MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

File No. DOIA 1920-0860

15 JAN 2020

Robin Martin
Taranaki Whanganui reporter
Radio New Zealand
Robin.Martin@rnz.co.nz

Dear Robin

Thank you for your email of 27 November 2019 requesting the following under the Official Information Act 1982 (the Act):

> *I'm wondering if it would be possible to see a copy of Petrofac's Onshore Petroleum Wells Technical Assessment report generated as a result of that tender we've been discussing?*

Please find attached the requested report. Some information within the report has been withheld under the following sections of the Act:

9(2)(a)	to protect the privacy of natural persons
9(2)(b)(i)	to protect information where the making available of the information would disclose a trade secret
9(2)(b)(ii)	to protect information where the making available of the information would likely unreasonably to prejudice the commercial position of the person who supplied or who is the subject of the information

Section 3.0 of the report outlines the methodology and contains intellectual property pertaining to Petrofac. The release of this information could be used to identify Petrofac trade secrets and negatively impact on Petrofac's commercial position. Therefore, section 3.0 has been withheld under section 9(2)(b)(i) as identified above.

In terms of section 9(1) of the Act, I am satisfied that, in the circumstances, the withholding of this information is not outweighed by other considerations that render it desirable to make the information available in the public interest.

You have the right to seek an investigation and review by the Ombudsman of my decision to withhold information relating to this request, in accordance with section 28(3) of the Act. The relevant details can be found at: www.ombudsman.parliament.nz.

Yours sincerely

pp

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MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Petrofac

Onshore Petroleum Wells Technical Risk Assessment

Client:	Ministry of Business, Innovation & Employment
Client Ref:	652
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Issue date:	28 Nov 2017
Attention:	Ben Harford

RACI RECORD

RAC	Title	Name	Organisation	Signature	Date	Review Required Yes/No
R:	Senior Drilling Engineer	s 9(2)(a)	Petrofac Well Engineering	s 9(2)(a)	06/02/18	Yes
A:	Well Engineering Manager		Petrofac Well Engineering		06/02/18	Yes
A:	Senior Exploration Geologist		Ministry of Business, Innovation & Employment		13/02/18	
C:						
I:						

RACI TERMS

R – Responsible The party who produces the document; implements the work or causes it to be done.
A – Accountable The party who has the necessary authority to authorize the document or the implementation of the work.
C – Consulted The party(s) whose views are solicited before the document is produced or before the decision is made or who has a presence in the team preparing for the decision.
I – Informed The party(s) who must be informed for effective implementation to be achieved.
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REVISION CONTROL

Issue	Description of Change	Date	By
A	Initial Draft	25/11/17	s 9(2)(a)
B	Issued for Comment	25/11/17	
C	Issued for Review (Formal Dist and set time limits)	28/11/17	
D	Issued for Approval	18/12/17	
0	Approved and Issued for Use	06/02/18	
01,02,03	Subsequent revision of approved document		

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LIST OF ABBREVIATIONS

ALARP	As Low as Reasonably Practicable
BHA	Bottom Hole Assembly
CBL	Cement Bond Log
CMA	Crown Minerals Act 1991
CTU	Coil Tubing Unit
CO2	Carbon Dioxide
DST	Drill Stem Test
EEZ	Exclusive Economic Zone
ECD	Equivalent Circulating Density
EMW	Equivalent Mud Weight
EPA	Environmental Protection Authority
EZSV	Trademark of a Drillable Bridge Plug
HC	Hydrocarbon
HHU	High Hazards Unit
HSE	Health and Safety Executive
HSWA	Health and Safety at Work Act 2015
HWU	Hydraulic Workover Unit
H2S	Hydrogen Sulphide
JULB	Jack-up Lift Barge
LEL	Lower Explosive Limit
LWIV	Light well intervention vessels
MAWOP	Maximum Annular Working Pressure
MBIE	Ministry of Business, Innovation and Employment
MD	Measured Depth
MfE	Ministry for the Environment
MoT	Ministry of Transport
NORSOK	Norsk Sokkels Konkuranseposisjon
NZP&M	New Zealand Petroleum and Minerals
OGUK	Oil & Gas UK
P&A	Plug and abandon
RMA	Resource Management Act 1991
RP	Recommended practice
SEWOP	Self-elevating work over platform
TA	Temporary Abandonment
TCP	Tubing Conveyed Perforation
TD	Total Depth
TVD	Total Vertical Depth
WIST	Well Integrity Status Tool

1.0 EXECUTIVE SUMMARY

More than 960 onshore wells have been drilled in New Zealand over the last 150 years. The majority of these wells have been or will in due course be correctly abandoned.

MBIE have recently undertaken a review of all onshore wells and have identified 104 wells without active permit holders that may have outstanding plugging and abandonment (P&A) commitments, i.e. wells that were not recorded as having been plugged and abandoned or where the data is questionable. These wells in their current state represent an unknown risk to health and safety and the environment if hydrocarbons are able to migrate up the well to either shallow water aquifers or surface.

Petrofac Well Engineering (Petrofac) were contracted by MBIE to conduct a desktop review to determine the technical integrity of the 104 wells, and provide a methodology that ranks the risk these wells pose, which will be used to prioritise any activities to address this risk.

Whilst a number of these 104 inactive wells may pose an increasing safety and environmental risk over time due to them being inadequately abandoned, it should be noted that from all the data reviewed there is no evidence that any of these wells pose an immediate threat. None of the wells reviewed were large producers at the time they were active and the majority of the wells are incapable of flowing hydrocarbons to surface unaided.

To provide MBIE with a risk ranking of 104 wells in relation to their well abandonment integrity the following objectives were agreed:

- Provide a desktop-based technical integrity assessment of 104 wells which shall include, but is not limited to, the evaluation of:
  a. well integrity;
  b. wellbore surrounding risks;
  c. Wellbore Energy; and
  d. wellbore fluids.
- Provide a risk ranking of the 104 wells; and
- Identify the actions required to address the risks for the 104 wells, and estimate the costs of these actions.

The purpose of this study is to provide a technical integrity assessment of the 104 wells, a risk ranking of these wells, the actions required to address any outstanding plugging and abandonment commitments for these wells, and the likely costs of these actions. In addition, this study provides an overview of future diagnostic work required for detailed P&A planning.

The integrity assessment for each well considered various sources of information and a combination of 'intrinsic' and 'extrinsic' attributes. The method allowed sufficient transparency to track and understand where and how certain attribute scores affect results. Petrofac did not undertake any site visits as part of this work, and all references to information visible at wellsites is drawn from the Well Investigation Project Report of MBIE, dated 12th July 2016.

Petrofac evaluated the wells based on their threat to human health, safety and the environment if left in their current condition. Of the 104 wells, 14 wells are stratigraphic boreholes to determine the vertical location of rock units in a particular area, drilled to shallow depths (100m) and have likely collapsed. All 104 wells were reviewed individually and a summary of the final well ranking is as follows:

Priority Action	6 wells
Priority Action (missing data)	8 wells
Schedule for Action	22 wells
Watching Brief	48 wells
Minimum Risk	18 wells

Priority Wells have been defined in this report as as a well that has the potential to flow to surface and either the abandonment activity has been assessed as being inadequate or no abandonment activity has been performed.

While none of these 6 Priority Action wells are leaking or an immediate danger to personnel or the environment, they have the potential to flow oil/gas to surface if they are not properly abandoned.

8 wells were classed as Priority Action (missing data) due to having limited or missing data. Not all wells with missing data were classed as Priority Action as in some cases the available data was sufficient to determine a lower risk profile.

The well types were scored against a number of criteria (See Section 3) to provide an overall risk level. A summary of all the 'Priority Action' wells is tabulated below and further well details are in Section 5.

Priority Action Wells					
Well name	**Well type**	**Content**	**Spud**	**Total MD (m)**	**Basin/Region**
Blackwater-1	Priority Action	Gas	1968	613	Tasman Region
Horotiu-2	Priority Action	Gas	1967	198	Waikato, Hamilton Lowlands
Kauhauroa-1	Priority Action	Gas	1998	1222	East Coast Basin - Wiaora
Kauhauroa-3	Priority Action	Gas	1998	1326	East Coast Basin - Wiaora
Kauhauroa-4B	Priority Action	Oil/Gas Show	2001	2047	East Coast Basin - Wiaora
Waitahora-1	Priority Action	Oil/Gas Show	2007	1352	East Coast Basin - Wiaora
Ardmore-1	Priority Action (missing data)	Unknown	1959	137	Auckland
Centre Bush-1	Priority Action (missing data)	Unknown	1932	498	Southland Region
Norfolk Road Bore	Priority Action (missing data)	Unknown	1907	Unknown	Taranaki Basin

Peep-O-Day	Priority Action (missing data)	Unknown	1912	917	Manawatu Manganui
Waihihere-1	Priority Action (missing data)	Unknown	1911	421	East Coast Basin
Waikaia-1	Priority Action (missing data)	Unknown	1974	197	Southland Region
Waipai-1	Priority Action (missing data)	Unknown	1973	Unknown (45m?)	Bay of Plenty Region
Waitangi-1 (Gisborne Oil)	Priority Action (missing data)	Oil/Gas Show	1909	390	East Coast Basin

Table 1 – Priority Action Wells

The cost to abandon the 6 ‘Priority Action’ wells where there is sufficient well data is estimated to be $3.54mm. For the remaining 8 ‘Priority Action (missing data) wells where there is poor data, it is recommended that a field data acquisition programme is undertaken to determine if the wells require abandonment. It is not possible to determine the accurate well abandonment cost of the 8 wells where the data is poor and basic information such as well depths, casing sizes, pressures and status is unknown. Costs for these wells have been estimated with broad assumptions. Where the data is non-existent costs have been assumed for well investigation only and not full well abandonment. Estimated costs for these 8 wells are $944K, which includes the data acquisition and also P&A costs where these could be estimated.

Petrofac estimate it would cost in excess of $4.43mm and $4.46mm to abandon the remaining ‘Schedule for Action’ and ‘Watching Brief’ wells respectively. Due to the low risk posed by the ‘Watching Brief’ wells and given the expense and risk to plug these ‘Watching Brief’ wells, these wells could be left in their current state and regularly monitored until such time a rig is close-by and an opportunity arises to perform the abandonment at that time.

The abandonment costs are based on recent experience of abandoning onshore wells in New Zealand but must be recognised as Level 1 costs estimates (+/-40%). Well abandonment costs can increase significantly if downhole condition differs from that documented or assumed. Generally, the deeper the well the more the cost of abandonment.

The total cost to abandon all wells is estimated to be $14.3mm excluding the eight wells where further data acquisition is required.

2.0 INTRODUCTION

Well abandonments and integrity are currently managed through regulations under the Health and Safety at Work Act 2015 (HSWA) and WorkSafe New Zealand's High Hazards Unit (HHU) who ensure any risks to health and safety arising from these operations are as low as is reasonably practicable. Independent assurance is achieved through the use of the Well Examination process where an independent expert must review the well abandonment design and operation. This process works well and recent wells have been abandoned to a high standard. Wells of an older age were abandoned according to oilfield practices at that time and during this review a number (examined as offset wells for some of the 104 wells that are the focus of this study) were identified as not meeting current standards.

There are many types of wells encountered onshore New Zealand. For simplicity, these well types have been categorised into six types which align with similar categories from previous MBIE work.

Well Type	Description
Oil	Well data records state that well encountered movable oil whilst drilling. Well may/may not have produced oil.
Gas	Well data records state that well encountered movable gas whilst drilling. Well may/may not have produced gas.
Shows	Well data records state that well had hydrocarbon shows whilst drilling. This may have been background gas or fluorescence. Well did not flow hydrocarbons to surface.
Dry	Well did not encounter any hydrocarbons whilst drilling.
Unknown	Well data is insufficient to determine if hydrocarbons present.
Water	Well data records only record water-bearing formations as being encountered whilst drilling. No hydrocarbons recorded.

Table 2 – Well Type Categories

MBIE have over the years reviewed a considerable quantity of well data and used specific well status classifications in their previous work. For consistency, Petrofac have elected to adhere to the same classification system in this study. A number of wells reviewed had differing actual well status than that recorded on the MBIE database, this is likely due to differing Operators' terminology and well status definitions not being consistent. For example, the definitions of well status have changed from the early 1900s, e.g. "abandoned" at that time often meant placement of a mechanical plug whilst today abandonment requires isolation via two verified cement plugs and severance of the casing at surface.

Well Status Terminology	Description
Abandoned	A well that is filled with cement and decommissioned.
Completed	A well that has been completed for production with completion tubing and surface Xmas tree installed
Suspended / Temporary Abandoned	A well that has temporarily discontinued operations - generally with a downhole barrier.
Shut-in	A well that has had its valves closed to stop the well from flowing. Generally, does not have downhole barriers.
Unknown	Well data is insufficient to determine well status

Table 3 – Well Status Classifications

As part of the study, Petrofac updated the status of the wells where appropriate.

A significant challenge with this study is the lack and quality of available data. Whilst MBIE have an extensive database, there are still gaps in the data, especially with older wells. A system was put in place (see Section 3.1) to address this lack of data.

Once wells are no longer in use, or have reached the end of their useful life, they must be plugged and abandoned in line with the regulations (e.g. Crown Minerals Act 1991, Resource Management Act 1991 and Health and Safety at Work Act 2015) and industry best practice. For various reasons, this has not always occurred and of the 104 wells reviewed, their status has been identified as follows:

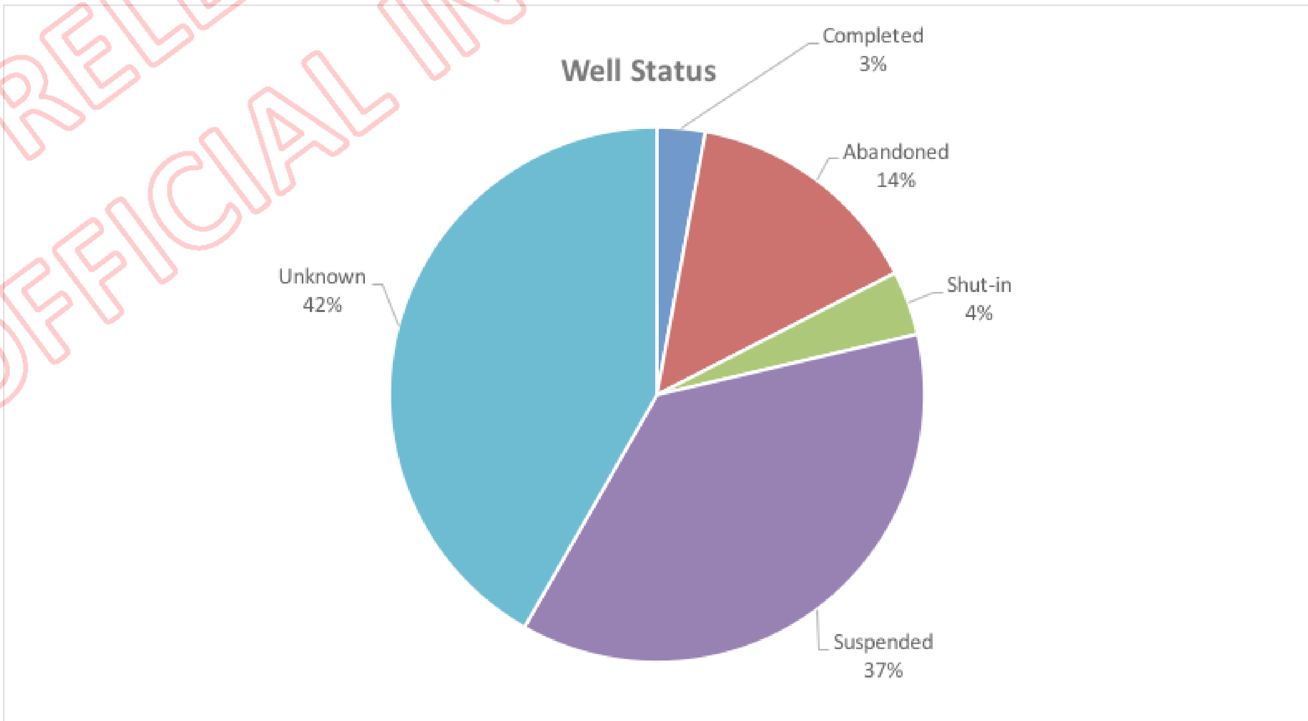

Figure 1 – Well status of the 104 wells

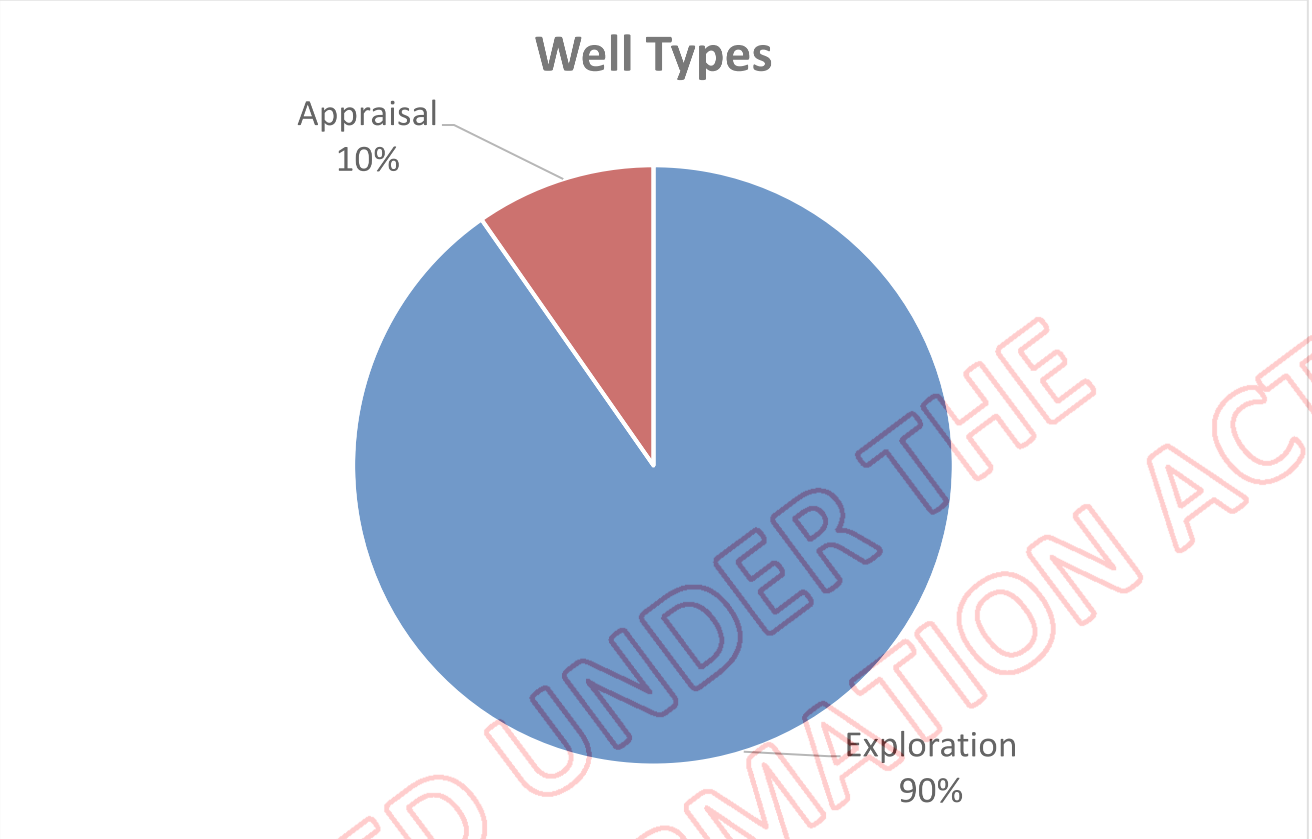

Figure 2 – Well type distribution of 104 wells

The reason why these wells were not abandoned at the time is unknown but is likely due to Operators being unsure of their future requirements and the wells being suspended for the following reasons:

- Further evaluation;
- Donor wells for side-tracking;
- Well conversion (modifying the well from a producer to an injector); and
- Observation wells.

