Gas Migration Preliminary Investigation Report – December 2013

EXECUTIVE SUMMARY

Gas migration is defined as the flow of gas outside of the surface casing of a well. In 2013, the gas migration project was initiated in order to obtain a preliminary understanding of the extent and causes of gas migration. The project included inspections of 308 wells, with 11 new cases of gas migration identified. Gas isotope data, geological data and well files were reviewed to determine what areas and practices might increase the risk of gas migration.

Key findings:

1. Field screening techniques for the detection of gas migration were generally ineffective. The only reliable method for the detection of gas migration was the observation of bubbling in standing water around the wellhead. Vegetation stress and the use of a portable gas detector were not effective for detecting gas migration. More sophisticated techniques such as closed chamber measurements or soil vapour surveys in the future.

2. The use of gas isotope analysis appears to be effective at distinguishing between biogenic and thermogenic gas sources. Gas isotope analysis is not effective in determining the source depth of thermogenic gas sources, likely due to the lack of adequate background data for comparison, particularly at shallow depths. Gas source interpretation from isotope data relies on proprietary data.

3. The Commission does not have an accurate understanding of the total number of wells with gas migration. There are currently 47 reports of existing gas migration, however based on inspection results, there may be 235 instances of visible gas migration and 900 instances of gas migration in the north zone. The confidence level of this estimate is very low and there is no estimate of the frequency of gas migration for the central or south zones.

4. There is no evidence to suggest that any of the current wells with gas migration pose a risk to domestic water wells.

5. There are two primary risk factors for gas migration. The use of underbalanced drilling and the presence of gas above the base of the surface casing. There is insufficient information available to justify any changes to regulation in order to address the above risk factors. The benefits of regulatory changes would have to be carefully weighed against their effects on drilling safety and well economics.

6. Current policy for the management of gas migration may not be consistent with *OGAA* provisions related to spillage.

7. There is no timeline for the repair and abandonment of wells with gas migration or surface casing vent flows.

Recommendations:

1. Conduct additional monitoring for gas migration in the summer of 2014 using improved screening techniques. Sampling should focus on determining whether gas migration is present in wells in the south and central zones. A sample size of at least 200 wells would be required in order to obtain representative data. Field sampling could be completed by summer students.

2. Develop and implement a program to collect a comprehensive, publically available database of gas isotope data in order to improve gas isotope interpretation.

3. Review *OGAA* provisions related to spillage and update policy and regulation as required.

4. Implement repair timelines for inactive wells with gas migration or surface casing vent flows. This should be completed as part of the work to develop and implement mandatory abandonment and reclamation timelines.

5. The Commission should continue to support initiatives that support improvements to well integrity, including but not limited to, academic research, the development of best practices and industry standards.

1.0 Background

Gas migration is the flow of gas outside of the surface casing. Gas migration (GM) may be detected visually, by observing gas bubbling in standing water around the wellhead, by the presence of dead vegetation, or by conducting a soil vapour survey.

Methane can occur naturally in soil and groundwater, due to the natural breakdown of organic material (biogenic methane) and may possibly be considered ubiquitous. Where GM occurs from greater depths (typically thermogenic gas), there is the potential for gas to enter potable water aquifers and cause groundwater contamination. Migration of thermogenic gas may result from wellbore integrity issues such as casing or cementing defects, or through natural processes. Thermogenic gas has been detected in shallow aquifers of the North Appalachian Basin prior to the drilling of Marcellus shale gas wells (Baldassare, 2011). In British Columbia, the Commission has designated two Quaternary gas pools in the Helmet field.

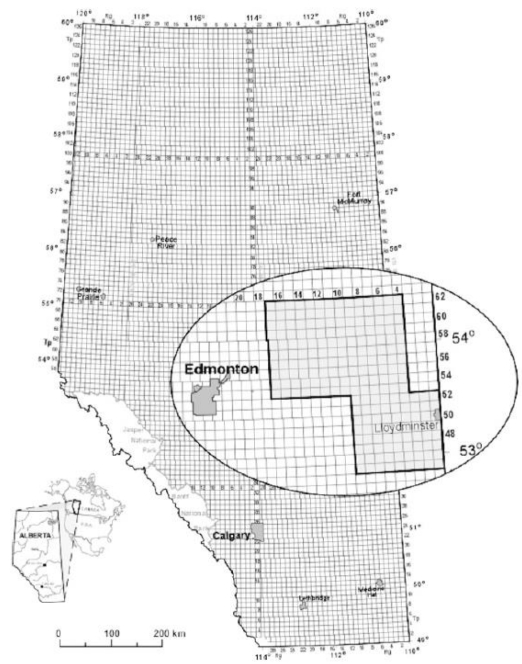
GM is a concern due to the potential for risks to health, safety and the environment. Although methane is non-toxic, if methane is introduced into a drinking water system, there is the potential to create an explosive atmosphere in confined spaces. Additionally, GM is a source of GHG emissions. Finally, the presence of GM increases the cost of abandoning and reclaiming wellsites. Repairs of GM at the time of well abandonment typically cost in the range of $100 000 to $1 000 000 per well.

