplicate what is achieved through compliance with the HSE(PEE) Regulations (see Appendix F), and councils are encouraged to maintain working relationships with the High Hazards Unit (as discussed above in section 3.8.3).

Earthworks associated with well site establishment (eg, access tracks, well pads) also have the potential to disturb archaeological sites. Land use consent conditions should be used as appropriate to cease work, notify authorities (including the council, New Zealand Historic Places Trust, iwi and/or Police), and not reconvene work until appropriate approvals have been obtained. An example of such a condition is contained in Appendix C2 (condition 16).

Well design and construction

Good oilfield practice requires the use of fresh water as a base drilling fluid at shallower depths (such as 500 metres) to minimise problems with the very small amount of fluid leak-off in shallow, highly permeable formations that may occur before the freshly drilled hole is cased. Then, if necessary, the mud is changed to an oil-based or synthetic-oil-based formulation once the surface casing string has been set across shallow aquifers (Taranaki Regional Council, 2013b).

In the UK, for example, standard practice is for at least two casings to pass through any freshwater zone to ensure isolation. Best practice is to cement casings all the way to the surface depending on local geology and hydrogeology conditions (Royal Society and Royal Academy of Engineering, 2012).

Good cementing techniques are critical for obtaining the desired hydraulic isolation between zones and between the well and the rock formation (American Petroleum Institute, 2009b). It is important that the cement fully displaces the drilling fluid in the space between the casing and the exposed rock without leaving channels that may eventually lead to behind-pipe flow conditions. Guidelines developed by the American Petroleum Institute have detailed recommended cementing practices that should be undertaken to achieve isolation of zones.

American Petroleum Standard 65 specifically addresses the requirements for ensuring proper design, planning, slurry testing and cement job execution (American Petroleum Institute, 2010b). The most important part of this process is post-job verification. The International Energy Agency has described American Petroleum Institute guidelines as “comprehensive

standards and best practices pertaining to the construction of wells to ensure their integrity” (International Energy Agency, 2012, p 55).

For matters covered by the HSE(PEE) Regulations 2013 or regulations under HSNO, additional regulation through the RMA would not be necessary (see Appendix F in relation to matters covered by the HSE(PEE) Regulations). For example, operators are required to prepare and review emergency response plans under regulations 79 and 80 of the HSE(PEE) Regulations. Councils should work closely with the High Hazards Unit to consider the independent examination of a particular well, conducted for the purpose of the HSE(PEE) Regulations, and the extent to which this has addressed all potential environmental effects.

Hydraulic fracturing

The case study below details the material provided in a resource consent application for hydraulic fracturing, which includes information to help assess well integrity (along with other environmental effects, which are discussed later in this section). For potential contamination of groundwater, a council will need to be satisfied that:

- the well design and the integrity of the well avoid or mitigate the risk of groundwater contamination (note, regional councils should liaise with the High Hazards Unit to help them assess that well integrity is adequate to avoid risk to the environment)
- the applicant has an appropriate groundwater monitoring programme that allows an understanding of the particular groundwater environment before the exercise of the hydraulic fracturing consent, and the ability to sample and evaluate groundwater in the period following the exercise of the consent
- the well has been pressure tested to a level that ensures its integrity (note that this will generally be required under the HSE(PEE) Regulations 2013 – councils should liaise with the High Hazards Unit on the details of a particular well)
- the applicant has provided a comprehensive pre-fracturing discharge report to demonstrate the ability to comply with consent conditions overall, and to demonstrate consistency between the report, the consent application as lodged and the supporting assessment of environmental effects (AEE)
- the applicant has provided a post-fracturing discharge report to give confidence that the fracturing operation has proceeded as planned, and that the discharged proppant has remained within the interval where the fracturing operation took place
- the applicant has consistently applied the ‘best practicable option’ to ensure the discharge is contained within the fractured interval, regular reviews are undertaken, and flow-back fluids are managed, treated and discharged appropriately.

Examples of resource consent conditions to address these matters are included in Appendices B and C.

Case study 1: Shell Todd Oil Services Ltd application to Taranaki Regional Council for four discharge consents and assessment of environmental effects: Hydraulic fracture stimulation at four existing well sites within the Kapuni field (January 2012)

In January 2012, Shell Todd Oil Services (STOS) filed resource consent applications with the Taranaki Regional Council to enable the hydraulic fracturing of four existing wells in the Kapuni field. In the context of the guidance set out above, the important components of the application to note are:

- demonstration of the separation between the fracture zones and potable water and the presence of a viable geological seal so that these zones are isolated
- an understanding of the water quality associated with potable water resources within the vicinity, and the nature of water abstractions in the vicinity of the site
- an understanding of the lithology and the overpressure containment of the field, based on the long association that STOS have with the field and the amount of data available regarding reservoir overpressure
- an understanding of the faulting associated with the field and outputs of geotechnical studies that demonstrate the faults associated with the field are not likely to slip.

The consent application deals specifically with the following key environmental issues:

- well design and integrity as the primary method of avoiding adverse effects associated with potential contamination of freshwater aquifers, accompanied by detailed information on the well's design, associated mitigation measures (including isolation of freshwater aquifers), thorough cement design and testing procedures, pressure testing of casing strings based on a full range of life-cycle loads, and real-time monitoring of annulus pressures during perforation, stimulation and flow back
- risk of leakage through the geological media
- leakage or improper handling of chemicals or wastewater
- management of the risk of well blowout
- groundwater monitoring
- the use and treatment of water for hydraulic fracturing, including sourcing from municipal supplies
- the risks associated with induced seismicity.

The assessment of environmental effects contains detailed information in its appendices on well logs and well schematics for the drilling programme, which links back to the discussion on well design and integrity, detailed fracture treatment operational procedures, and safety data sheets for each component of the hydraulic fracturing fluid and for the components of the down-hole tracers.

This application is accessible on the Taranaki Regional Council website at <http://www.trc.govt.nz/assets/Publications/guidelines-procedures-and-publications/hydraulic-fracturing/stos-ae-kapuni-jan2012w.pdf>.

Site decommissioning and well abandonment

The actual or potential effects of well abandonment are mainly related to the potential for groundwater contamination, which can be managed by decommissioning in a manner that is

consistent with good oilfield practice. Well abandonment will generally take into consideration resource consent or plan provisions at both the regional council and territorial authority levels.

In summary, the key environmental factors to be considered at abandonment are:

- the decommissioning strategy, and the integrity of the well once the well has been plugged and the head works have been removed
- identification of areas at risk of potential contamination, well site clean-up strategies and methodologies
- the removal of well site equipment and facilities, and the timeframe for this process
- the number of heavy vehicle movements associated with the decommissioning site, and the timing of the required trips
- earthworks associated with rehabilitation of the site, particularly if consent conditions require the site to be reinstated to the same condition as existed before the activity being established
- amenity effects associated with the decommissioning and reinstatement process.

Regional issues – risk of discharges

Before an operator decommissions a well, the consent authority will need to be satisfied that there is no residual risk associated with any hydraulic fracturing activity that may have been undertaken in the well. These conditions may include requiring consent holders to demonstrate:

- that the well has been plugged (including at the base of the lowermost groundwater zone, and other areas throughout the well as appropriate), and that diagnostic and monitoring procedures have been followed to show that the proppant material has been retained in the interval (the section between plugs)
- the volume of fracturing fluid and hydrocarbons still contained in the interval.

This will form the basis of any risk assessment relating to potential groundwater contamination. At significant depths (eg, in excess of 3000 metres), the risk of contamination is likely to be minimal due to the vertical distance to groundwater. However, where the fracturing is undertaken at shallow depths, the groundwater monitoring regime would need to demonstrate that contamination had not occurred before well decommissioning and that the risk of it occurring in the future is low.

As with drilling, HSE(PEE) Regulations provide for the management of well plugging and abandonment to ensure any risks to health and safety arising from these operations is managed to as low as is reasonably practicable. Regional councils are responsible for ensuring that any risk of groundwater contamination arising from defective well abandonment is appropriately managed (eg, risk of leakage through the well casing). Regional councils should liaise with the High Hazards Unit in assessing the extent to which a well has been adequately plugged to mitigate risk to the environment.

The use of bond conditions on regional resource consents (under section 108A of the RMA), or as a condition on a permitted activity, may be appropriate to ensure well abandonment is satisfactorily completed, and to maintain well integrity after decommissioning (including monitoring requirements), in relation to managing the risk of groundwater contamination. More information about bond conditions is available at <http://www.qualityplanning.org.nz/index.php/consents/conditions#Bonds>.

District issues – site restoration

Land-use consents issued by territorial authorities typically require the abandoned well site to be restored to the same condition as existed before establishing the well site. Regional council consent conditions can generally focus on managing or avoiding discharges and managing risk.

In some cases it may be appropriate to implement side agreements between land owners and the consent holder relating to certain assets being retained after decommissioning and abandonment. Examples of these include areas of the metallised well site being retained as feed-out pads, utility structures being retained for on-farm use, and/or the retention of access roads. These matters should be anticipated at the start of the consenting process and identified in the consent application, otherwise the consent holder may need to apply to change the consent conditions.

Councils should seek coordinates for the site extent from the operator for future reference regarding any potential land contamination.

The use of bond conditions (under section 108A of the RMA) on district consents for well sites may be appropriate to ensure well site abandonment and decommissioning are satisfactorily completed.

5.4 Water demand and use

5.4.1 Issues

The availability of water and freshwater management is a critical issue for some regions of New Zealand, such as Hawke's Bay. The extent of water use can be a key issue for oil and gas development and has generated considerable public concern.

In circumstances where multiple fracturing operations are required for shale gas wells, the highest volumes of water use are generally associated with hydraulic fracturing operations (rather than well-drilling operations); however, the amount of water required largely depends on the individual site geology, and in other cases more water is needed for drilling operations than hydraulic fracturing operations.

Tight reservoirs and coal seam gas do not require the same quantities of water as is required for shale gas, and New Zealand's hydraulic fracturing operations have not used the volumes of water seen overseas. Tight deposits in Taranaki have typically used about 700 barrels of water per operation (Power Projects Ltd, 2012). However, hydraulic fracturing for more unconventional deposits (eg, shale) generally requires considerably higher volumes of water than conventional deposits per unit of energy extracted, as table 7 shows.

There are undeveloped shale deposits on the East Coast, an area that also coincides with high existing demand for water. Demand for water for use in hydraulic fracturing of shale resources could place additional demand on catchments that are already under pressure. If catchments are already fully or over-allocated, the operator may need to seek to transfer allocation from an existing consent holder for the duration water is required.

There remains some uncertainty about whether the shale resources on the East Coast are comparable to shale overseas in terms of likely water demands. The hydrocarbons may be more easily extracted than from true 'shale plays', which would affect the amount of drilling, hydraulic fracturing and water required.

Table 7: Water use per unit of gas and oil produced (cubic metres per terajoule)²⁹

	Water consumption	
	Production	Refining
Natural gas		
Conventional gas	0.001 - 0.01	
Conventional gas with fracture stimulation	0.005 - 0.05	
Tight gas	0.1 - 1	
Shale gas	2 - 100	
Oil		
Conventional oil*	0.01 - 50	5 - 15
Conventional oil with fracture stimulation*	0.05 - 50	5 - 15
Light tight oil	5 - 100	5 - 15

Source: IEA analysis.

* The high end of this range is for secondary recovery with water flood; the low end is primary recovery.

Surface water, local bores, municipal supply (piping) or trucking in the water are all possible sources of water. The location of the drill site may be linked to the source of water, but in some cases water may be trucked to the drill site from elsewhere (eg, from municipal supplies).

The volume of water required for a hydraulic fracturing operation is a function of the well characteristics (eg, diameter and depth) and the properties of the proposed fracture zone. Generally, horizontal wells require more water than vertical wells, given that the length of horizontal wells is greater. Variation in water demand occurs between regions for associated processes due to differences in geology, such as shale versus tight reservoirs (which are typically found in the Taranaki region).

The need for water in water-scarce areas has driven technological development in the US, where fracturing operations are often carried out in arid areas. Various techniques for cleaning produced water to allow it to be reused in hydraulic fracturing or for other purposes are being developed (MBIE, 2013a). Guidance on managing produced water is provided in section 5.6.

Water is also used on conventional oil and gas sites. For example, sufficient water needs to be stored on-site for water-based drilling muds and other activities.

During the decommissioning/restoration phase, fresh water is used to control dust from road traffic, the dismantling of well-pad facilities, pipelines, compressor stations or pumping stations, and for consumption by workers.

Large-scale coal seam gas developments in the same region can have significant cumulative impacts on water quantity, quality and availability in particular areas, due to the combined effects of aquifer drawdown (IESC, 2013).

5.4.2 Effects management

Water use is allocated under the RMA through a regional plan and the resource consent regime. Regional councils manage water use, and they may adopt provisions in their plans to permit and

²⁹ Source: International Energy Agency, 2012, p 31. This table is © OECD/International Energy Agency, 2012, table 1.1, p 31.

restrict these activities. These controls typically use measurable thresholds, beyond which a resource consent will be required.

In the New Zealand context the volumes of water required for well drilling and hydraulic fracturing have been relatively low. This water has generally been sourced from potable municipal water supplies to ensure a high water quality and to avoid bacterial contamination of the reservoir. If non-potable water is used, then biocides can be added to the fracturing fluid. An application and AEE should provide information including:

- an estimate of the potential volume of water required, and the duration of when this water will be used
- details of where the water will be sourced
- details of any measures that will be implemented to reduce water usage on site
- relevant hydro-geological information about the proposed sites and groundwater composition and characteristics in the vicinity of the site.

Water demand and availability vary greatly around New Zealand. The evaluation of the volume of water to be used for hydraulic fracturing and its associated process, and the differences of geology between regions (shale versus tight sand), mean councils assessing the effects on the environment need to do this on a case-by-case basis.

Conditions of consent are typically set to deal with each of the effects listed above. Examples are provided in Appendices B and C. Typically these relate to the:

- maximum rate of injection (cubic metres per hour) allowed
- maximum volume of fluid injected (cubic metres per day) allowed
- keeping of daily records of the volume of fluid used
- provision of a traffic management plan to the council for approval if water needs to be transported.

The level of water required to undertake hydraulic fracturing of a particular formation is affected by its local geology (see table 7 above). If the operator is applying for resource consent to drill a new well that will require fracturing (eg, shale), any consents required for fracturing should be applied for at the same time. However, it may be difficult to estimate the actual level of water required to fracture a particular well before it is drilled, as this requires a technical understanding of the formation geology. In this situation, consent conditions may be placed to impose *maximum* (rather than actual) rates of water and fluid injection by volume, based on estimates of what will be required.

Case study 2: Water usage in the Taranaki region for hydraulic fracturing

Water volumes

Taranaki Regional Council has reported that the volume of water used in a hydraulic fracturing operation in vertically drilled wells varies between 77 cubic metres (Cheal A7 well) to 1500 cubic metres (Mangahewa 6 well). The well depths were 1750 metres and 4190 metres, respectively. There were four fracture operations at the Mangahewa 6 well, with three averaging 224 cubic metres' water use.

In 2012, Shell Todd Oil Services estimated that between 50 and 500 cubic metres of water would be required for each stimulation operation for the KA-14 and KA-19 wells in the Kapuni field. Each well would potentially have up to nine intervals (the section below the plug) that would be fractured. Assuming the maximum expected volume of 500 cubic metres of water is required for each of these stages, a total of 4500 cubic metres of water could potentially be required for the full stimulation programme at one of these wells. In comparison, volumes ranging from 7570 to 18,900 cubic metres of water have been used for hydraulic fracturing stimulations of one horizontally drilled well in a US shale formation.

Water sources

Water for hydraulic fracturing is sourced from municipal supplies in Taranaki and trucked to the well site. The resource consents held by the district councils in Taranaki for municipal supply allow water to be extracted for industrial use such as hydraulic fracturing. Given the high water quality requirements, treated supplies are favoured to avoid introducing unwanted bacteria into the reservoir and creating sour gas. The water is also treated with a biocide (eg, glutaraldehyde) before use to further address the bacterial risk.

The water take is not continuous because hydraulic fracturing activities are intermittent. No compliance issues have arisen from the supply of water for this purpose in the Taranaki region.

Source: Taranaki Regional Council, 2013b.

If large-scale coal seam gas developments are proposed in a region, regional councils should consider developing management strategies to address the cumulative impacts of proposals, including potential aquifer drawdown, using risk-based appraisal methods. Guidelines have been prepared in Australia, and councils should refer to these when developing such strategies (IESC, 2013).

5.5 Chemical substances

5.5.1 Issues

A variety of chemicals are used in fluids required for drilling and hydraulic fracturing operations. The environmental effects of these chemicals are primarily related to the transportation, storage and make-up of the hydraulic fracturing fluids before injection, along with managing the flow-back fluids after stimulation of the well. The former are discussed below. The management of the flow-back fluids is discussed in section 5.6.

Many of the additives used in fracturing in their concentrated (pure) form are toxic, as indicated by the safety data sheets required by HSNO. However, once mixed in the blender (the unit used to mix the water, sand, proppant and chemicals), they are heavily diluted and are therefore present in relatively low concentrations. These concentrations decline further in the produced water coming back to the surface after the hydraulic fracturing operation has been completed.

As a result, the proportion of any particular hazardous substance in a fracturing fluid mixture will be greatly diluted – typically well below 1 per cent of product concentrations on injection and even less on return to the surface. When diluted to this extent, some hazardous substances may no longer pose an environmental hazard.

Nonetheless, even in low concentrations, care is needed in the use of some of the compounds to avoid any potential impacts on human health or the environment. When used properly in hydraulic fracturing operations (including ensuring the additives are not introduced into overlying groundwater or other sensitive environments), adverse effects on human health and the environment can be avoided.

The transport and storage of fracture fluids, chemicals and equipment are potential sources of contamination. The risk of this contamination can be substantially reduced or mitigated by storing chemicals in double-wall containers, or in bunded areas.³⁰ Surface storage vessel leaks and spills can range from less than a few litres when connecting fracture fluid lines, to the very rare leak of greater volumes if both container and secondary containment fail.

Effects on human health

As with other activities, if contaminants from oil and gas exploration activities enter water that is used for community drinking water supplies, there is the potential for effects on human health. In addition, sediment may be discharged as a result of oil and gas activities, and this can reduce the effectiveness of drinking water treatment processes.

The health effects of most concern in relation to chemical contaminants arise from prolonged exposure at low concentrations, although exposure as a result of high concentrations, such as from an accidental spillage, can have immediate consequences on human health. A wide range of health effects can result, depending on the contaminant and its concentration.

5.5.2 Effects management

Substance approvals

The importation, manufacture, use, storage and disposal of hazardous substances are covered by HSNO. The approval of such substances is carried out by the Environmental Protection Authority (EPA). In most cases, the additives that are needed for the fracturing process to work can be self-classified and self-assigned under the applicable Group Standard, and will not need a new approval from the EPA. Proof of authorisation for use in New Zealand and disclosure of the composition of the various trademarked compounds can be sought directly from the user by requesting proof of their HSNO approval and the consequent documentation, as stipulated by the EPA.

³⁰ Note that requirements under the HSNO Act will apply to the storage of chemicals.

Safety data sheets for each compound or chemical will usually provide complete information on composition (ingredients and proportions). In some cases the data sheets may make reference to proprietary information that is not readily available. In such cases, reference should be made to the supplying company. Confidentiality agreements may be necessary under section 42 of the RMA.

The disclosure of all fracturing compounds intended for use should be part of the consent application, and this information may be requested under section 92 of the RMA if it is not supplied in the initial application. Regional councils should require safety data sheets to be provided with an AEE for hydraulic fracturing to assess the effect of those fracturing fluids potentially entering groundwater through migration pathways at that dilution. Following fracturing activities, confirmation should be provided of the volumes and compounds actually used, and return fracturing fluids should be routinely collected for independent analysis. There are several authoritative or regulatory checklists on matters for consideration, and key parameters for analysis.³¹

Like any information held by councils, the provisions of the Local Government Official Information and Meetings Act 1987 apply to information about fracturing compounds supplied with a consent application.

Currently the EPA does not set environmental exposure limits (EELs) on substances, including any substances that might be used during hydraulic fracturing. Before 2003, the EPA (as the Environmental Risk Management Authority) set some EELs using the provisions in Part 3 of the Hazardous Substances (Classes 6, 8, and 9 Controls) Regulations, but only for some pesticides, anti-fouling paints and BTEX from petrol (but not diesel). The EPA has indicated that at this time it will not be extending EELs to fracturing substances.

As a result, a regional council can set environmental limits that it considers appropriate, taking into account section 142 of HSNO.³² If a regional council chooses to do this, it will have to determine appropriate criteria elsewhere. Existing guidance from the Ministry for the Environment on environmental limits for contaminated land,³³ or Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines for water quality,³⁴ may be useful. These guidelines are currently under review, and further information is available on the Ministry for the Environment website at: <http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/>.

³¹ For example, New Brunswick Natural Gas Group, *Responsible Environmental Management of Oil and Gas Activities in New Brunswick*, pp 35–36; Ohio Department of Natural Resources, Senate Bill 315, ss 1509.2–1509.23; Ohio Department of Natural Resources, *Best Management Practices for Pre-drilling Water Sampling*, 28 April 2005; Ohio EPA, *Recommendations for Water Well Sampling Before Oil and Gas Drilling*, June 2011; Colorado Oil and Gas Conservation Commission, Docket No 1112-RM-04; United States House of Representatives, *Chemicals Used in Hydraulic Fracturing*, April 2011; American Petroleum Institute, Guidance document HF2, *Water Management Associated with Hydraulic Fracturing*, 1st edition, June 2010; American Petroleum Institute, Guidance document HF3, *Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing*, 1st edition, January 2011.

³² See the Quality Planning Guidance note Managing Hazardous Substances: <http://www.qualityplanning.org.nz/index.php/related-laws/hazardous-substances>.

³³ See <http://www.mfe.govt.nz/publications/hazardous/#guides2>.

³⁴ Australian and New Zealand Environment and Conservation Council, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*, <http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/index.html>.

The EPA regularly sets values for workplace exposure standards for substances and/or components of a substance. The EPA does this by adopting values from MBIE.³⁵ These generally relate to air quality as the means of exposure.

Containment, storage and transport, and use of substances

As mentioned earlier, water and sand generally make up around 98 to 99.5 per cent of the fluids used to hydraulically stimulate a well. Hydraulic fracturing will use between 3 and 12 different chemicals or additives at high levels of dilution. It is important to consider the actual volumes being transported or stored, the facilities or containment system, and the methods used to manage the risk of discharge to the surrounding environment.

The transportation of hazardous chemicals and equipment is regulated, where relevant, by the Land Transport Act 1998, the Land Transport Rules, the Maritime Safety Rules, and the Civil Aviation Rules. The provisions of HSNO apply to the transportation, use and storage of hazardous substances and provide additional controls.

The environmental risks are primarily associated with the pumping of fracture fluids from storage: first to the chemical additions trailer, and then to the blender, where sand is added, before going to the high-pressure pumps and down the well.

The risks of personal exposure and potential environmental effects can be appropriately mitigated as follows, under HSNO requirements:

- storing chemicals in double-walled containers or within bunding (lined adequately to contain spills)
- providing containment or capture under pipe connections, portable tank containment berms, and tank monitoring to immediately identify spot leaks
- replacing various chemical concentrates with non-toxic or even food-grade additives, where these are available and effective
- having a hazardous substances emergency plan and appropriate training of staff to deal with accidental spills.

When considering the impact of fracturing fluid leaks, it is important to consider whether contaminant concentrations are stored separately from base fluid and water.

HSNO is the principal legislation controlling hazardous substances. The HSNO Act requirements apply to chemicals during their entire life cycle, including manufacturing or importing a substance, through its use, to disposal. This ‘cradle-to-grave’ approach is intended to ensure that the specific adverse effects posed by hazardous substances are managed consistently and comprehensively.

In general, hazardous facilities that comply with the HSNO Act requirements should not have significant actual adverse effects on the environment. Controls under the RMA need only deal with particular risks associated with a particular site that are not already managed by the generic controls under HSNO.

³⁵ See Workplace Exposure Standards and Biological Exposure Indices, <http://www.business.govt.nz/worksafe/information-guidance/all-guidance-items/workplace-exposure-standards-and-biological-exposure-indices/workplace-exposure-standards-and-biological-indices-2013.pdf>.

Additional land-use controls under the RMA may be appropriate for issues that are not within the scope of HSNO, such as reverse sensitivity. They may also be appropriate where a site has unusual characteristics that are not contemplated or addressed by the relevant HSNO controls. These local site issues might include proximity to water courses or potable water supplies, wetlands, cultural issues, and effects on adjoining sites that have not been considered in a HSNO evaluation. For example, controls may be placed on traffic routes and timing for the transportation of hazardous substances, based on the circumstances of the local environment. Plan provisions should not duplicate requirements imposed by HSNO or other statutes.

Any site-specific aspects may also be dealt with under the RMA, and the use of hazardous substances may also require a resource consent in some circumstances. The consenting of the well site and the hydraulic fracturing operation may consider incorporating advisory notes on a consent recommending that:

- hazardous material disposal sites be identified
- spills or hazardous substances emergencies be notified to the council.

Section 97 of the HSNO Act specifies the persons who are responsible for enforcement of HSNO for different purposes. Of particular note, the Chief Executive of the Ministry of Health is responsible for ensuring that provisions are enforced where it is necessary to protect public health (under section 97(1)(g) of HSNO). District health board (DHB) officers have delegated authority to undertake this enforcement. Local authorities should work closely with DHBs to help assess risk and provide advice on risk management on matters of public health arising from oil and gas development applications. Councils should also work closely with WorkSafe New Zealand, which is the enforcement agency for HSNO in workplaces generally, including for environmental risks.

5.6 Waste management and disposal

5.6.1 Issues

A variety of wastes are produced as part of the exploration, hydraulic fracturing and production phases of a well. Solid wastes are produced as part of the drilling process, liquids are produced as part of hydraulic fracturing and hydrocarbon production, and gases also need to be disposed of. The flow-back fluids can contain a mixture of fracture fluid, saline water from the formation, and hydrocarbons.

Drilling muds

On a drilling rig, mud is pumped from a mud storage tank down the drill string to the bit, where it exits through nozzles, cleaning and cooling the bit before lifting the cuttings to the surface. Lifting up the cuttings in the space between the outside of the drill string and the drilled hole requires both sufficient flow velocity and a viscous mud. The returning mud may contain natural gases liberated by the bit, which are separated from the mud and either vented or flared during drilling. Rock cuttings are separated or filtered out of the mud, and the mud returns to the mud pit or tank.

Although inert, the mud and cuttings may have adhering mud additives and trace levels of hydrocarbons. Options for disposal include disposal to land or transporting the wastes to a treatment facility.

Fracturing fluids

Fracturing fluids that are returned to the surface as a component of the flow-back fluid require appropriate management to avoid adverse effects on the environment. Measures include:

- stockpiling the fluid in lined pits³⁶ or tanks to prevent any spills
- storing the fluid separately from other wastes
- labelling the fluid to indicate the individual well or source
- discharging the fluid by injecting it into consented deep disposal wells (well below existing freshwater aquifers) or disposing of the fluid at an industrial waste disposal facility (eg, a landfill). Further discussion can be found in section 5.5.2, and example consent conditions for deep well injection are provided in Appendix B.

Return flow / produced water

A primary waste issue during hydraulic fracturing and production is the removal of sometimes large amounts of deep saline groundwater from the oil and gas reservoir, referred to as ‘return flow’ or ‘return fluid’ (which refers to the flow back of fluid at the end of a hydraulic fracturing operation), and ‘produced water’ (which refers to brine from the reservoir entrained with hydrocarbons in the production phase). Produced water usually becomes a greater waste management concern over the long-term operation of an oil or gas field because water production typically increases with the age of the production well and the nature of the reservoir drive.³⁷ Water is also produced from ‘dewatering’ of coal beds to enable coal seam gas extraction (which is not associated with the production phase of a coal seam gas well).

Substances that can be found in high concentrations in produced water include chloride, sodium (from saline formation fluid), calcium, magnesium and potassium. Other contaminants can include polycyclic aromatic hydrocarbons³⁸ (produced oil and gas), lead, arsenic, barium, antimony, sulphur, zinc, and naturally occurring radioactive material (NORM). There may also be residual wastes that remain after separation of the oil and natural gas.

Most produced water is unfit for domestic or agricultural purposes (generally because it is extremely salty). If it is disposed of by release to the surface without treatment, it can cause soil, surface-water, groundwater and aquifer contamination.

Produced water can be disposed of by underground injection, either in disposal wells or in enhanced recovery wells (ie, wells that allow produced water and other materials to be injected into a producing formation to increase formation pressure and production). Aquifers and groundwater could be affected during the injection of produced water if the injection well casing integrity is compromised (ie, if the injection well is not properly completed or is poorly maintained over time, and the geological integrity of the injection formation is compromised). The depths of wells for disposal can range from a few hundred to a few thousand metres, depending on geological conditions. Generally the disposal wells are significantly deeper than the valuable fresh groundwater resources to minimise any risk of contamination.

³⁶ Note that the operator may need to obtain archaeological authority under the Historic Places Act 1993 to excavate pits.

³⁷ Reservoir drive is the physical movement of hydrocarbons through the reservoir. This is caused by reservoir drive mechanisms, which are “natural forces that displace hydrocarbons out of the reservoir into the wellbore and up to surface” (Schlumberger Limited, 2013c).

³⁸ Polycyclic aromatic hydrocarbons may be more hazardous than BTEX compounds.

In Australia, reinjection to groundwater has been identified as a disposal option for water produced from coal seam gas dewatering, provided this does not result in contamination of that groundwater supply. This enables water to be available for beneficial use by replenishing the groundwater resource. More information about this practice is available on the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development website at <http://www.environment.gov.au/coal-seam-gas-mining>.

Underground injection of produced water has also been associated with induced seismicity, as discussed in section 5.10.

Naturally occurring radioactive material and radioactive tracers

Radioactive elements – called naturally occurring radioactive material, or NORM – can be found in very low concentrations in the Earth’s crust and brought to the surface when drilling for and extracting hydrocarbons. In high concentrations, NORM can be hazardous to human health.

The use and management of radioactive materials, including those that are naturally occurring, is managed by the Radiation Protection Act 1965, administered by the Office of Radiation Safety within the Ministry of Health. The Act defines radioactive material as “any article containing a radioactive substance giving it a specific radioactivity exceeding 100 kilobecquerels per kilogram and a total radioactivity exceeding 3 kilobecquerels”. There is also a general duty for employers to take all practicable steps to ensure the safety of employees while at work, under the Health and Safety in Employment Act 1992.

NORM above normal background levels can be found in some US petroleum hydrocarbon reservoirs but is not known to occur in Taranaki or elsewhere in New Zealand. For example, Shell Todd Oil Services (STOS) has reported that average flow-back material has 37 becquerels of radiation. By way of comparison, a banana has around 15 becquerels and a smoke detector around 18,500.

In addition to NORM, radioactive tracers can be used to accurately measure fractures. Users of radioactive tracers need a licence from the Office of Radiation Safety to use ionising radiation. To get this licence, companies need to demonstrate that they understand how radioactive material should be handled, both before and after it is discharged for a hydraulic fracturing operation. Companies generally use isotopes with a short half-life so that radiation is minimal when the hydraulic fracturing fluid returns to the surface.

Any substance with a radioactivity level in excess of that set out in the Radiation Protection Act may become a potential issue regardless of the means of gas extraction from the source reservoir (Taranaki Regional Council, 2013b).

5.6.2 Effects management

The management and disposal of waste solids, liquids and gas can be summarised as follows.

- Drilling waste (muds and cuttings) can be disposed using a consented land-based disposal technique, or at a landfill.
- Gas is separated and flared on-site if there is no pipeline connection (eg, at an exploratory well site).

- The liquid component of fracturing return fluid (primarily water) is normally directed to on-site storage tanks.
- Separation of the solid and liquid components of waste fluid occurs on-site, using storage tanks or settling mud pits.
- Waste liquid can be disposed of into a consented reinjection well or at a landfill. Note that the volume of produced water from coal seam gas wells is typically greater than that of tight sandstone or shale (due to dewatering requirements).
- Solid waste is tested for the presence of radioactive tracer (if such tracers have been used). If a tracer is absent, the solid waste can be disposed of to an appropriate waste disposal facility (eg, a consented landfill) provided the waste meets the relevant acceptance criteria.
- Solid waste that contains radioactive tracer or NORM can be managed on-site until such time as the radioactivity has decreased to a level appropriate for off-site transportation and disposal.

Disposal of drilling waste (including muds and cuttings), return fluids and produced water may affect water quality if it is not undertaken correctly. Water quality can be affected either through surface-water or groundwater contamination.

Note that for the establishment of a land-based disposal facility, or for the excavation of pits, the operator may need to obtain archaeological authority from New Zealand Historic Places Trust if an archaeological site may be affected.

Effects on surface water

An appropriate site selection process is crucial to minimise the risk of contaminant spills at the surface entering surface-water. Generally, sites without any overland water courses are preferred for such activities. If a site is close to one or more streams, lakes or farm drains, buffer zones are established to prevent overland flow from the activity into any waterways. Adequate buffer distances from surface-water bodies should be used to reduce the risk of overland/through-flow spreading into areas with surface water. These distances should be determined on a case-by-case basis. Storage areas should not be close to surface-water resources.

To establish baseline water quality, testing before any disposal activities (including stockpiling) should be conducted by the operator and reviewed by the regulatory authority.

Site selection, buffers and other mitigation measures should have regard to the significance of water bodies for indigenous species, trout and salmon, as relevant.

Effects on groundwater

AEEs must contain relevant hydrogeological information about proposed sites, which should include a depth-to-water-table analysis. Groundwater monitoring bores should ideally be installed before the activity begins at the site to confirm groundwater flow paths and background water quality to provide a comparative baseline. A groundwater scientist can best assess the location, design, depth and quantity of groundwater bores needed at a site. This should be done as part of the application and approved by the regulatory authority to ensure it is done to the required standard.

The permeability of storage pits should also be assessed, as waste can be stored in these pits for months in a concentrated form. Such wastes pose a greater risk to groundwater resources than the wastes in their diluted form at the later stage after application to land. With water-based and synthetic-oil-based mud wastes, common constituents barite and bentonite have a natural sealing effect and help to reduce the permeability of pit floors, minimising the risk of groundwater contamination. However, these pits should be lined.