New Zealand has not had an explicit limit on how long a well can be shut-in/suspended and as a result there has been an accumulation of temporary abandoned wells over time. The age of the 104 wells varies but 49% are greater than 50 years old as can be seen in Figure 3 on the following page.

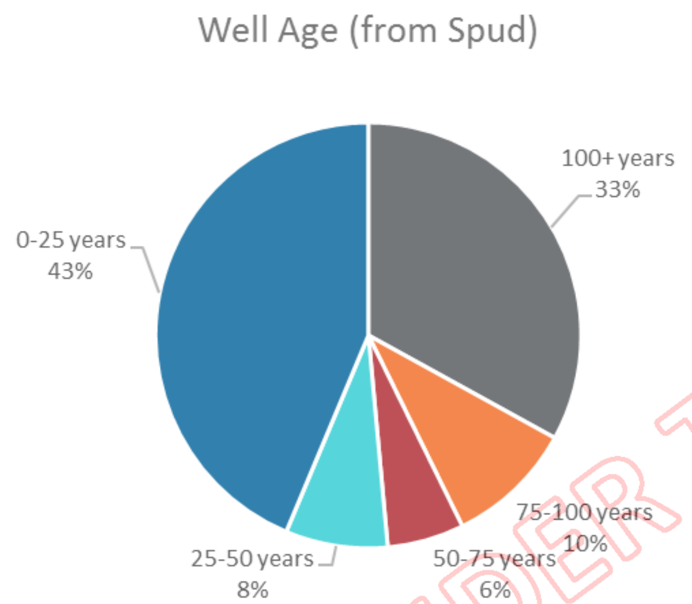

Figure 3 – Age of wells

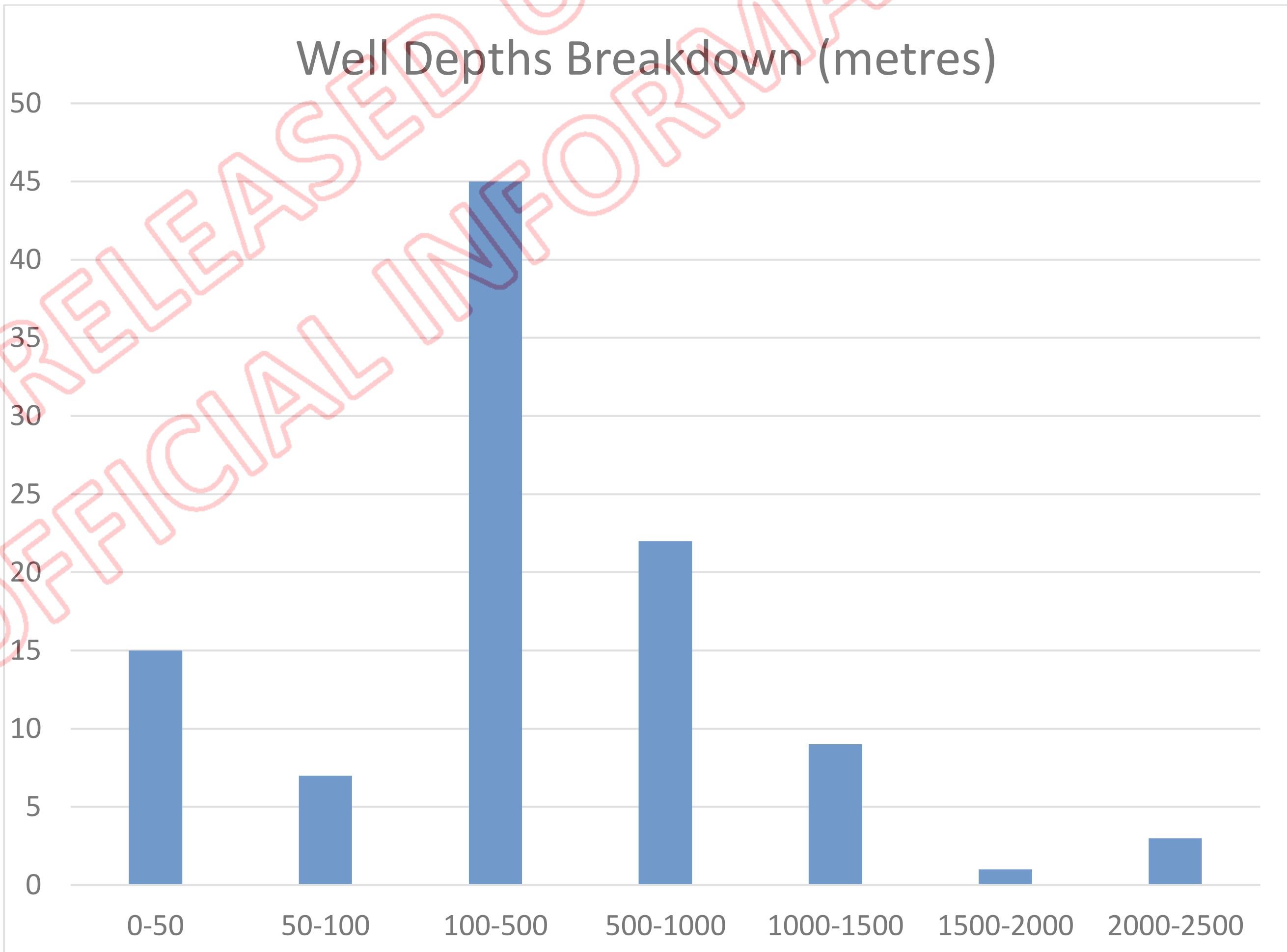

Figure 4 – Depth breakdown of wells

51 of the 104 wells (49%) investigated were drilled prior to 1960 which broadly coincides with the introduction of modern oilfield practices and international companies' entry to the New Zealand market. The age of the wells does not necessarily mean that the wells are at higher risk as a well that has been adequately abandoned should be adequately isolated for eternity (although a very small residual risk remains).

14 out of the 104 wells (14%) did not encounter movable hydrocarbons while 49 wells have unknown well contents due to limited data being available.

The main challenges with the age of the wells is the poor quality and lack of data as documentation may have been lost over the years and often the original Operators who drilled the wells no longer exist.

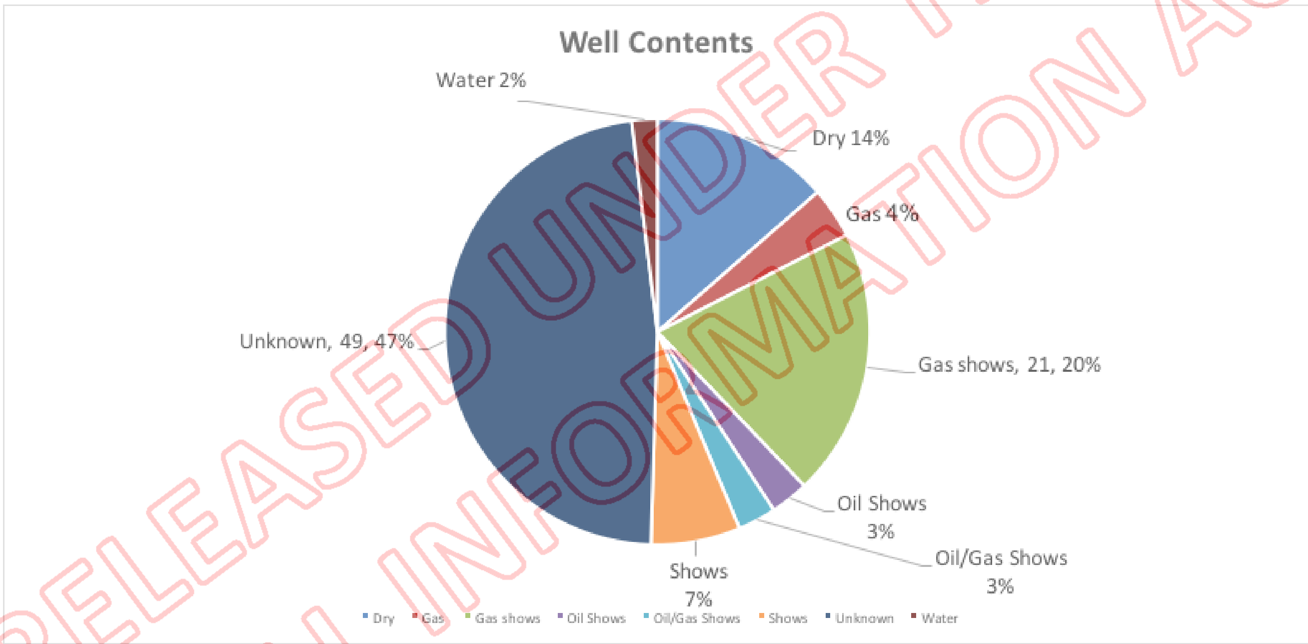

Figure 5 – Contents of wells (104)

There have been a small number of instances in New Zealand where an abandoned well has had an integrity failure and required remedial action. Possibly the most prominent recent example of this was the Blenheim-1 well which in August 2001 began leaking a mixture of water/oil under a residential property and was subsequently re-abandoned. Potential consequences of failure of a well include:

- Pollution;
- Risk to personal/property though fire/explosion;
- Loss of agricultural land;
- Fire damage to surrounding areas; and
- Reputational damage to the oil & gas industry.

NORSOK D-010 defines well integrity to be "application of technical, operational and organisational solutions to reduce the risk of uncontrolled release of formation fluids throughout the life cycle of a well". The main consequences of a loss in integrity is environmental, impact on underground sources of drinking water, injury, material damage and costly and risky repairs.

Of particular concern are wells which encountered shallow aquifers whilst drilling. Isolation of these wells is critical to ensure the water quality in these aquifers is not compromised, which may be a primary source of drinking water.

2.1. Scope

The scope of this study is to determine what action if any is required for the 104 wells reviewed, and estimate the cost and duration of any required activity, on a well-by-well basis. The study took into account the underlying strata, well design, drilling and completion practices and technology at the time of drilling, New Zealand's regulatory requirements and industry good practice. The provisions of a well risk ranking methodology that outlines the relative priority for addressing the outstanding commitments for these wells is also provided.

The Study includes:

- Technical evaluation criteria;
- Risk ranking methodology;
- Qualitative risk assessment to allow the government to prioritise higher risk wells. This will identify failure mechanisms such as, but not limited to, hydrocarbon and saline water to surface and groundwater contamination; and
- An assessment of any remedial action required and the cost of this.

No physical well inspections or site visits were performed by Petrofac.

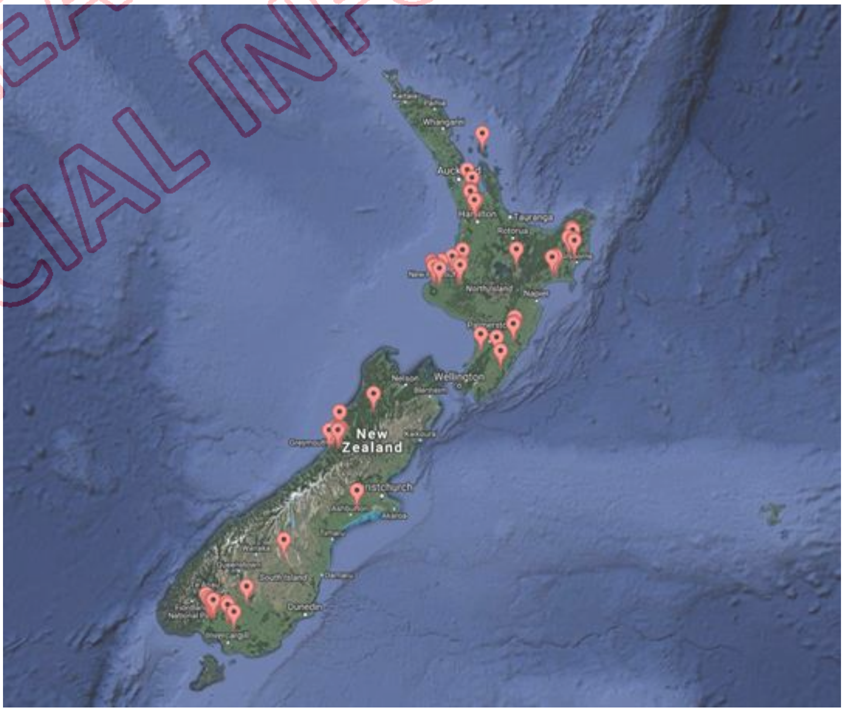

Figure 6 – Location of the assessed wells (104)

MBIE provided the list of the wells below that were to be assessed in the study, with summary information for these wells where available. The information provided by MBIE was not necessarily exhaustive regarding each well, but was everything that they had available.

Well name	Well operator	Well Type	Content	Status	Spud	Lat (DD)	Long (DD)
Corehole-8	Superior Oil Co NZ Ltd	Exploration	Unknown	Unknown	1942-09-07	42.59108	171.175925
Corehole-11	Superior Oil Co NZ Ltd	Exploration	Unknown	Unknown	1942-01-02	42.55772	171.277352
A1	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1909-01-01	42.53911	171.463466
Moa Bore	Moa Petroleum	Exploration	Unknown	Unknown	1907-01-01	39.15018	174.209646
Norfolk Road Bore	Inglewood Oil Boring Prospecting	Exploration	Unknown	Unknown	1907-01-01	39.19546	174.225757
Angelo-1	MINES50	Exploration	Unknown	Unknown	2008-01-01	40.60347	175.356216
B1	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1902-01-01	42.54078	171.463466
B4	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1909-01-01	42.53995	171.46346
Shaft	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1908-01-01	42.53995	171.46346
No1 Kotuku Oil & Gold	Unknown	Exploration	Unknown	Unknown	1934-01-02	42.54078	171.463466
B5	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1909-01-01	42.53990	171.463500
B2	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1902-01-01	42.54161	171.463466
B6	Kotuku Consolidated Oil Co	Exploration	Unknown	Unknown	1909-01-01	42.54161	171.463466
Petroleum Creek-3	Petroleum Resources Ltd	Exploration	Shows	Suspended	1985-11-16	42.53990	171.463500
Waipai-1	Unknown	Exploration	Unknown	Unknown	1973-01-01	38.79100	176.344381
Waitangi Hill-1	McConnell Dowell Mining Ltd	Exploration	Unknown	Unknown	1874-01-01	38.34267	177.899378
Petroleum Creek-4	Petroleum Resources Ltd	Exploration	Shows	Suspended	1985-11-18	42.53042	171.465971
Westcott-1	East Coast	Exploration	Oil Shows	Abandoned	1991-01-01	40.34837	176.283932

Well name	Well operator	Well Type	Content	Status	Spud	Lat (DD)	Long (DD)
	Petroleum Ltd						
Great Barrier-2	Auckland Water Transport and Others	Appraisal	Dry	Abandoned	1965-01-01	36.24651	175.398528
Samuel Syndicate-6	Unknow	Exploration	Unknown	Abandoned	1898-	39.10463	174.062700
OM-6	L & m Coal Seam Gas Ltd	Appraisal	Appraisal	Dry	2011	45.94987	167.959743
Taranaki Petroleum-1 (1866)	Unknown	Exploration	Unknown	Unknown	1866-01-01	39.06353	174.039711
Totangi-1	London Oil Syndicate	Exploration	Unknown	Abandoned	1902-01-01	38.52823	177.800769
PRDH19	Pike River Coal Co Ltd	Exploration	Unknown	Unknown	2006-06-01	42.21238	171.454817
PRDH034	Pike River Coal Co Ltd	Exploration	Dry	Abandoned	2008-01-17	42.21134	171.454760
H2	Kenham Holdings Ltd	Exploration	Gas	Suspended	2002-11-21	44.78255	169.911854
Carrington Road-2	British Developments Ltd	Exploration	Unknown	Unknown	1912-01-01	39.14574	174.058534
Ardmore-1	P. Oshannessy & Others	Exploration	Unknown	Unknown	1959-01-01	37.04958	174.981028
A2	Kotuku Consolidated Oil Co.	Exploration	Unknown	Unknown	1909-01-01	42.53910	171.463500
Victoria	Unknown	Exploration	Unknown	Unknown	1866-01-01	39.0594639	174.0332861
Hawk-11	L & M Coal Seam Gas	Exploration	Gas Shows	Suspended	2009-03-10	44.78439	169.910924
Kauana-1	Unknown	Exploration	Unknown	Unknown	1931-01-02	45.99923	168.342578
Horotiu-2	Waikato Natural Gases Ltd	Appraisal	Gas Shows	Abandoned	1967-01-01	37.71682	175.190199
Beta	Unknown	Exploration	Unknown	Unknown	1867-01-01	39.05658	174.029397
H3	Kenham Holdings Ltd	Exploration	Gas	Suspended	2002-11-27	44.77591	169.923341
TWB-1	L & M Petroleum	Exploration	Water	Completed	2009-07-31	45.95867	168.006863
Corehole-9	Superior Oil Co NZ Ltd	Exploration	Unknown	Unknown	1942-01-02	42.54078	171.465689
Tikorangi-1	Unknown	Exploration	Unknown	Unknown	1913-01-01	39.04935	174.254922
Hudson-1	L & M Coal Seam Gas	Exploration	Dry	Suspended	2007-07-12	46.17736	168.514753

Well name	Well operator	Well Type	Content	Status	Spud	Lat (DD)	Long (DD)
	Limited						
No9 Lake Brunner	Kotuku Consolidated Oil Co.	Exploration	Unknown	Unknown	1902-01-01	42.53995	171.470133
Hudson-2	L & M Coal Seam Gas Limited	Exploration	Dry	Suspended	2007-10-06	46.17377	168.521390
Waitangi-1 (Gisborne Oil)	Gisborne Oil Pty Ltd	Exploration	Oil Shows	Unknown	1909-01-01	38.33830	177.896852
Samuel Syndicate-1	Unknown	Exploration	Unknown	Abandoned	1891-01-01	39.05714	174.030183
Belmont Strat-1	L & M Petroleum	Exploration	Dry	Suspended	2009-07-24	45.84019	167.754513
Back Ormond Road-2	Asia Pacific Oil Co. Ltd	Exploration	Gas Shows	Suspended	1992-11-11	38.59791	177.957431
Samuel Syndicate-9	Unknown	Exploration	Unknown	Unknown	1900-01-01	39.06240	174.033810
PRD037	Pike River Coal Co. Ltd	Exploration	Unknown	Unknown	2008-12-02	42.20614	171.453461
PRD038	Pike River Coal Co. Ltd	Exploration	Unknown	Unknown	2009-02-25	42.20613	171.453457
NW2	L & M Coal Seam Gas Ltd	Exploration	Gas Shows	Suspended	2005-11-20	37.23019	175.129701
NW-1A	L & M Coal Seam Gas Ltd	Exploration	Gas Shows	Suspended	2005-11-05	37.22359	175.139047
Waitaanga-1	Solid Energy New Zealand	Appraisal	Dry	Shut-in	2006-10-31	38.80282	174.855452
20101	Solid Energy New Zealand	Exploration	Dry	Suspended	2010-03-22	37.51970	175.073500
Waingaromia Bore	Unknown	Exploration	Unknown	Unknown	1884-01-01	38.37213	177.911285
20102	Solid Energy New Zealand	Exploration	Dry	Completed	2010-03-22	37.51960	175.073100
Waihihere-1	Unknown	Exploration	Unknown	Unknown	1911-01-01	38.57275	177.943440
OM-3	L & M Coal Seam Gas Ltd	Exploration	Gas Shows	Suspended	2009-06-08	45.94900	167.962580
Prospect Valley-2	NZ Oil Syndicated	Exploration	Gas Shows	Unknown	1929-01-02	39.09601	174.720202
Beckett-1	Solid Energy New Zealand	Exploration	Gas Shows	Suspended	2011-03-07	37.50964	175.085705
Corehole-10	Superior Oil Co. NZ Ltd	Exploration	Unknown	Unknown	1942-12-02	42.55217	171.437910
OM-7	L & M Coal Seam Gas	Appraisal	Unknown	Suspended	2011-01-19	45.94601	167.957023
Samuel Syndicate-7	Unknown	Exploration	Unknown	Abandoned	1898-01-01	39.06285	174.034472