Figure 1: Examples of gas migration.

Prior to October 2010, there was no explicit requirement to report GM to the Commission and consequently, there were few reported incidences. From the time when mandatory reporting of GM was incorporated into the Drilling and Production Regulation in October 2010 until spring 2013, the Commission had received 84 reports of GM. At the present time, there is no reason to expect that any of the confirmed GM wells have had a negative impact on any domestic source of groundwater as none of the GM wells are in close proximity to domestic water wells.

A study of well leakage in Alberta indicated that the rate of GM in Alberta was 0.6% of wells (Watson & Bachu, 2009). Alberta has designated a mandatory test area for GM due to the elevated risk of GM occurrence (Figure 2).

Figure 2: Alberta Gas Migration Mandatory Test Area



In the test area, the rate of GM is reported as 5.7% of wells (Watson & Bachu, 2009). Studies of GM in the test area have determined that the source of gas migration is gas contained in unconsolidated sands and non-competent shale horizons of the Colorado Group shales. In this region, the Colorado Group shales typically occur at a depth of 100 to 400 m.

2.0 Scope

The GM investigation project was initiated in May 2013 in order to better understand the frequency and causes of GM. The investigation included the following:

1. File review and field inspections to validate existing GM reports and to assess the frequency of GM.

2. Well file review and gas isotope analysis of GM wells in order to determine the gas source.
3. Review of operational practices for GM wells to identify any operational practices that increase the risk of GM.
4. Review of geological information associated with GM wells to determine what influence geology may have on the occurrence of GM.

The above activities were intended to provide an initial understanding of the frequency and causes of GM. It was envisioned that additional study may be undertaken at a future date to determine what effect GM may be having on shallow groundwater zones.

At the time of project inception, almost all GM reports were in the North Zone (north of the Sikanni Chief River and north of the boundary between NTS mapsheets 094H and 094I), therefore, field investigations conducted during the project focused on that area.

3.0 Methods

During the summer of 2013, field inspections of the 84 reported GM wells, 95 audit wells and 213 planned inspection wells were undertaken. Audit wells were randomly selected Jean Marie wells due to the concentration of reported GM in wells targeting the Jean Marie formation. Planned inspection wells were wells that were inspected as part of the OGC inspection program. Where possible, wells were accessed by road, however a large number of wells were only accessible by air. Total costs for helicopter rental during the project were approximately $60 000.

Wells were screened for evidence of gas migration by visible methods, including observing the well cellar and areas of standing water on the lease for signs of bubbling, the use of an Altair 5x portable methane detector and by looking for evidence of vegetation stress.

Soil vapour monitoring was not conducted as the soils on many leases were saturated making soil vapour monitoring ineffective and due to time / budget constraints and ground disturbance considerations.

4.0 Findings

4.1 Review of initial reports of gas migration.

At the outset of the GM project, the Commission had reports of 84 instances of gas migration. The 84 reports can be summarized as follows:

- False positive due to data entry error: 2
- Repaired: 2
- Active: 29
- False positive, no evidence of gas migration during subsequent inspections: 51

All of the false positives were submitted by a single operator and in many cases, subsequent reports had been submitted indicating that there was no evidence of gas migration. All of these sites were re-inspected by Commission inspectors and no evidence of GM was found. Neither the Commission nor the operator was able to determine why the false positives were reported.