Landfill guidelines published in 2000 (Centre for Advanced Engineering, 2000) provide three examples of liner designs that minimise the risk of leachate discharge to provide a suitable level of protection to the receiving environment. These examples are summarised below:

- single liner: 900 millimetres of clay or other low permeability soil, in layers of 150 millimetres thick, with a coefficient of permeability not exceeding 1×10^{-9} metres per second
- composite liner: 1.5 millimetre thick synthetic flexible membrane, overlying 600 millimetres of clay, with a coefficient of permeability not exceeding 1×10^{-9} metres per second
- composite liner: 1.5 millimetre thick synthetic flexible membrane, overlying a geosynthetic clay liner (minimum 5 millimetres thick), coefficient of permeability not exceeding 1×10^{-11} metres per second, overlying a 600 millimetre thick compacted sub-base layer with a permeability not exceeding 1×10^{-8} metres per second (Centre for Advanced Engineering, 2000).

Best practice is to use a combination of high-grade HDPE³⁹ synthetic liner in conjunction with compacted clay. AEEs should contain information on pit design and lining plans. Preferably, engineering assessments of pit integrity would be provided to the regulatory authority after construction but before operations begin on site. Groundwater monitoring can be used to help assess pit integrity over time.

The significance of nearby water bodies for indigenous species, trout and salmon should be considered in setting mitigation measures to minimise effects on groundwater.

Case study 3: Todd Energy

The current practice of Todd Energy is to separate out fluids before flaring the natural gas, which enables cleaner combustion than if the full well stream were sent to the lined flare pit. Occasionally, under emergency conditions, it is necessary to divert the full well stream to the lined flare pit without separation so that the entrained gas can be combusted safely. Todd Energy recently installed shallow piezometer bores in the immediate vicinity of a flare pit, which enables them to analyse samples for hydrocarbons and chlorides. No contamination was found from this monitoring, and monitoring is ongoing.

Source: Todd Energy, 2012.

³⁹ High-density polyethylene

National Environmental Standard for Sources of Human Drinking Water

The National Environmental Standard for Sources of Human Drinking Water came into effect on 20 June 2008. The purpose of the NES is to include catchments in the management of drinking water, and in doing so give greater protection to source water (including aquifers or springs, rivers, lakes and other natural waters). The Ministry for the Environment has produced a user's guide that explains the regulations and provides guidance to territorial and unitary authorities on implementing the NES.

The NES requires regional councils to ensure that effects on drinking water sources are considered in decisions on resource consents and regional plans. Specifically, councils are required to:

- decline discharge or water permits that are likely to result in community drinking water becoming unsafe for human consumption following existing treatment
- be satisfied that permitted activities in regional plans will not result in community drinking water supplies being unsafe for human consumption following existing treatment
- place conditions on relevant resource consents requiring notification of drinking water suppliers if significant unintended events occur (eg, spills) that may adversely affect sources of human drinking water.

Regulations 6, 7 and 8 of the NES apply to applications for water and discharge permits issued by regional councils. These provisions apply only to activities that may affect the quality of a registered drinking water supply providing 501 people or more with drinking water for 60 or more calendar days in a year. Regulations 11 and 12 relate to emergency notification provisions, and these apply to smaller drinking water supplies and to district and regional councils.

The NES does not apply to all contaminants, only to a group of substances that can adversely affect human health or the aesthetic properties of drinking water, grouped into microbiological or chemical, and guidance is provided on maximum acceptable values for these contaminants.

Resource consent applicants are expected to include sufficient information with their AEEs for council staff to be able to make a decision on how a proposed activity will affect water quality in a registered drinking water source. Other organisations – chiefly public health units and drinking water suppliers – can assist councils by providing information on how a proposed activity could affect drinking water quality.

Oil and gas exploration activities have the potential to affect drinking water supplies if they are located near or upstream of those supplies. Under the NES, applications for water and discharge permits for these activities will need to specifically address whether registered drinking water sources are located downstream, to what extent the activities will affect these supplies, and ways to ensure effects are avoided, remedied or mitigated.

Note that the migration of fracturing fluid through pathways could affect water supplies upstream of the discharge point, depending on the nature of the underlying geology. This situation does not trigger the NES; however, risk of this occurring needs to be assessed in an application for hydraulic fracturing, as it may produce adverse effects on upstream water quality.

Effects on soil quality

Disposal to land refers to the disposal of drilling waste (cuttings and drilling muds) to land. This form of disposal is carried out largely using one or other of three methods:

- *mix-bury-cover*, which involves mixing the drilling solids with clean soil and burying the mixed material in an unlined pit
- *land spreading*, which involves spreading the drilling solids on the land surface and mixing them into surface soil
- disposal of waste material onto an impervious pad for *composting*, so that there is no discharge to land.

Land spreading, also known as ‘land farming’, is the process of spreading drilling waste onto land, incorporating it into the soil, then re-sowing the pasture to allow for natural bioremediation as various soil processes transform and assimilate the waste. Taranaki Regional Council is satisfied that land farms used for the disposal of drilling waste (with appropriate consent conditions) may be later used for agricultural production, based on a report undertaken by agKnowledge Ltd (Edmeades, 2013).

More detail about the different methods available for land-based disposal of drilling waste can be found in the Alberta Energy Regulator’s *Directive 050 – Drilling Waste Management* (Alberta Energy Regulator, 2012).

Essentially, both mix-bury-cover and land spreading involve using bacterial activity within the soil to consume the free or dissolved hydrocarbons present in the drilling muds and drill cuttings. In Taranaki, the practice of disposal to land has predominantly been for drill cuttings and muds rather than for flow-back fluids.

The disposal of return fluid from hydraulic fracturing operations (including formation fluid) using land-based disposal is not endorsed by these guidelines. Disposal of return fluids is considered better suited to deep-well injection or disposal at an industrial waste facility. Return fluids may also be recycled (used for subsequent hydraulic fracturing operations).

Guidelines on the disposal of drilling waste to land in Taranaki (Taranaki Regional Council, 2005) suggest that land-based disposal should occur on relatively flat, sandy country that is prone to wind erosion, because this is where the greatest environmental benefits from muds and cuttings are likely to be obtained. Disposal to land is not suitable for wastes that contain significant levels of biologically available heavy metals, persistent or ecotoxic compounds or NORM.

If disposal to land is proposed, AEEs should address the background soil characteristics, and the proximity and depth of groundwater. These soils will generally – but not necessarily – be sandy. Basic soil profiling will help the assessment of possible effects and will enable consenting authorities to make informed decisions on site suitability. The potential effects on soil quality that should be addressed are the effects of excess salts and chlorides on the health of soil biota and, potentially, pasture establishment. Coastal sites will generally have high background chloride levels, and increasing these levels further may affect the ability of soil biota to degrade hydrocarbons and other biodegradable contaminants. AEEs and site plans must consider these effects and how to manage waste application.

In Taranaki, these effects have been shown to be relatively short term as excess chlorides are leached from the soil within a few months of the application of wastes. However, in coastal

areas chloride levels can be naturally high due to the effects of storm events and prevailing wind directions (Taranaki Regional Council, 2013b).

Appendix B provides example consent conditions for a discharge permit to dispose of drilling waste to land. Such conditions may be placed with respect to the concentration of hydrocarbon in the soil, the thickness and depth of application, and compliance with soil conductivity, sodium absorption ratio and composition standards (eg, heavy metals, chloride and sodium).

Note that the establishment of a land-based disposal facility may result in the disturbance of archaeological sites, and in such cases the operator would need to obtain an archaeological authority under the Historic Places Act 1993.

National environmental standard for contaminants in soil

The Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 came into force on 1 January 2012. The Ministry for the Environment has produced a user's guide that explains the regulations and provides guidance to territorial and unitary authorities on implementing the NES.

The objective of the NES is to ensure that land affected by contaminants in soil is appropriately identified and assessed when soil disturbance and/or land development activities take place. If necessary, soil should be remediated or contaminants contained to make the land safe for human use. The NES enables the safe use of affected land by:

- establishing regulations for five activities that ensure district planning controls relevant to assessing and managing public health risks from contaminants in soil are appropriate and nationally consistent
- establishing soil contaminant standards protective of human health and requiring their use when decisions are made under the NES
- ensuring that best practice and consistent reporting on land affected, or potentially affected, by contaminants is applied that enables efficient information gathering and consistent decision-making.

The focus of the NES is on territorial authority functions under section 31 of the RMA, and it provides a nationally consistent methodology for identifying, assessing and managing the risks to human health on land that is being used, has been used, or is more likely than not to have been used for a specified hazardous activity or industry (HAIL land).⁴⁰

The NES does not address discharges of contaminants (eg, by leaching) from contaminated land. These are a regional council function under the RMA. The NES does not pertain to land currently used, or to be used, for agricultural production. However, converting any part of a piece of land previously used for oil and gas development activities back to agriculture or some other activity triggers the NES.

Territorial authorities apply the NES requirements to all activities (land-use changes, subdivision, soil disturbance, and removal of fuel storage tanks) of all HAIL land. The

⁴⁰ The Hazardous Activities and Industries List (HAIL) identifies activities and industries considered likely to cause land contamination resulting from hazardous substance use, storage or disposal. For more information see <http://www.mfe.govt.nz/issues/managing-environmental-risks/contaminated-land/is-land-contaminated/hail.html>.

likelihood of a site being contaminated will continue to be assessed in the first instance by considering previous land uses that are known to bring risks of contamination.

Soil disturbance on HAIL land is permitted by the NES provided that specific requirements are met. Requirements restrict the duration of the activity, the volume of soil disturbed, and the removal of soil, and require minimisation of exposure to contaminants, reinstatement to an erosion-resistant state, and the protection of contamination enclosure structures. If these requirements are not met, soil disturbance is a controlled activity (consent must be granted) and the council must be provided with a detailed site investigation.

A wide variety of land-use activities such as industry and farming can result in the chemical contamination of soil, air and water. As exploratory wells are often in rural areas, the NES may apply to the disturbance of contaminated soil for new well sites.

Effects of NORM

The effects on the environment from the potential release of naturally occurring radioactive material (NORM) during exploration, production or the recovery of natural oil and gas from the hydraulic fracturing process have been investigated by Taranaki Regional Council (see case study 4). The investigation found no evidence of a health or environmental issue with the levels of radioactive materials involved in oil and gas activities, or hydraulic fracturing specifically. In fact, the same or higher levels of exposure can occur in a person's daily life, such as in food, soil or consumer products.

Case study 4: Taranaki Regional Council investigation into NORM

In February 2013, Taranaki Regional Council published a report investigating radioactivity in hydrocarbon exploration, including hydraulic fracturing. This report canvassed the issue of naturally occurring radioactive material (NORM). The investigation is based on a range of sampling and analytical research commissioned by the Council since 1995 on radioactivity and hydrocarbon exploration and production in the Taranaki region.

The report notes that not all field operators in Taranaki use radioactive tracers, and that not all uses of radioactive tracers relate to hydraulic fracturing. A conventional well-drilling operation can use chemical and radioactive tracers for a range of purposes, including demonstrating well integrity, the accurate placement of down-well equipment, tracking drilling muds during drilling operations, and flow testing.

The Council took several samples of produced fluids and soil at land farming sites. These were supplemented by samples of produced water and sludges from four different producing fields in Taranaki (Pohokura, Kapuni, Waihapa and Cheal). The National Radiation Laboratory (now part of the Institute of Environmental Science and Research Ltd – ESR) undertook a comprehensive analysis of these samples.

The results were below levels of radioactivity that would require control under the National Radiation Regulations 1982 and were not considered radioactive under the terms of the Regulations. The conclusion of the investigation was that there was no evidence of a health or environmental issue arising from the use of radioactive tracers, the use of radioactive materials within well-logging activities, disposal of drilling wastes potentially containing radioactive materials, or the release of NORM during exploration or production.

Source: Taranaki Regional Council, 2013c.

5.7 Discharges to air

5.7.1 Issues

Air discharges from oil and gas development activities are important matters for regional councils to manage. Air emissions arising from hydrocarbon operations include:

- exhaust emissions from diesel engines (generators, compressors, pumps, trucks)
- dust from earthworks associated with well site preparations
- combustion products from the flaring of hydrocarbons (primarily the burning of gas)
- fugitive emissions (emissions of gases or vapours from pressurised equipment due to leaks)
- venting of gases and vapours from atmospheric-pressure tanks or at the flare pit (if there is no ignition).

Emissions from a well can be significantly higher if hydraulic fracturing is used than if it is not used. For example, a 2011 study of fugitive emission estimates in the United States found that the approximate volume of uncontrolled emissions of methane, volatile organic compounds (VOCs) and organic hazardous air pollutants (HAP)⁴¹ from natural gas well completions and recompletions, with and without hydraulic fracturing, was as follows:

Table 8: Uncontrolled emission estimates from oil and natural gas wells

Well category	Emissions (tons/event)		
	Methane	VOC	HAP
Natural gas completion without HF	0.8038	0.12	0.009
Natural gas completion with HF	158.5	23.13	1.68
Oil well	0.0076	0.00071	0.0000006
Natural gas recompletion without HF	0.0538	0.0079	0.0006
Natural gas recompletion with HF	158.55	23.13	1.68
Oil well recompletion	0.00126	0.001	0.0000001

Source: United States Environmental Protection Agency, 2011, pp 4–7.

Note: HF = hydraulic fracturing, VOC = volatile organic compounds, HAP = hazardous air pollutants.

Flaring

Flaring involves combustion (burning off) of natural gas, either as a waste product during well testing, when it is uneconomic to sell or conserve, or in emergency situations (MBIE, 2013b). Waste gas can also be incinerated in an incinerator unit or vented directly into the atmosphere. Flaring can occur at ground level in a flare pit, or in a vertical flare stack.

Compounds in the discharge of contaminants to air from flaring activity associated with a well site typically include:

- particulates
- dioxins and furans
- polyaromatic hydrocarbons (PAHs)

⁴¹ HAP are most commonly n-hexane and BTEX compounds.

- VOCs
- methane
- the more common products of combustion, including carbon dioxide, carbon monoxide, nitrogen oxides, hydrogen sulphide and sulphur dioxide.

All of the above compounds are generally present in the natural environment, but they can have significant adverse effects when discharged at high concentrations. The issue is the degree to which the well-drilling and production-testing operation (and any associated hydraulic fracturing operation) generates elevated levels of these compounds to a degree that they could compromise public health or have other adverse environmental effects. Over 250 toxins have been identified as being released from flaring, and exposure to substances such as benzene at high concentrations has been linked to human health risks, including respiratory illnesses and cancer (Ismail and Umukoro, 2012).

Storage or disposal of waste fluid in flare pits is not considered to be good practice, and liquid in these pits should be removed as soon as possible (American Petroleum Institute, 2009a).

The environmental effects of flaring are controlled by the RMA and the Climate Change Response Act 2002. The Crown Minerals Act 1991 also controls flaring and venting. Operators are permitted to flare or vent in emergencies, as a result of equipment failure, during well testing, or if agreed as part of a work programme or with the consent of MBIE's Chief Executive (subject to regulation 27 of the Crown Minerals (Petroleum) Regulations 2007).

The Petroleum Programme 2013 sets the Government's expectation that permit holders will implement practical and economic options to collect and use gas and not to vent, except during emergencies or equipment failures.

Methane is not toxic, but it is a potent greenhouse gas. The direct radiative effect of methane is about 20 times stronger than carbon dioxide over a 20-year timeframe. Release of methane into the atmosphere is also a waste of natural resources.

Dioxins and furans are covered by the Stockholm Convention, to which New Zealand is a signatory and accordingly has responsibilities to reduce these emissions. More information about the Stockholm Convention is available on the Ministry for the Environment website at <http://www.mfe.govt.nz/laws/meas/stockholm.html>.

Air quality at land-based disposal sites

Monitoring of air quality effects at land-based waste disposal sites in Taranaki has shown that any odour effects are generally localised, with detection unlikely beyond property boundaries (see figures 7 and 8). These odours are generally hydrocarbon based and are more likely to be sourced from synthetic-based muds rather than flow-back fluids, which generally have a lower hydrocarbon content. Dust emissions can arise from unsealed access tracks and around storage areas.

AEEs should consider the location of storage pits in relation to odour effects, because pit areas are likely to be the main source of any odours. Proximity of storage areas to property boundaries, prevailing wind directions, and neighbouring land uses should all be addressed in AEEs and/or site management plans.

Taranaki Regional Council has also undertaken monitoring at a land-based disposal site for ambient levels of BTEX and formaldehyde, the chemicals present in return fracturing fluids that are generally of most interest because of their potentially toxic nature and high volatility. The survey showed that such air emissions were negligible and were barely distinguishable from background (baseline) concentrations. The highest boundary concentration of formaldehyde detected downwind of the disposal site was less than 15 per cent of the national air quality guideline, which in turn is about half of what indoor air can typically contain. Other results were within background ranges (Taranaki Regional Council, 2013b).

No benzene could be detected at a level that was 5 per cent of the national guideline and much less than 10 per cent of what is typically found in urban areas around New Zealand. Toluene and xylene were detected (ethyl benzene was not), with the highest downwind concentration only 5 per cent of national guidelines at the boundary (Taranaki Regional Council, 2013b).

It may be more appropriate to monitor total hydrocarbons or volatile organic compounds (eg, there could be sulphur-containing hydrocarbons) and look for BTEX within this, because the proportion of BTEX in total hydrocarbon emissions is likely to be low.

5.7.2 Effects management

The only detailed examination of the composition of the flare combustion zone emissions in New Zealand is that undertaken by Taranaki Regional Council in 2012 (see case study 5). However, the buffer zone determined in this case will not necessarily translate to other regions. For example, a study on human health risk of air emissions from unconventional natural gas development in the United States indicated a greater risk of adverse health impacts on residents living at or less than half a mile from unconventional gas wells than on those living further than half a mile away, and that further study is warranted in this area (McKenzie et al., 2012).

An air discharge consent application should detail all potential effects on the environment of that particular air discharge, and a council may wish to commission expert advice to confirm the adequacy of mitigation measures in the circumstances. A regional council assessment of an appropriate buffer for a particular discharge permit application needs to consider the local circumstances and constituents of the proposed discharge (in the same way as for any other discharge permit application).

Appendix B, section B4, provides examples of consent conditions for the discharge of contaminants to air via flaring from a well site.

As shown above, hydraulic fracturing of natural gas wells can result in significant fugitive emissions. This can be minimised using well completion techniques, particularly the following.

- **Reduced emission completions**, which involve equipment to capture and treat gas during the flow-back phase after fracturing (including additional tankage, gas-liquid-sand separator traps and a gas dehydrator). This technology also enables gas to be redirected to the sales line rather than vented to the atmosphere, which is beneficial to the operator. Reduced emission completions can result in a 90 per cent reduction in fugitive emissions during well completion (United States Environmental Protection Agency, 2011). In the United States, reduced emission completions will become compulsory on all new onshore gas wells (ie, those primarily used to produce natural gas as opposed to primarily oil) from 1 January 2015 (United States Environmental Protection Agency, 2012).
- **Completion combustion devices** (flaring): additional gas that cannot be captured can be redirected to a flare pit or stack to enable combustion. Flaring is preferable to venting, as

volatile compounds (VOCs) can be combusted (United States Environmental Protection Agency, 2011). However, incomplete combustion can result in VOCs being released to the environment. The use of flaring should therefore be minimised, wherever possible, to reduce emissions.

The Alberta Energy Regulator has a detailed directive for flaring, incinerating and venting, which regional councils should consider for managing these activities (Alberta Energy Regulator, 2011).

Case study 5: Taranaki Regional Council investigates air quality from flaring

Taranaki Regional Council investigated air quality from flaring in 1998 and 2012. The main conclusion was that there were minimal effects on ambient air quality in the vicinity of the flare, and that air quality remained high by comparison with guideline values, even 70 metres downwind.

The initial field measurement of emissions has been translated into a modelled form that allowed its application under different meteorological conditions (worst case scenario) (Taranaki Regional Council, 2013a). The results back up previous work done in 1998, which suggested that a separation distance of 300 metres between a flare and residential properties gave a substantial health and safety buffer in this case. The finding of the modelling of air emissions was that ambient ground-level concentrations predicted by the model were well below the corresponding air quality guidelines.

- For volatile organic compounds (including BTEX), it was noted that benzene levels had decreased to background levels within 300 metres of the flare, and at 140 metres were half those required by the National Air Quality Standard values.
- For particulates (PM_{2.5} and PM₁₀), levels approximated background levels at 120 metres downwind of the flare (the closest monitoring point), well below the national environmental standards for air quality. This suggested that the level of combustion at the flare was very high.
- This conclusion was supported by the very low levels of dioxins and furans measured.
- Polyaromatic hydrocarbons were detected in the combustion and evaporation zones associated with the flare, but they tended to be no higher than typical concentrations in central city locations in New Zealand (derived from vehicle emissions).

An important finding of the 2012 study was that at the temperatures encountered in the flares, contaminants associated with hydraulic fracturing fluids were largely destroyed and combustion products were not of a type or concentration that is of concern from a regulatory perspective. Other conclusions were as follows.

- The atmospheric concentrations of all contaminants had reduced at a distance of 250 metres downwind to a level typical of elsewhere in the Taranaki environment (eg, in urban areas). The levels were below any concentrations at which there is any basis for concern over potential health effects (1998 study).
- “A separation distance of 300 metres between a flare and residential properties gave a substantial health and safety buffer for the protection of local populations” (2012 study).

It was reasonable to conclude in this circumstance that the disposal of fracturing fluids by flaring should not result in any adverse effects on air quality beyond the well site.

Source: Taranaki Regional Council, 2013b.

Multiple sources of discharges to air in close proximity can have cumulative effects on air quality in that area. Regional councils may wish to establish airsheds in rural or semi-rural areas that have multiple flare stacks or pits discharging contaminants, to manage any effects on air quality. More information about airsheds can be found in the *2011 Users' Guide to the Revised National Environmental Standards for Air Quality* (Ministry for the Environment, 2011).

Under the Resource Management (National Environmental Standards for Air Quality) Regulations 2004, once an airshed has reached an acceptable limit for a stated contaminant, the regional council should not approve consent for additional flaring operations if they are likely to result in regular exceedances to the air quality limits, as set out in the NES for Air Quality. This NES for Air Quality provides ambient standards for carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone and PM₁₀. *The Ambient Air Quality Guidelines 2002* provide recommended limits for additional pollutants, including benzene and hydrogen sulphide (Ministry for the Environment, 2002).

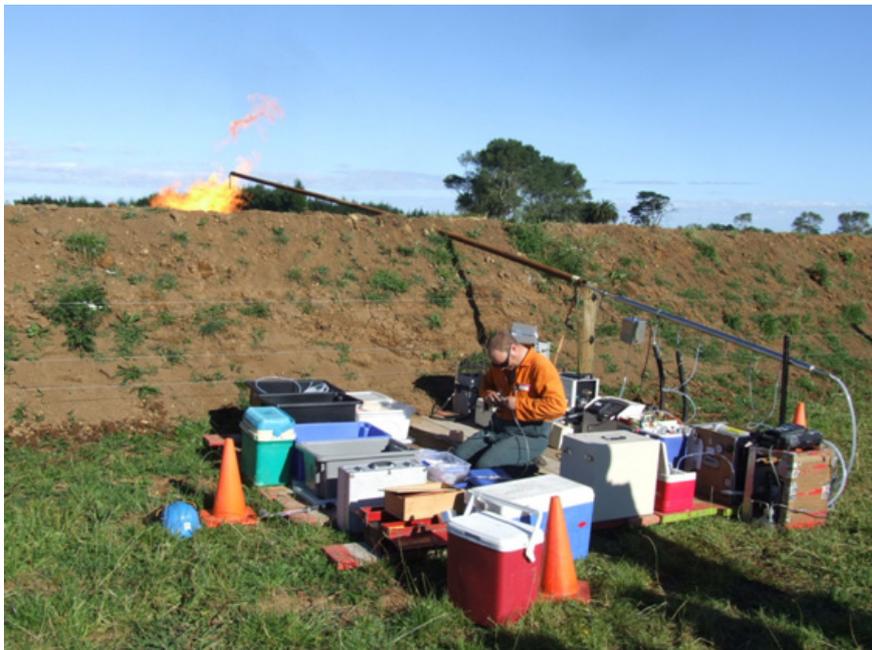
Effects on amenity

The amenity effects of flaring include the generation of noise, and visual effects from light spill and/or glare. These issues are discussed in more detail in sections 5.9 and 5.10, respectively.

Assessments of environmental effects should also consider the location of storage pits in relation to odour effects, because pit areas are likely to be the main source of any odours. Proximity of storage areas to property boundaries, prevailing wind directions and neighbouring land uses should all be addressed in AEEs and/or site management plans.

Dust effects (including mitigation measures) should also be considered as part of an AEE, and consent conditions may be used to mitigate dust effects beyond the well site.

Figure 7: Air quality sampling by the Taranaki Regional Council of fracture fluids flaring at a well site



Source: Taranaki Regional Council, 2012a.

Figure 8: Lined flare pit with hydrocarbons being flared (with entrained fracturing fluids) and air quality sampling (at far left) by the Taranaki Regional Council



Source: Taranaki Regional Council, 2012a.

5.8 Traffic and transport

5.8.1 Issues

Hydraulic fracturing can increase traffic movements for the transportation of specific equipment required for the activity, including the transportation of water, which can have considerable effects on the area surrounding an oil and gas development site. The mobilisation of drilling equipment to each well site and the transportation of fluid generate the greatest volumes of heavy vehicle movements.

Territorial authorities are likely to be well versed in the issues associated with traffic generation from a wide variety of industrial activities, but oil and gas exploration activity introduces some additional factors that need to be taken into account.

Traffic generation associated with well sites comes in distinct phases. The initial seismic data acquisition phase has a relatively low level of effects on the local roading network. This depends on the nature of the data acquisition, but the rigs used for shot holing are relatively small, and proper traffic management planning can deal with the effects of delay and traffic conflicts associated with the laying of the seismic array.

Site preparation and earthworks are familiar in a wide range of rural development activities, and again proper traffic management planning around heavy vehicle movements can adequately mitigate adverse effects.

The actual mobilisation of a rig and its associated infrastructure represents a major component of the traffic-related activity. This typically represents between 70 and 90 heavy vehicle

movements, with associated light vehicle movements for crew movements, support and managerial trips. The rig mobilisation tends to take place over a concentrated period, and, depending on the nature of the local roading network, can create significant conflicts with local traffic. This is particularly so where the primary access road is relatively remote, narrow and unsealed.

Negotiations in these cases will be required between the applicant and the local authority road asset management team to ascertain what improvements to the road alignment may be necessary to facilitate access to the site. This needs to bear in mind disposal of drill cuttings and tankering of produced water, eventual rig demobilisation, future requirements for well workovers, and the possibility that the site will be developed into a production station. In the initial life of the field it may be necessary for product to be trucked from the site until a network of well sites can be reticulated into one product pipeline to a more remote production facility.

On the positive side, the development of the well site tends to result in an improvement to the local roading network, with wider alignments, corner easing and pavement improvements. These have spin-off effects for the local community and other rural land uses.

A number of transportation issues relating to the wider oil and gas processes are also relevant to specific hydraulic fracturing operations. The key environmental issues and effects from traffic and transport are:

- the volume of heavy vehicle traffic movements for:
 - metal and gravel for well sites and access tracks
 - heavy equipment, such as the rig, cranes, forklifts, loaders and earthmoving equipment
 - trucking of water to the site for well site development and hydraulic fracturing
 - waste removal from the well site (including flow-back fluid)
 - personnel movement (a significant level of which is daily)
 - consumables, such as food and water for staff
- earthworks from well site and access track establishment and upgrading may disturb archaeological sites
- heavy goods and oversized vehicles
- the transportation of hazardous substances in accordance with HSNO and the Land Transport Rule: Dangerous Goods 2005
- trip movements during normal school bus travel hours, on bus routes and through sensitive areas (such as rural towns)
- cumulative effects on country areas, even some distance from the site, when there are several well sites and/or production stations with different operators
- potential for further traffic movements for additional drilling if a single-well site is developed into a multiple-well site
- coinciding traffic peaks, especially some temporary but intensive peaks relating to truck movements for production site construction
- upgrading and maintaining the roads used as traffic routes.

5.8.2 Effects management

Each application for consent that involves the construction of a new well site should be accompanied by a traffic impact assessment prepared by a suitably qualified professional. Traffic management plans should clearly identify and plan for what needs to be undertaken to cause as little disruption, inconvenience and delay to road users as possible without compromising safety. They should detail how, what, where and when traffic management (including temporary traffic management) will occur.

These plans may include details of:

- vehicle occupancy rates
- staff travel routes and transportation options to reduce traffic (such as mini-buses)
- heavy goods transport and oversized loads, including backloading (the use of return trips to promote efficiency in transportation), routes, times, GPS reporting to confirm compliance
- industry standards and rules from the New Zealand Transport Agency
- avoidance of traffic-sensitive activities, such as schools and school bus routes
- contractor briefings
- transportation of hazardous substances
- driver road safety
- vehicle road safety
- monitoring of traffic
- communication protocols
- emergency response and incident management.

The New Zealand Transport Agency has a range of temporary traffic management signs and forms, and a series of sample traffic management plans on their website. The *Code of Practice for Temporary Traffic Management* is the standard reference for all temporary traffic management on state highways and local roads.⁴²

Consent conditions on the following matters can be imposed to manage the potential adverse environmental effects:

- hours of operation
- approved traffic routes for transport to and from the well sites
- avoidance of school bus routes and heavy vehicle movements during school bus hours
- vehicle requirements
- designated areas for vehicle parking
- site traffic management, including the provision of a traffic management plan
- a heavy transport safe load checklist
- a journey management system for any high-risk transport activity (eg, equipment mobilisation, dangerous goods, night transport)

⁴² <http://www.nzta.govt.nz/resources/code-temp-traffic-management>.

- a journey management system
- restrictions on operating and transporting times to reduce noise and traffic disturbances
- a monitoring and complaints process
- process to follow if archaeological sites are disturbed in the development and maintenance of access tracks.

The traffic impact assessment should act as a benchmark for monitoring the performance of the site in terms of traffic generation and implementing the traffic management plan.

The monitoring component is important in the context of checking the traffic generation predictions made in the resource consent application and AEE against the actual traffic volumes generated by the activity. Experience in Taranaki indicates a tendency for heavy commercial vehicle and other traffic movements to be underestimated (Ralph Broad, New Plymouth District Council, pers. comm., 6 March 2013).

A related issue is cumulative effects. As a field becomes more mature in terms of the level of exploration and hydrocarbon production, the cumulative effects of traffic movements associated with hydrocarbon exploration development activity will grow. Depending on the nature of the road network and the traffic generated by normal rural activities, traffic conflicts can also grow. Community perceptions of the effect this ‘new’ activity is having on their local community are typically driven by a range of actual or perceived adverse effects. Traffic generation, heavy vehicle movements, and traffic conflicts tend to be at the forefront of these concerns.

Appendix C provides examples of consent conditions.

5.9 Noise and vibration

5.9.1 Issues

A number of sources of noise resulting from oil and gas exploration and production have the potential to exceed district plan noise standards beyond the location of a well site and affect neighbouring properties. The key sources of noise from exploration activities are well drilling and flaring.

Noise associated with well drilling

Equipment associated with drilling activities includes generator sets, mud pumps and shakers, and the operation of the drilling rig itself. Depending on the duration of the drilling programme, drilling can occur 24 hours a day and can last for up to several weeks. Depending on the type of rig, the principal noise source tends to be the generator sets, with the draw brake also generating intermittent noise that may create off-site nuisance effects, particularly at night. Drill-bit pressure and the hardness of strata can affect noise levels.

A recent example, the Managapehi consent application for TAG Oil Ltd, is based on the Nova-1 rig, with an assessed sound power level of 117 dBA_w. During the drilling phase the assessed noise levels at each of the sensitive receptors within the vicinity of the site (primarily residential dwellings on surrounding farms over 1.2 kilometres from the well site) were less than the night-time noise standard contained in the district plan (45 dBA_{L10}). In a case such as this, it could be argued that no specific mitigation is required. However, in other circumstances it may

not be technically feasible to locate a well site with these kinds of separation distances from sensitive receptors.

Noise associated with hydraulic fracturing

Fracturing of the wells involves the use of high-powered diesel engines / pump sets, which are lined up side by side to inject high volumes of fluid down the hole. The pumps operate at high flow rates and high pressure, creating the main source of noise during the operation of hydraulic fracturing. The high revving of engines is the type of noise experienced. These pumping operations typically last between 30 minutes and 1 hour.

A coiled tubing unit is used to clean out a well after the conclusion of the hydraulic fracturing activity and for other jobs. The coiled tubing unit generates noise and operates for 24 hours a day, generally for three to five days at each well site.

It is good practice for well operators to aim to undertake the significant noise-producing activities during daytime hours to avoid non-compliance. However, during well-drilling operations it is typical for the drilling operation to be conducted on a 24/7 basis. Close liaison should occur between operators and occupants of dwellings in close vicinity to well sites as part of the initial consultation, before site establishment.

The blender that mixes chemicals before hydraulic fracturing is a significant source of noise rather than the activity of hydraulic fracturing itself. However, compressors, generator sets on the rigs and pump engine operations required during the fracturing process are also significant sources of noise. In many cases the rig will not be present during the hydraulic fracturing operation (Fred McLay, Taranaki Regional Council, pers. comm., 14 May 2013).

Noise associated with flaring

Flaring may occur from time to time, during the day or night, as part of the completion of the well. Flaring can occur on a more sustained basis when an interval, or the entire well, has been completed and it is desirable to test flow the well to assess its capability, when the gas that is produced is uneconomic, or in emergencies.

When drilling operations target oil rather than gas reserves, it is not anticipated that high volumes of gas will be found that must be flared. Traditionally gas has been flared in a banded flare pit. Depending on the volume and flow rate of gas to be flared and the design of the flare pit, there is the potential for adverse noise effects during flaring. These can be minimised by the appropriate location of the flare pit in relation to adjacent sensitive receptors, and by minimising the amount of flaring required per testing zone. This is consistent with minimising the wastage of gas and emissions to air. Typically flare pits have an assessed sound power level similar to well-drilling operations (100–110 dBA).

More recently, new technology in the form of a flare tank and stack system has been able to be installed for flaring natural gas, which is usually quieter than an open flare pit. The flare tank and stack approach includes an inline vessel, which collects liquids before combustion, which in turn results in lower noise emission. As such, a flare tank/stack with inline liquid separator represents the best practicable method for reducing flaring noise currently available in New Zealand.