Well name	Well operator	Well Type	Content	Status	Spud	Lat (DD)	Long (DD)
OL-2	L & M Coal Seam Gas	Exploration	Shows	Suspended	2006-05-10	45.95050	167.958805
Waitaanga-5	Solid Energy New Zealand	Appraisal	Dry	Suspended	2009-07-29	38.81385	174.853563
Mt Linton-2	L & M Petroleum	Exploration	Shows	Suspended	2009-06-28	45.91299	167.82781
Renouf-1	Solid Energy New Zealand	Exploration	Gas	Suspended	2011-02-25	37.50192	175.08935
Centre Bush-1	Unknown	Exploration	Unknown	Unknown	1932-01-02	46.04479	168.34591
OL-1	L & M Coal Seam Gas	Exploration	Dry	Suspended	2005-02-25	45.95053	167.95842
Waitangi-1	Taranaki Oilfields Ltd	Exploration	Dry	Abandoned	1930-12-07	38.34517	177.90160
Whitianga-1	Shell BP and Todd Oil Service Ltd	Exploration	Dry	Abandoned	1963-12-16	39.05718	174.81242
Birchwood-1	L & M Coal Seam Gas	Exploration	Gas Shows	Suspended	2007-07-23	45.94810	167.91522
Beckett-2	Solid Energy New Zealand	Exploration	Gas Shows	Suspended	2011-03-14	37.50687	175.07855
Kauhauroa-4A	Westech Energy New Zealand Ltd	Exploration	Gas Shows	Suspended	1999-03-05	38.95047	177.44847
Renouf-2	Solid Energy New Zealand	Exploration	Gas	Suspended	2011-02-14	37.50002	175.08100
Spotswood-1	New Plymouth (NZ) Oil Wells Ltd	Exploration	Gas Shows	Unknown	1930-12-10	39.06515	174.02861
Samuel Syndicate-8	Unknown	Exploration	Unknown	Abandoned	1898-01-01	39.06308	174.03520
Blackwater-1	Australian Oil Corporation	Exploration	Oil/Gas	Shut-in	1968-03-25	41.83938	172.39543
OM-5	L & M Coal Seam Gas	Appraisal	Shows	Suspended	2010-12-16	45.95052	167.95214
Chertsey Bore	Canterbury Petroleum Prospecting	Exploration	Unknown	Abandoned	1914-10-22	43.80666	171.93761
OM-7A	L & M Coal Seam Gas	Appraisal	Unknown	Suspended	2011-03-06	45.94601	167.957023
Blair-1	Solid Energy New Zealand Ltd	Exploration	Unknown	Suspended	2009-08-18	37.49788	175.084652
Putikituna-1	Solid Energy New Zealand Ltd	Exploration	Gas Shows	Suspended	2011-01-20	39.1346	174.802552
Niagara-3	Ocean	Appraisal	Oil/Gas	Shut-in	2008-05-27	42.59031	171.409500

Well name	Well operator	Well Type	Content	Status	Spud	Lat (DD)	Long (DD)
	Harvest International Ltd						
River Road-1	NZ Petroleum Exploration Co Ltd	Exploration	Dry	Unknown	1963-11-08	37.71904	175.226311
Bonithon-1	Bonithon Freehold Petroleum Ltd	Exploration	Oil/Gas	Unknown	1907-03-21	39.06119	174.055605
Peep-O-Day	Mangaone Oilfields Ltd	Exploration	Unknown	Unknown	1912-11-28	40.66798	175.807431
Makareao-1	Westech Energy New Zealand Ltd	Exploration	Gas Shows	Suspended	1998-06-05	38.95304	177.34834
New Plymouth-1	Phoenix Oil Co	Exploration	Unknown	Unknown	1913-06-01	39.06515	174.041144
OM-4	L & M Coal Seam Gas Ltd	Exploration	Gas Shows	Suspended	2010-01-21	45.94361	167.89318
Carrington Road-1	Unknown	Exploration	Unknown	Unknown	1907-01-01	39.12852	174.05992
Waipatiki-1	Waipatiki Oil Wells Ltd	Exploration	Gas Shows	Unknown	1912-01-01	40.37686	176.26798
Ranui-1	Discovery Geo (Australia) Corporation	Exploration	Gas Shows	Suspended	2008-04-21	40.94236	175.91774
OM-7B	L & M Coal Seam Gas Ltd	Appraisal	Ranui-1	Suspended	2011-03-16	45.94601	167.95702
Kauhauroa-1	Westech Energy New Zealand Ltd	Exploration	Gas Shows	Suspended	1998-03-04	38.94828	177.42625
Kauhauroa-3	Westech Energy New Zealand Ltd	Exploration	Gas Shows	Suspended	1999-06-20	38.94917	177.43892
Waitohora-1	Westech Energy New Zealand Ltd	Exploration	Water	Suspended	2007-04-01	38.94755	177.42649
Ngapaeruru-1	TAG Oil Ltd	Exploration	Gas Shows	Shut-in	2013-04-22	40.24024	176.30006
Niagara-1	Petroleum Resources Ltd (NZOG)	Exploration	Oil Shows	Suspended	1985-09-27	42.59106	171.41152
Crusader-1A	GEL Exploration Inc	Exploration	Shows	Suspended	2000-09-11	39.11894	174.09571
Blenheim-1	Taranaki Oil Lands AQ and Dev Co Ltd	Exploration	Gas Shows	Abandoned	1913-04-19	39.06241	174.04216

Table 4 – MBIE Study Wells Summary

2.2. Background / History

Well abandonment refers to the decommissioning of a well and generally involves the removal of equipment from the well, the plugging of the wells with cement, cutting and capping the casing below the surface level, the removal of surface equipment, and rehabilitating and reclaiming the land. Most wells are abandoned because of uncommercial flow rates or the wells failing to encounter hydrocarbons. A well that is classed as an oil exploration well may not encounter any hydrocarbons during drilling. Often, if reservoirs are encountered instead of hydrocarbons the reservoirs may contain fresh or saline water. These wells which encounter no hydrocarbons are called dry wells.

Cement is typically used to seal and plug wells as it is durable, has low-permeability and is inexpensive. Furthermore, it is easy to pump in place, allows bonding to the formation as well as to the casing surface and has a practical setting time. Well abandonment typically accomplishes the following:

1. Eliminates the physical hazard of the well;
2. Eliminates a pathway for migration of well fluids; and
3. Prevents changes in different subsurface formations, such as changes in pressures and the mixing of fluids between formations and in particular shallow water aquifers.

The proper decommissioning method will depend on both the reason for abandonment and the condition and construction details of the boring or well.

An example of an actual onshore well abandonment in Taranaki is shown overleaf in Figure 7. The well in question was shut-in at surface and no barriers were placed in the wellbore – 'Before'. The planned abandonment is shown in the 'After' portion of the figure.

'Before' describes the well in its current state and 'After' describes what the well will look like when fully abandoned.

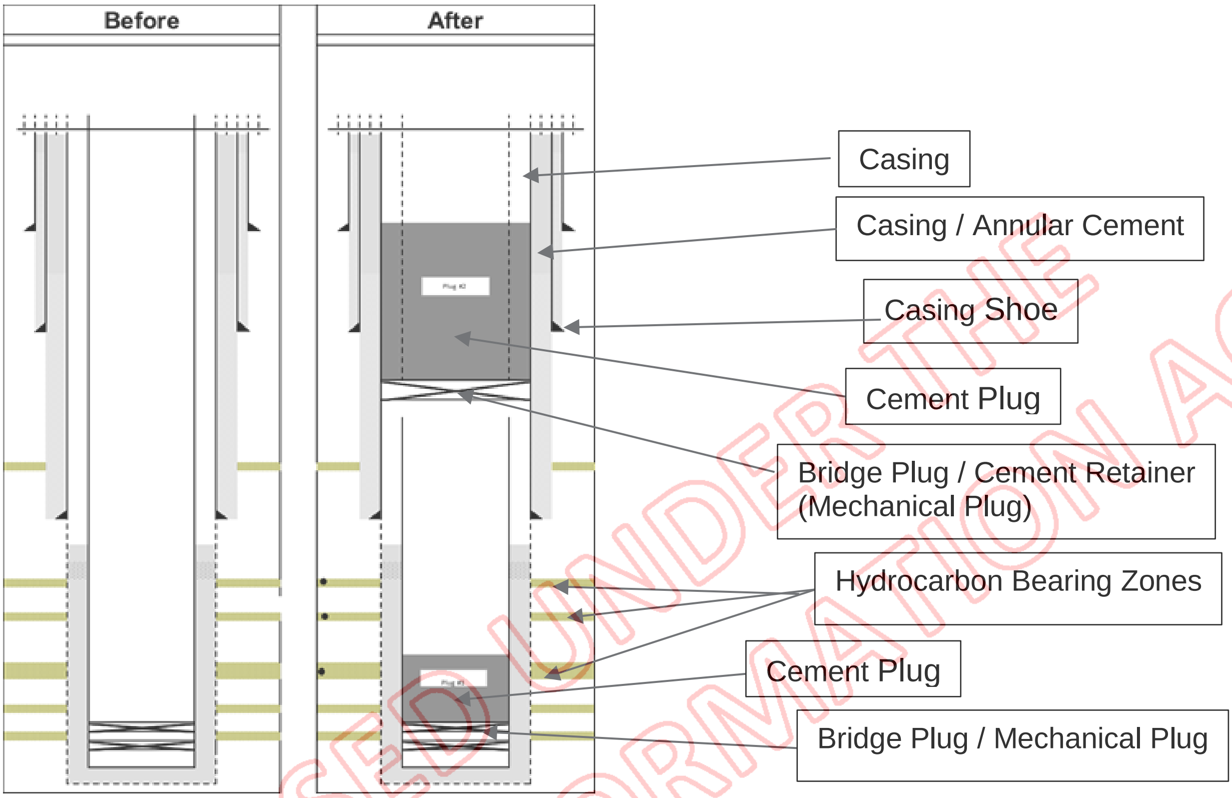

Figure 7 – Example schematic of an actual well abandonment

Hydrocarbon drilling operations have been performed in New Zealand since 1865 and subsequent well suspension and/or abandonment operations performed for as long. Whilst over 960 wells have been drilled onshore, a large number of these wells were not produced from as they either encountered uneconomic quantities of hydrocarbons or were dry (no hydrocarbons encountered).

Frequently, well locations were selected beside naturally occurring oil seeps and this at times has led to misinformation about the wells causing the oil/gas to appear at surface when this is not the case.

With older wells there were no strict abandonment regulations in place at the time and there are early occurrences of Operators occasionally leaving the wells closed-in at surface indefinitely. Early oil wells were often abandoned by simply filling the wells with whatever was available locally – well cuttings, scrap iron, sand, rocks, gravel and wood. For wells drilled up to 1960 it was not uncommon to abandon the wells using wood plugs. It is only since 1960 that modern abandonment practices have been utilised.

Over the years, a number of Operators have 'disappeared' through bankruptcy, mergers & acquisitions and transferring their businesses overseas. The wells left behind by these Operators are not always plugged and abandoned (internationally these are sometimes referred to as orphaned wells).

In many cases, particularly for the more recent wells (post 1960), the final well abandonment will be an efficient process and may just require that the wellhead is removed or possibly a final abandonment plug placed to complete the permanent abandonment.

The MBIE wells database contains information regarding available data on the well status, contents, casing depths, testing and hydrocarbon types where available. The database is updated as new data becomes available or the well conditions change.

Due to the age of some of the wells in the MBIE database, and lack of well data, it is not always possible to determine the actual condition of the wellbore and the extent of abandonment activities. Even after visiting the well location it is often not possible to determine the status or condition of the well.

Figure 8 – Well A-2 picture

Even after locating a well such as A2 on the West Coast, it is unlikely that an accurate status of the well will be possible unless additional well data is obtained. Intervention work will be difficult due to corrosion of the casing, formation collapse and debris in the wellbore.

Figure 9 – Well Waitangi Hill-1 picture

A large number of wells in the study (26) were less than 200m total depth and were likely stratigraphic wells. Waitangi Hill-1 well was drilled 64m and is 3m from a naturally occurring oil seep. For wells such as this, which were not properly abandoned, the benefits of abandoning the shallow well bore need to be weighed against the safety risks of re-entering the wellbore and the probability of success as it is likely zones are already isolated through formation collapse.

MBIE conducted field work in 2016 to determine the location of a number of wells on the database but were unable to locate 39 wells even with well coordinates and the use of a magnetometer. This was likely due to the wells being abandoned soon after drilling, all equipment being removed and the land being re-used. An example is shown in Figure 10 below, wherein records show that Tikorangi-1 well (Taranaki) should be located in the paddock but no evidence of the well could be found.

Figure 10 – Photo of Tikorangi-1 location

Even though a well may be classed as “abandoned” this does not necessarily provide certainty that the well has been permanently isolated. For example, Figure 11 shows a well that was drilled and abandoned in the 1980s. In the 1980s, this well met all local regulations and best practices but when compared to modern abandonment requirements/standards there are multiple items that would fail to meet today’s abandonment guidelines and accepted good oilfield practice. Figure 12 shows how the same well abandonment would look if it were to meet today’s standards.

