Report to Hawke's Bay Regional Council

Oil and Gas Plan Change - Background Information Review

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1 Executive Summary

The Hawke's Bay Regional Council is preparing a draft plan change, which will consider options for prohibiting oil and gas activities in the region's productive aquifers, aquifer recharge areas, surface water bodies (i.e. rivers, lakes, streams, wetlands and estuaries) and the coastal marine environment.

To help support the plan change and facilitate community feedback, a background information review has been undertaken and is reported in this document. The report is organised around the following areas, which are briefly summarised below:

- Oil and Gas Activities
- Oil and Gas in Hawkes Bay
- Regulatory Environment
- Environmental Context
- Economic Context
- Environmental Risk

The report also identifies three possible options for the plan change. These are described at a high level and are intended for facilitating community discussion. They are not the current position of HBRC or the Regional Planning Committee. The Council is keen to understand the views of tangata whenua and the wider community before finalising the plan change options and deciding how best to progress.

It is important to note that this is a literature review of existing information. It is not a technical review and does not provide any technical analysis. However, it does identify areas where there is uncertainty and a general lack of information. The potential for the oil and gas industry in Hawke's Bay and the associated environmental risks are not well understood. This is understandable, given the industry has very little experience in Hawke's Bay and no commercial discoveries of oil or gas have been made.

Following community engagement and feedback, consideration will be given to any technical information that would better support the plan change. The cost of commissioning technical advice will need to be balanced with the benefit it will bring to the plan change. Ultimately, without more seismic surveying, exploratory drilling and resource appraisal, the level of environmental risk and economic benefit to the region will remain uncertain.

1.1 Oil and Gas Activities

The oil and gas industry involves a number of activities that are relevant to HBRC's environmental responsibilities under the RMA. This includes:

- Seismic survey assessment
- Well design and construction
- Well completion and production

- Hydraulic fracturing
- Waste disposal

1.2 Oil and Gas in Hawkes Bay

- Hawkes Bay lies within the East Coast Basin, an area of oil and gas potential.
- There are numerous oil and gas seeps throughout the region that have attracted commercial interest for over 100 years.
- The Whangai and Waipawa rock formations below central and coastal Hawkes Bay have shown the most potential as oil and gas producing layers.
- Based on comparisons with similar oil and gas producing areas, it is likely that hydraulic fracturing will be required to extract oil and gas from these formations.
- More seismic surveying and exploratory drilling is required to understand the commercial potential and methods required to extract the resource.
- Two exploratory wells recently targeted the Whangai and Waipawa formations near Dannevirke and Gisborne. One was abandoned, the other reached it's target. The detailed analysis is not publically available as it is commercially sensitive.
- There is unlikely to be any onshore exploration in the next ten years. Beyond that, a number of economic and political factors would need to align for renewed interest in the region.

1.3 Regulatory Environment

- The government issues permits to prospect, explore and extract oil and gas. They receive financial royalties from commercial production.
- HBRC is responsible for the regulation of the environmental impacts of oil and gas activities. This includes the impacts on soil, air, fresh and coastal water.
- The HBRC resource management plans do not have specific objectives or policies in relation to oil and gas activities.
- The Regional Coastal Environment Plan contains some rules for oil and gas exploration activities
- The Regional Resource Management Plan does not have any specific rules for oil and gas activities but resource consent is still required for most activities that have the potential to impact the environment.
- WorkSafe and Maritime New Zealand have responsibilities for health and safety and oil spill procedures respectively

1.4 Environmental Context

- The Heretaunga and Ruataniwha aquifer systems are nationally significant groundwater resources.

- Lakes and rivers are the lifeblood of the region. They are ancestors to tangata whenua; they provide invaluable ecosystem services; they supply food, water, power and recreational opportunities.
- Hawkes Bay has been shaped by earthquakes; there are many active faults onshore and offshore.
- All of New Zealand is at risk from tsunami but particularly the East Coast.
- Flooding is Hawke's Bay most common natural hazard. Even with large investments in flood protection works, rivers still have the potential to cause significant damage.
- There are 20 Areas of Significant Conservation Value listed in the Regional Coastal Environment Plan.
- Other than a few species, very little is known about the marine mammals in the waters off Hawke's Bay.
- Hawke's Bay has traditionally been known as a "mixed species fishery" but some species such as red gurnard, snapper, hapuka, kahawai, terakihi and trevally are thought to have declined substantially over the last 5-10 years. There are significant gaps in understanding around this and other aspects of fisheries management within the region.

1.5 Economic Context

- The oil and gas industry makes a significant contribution to the New Zealand economy.
- Even as world economies adapt to cleaner technologies, oil and gas is likely to play an important role in economic and social well-being.
- The Hawkes Bay economy is dominated by the primary and manufacturing sectors. Like many other regions, there are concerns around the lack of economic diversity, adaptation and job creation. There are numerous challenges to addressing this.
- Oil and gas has made a significant contribution to the strength of the Taranaki economy but it is not immune to the challenges faced by other regions.

1.6 Environmental Risk

There are a number of environmental risks associated with the oil and gas industry. This report has grouped them into the following areas:

1.6.1 Well Integrity

- Modern oil and gas wells are carefully designed and the rate of failure is low. However, it is still a reality.
- Oil and gas wells consist of multiple layers of cemented casings designed to separate the well from the surrounding geological layers, including fresh water layers.
- Drilling conditions in Hawkes Bay will be different to Taranaki. There are likely to be higher drilling pressures at shallower depths.
- A blowout is the uncontrolled release of oil or gas from a well after pressure control systems have failed. Modern well design means blowouts are less frequent but they still occur.

- Overtime, the well casing and cement can deteriorate. If not properly managed, abandoned wells present an ongoing risk.

1.6.2 Hydraulic Fracturing

- Hydraulic fracturing creates significant pressure and temperature changes on a well.
- Not much is known about the underground network of fractures created by fracking. However, the greater the distance between groundwater layers and the oil or gas layers, the less risk of groundwater contamination.

1.6.3 Waste Management

- The waste from oil and gas activities needs to be managed carefully to avoid soil or water contamination.
- Solid waste is made up of drilling muds and rock cuttings and is usually disposed of through landfarming in Taranaki. Whether landfarming will be an appropriate way of disposing of waste from oil and gas wells outside Taranaki is unclear.
- Produced water is usually disposed of through deep well injection.

1.6.4 Seismicity

- Deep well injection and hydraulic fracturing can trigger small earthquakes. The level of risk has not been assessed on the East Coast, which is the most seismically active region in New Zealand.

1.6.5 Hazardous Substances

- There are a variety of hazardous substances required for oil and gas drilling; these are mostly additives used in drilling muds and hydraulic fracturing fluids.
- Spills and leaks of hazardous substances are the most common cause of soil and water contamination, primarily through equipment failure and human error.

1.6.6 Air Discharges

- The main air discharge is from flaring gas that cannot be processed or sold.
- At times there is an operational requirement to discharge well fluids to a flare pit, which may require combustion.
- Air emissions from landfarming have been found to be barely distinguishable from the background air quality.

1.6.7 Coastal Marine Area

- Offshore oil and gas drilling presents a unique set of challenges and seems to have a higher risk of well failure.
- The risk of oil spills from oil and gas production facilities is very low in New Zealand compared to the risk from vessels travelling around and through New Zealand.
- Natural sources of noise are important for marine animals to sense their environment. The effects of noise and vibration from seismic surveys is poorly understood for many species, especially fish.

- Collisions, entanglement in surface structures, noise, vibration and ecosystem changes such as prey distribution and abundance are all impacts from offshore activities that can affect marine mammals.
- Fisheries displacement is unlikely to be an issue unless there is a significant amount of offshore drilling activity but the effects on fish behaviour is unclear.

1.7 Plan Change Options

Three potential options for the plan change have been put forward to manage the risks from oil and gas activities. These options are preliminary and for the purpose of stakeholder discussions. They may change after stakeholder engagement or after a more detailed policy analysis.

1.7.1 Modified Status Quo

- Some basic changes to strengthen the assessment processes for oil and gas drilling
- Activity status strengthened to non-complying for sensitive areas already identified in the RRMP and RCEP. This would include:
    - Areas of Significant Conservation Value (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
- All other activities to retain their current activity status.

1.7.2 Prohibited Activity Status – Narrow Focus

- Prohibited activity status for specific areas. This would include:
    - Areas of Significant Conservation Value (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
- Seismic surveying and other low impact activities to retain current activity status
- Strengthen assessment policies for other areas

1.7.3 Prohibited Activity Status – Wide Focus

- Prohibited activity status with a wider spatial scope. This would include:
    - Coastal marine area and coastal margins (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
    - Terrestrial areas that provide a known and important aquifer recharge function (yet to be determined)
    - Any other protected terrestrial areas (yet to be determined)
- Seismic survey to be a discretionary activity in sensitive marine areas
- Strengthen assessment policies for all other areas.

2 Introduction to Plan Change

The Hawke's Bay Regional Council is preparing a draft plan change, which will consider options for prohibiting oil and gas activities. The plan change would consider the merits of prohibition in the region's productive aquifers, aquifer recharge zones, surface water bodies (i.e. rivers, lakes, streams, wetlands and estuaries) and the coastal marine environment.

The Regional Planning Committee, which is driving the Plan Change, is conscious there is significant public interest in oil and gas exploration and there is a lot of debate in the community around the environmental issues and risks associated with these activities, both on and offshore.

The objectives of the plan change are to:

- Avoid contamination of freshwater and coastal environments as a result of oil and gas activities
- Avoid conflicts with other values and uses of water resources
- Provide certainty and avoid unnecessary costs for resource users and the wider community
- Consider a precautionary approach to oil and gas activities where there is insufficient information or uncertainty around the risks to freshwater resources and the coastal marine area.

2.1 Background

In recent years, HBRC has heard concerns from the community about the risks of drilling for oil and gas (fracking in particular) based on experiences from around the world. Some have demanded HBRC impose a 'moratorium' on oil and gas exploration activities in Hawke's Bay. However, current laws do not allow a council to place a moratorium on a particular type of activity simply by passing a resolution, and certainly not without wider community input. One option available to the Regional Council is to draft and propose an amendment to rules in its RMA planning documents to prohibit specific types of effects and/or activities arising from oil and gas activities.

Recently, Hastings District Council has introduced rules in its new District Plan that prohibit some oil and gas exploration activities over unconfined parts of the Heretaunga Plains aquifer. Those rules do not apply to other water bodies in other parts of Hastings District or the wider Hawke's Bay region.

In 2016, the Council considered two reports on the effectiveness of current regional plans in regulating oil and gas activities in Hawke's Bay. One of those reports in particular followed on from a wider-reaching report by the Parliamentary Commissioner for the Environment in June 2014, which looked at environmental oversight and regulation of oil and gas onshore drilling in New Zealand.

Meanwhile New Zealand Petroleum and Minerals (a division of the Ministry of Business Innovation and Employment) continued with its regular annual Block Offer processes.

For the past few years, Block Offers have related to offshore parts of Hawke's Bay – no onshore areas. In 2016, the Regional Council submitted in opposition to the [then] proposed offshore Block Offer area. It requested removal of those proposed Blocks which were inside the 12 nautical mile limit (approx. 22km from the shoreline). However, the Minister of Energy and Resources only removed those Blocks inside three nautical miles. Within the 12 nautical mile limit of Hawke's Bay region, the regional council has a role and responsibility for promoting sustainable management of natural and physical resources under the RMA. Those responsibilities can include controlling adverse effects of activities on the environment (such as petroleum exploration and development). Similar resource management responsibilities also apply onshore in relation to fresh water.

2.2 Next Steps

During the remainder of 2017, HBRC will consult with key stakeholders, iwi and statutory agencies such as other local councils. If a regional plan change still proves worthwhile, a proposed plan change will be released for public comment.

For more information on this plan change visit the HBRC website: http://www.hbrc.govt.nz/our-council/policies-plans-strategies/plan-changes/oil-and-gas-regulation/

3 Oil and Gas Activities

3.1 Seismic Survey assessment

The first stage in oil and gas exploration is seismic surveying. This is used to map the structure of subsurface geology to identify possible petroleum reservoirs. The data obtained and the subsequent modelling of this data, allows exploration companies and regulators to characterise geological formations. On land, seismic surveying involves digging holes along a survey line and setting off small explosive charges. Offshore, survey boats create sound waves that reflect the geological layers below.

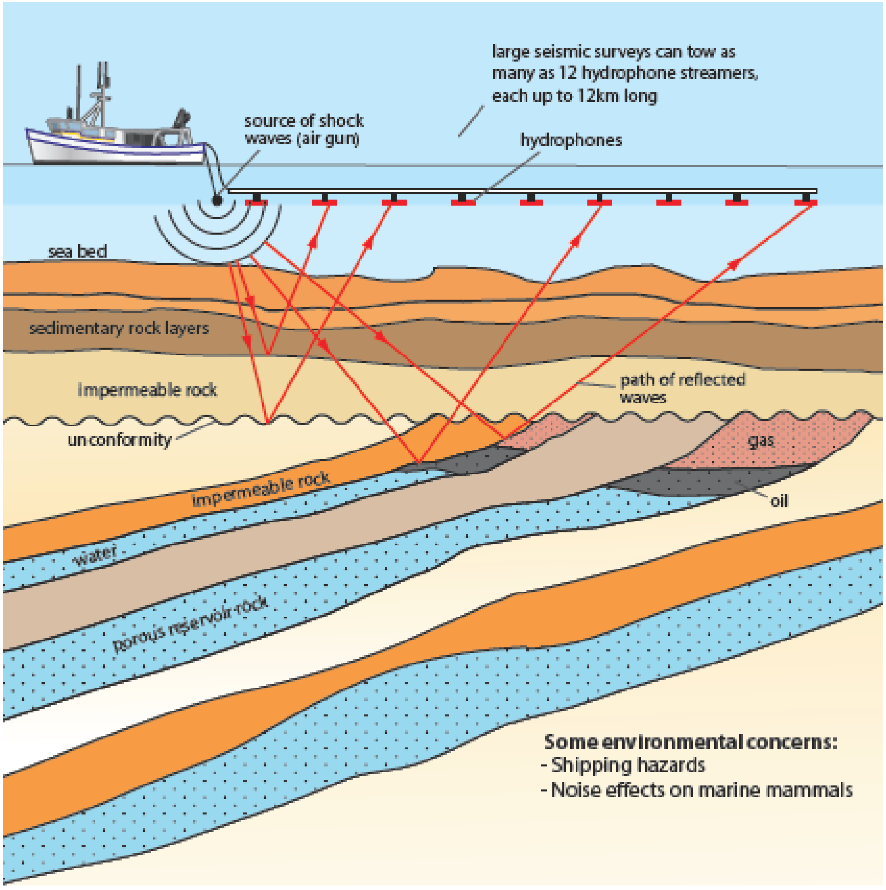


Figure 1: Seismic Surveying (Source: University of Otago)

3.2 Well design and construction

Following seismic and other geological data analysis, drilling an exploration well is the next step to determine whether oil and gas is present in economic quantities.

A well contains multiple steel casings inside each other and cemented in place. 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. The casings isolate the well from surrounding rock and fresh water layers and provide a conduit for oil and gas to flow to the surface. They also control subsurface pressure.

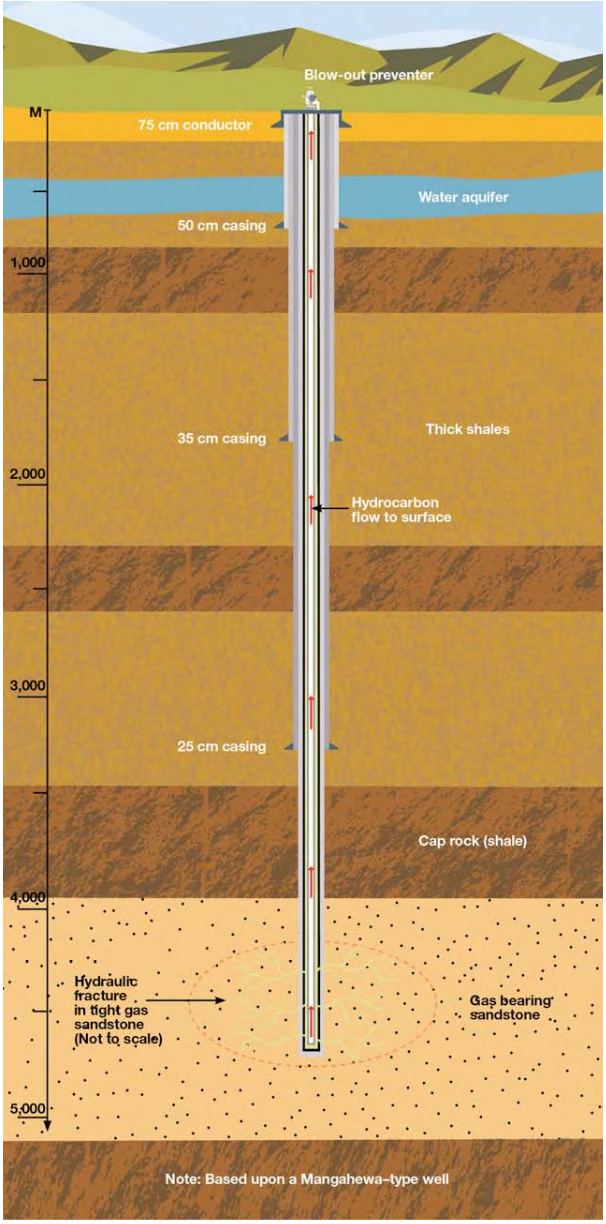


Figure 2: Well schematic of a Taranaki tight gas well, showing four levels of casing. Source Power Projects Ltd, 2012.