During the course of the project, an additional 5 cases of gas migration were identified through operator reports and field inspections outside the scope of the project. The subsequent reports are as follows:

- Repaired: 2
- Active: 3

4.2 Results of field inspections.

Field inspections were divided into two categories – audit wells and planned inspections. Audit wells focused on Jean Marie wells as they had the highest reported frequency of GM at the time of project inception. Planned inspections are other wells in the Fort Nelson area that were inspected as part of the Commission field inspection program. A total of 95 audit and 213 planned inspection wells were inspected. 11 new instances of gas migration were identified consisting of 8 Jean Marie wells (4.5% of wells inspected) and 3 (2.3% of wells inspected) wells targeting other formations. Field inspection data is contained in Tables A.2 and A.3, attached.

As instances of gas migration were detected visually by observing bubbling in standing water around the wellhead (there were no instances of GM detected by gas monitoring or observing dead vegetation), the actual frequency of GM may be higher than observed. Depending on location (upland vs. muskeg areas), 15 – 50% of well cellars in the north zone may contain standing water. As Jean Marie wells tend to be located in lowland areas, the increased frequency of GM may result from detection ability. Figure 3, below, shows the locations of wells that were inspected for GM and the locations of wells with reported GM.

Based on a total inventory of approximately 1 700 Jean Marie wells and 7 500 other wells in the north zone, there may be as many as 235 instances of visible GM and about 900[1] total instances of GM in the north zone of BC. The confidence level around this estimate is very low and additional field sampling using more sophisticated methods to detect GM is required.

[1] Calculated by as follows: # Jean Marie wells x % with visible GM / 40% with water-filled cellars + # of other wells x % with visible GM / 25% with water-filled cellars

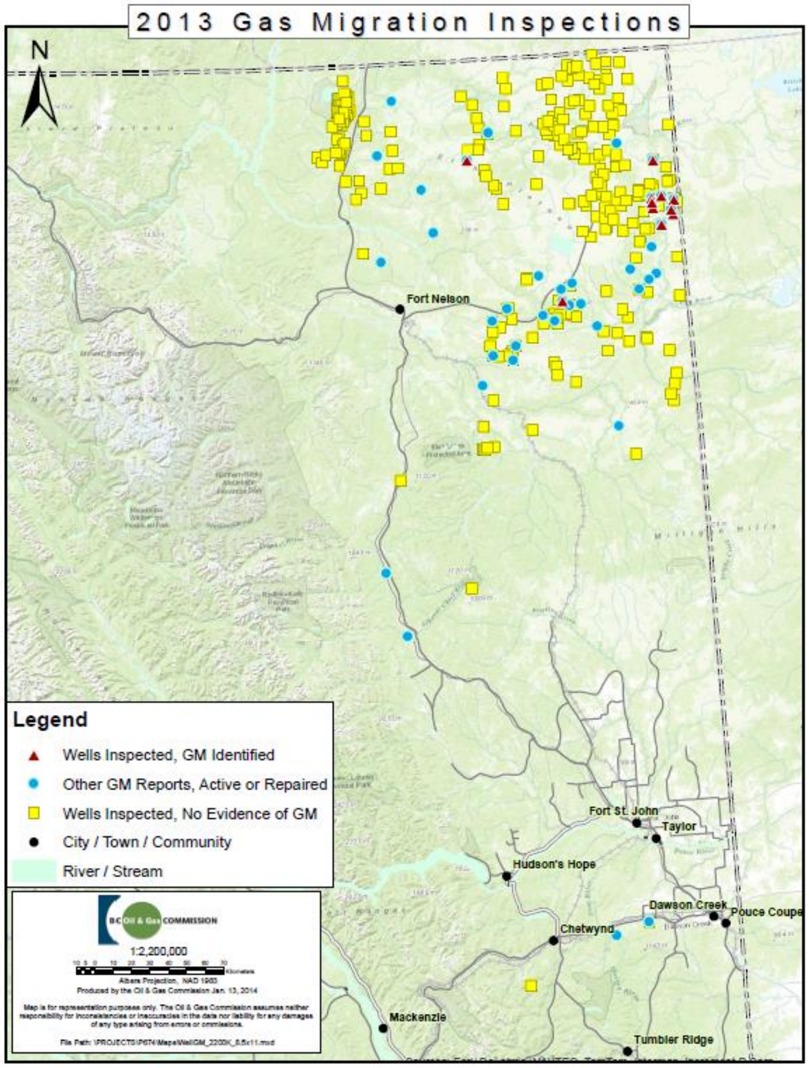


Figure 3: Wells inspected and locations of wells with GM.