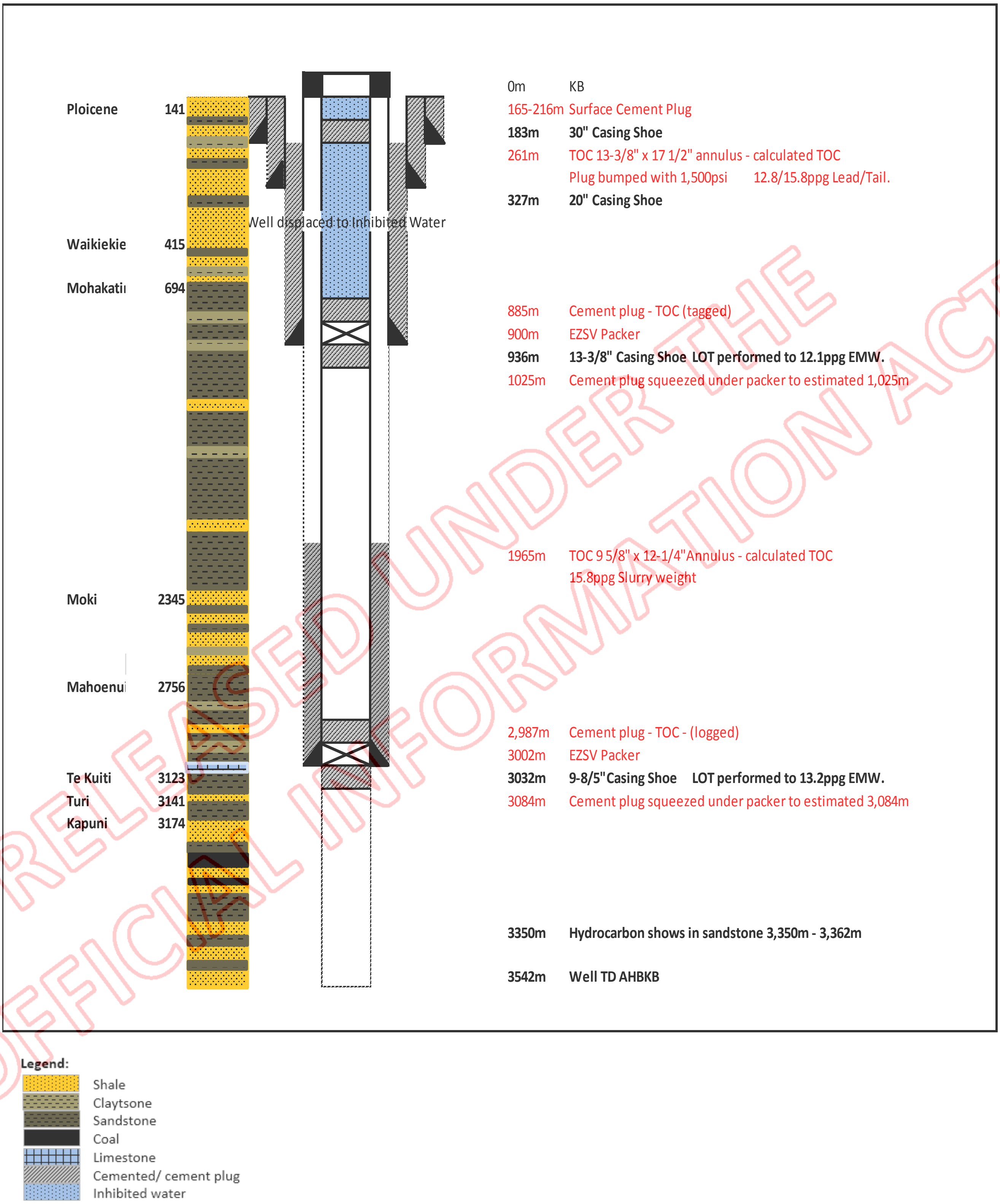

Figure 11 – Well abandoned in the 1980s

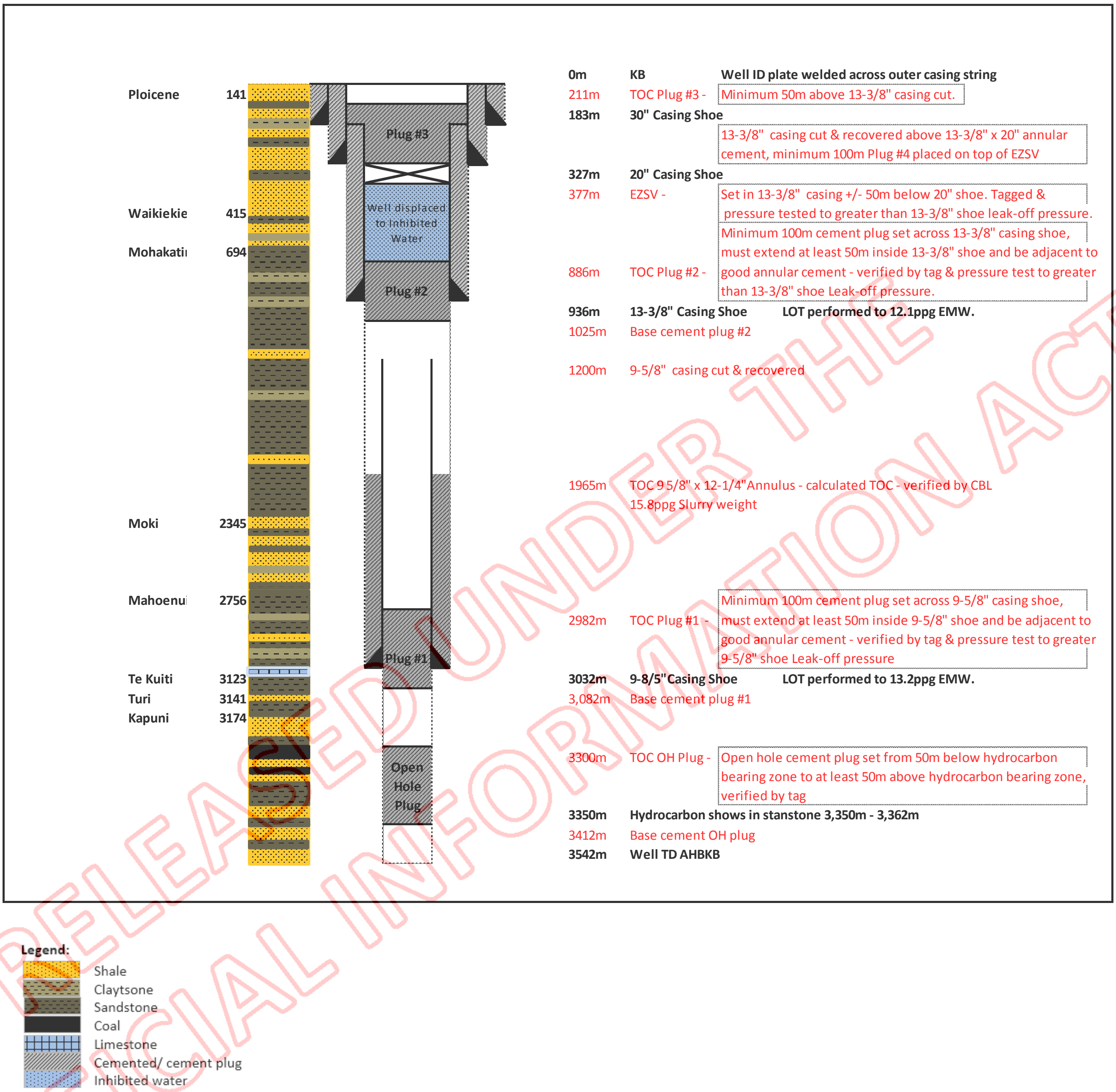

Figure 12 – The same well if it were to be abandoned in 2017

Well Abandonment Comparison for Figure 11 and Figure 12		
	1980s Well Abandonment	**Modern Well Abandonment**
Open Hole	• No open hole plug placed across the hydrocarbon bearing zones. (Open hole plug is a well barrier element that is set along an uncased section of the borehole, normally a cement plug.)	• Open hole cement plug set from 50m below hydrocarbon bearing zone to at least 50m above hydrocarbon bearing zone. • Plug verified by tagging. Tagging is done by running the cement stinger and applying a weight to ascertain the location of the top of cement plug after the cement has set.
Plug #1	• Mechanical bridge plug (i.e. Bridge Plug, Packer, EZSV or Cement Retainer) does not constitute a barrier. • Cement squeezed below barrier – no way to know if in place. • Only 15m of cement placed on top of mechanical plug. • Cement plug not verified by tag or pressure test.	• Minimum 100m cement plug set across 9-5/8" casing shoe (base of a casing string). • Must extend at least 50m inside 9-5/8" shoe and be adjacent to good annular cement. • Plug verified by tag & pressure test to greater 9-5/8" shoe Leak-off pressure. • Top of annular cement verified by CBL.
Plug #2	• Mechanical bridge plug does not constitute a barrier. • Cement squeezed below barrier – no way to know if in place. • Only 15m of cement placed on top of mechanical plug. • Cement plug not verified by pressure test. • Cement plug does not extend across full cross-section of wellbore & not adjacent to good annular cement.	• Minimum 100m cement plug set across 13-3/8" casing shoe. • Must extend at least 50m inside 13-3/8" shoe and be adjacent to good annular cement. • Verified by tag & pressure test to greater than 13-3/8" shoe Leak-off pressure.
Plug #3	• Cement plug #3 only 50m in length. • Cement plug does not extend across full cross-section of wellbore & not adjacent to good annular cement. • Plug not verified by tag or pressure test.	• Bridge plug cement retainer set in 13-3/8" casing +/- 50m below 20" shoe. Tagged & pressure tested to greater than 13-3/8" shoe leak-off pressure. • 13-3/8" casing cut & recovered above 13-3/8" x 20" annular cement. • Minimum 100m Cement plug placed on top of EZSV. • Minimum 50m above 13-3/8" casing cut.

Table 5 – Well abandonment comparison

3.0 METHODOLOGY

The following 24 pages have been withheld under s 9(2)(b)(i)

4.0 OVERVIEW OF REGULATORY FRAMEWORK FOR WELL ABANDONMENT

There is no globally accepted standard describing “good oilfield practice” for plugging and abandoning wells, though OGUK and NORSOK guidelines are frequently used as a basis for a well abandonment design. International industry experience shows that if the methods prescribed in such codes are adopted, the risk of a petroleum well failing is considered to be low. However, it is noted that studies into well integrity over a period of decades is sparse, with little research conducted on the potential longer-term impacts of petroleum wells. OGUK and NORSOK standards are appropriate regarding abandonment of existing hydrocarbon wells, but were not in effect for historic petroleum wells.

It should be noted that during the course of this study, a number of previously abandoned onshore wells were also reviewed as part of examining offset wells. There is a concern that some previously abandoned older wells may not meet today’s abandonment specifications as a number of older wells have plugs which are of insufficient type, length and have questionable verification.

New Zealand’s oil and gas resources are regulated by New Zealand Petroleum & Minerals (NZP&M), which is part of MBIE. NZP&M works with five other government agencies and 16 regional councils to provide consistent regulation of the petroleum and minerals industries in New Zealand. These government agencies are WorkSafe New Zealand (WorkSafe NZ), Maritime New Zealand, the Environmental Protection Authority, the Department of Conservation, and the Ministry for the Environment.

New Zealand well abandonment regulations are defined by the:

- Crown Minerals (Petroleum) Regulations 2007; and
- Health and Safety at Work (Petroleum Exploration and Extraction) Regulations 2016

An Operator must ensure, so far as is reasonably practicable, that there can be no unplanned escape of fluids from the well or from the reservoir to which it led after its abandonment.

The Health and Safety at Work (Petroleum Exploration and Extraction) Regulations 2016 do not prescribe specific standards for abandonment. To assist Operators to interpret and meet the requirements, WorkSafe NZ have developed a series of interpretive guidelines.

Petroleum: Well Operations and Well Examination Schemes provides explanation to the regulations associated with design, construction, suspension, and abandonment of wells.
Petroleum Notifications: Quick Guide provides information on Petroleum Notifications required prior to starting the well operations.
Petroleum: Notifications and Submissions explains the regulations associated with all notifications and submissions of documents.
Petroleum Verification Schemes explains the obligations of well Operators and independent well examiners.
Petroleum: Certificate of Fitness explains the regulations associated with certificates of fitness and verification schemes.
Petroleum: Major accident prevention policy and safety cases explains the regulations associated with major accident prevention policies and safety cases.

4.1. New Zealand Regulatory Framework

WorkSafe NZ and regional councils share the responsibility for managing well abandonment and decommissioning activities in New Zealand.

Worksafe NZ hold the inspection and enforcement role for the rules that ensure no wellbore fluids can escape and the risk of a well failure is as low as reasonably practical (ALARP).

Regional councils are responsible under the Resource Management Act 1991 for managing the effects of activities on the environment.

4.2. Gap Analysis of Regulations

While the Regulations do not prescribe specific standards for abandonment, the WorkSafe NZ Well Operations and Well Examination Schemes interpretive guidelines specify some requirements that apply to well abandonment. The guidelines recommend wells to be abandoned in line with internationally accepted good oilfield practice, incorporating continual improvement in practices and technology.

A gap analysis was performed on WorkSafe NZ, OGUK and NORSOK guidelines. Generally, it was found that all guidelines are in agreement with their intent for most requirements.

- Number of permanent barriers: All three guidelines / standards agree a minimum of two barriers required from hydrocarbon bearing zones or over pressured zones; and one barrier for any normally pressured water bearing zones.
- Material requirements: All are practically in line regarding barrier material specifications. Barrier must display characteristics of low permeability, non-shrinking, resistant to downhole fluids, long-term integrity, bonding properties to casing and formation.
- Barrier positioning and placement: All are in agreement that barriers should be set across or above highest point of potential flow, with varying length requirements (30m for OGUK standards, 50m for NORSOK and 100m for WorkSafe NZ). A mechanical plug may be used as a foundation to set cement but itself does not constitute a permanent barrier.
- WorkSafe NZ recommend plugs of a minimum 100m, extending at least 50m above and below source of inflow.
- Barrier verification: OGUK and NORSOK accept open hole barriers and verification of the barrier by tagging. Cased hole barrier should be tagged or pressure tested to minimum 500 psi above leak-off pressure, with consideration for corrosion. A cement plug placed on top of verified mechanical plug is not required to be tested but should be tagged. OGUK standards state that annular cement should be verified by logging or estimation on the basis of good records from the cement operation, while NORSOK only accept a logged annulus. WorkSafe NZ describe testing of barrier integrity which may involve pressure, weight and logging but doesn't describe specific requirements.
- Well Examination Scheme: In UK and NZ, it is a regulatory requirement to conduct well examinations for well abandonment covering the design and operation stages. In NZ, it is specified in Regulation 71, Health and Safety at Work (Petroleum Exploration and Extraction) Regulations 2016. Wells must be examined by an independent and competent person.

All regulations prescribe that oil and gas wells are plugged with cement at abandonment in order to prevent fluid flow from the reservoir towards other strata or towards the surface. In general, a minimum of two cement plugs are placed during abandonment operations to adhere to regulatory requirements. However, actual abandonment measures depend on specific conditions that could influence the requirements on the number and length of cement plugs.

4.3. WorkSafe NZ and OGUK Guidelines for the Abandonment of Wells

The OGUK Guidelines for the Abandonment of Wells publication is now at Issue 5, published July 2015. The guidelines provide highly detailed descriptions of minimum criteria to ensure full adequate isolation of formation fluids both within the wellbore and from the surface. The guideline focuses on the concept of restoring the reservoir cap rock and isolation of formations with flow potential (Figure 19).

An instance where WorkSafe NZ supersedes OGUK recommendation would be the cement plug length requirements. WorkSafe NZ guidelines requires a cement plug to extend at least 50m above and below any source of inflow. OGUK requires a minimum of 30m of good cement above the source of inflow with 150m of placement length recommended to guarantee the 30m of good cement.

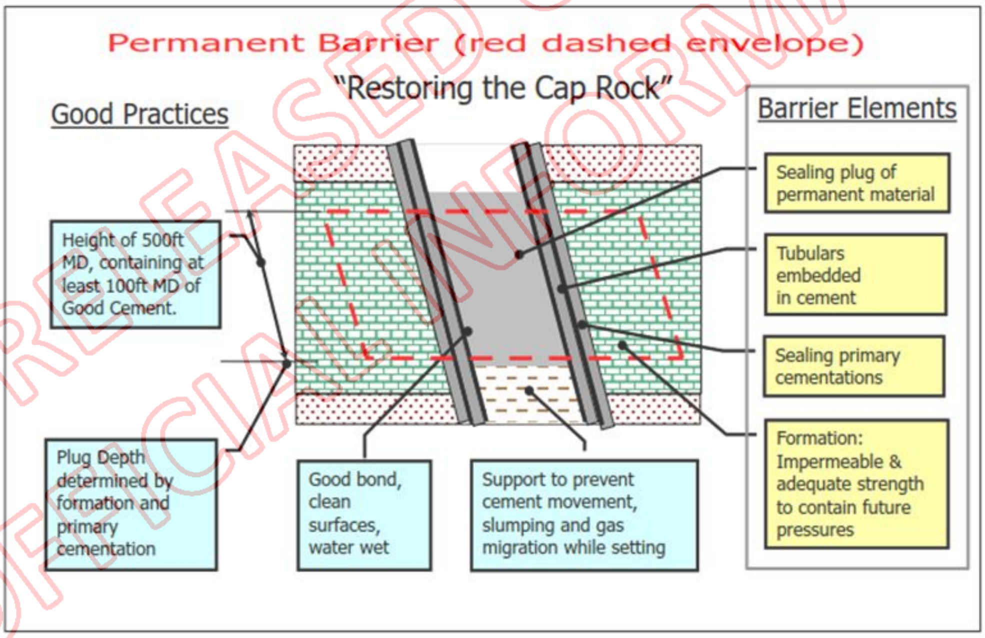

Figure 19 – Barrier envelope to restore reservoir cap rock

4.3.1.1. Requirements of Permanent Barriers

Number of Permanent Barriers

Two permanent barriers are required to isolate hydrocarbon-bearing or overpressured and water-bearing zones. The two barriers may be combined into a single large permanent barrier, provided it is as effective and reliable as the two barriers.

Regardless of whether casing is perforated or not, zones with flow potential that belong to different pressure regimes should be separated by one internal permanent barrier overlapping good annular cement. If the pressure is anticipated to exceed the formation fracture anywhere in the open hole, it should be isolated by two permanent barriers or a combination barrier. In Figure 20, due to different pressure regimes, Zone A requires isolation from Zone B. However, as pressure from Zone A is less than casing shoe fracture pressure, one permanent barrier is sufficient to isolate Zone A from Zone B. If pressure from Zone A exceeds the casing shoe fracture pressure, Zone A should be isolated with two permanent barriers as illustrated in Figure 21.

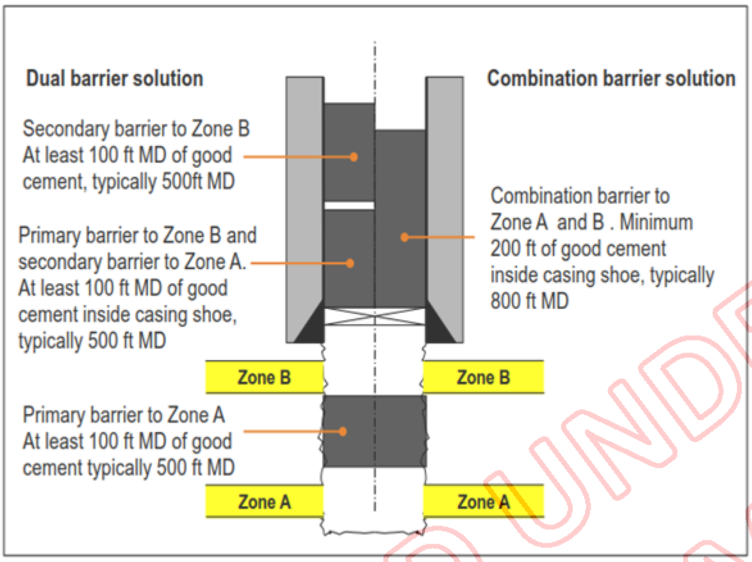

Figure 20 – One permanent barrier isolating zone A from zone B

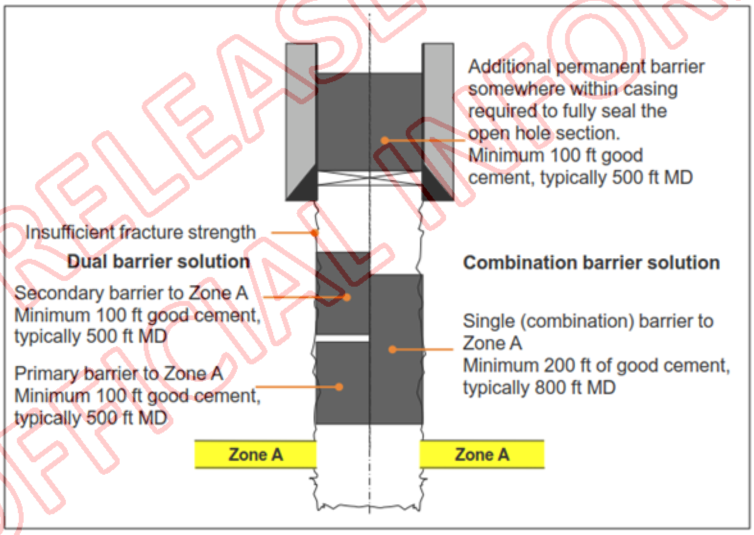

Figure 21 – Zone A isolated by two permanent barriers

Material Requirements

A permanent barrier should satisfy the characteristics as follows:

- Very low permeability to prevent flow of fluids;
- Able to provide seal along interface to prevent flow of fluids around the barrier;
- Long term integrity and not deteriorate and shift over time; and
- Resistance to downhole compounds.

Position Requirements

The primary barrier should be set across or above the highest point of potential inflow. It should be lapped by annular cement if set inside a casing or liner. If the base of the barrier is significantly above the point of inflow, the formation fracture pressure at the base of the barrier should be in excess of the maximum anticipated pressure. The same considerations apply for the secondary barrier.

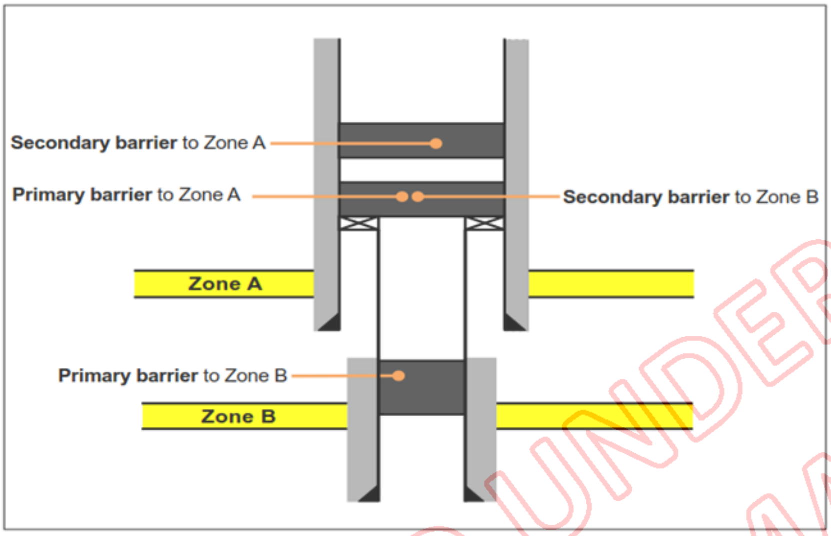

Figure 22 – General position requirements

Cemented casing does not constitute a permanent barrier to lateral flow as there is potential for a casing leak in conjunction with an incomplete localised cement sheath (Figure 23). However, cemented casing with confidence in the cement quality and quantity is accepted as a permanent barrier to flow in the annulus as shown in Figure 24.

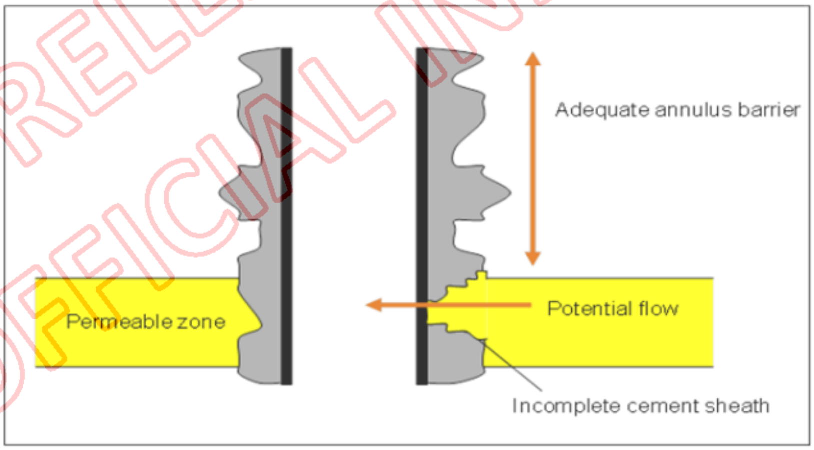

Figure 23 – Cemented casing as permanent annulus barrier but not lateral flow

Length Requirement

To comply with New Zealand regulations, a minimum of 100m of plug, with at least 50m of cement plug extending above and below any source of inflow is recommended.