Other sources of noise

Other sources of noise in the oil and gas exploration and production industry are:

- significant traffic movements for the transportation of equipment to and from the well site (particularly during the site establishment, drilling, fracturing and decommissioning phases)
- helicopter movements (temporary activities)
- on-site engines (for power generation/pumps)
- the rig floor (the work area where the rig crew undertake drilling operations (Schlumberger Ltd, 2013d))
- mixing equipment
- well-servicing activities, such as the use of a coiled tubing unit to clean out a well prior to connection to production facilities
- on-site alarms.

The key environmental effect stemming from noise is the disturbance to those residing closest to the site in residential dwellings and along transport routes to the site (especially during night-time hours) and disturbance to the rural amenity of the area. These effects may be cumulative if more than one operation is established in close proximity.

Vibration

Ground-borne vibration issues can result from construction and large-scale equipment such as compressors. Factors to take into account include the type of subterranean material through which the energy (vibration) must travel. Soil is one factor that provides a level of attenuation of ground-borne vibration over distance. Similarly, alluvial material attenuates ground-borne vibration because it is discontinuous. By contrast, bedrock material is ‘stiff’ and homogeneous and can efficiently transmit energy.

Generally, the greater the distance from the site, the less likely it is that adverse effects from ground-borne vibration will be felt at sensitive receptors such as nearby dwellings.

5.9.2 Effects management

Management of the noise effects of the hydraulic fracturing operation is an integral part of the overall management of noise from well-drilling, completion, production and the decommissioning process. Hydraulic fracturing is a relatively short activity in the whole life cycle. Consent conditions are an effective mechanism to manage noise and vibration, depending on the noise rules affecting the particular site (refer to Appendices B and C).

Mitigation measures for managing noise during well-drilling and hydraulic-fracturing operations include:

- locating well pads at suitable distances from the nearest homes
- undertaking hydraulic fracturing pumping during daylight hours only
- utilising noise data loggers to monitor noise levels on site in real time to ensure noise limits are not exceeded, or to initiate action under a noise management plan to identify, isolate and remediate any specific noise sources contributing to non-compliance

- erecting portable sound barriers (eg, bunds, stacked containers) around noisy equipment
- restricting vehicle movements during quiet hours
- installing protective sound walls
- undertaking a noise audit to identify sources that can be eliminated
- staff training on noise avoidance
- requiring a noise report to verify noise modelling on the first well.

Case study 6: Todd Energy well site noise mitigation

Todd Energy undertakes continuous noise monitoring at various locations around well sites using sound level meters, and erects portable sound barriers around particularly noisy equipment such as diesel engines.

Source: Todd Energy, 2012.

Noise management plans

Noise management plans are a useful tool for managing the adverse effects of noise. A noise management plan may contain:

- identification of the range of potential noise sources
- specific steps that will be taken to ensure compliance with specified noise limits (such as those listed above) – these may be included as either consent conditions or plan provisions
- a written undertaking from an acoustics engineer or noise consultant that these specific steps will be adequate to ensure compliance with the specified noise limits
- a programme of noise measurement to check that compliance has been achieved through monitoring and testing.

It is good practice for noise management plans to be developed in conjunction with site users and affected parties to allow a range of options to be explored and to help assess what is practicable.

District plan provisions

District plans generally set day and night noise limits in the rural environment, with stricter noise limits for night hours. These provisions protect residents in dwellings from excessive and prolonged exposure to noise, especially during night-time hours.

Typically these are a combination of an L_{10} noise level (the noise level exceeded 10 per cent of the measuring period) and an L_{max} . Some councils, such as Gisborne District Council, also prescribe vibration rules in relation to residential and rural zoned properties.. These are usually generic standards that apply across all activities within the relevant zone.

In some cases, noise rules cannot be met even on an intermittent basis. In this situation, operators must apply for land-use consent to exceed the noise limits of a district plan.

Noise models

Applicants should engage noise consultants to undertake background noise monitoring at well sites. Monitoring data is typically obtained for about one month and filtered to provide representative data, then evaluated against the permitted activity noise rules of the district plan. Analysis of noise data from other well sites is also undertaken to help predict noise levels for similar well sites.

Applicants typically contract noise consultants to model and prepare noise assessments to assist in the design of the site layout, the design of noise mitigation for the relevant drilling rig and equipment set-up, and as part of the application to demonstrate compliance with district plan noise rules. Noise models can take into account the following factors when predicting noise levels:

- the noise level generated by the equipment
- the relative location of equipment within the terrain
- artificial, terrain and natural screening
- attenuation due to ground effects and air absorption.

Models then provide data for predicted noise contours, which are displayed as an overlay on a map or aerial photograph in relation to residential dwellings or other sensitive receptors.

More information about noise management under the RMA is provided on the Quality Planning website at <http://www.qualityplanning.org.nz/index.php/planning-tools/air/noise-management-in-mixed-use-urban-environments>.

5.10 Visual amenity

5.10.1 Issues

Visual amenity effects of oil and gas exploration activity tend to be experienced on a localised basis in New Zealand, mainly because the density of well sites by international standards is presently comparatively low. The extent to which the visual amenity effects of a particular well site extend beyond the well site (eg, to neighbouring properties) depends on the location of that site and the proposed mitigation measures.

The issues relating to adverse visual amenity effects, and in particular cumulative effects, are beginning to be felt in parts of Taranaki as field development becomes more mature. Examples include the Tikorangi community in North Taranaki (New Plymouth District Council) and the Ngaere community (Stratford District), where adverse visual effects associated with rig assemblies, flaring (glare) and earthworks have been bundled with the wider adverse effects associated with noise and traffic generation.

The adverse visual effects associated with the exploration phase are generally higher than those associated with the production phase. However, some communities have identified a broader set of adverse effects associated with having quasi-industrial activities located within rural environments. There is a concern that these facilities, typically small production stations, are inconsistent with the broader rural landscape. These matters should be considered for other industrial activities with similar visual effects that could potentially be located within rural areas.

The East Coast Oil and Gas Study (MBIE, 2013a) provides a description of the different types of physical infrastructure that can contribute to potential visual amenity effects on the environment in the context of using hydraulic fracturing on multiple sites within a mature oil or gas field. A summary is provided below.

Drill sites

Unconventional petroleum development in various overseas jurisdictions requires a lattice of drill sites, with each site containing a number of wells connected by intra-field pipelines to processing facilities that separate gas, oil and any water. Drill pads typically occupy an area of 1 to 2 hectares. Developing the drill site and wells involves a burst of activity, which is the most visible and disruptive part of the development. Activity stabilises during the production phase. Drilling typically runs 24/7 and needs to be well lit.

The development of a well site involves a drilling rig, associated equipment, and lined pits to store drilling fluids and waste. Roads and pipelines may need to be built. This can involve between 100 and 200 truck movements to set up drilling in a new location. Visual activity during the hydraulic fracturing operations can be intensive.

The site becomes less visible after drilling has finished and production starts. A ‘Christmas tree’ of valves, typically 1 metre high, is left on top of the well, with petroleum being piped to processing facilities.

Pumping

When the oil cannot reach the surface unaided, some form of additional lift is required, such as a pumping mechanism.

Pipelines

Infield pipelines carry fluids from a cluster of wells on a drilling pad to a processing facility. They are relatively small in diameter (about 100 millimetres) and are buried in a trench to a depth that allows local activity (such as ploughing) to be carried out. Export pipelines are larger and take petroleum from the oil field to a tank farm, and eventually to a port terminal.

Roading

New roads may be required on private land to get to the drill site. The upgrading of roads may be necessary to enable crew and equipment to be mobilised to carry out exploratory drilling. New roads may be required to build production facilities in rural areas, if the exploration phase is successful. New roads in rural areas can improve long-term access for farmers.

Hydraulic fracturing infrastructure

Hydraulic fracturing creates a relatively small ‘footprint’ and is consistent with the footprint of a producing well head or a small production station. The equipment to perform hydraulic fracturing is usually truck mounted and portable, so it can arrive at a well site temporarily and perform the service. The hydraulic fracturing process demands the integrated system of equipment to perform continuously over the job duration.

Figure 9: Mangahewa well site photographic mosaic showing (left to right): coil tubing; storage tanks; and pump trucks around the well head and flare



Source: Taranaki Regional Council, 2013b.

5.10.2 Effects management

Visual amenity effects will vary depending on the scale of the production phase, including the number of drill sites under development concurrently. The majority of existing well sites are in rural areas, predominantly surrounded by farmland. The most common environmental effects on visual amenity are:

- the development and operation of drill pads, which can be responsible for light and dust
- other physical industrial infrastructure, including drilling rigs, production stations, equipment spreads, bunding, roading and pipelines
- traffic during development
- earthworks, access clearance and construction
- temporary lighting for night-time activities
- lit-up sky effects from flaring
- the cumulative effect of more than one operation in close proximity.

In the conventional well site development, drilling and production testing phases, the dominant visual element is the drilling rig. It is usually visible during the day (given its height) and night (due to lighting-related effects) to allow 24/7 operations. Visual amenity effects from specific hydraulic fracturing operations (ie, truck-mounted and portable equipment) are generally no more significant in scale than the type of equipment used for prior stages of the well cycle, and in most cases may be less intrusive depending on whether the rig is on-site.

Careful site selection can minimise effects on visual amenity, as the natural terrain of an area can be used to mitigate the visual impact of development activities. For example, locating a well site in a natural depression surrounded by hills, rather than on a hilltop, can help reduce the visual impact of a drilling rig on the surrounding landscape.

Site selection should also consider any effects of development on neighbours (potentially affected parties), as well as outstanding natural features and landscapes, and other sensitive locations. Regional and district plan provisions often have restrictions on industrial development in these locations, and these matters should be addressed in an AEE (as with other types of activity).

Site illumination assessments can be used to determine ways to mitigate lighting effects (as well as improving on-site health and safety). Flare stacks are generally preferable to flare pits, to reduce noise, light and the potential for soil contamination.

Appendix C provides examples of consent conditions related to visual amenity, including land-use consents for: well site establishment, the drilling of wells for exploration and production, and production station facilities. These conditions include:

- interim re-instatement works to areas of the well site that are no longer in use, such as requiring the operator to re-grass areas
- directing lighting away from dwellings and avoiding light spill to adjoining properties
- minimising dust nuisance and adopting dust suppressing measures
- erosion and sediment control measures in line with good practice standards
- landscape planting
- limiting the timing of heavy traffic movements
- requiring a local newspaper alert for rig mobilisation to and from the well site
- limiting flaring duration and purpose, and limiting flaring to a number of target formations per well
- standards for well site restoration, such as by contouring, levelling and preparing for vegetation (a bond might be used to ensure this occurs).

5.11 Induced seismicity

5.11.1 Issues

Injecting fluids under pressure deep underground can cause ‘induced seismicity’, a term that refers to human-induced micro-earthquakes. Activities that can cause induced seismicity include hydraulic fracturing, conventional oil and gas production, deep-well injection of waste fluids, mining, and geothermal and hydro development.

In hydraulic fracturing the injection of high-pressure fluids has two effects. Firstly, it aims to induce growth of hydraulic fractures, a process that releases small amounts of seismic energy, meaning that the ‘fracks’ can be detected by down-hole seismic monitoring. Secondly, the high-pressure injection will change the stress field around the borehole, which may bring pre-existing fractures closer to failure. If a pre-existing fracture fails, it will be detectable via down-hole seismic monitoring or, rarely, felt at the surface.

There are a few examples overseas where hydraulic fracturing has been linked with felt seismic events. Perhaps the most well known are the two earthquakes in April and May 2011 near Blackpool, UK, that were conclusively linked with hydraulic fracturing. These two events measured 2.3 and 1.5 on the Richter scale.

A report by the US National Research Council collated US and international data and suggested that in the US, where 35,000 shale gas wells had been hydraulically fractured at the time the report was written, only one had been *suggested* to have caused induced seismicity that could be felt at the surface, and that, globally, only the UK Blackpool events had been conclusively linked to hydraulic fracturing for shale gas (National Research Council, 2012).

A number of reports have studied induced seismicity, including one specifically commissioned for the Taranaki region (refer to case study 7 below). These reports indicate that an injection of fluid for a short period, such as in the case of hydraulic fracturing, can create induced seismicity at levels that would not be felt at the surface (or felt by few people). The Parliamentary Commissioner for the Environment's Interim Report cited reports (de Pater and Baisch, 2011; Holland, 2011; British Columbia Oil and Gas Commission, 2012, cited in PCE, 2012) that concluded that a more significant earthquake could be triggered if the fluid finds its way into an active fault.⁴³

There are three ways activities associated with hydraulic fracturing can induce seismicity, summarised below (Taranaki Regional Council, 2013b).

1. Tensile fracturing

Hydraulic fracturing is a process whereby fluids are pumped into a target reservoir via a well at pressures sufficient to exceed the tensile strength of the reservoir rock. The high-pressure fluid creates the fracture and holds it open, but as the fracture grows, the pressure begins to drop, so fracture growth will eventually stop. Tensile failures from fracturing are usually only detected by specialised down-hole instruments and are highly unlikely to be detected at the surface (Sherburn and Quinn, 2012). In fact it is almost impossible for tensile failures to be felt at the surface, as the intensities are thousands of times too small to cause effects detectable by humans, even when fracturing in shallow reservoirs.

Hydraulic fracturing typically involves tensile fracturing of a few metres to perhaps one hundred metres in length (Davies et al., 2012), with actual lateral movement of a few millimetres (ie, opening of the fracture). The pore pressure effects generated by hydraulic fracturing will dissipate as the pressure front spreads and before they can reach the depth that is generally understood to be necessary to trigger damaging earthquakes.

2. Shear failures

Shear failure occurs when elevated pressure spreads through the reservoir rocks to the extent that pre-existing favourably oriented fractures under existing high shear stress, and already close to failure (release), slip and produce an earthquake. The area of the fracture and how much it slips determines the size of any seismic event. Shear failure is a secondary effect, as it does not open the fractures which occur as a result of hydraulic fracturing. More often than not it improves permeability. It is likely that the earthquakes that occurred in the UK in 2011 were of this type.

3. Deep well injection

Waste fluids can be disposed of by re-injecting the fluids deep underground. Re-injection is the main means of disposal in the US oil and gas industry (Department of Energy, 2009, cited in Royal Society and Royal Academy of Engineering, 2012) and is used in New Zealand in the oil

⁴³ The UK Royal Society and Royal Academy of Engineering noted an emerging consensus that the magnitude of seismicity induced by hydraulic fracturing would be no greater than magnitude 3 (felt by few people and resulting in negligible, if any, surface impacts). The Parliamentary Commissioner for the Environment's Interim Report concluded that the practice can create small seismic events, generally less than magnitude 2, which cannot be felt at the surface. Other reports include Colorado Oil & Gas Association, 2012.

and gas industry. The majority of felt seismicity associated with shale gas has been related to injection at disposal wells rather than the fracking process (National Research Council, 2012). In New Zealand, reinjection of waste fluids is commonly seen in the geothermal industry, where it has become the standard practice for disposing of fluids.

Reinjection of geothermal fluid (not related to hydraulic fracturing) has been known to induce seismicity. For example, the Rotokawa geothermal field near Taupo has resulted in a number of micro-earthquakes thought to be attributable to geothermal reinjection, ranging between magnitudes 1 and 3.5, though only two have been greater than magnitude 3. Micro-earthquakes thought to be caused by geothermal reinjection are similar in magnitude to those that have occurred naturally in that region.⁴⁴

No detectable earthquakes have been triggered in Taranaki from the injection pressures required to overcome formation hydrostatic pressures. These injection pressures are still significantly lower than the pressures needed to cause fracturing of the reservoir rock.

5.11.2 Effects management

Overseas and New Zealand investigations have highlighted the low risk of induced seismicity occurring as a result of hydraulic fracturing and its associated activities. It is extremely unlikely that hydraulic fracturing would lead to a damage-causing earthquake. If this unlikely event did occur, it would most likely be a result of injecting fluid directly into a fault that was close to being critically stressed.

To characterise the risk posed by hydraulic fracturing and deep well injection, an operator would need to determine the location, size and orientation of any likely critically stressed, 'capable' faults. This requires integrating:

- a 3D geological model of an area (based on pre-existing maps, legacy seismic survey data and potentially new seismic survey data)
- borehole data (which can provide information on fracture orientation and frequency, but not length)
- data on the local stresses (from borehole breakout data, local earthquake focal mechanisms, etc)
- background seismicity data, which can also be used to 'illuminate' critically stressed faults, and which may be required to give a high-resolution location of potential planes of weakness, and precise *in situ* stress data (Pytharouli et al., 2011).

Uncertainties in predictions can be reduced by checking for consistency between these data sets, each of which samples a different class of feature at different scales. It is important to work with multiple conceptual geomodels, and not to over-analyse a single model built from sparse data (Bond et al., 2012).

The potential effects of induced seismicity from a hydraulic fracturing operation should be considered by a local authority through the resource consent process, and should have already been taken into account by operators when selecting the site. An AEE should include information on the geology of the area, survey results of the area with faults identified, the

⁴⁴ See the GNS report on this subject for more information: <http://www.gns.cri.nz/Home/News-and-Events/Media-Releases/micro-earthquakes>.

regional stress regime, and resulting resolved stress on any faults to ensure that the effects of induced seismicity are understood when considering a resource consent for hydraulic fracturing. As an example, Taranaki Regional Council requires applicants to provide an analysis of the active faults, assess the risk of seismic activity, and provide details of any monitoring to be carried out in the AEE.

Relevant conditions of consent would include:

- seismicity monitoring before, during and after any hydraulic fracturing and low-pressure ‘mini’ fracture jobs; associated thresholds for stopping/reassessing activities may be set
- seismic surveying before drilling, as major faults (subject to vertical offset in the order of 10 metres or greater) can be detected at this time (eg, Taranaki operators are required to provide the Council with a ‘pre-fracturing discharge report’ at least 14 days before the discharge is proposed to begin).

The precise requirements of monitoring are most appropriately determined by a regional council on a case-by-case basis, taking into account local conditions.

The East Coast Oil and Gas Development Study noted that operators have an incentive to avoid medium and large faults because of the potential for these faults to disrupt their operations. While minor faults can be drilled, an operator will only pursue this where they are confident that the fault is sealed. The report noted that operators will avoid hydraulic fracturing near an open minor fault because its presence can lead to pressure loss and lower recovery. In the event that a well pipe passes through a fault that is subject to movement, it is likely that the bore will be deformed. For small offsets this can happen without any loss to the integrity of the casing, but in a worst-case scenario a bore may be severed. The risk of adverse effects arising from bore deformation may be managed through the common practice of installing an automatic shut-off valve (subsurface safety valve) below the level of any potable aquifers (MBIE, 2013a).

Some areas of New Zealand are more seismically active than others, so an application for resource consent should include a site-specific assessment of seismic risk, and proposed mitigation measures as appropriate to that site. The Royal Society and Royal Academy of Engineering recommend that to mitigate induced seismicity from deep well injection:

- injection into active faults should be avoided (faults can be determined through seismic imaging methods, which should be included in an AEE)
- pressure changes at depth should be minimised (eg, by injecting into highly permeable formations, or using smaller volumes of fluid)
- having modification protocols, and being prepared to alter plans or stop completely to respond to induced seismicity if it occurs at certain levels (Royal Society and Royal Academy of Engineering, 2012).

Case study 7: Findings on induced seismicity by GNS Science (commissioned by the Taranaki Regional Council)

The Taranaki region accounts for 1–2 per cent (about 300 annually) of all located earthquakes nationwide. The surface effects of an earthquake depend on the strength of the earthquake, the depth and location of the focus of the earthquake movement, and the surface geology.

Seismic monitoring in Taranaki is carried out by GNS Science through the GeoNet project and has been undertaken since 1994. Postings of felt events on the GeoNet web page, along with non-felt earthquakes, are archived in a publicly available National Earthquake Information Database. Data is reported annually to the Taranaki Civil Defence Emergency Management Group, and this report is available to the public on the Taranaki Regional Council's website.

The Council commissioned GNS Science to examine the Taranaki earthquake database to determine if there was any evidence of induced seismicity related to hydraulic fracturing and deep-well injection, how that could be assessed, and what the effects on people and structures could be if hydraulic fracturing were to trigger earthquakes in Taranaki.

The report examined seismic data over the period 2001–2011 and found that:

- there was no evidence that hydraulic fracturing activities in Taranaki between 2000 and mid-2011 had triggered, or had any observable effect on, natural earthquake activity
- there was no evidence that long-term deep injection activities, typically associated with wastewater disposal at oil and gas operations in Taranaki, had any observable effect on natural earthquake activity
- there was no evidence of any effect on volcanic activity at Mt Taranaki, given the location of hydraulic fracturing and deep injection operations
- it was unlikely that any earthquakes that may be induced by hydraulic fracturing operations in the Taranaki region would have a significant effect
- observations do not support suggestions that hydraulic fracturing or deep well re-injection activities could trigger a large earthquake, a sequence of moderate-sized earthquakes or a widespread zone of earthquakes in Taranaki.

A copy of the full report is available at:

<http://www.trc.govt.nz/assets/Publications/guidelines-procedures-and-publications/hydraulic-fracturing/gns-seismic-feb2012.pdf>.

Source: Sherburn and Quinn, 2012.

5.12 Social, economic, historic heritage and cultural issues

5.12.1 Issues

Social, economic and cultural issues feature as important parts of the RMA. These issues are specified as key elements of both 'sustainable management' (the purpose of the RMA, section

5), and the definition of ‘environment’ (contained in section 2). Accordingly, these issues will form part of plan making and consenting decisions that local authorities make under the RMA.

Oil and gas production may result in a number of social, economic and cultural issues for their communities, and may affect historic heritage. No two communities are the same; they are shaped by a combination of factors including demographics, cultural influences, community values, and employment. As such, the issues for each community will vary.

Many of these issues relate to the quality of the environment in which the local community lives, works and plays. As such, there is an overlap with the general environmental effects of oil and gas production discussed elsewhere in section 5, such as odours created by drilling muds, the use of chemicals, or the impact of gas flaring on amenity. However, these issues may also have a particular social, economic or cultural dimension that needs to be considered. For example, the noise created by traffic travelling to and from a production facility may have a different impact if it travels past a rural school rather than along a major state highway.

In addition to the quality of the environment, other community issues include cultural impacts, socio-economic impacts and public anxiety.

Cultural issues may arise if an oil and gas development is likely to have an impact on a site of cultural significance and/or historic heritage, such as a wāhi tapu. In addition, a number of effects relevant to oil and gas production relate closely to tangata whenua values (eg, the potential for fracking activities to affect freshwater resources, or disposal of waste sourced from a different region/rohe). Particular values and sites of significance vary throughout New Zealand, and engagement with local iwi (which hold mana whenua as kaitiaki over the particular rohe, or area of interest) is required to understand the issues relevant to a particular development or area. A number of iwi also provide guidance on cultural issues through iwi management plans (see section 6.1.3).

In areas where mana whenua is claimed by more than one iwi/hapū, councils should adopt an inclusive approach to enable any affected iwi/hapū to be involved in the process for planning for potential oil and gas development in particular areas.

Developments undertaken by the oil and gas industry may be on a significant scale and have the potential to affect the economy of a community. Developments could create jobs and shift employment locations and, as a consequence, could change the make-up of communities. For example, the East Coast Oil and Gas Development Study (MBIE, 2013a), provides an economic impact analysis of potential petroleum sector development scenarios in the East Coast of the North Island.

Effects associated with oil and gas development have been identified in section 5, including those specifically related to social, economic, historic heritage and cultural elements of the environment. However, in addition to consideration of these effects, it should be noted that for some members of the community, oil and gas production, and the fracking process in particular, have generated public anxiety in the past. The impact this may have on a community’s fears and aspirations is something that can be considered as part of a plan-making or consenting process and should be balanced alongside the other effects of the activity.

5.12.2 Effects management

A fundamental step in understanding and managing the effects of oil and gas development on the community is engagement with affected groups. This engagement should provide the

community (including stakeholders and iwi) with information about the oil and gas development process and enable a project or plan to build on local knowledge, not only to identify effects but also to develop appropriate mitigation measures.

The engagement process undertaken should be tailored to the scale of the project and the particular needs of the community. The International Energy Agency provides guidance for those in the gas industry, including a recommendation to:

Integrate engagement with local communities, residents and other stakeholders into each phase of a development starting prior to exploration; provide sufficient opportunity for comment on plans, operations and performance; listen to concerns and respond appropriately and promptly. (International Energy Agency, 2012, p 43)

The Quality Planning website also provides guidance on consultation as part of plan-making and consenting processes, which can be found at:

- <http://www.qualityplanning.org.nz/index.php/plan-development-components/consultation>
- <http://www.qualityplanning.org.nz/index.php/supporting-components/consultation>.

Engagement with iwi should form an important part of this engagement process where a project or plan may affect iwi values, interests or associations. Local iwi organisations often provide advice on the cultural impacts and management techniques related to oil and gas production in their area. Quality planning guidance on consultation with tangata whenua can be found at <http://www.qualityplanning.org.nz/index.php/plan-development-components/consultation-with-tangata-whenua>.

There is the potential for an iterative process of consultation and engagement between the permit holder and the relevant regional councils and territorial authorities, land owners, stakeholders, the New Zealand Historic Places Trust and communities as a work programme (specified by conditions of a minerals permit granted under the Crown Minerals Act) progresses.

Permits granted under the Crown Minerals Act are available for public viewing on the New Zealand Petroleum and Minerals website (<http://www.nzpam.govt.nz/cms/petroleum>), which can give councils an early ‘heads up’ of where future petroleum development is likely to occur and who the permit holders are.

Although there is no requirement under the RMA for a permit holder to engage with local authorities, iwi or the community, councils need to ensure the adverse effects of activities on people and communities are accounted for in plan making and resource consenting.

Councils cannot control the level of pre-engagement an operator undertakes before lodging an application. However, if an operator engages with the council before lodging an application, councils may wish to alert applicants that the benefits of an engagement process are that:

- it provides local authorities with an opportunity to identify constraints on site selection, which act as a ‘heads up’ for the project proponent well in advance of the final site selection process
- potentially, it provides the ability for the project proponent to identify the likelihood of utilising hydraulic fracturing for well stimulation
- it enables regulatory bodies to anticipate information requirements and the scope of the consent applications and AEE

- it can lead to a stronger understanding of the issues, and result in better environmental outcomes
- community concern can, at times, be heightened by the feeling of not being involved in the process, and engagement is a way to involve tangata whenua, land owners, stakeholders and the wider community, and thereby build a ‘social licence to operate’ on issues of oil and gas development, for both local authorities and applicants.

6 RMA policy framework and plan rules

The majority of hydraulic fracturing projects undertaken in New Zealand have been to improve oil or gas flow from tight-gas sandstone reservoirs in Taranaki. New Zealand's first hydraulic fracturing operation (also known as a 'frack job') occurred in Taranaki in 1989, and since then over 606 wells have been hydraulically fractured nationwide. There have been several fracturing operations on coal seams in both the Waikato coalfield and the Ohai area of Southland. More recently, operators have shown interest in developing shale resources on the East Coast, and hydraulic fracturing operations will most likely be required to extract this resource.

This section outlines the RMA policy and plan framework. It includes two case studies of how the effects of hydraulic fracturing and associated activities can be managed through RMA plans.

6.1 Policy development and plan preparation

The environmental effects of hydraulic fracturing and associated activities are managed through the provisions of regional policy statements, regional plans and districts plans, which are prepared by local authorities under the RMA. These planning documents vary in the way they address hydraulic fracturing across New Zealand.

The purpose of this section is to provide examples of the policy framework for managing oil and gas activities. Two case studies have been selected to illustrate provisions from a region where oil and gas activities have been established for some time (Taranaki Regional Council), and provisions from a region where oil and gas activities are emerging (Gisborne District Council).

The two case studies are intended to provide practical examples for local authorities who are considering policy options for addressing hydraulic fracturing and related activities under the RMA. Please note that the specific provisions adopted in the case studies will not necessarily be appropriate for all other regions and districts in New Zealand. Any provisions that are developed for hydraulic fracturing and associated activities in regional policy statements, regional plans and district plans must be based on the particular local environment and undertaken with consultation with the relevant communities.

For example, local conditions can vary in relation to:

- resource pressures, such as water quality, water demand, earthquake risk, land-use patterns and air quality
- the hydrogeology in the region
- the level of support and engagement from the community for the oil and gas industry.

Local authority decisions under the RMA are required to take into account effects on the principles of the Treaty of Waitangi, and many iwi will have a particular interest in oil and gas development. Councils should work closely with iwi to identify resource management issues that are significant to iwi, and how these can be addressed through regional and district planning provisions.

Further guidance on unconventional gas for policy-makers is provided in the ‘Golden Rules’, which were developed by the International Energy Agency (2012). The Golden Rules establish principles for policy-makers, regulators and operators to address the environmental and social impacts of the industry. The Golden Rules highlight the need for full transparency, measuring and monitoring of environmental impacts, and engagement with local communities as critical matters for addressing public concerns. Further information is provided in Appendix E.

The Quality Planning website also provides general guidance on the development of plans in New Zealand (<http://www.qualityplanning.org.nz/index.php/plan-steps>).

6.1.1 Regional policy statements

The purpose of a regional policy statement (RPS) is to provide an overview of the resource management issues of a region and the policies and methods to achieve integrated management of the natural and physical resources of the whole region. Current experience shows that there is considerable variability in the degree to which hydraulic fracturing and associated activities in the oil and gas industry are specifically addressed in RPSs. In many instances, local authorities do not deal with oil and gas development specifically, but do so through other resource management issues such as water quality, water demand, or land availability.

RPSs must give effect to national policy statements, including the New Zealand Coastal Policy Statement (NZCPS). The NZCPS does not have any specific policies relating to oil and gas exploration, but it does have general policies of relevance to the effects of activities on the coastal environment.

Councils have the ability to identify oil and gas development as a significant resource management issue in an RPS and to proactively plan to address effects arising from the potential growth of oil and gas development activities (including cumulative effects). This should involve a process of public consultation (including with tangata whenua and communities).

6.1.2 Regional and district plans

The provisions in regional plans that are likely to be of most relevance to hydraulic fracturing and related activities are water takes, discharges to water, stormwater treatment and discharge, discharge of contaminants to land, discharges to air, natural hazards, and the storage and management of hazardous substances.

The provisions in district plans that are likely to be of most relevance to hydraulic fracturing and related activities are land-use consents for well sites and production stations, the control of noise and light spill, traffic generation and traffic management, and the transportation, storage and use of hazardous substances. Note that plans should not duplicate or restate HSNO requirements, and justification must be given for any additions on top of HSNO.

No districts or regions in New Zealand have identical provisions in their plans for oil and gas development.

National policy statements and/or national environmental standards may also be relevant to hydraulic fracturing and related activities. The NES for Assessing and Managing Contaminants in Soil to Protect Human Health is discussed in section 5.5. RPSs, regional plans and district

plans must not be inconsistent with an NPS or NES; however, plans generally have other relevant provisions that are not covered by an NPS or NES.

Typically, the effects of seismic data acquisition on the surrounding natural and physical environment are no more than minor. This has been reflected in district plans by providing for seismic data acquisition as a permitted activity in various areas, subject to specific performance criteria.⁴⁵ A distinction is usually drawn in plans between petroleum prospecting and seismic data acquisition (permitted activity), and petroleum exploration and production testing.

Performance criteria or consent conditions to address the effects of seismic surveying may include traffic and noise management requirements (discussed in more detail in sections 5.6 and 5.7), appropriate separation distances between seismic surveying activities and other land uses (such as dwellings, or existing bores for water supply), requirements to notify adjacent land owners, and land rehabilitation following completion of the activity.

Regional and district plan provisions may also restrict or prohibit hydraulic fracturing and related activities (such as well construction) in particular areas (eg, areas that have particular ecological, seismic, historic heritage or cultural sensitivity, which could otherwise be significantly affected by activities). Any plan change to restrict activities in particular areas would need to be developed through the Schedule 1 process under the RMA (which involves public notification and submissions). For example, the Ministry for the Environment has produced previous guidelines for resource management planners in New Zealand on *Planning for Development of Land on or Close to Active Faults*.⁴⁶

6.1.3 Iwi planning documents

Iwi planning documents, commonly known as iwi or hapū management plans, are relevant planning documents recognised by an iwi authority and lodged with the council. These documents have statutory weight, in that the RMA requires these documents to be taken into account by councils in the preparation of regional policy statements (section 61(2A)(a)), regional plans (section 66(2A)(a)) and district plans (section 74(2A)). Councils should work with iwi to develop resource management provisions, giving due consideration to matters raised in iwi management plans.

A consent authority should also have regard to any relevant issues raised in iwi or hapū management plans, as appropriate, in processing resource consent applications, under section 104(1)(c) of the RMA.

Iwi planning documents may raise specific issues about oil and gas development in the rohe of the iwi or hapū. For example, the iwi management plans of Ngāti Ruanui (South Taranaki area) (Te Runanga o Ngāti Ruanui Trust, 2012) and Nga Ariki Kaiputahi (Gisborne area) (Hapū/Iwi

⁴⁵ Examples include the:

- Tararua District Plan, where ‘prospecting’ (including seismic surveying) is a permitted activity in the Rural Management Area
- Stratford District Plan, where ‘pre-drilling and exploration activities’ (including seismic surveying) are permitted activities in the Rural Area
- Gisborne District Plan, where ‘geological and geophysical prospecting activities’ are permitted in certain Rural and Industrial Zones.

⁴⁶ <http://www.mfe.govt.nz/publications/rma/planning-development-active-faults-dec04/index.html>.

Environmental Project Consultancy, 2012) refer to oil and gas development, and to hydraulic fracturing in particular.

Detailed guidance on the role of iwi management plans, and how they should be used by local authorities, is available on the Quality Planning website at <http://www.qualityplanning.org.nz/index.php/supporting-components/faq-s-on-iwi-management-plans>.

6.1.4 Non-statutory strategies

There has been an increased use of non-statutory strategies and plans by councils to coordinate land use, infrastructure and financial needs when a coordinated strategy is required on a particular issue and/or for a particular geographical area. The development of non-statutory guidance provides an opportunity for delivery agencies, industry, iwi and community groups to work collaboratively. Aspects of non-statutory strategies that are relevant to land-use activities can then be implemented through RMA policies and plans, and hence inform planning and consenting decisions.