At the surface, a blowout preventer is installed, which is a specialised piece of equipment through which the drilling 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.

3.3 Well Completion and Production

A production well is designed and constructed in a similar way to an exploratory well and may be the same well. When the well is ready for production, the blowout preventer is replaced with a well head that contains pressure valves and connects to production facilities.

This stage would also involve the development of pipelines and processing facilities if oil and gas is recovery is commercially viable.

3.4 Hydraulic Fracturing

Hydraulic fracturing is a well stimulation technique in which rock is fractured by a pressurised liquid. The process involves the high-pressure injection of 'fracking fluid' into a well to create cracks in the underground formations through which oil and gas will flow more freely. When the hydraulic pressure is removed from the well, small grains of hydraulic fracturing proppants (either sand or aluminium oxide) hold the fractures open. A single well can drill and perforate multiple sections along a length of several kilometres. Hydraulic fracturing is usually required to facilitate production from shale, which is characterised by low permeability.

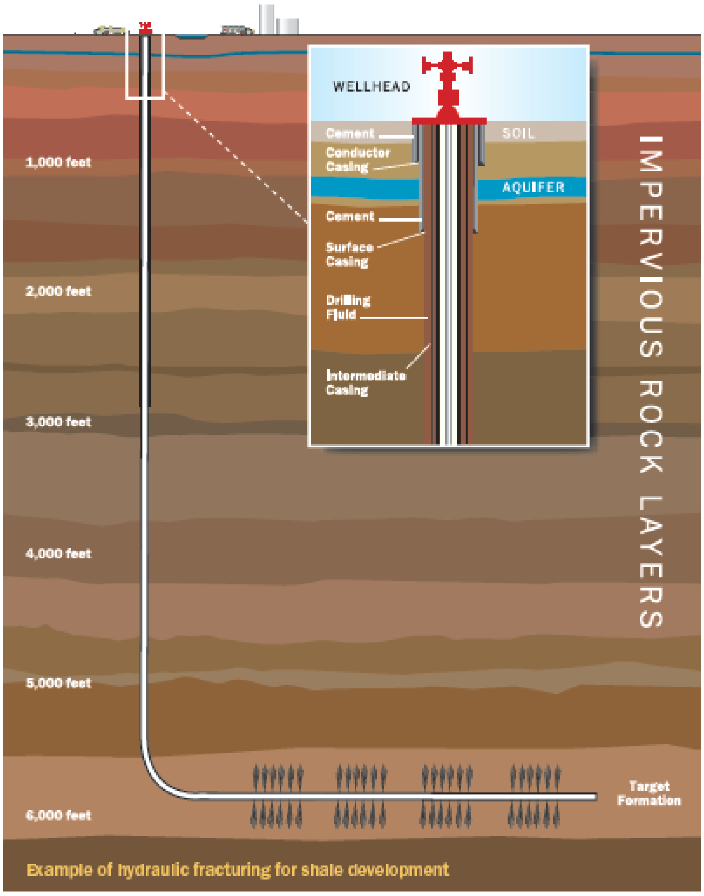


Figure 3: Hydraulic Fracturing (Source: American Petroleum Institute)

3.5 Well Abandonment

Abandoning a well typically involves plugging sections of the well with cement to prevent material migrating between geological layers, leaking into groundwater or leaking at the surface. The well head is removed and a cap is sealed in the well, which is then buried below the surface.

3.6 Waste Disposal

Oil and gas operations produce waste as part of their operations, sometimes in large volumes. This can be broadly categorised into solid and liquid waste.

3.6.1 Deep Well Injection

Deep well injection is often used to dispose of liquid waste. It involves injecting the waste material back into depleted oil and gas reservoirs or into another underground formation that is capable of absorbing the liquid waste. The depth of injection wells can range from a few hundred to a few thousand metres depending on the geological conditions.

The injection of liquid waste from oil and gas sites into the ground is a well-established method and has been used in Taranaki since the 1970s. It is also a common waste disposal method in the geothermal industry. As noted by the PCE Report:

"Almost all the liquid waste is produced water that has come up out of the ground with the oil and gas, so returning it deep underground makes sense."

Solid waste cannot be disposed of in this way as it is likely to block the injection process. It is generally disposed of to land.

3.6.2 Land Disposal

Landfarming is sometimes used to dispose of solid wastes such as drill cuttings, drilling muds, sludges, and contaminated soil. The solid wastes are spread as a slurry on the land and mixed in with the top soil and sometimes other organic matter such as sawdust. Over time, microbes in the soil break down the hydrocarbons (but not the salts or heavy metals that are sometimes present). Eventually, the land can be resown in pasture.

Several sites in Taranaki have been consented for the disposal of rock cuttings and drilling muds in this way. The focus has been on coastal sandy soils where sand dunes have been re-contoured and re-sown back to pasture. This has been seen as a way to significantly increase the agronomic value of these otherwise poor farming soils.

Mix-bury-cover is also used to dispose of solid waste. The waste is buried, often in a sump hole beside the well, after being mixed with soil. It should be buried above the water table, but below the reach of plant roots. Because the waste is not mixed with soil at the surface (as it is with landfarming) microbial breakdown of hydrocarbons is much slower. The PCE noted that there were 38 sites in Taranaki where this method has been used.

4 Oil and Gas in Hawke's Bay

Hawke's Bay lies within the East Coast Basin, an area of oil and gas potential.

Although the Taranaki Basin is New Zealand's main oil and gas exploration region, the East Coast (among other areas) has attracted interest as an emerging area of oil and gas potential. The East Coast Province covers at least 180,000 km2, and incorporates the Raukumara Basin, the East Coast Basin and the Pegasus Basin, which all have a common geological history. The East Coast Basin includes the onshore and offshore areas of Hawke's Bay.

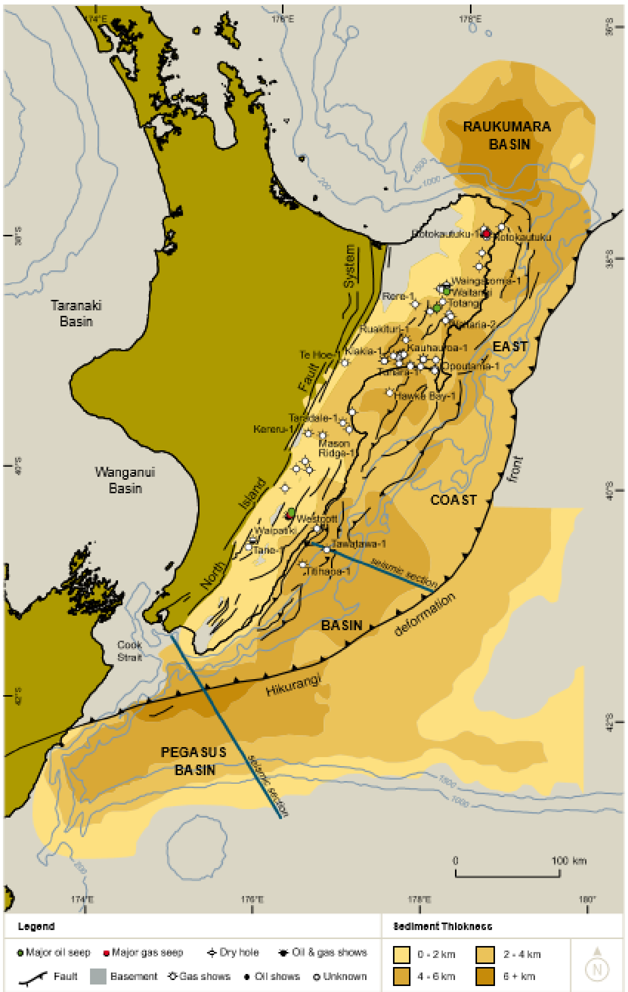


Figure 4: East Coast Basin. (Source: New Zealand Petroleum and Minerals)

4.1 Geology

The presence of commercial accumulations of oil and gas is dependent on a number of geological factors such as:

- The deposition and preservation of adequate source rocks
- A suitable timescale and conditions for maturation of the source rocks
- The generation and expulsion of oil and gas from the source rocks

- Migration of the oil and gas to porous and permeable reservoirs bounded by geological seals.

4.1.1 Conventional vs Unconventional

Hydraulic fracturing may be required to extract oil and gas from the low permeability rocks of the East Coast Basin.

“Conventional” and “unconventional” are terms that are often used when discussing oil and gas prospecting, exploration and production.

Conventional exploration targets oil and gas that has migrated into geological ‘traps’. This is the traditional concept that people may have of a well tapping into a discrete underground reservoir of oil or gas. Up until about 2010, the majority of exploration across the East Coast Basin was ‘conventional’, targeting anticlines and sedimentary traps. This has failed to provide commercial discoveries.

Unconventional exploration is focussed on oil and gas within geological units that have low permeability that require hydraulic fracturing for extraction. It has only been with the development of modern fracking methods and subsequent advances in horizontal drilling, that these deposits have become commercially accessible. Hydraulic fracturing will potentially be necessary to unlock oil and gas in the low permeability formations that frequently occur within the East Coast Basin.

It should be noted that the International Energy Agency do not recognise any universally accepted definition for "conventional" or "unconventional" and has observed that the terms do not remain fixed. Over time, resources that were considered unconventional can migrate into the conventional category as economic and technological conditions evolve. Extraction techniques that are typically associated with “unconventional” oil have been used to extract “conventional” oil reserves. As the use of newer technologies have advanced, "unconventional" oil recovery has become the norm not the exception, especially in the US.

4.1.2 Hawke’s Bay Geology

The Whangai and Waipawa rock formations below central and coastal Hawkes Bay have shown the most potential as oil and gas producing layers.

The Whangai and Waipawa formations are regarded as being the two most important petroleum source rocks in the East Coast Basin. On the basis of geological mapping and a few drill holes, the formations are known to occur in northern and eastern Wairarapa, central and coastal Hawke’s Bay, and the Gisborne-Raukumara areas. The formations seem to be absent from almost all of central and southern Wairarapa, and western Hawke’s Bay, including the Ruataniwha Plains.

Preliminary work done by GNS indicates that the Whangai Formation has low to moderate source rock potential, although individual parts of the formation vary with respect to the quality of source rocks. Source rock properties of the Waipawa Formation indicate that this unit has high generative capacity. However, they consider it is immature or marginally mature where it outcrops and it’s subsurface maturity remains untested. Oil will only be present if the formations are at sufficient depth (and therefore had sufficient heat and pressure) to generate it.

The current depth places the formations outside or just inside the oil generation window. However, the geological history suggests that they will have been substantially deeper in the recent past and will have produced oil at that time, which is reflected by the seeps throughout the region.

GNS have concluded that oil seeps south of Hawke Bay can be typed to the Waipawa Formation source, whereas oil seeps north of Hawke Bay can be typed to the Whangai Formation. They suggest that additional areas where the Whangai and Waipawa formations lie in the oil window may exist, but based on current information they cannot define them any further.

More seismic surveying and exploratory drilling is required to understand the commercial potential.

Tag Oil has previously used the Bakken Shale oil fields in North America as a comparison for these formations. However, GNS consider the Waipawa and Whangai formations not to be true shales in the manner of the Bakken oil fields. They view them as formations of inter-bedded sands, silts and carbonaceous clay/silt stones. Oil and gas generated in these formations is likely to migrate into the adjacent silts and sands, which will be the permeable sources of oil or gas. GNS suggest a better analogy for these formations may be that of conventional ‘tight’ oil or gas plays. This means oil or gas that has migrated from it’s source rocks to reservoirs of low permeability. Hydraulic fracturing or other advanced drilling methods may be required to access the resource. If this is the case it is possible that accessing the oil and gas would involve less intensive development than the Bakken Shale oil fields but potentially produce lower volumes.

GNS describes any potential oil or gas from these formations as presently ‘undiscovered’. Seismic surveys have been acquired in some areas, but much of the data is older and coupled with difficult terrain and the complex geology makes interpreting it over wide areas impossible. Other information on these formations has been obtained from where they outcrop on the surface but these points are at the edges of the basin and have been exposed to the elements. This makes inferring their rock properties at depth subject to uncertainty. These difficulties are compounded by the complex geological history of the region. Most importantly, no oil or gas has ever been produced directly from the Whangai or Waipawa formations.

All these factors mean the real productive and commercial potential of these formations is unknown, and requires more wells and seismic investigation to commercially appraise it.

4.2 Oil and Gas Exploration

4.2.1 Historical Exploration

Oil and gas seeps throughout the East Coast have attracted commercial interest for over 100 years

Oil and gas exploration on the East Coast has been happening for more than 100 years. There have been numerous wells drilled and surveys conducted, but no proven commercial reserves have been discovered.

Over 300 known onshore oil and gas seeps occur, attesting to active petroleum systems. More than 40 wells have been drilled since 1955. A sub-commercial gas discovery was made in 1998 at Kauhauroa in northern Hawke's Bay. Small historical oil production has also occurred near the Waitangi and Totangi oil seeps, north of Gisborne.

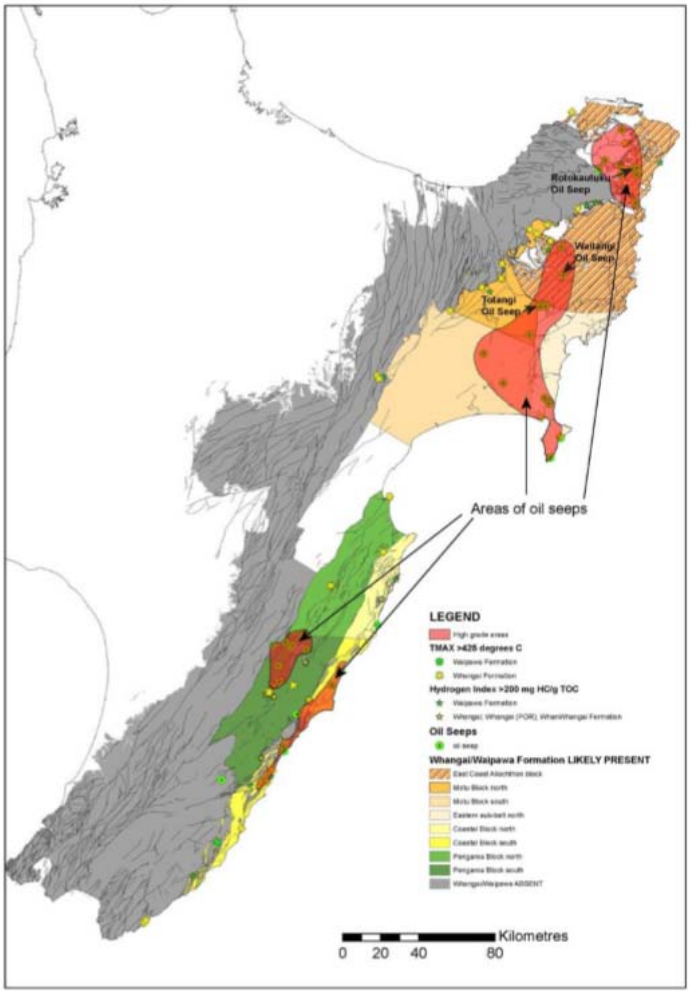


Figure 5: Distribution of oil seeps in the onshore East Coast region (in red). (Source: GNS Science)

Only three wells have been located offshore and all encountered significant gas shows:

- Hawke Bay-1 was drilled to a depth of 2,372m in 1976
- Titihaoa-1 was drilled to a depth of 2,727m in 1994
- Tawatawa-1 was drilled to a depth of 1,560m in 2004

The onshore component of the East Coast Basin is considered to be lightly explored (in terms of seismic surveys) in comparison to the offshore part of the basin. This is in part due to the rugged topography that often results in poor resolution seismic data.

4.2.2 Recent Exploration

Two exploratory wells recently targeted the Whangai and Waipawa formations near Dannevirke and Gisborne. One was abandoned, the other reached it's target. The detailed analysis is not publically available as it is commercially sensitive.

Given that conventional exploration has failed to discover commercial accumulations of oil and gas in Hawke's Bay region, recent exploration has focussed on more unconventional plays associated with the Whangai and Waipawa formations.

At the height of the most recent oil price peak in 2012, ten onshore exploration permits were either held or under application by international oil companies to explore (both conventional and unconventional) reserves within the East Coast Basin.

Since 2010, exploration by TAG Oil and the New Zealand Energy Corporation culminated in successful drilling of the Waipawa and the Whangai formations, although none of these wells were production tested.