4.3 Result of gas isotope analysis.

During the project, results of gas isotope analysis were received for 19 wells with gas migration. In most cases, the gas was identified as being thermogenic[2] in origin and bioaltered. Only one of the 19 samples was clearly biogenic in origin.

Determination of the source depth for gas migration samples was found to be problematic. While all of the samples came from the same general area and had similar results, samples analyzed by Maxxam were consistently identified as Jean Marie gas coming from a depth of about 1 000 m and samples analyzed by the U of A were consistently identified as coming from a depth of about 600 m. Table 1 shows the differences in depth interpretation for well pairs with nearly identical isotope data.

[2] Thermogenic gas is formed at depth through the transformation of buried organic matter by heat and pressure over a long period of time. Biogenic gas is formed at shallow depth through the breakdown of organic matter by methanogenic bacteria. Swamp gas and landfill gas are examples of biogenic gas.

Table 1: Gas migration isotope data for select Jean Marie wells showing discrepancies in depth interpretation.

Analytical Lab	**Location**	**C1**	**C2**	**Interpreted Depth of Gas Source (m)**
University of Alberta	a-69-C/94-I-12	-50.4	-32.7	650
Maxxam	d-48-F/94-I-16	-49.54	-32.17	1075
University of Alberta	d-41-K/94-I-11	-51.78	-36.07	600
Maxxam	d-12-I/94-I-15	-52.16	-36.85	1210
University of Alberta	a-a73-F/94-P-12	-47.38	-34.98	600
Maxxam	d-100-F/94-I-10	-47.77	-35.54	1150-1300

The accuracy of gas source determination from isotope analysis can be tested where other data sources such as well construction details or repair data provide useful information regarding the depth of the gas source. While examples are limited due to the small data set, three wells provide a useful illustration of the inaccuracies and uncertainties associated with the interpretation of gas source from isotope analysis.

The first well, WA 24471 is a vertical Debolt water source well, drilled to a depth of 875 m. Isotope analysis of gas from the surface casing indicated that the gas was from the Jean Marie formation, which is at a depth of 1450 m at the subject location. There were no existing migration pathways as WA 24471 was the first well on the pad.

The second example is WA 24514, a vertical shale gas exploration well in the Horn River. WA 24514 had both a surface casing vent flow and gas migration. Isotope analysis indicated the surface casing gas might have a deeper source than the GM gas. Results of repairs conducted on the well indicated that the GM gas came from a depth of 150 m and the SCV gas came from a depth of 2100 m. Isotope analysis was incapable of identifying the large vertical separation between the two gas sources.

The methodology for gas source determination through the use of isotope analysis was discussed with Maxxam (Andrey Tsyganok) and the UofA (Karlis Muehlenbachs).

Maxxam tends to rely on background data from production gas samples and do not rely on isotope data from drilling mud logs as the mud logs are less accurate and require a number of assumptions in order to interpret them. Maxxam also uses the standard gas analysis (liquids content) and relies on general trends in gas isotope variation with depth. Once Maxxam picks a source formation, gas source depth is determined based on formation tops. Maxxam stated that there is a large database of shallow gas data in central/southern Alberta, but very little if any in British Columbia.

UofA uses isotope data from mud logs as well as production samples, however, UofA stated that most mudlogs start quite deep, near the target horizon and usually sample every 50 to 100 m (sometimes as frequently as every 6 m) and mud logs are rare above the base of the surface casing except in special circumstances.

Due to the lack of shallow gas isotope data in British Columbia and the reliance on background data from production zones, there may be a bias towards interpreting gas sources from deeper zones. Additionally, gas isotope databases are proprietary, limiting the ability to verify results.

Development of a detailed, publically available database of gas isotope profiles with depth is required to improve the accuracy and consistency of the interpretation of gas isotope data. This data can be collected from a representative sample of wells during drilling.

4.4 Causes of gas migration.

4.4.1 Jean Marie Wells

Due to the higher frequency of reported GM in Jean Marie wells, a detailed review of geology and operational practices was completed. A detailed review of GM in other areas was not completed due to the lack of an adequate sample size.

4.4.1.1 Operational Practices

A detailed review of drilling, casing and cementing information for Jean Marie wells with GM did not identify any practices that correlated to the occurrence of GM. Over the time period examined, surface casing cement composition did not change, a variety of production casing cement compositions were used and the time spent waiting on cement prior to continuing with drilling generally decreased. A summary of the following wells illustrate changes in operational practices over time:

WA 14625

Drilled in March 2003. Surface casing was set at 353 m and cemented with Class G cement and 3% calcium. The casing shoe was drilled out 40 hours after cementing. Production casing was set at 1713 m and cemented from 0 – 168 m with Class G Quickseal Cement and from 168-1713 m with Class G Zoneseal cement. 7 days elapsed prior to drilling out the production casing shoe.