Councils in areas where interest in oil and gas development has been recognised (eg, areas open to bidding through the block offer process for permitting under the Crown Minerals Act) may wish to develop non-statutory strategies to facilitate early community engagement.

This approach is being progressed in the East Coast region. MBIE (2013a) prepared the East Coast Oil and Gas Development Study, in which it noted that a “petroleum management strategy” could provide a convenient mechanism for iwi and hapū, local and central government, permit holders, land owners and users, and the broader community to discuss petroleum development in the region and agree on key parameters. As part of implementing such a strategy, it could be consulted on using the special consultative procedure under the Local Government Act 2002.

A petroleum management strategy can have a number of potential benefits, including:

- a better opportunity for an appropriate engagement process at an early stage, which is necessary for a strategy that involves complex economic, cultural, social and environmental issues
- an opportunity for iwi to contribute to strategies to enable concerns, interests and values to be addressed
- an opportunity for iwi, land owners, neighbours and the wider community to be involved in strategic planning regarding oil and gas
- the flexibility to develop the guidance within an appropriate timeframe, because no statutory timeframes apply
- being a suitable vehicle for coordinating approaches across regional councils and territorial authorities, especially for areas where petroleum development is an emerging issue
- enhancing the impact of a strategy by engaging permit holders, which could, for example, lead to agreement by permit holders to share some aspects of infrastructure (eg, pipelines)
- being able to be supported by a range of associated information or plans (MBIE, 2013a).

Whether a non-statutory strategy extends to the development of a formal document or a less formal process is a question for local authorities to determine in conjunction with

ratepayers, iwi and stakeholders. Case study 8 provides another example of non-statutory guidance, illustrating a collaborative approach between local government and the community (including industry).

Case study 8: Hawke's Bay Land and Water Management Strategy – Hawke's Bay Regional Council

The Hawke's Bay Land and Water Management Strategy (the Strategy) outlines the Hawke's Bay region's vision and strategic directions for the future management of land and water. The Strategy also identifies how the region will respond to challenges and create new opportunities for innovation and better use of technologies.

Land and water in Hawke's Bay have been identified as vital resources. Challenges have centred around erosion, the impacts of drought, degraded water quality, and climate change effects on the security of water supply. The Strategy represents a milestone in the move from an individual self-interest focus to a collaborative community interest focus, and from short-term to long-term thinking.

In 2010, 115 people from throughout the region attended the Hawke's Bay Regional Water Symposium to discuss the issue of water quantity. This Symposium also identified the necessity to integrate water quantity with land use and water quality. Nominations at the Symposium helped establish an External Reference Group. This Reference Group represents stakeholders with an interest in the management of land and water in the catchment, such as land owners, irrigators, primary industry sectors, statutory agencies and conservation groups.

The Reference Group continued to encourage Hawke's Bay Regional Council to include land use and water quality within the scope of the Strategy and helped develop the vision, guiding principles and objectives for managing the region's water resources in the Strategy. This was undertaken over a 12-month period.

Feedback from the Reference Group was that they valued the experience of working together and listening to different perspectives on the development of the Strategy. This illustrates that the use of multi-stakeholder groups can help different stakeholders to understand differences and areas of common ground, to help build consensus.

Source: Hawke's Bay Regional Council, 2011.

6.2 Plan content and rules case studies

6.2.1 Taranaki Region

Taranaki Regional Council has been managing the environmental effects arising from oil and gas exploration and production activities for more than 30 years. With the introduction of the RMA, the Council, the oil and gas industry and the community developed a policy framework to manage environmental issues arising from oil and gas exploration and production activities. This work culminated in the regional policy statement for Taranaki, which became operative in 1994 and the subsequent completion of four regional plans. The regional plans cover the coast, land, fresh water and air quality. The regional freshwater and soil plans are currently under review by the Council.

Taranaki Regional Policy Statement 2010 (RPS)

The RPS and the regional plans in Taranaki recognise the development of petroleum as a particular issue to be managed in the region, and address this through policies on matters such as consultation with iwi, and subdivision in areas of potential petroleum mining. Relevant policies in the RPS for the oil and gas industry address:

- discharges of contaminants to air
- point source discharges to water
- water use and protection of in-stream values
- soil contamination
- landscape, heritage and amenity issues
- the effects of climate change
- energy efficiency
- effects on the coastal environment
- protection of wāhi tapu and recognition of the cultural and spiritual values of tangata whenua.

Taranaki Regional Air Quality Plan 2011

The Regional Air Quality Plan sets out specific rules for discharges from hydrocarbon well sites or gas treatment or production sites. For example:

- Rule 9 – Discharges from hydrocarbon exploration well sites are a controlled activity provided the environmental standards are met
- Rule 10 – Discharges from hydrocarbon exploration well sites that do not comply with Rule 9 are a restricted discretionary activity
- Rule 11 – Discharges from gas treatment or production plants are a controlled activity provided the environmental standards are met
- Rule 12 – Discharges from hydrocarbon producing well head or well sites are a restricted discretionary activity.

Rule 9 establishes that a discharge of contaminants to air from a hydrocarbon exploration well site is a controlled activity. While a resource consent is required, the council must approve the consent provided that the standards and terms set out in the rules are met. Based on the Council's experience of the effects of discharges from petroleum activities (particularly on people), it has chosen to retain control over discharges to air, including flaring. As a result, Rule 9 facilitates exploration activities where these are situated away from dwelling houses and do not exceed a particular length of time per zone to be appraised for flaring.

The standards that must be met for this activity to be a controlled activity are:

- the flare or incinerator point is at least 300 metres from any dwelling house
- the discharge to air from the flare must not last longer than 15 days cumulatively, inclusive of testing, clean-up and completion stages of well development or work-over, per zone to be appraised
- no material is to be flared or incinerated, other than those derived from or entrained in the well steam.

The specific time limit of 15 days per zone for the discharge from a flare has been adopted to cover the range of reservoir conditions in Taranaki and to ensure that adequate production performance information can be gained from well testing while protecting the environment.

The control/discretion that Taranaki Regional Council has over the activity includes:

- duration of the consent
- duration of flaring or other emissions
- material to be flared
- imposition of limits on or relating to the discharge or ambient concentrations of contaminants, or on or relating to mass discharge rates
- best practicable option to prevent or minimise any adverse effects on the environment
- location of any facilities or equipment for hydrocarbon flaring in relation to surrounding land uses
- separation of natural gas from liquid hydrocarbons and water
- notification of flaring to neighbours, affected parties and the Council
- recording of flare usages and smoke emissions
- oil recovery requirements
- visual effects, loss of amenity value of air, chronic or acute human health effects, soiling or damage to property, odour, annoyance and offensiveness, effects on ecosystems, plants and animals, and effects on areas identified in Policy 2.3
- monitoring and information
- contingency measures and investigations, remediation and response procedures for non-routine discharge events and complaints
- review of the conditions of consent and the timing and purpose of the review
- payment of administrative charges
- payment of financial contributions.

Taranaki Regional Fresh Water Plan 2001

The Regional Fresh Water Plan became operative in October 2001. All major industrial, trade and agricultural activities involving the use of water, beds of rivers and lakes, and discharges of contaminants to land or water are assessed through the regional rules in this Plan. A specific section in the Plan provides for discharges from hydrocarbon exploration. For example, the taking and use of small volumes of surface water and groundwater are permitted activities.

Seismic surveying into or under land, and bore drilling,⁴⁷ are permitted activities under rule 46 of the Regional Fresh Water Plan, subject to the following performance criteria:

- a seismic survey must be located 100 metres or more from any bore, well or spring used for water supply purposes

⁴⁷ In the Taranaki Regional Fresh Water Plan, 'bore' is defined as meaning "a hole drilled in the ground and completed for the abstraction of water or hydrocarbons to a depth greater than 20 metres below the ground surface". The definition of bore will vary in different regions, as provided for in their respective regional plans and/or regional policy statements. See also section 6.3 below.

- bores must be cased and sealed to prevent the potential for aquifer cross contamination or surface leakage, and must be located 50 metres or more from any effluent treatment pond, septic tank, silage stack or pit.

Any activity that does not comply with these criteria is a discretionary activity, for which resource consent would be required, and which may be granted or declined.

Under rule 41, discharges of surplus water used for drilling fluids, and production water from hydrocarbon exploration activities, to surface water are controlled activities and therefore require consent. The standards that must be met are the:

- discharger must at all times adopt the best practicable option to prevent or minimise any adverse effects of the discharge or discharges to any surface water body
- discharge shall have a pH range of 6.5–8.5
- discharge shall contain less than 15 gm⁻³ of oil and grease
- discharge shall contain less than 100 gm⁻³ suspended solids
- discharge shall not cause the temperature of the receiving water to increase by more than 2°C or the level of biochemical oxygen demand to increase by more than 2.00 gm⁻³ after reasonable mixing
- discharge shall not give rise to any or all of the following effects in the receiving water after reasonable mixing:
 - the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials
 - any conspicuous change in the colour or visual clarity
 - any emission of objectionable odour
 - the rendering of fresh water unsuitable for consumption by farm animals
 - any significant adverse effects on aquatic life
- applicant must provide with an application a contingency plan for avoiding, remedying or mitigating unauthorised discharges.

The control/discretion the council has over this activity covers (as per ruler 41):

- definition and delineation of the mixing zone
- approval of the contingency plan and all matters contained therein
- setting of conditions relating to adverse effects on aquatic life and the environment
- monitoring and information requirements
- duration of the consent
- review of conditions of consent and the timing and purpose of the review
- payment of administrative charges and financial contributions.

Under rule 42, the discharge of drilling muds, drilling cuttings and drilling wastes onto or into land from hydrocarbon exploration is a controlled activity and therefore requires consent. Standards that must be met to manage the environmental effects are:

- the discharge shall not result or be liable to result in any contaminant entering surface water
- the discharger must at all times adopt the best practicable option to prevent or minimise any adverse effects of the discharge or discharges to any water body or soil

- the discharge shall contain less than 15 mg/kg oil and grease
- there shall be no adverse chemical effects on groundwater beyond the site.

The control/discretion the Council has over this activity covers (as per rule 42):

- approval of the contingency plan and matters contained therein
- setting of conditions relating to adverse effects on soil, groundwater and the environment, site closure and rehabilitation
- monitoring and information requirements
- duration of the consent
- review of conditions of consent and the timing and purpose of the review
- payment of administrative charges and financial contributions.

The Taranaki Regional Council is currently carrying out a 10-yearly review of the Regional Freshwater Plan. This review is expected to be carried out over 2013 and 2014 and may result in changes to the plan framework summarised above.

Council guidance to the oil and gas industry on regional plans

In 2001, Taranaki Regional Council produced *A Guide to Regional Plans in Taranaki for Oil and Gas Exploration and Production Activities* (Taranaki Regional Council, 2001). The guide sets out the common activities of the industry, the classification of the activity under the relevant plan, and whether or not a resource consent is needed. The guide also includes good practice guidance for site earthworks, riparian management, flaring, and disposal of drilling wastes and production water.

The guide provides a starting point for those both involved in and interested in the industry in terms of how the various plans might affect particular activities within the industry. This is a draft guide and will be updated when all of the Council's second-generation regional plans are determined.

6.2.2 Example district plan provisions in Taranaki

The New Plymouth District Plan

The New Plymouth District Council District Plan is a second-generation plan under the RMA. It is one of the few district plans that is purely effects based. This means that it does not include lists of activities that are permitted, controlled, discretionary or non-complying. Rather, the characterisation of the activity and its consent status depend on the degree to which the activity complies with a suite of performance and development standards.

If oil and gas installations meet the relevant performance standards and development controls for a permitted activity within the Rural Zone of the Plan, then no resource consent is required. However, in reality such activities would be captured by the provisions relating to the storage, use and disposal of hazardous substances (which are addressed under HSNO), traffic generation thresholds, and the control of noise.

This approach focuses the assessment of effects on those specific factors, regardless of where the activity is in the life cycle of the well. In some cases this may allow a smoother transition from exploration to development and production.

The South Taranaki District Plan

By contrast, the South Taranaki District Plan is a more traditional plan, with lists of activities in relation to activity status. This is then augmented by performance standards and development controls, which may elevate an activity from (for example) a permitted activity to a controlled activity status if performance standards cannot be met.

The District Plan provides for petroleum prospecting, including seismic data exploration, as a permitted activity. Petroleum exploration and production testing is provided for as a controlled activity subject to performance standards. If performance standards related to flaring are not complied with, the activity becomes a restricted discretionary activity. Discretion is restricted to noise, landscaping, heavy vehicle movements, access and the duration of the activity. Petroleum production stations, well heads and associated buildings that do not meet height and setback standards are full discretionary activities.

The Stratford District Plan

Similarly to the South Taranaki District Plan, the Stratford District Plan lists a number of activities relevant to different stages of oil and gas development and provides an activity status for each. The activity status may be elevated if performance standards are not met.

In rural areas of the District, mineral prospecting and pre-drilling petroleum exploration activities are permitted. Mineral exploration, including petroleum exploration, production testing and interim production, are controlled in rural areas. These permitted and controlled activities must comply with standards, including consultation with affected parties, noise monitoring, flaring and restoration of land.

If controlled activities do not meet the relevant standards, their activity status is elevated to limited discretionary. Issues for discretion include flaring, hours of operation, transport, and effects on people and outstanding natural landscapes and features. Petroleum production facilities are a full discretionary activity.

6.2.3 Gisborne District Council

Gisborne District Council is the largest district council in the North Island, covering 8355 square kilometres of land. The Council is a unitary authority, and therefore performs the role of both a district and a regional council. The geology of the East Coast of the North Island has two extensive formations, Waipawa and Whangai, which have known petroleum resources. There are a number of locations where oil has seeped to the surface from these formations.

The Council has four operative regional plans:

- Air Quality Plan
- Coastal Environment Plan
- Discharges Plan
- Freshwater Plan.

In addition to the above plans, the Council's Combined Regional Land and District Plan (the Plan) became operative on 31 January 2006. The Plan recognises that the hydrocarbon resources in the district are likely to be investigated for their potential to be mined commercially. These activities are classified as industrial activities in the Plan, but are likely to occur outside of the industrial zones as a result of the location of the hydrocarbon resource. The Plan addresses this through rules that will apply to these activities across all of the Gisborne District area. The Plan also recognises that the effects from the various activities associated with petrochemical exploration will vary depending on the characteristics of the location.

The Plan anticipates that exploration for other minerals could also occur within the District and could generate a variety of environmental effects, depending on the exploration and extraction processes used. The Council also recognises that there continues to be an interest in petrochemical exploration in the area, and it will be necessary to identify the effects of exploration, testing and any eventual extraction processes to ensure that adverse effects on the environment are avoided, mitigated or remedied.

Geological and geophysical prospecting activities are permitted in the Rural G, Rural P and Industrial Zones (Rule 19.18.1), provided that the following standards are met.

- Notice shall be given to landowners within 100 metres of any prospecting activities, to the District Council and to tangata whenua, at least 30 days prior to commencement of operations. The notice is to include information on the nature, location, timing and effects of the activity.
- Public notice in a newspaper circulating in the prospecting area shall be printed seven days prior to commencement of operations.
- The minimum distance between a shot hole and any dwelling shall be 100 metres unless the written approval of the owner and occupier has been obtained.
- Restoration and rehabilitation of disturbed areas, including access tracks, shot holes, drainage areas, vegetation and gates and fences, shall be carried out.
- All activities must comply with the General Rules specified in Chapter 8 – Infrastructure, Works and Services and Chapter 11 – Noise and Vibration.

If an activity cannot meet the permitted activity standards, it will default to a discretionary activity. The discretionary activities provided for are:

- geophysical prospecting in all zones and areas other than Rural P, Rural G and Industrial Zones
- exploration and development appraisal well drilling within the Rural P, Rural G or Industrial Zones
- production (mining) in the Rural P, Rural G or Industrial Zones.

The Plan provides for petroleum activities in the Rural Zone as follows:

- **Controlled activities** – Petroleum exploration and production testing. Council may impose conditions relating to:
 - noise
 - landscaping
 - appearance
 - access
 - heavy vehicle movements
 - duration of production testing.

- **Discretionary activities** – Petroleum production stations and well heads.
- **Restricted discretionary activities** – Petroleum exploration and production testing which cannot meet one or more of the performance standards as a controlled activity. Council retains discretion over:
 - noise
 - landscaping
 - access
 - heavy vehicle movements
 - duration of activity.

6.3 Wells/bores

Regional plans may also contain particular provisions that relate to wells (also known as bores). If an oil or gas exploration activity involves drilling a bore/well, a resource consent may be required that deals with any adverse environmental effects. Permitted activity criteria associated with bore drilling in respect to the Taranaki Regional Fresh Water Plan are discussed above in 6.2.1.

In the context of the Proposed Horizons One Plan, resource consent would be required for the drilling, construction or alteration of any bore⁴⁸ or hole that extends below the seasonally highest groundwater level, and any associated discharge of water or contaminants (rule 15-13). The consent is dealt with as a restricted discretionary activity, and matters of discretion include:

- compliance with NZS4411:2001 Environmental Standard for Drilling of Soil and Rock
- bore location, size and depth
- bore screening
- backflow prevention
- information requirements such as bore logs, piezometric levels, and bore construction details.

Hawke’s Bay Regional Council also requires a resource consent for drilling bores.⁴⁹ They may be either controlled or discretionary activities (6.3.1 rules 1 and 2). The matters of discretion and control are very similar to those in the Horizons One Plan. Hawke’s Bay Regional Council includes a specific application for a bore permit, which sets out the information that is required to be submitted.⁵⁰

⁴⁸ In the Proposed Horizons One Plan, ‘bore’ is defined as “any hole, regardless of the method of formation, that (a) is created for the purpose of accessing groundwater, oil or gas; or (b) is created for the purpose of exploring water, oil or gas resources excluding piezometers installed for monitoring purposes”.

⁴⁹ In the Hawke’s Bay Regional Resource Management Plan, ‘bore’ is defined as meaning “any pipe, cylinder or hole inserted into the ground that either: (i) is created for the purpose of accessing underground water, oil or gas, or (ii) penetrates a confined aquifer, or (iii) in any way causes the release of water from a confined aquifer, or (iv) is created for the purpose of exploring water, oil or gas resources but excludes piezometers installed for monitoring purposes”.

⁵⁰ See <http://www.hbrc.govt.nz/HBRC-Documents/HBRC%20Document%20Library/Consent%20BorePermitApplication.pdf>.

6.4 The scope of an assessment of environmental effects

Resource consents for hydraulic fracturing and related activities will typically be required from district and regional councils. Section 88 and the Fourth Schedule of the RMA require certain information to be submitted with a resource consent application, including an assessment of environmental effects (AEE). If an application does not contain an adequate AEE, the consent authority can return the application as incomplete under section 88(3) of the RMA.

The AEE is an important component of an application to determine the likely adverse effects the activity will have on the environment and how those effects will be avoided, remedied or mitigated. The council is responsible for auditing the AEE to ensure the applicant has provided sufficient detail that corresponds to the scale and significance of the effects the activity may have on the environment.

Section 5 of this guidance identifies the main environmental effects associated with hydraulic fracturing-related activities and the type of information that should be included in an AEE to adequately assess the potential for these effects (including any cumulative effects if multiple operations are active or proposed in close proximity – see Appendix D5, point 14). If a council anticipates receiving an increasing number of resource consent applications for hydraulic fracturing, it may be useful to develop a checklist or guidelines on oil and gas applications. This will provide applicants with a clear understanding of the council's expectations, as well as assisting council staff responsible for assessing the adequacy of the information in the application.

Appendix D provides examples of the scope of AEEs for resource consent applications to a regional council and territorial authority. The applications relate to the following activities:

- discharge of earthworks and stormwater discharges from well site construction
- hydraulic fracturing
- deep well injection
- discharge of drilling waste to land.

For RMA purposes, a hydraulic fracturing operation is a discharge of water and contaminants to land. The key elements that should be covered in an AEE for hydraulic fracturing are:

- information on the geology, lithology and overpressure⁵¹ containment
- description and analysis of faults in the local area
- a description of the hydraulic fracturing process to be used
- a description and details of the well design and construction process, including details of the relevant standards adopted
- a description and details of the hydraulic fracturing fluids to be used, subsurface monitoring, and how the flow-back fluids will be managed on-site

⁵¹ Overpressure is where the sub-surface pressure in a geological formation is abnormally high. This can occur where the burial of fluid-filled sediments occurs at a fast rate, trapping pore fluids so they cannot escape, and pressure increases as the burial occurs. Drilling into overpressured formations can be hazardous as fluids can then escape quickly, so contingency measures such as blowout preventers should be specified (Schlumberger Ltd, 2013a).

- the effects on water quality of the discharge of water used in the well-drilling or hydraulic-fracturing operation
- the monitoring framework for potable groundwater resources in the site vicinity.

Assessments of environmental effects for significant coal seam gas developments should include details about the impacts of dewatering on groundwater. For example, the IESC Guidelines recommend that environmental impact assessments include details about:

- connectivity between aquifers
- existing aquifer recharge rates
- anticipated aquifer draw down
- existing and future groundwater uses
- groundwater-dependent ecosystems (including stygofauna, which are species that live permanently in underground water)
- produced water disposal methods (IESC, 2013).

Social, health, cultural and historic heritage impact assessments should also be included in applications, where relevant, to address potential impacts on community or tangata whenua values, interests, and associations with a particular area proposed for drilling and/or hydraulic fracturing.

As is the case with many other types of activities, the cultural impacts of oil and gas development proposals can be significant, and so resource consent applications should include an adequate cultural impact assessment. Detailed information about what to include in cultural impact assessments is provided on the Quality Planning website: <http://www.qualityplanning.org.nz/index.php/supporting-components/faq-s-on-cultural-impact-assessments>.

Further information on assessing AEEs is provided on the Quality Planning website: <http://www.qualityplanning.org.nz/index.php/consents/environmental-effects>.

6.4.1 Specialist advice

Local authorities are likely to require specialist advice to appropriately assess the adequacy of the information provided by an applicant, and to assess the potential effects of hydraulic fracturing and associated activities. Councils may use consultants to peer-review the AEE, and may commission reports on specific matters.

It is important to note that cultural, social and historic heritage impact assessments also require specialist expertise (along with other types of assessments, such as geophysical, hydrogeological or landscape assessments), and further independent specialist advice may be needed for the council to assess the adequacy of the information provided.

The RMA specifies situations where a council may commission specialist advice, including:

- under section 42A – before a hearing, a council may commission reports on any matters relevant to proposed policy statements, plans and resource consent applications, and on any matters raised by submitters to these proposals

- under section 92(2) – before a hearing, a council may commission reports from specialists when the activity may have a significant adverse environmental effect, the applicant is notified in writing of the reasons for requesting the report, and the applicant agrees to the commissioning of the report
- under section 41C(4) – at a hearing, the authority may commission reports from specialists when further information is required, the activity may have a significant adverse environmental effect, the applicant is notified in writing of the reasons for requesting the report, and the applicant agrees to the commissioning of the report.

Further guidance on commissioning specialists to process the application and assess the environmental effects further is available on the Quality Planning website at: <http://www.qualityplanning.org.nz/index.php/consents/environmental-effects#aretherenay>.

6.5 Bundling principle

Some operations consist of separate activities that each requires a resource consent. The general resource consent process for where there is more than one activity involved, and where those activities are inextricably linked, is to bundle the activities and apply the most restrictive activity classification to the overall proposal (a ‘bundle’). However, in some cases activities can occur at a later stage of the operation (as is the case with hydraulic fracturing in the overall oil and gas process) and consent may not be sought with the initial application.

Consent authorities have the decision-making powers to treat applications for oil or gas activity as a number of separate activities or as one overall classified activity (a ‘bundle’). The decision to treat specific oil and gas activities, such as hydraulic fracturing, separately from the other activity phases of the well cycle that require resource consent is a decision that will vary between councils. The bundling principle should be used on a case-by-case basis.

Well site preparation activities (such as earthworks, traffic movements, ancillary infrastructure, stormwater discharge, etc) should be considered alongside any district consent requirements across the life cycle of a well if they are conducted for the purpose of developing a site for drilling (ie, if they are integral to the overall proposal).

Operators may not know for certain whether hydraulic fracturing of a particular proposed well will be required to facilitate flow of that well. In the case of Taranaki, for example, decisions on whether hydraulic fracturing will be required have usually been made on the basis of the outcomes of drilling (Taranaki Regional Council, 2013b). However, in some cases the results of seismic surveying may make it clear before drilling occurs that hydraulic fracturing will be required to access a formation (which is likely with shale). If a resource consent for drilling is required, the application should specify whether or not the particular well will require hydraulic fracturing, or whether this will be determined based on the outcome of drilling.

If the operator is aware before drilling that hydraulic fracturing of the well will be required (based on the geological characteristics of the target formation), resource consent for hydraulic fracturing should be applied for at the same time (if required) so that the related applications can be assessed together. Under section 91 of the RMA, councils may in some circumstances decline to process an application until other related applications are made.

Case law has emphasised the need for all necessary and related applications to be filed so that all the effects of a proposal can be considered. The issue of good resource management is also relevant, the principles of which were established in the *AFFCO New Zealand Ltd v. Far North*

District Council [1994] NZRMA 224 case. Although that particular case involved lack of integration between district and regional resource consents, it is clear that the principle of integrated resource management requires that proposals be assessed holistically, and not in a piecemeal fashion, as stated in the judgement:

Unless all the effects, positive and negative, of a proposal are assessed together, the consideration of them required to make the ultimate judgment whether the consent should be granted or refused may be incomplete, and the balancing of them may be distorted.⁵²

More information about the bundling principle is available on the Quality Planning website: <http://www.qualityplanning.org.nz/index.php/consents/to-notify-or-not>.

6.6 Notification of oil and gas resource consent applications

Like other activities, each resource consent application should be assessed on its own merits in terms of whether it should be notified or not under section 95 of the RMA.

For the purposes of hydraulic fracturing and associated activities, the effects of the activity will be largely influenced by the hydrogeology, scale and type of oil and gas activity. These factors will therefore influence the consideration of requirements for notifying an application or not.

More general information on notification is available on the Quality Planning website at <http://www.qualityplanning.org.nz/index.php/consents/to-notify-or-not> or refer to *The Everyday Guide to the Resource Management Act* at: <http://www.mfe.govt.nz/publications/rma/everyday/>.

6.6.1 Do special circumstances apply for the notification of oil and gas applications?

With the high interest in the oil and gas industry (including hydraulic fracturing) in New Zealand, there may be situations where a council decides to publicly notify an application if it considers that special circumstances exist, even if the relevant plan or national environmental standard expressly provides that the application need not be publicly or limited notified (section 95A((4)) of the RMA).

‘Special circumstances’ has been determined as meaning circumstances that are unusual or exceptional, but they may be less than extraordinary or unique.⁵³ The purpose of considering special circumstances requires looking at matters that are beyond the plan itself. The fact that a proposal might be contrary to the objectives and policies of a plan may not be sufficient to constitute special circumstances. In effect, special circumstances override other notification provisions.

⁵² *AFFCO New Zealand Ltd v. Far North District Council [1994]*, NZRMA 224.

⁵³ *Peninsula Watchdog Group (Inc) v Minister of Energy [1996]* 2 NZLR 529 (CA) at 536.

Special circumstances must be more than:

- where a council has had an indication that people want to make submissions
- the fact that a large development is proposed
- the fact that some persons have concerns about a proposal.

If the council has concluded that there are special circumstances, it is still at the discretion of the council whether it does publicly notify it.

6.6.2 Identifying affected parties for oil and gas applications

It is the role of the council to determine who it considers to be affected, and to determine whether all such persons have given their approvals, before dispensing with notification. Identification of affected parties for oil and gas applications needs to be undertaken on a case-by-case basis (as with any type of activity requiring a resource consent). This may mean that individuals, communities or organisations who consider they have strong interests or concerns may not necessarily be considered an affected party.

Resource management case law has established that an affected person is one who is “affected in a manner different from the public generally”. Being ‘interested’ in a manner different from the public has generally not been enough. The decision whether or not to publicly or limited notify an application, and the reasons for doing so, must be well documented to show that the threshold tests set out in the RMA have been met and should include all those matters that were considered as part of the decision. The council should also document its consideration of whether special circumstances exist in terms of section 95A(4) of the RMA.

The role of tangata whenua as kaitiaki over their rohe may give them a particular interest above the general public, which means they may be considered an ‘affected party’ for the purpose of notification of resource consent applications for oil and gas development. A resource consent application should provide evidence of any pre-application engagement with iwi, and detail any effects on iwi interests (eg, by reference to provisions in any relevant iwi management plans and/or cultural impact assessments).

It is important to note that, although section 36A of the RMA specifies that applicants and councils do not have a duty to consult with any person about a resource consent application, a comprehensive assessment of environmental effects must give adequate consideration to the requirements of Part 2 of the RMA in terms of the effects of a proposal with regard to Māori values. Often engagement with iwi and/or hapū in the affected area is the only way to obtain adequate information to make this assessment.

Drinking water suppliers are required to prepare a plan for managing the risks of contamination under the Health Act 1956. If oil and gas activities have the potential to contaminate drinking water supplies (either through groundwater or surface-water contamination), councils should consider whether the relevant district health board and any drinking water suppliers should be treated as affected parties for the purpose of notification on resource consent applications (bearing in mind the responsibilities of regional councils under the National Environmental Standard for Sources of Human Drinking Water, discussed above in section 5.6).

If there is potential for a proposed well site development (including activities such as roading and well pad development) to affect historic heritage or archaeological sites, the New Zealand Historic Places Trust may need to be treated as an affected party to be notified of resource consent applications.

Case study 9 illustrates the approach Gisborne District Council has taken to keep the community informed of oil and gas applications, including the provision of notification decision reports on their website, to ensure transparency of rationale for the non-notification of two resource consent applications.

Case study 9: Provision of resource consent applications, notification assessments and resource consent decision reports on a council website – Gisborne District Council

In response to the high public interest in oil and gas development and in the interests of transparency, Gisborne District Council has made the application, assessment of environmental effects, notification decision reports and final decision reports available on their website. The Council website has the following oil and gas application documents available.

- TAG Oil and Apache Corporation resource consent application for the drilling of an exploratory well at 'Punawai' on Kanakanaia Road, Te Karaka. Associated with this are applications to take water, discharge water and contaminants to ground, discharge stormwater, and discharge contaminants to air.
<http://www.gdc.govt.nz/tag-oil-and-apache-corporation-resource-consent-application>
- Eastern Petroleum (NZ) Ltd to complete a stratigraphic test well approximately 1.3 kilometres off Christopher Road, Whangara. The well is to be known as Tangamatai stratigraphic 1.
<http://www.gdc.govt.nz/eastern-petroleum-nz-ltd-resource-consent-application/>

More information about affected parties is available on the Quality Planning website at: <http://www.qualityplanning.org.nz/index.php/consents/to-notify-or-not> or download a copy of the Ministry for the Environment's *Everyday Guide to the Resource Management Act* at: <http://www.mfe.govt.nz/publications/rma/everyday/>.

6.7 Monitoring case studies

Monitoring is an integral part of implementing the RMA. Councils are required to gather information, monitor, and keep records. The information gathered and records kept enable councils to:

- make informed resource management decisions based on all possible information available at the time
- keep the public better informed of their duties and those of the council
- help the community participate effectively in the resource management process.

Section 35(2)(d) requires every council to monitor resource consents that have effect in its region or district, and to take appropriate action (having regard to the methods available to it under the RMA) where this is shown to be necessary.

A council may 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. These can involve samples relating to air quality, water quality, contaminated soil, etc. It is also crucial that the council monitor compliance, and conditions need to be unambiguous, meaningful, measurable, appropriate and enforceable. If

consent conditions are not clear enough or easily interpretable, it makes it harder for the consent holder to comply and for the compliance officer to measure.

Section 36 of the RMA enables councils to charge consent holders for administering, monitoring and supervising consents. This may include paying for staff time and costs arising from each visit to inspect and test discharges. For some consents there is also a standard supervision, administration and monitoring fee payable each year, which covers compliance and other monitoring.

The two case studies below provide specific examples of the monitoring requirements undertaken by Taranaki Regional Council and Horizons Regional Council for oil and gas activities in their regions. The Quality Planning website provides further information on what to monitor and why (<http://www.qualityplanning.org.nz/index.php/monitor>), and enforcement under the RMA (<http://www.qualityplanning.org.nz/index.php/manual>).

Case study 10: Resource consent compliance monitoring summary – Taranaki Regional Council

Taranaki Regional Council has been regulating the oil and gas industry for over 30 years, which has involved the following activities.

- The Council established a thorough monitoring, inspection and enforcement regime that involves regular site inspections for consent compliance monitoring purposes, consent investigations, incident investigations, and advice and information to the industry. In the past 30 years there have been over 4500 site visits and more than 13,000 compliance monitoring inspections of specifically consented oil and gas activities.
- The Council has undertaken appropriate water, soil and air, physico-chemical and biological sampling surveys by trained professionals using accredited laboratories.
- Over the past 10 years sampling has involved over 700 freshwater bio-monitoring surveys and over 4600 water or soil samples, with around 30,000 parameter analyses. Freshwater biological surveys around new exploration sites were severely scaled back a few years ago because of the lack of any effects being found.
- Over the past 10 years the Council has undertaken over 20,000 recorded interactions with the oil and gas industry as part of its regulation of the industry.
- The Council has presented compliance monitoring reports from annual tailored monitoring programmes (and from one-off well site) to its Consents and Regulatory Committee meeting every six weeks for consideration. These monitoring reports provide an environmental performance ranking ('high', 'good', 'improvement desired', 'poor') and commentary about what enforcement action was taken for non-compliance. For example, a high level of environmental performance and compliance indicate that essentially there were no adverse environmental effects to be concerned about, and no, or trivial (such as data supplied after a deadline), non-compliance with conditions. Recommendations about next year's monitoring programme are also provided. Each report is submitted to the consent holder for comment before publication.
- Undertaking the above work is done on a cost-recovery, user-pays basis.

Source: Chamberlain, 2012.

Case study 11: Horizons Regional Council monitoring consent conditions imposed for land-use consents to drill a bore, a discharge permit (into and onto land x 2) and a discharge permit (to air)

Horizons Regional Council received an application from TAG Oil Ltd and Apache Corporation NZ LDC for resource consents to:

- drill and test an exploratory well and associated works and ancillary activities
- discharge water and contaminants onto and into land associated with well drilling and testing
- discharge stormwater onto and into land (including circumstances where it may enter water) from the well-drilling site and associated works and ancillary activities
- discharge contaminants to air from the combustion of petroleum gas associated with well testing (including flaring of gas).