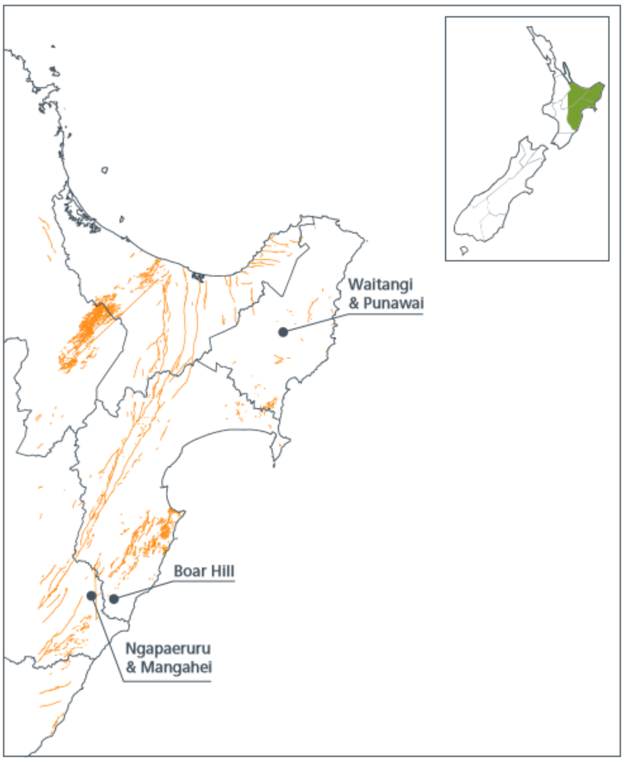


Figure 6: Location of Ngapaeruru and Waitangi well sites. (Source: GNS Science, Statistics NZ)

Ngapaeruru-1

A deep exploration well drilled east of Dannevirke in April 2013 reportedly encountered gas from the target formations. TAG Oil reported that the well reached a depth of 1417 metres after successfully drilling through the Waipawa and Whangai formations, which was the main objective of the well. They reported excellent mud gas shows (which indicate the presence of gas zones or soluble gas in oil) were recorded.

TAG's Chief Operating Officer was quoted as saying:

'Our team did an excellent job drilling this first ever unconventional target in the East Coast Basin ….. Diligence and communication made certain that the occasionally tricky drilling conditions in this Basin were handled as planned: safely, efficiently, and with no environmental incidents. The fact that early mud-log analysis has returned wet gas and oil indications is both encouraging and very exciting. We're looking forward to more detailed results once analysis of the data acquired from the Ngapaeruru-1 well is complete.'

Further details are still confidential.

Figure 7: Ngapaeruru-1 exploratory well site (Source: TAG Oil)

Waitangi Valley-1

The Waitangi Valley-1 well, drilled north of Gisborne in July 2014, does not seem to have been as successful. TAG Oil plugged and abandoned the well in the interest of safety after encountering extreme drilling conditions, including high pressure shallow hydrocarbon zones.

CEO Garth Johnson stated:

'Waitangi Valley-1 encountered very high hydrocarbon zone pressures at shallow depths that cannot easily be compared to anywhere else in the world. We understood this program would be challenging and we encountered extremely difficult drilling conditions in the first 856m of drilling. After consulting with worldwide drilling experts and considering all data ourselves, we have made a difficult decision to plug and abandon Waitangi Valley-1 before reaching the intended total depth of 3600m, to maintain the safety and integrity of the operation. The well will be abandoned following all regulatory requirements and with no environmental issues encountered to date.

4.2.3 Future Exploration and Potential

There is unlikely to be any onshore exploration in the near future. Beyond that, a number of economic and political factors would need to align for renewed interest in the region.

In their 2016 report reviewing oil and gas exploration in the Hawkes Bay region, Environmental Management Services (EMS) pointed out that considerable subsurface well data will be required before successful discovery, appraisal and production processes are realised to enable commercial quantities of oil and gas to be extracted.

The mapping of the Northern Hawke's Bay area has identified an area of interest but also presents logistical challenges due to the remote locations and rugged topography. Distance from major centres, service hubs, pipelines and access to ports will mean higher than normal costs.

EMS predict that any future exploration across the onshore East Coast Basin will likely focus on unconventional resources. This is likely to require drilling into shale supported by hydraulic fracturing. However, whether this is necessary may not be known for a number of years. EMS warn that new entrants to the East Coast Basin will carefully consider the poor results and lack of commercial success from historic and more recent costly and problematic drilling campaigns before embarking on further exploration. The continuing over-supply of shale oil from other parts of the world is also a critical factor.

They concluded that:

"It is highly unlikely, given forecasts for oil and gas prices and the global availability of unconventional-oil and gas, that large scale exploration in the ECB will be recommencing any time soon. We would say not within the next 10 years, based in part on current levels of global over-supply of oil and gas, but also on the time taken for oil companies to respond and commence exploration in the ECB once prices return to economically viable levels. This includes allowing for long lead-in times associated with researching, applying for, and obtaining exploration permits."

Interestingly, there has only been limited success at wide-scale hydraulic fracturing outside of the US. An article in Forbes Magazine in 2013, highlighted that only the United States has fracked it's shale into a national energy boom despite significant efforts in other countries. The article was reporting on a conference of industry experts in energy development and finance in Chicago and suggested that other countries are not expected to catch up to the US for ten to 15 years. According to the experts, there were six main reasons why hydraulic fracturing has been successful in the US and not elsewhere:

1. **Price**: The price of natural gas was peaking in 2008 when drillers were adopting hydraulic fracturing technology
2. **Regulatory Framework**: The United States has a regulatory framework that allows drillers to experiment with lateral drilling and hydraulic fracturing
3. **Property and mineral rights**: Individual landowners can lease mineral rights to their property in the US; this is not the case in many countries, including New Zealand
4. **Infrastructure**: Shale gas plays have been located near the pipelines and terminals needed to bring the gas to the market

5. **Water**: Water has been easily available to support the growth of hydraulic fracturing
6. **Expertise**: Expertise is concentrated in the US as hydraulic fracturing developed there and experts in the technology and shale geology developed with it.

5 Regulatory Environment

A number of government agencies, together with regional councils, share the responsibility for managing oil and gas activities in New Zealand.

5.1 Crown Minerals Act and Permits

The government issues permits to prospect, explore and extract oil and gas; financial royalties are received from production

Permits for the prospecting, exploration and extraction of oil and gas are allocated under the Crown Minerals Act. Companies obtain permits to explore for oil and gas through the annual Block Offer process run by New Zealand Petroleum and Minerals (NZPM). Block Offer areas are selected by NZPM to offer the petroleum exploration industry a variety of investment opportunities. Release areas are supported by geological and geophysical data and analysis, which is supplied by the government or previous industry exploration. Permits are decided based on the economic purpose of the Crown Minerals Act and the Government receives a financial return on production in the form of royalties.

Permit boundaries can be drawn to restrict where a well can be drilled, but only for commercial or cultural reasons, not for environmental reasons. Environmental jurisdiction is spread across different agencies depending on whether oil and gas activities are onshore or offshore. Offshore waters are classified in the following ways for the purpose of jurisdiction:

- Exclusive Economic Zone (EEZ) – the area from 12 to 200 nautical miles (nm) offshore
- Continental Shelf (CS) – the area where New Zealand's submerged landmass extends beyond the EEZ.
- Territorial waters – the area from the coast out to 12 nautical miles.

For oil and gas activities in the EEZ and Continental Shelf, the Environmental Protection Agency (EPA) are responsible for environmental assessment and management through the marine consent process. The responsibility for managing the environmental impacts of oil and gas activities onshore and within territorial waters falls on regional and district councils.

5.1.1 Prospecting

Petroleum prospecting permits give the holder the right to conduct reconnaissance and general investigations of an area. The company's proposed work programme and technical and financial capability are assessed. Permits are usually granted for up to two years. Activities include acquisition of geological and geophysical data collection, usually through seismic surveys. Drilling (other than for the seismic survey purposes) is not allowed to be undertaken under a prospecting permit.

Prospecting does not normally require a marine consent through the EPA but special conditions apply to seismic surveying. Operators are required to comply with DOC's Code of Conduct for minimising acoustic disturbance to marine mammals. There are also six marine mammal sanctuaries, which have their own mandatory seismic surveying regulations. Operators surveying in these areas must comply with these regulations in addition to the Code.

5.1.2 Exploration

Exploration permits grant the holder the right to identify petroleum deposits and evaluate their feasibility. A permit allows for geological and geophysical surveying, exploration and appraisal drilling, and testing of petroleum discoveries.

NZPM assesses a bidder's technical and financial capability, compliance history and a high level assessment of an operator's capability to meet applicable health, safety and environmental legislation. Permits are issued for up to 15 years. It is possible to get an extension of up to four years for appraisal purposes - a second four-year extension is also possible. Permits are exclusive, and carry subsequent rights to apply for a mining permit.

5.1.3 Production

When an exploratory well indicates that commercial quantities of oil and gas can be extracted, the company holding the exploration permit can then apply for a mining permit. NZPM will again assess their technical and financial capability, compliance history and the operator's capacity to meet health, safety and environmental legislation.

Petroleum mining permits grant the holder rights to develop a discovered petroleum field to extract and produce petroleum. Activities allowed under a mining permit include extraction, separation, treatment and processing of petroleum.

5.1.4 Flaring

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.

5.2 Resource Management Act

5.2.1 Regional and District Councils

HBRC is responsible for the regulation of the environmental impacts of oil and gas activities. This includes the impacts on soil, air, fresh and coastal water.

Under the RMA, regional and district councils are responsible for managing the environmental effects of activities on land and in territorial waters (out to 12 nautical miles offshore).

Regional councils are required to produce plans that include the following:

- The resource management issues for the region
- The resource management issues of significance to iwi authorities
- Objectives for managing the issues
- Policies to implement the objectives
- Rules to implement the policies

This sets up a hierarchy of planning provisions to manage environmental issues and activities that may have an impact on the environment. Councils also have the flexibility to change plans as required. This may be to manage a particular environmental issue or regulate a certain type of activity. The plan making process includes the requirement for community and iwi input.

The rules in a plan determine whether a resource consent is required or not. Oil and gas activities usually require a resource consent, although some low impact activities such as seismic surveying often do not.

In terms of oil and gas activities, the provisions in regional plans that are of most relevance are:

- water takes
- bore drilling
- discharges to water (including stormwater treatment and discharge)
- discharge of contaminants to land (e.g. fracking or waste disposal)
- discharges to air
- earthworks
- natural hazards
- storage and management of hazardous substances.

The provisions in district plans that are of most relevance to oil and gas activities are:

- land-use consents for well sites, pipelines and other infrastructure
- the control of noise and light spill
- traffic generation and traffic management
- transportation, storage and use of hazardous substances.
-

5.3 Hawkes Bay Resource Management Plans

The Hawke's Bay Regional Council plans do not have specific objectives or policies for oil and gas activities but there are some limited rules and resource consent is required for most activities that have the potential to impact the environment.

Hawkes Bay Regional Council (HBRC) has two key resource management plans; the Regional Resource Management Plan (RRMP) and the Regional Coastal Environment Plan (RCEP). The scope of the plan change includes looking at both in relation to oil and gas activities and their potential impacts on the environment.

A preliminary review was undertaken for HBRC in October 2015 in relation to oil and gas regulation in Hawkes Bay's regional and district plans. This was focussed on the 2014 Parliamentary Commissioner for the Environment (PCE) recommendations for regulating onshore oil and gas activities. The PCE recommendations are summarised as follows:

1. Classify drilling an oil and gas well, fracking, and waste disposal as 'discretionary' activities
2. Identify areas where oil and gas drilling can take place and where it cannot
3. Set out core requirements for environmental monitoring
4. Require applications for consents for establishing well sites and for drilling wells to be 'bundled' together
5. Make explicit the circumstances when consents will be publicly notified and when they will not be

6. Hold joint hearings with district councils whenever possible
7. Identify and plan for the cumulative effects of an industry that may expand very rapidly

The report outlined that neither the regional plans nor the district plans give full effect to the PCE's recommendations. In terms of the RRMP, the report noted the following:

- A plethora of rules cover oil and gas exploration and production activities
- The consent categories predominantly range from permitted to discretionary
- There is little if any guidance on whether or not applications should be publicly notified, which is understandable given the criteria within the RMA itself that guide decisions on whether or not to notify an application (sections 95A to 95E).

It also highlighted that both the RRMP and RCEP have no specific objectives or policies dealing with oil and gas exploration and production. This means there is no policy guidance that decision-makers can look to when assessing resource consent applications for oil and gas activities. The report considered that the regional plans were more deficient than the district plans and suggested a limited scope regional plan change would be both necessary and appropriate if HBRC wish to give effect to the PCE recommendations.

5.3.1 Regional Resource Management Plan

Prospecting: There are no rules specific to the shallow bores required for seismic surveys and a consent and site preparation activities (vegetation clearance and earthworks) could be undertaken as a permitted activity in most circumstances.

Exploration: An oil and gas well for exploration or production would require consent as a controlled activity. The key standard that needs to be met for controlled activity status is that the well must be cased and sealed to prevent aquifer cross-connection and leakage from the surface into ground water.

Production: A well for production would also require consent as a controlled activity. Other oil and gas production activities (such as hydraulic fracturing, deep well injection, land faming) would be discretionary activities.

Flaring: Air discharges from flaring hydrocarbons are likely to require resource consent as a discretionary activity.

De-commissioning: De-commissioning an oil and gas bore is a permitted activity if it is undertaken by a suitably qualified person.

5.3.2 Regional Coastal Environment Plan

Prospecting: There are no rules specific to oil and gas seismic surveying in the RCEP. Depending on the level of noise omitted, seismic survey will be treated as a permitted or restricted discretionary activity.

Exploration: There are permitted activity standards for drilling an oil and gas exploratory well. Standards include distances to protected areas, aquaculture management areas and port management areas. If these standards are not met, exploratory wells will be a discretionary activity.

Production: A well for production would require consent as a discretionary activity. Other oil and gas production activities (such as hydraulic fracturing and waste discharges) are also likely to be discretionary activities.

Flaring; Air discharges from flaring hydrocarbons are likely to require resource consent and will be a controlled activity or a discretionary activity if controlled standards cannot be met.

Decommissioning: The removal of structures over the foreshore or seabed may be a permitted activity depending on the level of disturbance and other standards. If not, the activity will be discretionary.

It is important to note that the RCEP already prohibits some activities that may be relevant to the oil and gas industry within Significant Conservation Areas. This includes the storage of petroleum products, the storage or dumping of hazardous substances and disturbances of the sea bed. This has the effect of prohibiting drilling in Significant Conservation Areas.

5.4 Environmental Protection Authority

Oil and gas activities that occur in the EEZ or Continental Shelf waters (beyond regional council jurisdiction) are regulated by the EEZ Act, which is administered by the Environmental Protection Agency. Activities such as drilling and discharges of drilling fluids will require a marine consent; non-notified for exploration drills, and publically notified for production wells. Less disruptive activities such as seabed sampling and seismic surveys do not require a marine consent if certain conditions are met.

Hazardous substances used in oil and gas production need to be approved by the EPA under the Hazardous Substances and New Organisms Act 1996 (HSNO). Councils can also require operators to disclose through resource consent applications what chemicals are to be used.

5.5 Maritime New Zealand

For offshore activities, Maritime New Zealand also have a role in environmental management through their requirement to have an Oil Spill Contingency Plan. Maritime New Zealand (MNZ) also need to approve an operator's Discharge Management Plan. MNZ need to be satisfied that an operator has in place procedures that reduce the environmental impacts from discharges of substances and is prepared for a worst-case scenario in the event of a blowout.

5.6 Health and Safety

The health and safety regulations are managed through the High Hazards Unit at WorkSafe New Zealand. They aim to ensure that wells are designed and constructed to prevent well failure, which indirectly provides an element of environmental protection. However, the High Hazards Unit have no mandate for protecting the environment and inspectors cannot take environmental effects into account if they have no potential for harming people.

6 Environmental Context

This section provides an overview of the Hawkes Bay environment. It covers the following aspects that are relevant to the scope of the plan change:

- Cultural Values
- Groundwater
- Surface water
- Natural hazards
- Coastal environment

6.1 Cultural Values

It is important to recognise tangata whenua as a fundamental part of the cultural and environmental landscape of Hawke's Bay. Hawke's Bays Regional Council has various provisions in their resource management plans that provide a basis for working together, understanding perspectives and managing environmental issues with tangata whenua.

The following tangata whenua principles are identified and described in the Regional Resource Management Plan as a basis for understanding iwi environmental management:.

- Wairuatanga
- Rangitiratanga
- Whanaungatanga
- Kotahitanga
- Manaakitanga

It would be inappropriate for this report to try and interpret how these principles relate to this plan change or provide a tangata whenua perspective on oil and gas. This will be explored through engagement with iwi and hapu as well as through the Regional Planning Committee.

6.2 Groundwater

The Heretaunga and Ruataniwha aquifer systems are nationally significant groundwater resources.

Groundwater is one of Hawke's Bays most important natural resources. It provides water for drinking, irrigation and industry, in addition to sustaining the flow of streams and rivers and maintaining riparian and wetland ecosystems.

Approximately 70% of all water consented in the Hawke's Bay is from groundwater. There are approximately 2,200 current groundwater consents within the region, with a combined weekly allocation of 16 million cubic metres per week. The main groundwater use is for irrigation which accounts for approximately 85% of the number of water consents issued and approximately 75% of the allocated volume.

On a national scale, the Hawke's Bay contains New Zealand's second largest groundwater resource, which accounts for 16% of all the current groundwater consents issued and 7% of the nation's total allocated volume.

The largest and most highly productive aquifer systems in Hawke's Bay occur on the Heretaunga and Ruataniwha Plains. Smaller alluvial aquifer systems are located in the Wairoa river valley, on the Mahia Peninsula, in the Esk valley, and in the Papanui basin (Figure 2-1). There are also hard rock aquifers in the hill country limestone and sandstone, such as the Poraiti Hills near Napier, where the limestone aquifer is extensively used for domestic water supply. Limestone rock aquifer systems also occur in the Poukawa catchment to the south east of the Heretaunga Plains which are used for irrigation and domestic supplies.