OGUK recommends:

- **Open Hole** – 30m measured depth (MD) of good cement. 150m MD cement is set where possible to achieve minimum 30m of good cement;

- **Annular Cement** – 30m MD of good cement in the annulus. Internal cement plug must be set adjacent to overlap 30m MD of the good annular cement; and
- **Liner Lap** – At least 30m MD of good cement in the liner lap. If there is doubt with the cement quality in liner lap, the cement barrier should be placed above or below the liner lap. Liner packer does not constitute a permanent barrier (Figure 25).

For the purpose of this study, a length of 150m and 250m would be the placement length recommendation for single and combination plug respectively.

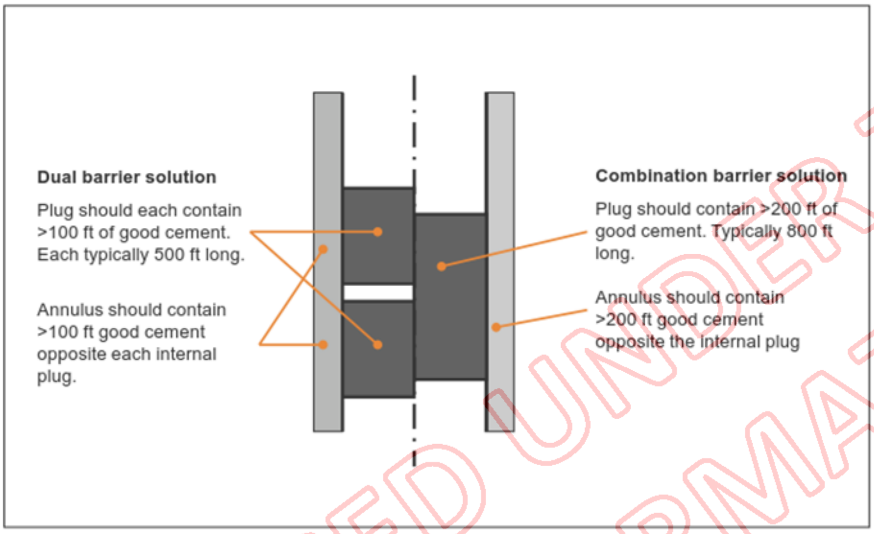

Figure 24 – Length requirements for dual and combination barriers

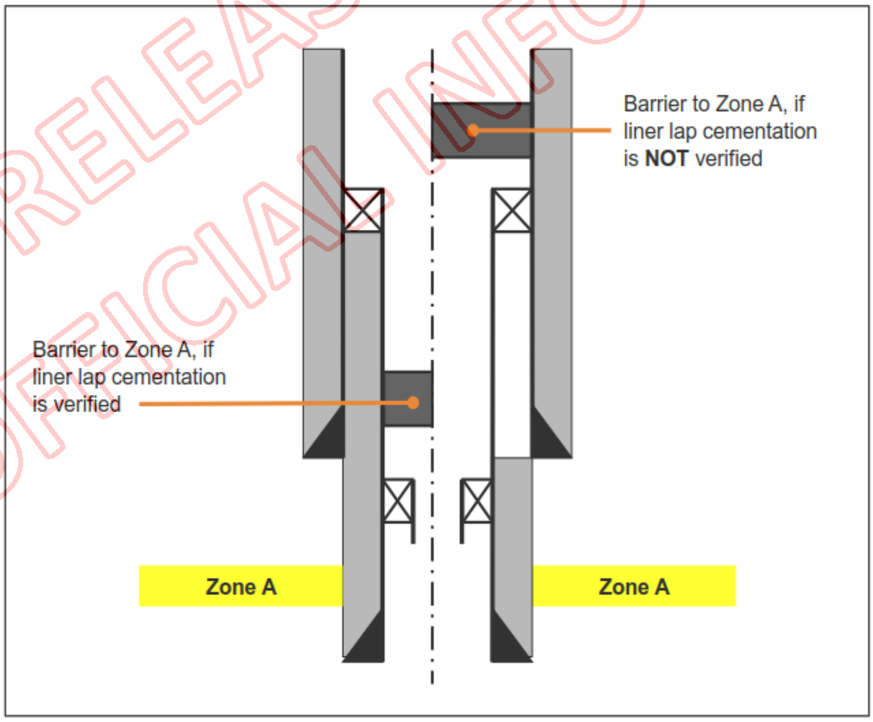

Figure 25 – Liner lap requirement

Verification

Tables 25 and 26 below summarise OGUK barriers verification requirement.

Single Permanent Barrier				
Barrier Type	Verification[2]			
	Wellbore / Tubing		Casing Annulus	
	Position	Sealing Capacity	Position	Sealing Capacity
Through-tubing	Tag	Pressure Test	Good cement bond, min. 30m, if previously logged or 300m above base of barrier if estimated from differential pressures	Estimation on the basis of records from the cement operation (volumes and pressures)
Through-tubing on a Mechanical Barrier	Tag cement, or measure volume to confirm depth of firm barrier, subject to risk assessment	Pressure test of mechanical barrier after release and pressure test cement in tubing and annulus separately	Good cement bond, min. 30m, if previously logged or 300m above base of barrier if estimated from differential pressures	Estimation on the basis of records from the cement operation (volumes and pressures)
Cased Hole	Tag	Pressure Test	Good cement bond, min. 30m, if previously logged or 300m above base of barrier if estimated from differential pressures	Logs (CBL, temperature, sonic)
Cased Hole on a Mechanical Barrier	Tag cement, or measure volume to confirm depth of firm barrier, subject to risk assessment	Pressure test of cement barrier or mechanical barrier after release	Good cement bond, min. 30m, if previously logged or 300m above base of barrier if estimated from differential pressures	Logs (CBL, temperature, sonic)
Open Hole	Tag	N/A	N/A	N/A

Table 25 – OGUK verifications summary of a permanent barrier – single barrier

[2]While OGUK requires a cement plug length of 30m, WorkSafe NZ recommends a minimum 100m of cement plug length for both internal and external barriers, with at least 50m extending above source of inflow to constitute a permanent barrier for source of inflow. This study adheres to WorkSafe NZ recommendations for plug length.

Permanent Combination Barrier				
Barrier Type	Verification[3]			
	Wellbore / Tubing		Casing Annulus	
	Position	Sealing Capacity	Position	Sealing Capacity
Through-tubing	Tag	Pressure Test	Good cement bond, min. 60m, if previously logged or 300m above base of barrier if estimated from differential pressures	Estimation on the basis of records from the cement operation (volumes and pressures)
Through-tubing on a Mechanical Barrier	Tag	Pressure test of mechanical barrier after release and pressure test cement in tubing and annulus separately	Good cement bond, min. 60m, if previously logged or 300m above base of barrier if estimated from differential pressures	Estimation on the basis of records from the cement operation (volumes and pressures)
Cased Hole	Tag	Pressure Test	Good cement bond, min. 60m, if previously logged or 300m above base of barrier if estimated from differential pressures	Logs (CBL, temperature, sonic)
Cased Hole on a Mechanical Barrier	Tag cement	Pressure test of cement barrier or mechanical barrier after release	Good cement bond, min. 60m, if previously logged or 300m above base of barrier if estimated from differential pressures	Logs (CBL, temperature, sonic)
Open Hole	Tag	N/A	N/A	N/A

Table 26 – OGUK verifications summary of a permanent barrier – combination barrier

[3]While OGUK requires cement plug length of 60m, WorkSafe NZ recommends a minimum 100m of cement plug length for both internal and external barriers, with at least 50m extending above source of inflow to constitute a permanent barrier for source of inflow. This study adheres to WorkSafe NZ recommendations for plug length.

4.4. Risk Based Abandonment

The prevalent P&A guidelines (NORSOK and OGUK) are prescriptive as to the number and size of permanent barriers required. These requirements are the same for all types of wells regardless of the flow potential. A hydrocarbon bearing zone with limited flow potential would have similar plug requirements to a moderate/high flow potential hydrocarbon bearing zone.

Well P&As are often perceived as high cost, which has driven an approach to differentiate between P&A requirements on a well-by-well basis. DNV GL is a global quality assurance and risk management company and has issued a new Recommended Practice (RP) DNVGL-RP-E103 on risk based abandonment. The RP provides the possibility for individualised, fit-for purpose well abandonment designs, a contrast to the prescriptive methodology available in the industry today. This allows cost-saving benefits to be gained from the least critical wells and spend more focus for complex wells, with flexibility to make use of new plugging technology.

It should be noted that this RP currently only applies to the evaluation of well P&A designs and optimisation planning, and is not applicable for currently suspended or temporarily abandoned wells.

5.0 RESULTS

A summary listing of the 104 wells reviewed is provided in Appendix 2. Full individual well review workbooks detailing data including well schematics (Before and After), outline procedures, Level 1 costs and risk assessments are provided separately in an attached zip file.

A total of 6 wells were determined as 'Priority Action' wells and 8 wells were classed as 'Priority Action (missing data)' due to having limited or missing data. 22 wells were classed as 'Schedule for Action, 48 were classed as 'Watching Brief' and 18 wells were classed as 'Minimum Risk' wells.

No wells were identified as requiring immediate remedial action, this was on the basis that these wells are not leaking significant volumes at surface (any leaks are minor bubbles or water seeps), are not close to urban populations and are not capable of prolific flow rates.

Note: There are 103 wells appearing in the MBIE database, however this review covered 104 wells. The discrepancy is brought about by the 2 wells that used the name Totangi-1, one drilled in 1912 and the other in 1938. This was discovered during the course of review of the wells. A site visit report had noted 2 wells with protruding casings from the ground which are just a few metres apart.

On the well summary sheet, it appears to be only 102 wells, due to 3 wells (OM-7, OM-7A and OM-7B) being combined in one line compared to the MBIE list in which these wells were considered separately. It was discovered during the well reviews that the OM-7A and OM-7B wellbores were sidetracks of the original OM7 wellbore and therefore the 3 wells were considered as a single entity.

A summary of the results is illustrated below in Figures 26, 27, 28 and 29.

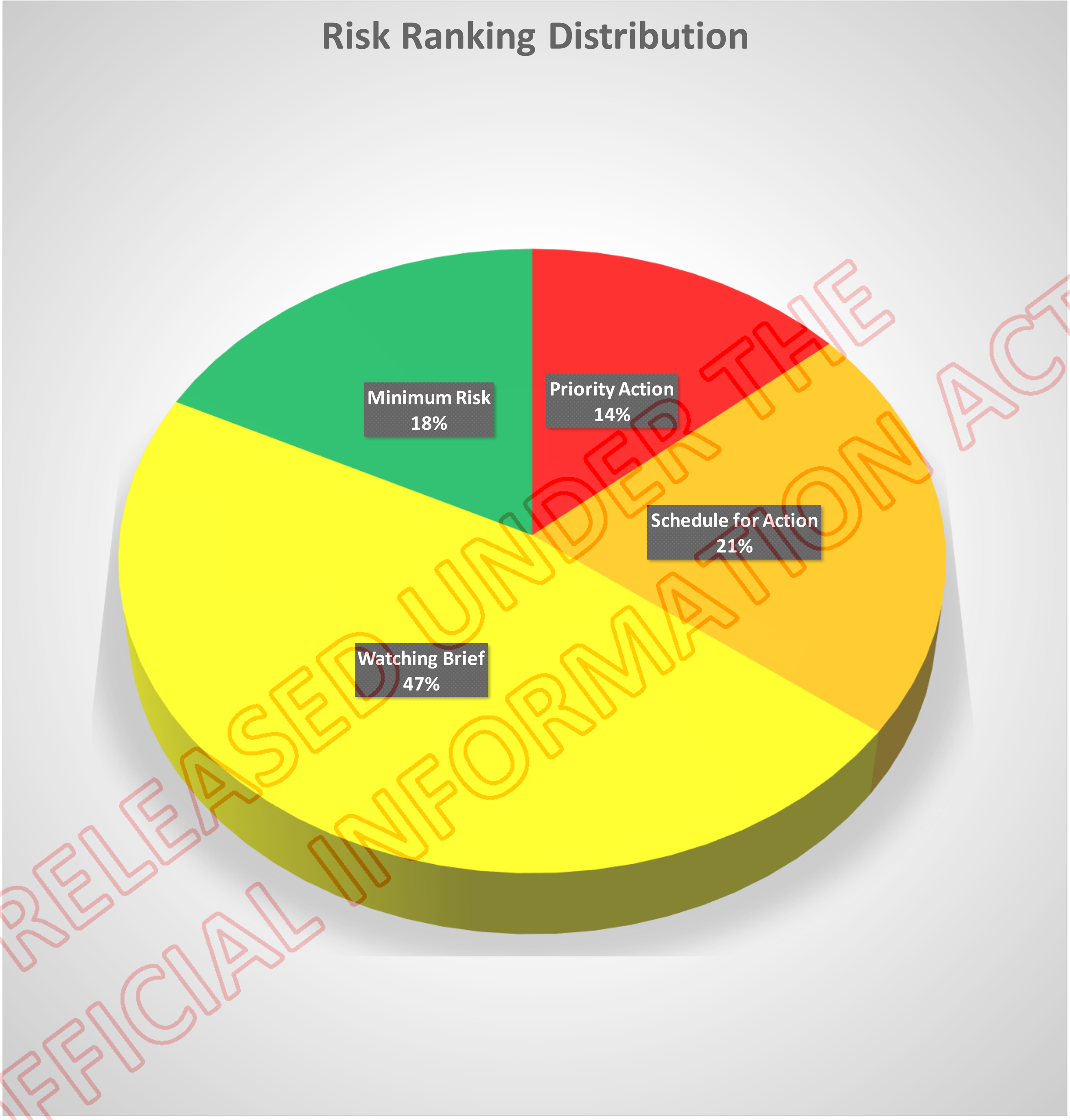

Figure 26 – Risk ranking distribution

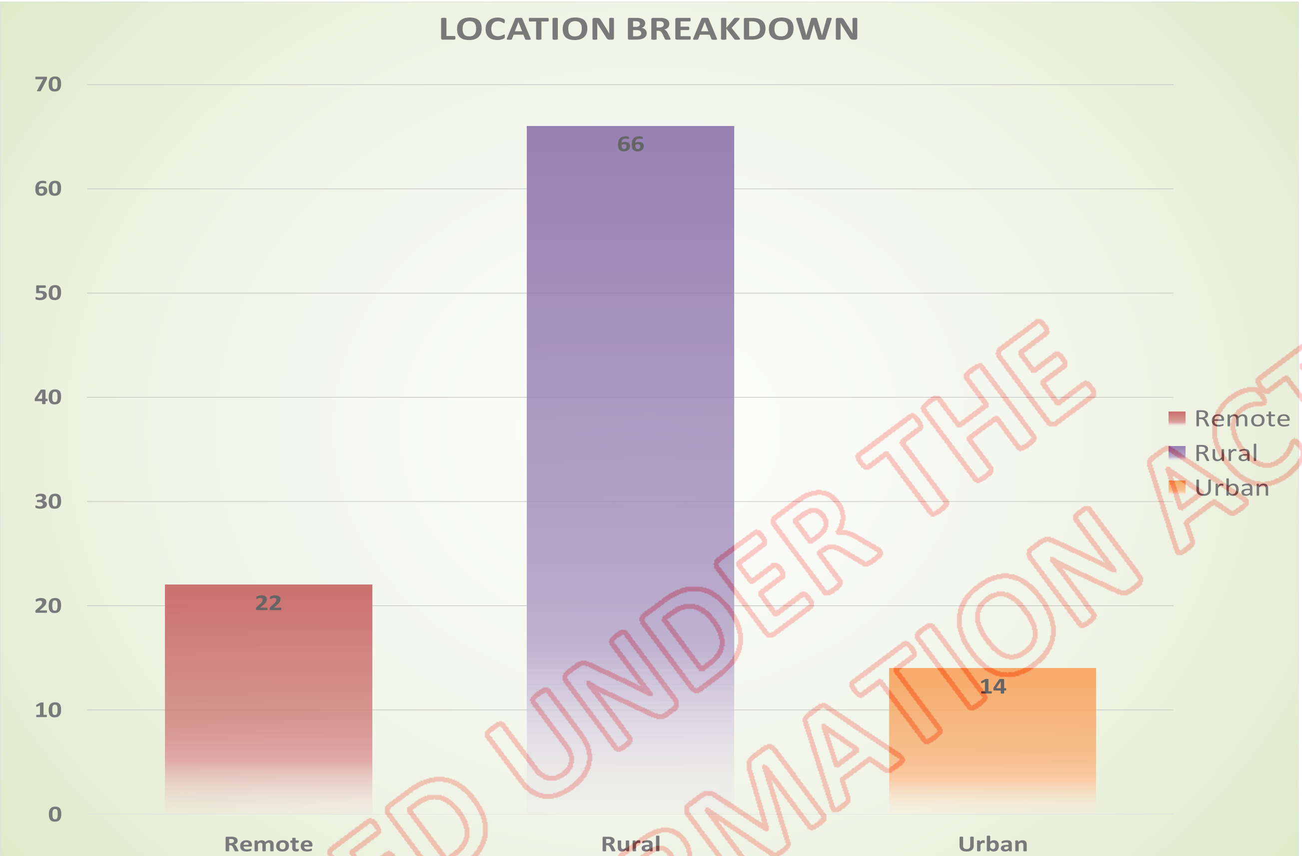

Figure 27 – Location breakdown

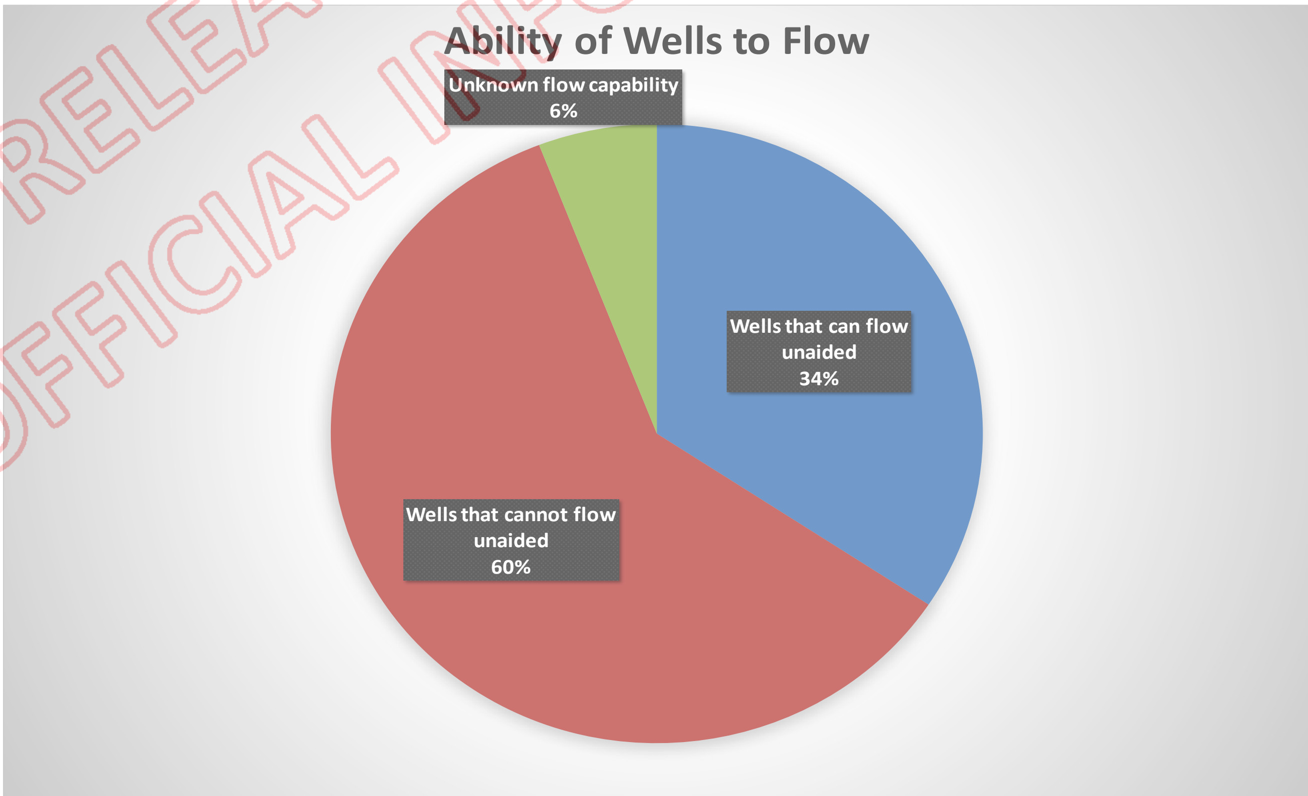

Figure 28 – Ability of wells to flow

‘Priority Action’ has been defined as wells where either an abandonment activity has been assessed as being inadequate, the well status is such that the well has the potential to flow hydrocarbons or there is significant missing data. None of the wells reviewed are an immediate danger to the environment or people, however P&A should be strongly considered for the six wells identified as ‘Priority Action’.