No hydraulic fracturing was proposed as part of these applications. Actual works planned are four weeks for the well drilling and three weeks for the well completion and testing.

Horizons Regional Council imposed conditions that require the consent holder to undertake monitoring relating to groundwater, surface water, stormwater and flaring. These are summarised below and reproduced in full in Appendix B7.

For groundwater monitoring, the consent holder is required to:

- install two groundwater monitoring wells within 40 metres of the drill site and located hydraulically down gradient of the main well
- in accordance with *A National Protocol for State of the Environment Groundwater Sampling in New Zealand 2006*, take groundwater samples from two groundwater monitoring bores (if groundwater is present), once before drilling operations begin, once a week during drilling and testing operations, and one week, one month, six months and one year after drilling and well completions are completed, to be undertaken by the environmental monitoring officer appointed under another condition or a suitably experienced and qualified person approved by Manawatu-Wanganui Regional Council
- install monitoring equipment for the purpose of fluid detection in the groundwater monitoring wells in consultation with Manawatu-Wanganui Regional Council staff – samples of any fluid present in the well shall be taken at the same time that groundwater samples would have been taken
- ensure that before sampling: (a) where practicable, each well is purged at least three times its well volume; and (b) temperature, electrical conductivity and pH measurements have stabilised
- maintain records of the standing water level, temperature, electrical conductivity and pH measurements collected, which shall be provided to the Manawatu-Wanganui Regional Council within five working days of receiving a request from the Regional Council.

For surface water monitoring, the consent holder is required to:

- undertake visual inspections for contamination on a weekly basis and whenever the stormwater pond is discharging to the overland flow path, to look for visible signs of contamination, including oil sheens and films, and a sample shall be taken if visual indications of contamination are observed during inspections
- take baseline surface-water samples from certain points and analyse these
- undertake surface-water sampling at three locations

- undertake surface-water sampling at three locations and from the outlet pipe on the stormwater pond (at different frequencies) once activities on consented activities have begun on site
- ensure all sampling is undertaken by the appointed environmental monitoring officer, or a suitably experienced and qualified person approved by the Manawatu-Wanganui Regional Council
- analyse groundwater and surface-water samples for field variables, general variables and petroleum-related contaminants
- re-sample if methane is detected in any ground- or surface-water samples, and the level is above the level detected in either the baseline monitoring, further comparisons, rehabilitation of the well, or additional ongoing ground and surface water sampling programme
- provide the results of sampling to Manawatu-Wanganui Regional Council's environmental protection manager
- undertake a risk assessment of nearby groundwater users
- maintain temperatures, pH range, turbidity of water etc at certain points on the site.

For stormwater monitoring, the consent holder is required to:

- sample the stormwater pond when water levels have exceeded a certain depth, and have it analysed for:
 - suspended solids
 - total dissolved solids (as well as in field measurement)
 - pH (as well as in field measurement)
 - chloride
 - total petroleum hydrocarbons
 - surfactants that are used on site
- sample any rainwater contained within the hazardous substances bund and analyse this for the above parameters
- provide of all samples to be provided to the Manawatu-Wanganui Regional Council's Environmental Protection Manager.

For discharges to air through flaring, the consent holder is required to record and make available to the Manawatu-Wanganui Regional Council's environmental protection manager a 'flaring log' that includes:

- the date, time and duration of all flaring episodes
- the zone from which flaring occurred
- the volume of substances flared
- whether there was smoke at any time during the flaring episode, and if there was, the time, duration and cause of each 'smoke event'
- monitoring of the gas production volume.

Glossary

The glossary below provides a summary of terminology used in this document. Where the terms are defined in legislation, this is indicated. In addition, the *Schlumberger Oilfield Glossary* provides comprehensive definitions for technical terms used in the oil and gas industry, and entries are available for viewing at <http://www.glossary.oilfield.slb.com/>.

Abandon

In relation to a well, means to seal the well in order to render it permanently inoperative, and ‘abandonment’ has a corresponding meaning (as defined in the HSE(PEE) Regulations 2013). See also ‘suspend’.

Appraisal well

A well drilled as part of an appraisal drilling programme, which is carried out to determine the physical extent, reserves and likely production rate of a field.

Archaeological site

(As defined in Part 2 of the Historic Places Act 1993) means any place in New Zealand that –

- (a) either –
 - (i) was associated with human activity that occurred before 1900; or
 - (ii) is the site of the wreck of any vessel where that wreck occurred before 1900; and
- (b) is or may be able through investigation by archaeological methods to provide evidence relating to the history of New Zealand.

Blowout

An uncontrolled escape of fluids from a well.

Blowout preventer

A high-pressure well head valve, designed to shut off the uncontrolled flow of fluids.

Borehole

The hole as drilled by the drill bit.

Casing

Metal pipe inserted into a bore hole and cemented in place to protect both subsurface formations (such as groundwater) and the well bore.

Christmas tree

The assembly of fittings and valves on the top of the casing which controls the production rate of gas and oil.

Completion

The installation of permanent well head equipment for the production of oil and gas.

Condensate

A low-density liquid hydrocarbon phase; a mixture of pentanes and higher hydrocarbons.

Cuttings

Rock chippings that are cut from the formation by the drill bit and brought to the surface with the mud. Used by geologists to obtain formation data.

Drill bit

Located at the end of the drill-string cutting head, it is generally designed with three cone-shaped wheels tipped with hardened teeth. Drill bits used for extra-hard rock are studded with thousands of tiny industrial diamonds.

Drilling fluids

While a mixture of clay and water is the most common drilling fluid, wells can also be drilled with air or water as the drilling fluid. See also ‘mud’.

Drilling rig

A drilling unit that is not permanently fixed to the land.

Drinking water supplier

(As defined in Part 2A of the Health Act 1956) means a person who supplies drinking water to people in New Zealand or overseas from a drinking-water supply, and

- (c) includes that person’s employees, agents, lessees, and subcontractors while carrying out duties in respect of that drinking-water supply; and
- (d) includes (without limitation)—
 - (iii) a networked supplier; and
 - (iv) a water carrier; and
 - (v) every person who operates a designated port or airport; and
 - (vi) a bulk supplier; and
 - (vii) any person or class of person declared by regulations made under section 69ZZY to be a drinking-water supplier for the purposes of this Part (a **prescribed supplier**); but
- (e) does not include—
 - (i) a temporary drinking-water supplier; or
 - (ii) a self-supplier; or
 - (iii) any person or class of person declared by regulations made under section 69ZZY not to be a drinking-water supplier for the purposes of this Part.

Drinking-water supply

(As defined in Part 2A of the Health Act 1956)

- (a) means a publicly or privately owned system for supplying drinking water to a person or group of persons, on a temporary or permanent basis, up to but not including the point of supply; and
- (b) includes, without limitation, a networked reticulation system, a well, a reservoir, or a tanker.

Exploration well

A well drilled to determine whether hydrocarbons are present in a particular area or structure. Note that ‘exploration’ has specific legislative meanings in both the Crown Minerals Act 1991 and the Exclusive Economic Zone (Environmental Effects – Permitted Activities) Regulations 2013.

Fairway

A mapped area in which the conditions for a particular play may occur.

Felt event / felt seismic event

A seismic event of large enough magnitude to be felt at the surface. The magnitude that can be felt at any given location will depend on the degree of background noise (urban areas are 'noisier' than rural areas), the size and depth of the seismic event, and the geology at the surface (loose soils will attenuate seismic waves more than solid bedrock).

Field

A geographical area under which an oil or gas reservoir lies.

Flaring

The burning off of natural gas as a waste product when it is uneconomic to sell or conserve it, or in emergencies when accumulations of gas become a safety concern. Discussed on page 55 of the Petroleum Programme 2013 (MBIE, 2013b). See also 'venting'.

Formation

A sedimentary bed or deposit composed substantially of the same minerals throughout, and distinctive enough to be a unit.

Formation pressure

The pressure at the bottom of a well when it is shut in at the well head.

Formation water

Salt water underlying gas and oil in the formation.

Fracture interval

The discrete subsurface zone to receive a hydraulic fracture treatment.

Hydraulic fracturing

A method of breaking down a formation by pumping fluid at very high pressure to exceed the tensile strength of the reservoir rock, for the purpose of opening fractures in the rock to increase production rates.

Gas kick

Back pressure in a well from invading gas.

Geology

A field of science concerned with the origin of planet earth, its history, its shape, the materials forming it, and processes that are acting or have acted on it.

Hydrocarbon

A compound containing only the elements hydrogen and carbon. It may exist as a solid, a liquid or a gas. The term is mainly used in a catch-all sense for oil, gas and condensate.

Injection well

A well used for pumping water or gas into the reservoir.

Leak-off

A reduction in pressure in the well during a hydraulic fracturing operation, which occurs due to the growth of fractures.

Liner

A small-diameter casing extending into the producing layer from inside the bottom of the final string of casing cemented in a well.

Mud

A mixture of base substance (eg, water or oil) and additives used to lubricate the drill bit and to counteract the natural pressure of the formation.

Perforate

To pierce holes through the well casing within an oil or gas-bearing formation, using a perforating gun lowered down the hole and fired electrically from the surface, to enable production from a formation that has been cased off.

Permeability

The property of a formation which quantifies the flow of a fluid through the pore spaces and into the well bore.

Petroleum

A term used generally to describe naturally occurring hydrocarbon (other than coal), whether in a gaseous, liquid or solid state. 'Petroleum' has a specific legislative meaning in section 2 of the Crown Minerals Act 1991, for the purpose of that Act.

Play

A group of fields with similar trap structures / reservoir rock.

Porosity

A ratio between the volume of the pore space in reservoir rock and the total bulk volume of the rock. The pore space determines the amount of space available for the storage of fluids. However, if pores are not connected, then no fluids can be extracted. Permeability is a measure of the *connected* porosity and the fluid properties.

Produced water

The water extracted from the subsurface with oil and gas, which may include water from the reservoir, water that has been injected into the formation, and any chemicals added during production and treatment processes.

Reservoir

The underground formation where oil and gas have accumulated, consisting of porous rock to hold the oil or gas and a cap rock that prevents its escape.

Safety case

In relation to an installation, means the document referred to in Schedule 4 of the HSE(PEE) Regulations 2013.

Screen-out

During a hydraulic fracturing operation, a screen-out occurs when a leak-off to the fracture exceeds the pumping rate of the operation, so that proppant accumulates in the fracture or well.

Seismic survey

A term used to describe measurements of seismic-wave travel using principles of reflection and/or refraction, for the purpose of surveying underlying geological structures. Note that ‘seismic survey’ has a more detailed specific legislative meaning in the Exclusive Economic Zone (Environmental Effects – Permitted Activities) Regulations 2013, for the purpose of those regulations.

Suspend

In relation to a well, means to render the well temporarily inoperative, and ‘suspension’ has a corresponding meaning (as defined in the HSE(PEE) Regulations 2013). See also ‘abandon’.

Venting

The direct release of natural gas into the atmosphere. Discussed on page 55 of the Petroleum Programme 2013 (MBIE, 2013b). See also ‘flaring’.

Well

A borehole drilled for the purpose of exploring for, appraising or extracting petroleum; includes any borehole for injection or reinjection purposes; and any down-hole pressure-containing equipment; and any pressure-containing equipment at the top of the well (as defined in the HSE(PEE) Regulations 2013).

Well head

The equipment at the surface of a well used to control the pressure; the point at which the hydrocarbons and water exit the ground.

Well log

A record of a geological formation penetrated during drilling, including technical details of the operation.

Well operation

The drilling, completion, suspension or abandonment of a well, and includes (i) the recommencement of drilling after a well has been completed, suspended or abandoned, and (ii) any other operation in relation to a well during which there may be an accidental release of fluids from the well that could give rise to the risk of a major accident (as defined in the HSE(PEE) Regulations 2013).

Work-over operation

An operation in which a well is re-entered for the purpose of maintaining or repairing it (as defined in the HSE(PEE) Regulations 2013).

Appendix A: Typical timeframes under the Block Offer Regime

1. Within 18 months of the commencement date of the permit, the permit holder shall:
 - a. submit a detailed geologic and geophysical review of the permit area
 - b. acquire, process and interpret a minimum of [specified amount] of 2D seismic data
 - c. re-process all available 2D seismic data within the permit area.
2. Within 36 months of the commencement date of the permit, the permit holder shall:
 - a. submit a detailed geologic and geophysical review the permit area
 - b. acquire, process and interpret a minimum of [specified amount] of 3D seismic data, and
 - c. either:
 - i. make a commitment by notice in writing to the Chief Executive of the Ministry of Business, Innovation and Employment to complete the work programme described in paragraph 3, or
 - ii. surrender the permit.
3. Within 48 months of the commencement of the permit, the permit holder shall drill one exploration well to a depth or target agreed by the Chief Executive of the Ministry of Business, Innovation and Employment, unless geological and/or engineering constraints encountered whilst drilling make this unreasonable:
4. Within 60 months of the commencement date of the permit, the permit holder shall submit a re-valuated permit prospectivity review.

More information about block offers is available on the New Zealand Petroleum and Minerals' website at <http://www.nzpam.govt.nz/cms/petroleum/block-offers>.

Appendix B: Examples of regional council resource consent conditions

- The example consent conditions below provide guidance on ways to avoid, mitigate, or offset environmental effects on the environment from onshore petroleum development activities. These examples are based on resource consents that have been granted in New Zealand.
- These examples should only be used for reference purposes. They have been developed for specific proposals on specific sites, and may not be appropriate for other proposals or sites.
- Specialist legal and planning advice should be sought to ensure conditions are drafted in a way that will be effective, efficient and enforceable in case of dispute.
- General information and good practice examples for drafting resource consent conditions are available on the Quality Planning website at: <http://www.qualityplanning.org.nz/index.php/consents/conditions>.
- Where appropriate, the applicant's name has been omitted and the text is left for consent authorities to insert.

B1. Discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3200 mTVDss. The contaminants are energy, hydraulic fracture fluids (municipal water), proppant, chemicals and possibly tracers

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

1. The discharge point shall be deeper than 3200 mTVDss. Note: mTVDss = metres true vertical depth subsea; ie, the true vertical depth in metres below mean sea level.
2. There shall be no discharge of hydraulic fracturing fluids into the reservoir after [date].
3. The consent holder shall ensure the exercise of this consent does not result in contaminants reaching any usable 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 freshwater resources to assess compliance with condition 2 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive of the Council ('the Chief Executive') before this consent is exercised, and shall include:
 - the location of the discharge point(s)
 - the location of sampling sites
 - sampling frequency with reference to a hydraulic fracturing programme.

5. The Monitoring Programme shall include sampling of groundwater from a bore installed in accordance with NZS 4411:2001. The bore shall be of a depth, location and design determined after consultation with the Council.
6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:
 - a. pH
 - b. conductivity
 - c. total dissolved solids
 - d. major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate)
 - e. trace metals (barium, copper, iron, manganese, nickel, and zinc)
 - f. total petroleum hydrocarbons
 - g. formaldehyde
 - h. dissolved methane and ethane gas
 - i. methanol
 - j. glycols
 - k. benzene, toluene, ethylbenzene, and xylenes (BTEX)
 - l. carbon13 composition of any dissolved methane gas discovered (13C-CH4).

Note: The samples required, under conditions 3 and 4 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.

7. All sampling and analysis shall be undertaken in accordance with a Sampling and Analysis Plan, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice, including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 33.

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 before 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 begin and shall detail the hydraulic fracturing programme proposed, including as a minimum:
 - a. the specific well in which each discharge is to occur and the intended fracture interval(s), and the duration of the hydraulic fracturing programme
 - b. the number of discharges proposed and the geographical position (ie, 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 safety data sheets for all the chemicals to be used
- d. the results of the reviews required by condition 164
- e. results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge
- f. the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 2
- g. the extent and permeability characteristics of the geology above the discharge point to the surface
- h. any identified faults within the modelled fracture length plus a margin of 50 per cent, and the potential for adverse environmental effects due to the presence of the identified faults
- i. the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures
- j. details of the disposal of any returned fluids, including any consents relied on to authorise the disposal.

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

10. The consent holder shall notify the Council of each discharge by emailing [email address]. Notification shall include the date that the discharge is to occur and identify the Pre-fracturing Discharge Report' required by condition 9, which details the discharge. Where practicable and reasonable, notice shall be given between three days and 14 days before the discharge occurs, but in any event, 24 hours' notice shall be given.
11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive Post-fracturing Discharge Report to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:
 - a. confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (ie, depth and lateral position) of the discharge point for each fracture interval
 - b. the contaminant volumes and compositions discharged into each fracture interval
 - c. the volume of return fluids from each fracture interval
 - d. an analysis for the constituents set out in conditions 4(a) to 4(k), in a return fluid sample taken within the first two hours of flow-back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled
 - e. an estimate of the volume of fluids (and proppant) remaining underground
 - f. the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production

- g. an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment
 - h. the results of pressure testing required by condition 6, and the well and discharge pressure durations and the maximum pressure reached during the hydraulic fracture discharge
 - 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; before, during and after each hydraulic fracture treatment
 - j. details of the disposal of any returned fluids, including any consents 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 2
 - l. an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.
12. The reports described in conditions 9 and 11 shall be emailed to [email address] with a reference to the number of this consent.
13. The consent holder shall provide access to a location where the 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 minimise any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:
- the discharge is contained within the fracture interval
 - regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects
 - 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 per cent water and proppant by volume.
16. The Council may review any or all of the conditions of this consent by giving notice of review during the month of [date] each year, for the purposes of:
- ensuring 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
 - further specifying the best practicable option as required by condition 11, and/or
 - ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

B2. Discharge permit for produced water, well drilling fluids, well work-over fluids and contaminated stormwater into a formation by deep well injection via a waste disposal well

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

1. Before this consent is exercised, the consent holder shall submit an “Injection Operation Management Plan” which shall include the operational details of the injection activities and identify the conditions that would trigger concerns about the integrity of the injection well, injection zone or overlying geologic formations. The plan will also detail the action(s) to be taken by the consent holder if trigger conditions are reached.
2. Before this consent is exercised the consent holder shall provide to the Chief Executive of the Council:
 - a. a final well completion log for the injection well including subsurface construction details, design of the exterior surface casing, the intermediate protective casing, and the innermost casing, tubing, and/or packer(s)
 - b. well cementing details, cement bond log, and results of annular pressure testing which demonstrates well integrity
 - c. details of on-going well integrity monitoring, well maintenance procedures, and safe operating limits for the well
 - d. a detailed geologic log of the well
 - e. details and results of the formation integrity testing carried out on the receiving formation and confining layers and an assessment of the results against the estimated modelled values submitted in the consent application
 - f. results of an electrical resistivity survey, clearly showing the confirmed depth of fresh water as defined in condition 11
 - g. a full chemical analysis of the receiving formation water.

(**Note:** These details can be included within the “Injection Operation Management Plan”.)
3. The injection pressure at the well head shall not exceed 1077 psi (73 bars). If exceeded, the injection operation shall be ceased immediately and the Chief Executive of the Council informed.
4. The rate of injection shall not exceed 8.6 cubic metres per hour (0.9 bpm).
5. The volume of fluid injected shall not exceed 206 cubic metres per day (1296 bpd).
6. The injection of fluids shall be confined to the Mt. Messenger Formation, deeper than –995 metres total vertical depth sub-sea.
7. 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; in particular, ensuring that the injection material is contained within the injection zone.
8. Only the fluids listed below and originating from the consent holder’s operations may be discharged:

- a. produced water
 - b. well-drilling fluids
 - c. well workover fluids, including hydraulic fracturing return fluids
 - d. contaminated stormwater.
9. Once the consent is exercised, the consent holder shall keep daily records of the:
- a. total injection hours
 - b. volume of fluid injected
 - c. maximum and average rate of injection
 - d. maximum and average injection pressure
10. For each waste stream arriving on site for discharge, the consent holder shall record the following information:
- a. type of fluid
 - b. source of fluid (site name and location)
 - c. an analysis of the fluid for:
 - i. pH
 - ii. suspended solids concentration
 - iii. temperature
 - iv. salinity
 - v. chloride concentration
 - vi. total hydrocarbon concentration.
- The analysis required by condition 10(c) above is not necessary if a sample of the same type of fluid, from the same source, has been taken, analysed and provided to the Chief Executive within the previous six months.
11. The information required by conditions 9 and 10 above, for each calendar month, shall be provided to the Chief Executive of the Council before the 15th day of the following month.
12. The consent holder shall ensure 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.
13. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on freshwater resources to assess compliance with condition 11 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive of the Council before this consent is exercised, and shall include:
- a. the location of sampling sites
 - b. well/bore construction details
 - c. sampling frequency.

14. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:
 - a. pH
 - b. conductivity
 - c. chloride
 - d. total dissolved solids.

Note: The samples required, under conditions 13 and 14, could be taken and analysed by the Council or other contracted party on behalf of the consent holder.

15. All sampling and analysis shall be undertaken in accordance with a Sampling and Analysis Plan, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 11.

Note: The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 12.

16. The consent holder shall provide to the Council, during the month of [date] of every year, a summary of all data collected and a report detailing compliance with consent conditions over the previous [year] period. The report shall also provide and assess data which illustrates the on-going integrity and isolation of the well bore, well performance and condition. The consent holder shall also provide an updated injection modelling report, illustrating the ability of the receiving formation to continue to accept additional waste fluids and estimating its remaining storage capacity.
17. The consent holder shall notify the Chief Executive of the Council, in writing at least five days before the first exercise of this consent. Notification shall include the consent number and a brief description of the activity consented and be emailed to [email address].
18. There shall be no fluids discharged under this consent after [date].
19. In accordance with section 128 and section 129 of the Resource Management Act 1991, the 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 [date] each year, for the purpose of ensuring 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.

B3. Discharge permit for drilling waste (consisting of drilling cuttings and drilling fluids from water-based muds and synthetic-based muds) via land farming

Standard condition: The consent holder shall pay to the Council all the administration, monitoring and supervision costs of this consent, fixed in accordance to section 36 of the Resource Management Act.

1. For the purposes of this consent the following definitions shall apply:
 - a. Stockpiling means a discharge of drilling wastes from vehicles, tanks, or other containers onto land for the purpose of interim storage before land farming, but without subsequently spreading onto, or incorporating the discharged material into the soil within 48 hours.
 - b. Land farming means the discharge of drilling wastes onto land, subsequent spreading and incorporation into the soil, for the purpose of attenuation of hydrocarbon and/or other contaminants, and includes any stripping and relaying of topsoil.
2. The consent holder shall adopt the best practicable option (as defined in section 2 of the Resource Management Act 1991) to prevent or minimise any actual or potential effects on the environment arising from the discharge.
3. Before the exercise of this consent, the consent holder shall provide a stockpiling and land-farming management plan that, to the reasonable satisfaction of the Chief Executive of the Council, demonstrates the activity can and will be conducted to comply with all of the conditions of this consent. The management plan shall be reviewed annually (on or about the anniversary of the date of issue of this consent) and shall include as a minimum:
 - a. procedures for notification to Council of disposal activities
 - b. procedures for the receipt and stockpiling of drilling wastes onto the site
 - c. methods used for the mixing and testing of different waste types
 - d. procedures for site preparation
 - e. procedures for land farming drilling wastes (including means of transfer from stockpiling area, means of spreading, and incorporation into the soil)
 - f. procedures for sowing land-farmed areas, post-land-farming management, monitoring and site reinstatement
 - g. contingency procedures
 - h. sampling regime and methodology
 - i. control of site access
 - j. documentation for all the procedures and methods listed above.
4. Before the exercise of this consent, the consent holder shall, after consultation with the Chief Executive of the Council, install a minimum of three groundwater monitoring bores. The bores shall be at locations, and to depths, that enable monitoring to determine any change in groundwater quality resulting from the exercise of this consent. The bores shall be installed in accordance with NZS 4411:2001 and all associated costs shall be met by the consent holder.
5. The consent holder shall notify the Chief Executive of the Council [by emailing] at least 48 hours before permitting drilling wastes onto the site for stockpiling, from each well drilled. Notification shall include the following information:
 - a. the consent number
 - b. the name of the well(s) from which the waste was generated
 - c. the type of waste to be stockpiled
 - d. the volume of waste to be stockpiled.

6. The consent holder shall notify the Chief Executive of the Council [by emailing] at least 48 hours before land farming stockpiled material, or material brought onto the site for land farming within 48 hours. Notification shall include the following information:
 - a. the consent number
 - b. the name of the well(s) from which the waste was generated
 - c. the type of waste to be land farmed
 - d. the volume and weight (or density) of the waste to be land farmed
 - e. the concentration of chlorides, nitrogen and hydrocarbons in the waste
 - f. the specific location and area over which the waste will be land farmed.

7. The consent holder shall take a representative sample of each type of waste, from each individual source, and have it analysed for the following:
 - a. total petroleum hydrocarbons (C6-C9, C10-C14, C15-C36)
 - b. benzene, toluene, ethylbenzene, and xylenes
 - c. polycyclic aromatic hydrocarbons screening
 - d. chloride, nitrogen, pH, potassium, and sodium.

8. The consent holder shall keep records of the following:
 - a. wastes from each individual well
 - b. composition of wastes (in accordance with condition 7)
 - c. stockpiling area(s)
 - d. volumes of material stockpiled
 - e. land farming area(s), including a map showing individual disposal areas with GPS co-ordinates
 - f. volumes and weights of wastes land farmed
 - g. dates of commencement and completion of stockpiling and land farming events
 - h. dates of sowing land farmed areas
 - i. treatments applied
 - j. details of monitoring, including sampling locations, sampling methods and the results of analysis

and shall make the records available to the Chief Executive of the Council.

9. The consent holder shall provide to the Chief Executive of the Council, by [date] of each year, a report on all records required to be kept in accordance with condition 6, for the period of the previous 12 months.

10. The discharge area shall be as shown in drawing no. [X] submitted with application [X].

11. There shall be no discharge within any buffer zone, being:
 - 25 metres of the [X] River
 - 25 metres of the unnamed tributary
 - 10 metres from any property boundary
 - 50 metres from the QE II covenant key native ecosystem areas.

12. For the purposes of land farming, drilling wastes shall be applied to land in a layer not exceeding:
 - a. 100 mm thick for wastes with a hydrocarbon concentration less than 50,000 mg/kg dry weight, or
 - b. 50 mm thick for wastes with a hydrocarbon concentration equal to or greater than 50,000 mg/kg dry weight, and
 - c. in a rate and manner such that no ponded liquids remain after 1 hour, for all wastes; before incorporation into the soil.
13. As soon as practicable following the application of solid drilling wastes to land, the consent holder shall incorporate the wastes into the soil to a depth of at least 250 mm.
14. The hydrocarbon concentration in the soil over the land farming area shall not exceed 50,000 mg/kg dry weight at any point where:
 - a. liquid waste has been discharged, or
 - b. solid waste has been discharged and incorporated into the soil.
15. An area of land used for the land farming of drilling wastes in accordance with conditions 10 and 11 of this consent, shall not be used for any subsequent discharges of drilling waste.
16. All material must be land farmed as soon as practicable, but no later than 12 months after being brought onto the site.
17. As soon as practicable following land farming, areas shall be sown into pasture (or into crop). The consent holder shall monitor re-vegetation and if adequate establishment is not achieved within two months of sowing, shall undertake appropriate land stabilisation measures to minimise wind and stormwater erosion.
18. The exercise of this consent shall not result in the concentration of total dissolved salts in any freshwater body exceeding 2500 g/m³.
19. Other than as provided for in condition 18, the exercise of this consent shall not result in any contaminant concentration, within surface water or groundwater, which after reasonable mixing, exceeds the background concentration for that particular contaminant.
20. The conductivity of the soil/waste layer after land farming shall be less than 400 millisiemens per metre (mS/m), or alternatively, if the background soil conductivity exceeds 400 mS/m, the land farming of waste shall not increase the soil conductivity by more than 100 mS/m.
21. The sodium absorption ratio (SAR) of the soil/waste layer after land farming shall be less than 18.0, or alternatively if the background soil SAR exceeds 18.0, the land farming of waste shall not increase the SAR by more than 1.0.
22. The concentration of heavy metals in the soil over the disposal area shall at all times comply with the Ministry for the Environment and New Zealand Water & Wastes Association's guidelines for the safe application of biosolids to land in New Zealand (2003), as shown in the following table:

Constituent	Standard (mg/kg dry weight)
Arsenic	20
Cadmium	1
Chromium	600
Copper	100
Lead	300
Mercury	1
Nickel	60
Zinc	300

23. From [date] (three months before the consent expiry date), constituents in the soil shall not exceed the standards shown in the following table:

Constituent	Standard
Conductivity	290 mS/m
Chloride	700 mg/kg
Sodium	460 mg/kg
Total soluble salts	2500 mg/kg
MAHs PAHs TPH	<i>Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand</i> (Ministry for the Environment, 1999). Tables 4.12 and 4.15, for soil type sand

Notes:

MAHs = benzene, toluene, ethylbenzene, xylenes

PAHs = naphthalene, non-carc. [pyrene], benzo(a)pyrene eq

TPH = total petroleum hydrocarbons (C7–C9, C10–C14, C15–C36).

The requirement to meet these standards shall not apply if, before [date], the consent holder applies for a new consent to replace this consent when it expires, and that application is not subsequently withdrawn.

24. This consent may not be surrendered at any time until the standards in condition 22 have been met.
25. If any archaeological site, taonga or koiwi (bone) is discovered during the works authorised by this consent, the consent holder shall immediately cease work at the affected site. The consent holder shall notify [iwi], the Historic Places Trust, the [Council], and in the case of koiwi, the Police, and shall not recommence works in the area of the discovery until the relevant Historic Places Trust and [iwi] approvals to damage, destroy or modify such sites have been obtained, and [Council] has given authorisation to recommence the activities.

Note: The Historic Places Act 1993 (HPA) provides for the identification, protection, preservation and conservation of the historic and cultural heritage of New Zealand. Under Section 2 of the HPA, an archaeological site is defined as a place associated with pre-1900 human activity where there may be evidence relating to the history of New Zealand. Section 10 directs that an authority is required from the New Zealand Historic Places Trust if there is 'reasonable cause' to suspect an archaeological site (recorded or unrecorded) may be modified, damaged or destroyed in the course of any activity. An authority is required

for such work whether or not the land on which an archaeological site may be designated, or a resource or building consent has been granted, or the activity is permitted in a regional or district plan. Evidence of archaeological sites may include oven stones, charcoal, shells, ditches, banks, pits, terraces, stone walls, building foundations, artefacts of Māori and European origin, or burials.

26. This consent shall lapse on [date], unless the consent is given effect to before the end of that period or the Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.
27. In accordance with section 128 and section 129 of the Resource Management Act 1991, the 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 [date] and/or [date], 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.

B4. Discharge of well site emissions to air

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

1. For the purposes of this consent:
 - a. ‘flaring’ means the uncontrolled or partially controlled open air burning of hydrocarbons derived from or entrained in the well stream; ‘flare’, as a verb, has the corresponding meaning and, as a noun, means the flame produced by flaring
 - b. ‘incineration’ means the controlled, enclosed burning of formation hydrocarbons within a device designed for the purpose; ‘incinerate’ has the corresponding meaning
 - c. ‘combustion’ means burning generally and includes both flaring and incineration as well as other burning, such as fuel in machinery.
2. Incineration shall only occur in a device with a minimum chimney height determined by the method detailed in Appendix VIII of the *Regional Air Quality Plan*.
3. Flaring shall only occur over a pit, or similar containment area, consisting of impermeable material that prevents any liquid from leaking through its base or sidewalls and discharging to land.
4. Flaring and incineration shall only occur within 20 metres of the location defined by NZTM 1694593-5640370.
5. Discharges to air from flaring or incineration shall not last longer than 15 days, cumulatively, inclusive of testing, clean-up, and completion stages of well development or workover, per zone to be appraised, with a maximum of four zones per well and 12 wells.
6. The consent holder shall notify the Chief Executive of the Council at least 24 hours before the flaring or incineration from each zone begins. Notification shall include the consent number and a brief description of the activity consented, which shall be emailed to [email address].

7. At least 24 hours before any flaring or incineration, other than in emergencies, the consent holder shall provide notification to the occupants of all dwellings within 300 metres of the well site and all land owners within 200 metres, of the beginning of flaring or incineration. The consent holder shall include in the notification a 24-hour contact telephone number for a representative of the consent holder, and shall keep and make available to the Chief Executive of the Council a record of all queries and complaints received about any combustion activity.
8. No material shall be flared or incinerated other than those derived from or entrained in the well stream.
9. To the greatest extent possible, all gas that is flared or incinerated must first be treated by effective liquid and solid separation and recovery.
10. Only gaseous hydrocarbons originating from the well stream shall be flared or incinerated, except that if, for reasons beyond the control of the consent holder, effective separation cannot be achieved and combustion of liquid hydrocarbon is unavoidable, the consent holder shall reinstate effective separation as soon as possible, and if separation cannot be achieved within 3 hours, combustion must cease.
11. If liquid hydrocarbon is combusted in accordance with the exception provided for in condition 10, the consent holder shall prepare a report that details:
 - a. the reasons that separation could not be achieved
 - b. the date and time that separation was lost and reinstated
 - c. what was done to attempt to reinstate separation and, if it the attempt was unsuccessful, the reasons why.

The report shall be provided to the Chief Executive of the Council within five working days from the date of combustion of liquid hydrocarbon.

12. The consent holder shall adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimise any actual or potential effect on the environment arising from any emission to air, including, but not limited to, having regard to the prevailing and predicted wind speed and direction at the time of initiation, and throughout, any episode of combustion so as to minimise off-site effects (other than for the maintenance of a pilot flame).
13. The discharge shall not cause any objectionable or offensive odour or any objectionable or offensive smoke at or beyond the boundary of the property where the well site is located.
14. The consent holder shall control all emissions of carbon monoxide, nitrogen dioxide, fine particles (PM₁₀) and sulphur dioxide to the atmosphere from the site, so the maximum ground level concentration of any of these contaminants arising from the exercise of this consent measured under ambient conditions does not exceed the relevant ambient air quality standard as set out in the Resource Management (National Environmental Standards for Air Quality Regulations, 2004) at or beyond the boundary of the property on which the well site is located.
15. The consent holder shall control all emissions of contaminants to the atmosphere from the site, other than those expressly provided for under special condition 14, so they do not individually or in combination with other contaminants cause a hazardous, noxious,

dangerous, offensive or objectionable effect at a distance greater than 100 metres from the emission source.