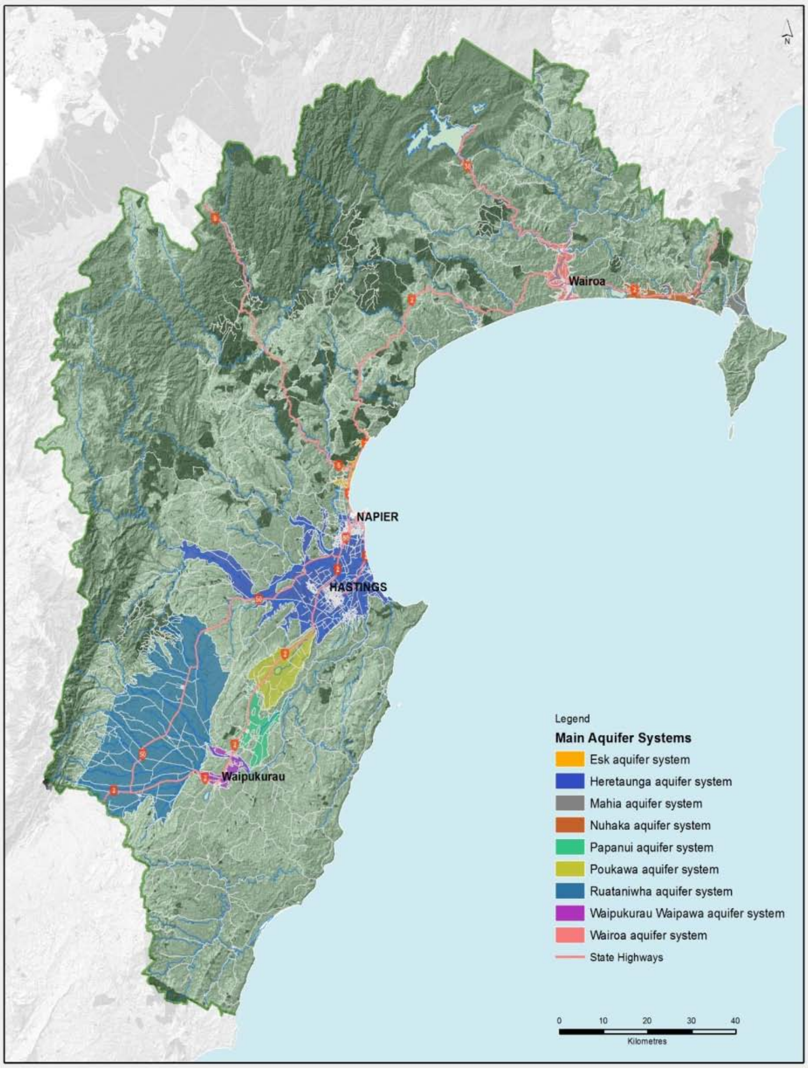


Figure 8: Aquifer systems in Hawke's Bay (Source: Hawke's Bay Regional Council)

6.2.1 Heretaunga Plains

The aquifers below the Heretaunga plains are mostly fed by the Ngaruroro River and to a lesser extent by rainfall and other river systems.

The Heretaunga Plains consists of at least 5 and maybe as many as 7 primary aquifers that formed during the last 250,000 years. From the westernmost edge of the Plains to about Hastings the aquifer system is predominantly unconfined. Further east, the aquifer system becomes progressively confined and overlain by layers of clay and silt.

Water balance investigations indicate the greatest source of groundwater recharge is the river recharge. Between July 1994 and June 1995 approximately 84% of inflows to the aquifer system were estimated to have come from the Ngaruroro River (Dravid, 1997). For other periods the river contribution ranges between 64-70% (Brooks, 2006). This difference in contribution reflects a combination of uncertainty in the estimate and the different losses calculated for the different time periods. The remainder of the recharge to the aquifer system varies between studies. Brooks (2006) study suggest the remainder comes from rainfall with a small contribution from the Tukituki River. However, Dravid (1997) suggests the remainder is mainly from the Tutaekuri River and rainfall a minor contributor.

Most groundwater leaving the system returns to streams and rivers in the Lower Heretaunga. Between 1994 and 1995 leakage to spring flows were estimated to represent approximately 64% of the outflow with the remainder made up of groundwater pumping and drainage dewatering (Dravid, 1997). These figures are similar to the findings by Brooks (2006) who suggests rivers represent 69% of the outflow with pumping representing 31%.

Inputs		Outputs	
Source	**Percentage**	**Source**	**Percentage**
Ngaruroro River	84%	Pumping and de-watering	36%
Tutaekuri River	13%	Spring leakage	64%
Rainfall	3%	Submarine outflow	unknown

Table 1 summarises the groundwater balance for the Heretaunga Plains from July 1994 – June 1995

There are currently 1,900 groundwater consents in the Heretaunga Plains with a combined groundwater take of approximately 7,440,500 m3/week. This represents 87% of all the Hawke's Bay groundwater consents and 72% of the consented weekly allocated volume. The main groundwater use is for irrigation and municipal supply which accounts for 87% of the number of groundwater consents and 88% of the consented weekly allocated volume.

The greatest numbers of groundwater consents are situated between Hastings and Havelock North, but consented pumping locations are generally distributed across the basin relatively evenly.

6.2.2 Ruataniwha Basin

The aquifers below the Ruataniwha Basin are mostly fed by rainfall with a smaller contribution from rivers.

Over the last 1 million years sediments have infilled the Ruataniwha Basin to form a complex multi-layered aquifer system. Two main gravel layers form the main aquifers within the Basin.

Aquifer recharge mainly occurs from rainfall and river flow loss. The annual average recharge from rainfall is approximately 270 million m3/year (Baalousha, 2009 – Table 7). Weighted recharge maps suggest rainfall recharge is likely to occur more easily within the centre of the Ruataniwha Plains, where more permeable soil types and flatter topography facilitate the movement of rainwater to the aquifer system (Baalousha, 2009).

Inputs		Outputs	
Source	**Percentage**	**Source**	**Percentage**
Rivers	11%	Pumping and de-watering	13%
Rainfall	83%	Spring leakage	82%
Amount in storage	6%	Amount in storage	5%

Table 2 summarises results of the cumulative groundwater balance for the Ruataniwha Basin from 1990-2009.

The Ruataniwha Basin contains a total of 69 groundwater consents, with a combined take of 1,596,135 m3/week (Table 2-3). This represents 3.2% of Hawke's Bay groundwater consents and 15% of the consented weekly allocated volume. Most groundwater is used for irrigation, which accounts for 86% of all the current Ruataniwha groundwater consents and 92% of the current consented weekly allocated volume. Most irrigation is used for crops and pastoral farming and accounts for 90% of the total consented volume. Between 1990 and 1999 approximately 3-6 GL of groundwater was used each year. From 1999 to 2009 groundwater use quadrupled with the greatest increases occurring between 1999 and 2005 (Baalousha, 2010).

The greatest density of groundwater consents, shown in Figure 2-8, are located on the central Ruataniwha Plains. Groundwater allocation is slightly higher on the northern side of the Plains and toward the western edge, but generally groundwater is allocated relatively evenly across most of the Plains.

6.2.3 Groundwater Quality

Groundwater quality is mostly good but there are some areas where the quality is deteriorating.

Groundwater is relied upon as a source for drinking, industrial, irrigation and stock water supplies across the Hawke's Bay region. Groundwater discharge also performs an important role in the maintenance of surface water flows in the region.

Monitoring data for the five year period 2009 to 2014 indicates that Hawke's Bay aquifer systems are generally suitable for drinking water supply for key chemical water quality parameters except where they are affected by naturally occurring iron, manganese and hardness.

Key water quality parameters and their trends are outlined below:

Parameter	Units	Percentage of sites with trend		
		Increasing	Decreasing	No trend
pH	units		2.5%	97.5%
Ammoniacal-N	mg/L	5.0%	20.0%	75.0%
Nitrate-N	mg/L	17.5%	2.5%	80.0%
Nitrite-N	mg/L	2.5%	0.0%	97.5%
Phosphorus (soluble)	mg/L	27.5%	0.0%	72.5%
Manganese (soluble)	mg/L	7.5%	30.0%	62.5%
Iron (soluble)	mg/L	2.5%	30.0%	67.5%
Sulphate	mg/L	27.5%	15.0%	57.5%
Sodium (soluble)	mg/L	2.5%	7.5%	90.0%
Chloride	mg/L	5.0%	12.5%	82.5%
Total hardness	mg/L	15.0%	10.0%	75.0%
Total dissolved solids	mg/L	15.0%	10.0%	75.0%
Electrical Conductivity	(uS/cm)	7.5%	10.0%	82.5%
E.coli	cfu/100 ml	0.0%	0.0%	100.0%

The State of the Environment Report shows that, for the most part, groundwater quality is good with some areas of concern around phosphorus, nitrogen and sulphates. These parameters are potentially influenced by agricultural and horticulture land uses. No pesticides were detected in groundwater during either the 2010 or 2014 regional pesticide survey.

6.3 Surface Water

Lakes and rivers are the lifeblood of the region. They are ancestors to tangata whenua; they provide invaluable ecosystem services; they supply food, water, power and recreational opportunities.

The major river systems in Hawke's Bay are the Wairoa, Mohaka, Esk, Tutaekuri, Ngaruroro, Tukituki and Porangahau Rivers. These are mostly fast flowing, clean, gravel rivers, with extensive braided reaches. They support a rich and diverse wildlife, and are well known for the recreational opportunities they offer, including fishing, jet boating, canoeing, rafting and swimming. They are used for water supply and irrigation purposes, but do not receive a large number of point source waste discharges. River flows and temperatures fluctuate markedly due to droughts, causing problems for instream biota and for water supply.

However, there are water quality issues in some areas of the region, especially around the Heretaunga Plains where rivers and streams have been extensively modified, channelled and straightened. Nuisance macrophytes and algal growth in these areas is common. Another key environmental issue is sediment and its effect on aquatic ecosystems and the availability of water, especially in the north of the region.

The four major lakes in Hawke's Bay are Lake Waikaremoana, Lake Waikareiti, Lake Tutira and Lake Poukawa. The lakes vary substantially in their physical characteristics. The deeper lakes (Waikaremoana and Waikareiti) tend to have clear water, whereas the shallower lakes (Tutira and Poukawa) can be very turbid or dominated by aquatic weeds.

It is highly unlikely that oil and gas activities will need to be located within or immediately adjacent to surface water bodies. However, it is important to recognise their significant contribution to the region's well-being through aspects such as cultural associations, groundwater recharge, ecosystem services and water supply to name a few.

6.4 Natural Hazards

All info below provided by Hawke's Bay Civil Defence Emergency Management (CDEM) Group.

6.4.1 Earthquake

Hawkes Bay has been shaped by earthquakes; there are many active faults onshore and offshore.

Hawke's Bay is one of the most seismically active regions of New Zealand and in the 160 years since substantial written records began, several large and damaging earthquakes have occurred. Most notably the earthquake of 1931, has remained a prominent feature in Hawke's Bay's living memory. Hawke's Bay experiences many smaller earthquakes each year, but another large earthquake can occur at any time.

Earthquakes can cause ground shaking, liquefaction, surface rupture, lateral spread and other ground damage, regional subsidence or uplift along with tsunami, landslides and rockfalls. This has the potential to damage above and below ground infrastructure.

Faults

There are numerous active faults in Hawke's Bay, both onshore and offshore. Many are surface faults where a rupture has left a visible fault trace on the surface. Others are buried and show no evidence on the surface so these are harder to recognise. The Active Fault Map below shows generalised traces of active surface faults in the Hawke's Bay region. Active faults are those faults that have moved within the last 125,000 years.

No active faults have been mapped in the Napier and Hastings city areas because historic floods and development have covered them over. Scientists believe both cities have 'buried' or 'blind' fault sources including the large fault source that caused the Hawke's Bay earthquake of 1931. However, they are currently unable to map them. The subduction interface between the Australian and Pacific plates is the largest offshore fault in the region.

Liquefaction

Liquefaction occurs when waterlogged sediments are agitated by an earthquake. Buildings can sink and underground pipes may rise to the surface. When the shaking stops, groundwater is squeezed out of the ground causing flooding, which can leave areas covered in mud. Hawke’s Bay has several areas with high liquefaction susceptibility. There were numerous reports of liquefaction following the 1931 earthquake.

Low-lying areas in the region, especially those near the coast, and reclaimed land are particularly susceptible. Liquefaction susceptibility maps for Hawke's Bay and Napier/Hastings completed by GNS Science in 1996.

6.4.2 Tsunami

All of New Zealand is at risk from tsunami but particularly the East Coast.

Hawke's Bay's position on the Pacific Ocean means there are risks of tsunami from both local, regional and distance sources. The East Coast of NZ has the highest risk in the country. Risks include destruction of homes, businesses and infrastructure in inundation zones, along with injuries and loss of life, with environmental devastation and the slow process of recovery.

The massive Indian Ocean tsunami in 2004, the South Pacific tsunami in 2009 and Japan in 2011 overturned many assumptions regarding the potential for severe tsunami to be generated on subduction zones throughout the Pacific. As new research into New Zealand’s subduction tsunami sources will take time, it is best to assume that our subduction zone could generate severe tsunami from earthquake sizes of MW 8-9.

Although there are only a few written records of tsunami striking the Hawke's Bay coastline, the geological record shows that the area has been impacted by large tsunami in the past, on average approximately one every 900 years. Several moderate-size tsunami have been observed along Hawke’s Bay coasts in the 160 years or so of written historical record including from the 1931 magnitude 7.8 earthquake.

Tsunami from far off locations have also caused damaging tsunami surges in Hawke's Bay. The 1868, 1877 and 1960 tsunami generated by large earthquakes in South America have had the greatest impact. The surges lasted several days in each case, the largest of the surges generally occurring within the first 24 hours.

6.4.3 Flooding

Flooding is our most common natural hazard. Even with large investments in flood protection works, rivers still have the potential to cause significant damage.

Much of the settled Hawke’s Bay region is low lying and built on river flood plains. This brings the risk of flooding, which is our most common natural hazard - a severe storm or flood happens every 10 years on average. Major storms affect wide areas and can be accompanied by strong winds, heavy rain or snowfall, thunder, lightning, and rough seas. They can cause damage to property and infrastructure, affect crops and livestock, disrupt essential services and cause coastal inundation.

There have been significant flood protection systems completed on the Heretaunga Plains and the Ruataniwha Plains designed to contain a 1% annual exceedance probability (AEP) flood. These works have significantly reduced the effect of small to medium sized floods, but a large flood could still overwhelm the protection works and have a devastating effect.

Examination of the rainfall and flood records shows that there have been long periods without major floods and other periods where they have been more frequent. Despite the long breaks, the potential for flooding is high and any large flood would have a major effect on the regional community, environment and economic infrastructure.

There are a number of common factors in most flood events in Hawke's Bay.

- Heavy prolonged easterly or southeasterly rains.
- The greatest percentage variation of rainfall in New Zealand, with hot dry spells followed by heavy rains, resulting in high runoff.
- Local soils are comparatively shallow and have limited capacity to absorb large amounts of rainfall. They are frequently underlain by impermeable sub strata, especially mudstone.
- Short, steep catchments resulting in rapid runoff. This is aggravated by highly erodible soils.
- The lack of lake storage with few ponding areas.
- Three major rivers on the Heretaunga Plains, the Ngaruroro, Tukituki and the Tutaekuri, discharge into the sea within about 5 km of each other.
- Many major river headwaters are in areas where the rainfall averages are much higher than the plains. The annual rainfall for the ranges is 3500 mm a year compared to 800 mm for the Napier/Hastings area

With climate change, rainfall patterns in the Hawke's Bay will change over the next century; winters are predicted to become drier, but overall flood risk is not expected to decrease as single events may be more intense.

6.5 Coastal Environment

Hawke's Bay has a diverse coastline highly valued by the community. There are a range of existing environmental issues that are of concern.

The diverse 360km Hawke's Bay coastline stretches from the sandy beaches and reef platforms of Mahia Peninsula in the north to the ecologically significant estuary at Porangahau in the south. The coast provides a wide variety of habitats, including undulating coastal cliffs, sandy beaches, extensive dune systems, rock platforms, gravel beaches and associated herb fields. These environments support a range of species from the microscopic through to the huge Southern Right Whales that use the coastal waters of Hawkes Bay as a nursery for their young. The coastal environment is highly valued for cultural reasons (waahi tapu, taonga, kaimoana etc) recreational activities such as swimming, fishing, surfing, diving and boating (HBRC, 2015).

There are a wide range of existing threats to the Hawke's Bay estuarine, coastal, and marine habitats from land-based activities within the region. Farming, forestry, horticulture, industrial, and residential activities all have an impact. The scale of those impacts will depend on the physical characteristics of their catchments (steepness, soil type, composition, erodibility) and the proximity to and sensitivity of the receiving environment. There are also coastal activities that have the potential to directly impact the seabed such as aquaculture, trawl fishing, dredging and the disposal of dredge spoil. A range of storm water outflows are also present along the intertidal gravel beaches around Napier as well as three ocean outfalls that discharge wastewater into Hawke Bay (Haggit and Wade 2016).

At the forefront of threats to coastal habitats within Hawke's Bay is land-based sediment. The effects of sedimentation are multifaceted and range from direct deposition and smothering of habitats and species, reduced water clarity due to increased suspended sediment loads, to increased nutrient enrichment and contamination (from sediment bound nutrients and contaminants). There are numerous examples of active erosion throughout the region from cliff-line attrition through to catchment, stream, river, and estuary bank erosion.