Of the 14 Priority wells (including the 8 wells with missing data), 5 wells are of relatively shallow depths of less than 1000 metres, 3 of which are less than 500 metres. Even if these shallow wells were to leak hydrocarbons it would likely be at relatively low pressures and quantities.

There is an opportunity to batch abandon the three Kauhauroa wells due to their close proximity to one another.

Whilst performing this study, three wells (Niagara-1, Niagara-3 and Ngapaeruru-1) were successfully abandoned as per good oilfield practice, local regulations and OGUK guidelines.

Many of the wells reviewed have poor/old or non-existent well data available and “worst case” assumptions have been made until such time that accurate data becomes available. 8 wells that were classified as ‘Priority Action (missing data)’ wells have insufficient data available to determine the integrity of the wells.

5.1. Abandonment Costs - Actual

Well costs were calculated for each specific well and are broken down into the four Risk Ranking categories as shown in Figure 29.

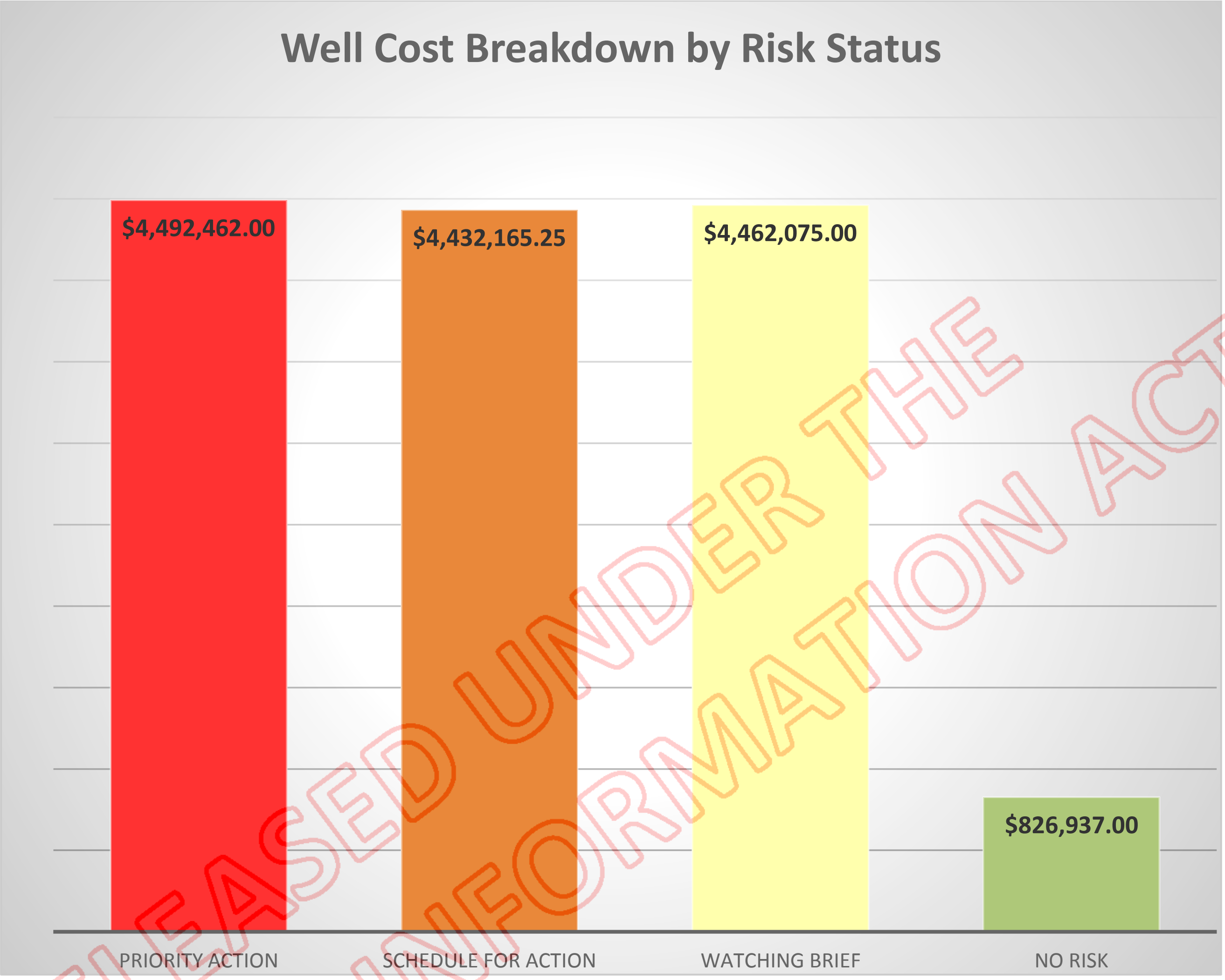

Figure 29 – Well abandonment cost breakdown by risk status

Total well abandonment Level 1 costs are calculated at $14.21mm. As this is a Level 1 cost the range could be as high as $19.9mm to a low of $8.6mm (P50 cost estimate).

P90 and P10 abandonment costs were not calculated but for budgeting purposes the P50 cost estimate could be multiplied by the industry norm of +60% / - 30% respectively. This would generate total P90 and P10 costs as shown in Table 27 below.

Description	P50 Cost Estimate (includes 20% contingency)	P90 Cost Estimate	P10 Cost Estimate
Priority Action	$4.49mm	$7.18mm	$3.14mm
Schedule for Action	$4.43mm	$7.09mm	$3.10mm
Watching Brief	$4.46mm	$7.14mm	$3.12mm
Minimum Risk	$0.83mm	$1.33mm	$0.58mm
Total	$14.21mm	$22.74mm	$9.94mm

Table 27 – Well Cost Range

Given the expense and risk to plug 'Watching Brief' and 'Minimum Risk' wells and the relatively low risk associated with leaving the wells in their current condition, consideration must be given to monitoring these wells for the foreseeable future.

5.1.1. Priority Action Wells Summary

5.1.1.1. Kauhauroa-1 (Priority Well)

Well drilled in 1998 to a depth of 1222m TD (Total Depth) and completed in 1998 – Significant gas shows were reported from 390m to well TD. At well TD the drill string became stuck. The decision was made to use the drill string as the completion string. The drill string was cemented in place with 1" pipe and a 60m surface plug installed in the A-annulus.

The drill string was perforated at 1,196m - 1,199m to test the Kauhaura Limestone, a stabilised flow rate of 11.5MMSCFD was achieved. This interval was re-tested in 1999 with a flowrate of 6.2MMSCFD and water of 2300bbl/day. These perforations were cement plugged in 1999 after the re-test.

A new zone was perforated at 1158.5m - 1159.1m and at 1100.6m - 1101.2m to test the Rere Sandstone. Test at 1,158.5m - 1159.1m yielded maximum flow rates of 537 MSCFD and 550bbl/day water. The well was then suspended.

Well classed as 'Priority Action' as it encountered hydrocarbons, is over-pressured, well has not been abandoned and can flow unaided as is evident from the bottom hole pressure recorded. Plug and abandonment operation will require a Coil Tubing unit and Wireline to perforate and circulate / set the cement plugs.

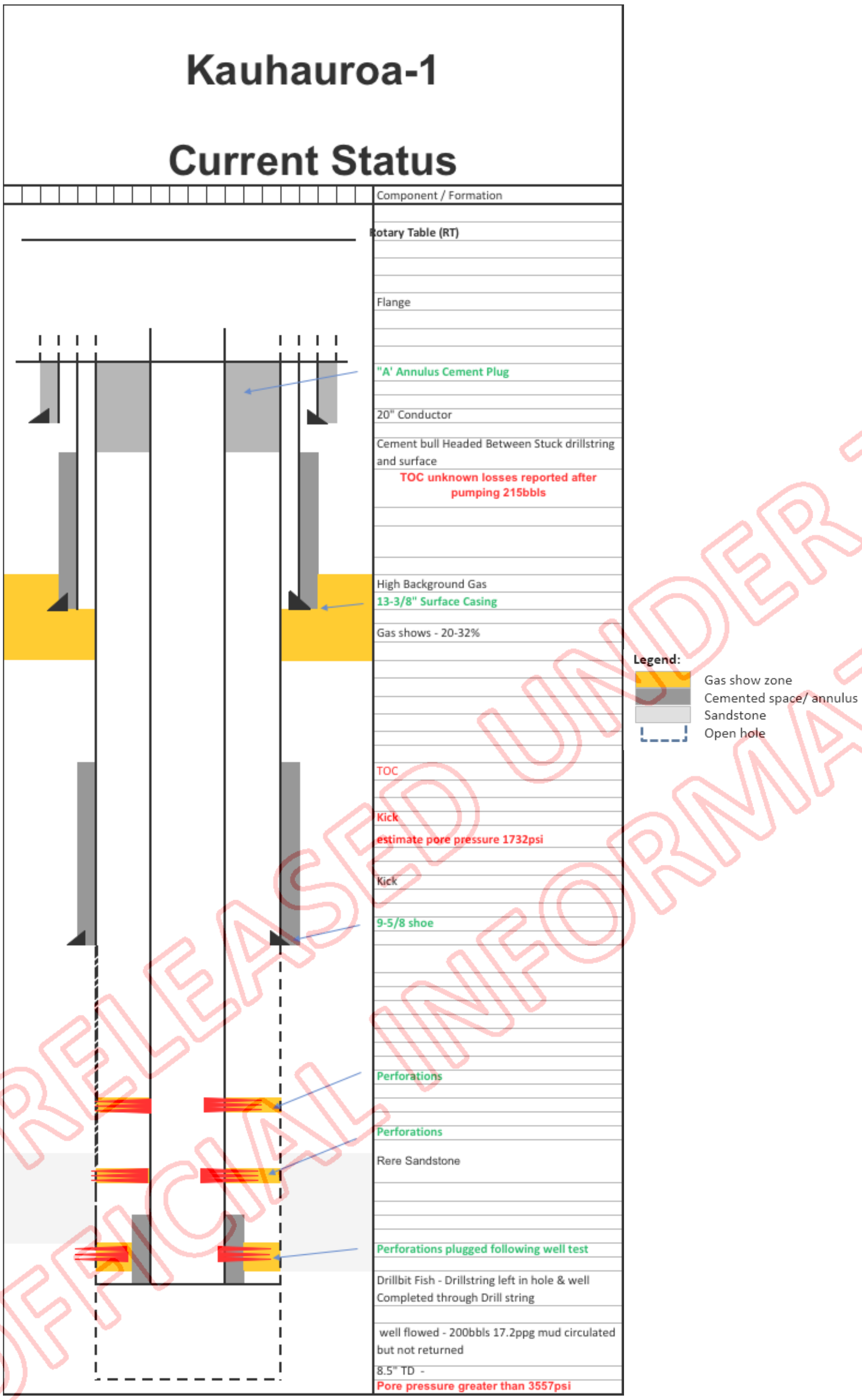

Figure 30 – Kauhauroa-1 well schematic

5.1.1.2. Blackwater-1 (Priority Well)

Well drilled in 1968 to 613mTD with gas cut mud observed from surface. Very strong oil and gas shows at 1,515ft (462m), 1,530ft (466m) & 1,545ft (471m). Final testing of the well failed to produce any large oil or gas flows. After performing an acid treatment, a small flow of gas & condensate was recorded and this was then shut in overnight. In the morning, well pressure had built up to 80psi which resulted in an initial flare of 40ft; this quickly reduced to 1ft. Strong oil fluorescence observed from 1,515m.

Reported extensive well cavings prevented further well testing – tubing was recovered, a heavy duty surface valve installed and well shut in.

Wellsite visited recently with pipe at surface – evidence of fluid leaking from top of flange to the well pad. Gas readings gave 20% Lower Explosive Limit (LEL) of methane.

The well, near Murchison in the South Island, was reported by MBIE as leaking hydrocarbons at the wellhead. There was some evidence of local residents intermittently flaring gas build-up. This was despite the valve handles being removed. As a result, a metal cage was installed in 2016 over the well head to prevent access. The actions at Blackwater-1 were consistent with previous measures taken at the Westgas-2 and Ron MacDonald-1 wells. The wells had been similarly flared by locals until the installation of a cage over the well heads.

Well classed as 'Priority Action' as well encountered hydrocarbons, is normally pressured, well has not been abandoned and can flow unaided as is evident from locals periodically flaring the well.

Plug and abandonment operation will require a Coil Tubing unit and Wireline to perforate and circulate / spot the cement plugs. A Cement Bond Log may be required to determine the integrity of cement behind casing.

Figure 31 – Blackwater-1 Well (prior to cage being installed)

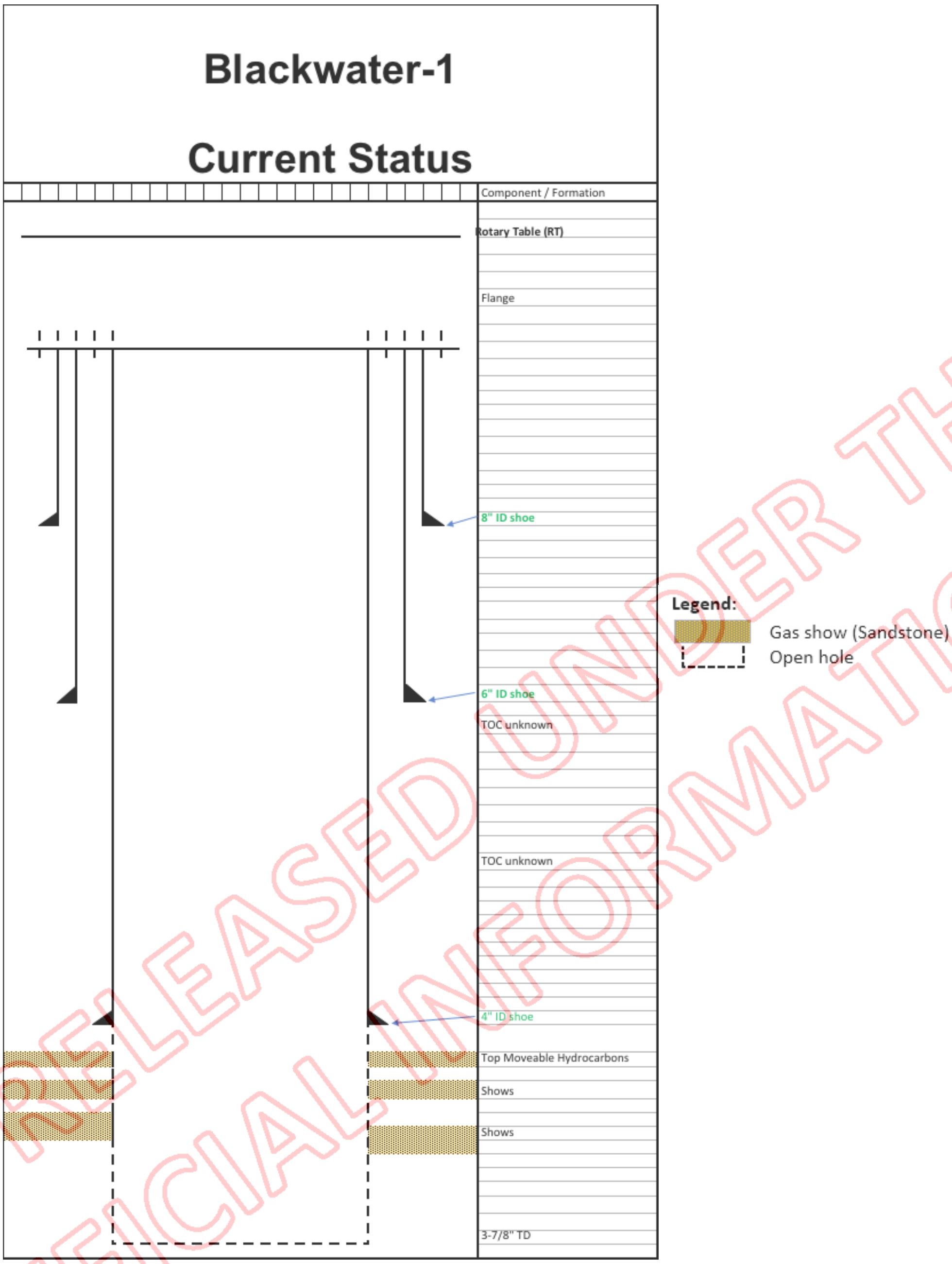

Figure 32 – Blackwater-1 well schematic

5.1.1.3. Kauhauroa-3 (Priority Well)

Well was drilled in 1999 to 1,325.6mTD and completed with 2-3/8" completion tubing.

Drill Stem Tests (DST) were conducted. DST #1 tested the Kauhauroa limestone which flowed water and a small amount of gas – well flowed 5ft gas flare then formation water at 136bbl/day at 1060psi. Shut in pressure was 1,640psi. DST #5 tested the upper Rere Sandstone and produced a very small gas flare. DST # 6 tested the Wheao Formation which flowed formation water. The well was then suspended after testing.

Well was classed as 'Priority Action'. It encountered hydrocarbons, is over-pressured, well has not been abandoned and can flow unaided as is evident from the bottom hole pressure recorded. Plug and abandonment operation of this well would require a workover rig due to the requirement to cut and pull the 7" Casing and set cement plugs.