WA 26570

Drilled in December 2010. Surface casing was set at 280 m and cemented with Class C TSC1700 cement. The casing shoe was drilled out 16 hours after cementing. Production casing was set at 1460 m and cemented from 0-1020 m with Class C THS1200 cement and from 1020-1460 m with Class C THS1300 cement. Production casing shoe drilled out after 38 hours.

Both of the above wells had gas migration even though time waiting on cement and cement composition were significantly different. Trends in GM occurrence with time may relate to well construction practices, or could simply be a reflection of geographical area. Even within a given play, activity is not uniformly distributed and will typically be concentrated in different areas of the play from year to year. Development of the Jean Marie play began in the late 1980's with the drilling of vertical wells targeting sweet spots in the reservoir. As the sweet spots were depleted and technology advanced, well trajectory changed from vertical to horizontal with progressively longer lateral sections. From 2001, underbalanced drilling[3] was widely used in place of conventional overbalanced drilling.

For Jean Marie wells drilled from 2001 to 2013, on average 2.5% of Jean Marie wells drilled in any given year had GM. In all years except for 2010, the variation was within one standard deviation of the mean. In 2010, 7.9% of wells had GM (3 of 38); however, the result did not show any pattern with time as none of the wells drilled in 2011 had GM. 1 018 Jean Marie wells have been drilled since 2001. None of the 355 Jean Marie wells drilled prior to 2001 have reported gas migration.

Results imply that a change in operational practices in about 2001 increased the frequency of Jean Marie GM. It was at about this time that underbalanced drilling became widespread in the Jean Marie play. Horizontal drilling was used in about 42% of wells drilled prior to 2001, so there does not appear to be a link between horizontal drilling and frequency of GM.

In conventional overbalanced drilling, the pressure in the wellbore at any given depth is equivalent to the hydrostatic pressure of the drilling fluid and the pressure at surface is atmospheric. In underbalanced drilling, the hydrostatic pressure of the drilling fluid is lower, allowing formation pressure to be transmitted to the wellbore. Underbalanced drilling fluids in the Jean Marie were typically foamed nitrogen or natural gas.

There are two possibilities by which underbalanced drilling may increase the risk of GM. First, the use of a low density drilling fluid would reduce cushioning between the drill pipe and the casing. Over time, the force of the drill pipe striking the casing may damage the cement bond. Second, the well casing would be exposed to repeated pressure cycling during the drilling process as the well is opened to flow or shut in. Pressure fluctuations during the drilling process may increase the risk that the cement bond is damaged or weakened, increasing the risk of gas migration. Data is limited, but in at least one case (WA 16905), logging indicated a poor casing to cement bond.

4.4.1.2 Geology

The Jean Marie Formation is a late-staged Devonian carbonate platform with a thick, continuous linear North/South trending margin reefal buildup at its western edge (Gunnell Creek Pool) and an interior platform containing thinner shoals or patch reefs (Helmet, Sierra, Elleh, Ekwan Pools) – see Figure 4, below. A key to the successful development of the Jean Marie tight gas play has been the application of underbalanced horizontal drilling techniques due to the low porosity, low permeability and low water saturation characteristics of the formation (prone to formation damage from contact with water in conventional drilling fluids).