6.5.1 Areas of Significant Conservation Value

There are 20 Areas of Significant Conservation Value listed in the Regional Coastal Environment Plan.

There are 20 sites identified as Areas of Significant Conservation Value in the Regional Coastal Environment Plan (RCEP). The RCEP identifies a set of objectives and values that are relevant to each area. Examples of the types of values that are identified include:

- Fisheries habitat
- Indigenous flora and fauna habitat
- Important ecosystems such as wetlands, estuaries and coastal lagoons
- Coastal landforms and scenic values
- Historic values
- Fossil locality and important geological sites.

Some of these values are regionally significant, others are significant at a national level. All areas are of significance to tangata whenua.

6.5.2 Marine Mammals

Other than a few species, very little is known about the marine mammals in the waters off Hakes Bay.

Out of the more than 84 species of cetaceans (whales, dolphins and porpoises) and 36 species of pinnipeds (seals and sea lions) known to exist world-wide, over 50 of these different species live or migrate through New Zealand waters.

In 2010, the Cawthron Institute produced a report for the Gisborne District Council on marine mammals in the Gisborne District. Some of the conclusions and information is relevant to the Hawkes Bay. It is important to note that the study was a desktop study only, it is based on data from reported sightings and strandings from Cape Colville to Cape Palliser (see maps below). There does not seem to have been any comprehensive field study into marine mammal distribution in Hawkes Bay or the surrounding waters.

Most sightings were reported around inshore islands within the south-eastern Bay of Plenty and throughout the northern coast of East Cape. Strandings were more evenly spread along the entire coastline. Historically Mahia Peninsula (particularly Opoutama Beach), Napier and to a lesser extent Te Kaha are particular hotspots for strandings (Brabyn 1990).

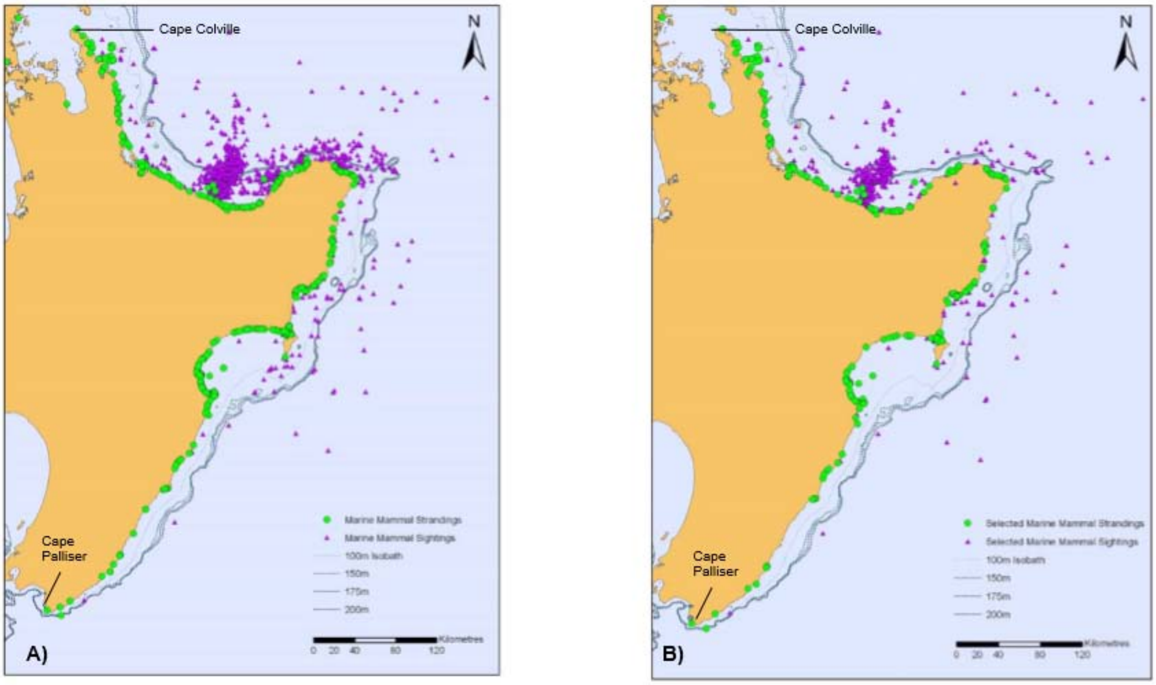


Figure 9: The distribution of strandings and sightings between Cape Colville and Cape Palliser (Source: Cawthron Institute)

Cawthron highlighted that in terms of important feeding or breeding habitats, little is known with the exception of a few species. While most resident species have been sighted with calves in Gisborne and/or neighbouring waters over summer months, the inshore coastal bays and waters between Bay of Plenty and Hawke's Bay are critical calving habitats for southern right whales over winter and spring. Based on stranding records, it is also suggested that offshore waters between East Cape and Hawke's Bay represent the main calving and nursery grounds for pygmy sperm whales. The presence of several beaked whale species and other deep-water species (within GDC waters at least) suggests that offshore shelf waters may be particularly rich in certain deep-water prey species such as cephalopods (squid and octopus).

The North Island's eastern coastline, particular south-eastern regions, represents the largest known groupings of common dolphins, orca, pygmy sperm whales, several beaked whale species and false killer whales while potentially supporting isolated subpopulations of bottlenose dolphins, southern right whales, humpback whales and Bryde's whale.

The Cawthron report concluded in the following way:

"Finally, the lack of scientific marine mammal surveys means that this review cannot determine if possible resident populations within GDC waters constitute a small subpopulation that remains within the general region, moving more north or south with the seasons, or one large population that meanders throughout the south-eastern region from Hawke's Bay to Bay of Plenty or further. Such information is important for assessing the level of effect coastal developments

might have on a population and in turn, its ability to withstand it. For more site specific information concerning future coastal consent or permit applications, more scientifically rigorous and fine-scale data would need to be collected."

6.5.3 Fisheries

Hawke's Bay has traditionally been known as a "mixed species fishery" but some species such as red gurnard, snapper, hapuka, kahawai, terakihi and trevally are thought to have declined substantially over the last 5-10 years. There are significant gaps in understanding around this and other aspects of fisheries management within the region.

Hawke's Bay has traditionally been known as a "mixed species fishery" consisting of at least 7-8 main species. Common fishes that were traditionally targeted by trawlers included flounder/flatfishes, gurnard, snapper, dogfish, small sharks, trevally, terakihi, moki, kahawai and crayfish. These species continue to be fished today but discussions held with Iwi and a range of commercial and recreational fishers suggest that for many species their abundance and distribution have changed within the region, particularly over the last decade. Some species (e.g., hoki) are no longer abundant in trawl catches, and the mixed fishery status is widely regarded as being less prominent (Haggit and Wade, 2016).

In their 2016 report, *Hawke's Bay Marine Information: Review and Research Strategy*, prepared for HBRC, Haggit and Wade undertook stakeholder interviews to obtain (anecdotal) spatial information on fishing hot spots and the species that are targeted in those areas. This was digitised and is shown below.

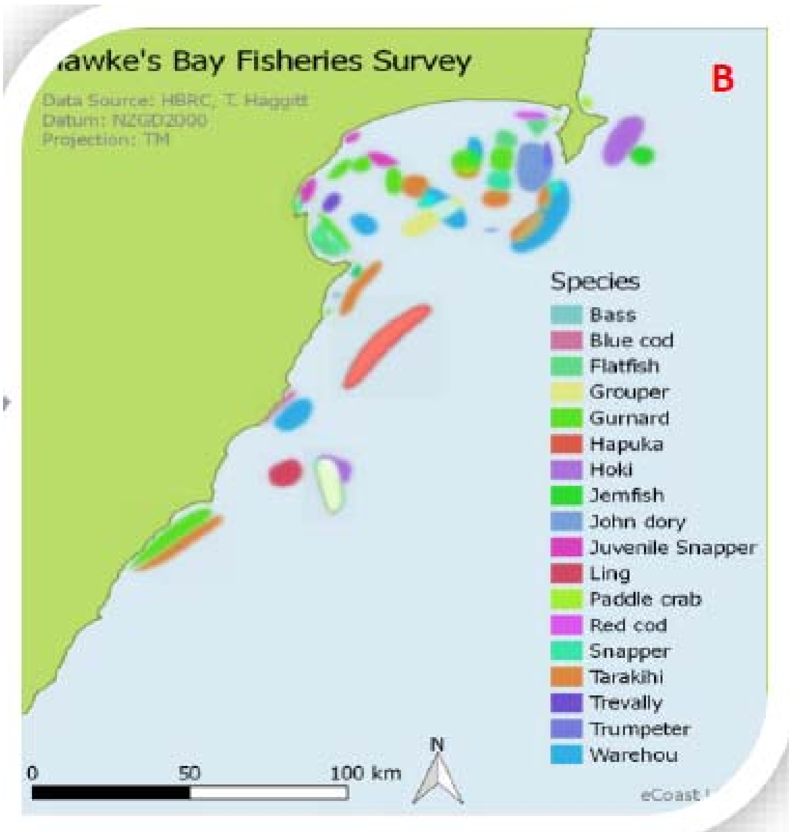


Figure 10: Fishing hot spots for various species. (Source: Haggit and Wade)

The diversity and composition of fish species within Hawke's Bay is representative of the numerous habitat types that occur across the region. This includes:

- offshore deep water formations such as the Madden and Lachlan Banks
- nearshore mixed habitats that comprise the Wairoa Hard and Clive Hard
- estuarine regions associated with the 5 main river systems
- lagoons that provide important nursery and foraging habitat.

The Hawke's Bay region is also recognised as being a migratory pathway for blue moki, terakihi, snapper, and warehou (Morrison et al. 2014a).

It is has becoming increasingly evident over the last 20 years that many of the fished species in New Zealand may depend on several habitat types as they transition through different life stages. Consequently, the quality and integrity of these habitats is paramount in determining survival through to the adult population. Morrison et al. (2014a) suggest that there may be 'habitat bottlenecks' where important habitats are limited in spatial extent, or are of such poor quality that they in-turn limit the survival of juvenile fish into the adult population.

Hawkes Bay has a long history of boom and bust phases attributed to overfishing, climate variability or both. The coastal marine area has numerous fishing restrictions with new areas added as recently as 2015. Currently the state of fisheries within Hawke's Bay is a contentious issue due to very low catches compared to previous decades, particularly within the recreational sector. Of those species that have traditionally been caught within Hawke Bay, red gurnard, snapper, hapuka, kahawai, terakihi and trevally are thought to have declined substantially over the last 5-10 years (Haggit and Wade, 2016).

There are also significant gaps in our understanding of fisheries. Haggit and Wade (2016) identified the following key gaps in understanding:

- Climatic variability and its role in driving the Hawke's Bay fishery
- Change in species distributions across Hawke's Bay through space and time including movement patterns of various fished species
- The importance of various habitat types in supporting fishery production and different life history stages of fished species
- Effect of land-based stressors on fisheries
- Effect of trawl fishing on benthic communities and the physical structure of the benthos
- Effects of bycatch on overall fisheries production
- Effectiveness of various fisheries closures within Hawke Bay.

7 Economic Context

7.1 Oil and Gas Contribution to the New Zealand Economy

The oil and gas industry makes a significant contribution to the New Zealand economy. Even as world economies adapt to cleaner technologies, oil and gas is likely to play an important role in economic and social well-being.

The oil and gas industry makes a significant contribution to the New Zealand economy and society generally. Oil is New Zealand's fourth largest export (after dairy, meat and wood) with a value of around $2.2 billion. Gas is an important contributor to domestic industries and electricity generation, generating 18% of New Zealand's electricity supply in 2011 (PEPANZ, 2012).

Petroleum plays a vital role in transport and many other sectors. It is likely to continue to do so for many decades as economies adapt for a future where carbon resources are more constrained. For the next few decades at least, the world and New Zealand will need oil and gas for secure and affordable energy that is needed to maintain our economic and social well-being (PEPANZ, 2012).

Other key facts in relation to the oil and gas industry in New Zealand are:

- The oil and gas industry contributes close to $3 billion to national GDP, most of which is captured in Taranaki
- The Government collects about $300 million in company tax and more than $400 million in royalties per annum
- The industry provides close to 4,000 direct, well-paid jobs (most of which are in Taranaki) and supports a further 4,000 downstream jobs in other parts of the economy (almost 8,000 jobs nationwide)
- New Zealand companies capture between 30% and 80% of the construction of major oil and gas projects in New Zealand and there is potential to capture more
- The government will receive around 42% of the profit of new oil and gas developments
- Future royalty income from known oil and gas reserves is estimated at $3.2 billion net present value. Royalty income could rise to $12.7 billion with a 50% increase in exploration (Venture Taranaki, 2010, and PEPANZ, 2012).

By international standards, New Zealand remains underexplored but the government has indicated that there is genuine international interest in New Zealand's potential. While the ultimate extent of New Zealand's petroleum resources remains uncertain, successful exploration and development in these basins would significantly contribute to economic development both nationally and regionally (NZPM).

The Ministry of Business, Innovation and Employment (MBIE) has assessed the benefits of New Zealand's petroleum potential. The Ministry's report concludes that based on plausible oil and gas discovery and development scenarios, exports could grow by $1.5 billion per annum, royalty payments could increase by $320 million per annum, and a further 5,500 jobs could be created. Counting both direct and indirect effects, MBIE estimates that national GDP could be increased on average by $2.1 billion for each year of a 30 year development of a new basin (Ministry of Business, Innovation and Employment, 2012). They also estimate that a single field could generate between $557 million and $3.2 billion in regional GDP over the life of the development.

While their scenarios are hypothetical, MBIE's 2012 report concludes that

'*there is reason to be confident that ongoing exploration investment will lead to new field discoveries and that local economies can benefit from such developments*'.

7.2 Hawkes Bay Economy

The Hawkes Bay economy is dominated by the primary and manufacturing sectors. Like many other regions, there are concerns around the lack of economic diversity, adaptation and job creation. There are numerous challenges to addressing this.

Hawke's Bay generates an estimated 3% of national GDP. The Hawke's Bay economy is dominated by the primary and manufacturing industries. The region is a nationally significant producer of meat, wood and horticultural products, with equally significant processing facilities for these products. The Hawkes Bay Regional Economic Development Strategy (Matariki) summarises the importance of food production as follows:

The region excels in, and is world-renowned for, its quality food production. Our exports account for 52.5% of the region's GDP compared to 30.7% for total New Zealand...... Our competitive advantage is built on the foundation of fertile land, a quality water supply, a favourable climate and the ability to produce and export world leading quality products. Maintaining the quality of the natural resource base on which the region depends will be essential to attracting investment and securing the social license for businesses to grow value from the resource base.

While these industries are high value and high volume, over the last 10 years, primary production has been static and the manufacturing sector has shrunk (MBIE, 2013). Like many other regional centres, Hawkes Bay faces many demographic and skill challenges. A report prepared by Sean Bevin for the Local Government Commission in 2014 identified a range economic issues and challenges facing the Hawkes Bay region. This included:

- The significant lack of 'economic scale' in many respects.
- A relatively small and slow-growing population and decline in the traditional working-age population.
- Relatively limited and fluctuating employment opportunities and high rate of unemployment overall.
- Relatively low earnings and income levels.
- Generally low productivity levels and limited degree of 'added value' production.
- Significant manufacturing sector decline.
- Vulnerability of the region to 'external' factors adversely impacting its agricultural sector especially.
- Transport deficiencies including the cost of air services to and from the region.
- Tertiary education and industry research limitations.
- Lack of real commercial investment opportunities in Hawke's Bay.

- Significant regional economic development planning and policy uncertainty in the region.

A joint study between MBIE and East Coast councils in 2013 identified a range of potential oil and gas scenarios for the region (see below). The report also included analysis on the current economy and prospects from NZIER, which highlighted a number of economic indicators that limit the potential growth of the economy. This includes:

- The East Coast is one of the least economically complex regions in New Zealand. Broadly this means that there are a relatively limited number of distinctive capabilities – ie specialised businesses. This has been linked in the literature to lower growth potential.
- The East Coast has exhibited modest performance measures of economic dynamism. During 2011, the East Coast had a significantly lower than average number of new businesses (-15% for Hawke's Bay). The number of employees generated by new businesses was also lower than the national average.

NZIER do recommend caution should be exercised in basing projections on these indicators, but they suggest the prospects for growth across the East Coast region are below the national rate. It was also recognised that the availability of water is a critical issue for growth of agriculture and horticulture.

Other than fresh water, there do not seem to be major infrastructure constraints in the region, nor do there seem to be specific capital access issues. Economic growth will depend on further value add and diversification of the economic base (MBIE, 2013).

7.2.1 Potential Oil and Gas contribution to Hawkes Bay Economy

Oil and gas development would likely make a net contribution to the Hawkes Bay economy. However, the potential significance and scale is poorly understood.

The potential economic impacts of the oil and gas industry in Hawkes Bay are poorly understood. It is difficult to quantify the benefits (and the costs of regulation) when the scale of potential development is unknown. The scenarios identified in the East Coast Oil and Gas Development Study were based on the level of information that currently exists about the resource, and were developed on behalf of MBIE and Councils by independent experts. The scenarios are summarised in the report as follows:

Scenario 1 – Quickly abandoned exploration

In this first scenario, TAG executes the currently planned 4 well campaign on the East Coast. Results are so poor that they leave and the results discourage any further exploration.