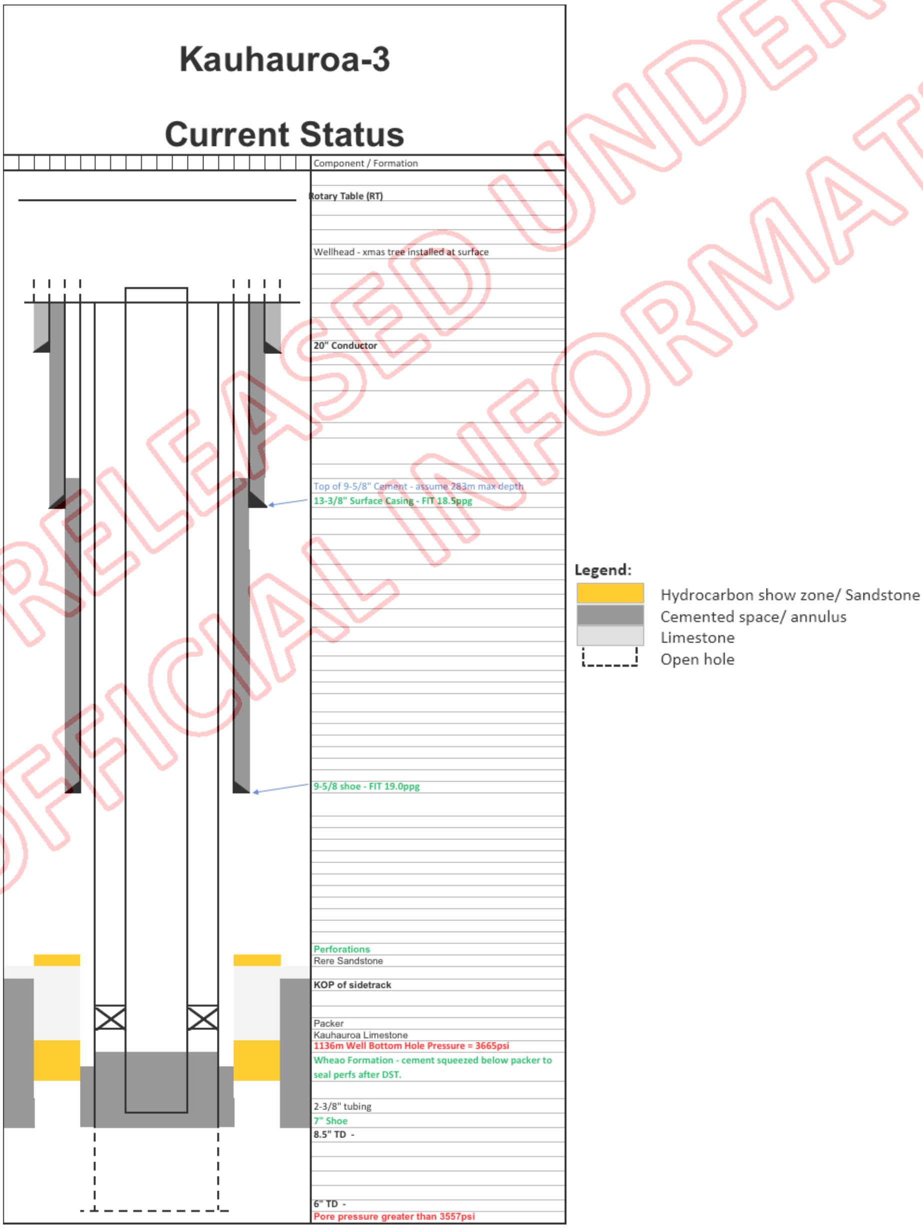

Figure 33 – Kauhauroa-3 well schematic

5.1.1.4. Kauhauroa-4B (Priority Well)

Well was drilled in 2001 to a depth of 2047m TD. Gas shows were reported through the Poha formation. Gas and water flowed to surface up the 13-3/8" annulus after running and cementing the casing. Major losses were reported while drilling the 12-1/4" section which required temporary cement plugs to cure, gas inflows reached 60% while circulating. Testing of the Whangara sandstone at 1,829 - 1,871m flowed water at 1080bbl/day with minor gas flows reported. Test 6 tested the lower Rere sandstone (1161m - 1164m & 1,128m - 1.132m) with only a slight flow reported. The well was swabbed with no further influx. No flow was obtained from the upper Rere sandstone (1,072m - 1,079m) on test 7.

Annular flows were encountered while performing the 7" cement job – this required 19.5ppg Mud Weight to kill the well.

The well was suspended pending further testing with the tubing removed and an Xmas tree installed. 2 downhole drillable plugs were installed of which one was tested to 2,000psi. Upper Rere perforations remain open above the shallow drillable plug. Well was displaced to diesel.

Well classed as 'Priority Action' as well did encounter hydrocarbons, is over-pressured, well has not been abandoned and can flow unaided as is evident from the bottom hole pressure recorded. P&A will require workover/drilling rig to drill out the EZSV plugs and set cement plugs across the hydrocarbon bearing zones, cut and pull the 7" & 9-5/8" casing strings and set cement plugs.

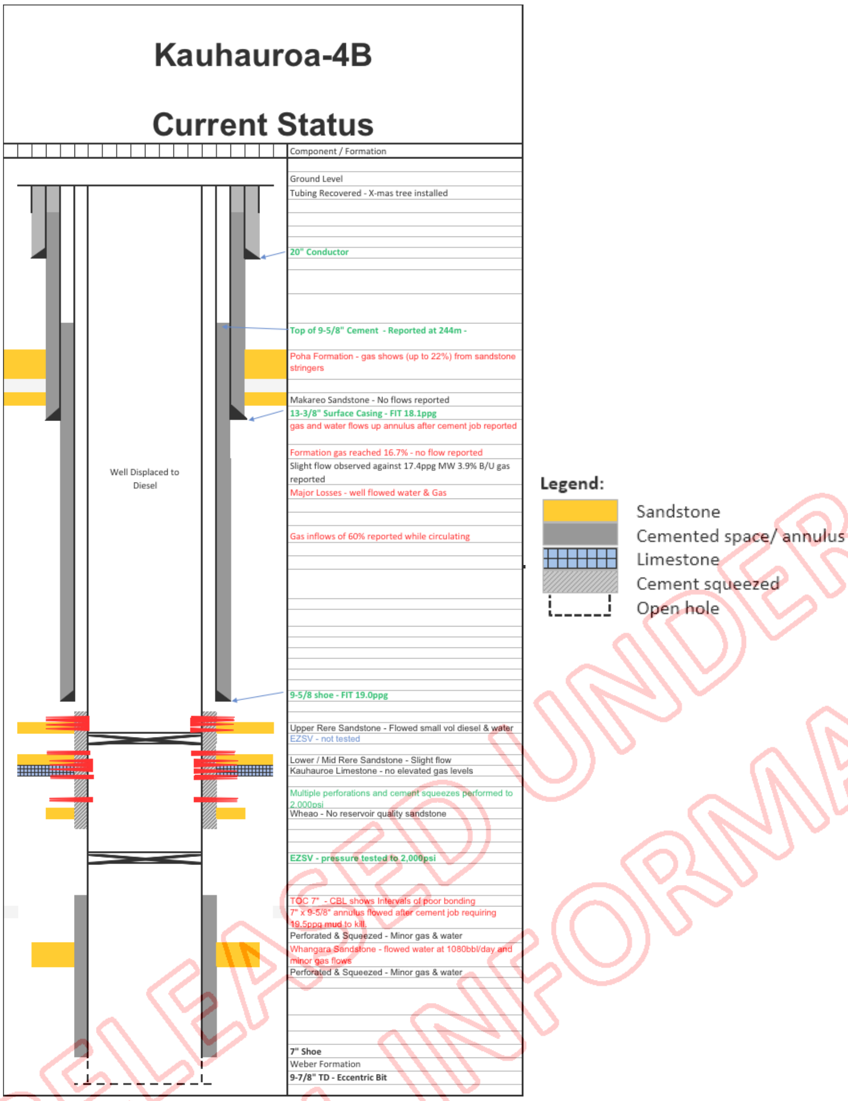

Figure 34 – Kauhauroa-4B well schematic

5.1.1.5. Waitahora-1 (Priority Well)

Well drilled in 2007 to 1352m TD in 8-1/2" hole and 7" Liner was run to TD. It was perforated along the Kauhauroa sandstone and tested which flowed water at 1060bbl/day. The well has been suspended since 2007 however no down hole barriers have been installed therefore technically only classed as shut-in.

Well classed as 'Priority Action' as well did encounter hydrocarbons, is over-pressured, well has not been abandoned and can flow unaided as is evident from the bottom hole pressure recorded. Shut in pressure was 1,690psi. P&A of this well would require a workover rig due to the requirement to cut and pull the 7" casing and set the required cement plugs.

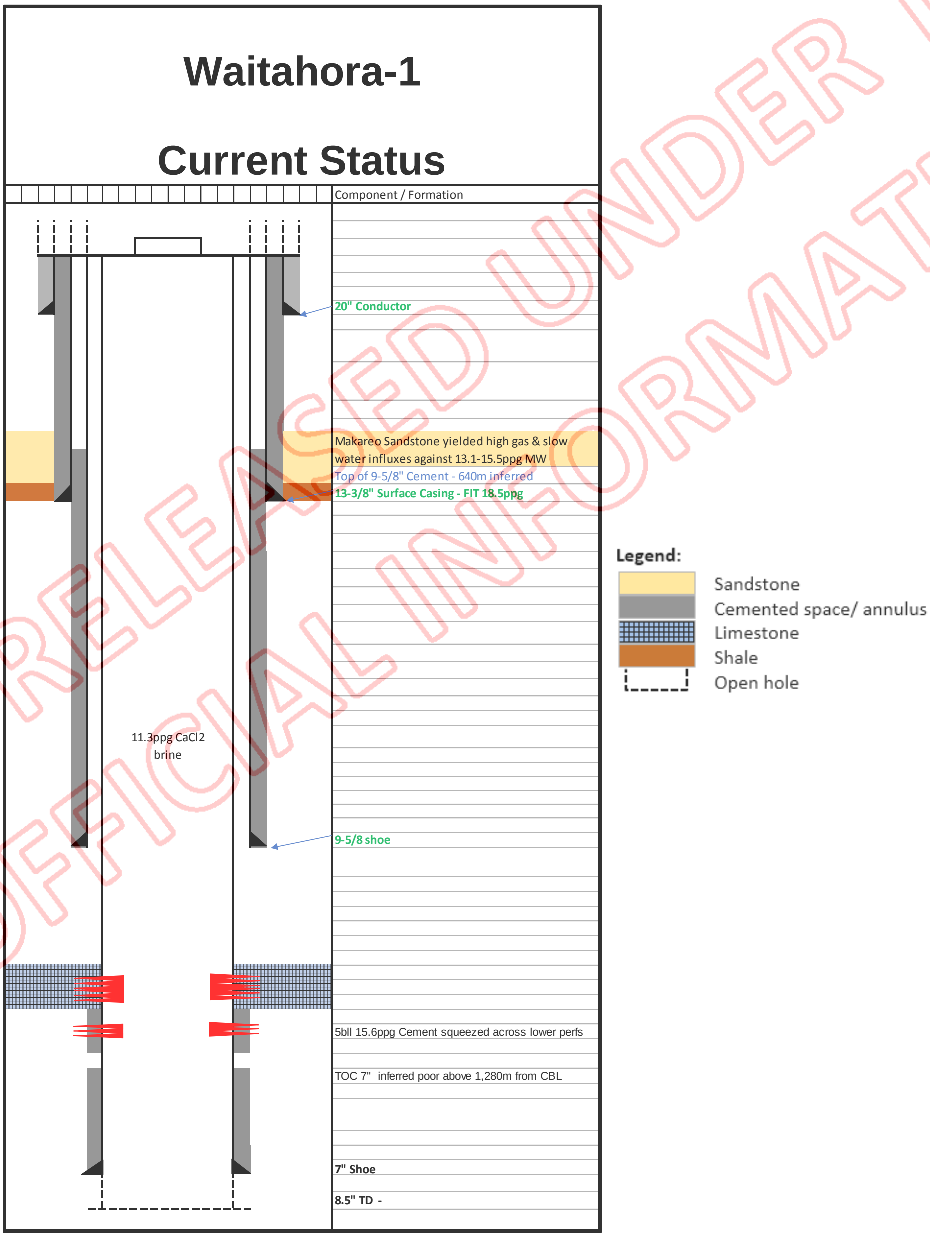

Figure 35 – Waitahora-1 well schematic

5.1.1.6. Horotiu-2 (Priority Well)

The well was spudded in 1967 and drilled to a total depth of 650ft (198m) with a final hole size of 5". 6" casing was set at 128ft (39m) and the 4" casing set at 400ft (122m). The 4" inner casing was later retrieved and the well sealed off with a steel cap. There are no records of abandonment plugs being placed therefore no abandonment plugs are expected.

High pressure water and some gas was encountered at 180ft (54.9m). Produced large volumes of water with the gas subsiding quickly. Ignition of gas proved unsuccessful. Gas analysis suggests a marsh gas.

Fluid (likely water) was flowing out of the well although no gas was observed at the wellsite during the recent site visit.

Well identified as 'Priority Action' - Although there was no gas observed at wellsite during site visit, fluid (likely water) was flowing out of the well. The well was not properly abandoned and is located in the middle of a paddock and along a drainage ditch. The fluid flowing out of the well has a potential of reaching and contaminating the surface water and/or the shallow aquifer.

The plug and abandonment operation would require a cement plug to fill the entire wellbore by using a skinny tubing to be run in hole. The uncased hole most likely has already collapsed in on itself overtime partially sealing the wellbore. It is not recommended to re-enter the uncased section due to the associated risk.

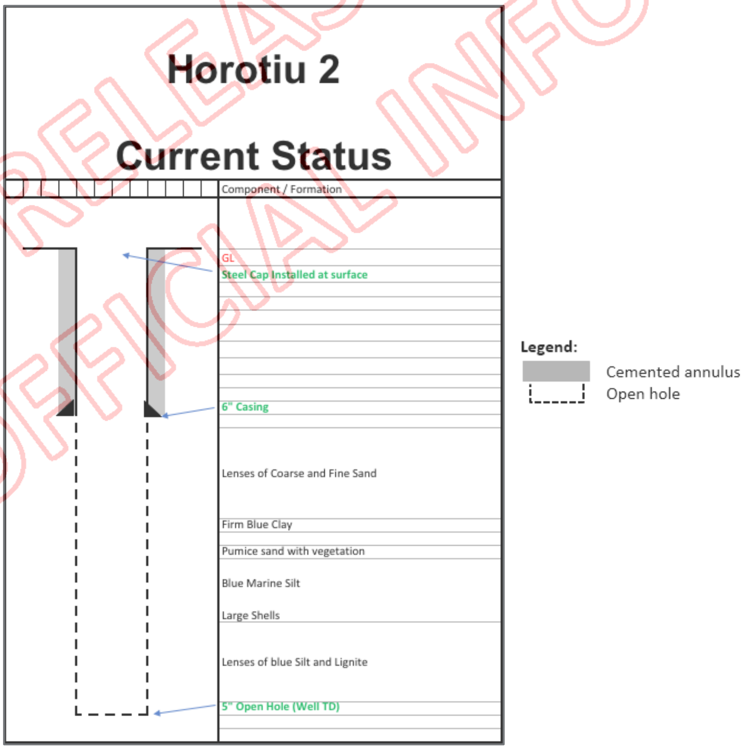

Figure 36 – Horotiu-2 well schematic

5.1.1.7. Centre Bush-1 [Priority Well – (missing data)]

The well was drilled in 1932 to 1846m TD. There is very limited information available for the well. No well completion report available, only supporting document is CR3523 Appendix C which states Centre Bush-1 Well was abandoned – no further records available to confirm. Site visit identified pipe at surface with cellar present. Anecdotal records state well used to seep oil or condensate and water.

Well identified as 'Priority Action (missing data)' due to there being very limited data available. Data available is contradictory – CR3523 states well showed no hydrocarbons and well was abandoned however anecdotal records states that the well at one time used to seep oil or condensate and water. Site visit revealed pipe/cellar at surface and is near a residential area. No hydrocarbons were observed.

P&A will require wireline to drift the well and perform a cement bond log. Placement of a cement plug may be possible via skinny tubing though due to the age it is possible that the casing was retrieved after drilling and the hole has since collapsed. Well schematic is unavailable.

Figure 37 – Photo of Centre Bush-1 Well

Recommend introducing regular monitoring regime. As pipe observed at surface can be investigated via wireline to determine actual well status.

5.1.1.8. Norfolk Road Bore [Priority Well – (missing data)]

Well was drilled in 1907 to an unknown depth. There is no data available to determine how the well was drilled or if any hydrocarbons were encountered or if the well was abandoned. Well Site visit located the well in a pasture land using magnetometer – magnetic anomaly suggests casing was left in the hole.

Well identified as 'Priority Action (missing data)' due to having no data available. There is insufficient data available to determine integrity of the well and if hydrocarbons were encountered or if the well was abandoned. Further investigation is required to identify if hydrocarbons were encountered and if the well was abandoned. Periodic monitoring of the wellsite is recommended to determine if there is hydrocarbon leakage.

Figure 38 – Inferred location of Norfolk Road Bore

5.1.1.9. Waitangi-1 [Priority Well – (missing data)]

Well was drilled in 1909 to 390m. 10", 8" and 6" casing strings were installed however it is difficult to determine the exact depth these were run to. These casing strings were driven in hole and were not cemented. First gas shows were observed at 62m. Sandstone was first reached at 159.1m and oil was struck at 199.6m and flowed 2-3bbl/day. Exited oil sandstones at 212m and drilling continued to 390m through Pug Clay with no further hydrocarbons reported.

No evidence to suggest downhole plugs were placed to abandon/suspend the well – evident from gas percolating at surface through the water filled pipe. Well identified as 'Priority Action (missing data)' as hydrocarbons were encountered during drilling and gas is percolating up the water filled pipe at surface indicating that there is communication between the formations and surface. Well has been in this current state for a long time, however should be considered for abandonment due to the hydrocarbons at surface. Considerable well data is missing from this well and a staged approach to the abandonment is required with physical data acquisition being a priority.

Multiple natural seeps were observed in the location. It is unknown however if the seeps and the hydrocarbon zone that was intersected by the well are coming from the same source. The well would likely be required to be P&A'd using a Coil Tubing Unit.

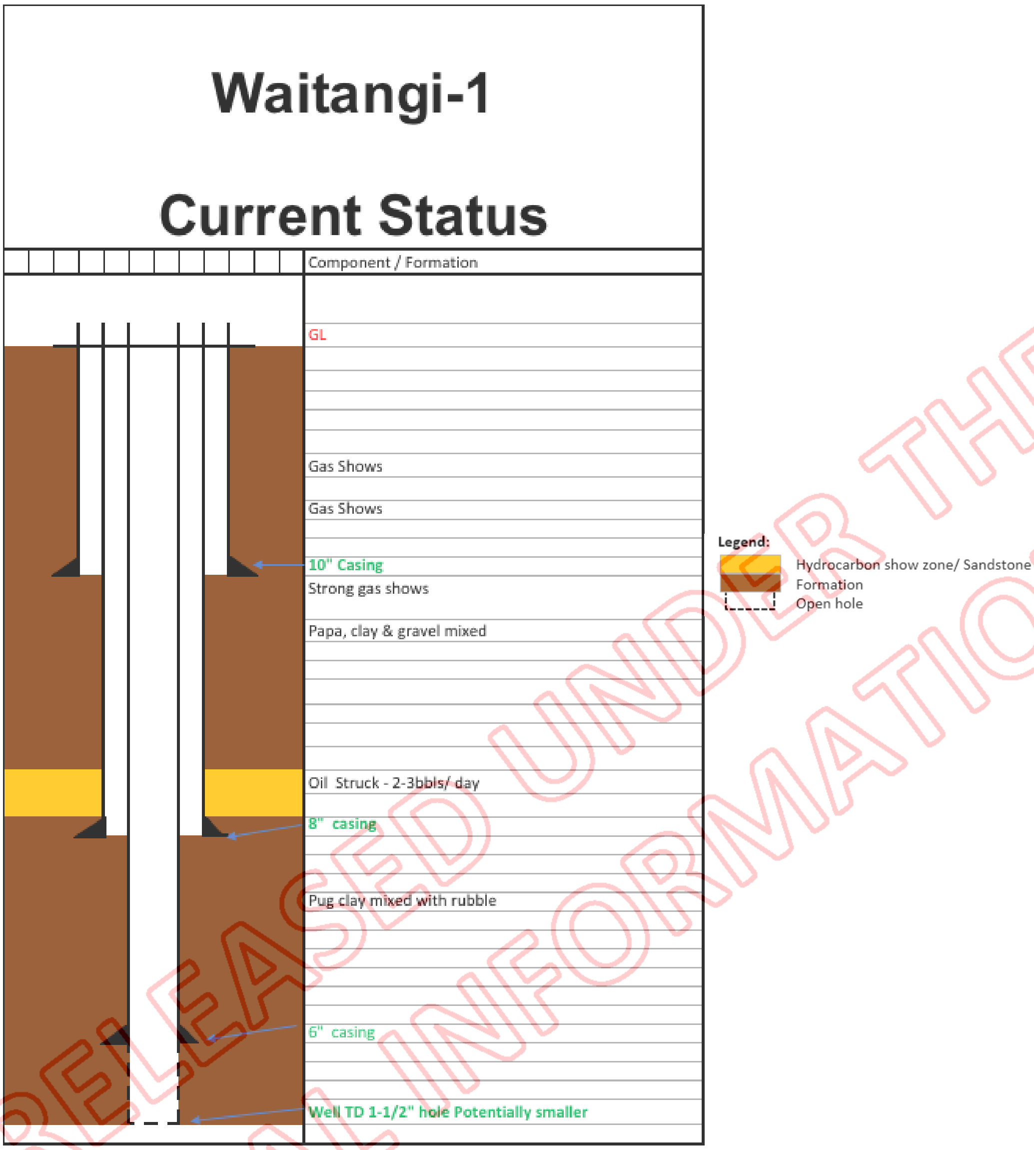

Figure 39 – Waitangi-1 (Gisborne) well schematic

Figure 40 – Waitangi-1 casing filled with fluid and bubbles percolating (minor)

5.1.1.10. Waikaia-1 [Priority Well – (missing data)]

Well was drilled in 1974. Depth is unknown and no other information is available to determine how the well was drilled, to what depths, if any hydrocarbons were encountered or if the well was abandoned. The well site was inferred due to the presence of a large diameter pipe at the database well location. This was located on the banks of an artificial pond presumably designed to capture water from a natural water spring approximately 20 metres away.