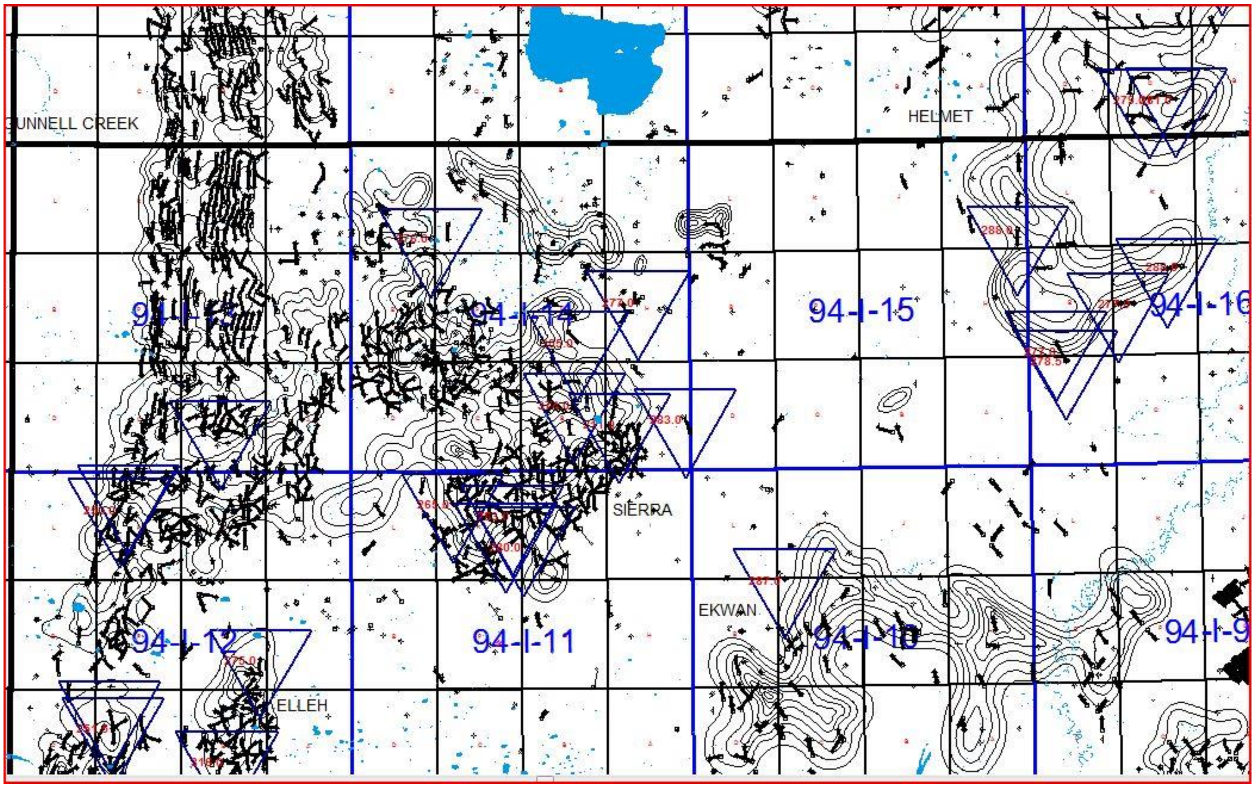
[3] During underbalanced drilling, the pressure in the wellbore is less than the formation pressure, allowing the well to flow while it is drilled. From 2001 to 2008, Jean Marie wells tended to use a nitrogen foam drilling fluid after 2008, natural gas was commonly used as the drilling fluid.

Generally, the reservoir within the Gunnell Creek area is thicker and better quality (higher porosity and perm) in comparison to Helmet, Sierra, Elleh, Ekwan etc. The long, linear trend to the Gunnell Creek Pool is due to the reservoir being developed along the westernmost edge of the platform and consists of a barrier like thick of good porosity and permeability due to increased energy levels when deposited. The areas back of this edge, within the platform itself, are generally poorer quality "localized shoaling" with reduced porosity and permeability. One exception is Sierra where Encana had been focusing their efforts until recently. It appears that the reservoir in this area has been enhanced by localized fracturing/faulting, exhibiting higher production rates.

Reported GM is much less prevalent in the Gunnell Creek field (0.2% of wells) compared to other areas of the Jean Marie play. As GM incidents within areas of the optimal reservoir quality were found to be minimal, it provides yet another reason to consider other possible sources of the migrating gas. One such possibility exists within the shallow, Cretaceous aged interval where two separate shales, possibly gas bearing, have been identified on wireline logging suites. The shallowest, deposited immediately above the Notikewan Formation, is often in close proximity to the base of the surface casing in many of the wellbores studied. Although there does not appear to be a consistent depth for SC within wells east of the Gunnell Creek pool, on average the distance between the base of SC and shallowest shale gas zone is much less. A review of several wells within the Gunnell Creek Pool was undertaken with the following observations made:

- There is a fairly consistent surface casing depth of approx. 225m to 270m within existing wellbores (may be due to single operator in this pool).
- Due to regional structure within the area, the drilling distance to the first shale is considerably greater within this area; therefore, the first shale is from approx. 330m to 450m depth, providing an average distance from SC to shale of over 140m.