Spend ($ billion)	Max Production (bopd)	Time Period (years)
0.1	Nil	1 - 2

Scenario 2 – Explore but no development

A step up from Scenario 1, Scenario 2 sees encouraging enough results to inspire additional exploration work along the East Coast basins over a number of years, and additional investigations by other permit holders. It is assumed this will involve some 12 wells and a proportionate increase in spend. On completion of the programmes there is deemed to be insufficient economic resources for commercial development.

Spend ($ billion)	Max Production (bopd)	Time Period (years)
0.3	Nil	4 - 6

Scenario 3 – Small-scale production

Scenario 3 sees economic oil production being established in 3 areas of the East Coast in a staggered manner. Each area would have around 5 drilling pads (each with around 6 wells) of 1 to 2 ha each. Different combinations of numbers of pads and wells can also be envisaged. There would be a total of 6 exploration wells and 90 production wells, with a total area drained of 300km2. The wells would use horizontal drilling and stimulation techniques to attain economic oil rates. Reservoir recovery for this scenario is based on the small amount of geological information available for the basin. The estimate in this scenario for recovery is some 20% less than the average in the Bakken Shales of North Dakota and only 45% of the high end of the range.

Spend ($ billion)	Max Production (bopd)	Time Period (years)
11	15,000	21

Scenario 4 – Large-scale Production

As with Scenario 3, economic oil production is established in 3 areas of the East Coast in a staggered manner. However each area drained is larger than in Scenario 3 and each well is more productive. It is assumed that each well is as productive as the Bakken Shale average in the United States. Each area is some 260 km2. This is an optimistic, commercially attractive scenario with a big step up in production.

Spend ($ billion)	Max Production (bopd)	Time Period (years)
85	150,000	41

Scenario 5 – Large-scale high-volume production

This scenario is at the upper end of what is plausible and could be described as a 1% chance. It also represents the upper end of potential impact in terms of the infrastructure required. In this scenario the unconventional reservoirs the East Coast Basin are found to be at the upper end of the range found in the Bakken (ie well above the Bakken average). This is possible, because the formations are thicker than found in the Bakken. This would provide nation-changing economic returns. The area drained (1,600 km2) is 9% of the potentially prospective area in the East Coast (and 7.3 % of the Study Region).

Spend ($ billion)	Max Production (bopd)	Time Period (years)
284	225,000	64

It is important to note that the scenarios are not predictions but intended to illustrate the range of possible outcomes from oil and gas development. The economic impacts could be anywhere within the range of the scenarios.

MBIE consider the economic gains of the oil and gas industry to be net gains, meaning there will be very little displacement of current economic activity. This is because it makes use of an untapped resource, involves overseas investment and is capital rather than labour intensive. However, they acknowledge there will be some movement between industries and sectors. While there is a risk that an oil boom creates pressures on housing supply and other infrastructure, the timeframe over which development is likely to ramp up, mean that there are opportunities to manage these pressures and for the local economy to adapt.

How the industry develops and at what speed will depend on number of wider political and economic factors that are simply unknown at this point in time.

7.3 Taranaki

Oil and gas has made a significant contribution to the strength of the Taranaki economy but it is not immune to the challenges faced by other regions.

Taranaki is the benchmark for regional economic development as a result of the oil and gas industry. It is the only region where the industry has an established presence and it is widely accepted that oil and gas makes a significant contribution to the Taranaki economy. The industry is estimated to contribute $2.2 billion to regional GDP and has contributed to buoyant economic conditions in Taranaki over a number of years and has helped cushion against economic downturns (Source).

There is also potential for ongoing development. Although over 600 onshore and offshore exploration and production wells have been drilled in the region to date, the Taranaki Basin still remains underexplored compared to many comparable basins elsewhere in the world and there is considerable potential for further discoveries (Taranaki Regional Council, 2013).

Taranaki frequently tracks above national trends in economic activity and employment as reflected in the regular National Bank Regional Economic surveys and this can in part be attributed to the strength of the oil and gas sector in the region (Chamberlain, 2012). It is estimated that the region has the highest average labour productivity and the highest level of output per capita in New Zealand. Mining was estimated to contribute 23% of regional GDP in 2011 (Source).

The following table compares some of key economic statistics of Taranaki and Hawkes Bay (MBIE, 2016):

Indicator	Year	Hawke's Bay	Taranaki

GDP per capita	2015	$41,000	$76,000
Participation rate	2016	66%	68%
Employment rate	2016	62%	64%
Unemployment rate	2016	6%	5%
Employment growth (CAGR 2005-2015)	2015	0.7%	1.3%
Annual average household income	2015	$77,042	$93,075
Average house value	2016	$327,138	$334,893
Average weekly rent	2016	$312	$312

However, Taranaki still faces economic challenges. This was highlighted in the recent Taranaki Regional Economic Development Strategy (August 2017) as follows:

Increasing maturity and breadth are evident in the Taranaki economy. Its concentration on two key sectors (dairy and energy) has been a source of growth in the past, but recent events have highlighted the volatility and vulnerability of the Taranaki economy. In the context of global trends that are having profound effects on communities, a continuing heavy reliance on natural resources and exporting basic commodities makes the region vulnerable. The way in which it has bounced back from softer oil and dairy commodity prices indicates a strong underlying resilience, as well as vulnerability.

Like Hawkes Bay, Taranaki also faces challenges around the following areas:

- Skills and qualification levels are behind national averages
- Loss of talented young people to larger centres
- Lack of depth in the labour market
- Limited access to tertiary education and research facilities
- Geographically distant from the main centres and arterial transport routes.

So although the Taranaki economy is strengthened and diversified by the oil and gas industry, there are still risks and vulnerabilities around the reliance on basic commodity exporting.

8 Environmental Risk

8.1 Introduction

There are a number of environmental risks associated with the oil and gas industry.

This section explores the environmental risks associated with oil and gas activities. The focus for this report is on the risks that are within the scope of Hawkes Bay Regional Council functions. As noted earlier, district councils are responsible for the management of issues such as noise, traffic and visual effects.

The following areas are covered:

- Well integrity
- Hydraulic Fracturing
- Waste management
- Seismicity
- Hazardous Substances
- Air discharges
- Coastal Marine Area

It is important to note that many of the risks are interrelated and cannot be managed or assessed individually. For example, well integrity is also critical to managing the risks from hydraulic fracturing. Likewise, waste management is dependent on the chemicals and hazardous substances used in the drilling or fracking process. The activities and risks relevant to an oil and gas operation will be specific to the location, equipment and methodologies used.

It is also important to note that the risks described below are poorly understood in the Hawke's Bay context. Although there has been a long history of exploring oil and gas potential, this has not been at a scale or level that provides a detailed understanding of the sub-surface geology and likely drilling conditions and risks. It seems the only way to overcome this lack of knowledge would be through further seismic surveying and exploratory drilling.

8.2 Well Integrity

Modern oil and gas wells are carefully designed and the rate of failure is low. However, it is still a reality.

Well failure is a significant risk to people's safety and the environment and the well design and examination process is fundamental to managing these risks. The probability of well failure is low if it is designed, constructed and abandoned according to best practice (PCE, 2014). However, as highlighted in the PCE Report:

Unfortunately, even wells designed to high standards can fail, usually due to deterioration of the cement seal. A study of over 300,000 oil and gas wells in Alberta, Canada found that around 5% had leaked at some stage during their operation. In Pennsylvania, a study of wells where fracking is used to extract gas from the Marcellus Shale Field found problems with the casing or cement in 1 to 3% of them.

Other reports (see hydraulic fracturing below) have identified higher failure rates.

If a well fails, there are three ways in which escaping gases and liquids can harm the environment and people.

- Blowouts that can lead to fires and are a major health and safety hazard. They can also lead to contamination of soil and water.
- A leak at the surface can contaminate soil and water. Leaking gas can explode and endanger people in the vicinity
- A leak of gases and liquids below the surface can also contaminate soil and water lead to gases and liquids getting into surrounding rock and migrating into an aquifer.

8.2.1 Well Design

Oil and gas wells consist of multiple layers of cemented casings designed to separate the well from the surrounding geological layers, including fresh water layers.

Oil and gas wells are designed and constructed to move fluids to and from the targeted rock formation without leaking and to prevent fluid movement along the outside of the well. The presence of multiple cemented casings that extend from the surface to below groundwater layers is one of the primary well construction features that protects groundwater resources.

Wells must be cased with pipes of sufficient strength and integrity to withstand corrosive effects and pressures encountered. Casing and the cement between the casing and the surrounding geological formation is needed to:

- Maintain borehole stability;
- Prevent contamination of surface water and groundwater;
- Isolate water from producing formations; and
- Control well pressures during drilling and production.

The overall integrity of a correctly designed casing is dependent upon a quality assurance programme that ensures damaged connections are not used and that operations personnel adhere to running procedures. Where casing failures occur, this is generally at connections and is attributed to incomplete cementing that leaves gaps and channels through which liquids and gas are able to pass, bypassing the cased borehole. The main contributing factors are:

- Improper design or exposure to loads exceeding the rated capacity;
- Failures in manufacturing;

- Damage during storage and handling; and
- Damage due to corrosion and wear.

8.2.2 Well Drilling

Drilling conditions in Hawkes Bay will be different to Taranaki. There are likely to be higher drilling pressures at shallower depths.

Well drilling is a critical risk period in the life cycle of an oil and gas well.

The drilling conditions in Hawkes Bay region will be different to those found in Taranaki where there is extensive experience with oil and gas extraction from the local sandstone geology. Hawkes Bay is likely to have less permeable target formations and higher drilling pressures at shallower depths.

High pressures at shallow depths create additional risk. For example, cementing the surface casing is more difficult as the high weight of mud required to keep the well from flowing back can make it difficult to cement across the entire gap between the casing and surrounding geological formations. Cementing can also be affected by ground temperature, groundwater chemistry, cement slurry design, surface equipment and downhole conditions (TRC, 2013).

The high pressure drilling muds that are pumped down the well during drilling create a primary barrier which exerts hydrostatic pressure to stop oil and gas coming to the surface. Mud weights are adjusted during drilling to ensure the balance is maintained. The blowout preventer generally acts as the second barrier, if the mud fails (TRC, 2013).

8.2.3 Well Blowouts

A blowout is the uncontrolled release of oil or gas from a well after pressure control systems have failed. Modern well design means blowouts are less frequent but they still occur.

Well blowouts occur when the pressure in the reservoir being drilled overwhelms the drilling mud pressure and the blowout preventer or other secondary barriers are unable to stop the flow. This can be a result of faults in the safety device that is intended to seal the well, poor well design, and human error (or a combination of these factors). Blowouts can sometimes be brought under control quickly, but in other situations they can last for a prolonged period (USEPA, 2016).

A well blowout may occur during any phase of oil and gas well operations, but the risk of a blowout is highest during drilling activities (Grottheim 2005). There are several types of blowouts that may occur. With respect to onshore sites, the two types of concern are surface and underground. A surface blowout can directly impact on surface water systems such as rivers and wetlands; groundwater can be contaminated through the connections and recharge mechanisms from the surface water system. In an underground blowout, fluids generally flow from deeper high pressure geological formations to shallower low pressure ones such as groundwater layers (Valleyo-Arrieta 2002).

The PCE Report found that reliable statistics on well blowouts and particularly wells undergoing hydraulic fracturing appear to be elusive. What information is available indicates that the probability of a blowout has decreased as oil and gas industry operational methods have improved (Jordan and Benson 2009). Modern wells have blowout preventers intended to prevent such an occurrence. However, they still occur. Data also indicates that the probability of blowouts increases with drilling depth (Grottheim 2005).

Although there have been no major well blowouts in New Zealand, the PCE highlighted the following examples of well integrity failures:

In New Zealand, there have been recorded failures of well integrity. One was the McKee-13 well blowout in 1995, which took 35 hours to get under control. Another occurred more recently in the Cheal Oil Field, when hot water injected to enhance oil recovery leaked from patches on two production wells into another deep rock formation.

Although the probability of a blowout may be low, it cannot be discounted. Blowouts have occurred during hydraulic fracturing operations in other countries (PCE, 2014). The risks may also increase if the oil and gas industry expands into frontier basins and new geological conditions. The wells that were recently drilled by TAG Oil in the East Coast Basin experienced high gas pressure at shallow depths.

8.2.4 Well Leakage

A well with poor integrity can allow unintended fluid movement, either from the inside to the outside of the well or vertically along the outside of the well. Gases or liquids released from the targeted rock formation or other formations can travel along these pathways to impact on groundwater resources. This is discussed in more detail under hydraulic fracturing below.

8.2.5 Aftercare

Overtime, the well casing and cement can deteriorate. If not properly managed, abandoned wells present an ongoing risk.

When a well reaches the end of its useful life, cement plugs are placed in the borehole to prevent migration of fluids between the different formations. End of life requirements are ideally considered during the initial well design, as the main risk around casing failure is as the well ages. The PCE identified that this is potentially the most significant and ongoing risk associated with well integrity.

Few groundwater monitoring programmes cover the entire life of a well and there appears to be little if any further monitoring after wells are abandoned and sealed off. As an example of recent monitoring conditions, aftercare monitoring for the Waitangi Valley-1 Well near Gisborne required groundwater sampling one week, one month, six months and one year after drilling and well completions.

Once a well has been abandoned and signed off by the relevant authorities, any leaks become the responsibility of the owner or occupier of the land. Currently, the cost of clean-up from historic activities (such as contaminated sites) is likely to fall on the public or owner of the land.

8.3 Hydraulic Fracturing

The main areas of environmental risk associated with the hydraulic fracturing are:

- Well blowouts and leakage caused by defective well installation or operation
- Leakage through the fracture network
- Potential seismic effects, including low-level induced seismicity
- The management, treatment and disposal of wastewater including produced water and recovered hydraulic fracturing fluids
- Spills and leaks of hazardous substances

Some of these matters are common to other drilling activities and are covered in other sections.

Hydraulic fracturing fluids primarily move along two pathways during the well injection stage: the oil and gas well and the newly-created fracture network. The potential for hydraulic fracturing fluids to reach groundwater resources is related to these pathways (USEPA, 2016).

8.3.1 The Well

Hydraulic fracturing creates significant pressure and temperature changes on a well.

During hydraulic fracturing, a well is subjected to greater pressure and temperature changes than during any other activity in the life of the well. As hydraulic fracturing fluid is injected into the well, the pressure applied to the well increases until the targeted rock formation fractures; then pressure decreases. Maximum pressures applied to wells during hydraulic fracturing have been reported to range from less than 14 megapascals (MPa) to approximately 83 MPa. A well can also experience temperature changes as cooler hydraulic fracturing fluid enters the warmer well. In some cases, casing temperatures have been observed to drop from 100°C to 18°C (USEPA, 2016).

A well can experience multiple pressure and temperature cycles if hydraulic fracturing is done in multiple stages or if a well is re-fractured. Casing, cement, and other well components need to be able to withstand these changes in pressure and temperature, so that hydraulic fracturing fluids can flow to the targeted rock formation without leaking. Figure 11 below shows some of the potential pathways for fluid movement in a cemented well (USEPA, 2016).

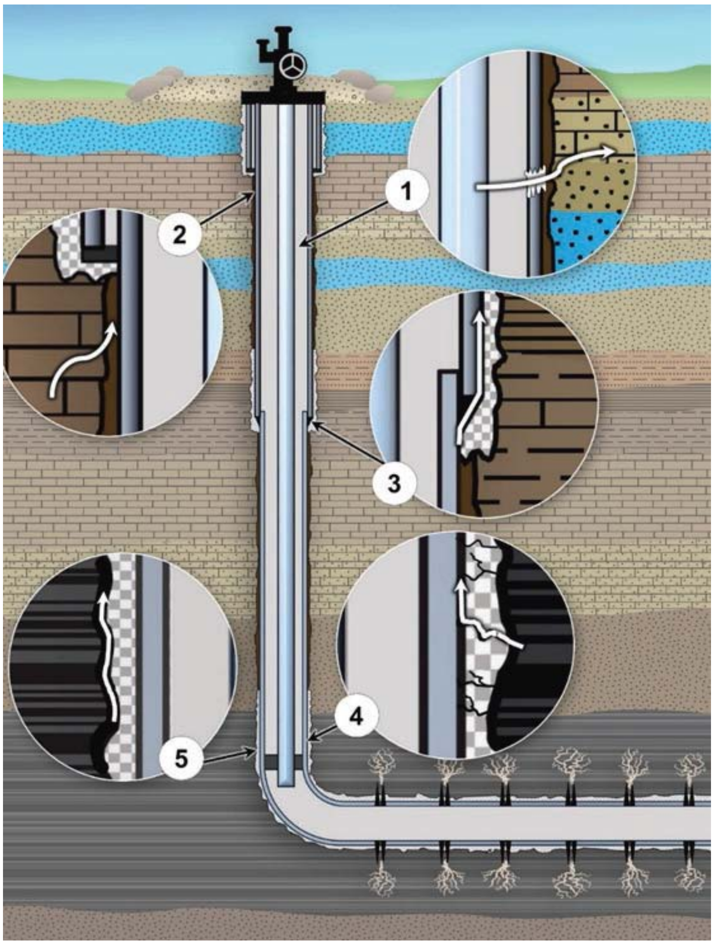


Figure 11 Potential pathways for fluid movement in a cemented well. These pathways (represented by the white arrows) include: (1) a casing and tubing leak into the surrounding rock, (2) an uncemented annulus (i.e., the space behind the casing), (3) microannuli between the casing and cement, (4) gaps in cement due to poor cement quality, and (5) microannuli between the cement and the surrounding rock. (Source: USEPA)

Examples of mechanical integrity problems have been documented in hydraulically fractured oil and gas production wells in the US. A survey of public data on operator performance in the Pennsylvania Marcellus Play (natural gas shale) highlighted that:

- 1609 wells were drilled in 2010 with 97 well failures – 6% rate of failure
- 1972 wells were drilled in 2011 with 140 well failures – 7.1% rate of failure
- 1346 wells were drilled in 2012 with 120 well failures – 8.9% rate of failure (Ingraffea, 2013).