The pipe was leaking water and ferric (Fe^{3+}) iron sheen was present in the waterway which fed into the pond. No gas was detected and the water appeared clear of contaminants. The well is classed as 'Priority Action (missing data)' due to a lack of well information and leaking water at surface.

The orientation of the pipe is inconsistent with typical petroleum well orientations (vertical). The pipe being horizontal means the pipe is most likely linked to drainage from the cellar.

It is recommended to undertake further work to confirm the location of the well and identify if this pipe represents the documented petroleum well. Costs for site investigation only. Wireline work will be required to determine hold-up depths and cement bonds. Perform monitoring for any hydrocarbon leakage.

Figure 41 – Waikaia-1 inferred location

5.1.1.11. Ardmore-1 [Priority Well – (missing data)]

Well was drilled in 1959 and identified as 'Priority Action (missing data)' due to there being insufficient data available. Unable to determine how the well was drilled, to what depths, if any hydrocarbons were encountered or if the well was abandoned. Site investigators identified a pipe which was approximately 3 inch in diameter surrounded by concrete. The concrete may have been part of the foundation to a cow shed previously on the site. Verbal information from the landowner informed the site investigators that the well has only been used for water extraction and stopped producing 50 years ago.

It is recommended that this well undergoes further site work to identify whether the pipe identified is the petroleum well or not and if the well was abandoned.

Figure 42 – Ardmore-1 Well

5.1.1.12. Peep-O-Day [Priority Well – (missing data)]

The well was drilled in 1912 to 917m. Well is identified as 'Priority Action (missing data)' due to it having very poor information available and historical evidence of hydrocarbons. Well schematic derived from a log. Well is located nearby a road side - some rusted parts of well, pipe collar and other miscellaneous metallic debris located on surface. However, there was no surface contamination observed. Well was reported during drilling to have small discharge of gas at around 945ft (288m) – able to blow water up the rods (pipe) to 4-5ft.

The well was drilled to 917m and no information is available on its abandonment. The well location was inferred based on the documented location. It is recommended to conduct further study to gain information and perform monitoring to determine if there are hydrocarbon leakages. The wellsite needs to be cleared of debris.

Figure 43 – Inferred well location of Peep O Day showing scattered metal debris

5.1.1.13. Waihihere-1 [Priority Well – (missing data)]

Well was drilled in 1911 to 420m based on GNS data. The well was identified as 'Priority Action (missing data)' due to no well information being available. Unable to determine the integrity of the well, if any hydrocarbons were encountered and if the well was ever abandoned. Access for an MBIE wellsite visit was not granted.

It is recommended to negotiate access and perform a wellsite visit to determine the surface status of the well and to monitor for hydrocarbon leakages. Wireline intervention will likely be required to determine if downhole plugs have been set. Likely that well formations have collapsed over time.

5.1.1.14. Waipai-1 [Priority Well – (missing data)]

Well spudded in 1973 however there is no data available to determine how the well was drilled, to what depths, if any hydrocarbons were encountered or if the well was abandoned. MBIE previously unable to perform site visit due to access consents.

It is recommended to perform site visit and further well studies. The well was identified as 'Priority Action (missing data)' due to no well information being available. Unable to determine the integrity of the well, if any hydrocarbons were encountered and if the well was ever abandoned

It is recommended to negotiate access and perform a wellsite visit to determine the surface status of the well and to monitor for hydrocarbon leakages. Wireline intervention will likely be required to determine if downhole plugs have been set. Likely that well formations have collapsed over time.

5.2. Recommendations

It is recommended action is taken on the 'Priority Action' wells (6) unless they are part of a regular monitoring programme. Wells which are not abandoned (whether shut-in, suspended or temporarily suspended) should be included in a well examination scheme.

For the eight 'Priority Action (missing data)' wells, further attempts should be made to acquire well data through site visits, well interventions (if possible) and further attempts to determine and contact the original well Operators (if possible).

Wells should be abandoned in batches so that efficiencies can be made, safety enhanced and costs minimised. This may necessitate mixing 'Priority Action' and 'Schedule for Action' wells so that wells in close proximity can be batched.

For the 12 wells where data quality is very poor, a data acquisition programme should be designed to obtain the missing well data. Any relevant information would help to determine the forward plan for their abandonment. This will likely entail well intervention to log the well to determine depths, plug locations, cement bonds, corrosion, perforation depths, fluid in the well and possibly pressures. Depending on the data found, the classification may be changed from a 'Priority Action (missing data)' well to a lower classification and will directly affect the abandonment selection strategy.

Consideration should be given to utilising Operators to abandon a number of the 'Priority Action' and 'Schedule for Action' wells if the Operator is performing well operations nearby. This will likely result in reduced costs and efficiencies.

All of the wells reviewed are relatively uncomplicated to abandon. One does not have to deal with excessive pressures, temperatures or H2S and rigless abandonments are possible for the majority of the wells reviewed. Novel abandonment techniques such as the use of high specification cements will likely not offer significant costs savings or benefits.

6.0 FUTURE WORK

Certain aspects have been identified requiring further diagnostic work and investigation prior to any well abandonment being performed. This work will vary depending on the well data availability, the well location and the risk ranking but generally the following will be required.

6.1. Well Abandonment Plan

A detailed well abandonment plan is required to allow future resources and costs to be allocated. This plan should include the following:

6.1.1. Planning Phase

s 9(2)(b)(ii)

s 9(2)(b)(ii)

7.0 REFERENCES

Crown Minerals (Petroleum) Regulations 2007

Health and Safety at Work (Petroleum Exploration and Extraction) Regulations 2016

WorkSafe New Zealand Interpretive Guidelines, Well Operations and Well Examination Schemes, July 2015

Guidelines for the Abandonment of Wells, Issue 5, July 2015, Oil & Gas UK, ISBN 1 903 004 50 0

Guidelines on Qualification of Materials for the Abandonment of Wells, Issue 2, 2015, Oil & Gas UK, ISBN 1 903 004 56 X

NORSOK Standard D-010 Well Integrity in Drilling and Well Operations

DNVGL-RP-E103, Risk-based Abandonment of Offshore Wells, DNV GL, Edition April 2016

WellAtlas® Risks and Lessons Register, Petrofac

High-level integrity assessment of abandoned wells, M.D.C. van der Kuipa, T. Benedictusa, N. Wildgustb, T. Aiken

Assessment and Management of Legacy Petroleum Wells New South Wales, December 2014, J.Berry & S.Hann

Preliminary Review of Onshore Petroleum Abandonment Risk, Advision, October 2016, G Hooper

WorkSafe Interpretive Guidelines
1. Petroleum: Well Operations and Well Examination Schemes, March 2017
2. Petroleum Notifications: Quick Guide
3. Petroleum: Notifications and Submissions, April 2015
4. Petroleum: Verification Schemes, April 2015
5. Petroleum: Certificate of Fitness, March 2017

8.0 APPENDIX 1 - DEFINITIONS

Active/Inactive Well
An active well is a well which has had operations occur within the past 24 months.
An inactive well is a well which has had no operations occur within the past 24 months.

ALARP
ALARP stands for "as low as reasonably practicable". The concept of "reasonably practicable"; this involves weighing a risk against the trouble, time and money needed to control it. Thus, ALARP describes the level to which we expect to see workplace risks controlled.

Artificial Lift
A process used on oil wells to increase pressure within the reservoir and encourage oil to the surface. When the natural drive energy of the reservoir is not strong enough to push the oil to the surface, artificial lift is employed to recover more production. Artificial-lift systems use a range of operating principles, including rod pumping, gas lift and electric submersible pump.

BOP
A common oilfield acronym used to call blowout preventer devices. BOP is a conditional surface pressure barrier often consisting of a set of hydraulically operated rams containing equipment designed to grip pipe, seal around pipe, shear off pipe or seal an open hole during drilling or a workover. It may also contain an annular preventer. Installed at the top of a well that may be closed if the drilling crew loses control of the formation fluids. A BOP is critically important and a mandatory requirement in well entry or while drilling.

Bull Heading
Forcing fluids in the pipe into the formation at a pressure higher than the pore pressure and sometimes higher than the fracturing breakdown pressure. Usually, bull heading is done in the event of a need for well control, but it is also performed if normal circulation cannot occur, such as after a borehole collapse. It is a simple and fast operation but intrinsically risky as compared to pumping through Coiled Tubing.

Casing Wear
Internal wear of casing because of rotating strings during drilling and workover operations. Casing wear is measured in reduction in thickness as compared to the original thickness.

Cement Bond
The strength and adherence of the cement to the pipe and the formation. Cement bond logging usually measures the integrity of the cement job, especially whether the cement is adhering solidly to the outside of the casing.

Coil Tubing (CTU)
Coiled tubing is a continuous reeled tube from 1 inch to over 3.5 inches in diameter. The tubing is injected into a well via a coiled tubing unit (CTU) and can be used to unload wells with liquid, foams or gasses, or for logging, fracturing, etc.. The CTU has reel, injector head, power pack, control unit and pressure control equipment. Coiled tubing jobs can include pumping fluid, pulling downhole devices, or be used to workover or drill wells.

Completion (Completed Well)
Completion, in petroleum production, is the process of making a well ready for production (or injection). This principally involves preparing the bottom of the hole to the required specifications, running in the production tubing and its associated down hole tools as well as perforating and stimulating as required.

Downhole Losses
The reduced or total absence of fluid flow up the annulus when fluid is pumped through the drill string. This reduction of flow may generally be classified as partial lost returns and total lost returns where no fluid comes out of the annulus. In this severe latter case, the hole may not remain full of fluid even if the pumps are turned off. If the hole does not remain full of fluid, the vertical height of the fluid column is reduced and the pressure exerted on the open formations is reduced. This in turn can result in another zone flowing into the wellbore, while the loss zone is taking mud, or even a catastrophic loss of well control. Even in the two less severe forms, the loss of fluid to the formation represents a financial loss that must be dealt with, and the impact of which is directly tied to the per barrel cost of the drilling fluid and the loss rate over time.

Fish (in hole)
Anything left in a wellbore. It does not matter whether the fish consists of junk metal, a hand tool, a length of drill pipe or drill collars, or an expensive MWD and directional drilling package. Once the component is lost, it is properly referred to as simply "the fish." Typically, anything put into the hole is accurately measured and sketched, so that appropriate fishing tools can be selected if the item must be fished out of the hole.

Formation Injectivity
A quantitative limit of rate and pressure at which fluids can be pumped into the treatment target without fracturing the formation. Most stimulation treatments and remedial repairs, such as squeeze cementing, are performed following an injection test to help determine the key treatment parameters and operating limits.

Good Oilfield Practice
Good oilfield practice means all things that are generally accepted as good and safe practices when planning and performing petroleum operations.

Hydrocarbon
A naturally occurring organic compound comprising hydrogen and carbon. Hydrocarbons can be as simple as methane [CH4], but many are highly complex molecules, and can occur as gases, liquids or solids. Petroleum is a complex mixture of hydrocarbons. The most common hydrocarbons are natural gas, oil and coal.

Inhibited Water
A type of mud or fluid used in a well operation with content as a corrosion inhibitor. A corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material, typically a metal or an alloy. The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water, and flow regime.

Lower Explosive Limit (LEL)
Lowest concentration (percentage) of a gas or vapor in air capable of producing a flash of fire in the presence of an ignition source (arc, flame, heat). Concentrations lower than LEL are 'too lean' to burn. Also called lower flammable limit (LFL). For Methane LEL is 5% by volume.

LOT – Leak Off Test
A test to determine the strength or fracture pressure of the open formation, usually conducted immediately after drilling below a new casing shoe. During the test, the well is shut in and fluid is pumped into the wellbore to gradually increase the pressure that the formation experiences. At some pressure, fluid will enter the formation, or leak off, either moving through permeable paths in the rock or by creating a space by fracturing the rock. The results of the leak off test dictate the maximum pressure or mud weight that may be applied to the well during drilling operations. To maintain a small safety factor to permit safe well control operations, the maximum operating pressure is usually slightly below the leak off test result.

Mechanical Bridge Plug
A downhole tool that is located and set to isolate the lower part of the wellbore. Bridge plugs may be permanent or retrievable, enabling the lower wellbore to be permanently sealed from production or temporarily isolated from a treatment conducted on an upper zone.

Open Hole
The uncased portion of a well. All wells, at least when first drilled, have open hole sections that the well planner must contend with. Prior to running casing, the well planner must consider how the drilled rock will react to drilling fluids, pressures and mechanical actions over time. The strength of the formation must also be considered. A weak formation is likely to fracture, causing a loss of drilling mud to the formation and, in extreme cases, a loss of hydrostatic head and potential well control problems. An extremely high-pressure formation, even if not flowing, may have wellbore stability problems. Once problems become difficult to manage, casing must be set and cemented in place to isolate the formation from the rest of the wellbore. While most completions are cased, some are open, especially in horizontal or extended-reach wells where it may not be possible to cement casing efficiently.

Packer (casing/tubing packer)
A device that can be run into a wellbore with a smaller initial outside diameter that then expands externally to seal the wellbore. Packers employ flexible, elastomeric elements that expand. The two most common forms of drilling packer are the production or test packer and the inflatable packer.

A well completion packer is a downhole device used in almost every completion to isolate the annulus from the production conduit, enabling controlled production, injection or treatment. A typical packer assembly incorporates a means of securing the packer against the casing or liner wall, such as a slip arrangement, and a means of creating a reliable hydraulic seal to isolate the annulus, typically by means of an expandable elastomeric element. Packers are classified by application, setting method and possible retrievability.

Petroleum Well
A petroleum well is a borehole which is drilled to discover, delimit or produce a petroleum deposit and/or undertake injection (gas, water or other medium), disposal, monitoring (well parameters) or workover operations.

Plugged and Abandoned (P&A) Well
Plugged and abandoned wells are sealed in such a way or manner as to render the well permanently inoperative and to prevent the escape of gas or fluid. Cement plugs are installed down hole to prevent the migration of oil, gas, groundwater, or other substances from one stratum to another. Once complete, site reclamation works begin.

Producing Well
A petroleum well from which hydrocarbons are currently being extracted.

Slurry Thickening Time
A measurement of the time during which a cement slurry remains in a fluid state and is capable of being pumped (duration).

Shut-In Well
A well which is capable of producing hydrocarbons but production has been ceased temporarily e.g. due to economic or operational reasons.

Site Remediation
Removal of all wellhead equipment and infrastructure and the restoration of the wellsite to its original condition with the well head capped, marked and buried beneath the ground surface, in line with current regulations, industry best practice and/or agreement with the landowner.

Spud
To start the well drilling process by removing rock, dirt and other sedimentary material with the drill bit.

Stratigraphic Well
Any well or hole, except a seismograph shot hole, drilled for gathering information in connection with the oil and gas industry with no intent to produce oil or gas from such well.

Suspended Well
A suspended well is a well which has been made temporarily inoperative.

Stuck Pipe
The portion of the drill string that cannot be rotated or moved vertically. During well (especially drilling) operations, a pipe is considered stuck if it cannot be freed from the hole without damaging the pipe, and without exceeding the drilling rig's maximum allowed hook load.

Tag Plug (tagging)
Tagging is performed by running a cement stinger and applying a weight to ascertain the location of the top of the cement plug after the cement has set.

Unconsolidated Formation
Formations with insufficient cementing agents between the grains to stop movement of individual grains when fluid flows through the formation. Usually less than 2 to 10 psi compressive strength.

Well Barrier Element
A barrier is an envelope preventing hydrocarbons from flowing unintentionally from the formation into another formation or to surface. Barrier elements that make up the Primary barrier are those elements which are or might be in direct contact with well pressure during normal operation. These elements provide the initial and inner envelope preventing unintentional flow of reservoir fluid to surface or another zone. Barrier elements that make up the secondary barrier are those which are or might be exposed to contact with well pressure should any of the elements described as a Primary barrier fail. These elements provide an envelope outside the Primary barrier envelope providing a second barrier preventing unintentional flow of reservoir fluid to surface or another zone.

Well Control
The technology & practices focused on maintaining pressure on open formations (that is, exposed to the wellbore) to prevent or direct the flow of formation fluids into the wellbore. This technology encompasses the estimation of formation fluid pressures, the strength of the subsurface formations and the use of casing and mud density to offset those pressures in a predictable fashion. Also included are operational procedures to safely stop a well from flowing should an influx of formation fluid occur. To conduct well-control procedures, large valves are installed at the top of the well to enable wellsite personnel to close the well if necessary.

Well Cuttings
Small pieces of rock that break away due to the action of the bit teeth. Cuttings are distinct from cavings, rock debris that spalls as a result of wellbore instability. Visual inspection of rock at the shale shaker usually distinguishes cuttings from cavings.

Well Test
A “well test” is simply a period during which the production of the well is measured, either at the well head with portable well test equipment, or in a production facility. Most well tests consist of changing the rate, and observing the change in pressure caused by this change in rate. To perform a well test successfully one must be able to measure the time, the rate, the pressure, and control the rate.

Wellbore Energy
Capability of fluid downhole in a wellbore to flow to atmosphere due to differential pressure.

Wellbore Fluids
Any fluids in the wellbore area usually are the formation fluids from the reservoir or could be the mud and its chemical composition that have been pumped or circulated downhole.

Well Integrity
Application of technical, operational and organisational solutions to reduce the risk of the uncontrolled release of formation fluids throughout the life cycle of a well.

Wireline
A general term used to describe well-intervention operations conducted using single-strand or multi-strand wire or cable for intervention in oil or gas wells. Although applied inconsistently, the term

commonly is used in association with electric logging and cables incorporating electrical conductors. Similarly, the term slickline is commonly used to differentiate operations performed with single-strand wire or braided lines.

Xmas Tree

Xmas Tree, also known as Christmas Tree and in schematics sometimes indicated as XT. It is a common oilfield name for set of valves, spools and fittings connected to the top of a well to direct and control the flow of formation fluids from the well. It may contain hangers, master valves, annular valves, wing valves, and gauges, or pressure, flow rate or other monitoring measurement equipment.

9.0 APPENDIX 2 – SUMMARY LISTING OF 104 WELLS REVIEWED