16. The consent holder shall make available to the Chief Executive of the Council, upon request, an analysis of a typical gas and condensate stream from the field, covering sulphur compound content and the content of carbon compounds of structure C6 or higher.
17. All permanent tanks used as hydrocarbon storage vessels shall be fitted with vapour recovery systems.
18. The consent holder shall record and make available to the Chief Executive of the Council a 'combustion log' that includes:
 - a. the date, time and duration of all flaring or incineration episodes
 - b. the zone from which flaring or incineration occurred
 - c. the volume of substances flared or incinerated
 - d. whether there was smoke at any time during the combustion episode, and if there was, the time, duration and cause of each 'smoke event'.
19. This consent shall lapse on [date], unless the consent is given effect to before the end of that period or the Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.
20. In accordance with section 128 and section 129 of the Resource Management Act 1991, the 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:
 - a. during the month of [date] and/or [date], and/or
 - b. within one month of receiving a report provided in accordance with condition 11

for any of the following purposes:

- i. dealing with any significant adverse effect on the environment arising from the exercise of the consent which was not foreseen at the time the application was considered or which it was not appropriate to deal with at the time
- ii. requiring the consent holder to adopt specific practices to achieve the best practicable option to remove or reduce any adverse effect on the environment caused by the discharge
- iii. to alter, add or delete limits on mass discharge quantities or ambient concentrations of any contaminant
- iv. reducing emissions or environmental effects that may arise from any loss of separation.

B5. Discharge permit for earthworks and stormwater from a well site

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

1. This consent authorises the discharge of stormwater from no more than 4000 m² of land where earthworks are being undertaken for the purpose of creating a working area for the re-establishment of the [X] well site, as shown in the details of the application for this consent.

2. 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.
3. At least seven working days before beginning earthworks for the purpose of well site construction and establishment, the consent holder shall notify the Council of the proposed start date for the earthworks. Notification shall include the consent number and a brief description of the activity consented and shall be emailed to the Council.
4. The consent holder shall notify the Chief Executive of the Council, in writing following the completion of the well-site construction and establishment and before beginning any drilling operation at the [X] well site. Notification shall be given at least seven working days before beginning the well-site drilling operation and shall include the consent number and a brief description of the activity consented and be emailed to the Council.
5. If any area of soil is exposed, all run off from that area shall pass through settlement ponds or sediment traps with a minimum total capacity of:
 - a. 100 cubic metres for every hectare of exposed soil between [date] to [date]
 - b. 200 cubic metres for every hectare of exposed soil between [date] to [date]

unless other sediment control measures that achieve an equivalent standard are agreed to by the Chief Executive of the Council.

6. The obligation described in condition 5 above shall cease to apply, and accordingly the erosion and sediment control measures can be removed, in respect of any particular site or area of any site, only when the site is stabilised.

Note: For the purpose of conditions 5 and 6, 'stabilised' in relation to any site or area means inherently resistant to erosion or rendered resistant, such as by using rock or by the application of base course, colluvium, grassing, mulch, or another method to the reasonable satisfaction of the Chief Executive of the Council and as specified in the Council's guidelines. Where seeding or grassing is used on a surface that is not otherwise resistant to erosion, the surface is considered stabilised once, on reasonable visual inspection by an officer of the Council, an 80 per cent vegetative cover has been established.

7. All earth worked areas shall be stabilised vegetatively or otherwise as soon as is practicable and no longer than six months after the completion of soil disturbance activities.

Note: For the purposes of this condition, 'stabilised' has the same definition as that set out in condition 6.

B6. Discharge permit for on-going operational stormwater

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

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. The stormwater discharged shall be from a catchment area of no more than 7700 m².
3. At least seven working days before, the consent holder shall advise the Chief Executive of the Council, of the commencement date of any:
 - a. site works
 - b. well drilling operation.

If either of these events is rescheduled or delayed, 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 the Council.

4. All stormwater and produced water (with a maximum chloride concentration of 50 ppm) shall be directed for treatment through the two skimmer pits, for discharge into an open man-made drain adjacent to the site. The skimmer pits shall have a minimum capacity of 180 m³.
5. All skimmer pits and other stormwater retention areas shall be lined with an impervious material to prevent seepage through the bed and sidewalls.
6. There shall be no discharge of produced water with a chloride concentration greater than 50 ppm.
7. Constituents of 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
Chloride	Concentration not greater than 50 gm ⁻³

This condition shall apply before entry of the treated stormwater into the receiving waters at a designated sampling point approved by the Chief Executive of the Council.

8. After allowing for a mixing zone of 10 metres, 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 10 metres downstream of the discharge point, the discharge shall not, either by itself or in combination with other discharges, give rise to any or all 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.

10. The consent holder shall maintain a contingency plan that, to the satisfaction of the Chief Executive of the 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 before discharging from the site.
11. Subject to the other conditions of this consent the design, management and maintenance of the stormwater system shall be undertaken in accordance with the stormwater management plan submitted in support of the consent application [x], in particular Appendix [x] of the assessment of environmental effects.
12. The consent holder shall advise the Chief Executive of the Council in writing at least 48 hours before reinstating 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 the Council.
13. This consent shall lapse on [date], unless the consent is given effect to before the end of that period or the [Council] fixes a longer period pursuant to section 125(1) (b) of the Resource Management Act 1991.
14. In accordance with section 128 and section 129 of the Resource Management Act 1991, the [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 [date] and/or [date], for the purpose of ensuring 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.

B7 Land-use consent (drill a bore), discharge permit (into and onto land x2), and discharge permit (to air)

1. The consent holder must undertake the activity in general accordance with the consent application including all accompanying plans and documents first lodged with the Regional Council on [date], and further information received on:
 - a. [date] via email being some details and discussion on well integrity, geology, regional hydrogeology and seismic effects
 - b. [date] via email being further details on well integrity, regional and local hydrogeology and seismic effects
 - c. [date] via email being completion of the original s92 request by providing the final details on well integrity and seismic effects.

Where there may be inconsistencies between information provided by the applicant and conditions of the resource consent, the conditions of the resource consent apply.

Note: Any change from the location, design concepts and parameters, implementation and/or operation may require a new resource consent or a change of consent conditions pursuant to section 127 of the Resource Management Act 1991.

2. The activities authorised by these consents shall be restricted to:
 - a. drill and test a 1895 metre exploratory oil and gas well

- b. discharge contaminants associated with the drilling of the exploratory oil and gas well into and onto land
- c. discharge stormwater into and onto land, including circumstances where it may enter water
- d. discharge contaminants from the combustion of petroleum gas associated with well testing (including flaring) to air.

Such works shall be undertaken at approximate map reference [NZ topographical map reference] on the property legally described as [legal description] (hereafter referred to as the site) and in general accordance with the application submitted except where otherwise required by conditions of this consent.

3. The consent holder shall ensure all activities occurring on the site are undertaken in accordance with the following management plans:
 - a. Stormwater Management Plan dated [X] by [company]
 - b. Spill Control Management Plan dated [X] by the consent holder
 - c. Waste Management Plan dated [X] by the consent holder
 - d. Hazardous Substances Management Plan dated [X] by the consent holder.
4. If any changes are made to any of the management plans outlined in Condition 3, the consent holder shall provide a copy of the updated plan to the Council's Environmental Protection Manager acting in a technical capacity **15 working days** before the implementation of the amendments occurring for certification.
5. The consent holder shall appoint a suitably qualified and experienced person as the Environmental Monitoring Officer, and shall provide the Council's Environmental Protection Manager with the name and contact details of that person before beginning any activities authorised by these consents. The Environmental Monitoring Officer shall be responsible for implementing all environmental monitoring and reporting activities required by the conditions of these consents.
6. The consent holder shall ensure that the Environmental Monitoring Officer is present on site at all times that drilling, casing, completion or testing activities are occurring.
7. The consent holder shall provide a local telephone number to neighbouring residents within a 2 kilometre radius of the well site so they have a specified and known point of contact to raise any concerns or matters that may arise during construction and operation of the exploration well site.
8. The consent holder shall maintain and keep a complaints register for any complaints received by the consent holder about environmental effects of the activities. The register shall record, where this information is available, the following:
 - a. the name and address of the complainant
 - b. the date, time and duration of the incident that has resulted in a complaint
 - c. the location of the complainant when the incident was detected
 - d. the nature of the complaint
 - e. the possible cause of the incident

- f. any corrective action taken by the consent holder in response to the complaint, including timing of that corrective action.
9. The complaints register required by Condition 8, shall be made available to the Council at all reasonable times and upon request. Complaints received by the consent holder that may imply non-compliance with the conditions of this consent must be forwarded to the Council's Environmental Protection Manager **within 48 hours** of the complaint being received.
10. The consent holder shall contact the Council's Environmental Protection Team at least **seven working days** before beginning the activities authorised by these consents and immediately on completion of the activities.
11. The consent holder shall notify the Council's Environmental Protection Manager within **48 hours** of when it is apparent that a breach in any conditions of this consent has occurred, or may be about to occur.
12. The consent holder shall also provide details on the cause of the breach notified under Condition 11, the anticipated or potential or actual environmental effects of the breach, and what actions are to be undertaken to ensure a breach of a similar or same nature does not reoccur. These details shall be provided **within 48 hours** of the breach occurring.
13. In the event that the Emergency Response Plan is activated as a result of a seismic event, the consent holder shall submit a report **within 20 working days** to the Council outlining the result of the assessment on the effects of the seismic event on the well and the well site and response to the seismic event, including any repairs to damage incurred.

Well-drilling conditions

14. **Within 10 working days** of the granting of these consents, the consent holder shall prepare and submit an updated well drilling programme document. The updated document must be consistent with the [Project Title] Proposal to Drill Well document. The consent holder shall undertake all well drilling in accordance with this document which will attach to and form part of this consent.

Note: As a result of elements of the well drilling document submitted as part of the application containing commercially sensitive information, the provision of an updated well drilling programme to attach to the consent (which is public information) is required. This will ensure the well drilling is done in specific accordance with the information provided as part of the application.

15. The consent holder must supply the well lithology for the upper 300 metres of the well to the Council within **one month** of the bore drilling being completed.
16. Before undertaking well completion and testing, the consent holder shall prepare and submit to Council, a detailed completion and testing programme. This document must contain, but not be limited to detailed step-by-step procedures for completion and testing the well which shall include as a minimum the following supporting data:
 - a. risk assessment / hazard and operability analysis (HAZOP) for the completion and testing programme
 - b. piping and instrumentation diagram (P & ID) drawings for the well test equipment
 - c. management and permit system to be used during completion and testing operations

- d. well test equipment limitations (flow rate, hydrogen sulphide (H₂S), CO₂ etc)
 - e. emergency shutdown (ESD) controls and emergency response procedures.
17. The consent holder shall ensure the completion and testing programme required under Condition 16 is independently certified by a suitably experienced and qualified expert. The certification statement will confirm that there will be no uncontrolled or unplanned discharge of hydrocarbons and that actual or potential adverse environmental effects of the well completion and testing are avoided, remedied or mitigated. Completion and testing of the well shall not begin until the completion and testing programme document required by condition 16 has been independently certified.

Note: It is understood that the consent holder will use [Company] for certification, unless they are unwilling or unable to process the certification in a timely manner.

18. If further drilling and development of the well site is proposed at a later date, the well shall be temporarily capped, and all stormwater managed to a standard which will prevent any adverse effects on the environment. To this effect, the site shall be managed in accordance with the stormwater management plan (and any subsequent certified amendments to this plan detailed in Condition 3).

Note: If further drilling and development on the site is planned, additional resource consents will be required.

19. If the consent holder decides that the well and well site are not required for further drilling, or the reinstated well has remained disused for a continuous period of five years, the well and well site shall be decommissioned in accordance with Conditions 20–24 below.
20. Before any decommissioning of the well under Condition 19, the consent holder shall provide the Council's Environmental Protection Manager with a decommissioning programme. This programme must include but not be limited to:
- a. depths of casing shoes and liner hangers
 - b. depth ranges of cement plugs planned, including the surface plug
 - c. statement that any abandonment / decommissioning will be in accordance with the relevant New Zealand requirements.

21. The consent holder shall ensure that the decommissioning programme required under Condition 20 is independently certified by a suitably experienced and qualified expert. The certification statement will confirm that there will be no seepage of oil and gas from the decommissioned well and that any actual or potential adverse environmental effects of decommissioning the well are avoided, remedied or mitigated.

Note: It is understood that the consent holder will use [Company], unless they are unwilling or unable to process the certification in a timely manner.

22. The decommissioning and abandonment of the site shall be undertaken in accordance with the decommissioning programme submitted under Condition 20, the Mineral Program for Petroleum 2005 and the Alberta Energy Resources Conservation Board Guide G-20 guidelines for abandoning wells.

23. The consent holder shall provide written notice to the Council's Environmental Protection Manager that all decommissioning has been completed and shall organise a site visit(s) for

the relevant environmental protection staff to enable them to view the site. The written notice shall be provided **within 30 working days** of the decommissioning works being completed.

24. **Within five working days** of completing all decommissioning and site abandonment works, the consent holder shall provide a statement signed by a suitably qualified and experienced professional certifying the decommissioning works have been done in accordance with the certified decommissioning programme required under Condition 20.

Note: The signed statement is not certified by the Council. Responsibility for the accuracy of the information provided in this statement lies with the consent holder.

25. **Within 10 working days** of completion of the well drilling and construction, the consent holder shall provide the Council with details of the final well design. This shall include written confirmation that the well head components meet the relevant American Petroleum Institute (API) standards.

Groundwater monitoring

26. The consent holder shall install two groundwater monitoring wells for the purpose of groundwater monitoring of the well site. The monitoring wells must be within 40 metres of the drill site and located hydraulically down gradient of the main well as determined by a suitably qualified hydrogeologist. The wells are to be as follows:
- a. a shallow well of approximate depth of 12 metres, with a surface sanitary seal, and
 - b. a deeper well of approximate depth of 70 metres, with a surface sanitary seal. The construction of this groundwater monitoring well shall be done in accordance with the conditions of Land-use Consent [consent number].

Note: No additional consents are required for these groundwater monitoring bores. The deeper bore will be consented under Land-use Consent [consent number]. The shallow monitoring bore is considered a permitted activity as the definition of bore in the [Regional Plan] excludes piezometers for monitoring purposes, of which the shallow well has been deemed in this case.

- 26B. Should the groundwater monitoring bore structurally fail and as a result, does not allow water samples to be taken in the 12-month period ending [date], the consent holder must re-drill a 6 inch groundwater monitoring bore **within five working days** of detection of the failure of the original bore, unless additional time is approved by the Council's Environmental Protection Manager. The new groundwater monitoring bore must be cased and gravel packed to the same depth as the first groundwater monitoring bore.

Note: If a failure of the groundwater monitoring bore occurs before moving the drilling rig for the exploratory oil and gas well off the site, the consent holder may postpone the drilling of the new groundwater monitoring bore until the drilling equipment is moved off site and therefore space is available to bring in the water bore drilling rig.

27. The consent holder shall ensure all groundwater monitoring wells are located using a GPS device with an accuracy of +/- 3 metres. These wells shall be marked on the site plan of an appropriate scale and detail.

28. The consent holder shall in accordance with *A National Protocol for State of the Environment Groundwater Sampling in New Zealand 2006*, take groundwater samples from two groundwater monitoring bores (if groundwater is present):
- a. once before drilling operations begin
 - b. once a week during drilling and testing operations
 - c. one week, one month, six months and one year after drilling and well completions are completed.

This sampling shall be undertaken by the Environmental Monitoring Officer as appointed under Condition 5 or a suitably experienced and qualified person who is approved in writing by Council. If the monitoring bores do not contain groundwater at the time of sampling, the requirements of this condition shall not apply.

Note: Groundwater is to be sampled for parameters detailed in Condition 37.

29. The consent holder shall install monitoring equipment for the purpose of fluid detection in the groundwater monitoring wells in consultation with Council staff acting in a certification capacity. Samples of any fluid present in the well shall be taken at the same time that groundwater samples would have been taken under Condition 28 if groundwater was present.
30. The consent holder shall ensure that before sampling:
- a. where practicable, each well is purged at least three times its well volume
 - b. that temperature, electrical conductivity and pH measurements have stabilised.
31. The consent holder shall ensure that records are maintained of the standing water level, temperature, electrical conductivity and pH measurements collected. These records shall be provided to the Council within **five working days** of receiving a request from the Regional Council.

Surface water monitoring

32. The unnamed tributary of the stream to the west of the site will be visually inspected by the Environmental Monitoring Officer appointed under Condition 5 for contamination on a weekly basis and whenever the stormwater pond is discharging to the overland flow path, for the duration of activities on the site. The inspection will look for visible signs of contamination including oil sheens and films. This inspection will extend 30 metres downstream of the discharge area from the stormwater pond overland flow path. A sample from sampling points A, B and C, as shown on Plan [X] shall be taken if visual indications of contamination are observed during inspections.
33. The consent holder shall, **five working days** before any activities occurring on the site, take baseline surface water samples from points shown on Plan [X]. The samples shall be analysed for the same parameters required under the ground and surface water sampling Condition 37.
34. The consent holder shall undertake surface water sampling at the following locations shown on Plan [X]:
- a. Point A: upstream of the drilling site on the unnamed tributary of the stream to the west of the well site

- b. Point B: upstream of the confluence of the unnamed tributary of the stream with the unnamed tributary of the stream to the southeast of the site
- c. Point C: downstream of the confluence with the unnamed tributary of the unnamed tributary of the stream to the south of the site.

Note: Plan [X] is intended to show and provide clarity on the sampling points detailed above.

35. Once any activities authorised by this consent begins, the consent holder shall undertake sampling from the outlet pipe on the stormwater pond:
- a. immediately, but no more than 6 hours after the first discharge for the week from the stormwater pond occurring through the outlet pipe
 - b. 24 hours after the first discharge beginning for the week if the discharge has been continuous for this period
 - c. weekly in the event of the discharge occurring for a continuous period.

If more than one continuous discharge event occurs per week, the consent holder shall only be required to sample as per above for the first discharge event.

Note: A discharge is considered to be continuous if discharge from the outlet pipe of the stormwater pond has occurred within the last 48 hours.

Note: This monitoring is to capture events when the unnamed tributary of the unnamed tributary of the stream is likely to be flowing and a discharge has occurred.

- 35B. The results of the analysis of samples taken under condition 35 shall be compared to the trigger values for the determinands identified in table 1:
- a. if one or more trigger values are exceeded, the consent holder shall notify the Council's Environmental Protection Manager **within 48 hours** of the results being received
 - b. if the total suspended solids (TSS) trigger value is exceeded the consent holder shall undertake an audit of erosion and sediment control on the site, including but not limited to:
 - i. sediment management (identification of areas of potential sediment generation and review of sediment suppression activities)
 - ii. runoff control (check of diversion channels and check silt retention ponds)
 - iii. condition of sediment control measures including bunds, silt fences and sediment retention ponds
 - iv. maintenance or improvements required
 - c. the outcome of the audit undertaken under Condition 35A(ii) shall be reported in writing to the Council's Environmental Protection Manager **within 48 hours** of its completion
 - d. if any trigger value in table 1 (other than the TSS trigger value) is exceeded, the consent holder shall undertake two further sets of samples as soon as practicable when the discharge from the outlet pipe on the stormwater pond is operating, at the surface water locations identified in Condition 34, and from the outlet pipe on the stormwater pond. The two sets of samples shall be taken on separate days. Samples shall be tested for all determinands that exceeded a trigger value

- e. the sampling required by Condition 35a(iv) shall be repeated until the two sets of samples show no further exceedance of the trigger value(s)
- f. the results of all sampling undertaken under Conditions 35a(iv) and 35a(v) shall be reported in writing to the Council’s Environmental Protection Manager **within 48 hours** of the results being received.

Table 1: Trigger values for determinands in the discharge from the stormwater pond

Determinand	Trigger value
Total suspended solids	100 mg/L
Dissolved arsenic	0.240 mg/L
Dissolved cadmium	0.0054 mg/L
Dissolved zinc	0.200 mg/L
Total petroleum hydrocarbon	Detection limit
Benzene, toluene, ethylbenzene, xylenes and naphthalene	Detection limit

Note: Access to the surface water sampling locations identified in Condition 34 is difficult and involves walking up and down the bed of a section of the unnamed tributary of the stream, which is in a steep gorge. For the purpose of this condition, ‘as soon as practicable’ specifically excludes the following times, to ensure the safety of personnel:

- a. night time
 - b. during and immediately following heavy rainfall
 - c. during times of high flows in the unnamed tributary of the stream, when access to the sampling locations is judged unsafe by the operator.
36. The consent holder shall take surface water samples at the locations identified in Condition 34 and undertake visual inspections as per Condition 32 as far as practicable, one week, one month, six months and one year after drilling and well completions have been completed. This sampling shall be undertaken by the Environmental Monitoring Officer, or a suitably experienced and qualified person who is approved in writing by the Council.

Note: Access to the surface water sampling locations identified in Condition 34 is difficult and involves walking up and down the bed of a section of the unnamed tributary of the stream, which is in a steep gorge. For the purpose of this condition, “as far as practicable” specifically excludes the following times, to ensure the safety of personnel:

- a. night time
 - b. during and immediately following heavy rainfall
 - c. during times of high flows in the unnamed tributary of the Stream, when access to the sampling locations is judged unsafe by the operator.
37. The groundwater and surface water samples taken under Conditions 28, 32, 33, 35, 35B and 36, shall be analysed for the following contaminants:
- a. field variables (conductivity and pH also to be measured in the lab) including conductivity, pH and temperature
 - b. general variables including:
 - i. major ions including Ca, Mg, K, Na, HCO₃, Cl, NO₃ and SO₄

- ii. total dissolved solids and total suspended solids
 - iii. turbidity (NTU)
 - iv. selected trace elements including dissolved arsenic, dissolved barium, dissolved boron, dissolved cadmium, dissolved iron, dissolved manganese, dissolved strontium and dissolved zinc
 - v. visual and odour observations.
- c. petroleum related contaminants including:
- i. methane and ethane (for groundwater sampling only)
 - ii. total petroleum hydrocarbons by gas chromatograph including GRO C6–C10 and DRO C10–C28 ranges
 - iii. volatile organic compounds (VOCs) by US Environmental Protection Agency method 8260b or equivalent certified by the Council, to specifically include benzene, toluene, ethylbenzene, and xylenes (BTEX) and naphthalene
 - iv. total organic carbon (TOC).
38. If methane is detected in any groundwater samples, and the level is above the level detected in the baseline monitoring required by Condition 33, the well shall be re-sampled and the sample analysed for methane, ethane and the x13C value of dissolved methane within **two working days** of receipt of the lab results from the first sampling.
39. If the re-sample under Condition 38 shows methane, ethane and the x13C value of dissolved methane, the consent holder shall compare the methane level returned from the exploration well through ethane ratios and the carbon isotope composition of methane (x13C) to determine if the well is the source of the methane in the groundwater. If the ethane ratios and x13C value shows a link to the exploratory gas well, an assessment of the well must be undertaken to identify any possible leakage pathways. If leakage pathways are identified, the consent holder must undertake rehabilitation of the well to ensure this pathway is blocked within **five working days** and notify the Council’s Environmental Protection Manager within **two working days** of receipt of confirmation that leakage pathways have been identified.
40. If methane levels are above baseline monitoring and rehabilitation of the well has occurred, the consent holder shall undertake an on-going groundwater sampling programme. This shall include sampling of groundwater at intervals of:
- a. weekly sampling for one month
 - b. fortnightly sampling for two months
 - c. monthly sampling until a declining trend is apparent, and then
 - d. quarterly sampling until baseline levels (or a level that Council considers acceptable) has been reached.
- The results of this sampling shall be provided to Council’s Environmental Protection Manager within **two working days** of the receipt of the lab results.
41. If methane levels in the groundwater levels are shown to be caused by the exploratory well, the consent holder shall prepare and submit a risk assessment of nearby groundwater users. If concentrations are above 25mg/L the consent holder shall provide assessment of whether

venting of the groundwater monitoring bore is required. If the groundwater monitoring bore is required to be vented, this must occur within **five working days**.

42. The consent holder shall compare the monitoring results obtained at point C on Plan [X] to the following standards (a) – (c) and receiving environment trigger values (d) – (h):
- a. a temperature change greater than 3 degrees Celsius, or
 - b. a pH change greater than 0.5 units or to fall outside the range of 7 to 8.5 pH units
 - c. the turbidity of the water shall not be changed by more than 52 per cent (this standard shall only apply at times when the discharge from the stormwater pond is operating)
 - d. a dissolved nitrate-nitrogen level greater than 4.9 mg/L
 - e. a dissolved cadmium level greater than 0.00054 mg/L
 - f. a dissolved manganese level greater than 1.9 mg/L
 - g. a dissolved zinc level greater than 0.020 mg/L
 - h. a dissolved arsenic level greater than 0.0 24mg/L.

Note: For clauses 42a, 42b and 42c above, the monitoring results obtained at monitoring point C shall be compared with those obtained at monitoring point B.

- 42B. Should any of the above standards or trigger values be exceeded at sampling point C, the consent holder shall:
- a. notify the Council's Environmental Protection Manager within **two working days** of the receipt of the lab results

compare the results obtained at sampling point C with those obtained at points B and A to establish whether the discharge may have caused, or contributed to, the measured trigger value exceedance.

If the assessment undertaken under condition 42B(b) above indicates that the discharge has likely caused, or contributed to, the measured trigger value exceedance at point C, the consent holder shall conduct an investigation into the risk of toxic effects due to the exceedance(s). The investigations shall be consistent with the ANZECC guidelines framework. The consent holder shall submit a Proposed Investigation Plan to the Council's Environmental Protection Manager for approval before the investigation is conducted.

43. All lab analyses undertaken in accordance with the conditions of these consents shall be carried out by an independent laboratory accredited to International Accreditation New Zealand.

Stormwater monitoring

44. In the event that there is more than 1 metre depth of stormwater contained in the stormwater pond and there has been more than one millimetre of rainfall at the site in the previous 24 hours, the consent holder must take a surface sample and have it analysed for the parameters detailed in Condition 48. Sampling under this condition shall continue on each day that the above situation eventuates. This sampling regime shall continue until one month after activities at the site cease.
45. At the same time as a sample from the stormwater pond is taken under Condition 44, a sample of any rainwater contained within the hazardous substances bund shall also be taken and analysed for the parameters in Condition 46.

46. The samples taken under Conditions 44 and 45 shall be sampled and analysed for the following parameters:
 - a. suspended solids
 - b. total dissolved solids (as well as in field measurement)
 - c. pH (as well as in field measurement)
 - d. chloride
 - e. total petroleum hydrocarbons
 - f. surfactants that are used on site.
47. The results of all analyses undertaken in accordance with the conditions of these consents and an assessment of the data, identification of any non-compliances and if non-compliance occurs an explanation in accordance with the requirement under Condition 12, shall be provided to the Council's Environmental Protection Manager within **five working days** of being received by the consent holder.

Stormwater conditions

48. Before releasing stormwater collected within the hazardous substance bunded areas into the stormwater system, the Environmental Monitoring Officer shall inspect the stormwater for any visual signs of contamination, including but not limited to oil sheen on the surface, or any leaks from the hazardous substance storage containers. If any signs of contamination are present, the water shall be collected by a vacuum truck and removed from the site for disposal at a consented facility. If the rainwater is not contaminated, it shall be released to the perimeter drain by the Environmental Monitoring Officer.
49. All hazardous substances shall be:
 - a. contained in a double skinned tank, or
 - b. stored in a dedicated chemical storage area that is:
 - i. covered, to prevent exposure to rain, wind etc
 - ii. elevated, with a false bottom above a drip tray or lined bund which has the capacity to contain a minimum of 120 per cent of the total volume of the stored substance contained within the storage area.
50. The stormwater pond must be inspected on a weekly basis, and before and after each rain event that results in surface runoff, while activities are occurring at the site. Visible floating hydrocarbons shall be removed and disposed of to an appropriate off-site disposal facility.
51. If the drilling and testing operations are suspended but the site is not decommissioned, the consent holder shall clear the site of any material that could cause stormwater contamination, and make the site secure. The inspections of the stormwater pond required under Condition 50 may cease after the Council inspects the site and confirms in writing that stormwater pond inspections are no longer required.
52. The consent holder shall ensure that the swales are stabilised to ensure erosion of the swales by the flow of stormwater does not occur.
53. The consent holder shall monitor the sediment levels in the stormwater pond on a weekly basis and if sediment build up in the stormwater pond exceeds 20 per cent of its volume, the

sediment shall be removed within **two working days** of detection of the exceedance of the 20 per cent level and disposed of at a consented landfill.

54. If additional hazardous substances are to be brought onto the site, the consent holder shall notify the Council's Environmental Protection Manager **five working days** before the change. The consent holder shall also provide an assessment for certification by the Council of whether any amendment to the monitoring regime is required to detect any of the additional hazardous substances.
55. The consent holder shall ensure all field equipment is calibrated in line with the manufacturer's instructions to ensure accurate readings.
56. The consent holder shall ensure all routine or event-based sampling of stormwater from all sumps, bunds and the stormwater pond is recorded in an electronic format.
57. The discharge of stormwater must not cause or exacerbate the flooding of any other property.
58. The discharge of stormwater must not cause erosion of any land or the bed of any water body beyond the point of discharge. If erosion does occur as a result of the discharge, the damage must be remedied within **five working days**.
59. If a spill of hazardous substances occurs,⁵⁴ the consent holder shall record the spill occurrence and take measures to clean up and avoid any environmental effects, and notify the Council's Environmental Protection Manager within **one working day**.

Discharge to air including flaring conditions

60. The discharge shall not cause any objectionable or offensive odour, dust or smoke at or beyond the boundary of the property where the well site is located.
61. All gas that is flared must first be treated by effective liquid and solid separation and recovery.
62. All separated liquids must be contained at all times to prevent discharge to land or water.
63. Only gaseous hydrocarbons originating from the well stream shall be combusted within the flare tank.
64. The consent holder shall ensure the well testing occurs for no more than 45 working days.
65. The consent holder shall ensure the flare point has the following buffer distances:
 - a. 300 metres from residences, public buildings and public recreation areas
 - b. 300 metres from any rare habitats, threatened habitats and at-risk habitats
 - c. 100 metres from water bores, surface water bodies and public roads.
66. The consent holder shall continuously measure the gas production volume at the separator.

⁵⁴ Note, also, the requirements of s.144 of HSNO Act may apply here.

67. The consent holder shall ensure the gas production volume measured at the separator does not exceed a 24-hour average of 10 million cubic feet per day.
68. The consent holder shall record and make available to the Council's Environmental Protection Manager, a 'flaring log' that includes:
 - a. the date, time and duration of all flaring episodes
 - b. the zone from which flaring occurred
 - c. the volume of substances flared
 - d. whether there was smoke at any time during the flaring episode and if there was, the time, duration and cause of each 'smoke event'
 - e. monitoring of the gas production volume as per Condition 66.

Appendix C: Examples of territorial and unitary authority resource consent conditions

- The example consent conditions below provide guidance on ways to avoid, mitigate, or offset environmental effects on the environment. These examples have been sourced from resource consents that have been granted in New Zealand.
- These examples should only be used for reference purposes. They have been developed for a specific proposal on a specific site, and may not be appropriate for other proposals or sites.
- Specialist legal and planning advice should be sought to ensure conditions are drafted in a way that will be effective, efficient and enforceable in case of dispute.
- General information and good practice examples for drafting resource consent conditions are available on the Quality Planning website at: <http://www.qualityplanning.org.nz/index.php/consents/conditions>.
- Where appropriate, specific names of companies and councils have been omitted.
- New Plymouth District Council is currently undertaking a review of their oil and gas resource consent conditions they impose and where appropriate standardise consent conditions across the region.

Territorial authority

C1. Land-use consent to construct a well site, drill wells from the site, test each well and undertake gas flaring associated with the testing, and produce oil and gas from the wells if they are successful

General conditions and scope

1. The proposed activity shall be established and carried out substantially in accordance with the application documentation and technical reports listed below, except as specifically modified by these conditions:
 - *Application for Consent and Assessment of Environmental Effects – (report title)*
 - *Hazardous Substances Risk Assessment Report – (report title)*
 - *Assessment of Noise Effects – (report title)*
 - *Traffic Management Plan – (report title)*
 - *Noise Attenuation Measures – (report title)*
 - *Land Care report – (report title).*
2. A total of X (number) wells may be drilled on the well-site pad.
3. Only one well may be drilling at any one time.

4. Consent for exploration drilling and testing shall be limited to a period of [X number] years from the commencement of this consent. For clarification, no term is imposed on any production from the wells.
5. The production shall be piped off site to a remote processing facility. Only minor well-head and associated facilities for production shall be located within the consented well-site pad.

Mitigation bund and planting and boundary planting

6. Before beginning any drilling activities (including drilling and flaring), and for the life of production from the well site, the consent holder shall establish the earth bund in accordance with (report title) and shall include bunding around the lay down area. The earth bund and perimeter of the well pad shall then be grassed and planted substantially in accordance with the report *Wise Land Care* prepared by (report author). The consent holder shall certify that these works have been completed and provide this certification to the Council.
7. The bund shall be [X number] metres wide at the base and [X number] metres wide across the top. The bund shall be a height of [X number] metres along the [describe] of the well site. Along the [describe] boundaries of the well site the bund shall taper uniformly from a height of [X number] metres at its northern end to [X number] metres in height at the southern end. The bund shall be permanent and not temporary.
8. For the duration of this consent, the consent holder shall maintain the bund structure and planting in a good condition.
9. The boundaries of the site, [legal description], shall be planted in accordance with Land Care planting plan. This planting shall be completed before any drilling activity on-site is established.
10. The area of the site to be utilised for the consented activity shall be limited to the area defined within the plans lodged as part of this resource consent and technical reports. The remainder of the site shall not be utilised for the consented activity.