8.3.2 Other Wells

The presence of other wells near hydraulic fracturing operations can increase the potential for hydraulic fracturing fluids or other subsurface fluids to migrate into groundwater. There have been cases in which hydraulic fracturing at one well has resulted in unexpected pressure increases, damage or spills at nearby wells (USEPA, 2016).

Abandoned wells near hydraulic fracturing operations can also provide a pathway for fluid movement into groundwater resources if those wells were not properly plugged or if the plugs and cement have degraded over time. For example, an abandoned well in Pennsylvania produced a 9-meter geyser of brine and gas for more than a week after hydraulic fracturing of a nearby gas well.

The potential for fluid movement along abandoned wells may be a significant issue in areas with historic oil and gas exploration and production.

8.3.3 The Fracture Network

Not much is known about the underground network of fractures created by fracking. However, the greater the distance between groundwater layers and the oil or gas layers, the less risk of groundwater contamination.

Low permeability layers, known as geological seals, act as natural barriers that hold oil and gas in their reservoir or source rocks. Without these seals the oil and gas would escape to the surface or dissipate into surrounding layers. Fractures and faults within these geologic seals could provide pathways for the migration of fluid to other layers including freshwater layers (GNS, 2012).

Fracture growth during hydraulic fracturing is complex and depends on the characteristics of the targeted rock formation and the hydraulic fracturing operation. The natural stresses placed on the rock formation due to the weight of the geological layers above affect how the rock fractures, including whether newly-created fractures grow vertically or horizontally. Fracture growth can be controlled by limiting the rate and volume of hydraulic fracturing fluid injected into the well.

Publicly available data on fracture growth are currently limited to data collected during hydraulic fracturing operations in five shale plays in the United States. Analyses of these data by Fisher and Warpinski (2012) and Davies et al.(2012) indicate that the direction of fracture growth generally varied with depth and that upward vertical fracture growth was often in the order of tens to hundreds of metres. One percent of the fractures had a fracture height greater than 350 meters and the maximum fracture height was 588 meters. This suggests that some fractures can grow out of the targeted rock formation and into overlying formations. It is unknown whether these observations apply to other hydraulically fractured rock formations because data from other rock formations are not available to the public (USEPA, 2016).

The USEPA Report on drinking water impacts stated that data on the location of induced fractures in relation to underground drinking water resources are generally not available because fracture networks are infrequently mapped and because there can be uncertainty in the depth of the water resource. Without such data, they were unable to determine with certainty whether fractures had reached underground drinking water resources.

Instead, they considered the issue in terms of the vertical separation distance between hydraulically fractured rock formations and the bottom of underground drinking water resources. They concluded that it is less likely that hydraulic fracturing fluids would reach an overlying drinking water resource if:

- the vertical separation distance between the targeted rock formation and the drinking water resource is large
- there are no open pathways (e.g., natural faults or fractures, or leaky wells).

The report concludes that the closer the hydraulic fracturing operations comes to drinking water resources, the greater the risk. This can be applied to groundwater resources in general.

This issue was also reviewed by GNS on behalf of Taranaki Regional Council. Their report stated that:

- The depth of hydraulic fracturing is relatively deep compared to the depth of freshwater aquifers
- The technology to properly design and install wells exists and there are methods that allow checking of the integrity of the well
- Petroleum hydrocarbon reservoirs have natural overlying "geologic seals" that trap the gas in place.

In Taranaki at least, there is a substantial distance between the oil and gas formations and the overlying freshwater aquifers. Based on the limited studies into oil and gas potential in the East Coast Basin, and the target depths of exploratory wells that have been drilled to date, this is also likely to be the case in Hawkes Bay. However, there have been no specific studies into hydrogeological risks in the Hawkes Bay context.

Large separation distances are generally reflective of deep shale formations where oil and gas production wells are drilled vertically and then horizontally along the targeted rock formation. Microseismic data and modelling studies done in the US suggest that under these conditions fracture networks are unlikely to reach groundwater resources (USEPA, 2016).

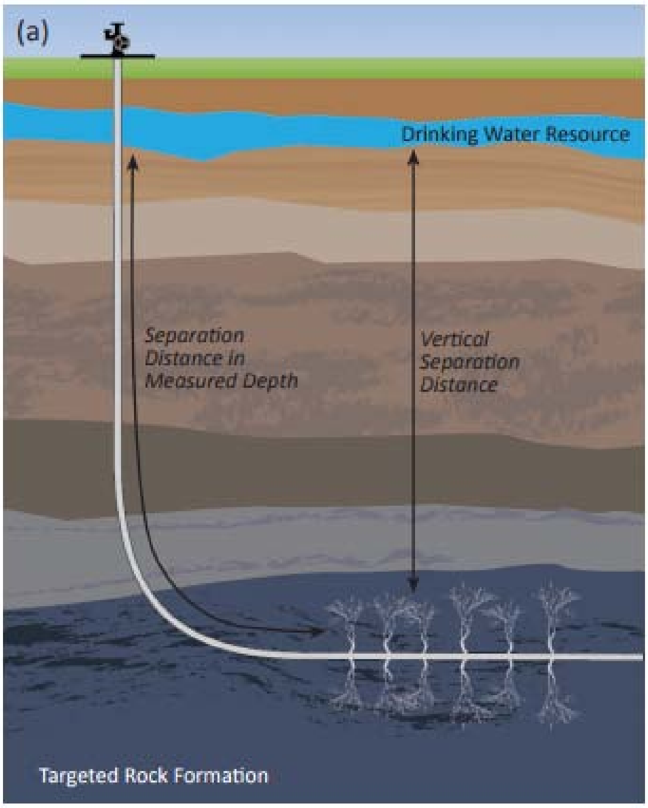


Figure 12: Separation distances between hydraulic fracturing and water resources. (Source: USEPA)

The GNS report concludes that the available information indicates that there is no evidence that the natural geological seals above the petroleum hydrocarbon reservoir have been breached during hydraulic fracturing operations in Taranaki. However, there does not seem to be any specific studies or publically available information on fracture networks and how they behave in New Zealand.

8.4 Waste Management

The waste from oil and gas activities needs to be managed carefully to avoid soil or water contamination.

A variety of wastes are produced from oil and gas activities. Some waste is relatively harmless and is common to many industrial activities (such as stormwater runoff). However, some is contaminated and needs to be disposed of carefully to avoid water and soil pollution. Managing the waste from oil and gas extraction has become a major issue in areas where hydraulic fracturing has enabled rapid expansion of the industry (PCE, 2014).

There are two broad categories of waste disposal discussed below:

- Solid waste which consists of drilling muds and drill cuttings
- Liquid waste which consists of produced water and fracking fluids.

Hazardous substances and the risk of spills and leaks are discussed in the next section.

8.4.1 Solid Waste

Solid waste is made up of drilling muds and rock cuttings and is usually disposed of through landfarming in Taranaki.

The two main types of solid waste produced as part of the drilling process are drilling muds and drill cuttings.

Drilling muds are an engineered slurry type material used in the well drilling process. They are discharged into the bore as it is being drilled and exit through the drill bit, cleaning and cooling the bit before lifting the cuttings to the surface. They also provide hydrostatic pressure to keep formation fluids out of the borehole and control pressure in the well (TRC, 2013).

There are three commonly used types of muds in the oil and gas industry: water-based mud, oil-based mud and synthetic oil-based mud. Various solid and liquid additives are added to enhance drilling performance. Some of the additives introduce potentially toxic compounds into the drilling process, which must be considered when the resulting wastes are managed. The main pollution of waste muds are caused by: biocides, oil, completion or stimulation fluid components, corrosion inhibitors, reservoir fluids (crude oil, brine), and drilling mud chemical components (TRC, 2013).

In some cases the waste would meet the definition of hazardous waste, and be required to be disposed of in a landfill capable of accepting these wastes. Where the waste is not considered hazardous, options for disposal include landfarming or other treatment process before being discharged. Drilling wastes are the second largest volume of waste, behind produced water (MfE, 2013).

Rock cuttings are separated or filtered out of the mud as they return to the surface, and the mud returns to the mud pit or tank for re-use. The drill cuttings provide the primary evidence of the geological layers being drilled so regular samples are taken for analysis (TRC, 2013).

Although, not strictly solid, the waste drilling muds are often combined with drill cuttings, which make them unsuitable for deep well injection. In Taranaki, drilling muds and drill cuttings are disposed of through landfarming.

Landfarming

Landfarming is a bioremediation treatment process that relies on microbes in the soil to break down the contaminants into harmless substances. But not all the contaminants are biodegradable; hydrocarbons, which form the bulk of the contaminants, are biodegradable. Heavy metals and salts are not biodegradable with cadmium a particular concern because it bioaccumulates in animals (PCE, 2014).

Solid waste products such as rock cuttings and drilling wastes have been incorporated into re-contoured paddocks and re-sown into pasture on the sandy coastal soils of Taranaki. In a report commissioned by the Taranaki Regional Council, it was concluded that:

"Based on the available evidence it is concluded that the Taranaki 'Landfarms' are 'fit for purpose' in terms of pastoral farming and particular dairy farming. This conclusion is based on considering the concentrations of nutrients (both macro and micro), heavy metals, barium and petrochemical hydrocarbons residues in both the soils and pastures at 3 sites."

There were 11 farms consented in Taranaki as of 2013. Monitoring reports from Taranaki Regional Council indicate that compliance with consent conditions is generally good but there have been some instances of non-compliance with abatement notices and infringement fines issued.

Whether landfarming will be an appropriate way of disposing of waste from oil and gas wells outside Taranaki is unclear. Allowable contaminant levels that are appropriate for the sandy coastal soils of Taranaki may not be appropriate elsewhere. The PCE Report noted that because of the way in which shale has been compacted under heavy pressures over millennia, the produced water coming out of wells in the east of the North Island would almost certainly contain greater concentrations of heavy metals, salts, and radioactive substances.

The PCE Report also noted that landfarming has been prohibited in New South Wales where rock cuttings from drilling are often used as roadfill. It was also highlighted in the PCE Report that the country's largest dairy company has indicated it will not take milk from any new landfarms:

The New Zealand dairy industry has learned from recent experience that the perception of contamination can be as damaging to export markets as the reality of contamination. And regardless of the actual food safety risk, cattle trampling drilling waste into paddocks does not inspire confidence.

8.4.2 Produced Water

Produced water is usually disposed of through deep well injection.

Produced water is a term used to describe water that is a by-product of the oil and gas recovery process. Most produced water is unfit for domestic or agricultural purposes (generally because it is extremely salty) and can cause soil, surface-water and groundwater contamination if not managed appropriately (PCE, 2014).

Produced water can contain many constituents, depending on the target rock formation and the composition of drilling and fracking fluids. Produced water has been found to contain:

- Salts, including those composed from chloride, bromide, sulphate, sodium, magnesium, and calcium;
- Metals, including barium, manganese, iron, and strontium;
- Naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes(BTEX), and oil and grease;
- Radioactive materials, including radium; and
- Hydraulic fracturing chemicals and their chemical transformation products.

Produced water volumes can vary by well, rock formation, and time after hydraulic fracturing. Oil wells sometimes produce large volumes of water, while gas wells tend to produce water in smaller proportion. The amount of produced water usually increases with the age of the well.

In general, produced water from oil and gas wells is managed through injection wells, reuse in other hydraulic fracturing operations, or various aboveground disposal practices. For hydraulic fracturing operations, the initial recovery from the well is likely to be fracture fluid and some solids (proppant) which can be sent directly to tanks for recycling or disposal offsite (TRC, 2013).

Waste Injection

Produced water can be disposed of by underground injection. This may be through a disposal well or an enhanced recovery well, which injects produced water and other materials into an existing reservoir to increase production. The PCE Report in 2013 identified that there are 20 resource consents for deep well injection in Taranaki; nine were in use at that time.

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 freshwater layers to minimise the risk of contamination. Any risk to groundwater or aquifers would be associated with well integrity and the separation between the target depth and freshwater layers. This was discussed in previous sections.

Veil (2015) estimated that 93% of produced water from the oil and gas industry was disposed of through deep well injection. Disposal of wastewater in this way is often cost-effective, especially when disposal well is located within a reasonable distance from a production well.

Disposal of wastewater through well injection has also been associated with earthquakes in several countries and should be considered as part of the environmental risk framework for Hawkes Bay. See below.

8.5 Seismicity

Deep well injection and hydraulic fracturing can trigger small earthquakes. The level of risk has not been assessed on the East Coast, which is the most seismically active region in New Zealand.

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 as well as other activities such as mining, geothermal and hydro development (PCE, 2014).

The majority of felt seismicity associated with oil and gas development has been related to waste disposal injection rather than the hydraulic fracturing process (National Research Council, 2012). The largest earthquake that has been attributed to fracking anywhere in the world measured 3.8 on the Richter scale. Earthquakes up to 5.3 on the Richter scale have been attributed to the reinjection of wastewater.

In a study undertaken for Taranaki Regional Council, GNS found no evidence for either hydraulic fracturing or long-term deep injection activities in Taranaki between 2000 and mid-2011 having any observable effect on natural earthquakes of magnitude 2 or larger. An earthquake of about magnitude 2 would be a relatively small event and at a depth of 2-4 km such an earthquake is likely to produce ground shaking similar to that caused by a nearby passing truck.

In addition to induced seismicity, natural earthquakes can damage wells, potentially allowing contaminants to leak into aquifers, and possibly lead to well blowouts and fires (PCE, 2014).

8.6 Hazardous Substances

There are a variety of hazardous substances required for oil and gas drilling; these are mostly additives used in drilling muds and hydraulic fracturing fluids.

Hazardous substances associated with oil and gas well drilling have the potential to impact human health and the environment. The main risk pathways are through well integrity issues and spills and leaks (see below).

The potential impact depends on the material, its concentration after release and the level of exposure (time and quantity). Most concentrations encountered during drilling activities are relatively low, therefore the environmental impact is generally observed only after chronic exposure (USEPA, 2016).

The human health effects of most concern in relation to chemical contaminants arise from prolonged exposure at low concentrations. However, high concentration exposure from an accidental leak or spill can have immediate consequences on human health and the environment.

In general, oil and gas operations that comply with the Hazardous Substances and New Organisms Act 1996 (HSNO) should not have any adverse effects on the environment. However, the HSNO does not cover all of the substances associated with oil and gas activities that could cause environmental damage. For example, the produced water extracted along with oil and gas is not classed as ‘hazardous’ by the EPA, although the heavy metals and salt in it could cause environmental damage were they to find their way into the environment (PCE, 2014). Councils can manage the potential effects of these substances through RMA processes; either through consent processes or plan changes.

8.6.1 Drilling and Hydraulic Fracturing Chemicals

A variety of chemicals are used in oil and gas drilling operations. This will be either the additives used in drilling muds or the hydraulic fracturing process.

Water based muds may range in formulation from fresh water to water with viscosifiers, weighting agents and various additives to control formation properties such as swelling clays. Barite ($BaSO_4$) is a commonly used weighting agent.

Good oilfield practice requires the use of freshwater as a base drilling fluid at shallower depths to minimise contamination from the very small amount of fluid leak-off in shallow, highly permeable formations that may occur prior to the freshly drilled hole being cased. Oil based muds and synthetic oil based muds have been used in Taranaki to control ‘swelling clays’ and to improve drilling performance in deeper sections. Synthetic oil based muds are increasingly favoured as they may have lower environmental impacts. However, water-based mud is universally used for near-surface drilling (to about 500m depth). If necessary, the mud system is then changed to an oil based or synthetic oils based system, once the casing has been set across shallow aquifers (TRC, 2013).

There have been public concerns about the chemicals involved in hydraulic fracturing fracking process (PCE, 2014). A range of chemicals are added to water to alter its properties for hydraulic fracturing. These chemicals perform many functions in the hydraulic fracturing process such as dissolve minerals, initiate fractures, eliminate bacteria, prevent corrosion, maintain viscosity and stabilise other chemicals.

A report prepared by Taranaki Regional Council identified that there are hundreds of chemicals that could be used as additives, however, a smaller number are routinely used. 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 with water 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 for disposal.

The US EPA compiled a list of 1,606 chemicals that are associated with hydraulic fracturing operations, including 1,084 chemicals reported to have been used in hydraulic fracturing fluids and 599 chemicals found in produced water. Individual wells are likely to use a fraction of the chemicals listed. They also identified that there may be other chemicals that are not included on the list.

The properties of a chemical influence how it moves and transforms through the environment and how it interacts with the human body. Some chemicals used in hydraulic fracturing are of more concern than others because they are more likely to move with water, persist in the environment, and/or affect human health (USEPA, 2016).

8.6.2 Radioactive substances

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.

Shale and sandstone formations also commonly contain radioactive materials, including uranium, thorium, and radium. NORM above normal background levels are found in some US oil and gas reservoirs but to date it is not known to occur in Taranaki or elsewhere in New Zealand.