Hazardous substances storage facilities

11. The maximum quantity and type of hazardous substances stored and used on the [name] well site shall not exceed that described in the application and assessed within [report title].
12. Before beginning any drilling activities, the consent holder shall provide a Hazardous Substances Environmental Management Plan (HSEMP) to the Manager Consents or nominee. The consent holder shall comply with the HSEMP at all times and update the HSEMP when circumstances change. The HSEMP may be part of a wider Environmental or Site Management Plan and shall include details of the hazardous substances use and storage as well as matters required under the Hazardous Substances (Emergency Management) Regulations 2001. The HSEMP shall specify a process for its ongoing review and updating.
13. Before beginning any drilling activities, the consent holder shall provide details of the waste management operator able to accept both process wastes and any contaminated material required to be disposed of off-site in the case of an incident to the Manager Consents or nominee.

14. Except during well testing, pipeline maintenance or in emergency situations in relation to the wells on the [name] well site or other infrastructure, produced hydrocarbons extracted from wells shall not be stored on site and shall be piped to the [name], or elsewhere.
15. Before all drilling activities, the coordinates of each well head shall be provided to the Consents Manager or nominee and confirmation provided that the risk contours remain within the site boundaries [report title].
16. In addition to all applicable requirements of the Hazardous Substances and New Organisms Act 1996 and associated regulations, all hazardous substances and materials shall be stored on site within bunded areas, and used on site in accordance with the manufacturers' instructions, and best industry practice.
17. In addition to other relevant statutory agencies the Council is to be advised of any spills or other hazardous substance emergencies on the site at the earliest possible opportunity, but no later than 72 hours after the event.
18. The secondary spill containment area is to be monitored by the consent holder as required (particularly during rain events). Any accumulation of rain water in the secondary spill containment area is to be emptied when the rain water reaches a maximum of 10 per cent of the bund capacity.⁵⁵
19. Any flaring during exploration may be intermittent but shall not exceed 15 days per zone for a maximum of four zones per well.

Transportation

20. The consent holder shall enter into a roading maintenance agreement with the Council before beginning the drilling activity. This agreement shall require the consent holder to make a contribution towards the strengthening (Area Wide Pavement Treatment) of [name] Road from [name] Road to the vehicle access point to [name] well site. The annual assessment of the condition of the road will begin once the roading work has finished.
21. The programme for each rig mobilisation and demobilisation shall be notified in writing to the Manager Consents or nominee and owners and occupiers along [describe] at least 10 working days before beginning each rig mobilisation or demobilisation.
22. Before beginning any activity authorised by this consent (including first rig mobilisation), the consent holder shall undertake the following physical works and measures to mitigate the effects of the additional traffic movements on the local roading network.

(Site-specific condition examples)

- a. To the [describe] of the existing access point. This will allow for better visibility in either direction. The access shall be constructed to Type H tanker crossing standard and shall be set back to a security gatehouse. The distance from the carriageway edge to the gatehouse shall be the length of the largest vehicle to access the site. This will ensure all vehicles are off the road before stopping at the gatehouse. The gatehouse

⁵⁵ Note that care should be taken when emptying rain water from containment areas as this water may be contaminated. This should be assessed in accordance with any regional council contaminant discharge requirements.

will have a security barrier. The radius of the access shall be great enough to accommodate the largest vehicle to use the site.

- b. The bank shall be cut back along the site's boundary edge with [name] Road to allow for improved visibility.
 - c. [name] Road shall be widened to a sealed width of [X number] metres from [describe] to the entrance of the proposed site.
 - d. Engineering plans for the road widening shall be provided to the Manager Consents or nominee for approval before the road widening construction begins.
 - e. As-built plans for the road widening shall be provided to the Manager Consents or nominee on completion of the road widening.
 - f. The entrance to [describe] shall be upgraded to a Type G rural vehicle access.
 - g. An acceleration lane leaving the site shall be constructed for a length of [X number] metres to the north from the vehicle access point to [name] well site.
 - h. Engineering plans for the acceleration lane shall be provided to the Manager Consents or nominee for approval before the acceleration lane construction begins.
 - i. As-built plans for the acceleration lane shall be provided to the Manager Consents or nominee on completion of the acceleration lane construction.
 - j. Parking spaces as required for a permitted activity under the District Plan shall be provided and they shall be constructed to an all-weather standard.
 - k. A double solid yellow centre line shall be painted over the crest of the road in front of the site entrance to prevent vehicles overtaking.
23. All vehicular traffic associated with the activities authorised by this consent shall use the route from and to [describe route].
24. All heavy and light vehicle equivalent movements (VEM) (excluding construction traffic) shall be restricted to 50 VEM per day and an average 30 VEM per day measured over any seven-day period.
25. All traffic movements will be managed and operated to be in accordance with the [report title], including the designated traffic route and restrictions on hours for heavy truck movements.
26. The consent holder shall install and operate in-vehicle GPS recording equipment for the purpose of monitoring compliance with the conditions of this consent. The consent holder shall submit a Traffic Monitoring Report to the Manager Consents or nominee on the last working day of any month in which well drilling occurs, which shall summarise the traffic monitoring data and specifically confirm full compliance with the conditions of this consent or detail any areas of non-compliance. If non-compliance is identified, then the consent holder shall be required to demonstrate how this non-compliance was rectified for any subsequent activity.
27. In addition to Condition 26, the consent holder shall make the traffic log required under that condition available to the Council's Manager Consents or nominee upon request within three working days of any such request.
28. No vehicles transporting hazardous substances shall travel past the [name] School or Playcentre between the open hours of 8.00 am and 3.45 pm on any school day.

29. No heavy vehicles associated with activities at [name] well site shall:
- use [name] Road on school days between the hours of 8.00 am – 9.00 am and 2.30 pm – 3.30 pm
 - pass [name] School or Playcentre on school days between the hours of 8.00 am – 9.00 am and 2.30 pm – 3.30pm
 - pass [name] School or Playcentre on (days) between the hours of 11:30 am and 12.30 pm.

Noise

30. All activities on the site shall not exceed the following noise limits at any point at or within the notional boundary of any habitable dwelling within the Rural Environment Area (other than those habitable buildings for which written consent has been provided):

On any day	7.00 am – 10.00 pm	50 dBA L ₁₀
	10.00 pm – 7.00 am	45 dBA L ₁₀
		70 dBA L _{max}

Noise shall be measured in accordance with NZS6801:1991 *Measurement of Sound* and assessed in accordance with NZS6802:1991 *Assessment of Environmental Sound*.

31. The following mitigation measures shall be utilised to ensure the compliance with the Permitted Activity noise standards and shall be installed before beginning any drilling activity. The mitigation measures shall include but not be limited to:

(application specific examples below)

- a [A X number] metre high earth bund
- mud motors fitted with new louvre silencers
- mud motors fitted with new silencers
- silencer added to draw works
- new sound barrier to surround platform
- new portable sound barriers
- second silencer added to the generator

as detailed in [report title].

Pre-installation noise emission report

32. At least two weeks before each well drilling begins the consent holder shall provide to the Manager Consents or nominee a noise emission report from a suitably qualified and experienced person that the sound levels from the drilling rig will not exceed those levels set out in Condition 32. The noise emission report shall state but not be limited to:

- which drilling rig is to be used
- the different drilling activities and other machinery
- the noise emissions from the drilling rig and ancillary equipment
- how those emissions were determined
- the potential noise levels at all habitable buildings where the predicted level exceeds 35dBA L₁₀

- f. noise mitigation measures including the location of silencers, muffling, shielding, enclosures and barriers/bunds
- g. the likely effectiveness of the mitigation measures
- h. the predicted noise levels with mitigation
- i. the meteorological conditions during which noise limits may be exceeded
- j. the likelihood of those conditions occurring
- k. any uncertainty in the predictions and safety factors employed in the calculations.

Noise monitoring

- 33. All noise monitoring of drilling activities shall be supervised by a suitably qualified and experienced person.
- 34. A noise logger and a weather station shall be deployed for the full duration of each drilling and testing operation of each well at or within the notional boundary of the habitable building on [legal description]. The weather station shall record wind speed, wind direction, temperature and the presence of rainfall at 15 minute intervals, which shall be correlated to the noise logger data.
- 35. The noise logger (referred to in condition 34) shall be installed before each well-drilling operation begins and remain for the entire period of each well-drilling and testing operation.
- 36. The noise logger shall be supported by attended noise monitoring. The attended noise monitoring shall be representative of all drilling and testing activities on site.
- 37. During any period of drilling and testing, a weekly noise monitoring report and results shall be provided to the Manager Consents or nominee. The results shall be analysed and provided in a form that allows a ready assessment of the readings so compliance can be demonstrated. This shall include graphs of noise levels and weather conditions. Where the monitoring demonstrates any period of non-compliance during any periods, details of the rig activity at those times shall be provided along with any other relevant description of circumstances, including a description of attended monitoring undertaken.
- 38. The weekly noise monitoring report and results shall be provided to the Manager Consents or nominee within five working days of the completion of weekly monitoring.

Noise management plan

- 39. The consent holder shall submit a noise management plan prepared by a suitably qualified person to the Manager Consents or nominee for approval before beginning any work at the site. The plan shall include, but not be limited to:
 - a. the identification of noisier activities and timing of those activities to avoid noise sensitive times (particularly at night)
 - b. a restriction on the use of amplified music between the hours of 8.00 pm and 8.00 am
 - c. education of workers and management in quiet work practices and in maintaining community good will
 - d. the process of community liaison, including any special measures for immediate residents

- e. the need to keep all sound-attenuating doors normally closed
 - f. the complaints procedure, including the person responsible for receiving complaints and actions to be taken regarding reducing noise, recording and feedback
 - g. consultation procedures for special works
 - h. any changes to the rig to minimise noise shall require an updated noise management plan.
40. The Council may review Conditions 32 to 40 of this Consent in accordance with Section 128 of the Resource Management Act 1991 at the conclusion of the testing of the first well drilled from this site to deal with any adverse acoustic effect that was not foreseen at the time of granting this Consent.

Site maintenance

41. During any periods where the site is not actively being used for drilling and testing activities, and throughout the operational life of any permanent production facilities on site, the consent holder shall inspect the site at least once a month and remove all visible rubbish, to ensure the site is maintained in a neat and tidy condition.

Consultation and notification

42. At least 48 hours before beginning any well-site (drilling, testing and flaring) activity the Manager Consents or nominee, [name] School and Playcentre and all property owners and occupiers within [X number] metres of the [name well site] shall be notified in writing as to when the activity will begin and its likely duration.
43. Should all activity at the [name] well site (drilling, testing and flaring) be suspended for a period of more than eight weeks with the intention of recommencement, the Manager Consents or nominee, [name] School and [name] well site shall be advised accordingly by the consent holder.
44. The consent holder shall include in the notification a 24-hour contact telephone number for a representative of the consent holder. The consent holder shall keep and maintain, and within 48 hours of request make available to the Council, a record of any complaints received regarding each drilling and testing activity authorised by this consent.

Decommissioning and restoration

45. The consent holder shall inform the Council's Manager Consents or nominee when the consented exploration and/or production at the site ceases. Subject to any land owner agreement (should the consent holder not remain the land owner at the time of decommissioning), the consent holder shall restore the site and prepare it for re-vegetation. Before beginning restoration works, the consent holder shall provide Council's Manager Consents or nominee with restoration details, including timeframes and plans, by way of notification.
46. Before decommissioning and restoration of the site, the consent holder shall provide to the Manager Consents or nominee a report from a suitably qualified person that assesses the risk of soil contamination on the land and, if required, a remediation action plan to manage those risks.

Monitoring

47. The consent holder shall pay Council's reasonable costs associated with monitoring the conditions of this consent in accordance with section 36 of the Resource Management Act 1991.

Review

48. The conditions of this consent may be reviewed by the Council in accordance with Section 128 of the Resource Management Act 1991 to deal with any adverse effects on the environment which may arise from the exercise of this consent that were not foreseen at the granting of the consent. The first such review (if necessary) shall occur within one month after the drilling of the first well.

Notes:

This application for Resource Consent has been considered in accordance with Section 104 of the Resource Management Act 1991 and has been approved, as the Council is satisfied that the proposal is consistent with Part II of the Resource Management Act 1991 in that the adverse effects on the environment of the activity will be minor and that no persons will be adversely affected by the granting of the Resource Consent.

This Resource Consent lapses five years after the date of its commencement unless the Consent is given effect to before that date; or unless an application is made before the expiry of that date for the Council to grant an extension of time for establishment of the use. An application for an extension of time will be subject to the provisions of Section 125 of the Act.

This Consent is subject to the Right of Objection as set out in Section 357A of the Resource Management Act 1991.

Unitary authority

C2. District land-use consent for an access track and well pad

1. The activity shall be carried out in general accordance with the details submitted with the application [Reference], unless altered by the following conditions.
2. The consent holder shall be responsible for all contracted operations related to the exercise of this resource consent, and must ensure contractors are made aware of the conditions of this resource consent and ensure compliance with those conditions.
3. If this consent is not given effect to within a period of five years from the date it begins it shall lapse under section 125 of the Resource Management Act 1991.

Parking

4. The consent holder shall ensure all vehicles associated with the activity shall park within the site and not within the road reserve.

Earthworks and stormwater management

5. All erosion, stormwater and sediment control measures shall be undertaken generally in accordance with the procedures and plans specified in the Earthworks and Stormwater Management Plan provided with the application.

Construction noise

6. Emissions of construction noise shall not exceed 168 calendar days in any 12-month period.
7. The background sound level (L_{95}), average maximum noise level (L_{10}) and maximum noise level (L_{max}) arising from any zone as measured at the notional boundary of any dwelling in a rural zone shall not exceed the following limits.

Construction and temporary activity noise measured within the	Time period	Average maximum noise (dBA)		
		L_{95}	L_{10}	L_{max}
Rural zone	Mon – Sat 0600–1800 hrs	60	75	90

Operational noise

8. The average maximum noise level L_{10} as measured at the notional boundary of any dwelling zoned Rural General shall not exceed 55dBA during the hours of operation.

Vibration

9. The maximum weighted vibration level (W_b or W_d) measured at the notional boundary of any dwelling zoned Rural General shall not exceed 60 millimetres per second squared (mm/s^2).

Dust

10. There shall be no dust or odour from the activity which is offensive or objectionable, as determined by a suitably qualified and experienced enforcement officer from the [Council], at or beyond the boundary of the site.
11. Should offensive or objectionable odour or dust be observed beyond the boundary of the site, the activity shall be modified or cease immediately and shall not restart until compliance is demonstrated to the satisfaction of the Regulatory Services Manager, [Council].

Hours of operation

12. No construction and well site establishment activities shall occur outside the daytime period of 6:00 am to 6:00 pm, Monday to Saturday.
13. No heavy goods transport and over-size vehicles shall arrive at, or depart from, the site outside the daytime period of 6:00 am to 6:00 pm, Monday to Saturday.
14. The consent holder shall ensure:
 - the drivers of the trucks delivering machinery and materials to the site are made aware of the hours of operation of the school bus on [name of road] (being 7.30 am to

8.45 am and again between 2.30 pm and 3.45 pm) and be requested to take extra care during those times

- the school bus driver is made aware of the days on which heavy vehicles associated with the [name] Site Establishment Works will be travelling on [name of road].

15. Please advise the Consent Authority at least 72 hours before beginning the activity.

Archaeological discovery

16. If any archaeological site, taonga or koiwi (bone) is discovered during the works authorised by this consent, the consent holder shall immediately cease work at the affected site. The consent holder shall notify [iwi], the Historic Places Trust, the [Council], and in the case of koiwi, the Police, and shall not recommence works in the area of the discovery until the relevant Historic Places Trust and [iwi] approvals to damage, destroy or modify such sites have been obtained, and [Council] has given authorisation to recommence the activities.

Note:

The Historic Places Act 1993 (HPA) provides for the identification, protection, preservation and conservation of the historic and cultural heritage of New Zealand. Under Section 2 of the HPA, an archaeological site is defined as a place associated with pre-1900 human activity where there may be evidence relating to the history of New Zealand. Section 10 directs that an authority is required from the New Zealand Historic Places Trust if there is 'reasonable cause' to suspect an archaeological site (recorded or unrecorded) may be modified, damaged or destroyed in the course of any activity. An authority is required for such work whether or not the land on which an archaeological site may be designated, or a resource or building consent has been granted, or the activity is permitted in a regional or district plan. Evidence of archaeological sites may include oven stones, charcoal, shells, ditches, banks, pits, terraces, stone walls, building foundations, artefacts of Māori and European origin, or burials.

C3. Regional consent for land disturbance (earthworks) to form an access track, a well pad and cellar

17. The activities authorised by this consent shall be undertaken generally in accordance with all the information and plans accompanying the application, titled [application name], [date].
18. If a conflict arises between any conditions of this consent and the application, the conditions of this consent shall prevail.
19. The consent holder shall be responsible for all contracted operations related to the exercise of this resource consent, and must ensure contractors are made aware of the conditions of this resource consent and ensure compliance with those conditions.
20. If this consent is not given effect to within a period of five years from the date of its commencement it shall lapse under section 125 of the Resource Management Act 1991.

Earthworks and stormwater management

21. All erosion, stormwater and sediment control measures shall be undertaken generally in accordance with the procedures and plans specified in the Earthworks and Stormwater Management Plan provided with the application.

22. Any springs encountered during the earthworks are to be intercepted by subsurface drains and discharged clear of the well pad and access track.
23. The diversion bund is to be constructed on a grade sufficient to avoid scour, with armouring included as necessary.
24. The culvert and the discharge from the sediment retention pond are not to discharge directly or indirectly onto unarmoured fill or sidecast material.
25. Base metalling of the access road and well pad shall be completed within four weeks of completion of earthworks.
26. All areas of bare ground shall be oversown with evenly distributed grass and legume seed mix during the spring or autumn immediately following completion of earthworks, whichever is the sooner.

Archaeological discovery

27. If any archaeological site, taonga or koiwi (bone) is discovered during the works authorised by this consent, the consent holder shall immediately cease work at the affected site. The consent holder shall notify [iwi], the Historic Places Trust, the [Council], and in the case of koiwi, the Police, and shall not recommence works in the area of the discovery until the relevant Historic Places Trust and [iwi] approvals to damage, destroy or modify such sites have been obtained, and [Council] has given authorisation to recommence the activities.

Note:

The Historic Places Act 1993 (HPA) provides for the identification, protection, preservation and conservation of the historic and cultural heritage of New Zealand. Under Section 2 of the HPA, an archaeological site is defined as a place associated with pre-1900 human activity where there may be evidence relating to the history of New Zealand. Section 10 directs that an authority is required from the New Zealand Historic Places Trust if there is 'reasonable cause' to suspect an archaeological site (recorded or unrecorded) may be modified, damaged or destroyed in the course of any activity. An authority is required for such work whether or not the land on which an archaeological site may be designated, or a resource or building consent has been granted, or the activity is permitted in a regional or district plan. Evidence of archaeological sites may include oven stones, charcoal, shells, ditches, banks, pits, terraces, stone walls, building foundations, artefacts of Māori and European origin, or burials.

C4. Regional consent to install a conductor pipe bore

28. The activities authorised by this consent shall be undertaken generally in accordance with all the information and plans accompanying the application, titled [application name], [date].
29. If a conflict arises between any conditions of this consent and the application, the conditions of this consent shall prevail.
30. The consent holder shall be responsible for all contracted operations related to the exercise of this resource consent, and must ensure contractors are made aware of the conditions of this resource consent and ensure compliance with those conditions.

31. If this consent is not given effect to within a period of five years from the date of its commencement it shall lapse under section 125 of the Resource Management Act 1991.
32. The consent holder shall comply in all respects with the Water Bore Construction Specifications of the [name of Regional Plan], as applicable attached as Appendix 1.
33. The bores shall be constructed in accordance with the New Zealand Environmental Standard for Drilling of Soil and Rock, NZS 4411:2001.
34. The conductor pipe bores shall be cased and sealed such that cross contamination of aquifers and leakage from the ground surface into aquifers cannot occur.
35. The Water Conservation Section of the [Council] shall be notified 72 hours before drilling of the bore begins.
36. A copy of the well drillers bore log shall be supplied to the [Council]'s Water Resources section within one month of bore completion.
37. The consent holder shall pay to the [Council] any administration, inspection or monitoring charges payable in respect of this permit. Any such charges shall be either fixed or additional charges set in accordance with section 36 of the Resource Management Act 1991 and section 150 of the Local Government Act 2002.
38. This consent is granted by [Council] subject to its servants and agents being permitted access to the relevant parts of the site for the purpose of carrying out inspections, surveys, investigations, tests, measurements or taking samples.
39. If any archaeological site, taonga or koiwi (bone) is discovered during the works authorised by this consent, the consent holder shall immediately cease work at the affected site. The consent holder shall notify [iwi], the Historic Places Trust, the [Council], and in the case of koiwi, the Police, and shall not recommence works in the area of the discovery until the relevant Historic Places Trust and [iwi] approvals to damage, destroy or modify such sites have been obtained, and [Council] has given authorisation to recommence the activities.

Note:

The Historic Places Act 1993 (HPA) provides for the identification, protection, preservation and conservation of the historic and cultural heritage of New Zealand. Under Section 2 of the HPA, an archaeological site is defined as a place associated with pre-1900 human activity where there may be evidence relating to the history of New Zealand. Section 10 directs that an authority is required from the New Zealand Historic Places Trust if there is 'reasonable cause' to suspect an archaeological site (recorded or unrecorded) may be modified, damaged or destroyed in the course of any activity. An authority is required for such work whether or not the land on which an archaeological site may be designated, or a resource or building consent has been granted, or the activity is permitted in a regional or district plan. Evidence of archaeological sites may include oven stones, charcoal, shells, ditches, banks, pits, terraces, stone walls, building foundations, artefacts of Māori and European origin, or burials.

Footnote 1: For further information about the [Council] charging policy, please refer to the current Manual of Fees and Charges.

Footnote 2: This consent is to install a bore, it is not a consent to take water. A separate resource consent is required for taking more than 10 cubic metres of water per day.

Appendix D: Examples of the scope of resource consent applications and assessment of environmental effects

Regional councils

D1. Hydraulic fracturing application

1 *Introduction*

1.1 Background

- Brief description of drilling history of site and any abandoned wells.
- Brief description of previous and current consents applied for by applicant.

1.2 Site location information

- Well site location address, map reference and grid reference.
- Catchment area.

2 *Resource consents sought*

- Description of proposed activity(s).
- Which rules in the Regional Fresh Water Plan apply to the activity?

3 *Related consents*

- More detailed description of related resource consents sought which are relevant to the proposed programme (eg, air discharge, stormwater).

4 *Existing environment*

4.1 General location and topography

- Map showing location of well site(s).
- Description of the topography of the land.

4.2 Land use

- Brief description of surrounding land-use activities.

4.3 Vegetation and wildlife

- Description of any significant native vegetation in the immediate area.
- Details of any scenic or recreation reserves, regional or national parks in the immediate vicinity of the site.

4.4 Adjacent waterways

- Location of adjacent waterways in relation to the well site (shown on a map).

4.5 Hydrogeology and groundwater resources

- Description and location of aquifers/water abstractions within the area of interest.
- Details of the freshwater/saltwater interface (FW/SW I).
- Resistivity logs, if available, and other data that support the depth determination for the SW/FW I.
- Petrophysical evaluation.
- Geology, lithology and overpressure contaminant (provide a schematic showing geologic formations identifying impermeable and laterally persistent units, any faults or shear zones, and the FW/SW interface).
- Description of the geologic formations and dominant lithology within the area.
- Description of formation properties including permeability and pressures.
- Geologic logs (including spontaneous potential, resistivity, sonic).
- Gamma ray logs.

4.6 Faulting

- Analysis of known faults within the area.

5 *Description of proposed activity*

- As required by section 1(a) of Schedule 4 of the RMA.

5.1 Overview of proposed hydraulic fracturing (HF) stimulation programme

- Description of the HF process.
- Indicative HF stimulation programme – details to include planned execution timeframe, number of HF treatments/well, target interval depth range (including the location of casing perforations in three dimensions in terms of New Zealand Map Grid co-ordinates and true vertical depth in metres below ground).
- Modelling and use of ‘mini-frack’ results to calibrate the model, conceptual design (eg, fracture pressure).
- Fracturing fluid fate modelling techniques used (eg, proppant concentration diagrams and interpretation of models and diagnostics).
- Assessment of modelling or tracer techniques used or reasons for not using tracers.
- Well integrity pressure testing (when it happened, what the results were).
- Operational procedures.
- Results of previous HF operations in similar formations and data in graphical form of: tubing pressure (psi); slurry rate (bpm); bottom hole proppant concentration (bpm); grid oriented hydraulic fracture extension replicator⁵⁶; surface predicted pressure (psi); modelled predicted bottom hole proppant concentration (lb/gal); borehole gauge pressure (psi); surface proppant concentration (lb/gal); grid oriented hydraulic fracture extension replicator predicted bottom hole pressure(psi); grid oriented hydraulic fracture extension replicator predicted slurry rate (bpm); grid oriented hydraulic fracture extension replicator predicted surface proppant concentration (lb/gal); before, during and after each hydraulic fracture treatment.

⁵⁶ ‘Grid Oriented Hydraulic Fracture Extension Replicator’ is a particular model used to predict fracture properties. Consent conditions could provide for model results, rather than requiring a particular model to be used.

- Detail the procedures to be carried out during the HF stimulation programme and the sequence of operations.

5.2 Well construction and design (well integrity) – noting many of these matters are the responsibility of the Ministry or Business, Innovation and Employment (formerly Department of Labour) under the Petroleum Regulations and would only be included for interest and completeness reasons.

- Provide details of well construction, materials used and relevant standards.
- Details of cementing practices, including cement bond logs and interpretation.
- Outline of pressure test results and interpretation.
- Well construction diagram.
- Details of on-going life-cycle well monitoring.
- Well maintenance programmes and procedures.
- For old wells that are subject to HF treatments the assessment needs to focus on the condition of the well casing and cement as this can slowly deteriorate over time.
- Consideration of any abandoned wells in the vicinity and their condition as possible contaminant pathways.

5.3 Details of HF stimulation fluids

- Provide details of the composition of the fluids to be used in the stimulation.
- Briefly describe the function of each fluid component.
- Provide safety data sheets for all products/chemicals used.
- Provide an estimate of fluid volumes to be used, expected return flow period and volumes.

5.4 Subsurface monitoring

- Provide details on the proposed diagnostic tools to be used.
- Monitoring and modelling of fracture extent (half-length).
- Monitoring and modelling of fracture extent.
- Assessment of modelling and tracer techniques used or reasons for not using specific techniques.
- Any other analytical tools or process monitoring data that will demonstrate the fate of injected fluids, proppant and the fracture growth (eg, well annulus pressure).

5.5 Waste management

- Detail how return fluids will be managed on-site. Include details on the storage, transport and disposal of waste fluids. Relevant construction standards for storage vessels and testing carried out should be included. Noting these matters are the responsibility of other regulatory agencies and could be included for interest and completeness reasons.

6 *Assessment of environmental effects and mitigation measures*

- As required by Sections 1 of Schedule 4 of the RMA. To assess the actual or potential effect on the environment and to outline mitigation measures, which will help prevent or reduce the actual or potential effects on the environment.

6.1 Potential adverse environmental effects

- Detail the potential environmental effects relating to the proposed activity. To include, but not be limited to, the issues identified in 6.2 below.

6.2 Potential contamination of freshwater aquifers

- Leakage due to defective well design/installation/operation.
- Leakage through geologic media.
- Leakage or improper handling of chemical or wastewater.
- Risk of well blowouts.
- Detail both the physical and process/procedural mitigation measures that will be implemented for each of the above to ensure actual or potential contamination will be avoided. May include details of the integrity of overlying geologic seals, results of testing undertaken on formations and the well bore, standard operating procedures, planning and design, construction standards, quality control and assurance, on-going process monitoring, alarms and response procedures. This may also include an assessment of the condition of nearby abandoned wells as a possible pathway for HF fluids and gas leakage to the surface.

6.3 Chemical handling and waste management

- Detail procedures for chemical handling, including the delivery, transport and storage of chemicals. Include standard operating procedures, construction details and relevant standards for storage vessels, bunding, and approved handler certification. Recognising these matters are the responsibility of other regulatory agencies and could be included for interest and completeness reasons.
- Provide details of plans and procedures to be carried out in the event of a spill.
- Provide details of any attempts made to minimise the volume and toxicity of chemicals being used in stimulation fluids.
- Outline the wastes to be produced on-site and expected volumes.
- Detail procedures for the handling, storage, transport and disposal of waste materials.

6.4 Use of water

- Provide an estimate of potential water-use volume.
- Provide details of where water will be sourced.
- Detail any measures implemented to reduce water usage on-site.

6.5 Potential seismic effects

- Assess the risk of the proposed activity inducing seismic activity.
- Detail any seismic or vibration monitoring to be carried out.

6.6 Positive environmental effects

- Detail the positive impacts of the proposed HF stimulation activities.

6.7 Assessment of alternatives

- Provide a brief assessment of any potential alternative location for the activity or HF stimulation methods.

6.8 Consultation and affected parties

- Provide details of any parties deemed to be affected by the proposed activities and any consultation undertaken.

7 *Regulatory context*

7.1 Regulatory background

- Brief description of section 104 of the RMA and description of additional documents which must be considered in assessing the application (Part II of the RMA, national policy statements, regional policy statement etc).

7.2 Part II of the Resource Management Act

- Assessment of how the proposed activities are in accordance with Part II (Sections 5, 6, 7 and 8) of the RMA.

7.3 National Policy Statement – Freshwater Management

- Assessment of how the proposed activities are in compliance with the relevant objectives outlined in the NPS for Freshwater Management. In particular objectives A1 and A2.

7.4 Regional Policy Statement

- Assessment of how the proposed activities are in compliance with the relevant policies outlined in the Regional Policy Statement.

7.5 Regional Freshwater Plan

- Assessment of the activities against the relevant policies and rules in the Regional Freshwater Plan and justification as to why the activities comply with the policies.
- In particular the following policies should be looked at: 4.1.1 to 4.1.6, 5.1.1, 5A.1.1, 5A.2.1, 6.2.1 to 6.2.7, and 6.5.1 to 6.5.5.

8 *Conclusion*

D2. Deep well injection assessment of environmental effects (AEE)

The information presented in the AEE must demonstrate that the proposed activity will not result in any adverse environmental effect that is deemed to be more than minor.

- Specific details of the proposed injection site including well site and well reference names, address, the legal description of property, ownership details, geographical coordinates of site and injection well and the location of any nearby water abstraction points.
- A summary section [schematic] showing geologic formations and identifying the impermeable and laterally persistent units [confining layer(s)], any major faults or shear zones, the disposal well path and well perforation intervals.
- The depth to which fresh water extends below the site and the location of the freshwater/saline water interface zone.
- Geophysical logs and interpretation to support geologic data and depth to freshwater/saline water interface zone.
- Details of the proposed injection well including a well engineering completion summary report, including the initial and proposed pressure test programme to show the disposal well will remain secure.

- Consideration of any abandoned wells in the vicinity and their condition as possible contaminant pathways.
- The location of the injection zone and associated casing perforations.
- A full and complete list of all contaminants to be disposed of (eg, contaminated stormwater, HF fluids and operational products used) in addition to saline produced water containing hydrocarbon residues.
- The maximum expected volumes of materials to be disposed of over the life of the activity, and the modelled radius of influence of the contaminant plume.
- A description of equipment installed on the disposal well used to monitor injection pressure and annular pressure.
- A written procedure that identifies the conditions which would trigger concerns about the integrity of the disposal well or injection zone, and the action to be taken by the consent holder when triggered.
- Results to show that the water chemistry in the disposal zone is compatible with that of the fluids to be disposed of and any possible adverse geochemistry effects that may arise.

The AEE must as a minimum adequately demonstrate that:

- the geologic formation into which the wastewaters are injected is sufficiently porous and permeable so the wastewater can enter the rock formation without an excessive build-up of pressure
- the injection zone is overlain by a relatively non-permeable layer of rock which will confine the injected fluids within the intended disposal interval and prevent them from moving vertically toward a freshwater aquifer
- the site-specific geologic properties of the subsurface around the well offer another safeguard against the movement of injected wastewaters to a freshwater aquifer
- there are no wells or other artificial pathways between the injection zone and freshwater aquifers through which fluids can travel
- the injection well is designed and constructed to prevent the movement of injected waste waters into freshwater aquifers
- a constant pressure will be maintained in the annular space and will be continuously monitored to verify the injection well's mechanical integrity and proposed operational conditions
- all of the materials of which injection wells are made are corrosion-resistant and compatible with the wastewater and the formation rocks and fluids into which they come in contact.

D3. Discharge permit for drilling waste via land farming

The assessment of environmental effects (AEE) should cover effects on:

- water quality
- surface water
- groundwater and relevant hydrogeological information about proposed sites. This should contain a depth to water table analysis
- soil quality – background soil characteristics

- air quality – consider the location of storage pits in relation to odour effects, as pit areas are likely the main source of any odours. Proximity of storage areas to property boundaries, prevailing wind directions and neighbouring land uses should all be addressed in AEEs and/or site management plans.

D4. Discharge permit for earthworks and stormwater discharges from well site construction

The AEE should cover:

- details about the stormwater catchment area
- some information about expected stormwater quality
- for operational stormwater discharges, details of how adverse effects are avoided including by establishing perimeter drains around the site and ensuring all site drainage goes to sealed skimmer pits
- for operational stormwater discharges, a contingency plan that is followed in an emergency or unforeseen event which results in a significant discharge at the well site to ensure adverse environmental effects associated with that event are avoided, remedied or mitigated
- for earthworks stormwater a sediment control plan is typically provided to comply with the controlled activity rule.