8.6.3 Spills and Leaks

Spills and leaks are the most common cause of soil and water contamination, primarily through equipment failure and human error.

Spills and leaks of chemicals, wastewater, and oil and gas are the most common cause of soil and water contamination associated with well sites. They can occur during transport, handling, storage, and use of waste material and hazardous substances. This was succinctly summarised in the PCE Report:

"Trucks can roll, storage tanks and pits can leak or overflow, and pipes can burst."

In a recent incident at an exploration well site in Taranaki, equipment failure led to oil collecting in a flare pit, leaching into a tile drain, through a manhole, and into a stream. In another more serious case, hundreds of litres of oil and produced water leaked from a pipeline into a stream (MfE, June 2014).

Produced Water

While produced water collection, storage, and transportation systems are designed to contain produced water, spills do occur. Common causes of produced water spills include human error and equipment leaks or failures. Common sources of produced water spills included hoses or lines and storage equipment (USEPA, 2016).

Spills of produced water have reached groundwater and surface water resources in the US. Documented cases of water resource impacts provide insights into the types of impacts that can occur. In most of the cases reviewed in the USEPA report, impacts included elevated levels of salinity in groundwater and/or surface water resources.

Site-specific studies of produced water spills have also looked at the role of local geology in the movement of produced water through the environment. Whittemore (2007) described a site in Kansas where low permeability soils and rock caused produced water to primarily flow overland to nearby surface water resources, reducing the amount of produced water that infiltrated soil and groundwater. In contrast, Otton et al. (2007) explored the release of produced water and oil from two pits in Oklahoma. In that case, produced water from the pits flowed through thin soil and into the underlying, permeable rock. Produced water was also identified in deeper, less permeable rock, potentially transported through natural fractures.

In addition, produced water can have high levels of total dissolved solids, which affects how the fluid moves through the environment. When a spilled fluid has greater levels of total dissolved solids than groundwater, the higher-density fluid can move downward through the groundwater resources. Depending on the flow rate and other properties of the groundwater resource, impacts from produced water spills can last for years.

The severity of impacts on water quality will depend on the volume of produced water that is able to enter surface water or groundwater, the type and amount of constituents within the produced water, the toxicity of those constituents, and the characteristics of the local geology and receiving waters (USEPA, 2016).

Hydraulic Fracturing

In the US, several studies have documented spills of hydraulic fracturing fluids or additives. Data gathered for these studies suggest that spills of hydraulic fracturing fluids or additives were primarily caused by equipment failure or human error. For example, an EPA analysis of spill reports from nine state agencies, nine oil and gas well operators, and nine hydraulic fracturing service companies identified 151 spills of hydraulic fracturing fluids or additives on or near well sites across 11 states between January 2006 and April 2012 (U.S. EPA, 2015c). These spills were primarily caused by equipment failure (34% of the spills) or human error (25%), and more than 30% of the spills were from fluid storage units.

Although impacts on surface water resources have been documented, site-specific studies into the factors that affect the frequency or severity of impacts were not available. Likewise for groundwater, a lack of data and groundwater monitoring after spill events means little known about the impacts on groundwater from spills of hydraulic fracturing fluids or drilling muds.

The severity of impacts on water quality from spills of hydraulic fracturing fluids or additives will depend on the amount of chemicals that reach groundwater or surface water resources, the toxicity of the chemicals, and the characteristics of the receiving water resource. Impacts on groundwater resources have the potential to be more severe than impacts on surface water resources because it takes longer to naturally reduce the concentration of chemicals in groundwater and because it is generally difficult to remove chemicals from groundwater resources.

8.7 Air Discharges

The main air discharge is from flaring gas that cannot be processed or sold

A well site has a number of emissions to air from drilling activities and site equipment. The major emission is from flaring, which is the burning of natural gas that cannot be processed or sold. This is done in a flare pit and/or a flare box or thermal oxidiser. There are a number of other miscellaneous emissions including:

- exhaust emissions from diesel engines (generators, compressors, pumps, trucks)
- dust from earthworks associated with well site preparations
- 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).

Most of these emissions are not specific to the oil and gas industry and would carry no more risk than other activities.

Figure 13: Lined flare pit with hydrocarbons being flared (Source: Taranaki Regional Council)

Upon well completion, the testing phase of a conventional well begins with 'cleaning up' the well (removal of drill cuttings and debris and/or drilling fluids from the well). A separator and clean burning flare system are used to eliminate the return of solids and liquids to the flare system, thus avoiding the potential for black smoke from the flare because of incomplete combustion of heavier hydrocarbons, during clean up and/or testing operations (TRC, 2013).

As well clean up continues hydrocarbon gas entrained in the fluid will start to flow back. The flowback stream, still mainly water, will be directed to the separator / flare system. The liquids will be separated out, to the greatest extent practicable, and again sent to tanks. The hydrocarbon gas will be sent to the flare system. This process continues until the well is essentially cleaned up of return fluids and is flowing primarily gas (TRC, 2013).

At times there is an operational requirement to discharge well fluids to a flare pit

Certain contingency scenarios exist in which solids may begin to plug up the surface equipment, risking overpressure, and the well would need to be directed to a lined flare pit without passing through the separator. In the event of such an emergency potentially dangerous levels of hydrocarbons could build up in the pit, and so the gas would be proactively ignited to prevent a potentially dangerous explosive atmosphere forming. After the emergency situation has been addressed the well will no longer be flowed to the pit, the flare will extinguish, and the fluid in the pit should be sucked out and disposed of appropriately. The intention of lighting the gas in the emergency flare pit is to burn off hydrocarbon gas to prevent explosive risk. Although the intention is not to burn off the liquids, some will evaporate in the process (TRC, 2013).

Air emissions from landfarming are barely distinguishable from the background air quality

Monitoring of air quality at land-based waste disposal sites in Taranaki has shown that any odour effects are generally localised, with detection unlikely beyond property boundaries. 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.

8.8 Coastal Marine Area

Many of the environmental risks associated with offshore drilling are similar to those of onshore drilling. However, there are a range of risks discussed below that are unique to the coastal environment:

- Well integrity
- Oil spills
- Noise
- Marine mammals
- Fisheries

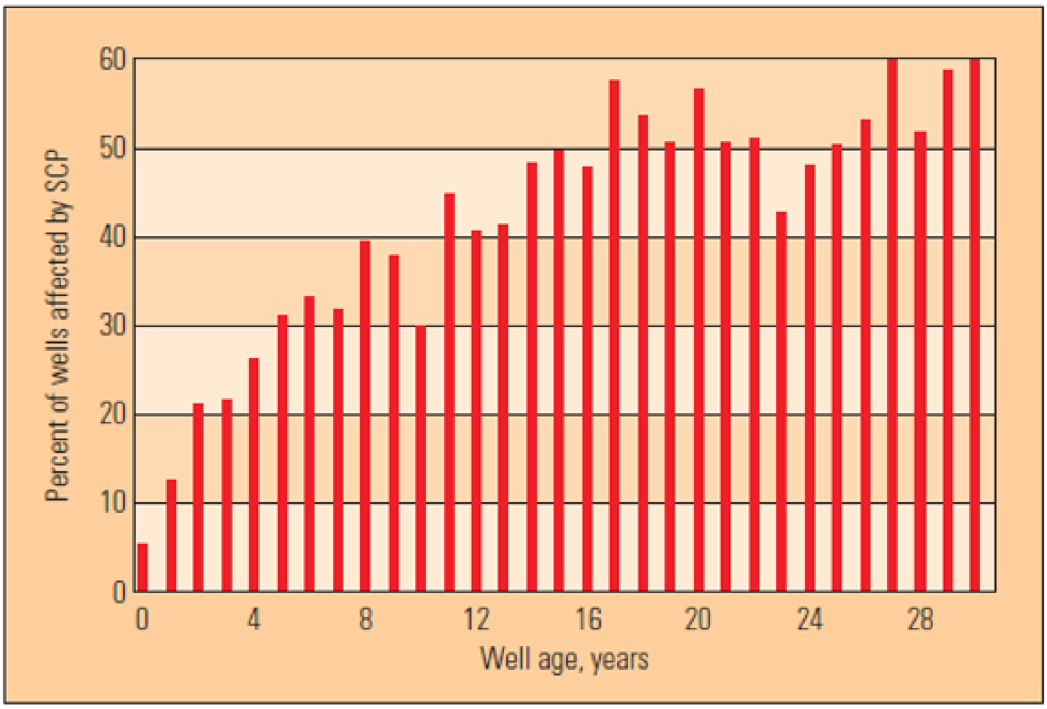
8.8.1 Well Integrity

Offshore oil and gas drilling presents a unique set of challenges and seems to have a higher risk of well failure.

Like onshore drilling, well design and integrity are critical elements to manage in order to avoid adverse effects on the environment. However, the extraction of volatile substances (oil and gas), sometimes under extreme pressure in a hostile environment, means there is an inherent and probably inevitable risk in the coastal environment. Accidents and tragedies associated with well integrity can and do occur.

The U.S. Minerals Management Service reported 69 offshore deaths, 1,349 injuries, and 858 fires and explosions on offshore rigs in the Gulf of Mexico from 2001 to 2010. Perhaps the most infamous is the Deepwater Horizon platform off the coast of Louisiana, which exploded on April 21, 2010, killing 11 people and sank two days later. The resulting undersea gusher (uncontrolled release of oil and gas from a well) was estimated to release 4.9 million barrels of oil becoming the worst oil spill in US history.

There seems to be a higher risk of well failure in the offshore environment. A presentation by Anthony Ingraffea from Cornell University and others on the historical record and rate of well integrity failures showed the following graph for offshore wells in the Gulf of Mexico:



In terms of sustained casing pressure (excessive pressure in a well that persistently rebuilds), their presentation outlined that about 5% of wells fail soon, more fail with age and most fail by maturity. This is based on a review of industry reported data on loss of well integrity.

8.8.2 Oil Spills

The risk of oil spills from oil and gas production facilities is very low in New Zealand compared to the risk from vessels travelling around and through New Zealand.

Maritime New Zealand have identified that the risks of oil spills from production facilities are very low compared to the risk from vessels travelling around New Zealand's coastline. This may be a matter of scale as there are few offshore production facilities and they are concentrated in Taranaki. As noted, Maritime New Zealand require operators to have an Oil Spill Contingency Plan and a Discharge Management Plan.

The impact of oil spills can vary from minimal, to the large scale mortality of marine life, depending on the sensitivity of the environment and its ability to recover. Potential impacts from oil spills are well documented and include any of the following environmental impacts:

- Habitats become unsuitable for feeding, nesting and other services they provide for marine life
- Intertidal areas, wetlands and mangroves become inhabitable
- Nursery areas for fish and shellfish species become damaged
- Direct mortality of marine life
- Oil coating limits the ability to swim or fly, and to maintain body temperature, feed properly and even reproduce
- Oil harms the eyes, mouth, nasal tissue, immune system, red blood cells and organs of marine animals

- Greater death of young animals which are usually the most vulnerable to the effects of oil
- Release of toxic and carcinogenic compounds from the oil into the marine environment including trace metals and polycyclic aromatic hydrocarbons (PAHs)

Social and economic impacts include:

- Significant loss to customary and recreational fishing
- Stress on subsistence communities who depend on fish and shellfish for food.
- Reduction in amenity and recreational values, particularly when oil reaches the shoreline
- Loss of incomes to tourism-based businesses and communities
- Financial loss to the commercial fishing industry, both because of impacts on the fisheries themselves, and on market perceptions
- High costs of clean-up

8.8.3 Noise

Natural sources of noise are important for marine animals to sense their environment. The effects of noise and vibration from seismic surveys is poorly understood for many species, especially fish.

Natural sources of noise in the marine environment are important for communication by animals and the ability to sense their environment. The effects of noise and vibrations from human activities (such as those associated with drilling and mining) are poorly understood for many marine species (NIWA 2017).

Seismic surveys may have an acoustic impact on marine fauna. The acoustic impact of seismic surveys on marine mammals could vary from none to behavioural (may leave the area) to acute injury (ear drum damage) to serious (death) depending on the noise level encountered, the species and the habitat. There may also be cumulative effects from repeated exposure.

There are international guidelines for assessing the effects on marine mammals and in New Zealand the potential effects of noise from seismic surveys are addressed in the 2013 Code of conduct for minimising acoustic disturbance to marine mammals from seismic survey operations prepared by the Department of Conservation.

The effects of noise on fish are less developed (Popper & Hastings 2009, Hawkins et al. 2014). Behavioural responses that have been identified include fish avoiding large approaching vessels, disruption of spawning sites in shallow coastal waters and altered predator-prey detection responses (see review by Stanley & Jeffs 2016). However, physiological impacts such as hearing damage, barotrauma and stress are not well understood.

8.8.4 Marine mammals

Collisions, entanglement in surface structures, noise, vibration and ecosystem changes such as prey distribution and abundance are all impacts from offshore activities that can affect marine mammals.

At present, there is very little information on marine mammals in the Hawkes Bay. A report was produced by the Cawthron Institute for Gisborne District Council in 2010, from which some inferences can be made for Hawkes Bay.

In terms of risks to marine mammals the report highlights the following:

- Within inshore waters, developments that involve the removal of habitat, include ropes or lines that could cause entanglement, create noise or vibration, increase the chances of colliding with an animal or that could irreversibly change the ecosystem dynamics would have the greatest impacts on marine mammals. Inshore species include, but are not limited to; common and bottlenose dolphins, fur seals and southern right whales which all utilise the coastline for feeding, resting and/or breeding.
- Species specialised to offshore waters are vulnerable to particular types of fishing techniques, offshore mining and drilling and seismic exploration and ecosystem changes that affect their prey. In particular, species that rely on cephalopods (includes squid and octopus) as their food source may be very sensitive to any change in prey distribution or abundance and may result in their abandonment of regional waters. This may affect species such as pygmy sperm whales, pilot whales and some beaked whale species.
- Migrating species, while generally only present over certain seasons and often found in more offshore waters, are potentially vulnerable to entanglement in surface structures or floating lines within their migration paths, large vessel strike and noise produced from offshore mining, drilling and seismic exploration.

8.8.5 Fisheries

Fisheries displacement is unlikely to be an issue unless there is a significant amount of offshore drilling activity but the effects on fish behaviour is unclear.

Permanent production activities may affect fisheries as fish may move away from the area of influence due to increased levels of activity. Any new structures will also alienate a small area of seafloor, so that it no longer provides foraging habitat for demersal fishes (which live and feed on or near the sea floor). However, these same structures may provide new artificial reef-like surfaces and increase reef habitat in the area (NIWA, 2012).

There may be impacts on fisheries management as production platforms and pipelines invariably have a zone of restricted access around them. The impact of a single production facility is unlikely to be great, but the cumulative impact could be problematic. However, unless production is concentrated in important habitat areas, this is unlikely to be a significant issue. It has been estimated that in the North Sea, where there are more than 500 platforms and thousands of kilometres of pipelines, the loss of fishing area was only around one per cent

The effects during decommissioning will depend on whether the infrastructure is dismantled and removed, sunk to the seafloor and abandoned, or left intact for another use such as carbon sequestration. Removal of the structure will have some impact on the seafloor and benthic organisms, as well as on the creatures which have become attached to the structure, and in some cases the environmental impacts may be less if it is left in situ.

Displacement of fishing activities from mining and drilling blocks, wider environmental effects on fish behaviour, and consumer concerns about seafood quality were considered in the recent Chatham Rock Phosphate application process through the Environmental Protection Authority, but their significance was uncertain in relation to that application.

9 Plan Change Options

Three options are outlined below to manage the risks from oil and gas activities:

- Retain the status quo with some minor changes to strengthen consent processes
- Prohibited activity status – narrow focus
- Prohibited activity status – wide focus

These options are preliminary and for the purpose of stakeholder discussions. They may change after stakeholder engagement or after a more detailed policy analysis.

9.1 Modified Status Quo

- No prohibited activity status (except existing rules in the RCEP)
- Some basic changes to strengthen the assessment processes for oil and gas drilling
- Activity status strengthened to non-complying for sensitive areas already identified in the RRMP and RCEP. This would include:
    - Areas of Significant Conservation Value (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
- All other activities to retain their current activity status.

9.2 Prohibited Activity Status – Narrow Focus

- Prohibited activity status for specific areas. This would include:
    - Areas of Significant Conservation Value (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
- Seismic surveying and other low impact activities to retain current activity status
- Strengthen assessment policies for other areas

9.3 Prohibited Activity Status – Wide Focus

- Prohibited activity status with a wider spatial scope. This would include:
    - Coastal marine area and coastal margins (RCEP)
    - Productive Aquifers (RRMP)
    - Surface water bodies including wetlands (RRMP)
    - Terrestrial areas that provide a known and important aquifer recharge function (yet to be determined)
    - Any other protected terrestrial areas (yet to be determined)
- Seismic survey to be a discretionary activity in sensitive marine areas
- Strengthen assessment policies for all other areas

These options will need to be reviewed in the light of community feedback and then considered under the requirements of the RMA. The RMA requires councils to evaluate plan changes in terms of:

- The efficiency and effectiveness of the proposed changes in achieving the objectives
- The costs and benefits of the environmental, economic, social and cultural effects
- Economic growth that is anticipated to be provided or reduced
- Employment that is anticipated to be provided or reduced
- The risk of acting or not acting if there is uncertain or insufficient information.

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