Territorial authorities

D5. Land-use consent application for hydraulic fracturing

An application and assessment of environmental effects (AEE) should cover:

1. Introduction
2. Land-use consents sought
3. Related consents
4. Statutory framework
 - Overview
 - RMA 1991
 - District plan provisions
 - Discussion of activity in relation to district plan policies and objectives
 - Regional policy statement
 - Regional plans
5. Existing environment
 - General location and topography
 - Land use and community
 - Traffic movements
 - Vegetation and wildlife
 - Adjacent waterways
 - Sites of archaeological and cultural significance
 - Existing noise environment

6. Description of proposed activity
7. Noise emissions and mitigation measures
 - Details of all sources of noise, details of those that exceed district plan limits, and their duration
 - Site plan demonstrating the location of residential dwellings and the level of noise received
 - Details of any background noise monitoring, noise modelling, and/or noise data from a suitably qualified professional
 - Consultation with residents and any affected party consent
 - Details of any real time noise monitoring on site
 - Mitigation measures proposed including details of any noise structures
8. Visual, lighting, amenity effects, and mitigation measures
 - Description of all above ground structures proposed
 - Details of proposed lighting, duration, and timing
 - Description of the short- and long-term activities on the well site, and their effect on the rural amenity of the area
 - Details of any erosion and sediment control measures to be used
 - Details of any landscape planting
 - Details of any interim or final re-instatement works to areas of the well site (eg, contouring, levelling or revegetation)
 - Details of any site illumination management.
9. Traffic and transportation effects, and mitigation measures
 - Provision of an overall traffic impact assessment by a suitably qualified professional
 - Details of the heavy goods and oversized vehicles to be used
 - Details of trip movements and traffic routes during normal school bus travel hours, on bus routes, and through sensitive areas
 - Details of the volume of heavy vehicle traffic movements for:
 - heavy equipment
 - metal and gravel
 - waste removal from the well site
 - personnel movement
 - consumables
 - Details for the transportation of hazardous substances in accordance with HSNO and the Land Transport Rule: Dangerous Goods 2005
 - Details of any coinciding traffic peaks, especially some temporary but intensive peaks relating to construction (eg, 90 concrete trucks delivering)
 - Details of any upgrade and/or maintenance works to roads proposed to be used as traffic routes, including any maintenance agreements
 - Provision of a traffic management plan providing details such as:
 - vehicle occupancy rates
 - staff travel routes
 - heavy goods transport and oversized loads

- industry standards and rules from the New Zealand Transport Agency
 - contractor briefings
 - transportation of hazardous substances
 - driver road safety
 - vehicle road safety
 - monitoring of traffic
 - communication protocols
 - emergency response and incident management
- Mitigation measures proposed
10. Hazardous substances and mitigation measures
- Hazardous substances risk assessments
 - Details of actual volumes of chemicals, and their transport, storage, and handling
 - Details of the spill containment facilities or containment system, and the methods to be used to reduce the risk of discharge to the surrounding environment to as low as reasonably possible
 - Provision of a spill contingency plan and hazardous substances emergency procedures as required by the Hazardous Substances and New Organisms (HSNO) Act
 - Mitigation measures proposed
 - Evidence of compliance with controls under the Hazardous Substances and New Organisms (HSNO) Act and associated Regulations (for example, any test certificates required)
11. Archaeological effects and mitigation measures
- Details of any recorded archaeological sites (including, but not limited to, those listed under the district plan or in New Zealand Historic Places Trust register)
 - Mitigation measures proposed including procedures in the event of the accidental discovery of artefacts or koiwi (bone)
12. Cultural effects and mitigation measures
- Engagement with local iwi
 - Impacts on wāhi tapu sites (if applicable) and/or sensitive cultural resources
 - Mitigation measures proposed
13. Community effects and mitigation measures
- Details of effects on the local community, including effects on any sensitive areas such as rural villages
 - Mitigation measures proposed
14. Cumulative effects (if applicable)
- Details of any adjacent active permits, the proximity of sites and combined effect of traffic, noise, visual, and general industrial activity
 - Mitigation measures proposed

15. Decommissioning (if applicable)

- Details of the decommissioning strategy and the integrity of the well once the well has been plugged and the head works have been removed
- Details of the well site clean-up strategies and methodologies particularly for potentially contaminated soil under the National Environmental Standard
- Details of the removal of well site equipment and facilities, and the timeframe for this process
- Details of the number of heavy vehicle movements associated with the decommissioning site, and the timing of the required trips
- Details of earthworks associated with rehabilitation of the site, particularly if consent conditions require the site to be reinstated to the same condition as existed prior to the activity being established
- Mitigation measures proposed

16. Assessment of alternatives

17. Consultation

- Details of all parties, including iwi consulted with
- Details of consultation methods used, timing, and duration
- Details of any concerns highlighted by parties consulted with, including whether their concerns have been incorporated into the proposal
- Details of any on-going consultation for the duration of the consent.

Appendix E: The Golden Rules for a Golden Age

The International Energy Agency (IEA) has published a ‘Golden Rules for a Golden Age’ World Energy Outlook Special Report on Unconventional Gas, which provides a set of “Golden Rules”, suggesting principles that can allow policymakers, regulators, operators and others to address these environmental and social impacts.

The IEA have called them Golden Rules because their application can bring a level of environmental performance and public acceptance that can maintain or earn the industry a “social licence to operate” within a given jurisdiction, paving the way for the widespread development of unconventional gas resources on a large scale, boosting overall gas supply and making the golden age of gas a reality.

The Golden Rules underline that full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical to addressing public concerns.

The Golden Rules are:

“Measure, disclose and engage

- Integrate engagement with local communities, residents and other stakeholders into each phase of a development starting prior to exploration; provide sufficient opportunity for comment on plans, operations and performance; listen to concerns and respond appropriately and promptly.
- Establish baselines for key environmental indicators, such as groundwater quality, prior to commencing activity, with continued monitoring during operations.
- Measure and disclose operational data on water use, on the volumes and characteristics of waste water and on methane and other air emissions, alongside full, mandatory disclosure of fracturing fluid additives and volumes.
- Minimise disruption during operations, taking a broad view of social and environmental responsibilities, and ensure that economic benefits are also felt by local communities.

Watch where you drill

- Choose well sites so as to minimise impacts on the local community, heritage, existing land use, individual livelihoods and ecology.
- Properly survey the geology of the area to make smart decisions about where to drill and where to hydraulically fracture: assess the risk that deep faults or other geological features could generate earthquakes or permit fluids to pass between geological strata.
- Monitor to ensure that hydraulic fractures do not extend beyond the gas producing formations.
- Isolate wells and prevent leaks’.
- Put in place robust rules on well design, construction, cementing and integrity testing as part of a general performance standard that gas bearing formations must be completely isolated from other strata penetrated by the well, in particular freshwater aquifers.

- Consider appropriate minimum-depth limitations on hydraulic fracturing to underpin public confidence that this operation takes place only well away from the water table.
- Take action to prevent and contain surface spills and leaks from wells, and to ensure that any waste fluids and solids are disposed of properly.

Treat water responsibly

- Reduce freshwater use by improving operational efficiency; reuse or recycle, wherever practicable, to reduce the burden on local water resources.
- Store and dispose of produced and waste water safely.
- Minimise use of chemical additives and promote the development and use of more environmentally benign alternatives.
- Eliminate venting, minimise flaring and other emissions.
- Target zero venting and minimal flaring of natural gas during well completion and seek to reduce fugitive and vented greenhouse-gas emissions during the entire productive life of a well.
- Minimise air pollution from vehicles, drilling rig engines, pump engines and compressors.

Be ready to think big

- Seek opportunities for realising the economies of scale and co-ordinated development of local infrastructure that can reduce environmental impacts.
- Take into account the cumulative and regional effects of multiple drilling, production and delivery activities on the environment, notably on water use and disposal, land use, air quality, traffic and noise.

Ensure a consistently high level of environmental performance

- Ensure that anticipated levels of unconventional gas output are matched by commensurate resources and political backing for robust regulatory regimes at the appropriate levels, sufficient permitting and compliance staff, and reliable public information.
- Find an appropriate balance in policy-making between prescriptive regulation and performance-based regulation in order to guarantee high operational standards while also promoting innovation and technological improvement.
- Ensure that emergency response plans are robust and match the scale of risk.
- Pursue continuous improvement of regulations and operating practices.
- Recognise the case for independent evaluation and verification of environmental performance.” (International Energy Agency, 2012, pp 13–14).

Appendix F: Regulatory regime: further information

An overview of the regulatory regime for oil and gas in New Zealand is provided in section 3 of these guidelines. Further detail about various aspects of this regime is provided below.

Key regulatory functions

	Ministry of Business, Innovation and Employment	WorkSafe New Zealand	Department of Conservation	Regional and district councils	Ministry for the Environment	Environmental Protection Authority	New Zealand Historic Places Trust
Crown Minerals Act	Allocation of permits to explore, prospect or mine for Crown-owned minerals Assessment of a company's health, safety and environmental capability Annual consideration of engagement with tangata whenua		Process for accessing DOC land for mineral prospecting, exploration or mining				
Health and Safety in Employment Act		Regulatory functions for the safety of wells and their operation					
Hazardous Substances and New Organisms Act		Enforces the requirements of the HSNO Act in places of work			Policy advice on the regulation of hazardous substances	Issue approvals and set controls for hazardous substances	
Resource Management Act			Develops national coastal policy statement	Develops management frameworks for environmental effects through plans and policy statements	RMA policy advice	Administers applications for proposals that are nationally significant	

	Ministry of Business, Innovation and Employment	WorkSafe New Zealand	Department of Conservation	Regional and district councils	Ministry for the Environment	Environmental Protection Authority	New Zealand Historic Places Trust
				Consenting and compliance of environmental effects			
Historic Places Act							Consideration of applications for archaeological authorities

Crown Minerals Act 1991

Permitting regime

a. Prospecting permit

A prospecting permit can be awarded for regional and area evaluations of geological and geophysical characteristics. A person may apply for a prospecting permit at any time. The permit can only be over an area of open acreage,⁵⁷ although the size of the area covered by the proposed permit is negotiable. A prospecting permit is usually non-exclusive (meaning multiple permits can be granted for the same area); however, exclusive permits may be granted in some circumstances, outlined in section 6.2 of the Petroleum Programme (MBIE, 2013b). Permits may be valid for up to four years, but will not normally be granted for more than two years (section 6.4 of the Petroleum Programme, MBIE, 2013b).

b. Exploration permit

An exploration permit can be awarded to identify petroleum⁵⁸ accumulations and evaluate any discoveries made by drilling. A proposed work programme for an exploration permit is likely to include geological and geophysical surveying (including reworking existing data and new data acquisition), processing and analysis, to be followed by exploratory drilling and appraisal drilling if a discovery is made. A work programme must include drilling, but this is usually part of the contingent, not the committed, work programme (ie, drilling to occur contingent on the success of earlier stages of the work programme).

Exploration permits are issued through 'block offer' rounds made on the basis of competitive work programme bids.⁵⁹ New Zealand Petroleum and Minerals (NZP&M) determines the location and size of the offer areas following consultation with affected iwi/hapū and local authorities. Permit areas within those offer areas are defined by the bidder. If there is competition for the same area, permits will be subject to competitive allocation through bids (either by work programme staging, or through a 'cash bonus' bid).⁶⁰

Exploration permits offer exclusive rights to the operator⁶¹ to explore, and a further right to submit a mining permit application if a discovery is made and appraised to have economic potential. Exploration permits usually have an initial five-year term but may be valid for up to 15 years. This can include up to two extension and relinquishment periods. Time extensions require a 50 per cent relinquishment of the acreage.

⁵⁷ Section 3.1 of the Petroleum Programme specifies some areas that are unavailable for permitting, and section 7.4 states that the Crown can reserve specific areas from allocation for up to three years (MBIE, 2013b).

⁵⁸ 'Petroleum' has a specific legislative meaning in section 2 of the Crown Minerals Act 1991, which covers oil and gas.

⁵⁹ Section 7.3 of the Petroleum Programme requires that petroleum exploration permits will only be issued through a competitive allocation round (ie, the block offer). More information about block offers is available on the NZP&M website at <http://www.nzpam.govt.nz/cms/petroleum/block-offers>.

⁶⁰ Section 7.2 of the Petroleum Programme provides details of competitive 'staged work programme' and 'cash bonus' bidding (MBIE, 2013b).

⁶¹ The 'permit operator' is the person responsible for the day-to-day management of activities under the permit, and must hold a specified share of the permit (section 4.6 of the Petroleum Programme, MBIE 2013b).

c. Mining permit

A mining permit allows the extraction and production of petroleum. A mining permit application must give details of the operator's plans to extract, separate, treat and process the petroleum. The permit is exclusive and can last for up to 40 years, depending on the size of the discovery and the proposed rate of production. There is no size limit, but a mining permit area will typically be smaller than an exploration permit area.

The information requirements for a mining permit application are more extensive than for the other types of permits. A mining permit application must satisfy NZP&M's evaluation process, which includes:

- sufficient information to confirm, identify and delineate the petroleum accumulation
- an acceptable work programme to produce the petroleum in accordance with good exploration and oil field practice, so the field can be soundly managed and wastage avoided
- the proposed mining permit area and term are appropriate to the delineated accumulation of petroleum (determined as a result of the exploration phase)
- the operator has the technical and financial capabilities to deliver the proposed work programme.

Failure to meet all of these conditions to NZP&M's satisfaction would lead to the refusal of a mining permit. NZP&M publishes and regularly updates maps of all existing permits and permit applications.

Access to land

The Crown Minerals Act also sets out how a petroleum permit holder can access land. A permit holder must have an access arrangement with the land owner and occupier for all activities other than minimum impact⁶² ones. If agreement cannot be reached, the terms of access will be determined by an arbitrator. For minimum impact activities, the permit holder must give notice to the land owner and occupier.⁶³

Applications for an access arrangement are not available for areas listed in Schedule 4 of the Crown Minerals Act 1991 (for example, national parks), except for specific activities, as specified in section 61(1A).

Well abandonment

The Crown Minerals Act also applies at the well abandonment phase. Under Regulation 47 of the Crown Minerals (Petroleum) Regulations 2007, "A permit holder must supply to the chief executive⁶⁴ a well abandonment report not later than 40 working days after the well concerned is abandoned".

⁶² 'Minimum impact activity' has a specific legislative meaning in section 2 of the Crown Minerals Act 1991, and includes activities such as particular types of surveying and taking samples in certain circumstances.

⁶³ More information about land access is available at <http://www.nzpam.govt.nz/cms/minerals/permits/what-about-land-access>.

⁶⁴ In the Crown Minerals Act, and Regulations under that Act, the 'chief executive' means the Chief Executive of the Ministry of Business, Innovation and Employment (MBIE). However, the Health and Safety in Employment Act, and Regulations made under that Act, refer to the 'Secretary', which is the same as the Chief Executive of MBIE.

Under Regulation 47(2),

“a well abandonment report must:

- a) identify the well by name and number; and
- b) state the date when the well was abandoned; and
- c) give a summary of the reasons for the abandonment; and

state:

- (i) the positions of any cement plugs or bridge plugs; and
- (ii) details of any casing, tubing or surface down-hole equipment recovered; and
- (iii) details of any items left in the well.”

Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013

The HSE(PEE) Regulations provide for the management of potential impacts on the health and safety of people who operate installations for petroleum exploration and extraction. The Regulations only apply to an installation while it is a place of work (as there is no risk to employees after work has ceased) so post-abandonment is not covered by the Regulations.

Well operation regulations are covered by Regulations 63 to 76 (Part 6), which provide for:

- general duties on operators
- assessment of subsurface conditions
- design and construction duties
- well control equipment
- well examination schemes (see c below)
- well operation notification requirements (see b below).

Regulation 64 places a general duty on operators to ensure that a:

“well is designed, constructed, commissioned, equipped, operated, maintained, modified, suspended, and abandoned, so that

- so far as is reasonably practicable, there can be no unplanned escape of fluids from the well; and
- risks to the health and safety of persons from the well or anything in it, or from strata to which the well is connected, are as low as is reasonably practicable”.

Regulation 68 of the HSE(PEE) Regulations requires well operators to ensure the:

“well is designed and constructed so that, as far as is reasonably practicable:

- the well can be suspended or abandoned in a safe manner, and
- after suspension or abandonment, there can be no unplanned escape of fluids from the well or from the reservoir to which it led”.

Each of Regulations 64 and 68 have two criteria, which are conjunctive, so the enforcement agency can only undertake enforcement under these Regulations if both criteria have been met.

a. Safety case

From 30 June 2016, duty holders for most land-based installations (drilling units and production facilities) will not be able to carry out operations without an accepted safety

case under Regulations 21 to 43. Smaller, lower risk land-based production facilities will be exempt from this requirement. Notice requirements for 'lower-tier' production facilities are covered in Regulations 16 to 20 of the HSE(PEE) Regulations.

The safety case is a document prepared by the duty holder of an installation that:

- identifies any hazards having the potential to cause a major accident
- describes how the hazards are, or will be, controlled
- describes the safety management system in place to ensure the controls are effectively and consistently applied.

The purpose of a safety case is to demonstrate that the duty holder, in terms of health and safety, has both the ability and the means to control major accident hazards effectively. The safety case is a living document that deals with all health and safety risk across the life cycle of the well. The relevant duty holder may change over the life of the well, and the safety case may therefore become the responsibility of different duty holders at different times.

For well operations, the safety case must include the well control equipment (blowout preventers, mud systems, and associated control systems) and arrangements that will be used to control pressure in the well and prevent the uncontrolled release of petroleum.

A safety case is usually based on providing evidence that the relevant control measures reduce the health and safety risks to a level that is as low as reasonably practicable (ALARP). A safety case will usually be based on a combination of:

- appropriate risk acceptance criteria
- the comparative assessment of risks, costs and benefits
- comparison with recognised codes and standards
- benchmarking against industry good practice
- the adoption of the best available technology to reduce and manage risk
- a clear description and justification for the adoption or rejection of various control measures
- layers of protection analysis
- the exercise of appropriate engineering judgement in the design of equipment and facilities
- the practical test of equipment and systems *in situ*.

The safety case must also include a description of the arrangements in place for an independent and competent person to verify the suitability and state of good repair of safety critical plant and equipment – including well control equipment – on the installation.

Because hazards may vary in significance from well to well, the safety case is unlikely to be able to describe fully all foreseeable operating conditions and hazards. Consequently, the notice of well operations complements the accepted safety case by providing the additional information needed to establish that the intended well work will take place in conditions for which the effectiveness of major hazard control has already been demonstrated in the safety case.

b. Well operations notice

In accordance with Regulation 73, all drilling, completion, suspension, and abandonment operations need to be notified to WorkSafe New Zealand at least 21 days before they begin. Workover or well intervention operations involving an alteration to the construction of a well or the insertion of a hollow pipe into a well need to be notified to the WorkSafe New Zealand's High Hazards Unit at least 10 days before they begin. This required review period provides the High Hazards Unit with an opportunity to comment before operations begin.

The primary purpose of the well operations notice is to complement the safety case. The notice provides site-specific information to demonstrate to the High Hazards Unit how risks specific to the well are being managed. It must also include verification by an independent and competent person that the well design and the procedures to be used are fit-for-purpose (see 'well examination scheme' below).

Well operations may legally begin after the notice period, unless the High Hazards Unit has taken enforcement action to prevent them. The High Hazards Unit has tools to compel the well operator to take appropriate remedial before beginning operations (improvement notice), or to prohibit the activity if there are serious deficiencies (prohibition notice).

c. Well examination scheme

Under the HSE(PEE) Regulations the operator is required to have a scheme of examination for each well with a particular focus on health and safety. Under this type of regulation, it is a requirement for the well examiner to be both competent and independent. The role of the well examiner begins before well design and continues through to final abandonment.

The well examination scheme provides a way to ensure well integrity throughout the life cycle of each and every well in a well operator's inventory (from initial design through to final abandonment). Well integrity provides the first line of defence against an uncontrolled release of petroleum (blowout) by preventing a loss of well control.

The purpose of well examination is to provide an independent check to ensure that a well is designed, constructed, operated, maintained, modified, suspended and abandoned so that, as far as is reasonably practicable, there can be no unplanned escape of fluids from the well, and risks to the health and safety of persons from the well or anything in it, or from strata to which the well is connected, are as low as is reasonably practicable (Regulation 71(4) of the HSE(PEE) Regulations 2013).

Typically, a well examination scheme will cover:

- the complete life cycle of the well
- the operational life of the well, including operations, production and routine maintenance
- operations during well interventions and workovers
- modifications to the well
- suspension of the well, either during construction or after full construction
- well abandonment.

The person or persons carrying out the examination of wells must be competent and independent and may be either an individual or a corporate body.

Based on United Kingdom experience, it is expected that:

- well operators with enough activity level to justify the staff resources will appoint engineers who are sufficiently competent to be their well examiners
- multinational well operators will use their central support groups dedicated to providing technical support
- smaller well operators will contract with independent well-engineering companies to develop and operate their well examination schemes.

The High Hazards Unit will inspect well examination schemes to ensure the arrangements are robust and to confirm the person carrying out the examination work is competent and independent.

Hazardous Substances and New Organisms Act 1996

Under HSNO, all possible adverse effects of a hazardous substance on the environment throughout the life cycle of the substance (ie, from a substance's importation or manufacture to its disposal) are considered and controls are applied to manage these adverse effects. These controls are mostly drawn from the suite of hazardous substances regulations made under the Act.

The controls on hazardous substances are specific to their hazards. These controls are the same irrespective of the location and, in general, the specific use of the substance. The controls constitute minimum performance requirements that have to be met under HSNO. Councils may place additional and/or more stringent requirements on the storage, use, disposal or transportation of hazardous substances, but only when they are considered necessary for the purposes of the RMA (which may occur where there are site-specific requirements or particular location characteristics). Where the HSNO controls are sufficient to meet the purposes of the RMA, more stringent controls would not be necessary. This is provided for under section 142 of HSNO.

Regulations are made under HSNO that control, among other matters, the disposal of hazardous substances and emergency management. The Hazardous Substances (Disposal) Regulations 2001 set out how hazardous substances are to be disposed of, depending on their classification. The classification system for hazardous substances is set out in another regulation – the Hazardous Substance (Classification) Regulations 2001. Substances are classified depending on their: explosiveness (class 1); flammability (classes 2–4); ability to oxidise (class 5); toxicity (class 6); corrosiveness (class 8); and eco-toxicity (class 9).⁶⁵

Among other matters, the Hazardous Substances (Classes 6, 8 and 9 Controls) Regulations 2001 require the Environmental Protection Agency (EPA) to set out acceptable daily exposure values and tolerable exposure limits for class 6 substances. For class 9 substances (those that are eco-toxic), the Regulations specify the environmental exposure limit. There are regulations with a similar purpose covering class 1–5 hazardous substances that place controls on these substances to reduce the likelihood of unintended fire or explosion and to control the adverse effects of these.

The Hazardous Substances (Emergency Management) Regulations 2001 is another key regulation that manages hazardous substances on sites. Together with the Hazardous Substances

⁶⁵ There is no class 7.

(Identification) Regulations 2001, it sets out requirements for certain information to accompany hazardous substances. For example, information on corrosive substances must describe exposure symptoms and first aid procedures. Sites must have emergency response plans if the volume of hazardous substances on site is higher than what is listed in Schedule 4 of the Regulations. The Regulations also set out requirements for secondary containment systems to contain accidental spills and minimise their impact.

Typically, a well site operator is required to:

- hold and maintain a register of hazardous chemicals held on site⁶⁶
- have readily accessible copies of HSNO-compliant safety data sheets for all hazardous chemicals held on site (these contain detailed information of the properties of substances, their safe handling and storage, and how to contain and clean up any spillage)
- have identified areas for storing chemicals
- hold appropriate test certificates under HSNO (such as location, stationary container and approved handler test certificates)
- observe mandatory separation distances between tanks
- have HSNO-compliant signage (site entrance and tanks)
- hold an Electrical Wiring Certificate.

The operator must also:

- provide secondary containment (at least 110 per cent of the capacity of the largest tank) by constructing bunds around all hazardous substance storage containers and tanks on site or use ‘double-skinned’ tanks
- provide tertiary containment in the form of a perimeter drain and a skimmer pit that has in excess of 200 cubic metres of containment capacity⁶⁷
- ensure the skimmer oil valve is closed during operations on the site⁶⁸
- comply with the requirements for emergency response plans in the Emergency Management Regulations
- ensure that only approved handlers handle hazardous substances where this is a requirement of that particular substance
- maintain a detailed spill contingency plan for the well site (this must remain in place for the lifetime of the well site, and is part of the overall emergency response plan above).

⁶⁶ This is not strictly a legal requirement, but is good practice.

⁶⁷ This is not expressly a HSNO requirement, but could be seen as compliance way to comply with the requirements for secondary containment and emergency response plans.

⁶⁸ As above.

Note that hazardous substances have a specific definition under HSNO. The definition of hazardous substances under the RMA⁶⁹ is broader than the HSNO definition.⁷⁰ This means that some potentially hazardous substances are not controlled by HSNO but may be controlled by local authorities under the RMA (although any hazardous substances used in oil and gas development are highly likely to be covered the HSNO definition).

Monitoring and enforcement under HSNO

Compliance with HSNO in the workplace is enforced by WorkSafe New Zealand, and so the on-site management of substances approved under WorkSafe will tend to fall to Ministry of Business, Innovation and Employment inspectors.

Sections 97(1)(h)(ii) and 97(2)(a) of HSNO allow, but do not oblige, district and regional council officers who are on a site for RMA purposes to also conduct HSNO functions. Officers would have to be appropriately warranted (under sections 98 and 100 of HSNO) for the purpose.

⁶⁹ Section 2 of the RMA states: “hazardous substance includes, but is not limited to, any substance defined in section 2 of the Hazardous Substances and New Organisms Act 1996 as a hazardous substance”.

⁷⁰ Section 2 of HSNO states: “hazardous substance means, unless expressly provided otherwise by regulations, any substance (a) with 1 or more of the following intrinsic properties: (i) explosiveness: (ii) flammability: (iii) a capacity to oxidise: (iv) corrosiveness: (v) toxicity (including chronic toxicity): (vi) ecotoxicity, with or without bioaccumulation; or (b) which on contact with air or water (other than air or water where the temperature or pressure has been artificially increased or decreased) generates a substance with any 1 or more of the properties specified in paragraph (a)”.

Appendix G: Potential environmental effects at life-cycle stages

The table below provides a general overview of where potential risks and effects may occur at the individual well site level. Assessments of environmental effects will need to provide a full explanation of effects on a case-by-case basis. In regions or districts where there is identified potential for future development, cumulative effects should also be considered. Issues of cumulative development at a district and/or regional level may be addressed through the RMA plan-making process (discussed further in section 6). This table has been compiled using material sourced from Appendix 6 of the AEA publication (AEA Technology plc, 2012).

Effect, and guidelines reference	Site selection / preparation	Well design, drilling, cementing	Hydraulic fracturing	Well completion	Production	Abandonment
Ground water See sections 5.2, 5.4 and 5.5 of these guidelines	–	Potential risk of well blowouts, mitigated through quality of well design, drilling control, cement/casing quality	Risks if: <ul style="list-style-type: none"> • perforations affect cement quality • fractures extending beyond target formation to aquifer, biogeochemical reactions in fracturing fluid, pre-existing fractures / faults / other wells in vicinity act as conduits • surface spillage or inadequate storage of chemicals/waste 	Risk of waste spillage and seepage to groundwater	Potential risk of well failure, mitigated through quality of well design, drilling control, cement/casing quality and location Refracturing (if applicable)	Inadequate sealing could result in subsurface contamination
Surface water See sections 5.4 and 5.5	Runoff from earthworks	Potential drilling mud / cuttings spillage to surface water	Risks associated with improper handling of chemicals, flow back fluid / produced water (including transportation)	Waste transport / treatment at facilities – risk of spillage / inadequate sealing. Runoff from well pad removal	Refracturing (if applicable)	Potential sedimentation during well abandonment phase
Water resource use Section 5.3	–	–	Effects vary depending on geology type / water sourcing (eg, municipal, stream, aquifer)		Refracturing (if applicable)	–

Effect, and guidelines reference	Site selection / preparation	Well design, drilling, cementing	Hydraulic fracturing	Well completion	Production	Abandonment
Air discharge See section 5.6	Minor risk of diesel spillage (fugitive emissions) from construction equipment	Minor risk of diesel spillage (fugitive emissions) from drilling equipment	Emissions from gas leakage, flow back / produced water Diesel from fracturing pumps	–	Flaring Fugitive emissions if leakage Refracturing (if applicable)	Fugitive from inadequate sealing
Noise See section 5.8	Shot holing (surveying) Earthworks machinery	Well head construction / drilling equipment noise Vibration from drilling	Water pumps / well equipment	Machinery to remove well pad	Noise from pipeline construction Refracturing (if applicable)	–
Traffic See section 5.7	Vehicle movements (shot holing / laying geophone patch / reinstatement / well site preparation)	Heavy vehicle movements – associated with drilling	Heavy vehicle movements – transport of water / chemicals	Heavy vehicle movements – transport of waste	Transportation of materials / equipment	Some vehicle movement associated with abandonment process
Visual amenity See section 5.9	Site buildings, stockpiles, fencing, heavy machinery	Well head, drilling rig / associated activity	'Frack spread' equipment	Waste water equipment Positive – infrastructure removal	Site equipment (effect much less than hydraulic fracturing stage) Pipelines Refracturing if applicable	Some well head equipment may remain
Induced seismicity See section 5.10	–	–	Low level fracturing	Low level in deep well injection	Low level from refracturing (if applicable)	–

Appendix H: Chemicals used in hydraulic fracturing, by product function

The table below provides a list of chemicals used most often in hydraulic fracturing operations (grouped by product function). This table is sourced from Taranaki Regional Council (2013b, pages 51–53). Note that some chemicals are listed more than once (eg, methanol), as they have more than one product function and some chemicals are referred to by different names (eg, ethylene glycol has multiple names, such as glycol alcohol and dihydroxyethane). Users should refer to the chemical's chemical abstracts service number for reference.

This is not an exhaustive list of all chemicals which may be used in a hydraulic fracturing operation, and any application for resource consent to undertake hydraulic fracturing should detail all chemicals proposed to be used.

Chemical name	CAS (chemical abstracts service) number	Chemical purpose
Acid		
Hydrochloric acid	007647-01-0	Helps dissolve minerals and initiate cracks in the rock
Biocides		
Glutaraldehyde	000111-30-8	Eliminates bacteria in the water that produce corrosive by-products
Quaternary ammonium chloride	012125-02-9	Eliminates bacteria in the water that produce corrosive by-products
Quaternary ammonium chloride	061789-71-1	Eliminates bacteria in the water that produce corrosive by-products
Tetrakis hydroxymethyl-phosphonium sulphate	055566-30-8	Eliminates bacteria in the water that produce corrosive by-products
Breakers		
Ammonium persulphate	007727-54-0	Allows a delayed break down of the gel
Sodium chloride	007647-14-5	Product stabiliser
Magnesium peroxide	014452-57-4	Allows a delayed break down of the gel
Magnesium oxide	001309-48-4	Allows a delayed break down of the gel
Calcium chloride	010043-52-4	Product stabiliser
Clay stabilisers		
Choline chloride	000067-48-1	Prevents clays from swelling or shifting
Tetramethyl ammonium chloride	000075-57-0	Prevents clays from swelling or shifting
Sodium chloride	007647-14-5	Prevents clays from swelling or shifting
Corrosion inhibitors		
Isopropanol	000067-63-0	Product stabiliser and/or winterising agent
Methanol	000067-56-1	Product stabiliser and/or winterising agent
Formic acid	000064-18-6	Prevents the corrosion of the pipe
Acetaldehyde	000075-07-0	Prevents the corrosion of the pipe
Crosslinkers		
Petroleum distillate	064741-85-1	Carrier fluid for borate or zirconate crosslinker

Chemical name	CAS (chemical abstracts service) number	Chemical purpose
Hydrotreated light petroleum distillate	064742-47-8	Carrier fluid for borate or zirconate crosslinker
Potassium metaborate	013709-94-9	Maintains fluid viscosity as temperature increases
Triethanolamine zirconate	101033-44-7	Maintains fluid viscosity as temperature increases
Sodium tetraborate	001303-96-4	Maintains fluid viscosity as temperature increases
Boric acid	001333-73-9	Maintains fluid viscosity as temperature increases
Zirconium complex	113184-20-6	Maintains fluid viscosity as temperature increases
Borate salts	N/A	Maintains fluid viscosity as temperature increases
Ethylene glycol	000107-21-1	Product stabiliser and/or winterising agent
Methanol	000067-56-1	Product stabiliser and/or winterising agent
Friction reducers		
Polyacrylamide	009003-05-8	'Slicks' the water to minimise friction
Petroleum distillate	064741-85-1	Carrier fluid for polyacrylamide friction reducer
Hydrotreated light petroleum distillate	064742-47-8	Carrier fluid for polyacrylamide friction reducer
Methanol	000067-56-1	Product stabiliser and/or winterising agent
Ethylene glycol	000107-21-1	Product stabiliser and/or winterising agent
Gelling agents		
Guar gum	009000-30-0	Thickens the water to suspend the sand
Petroleum distillate	064741-85-1	Carrier fluid for guar gum in liquid gels
Hydrotreated light petroleum distillate	064742-47-8	Carrier fluid for guar gum in liquid gels
Methanol	000067-56-1	Product stabiliser and/or winterising agent
Polysaccharide blend	068130-15-4	Thickens the water to suspend the sand
Ethylene glycol	000107-21-1	Product stabiliser and/or winterising agent
Iron controls		
Citric acid	000077-92-9	Prevents precipitation of metal oxides
Acetic acid	000064-19-7	Prevents precipitation of metal oxides
Thioglycolic acid	000068-11-1	Prevents precipitation of metal oxides
Sodium erythorbate	006381-77-7	Prevents precipitation of metal oxides
Non-emulsifiers		
Lauryl sulphate	000151-21-3	Used to prevent the formation of emulsions in the fracture fluid
Isopropanol	000067-63-0	Product stabiliser and/or winterising agent
Ethylene glycol	000107-21-1	Product stabiliser and/or winterising agent
pH adjusting gent		
Sodium hydroxide	001310-73-2	Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers

Chemical name	CAS (chemical abstracts service) number	Chemical purpose
Potassium hydroxide	001310-58-3	Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers
Acetic acid	000064-19-7	Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers
Sodium carbonate	000497-19-8	Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers
Potassium carbonate	000584-08-7	Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers
Scale inhibitors		
Copolymer of acrylamide and sodium acrylate	025987-30-8	Prevents scale deposits in the pipe
Sodium polycarboxylate	N/A	Prevents scale deposits in the pipe
Phosphonic acid salt	N/A	Prevents scale deposits in the pipe
Surfactants		
Lauryl sulphate	000151-21-3	Used to increase the viscosity of the fracture fluid
Ethanol	000064-17-5	Product stabiliser and/or winterising agent
Naphthalene	000091-20-3	Carrier fluid for the active surfactant ingredients
Methanol	000067-56-1	Product stabiliser and/or winterising agent
Isopropyl alcohol	000067-63-0	Product stabiliser and/or winterising agent.
2-Butoxyethanol	000111-76-2	Product stabiliser

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