Many of the other wells with GM had surface casing set closer or actually within the first radioactive shale interval which may explain the increased frequency of GM within wells outside of Gunnell Creek.



Gas Migration Wellbores

275.0 Surface Casing Depths

Figure 4: Jean Marie Formation Pools

Quaternary mapping of the 94-I mapsheet conducted by Hickin, et al[4], which includes a portion of the Jean Marie play area, demonstrated that there was a major quaternary valley system incised in the Cretaceous bedrock (Figure 5). The valley fill is complex, but includes thick sequences of unconsolidated sands and gravels. The paper notes 17 examples in the area of either artesian water or gas encountered while drilling in the surficial sedimentary cover. Bedrock topographic highs capped with glacial till may act as structural traps for naturally occurring gas migration in some cases. In the Helmet field, the Commission previously mapped two Quaternary gas fields.

[4] Hickin, et. Al. Mapping Quaternary paleovalleys and drift thickness using petrophysical logs, northeast British Columbia, Fontas map sheet, NTS 94-I, Canadian Journal of Earth Sciences, 45: 577-591 (2008).

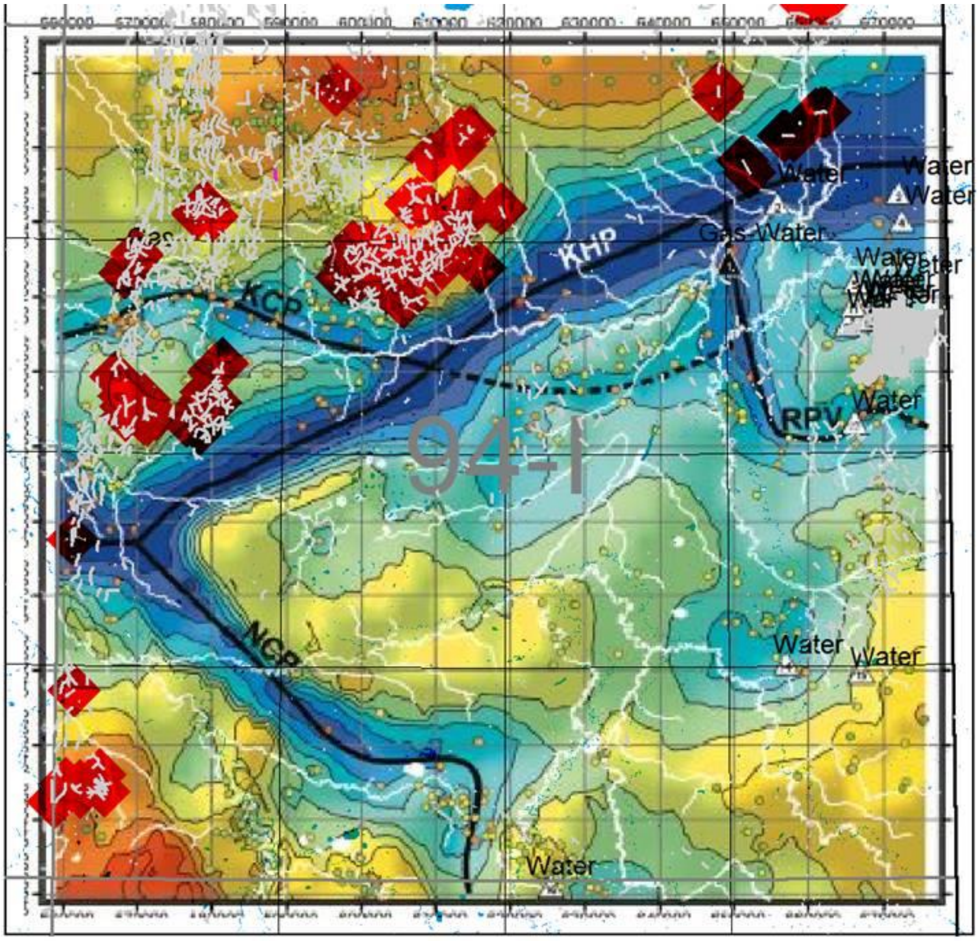


Figure 5: Quaternary Valley Mapping in Mapsheet 94-I

4.4.1.3 Conclusions

Results imply that the shallow gas at or above the surface casing shoe is prevalent in the Jean Marie play, increasing the risk of GM. In addition, there appears to be a correlation between the use of underbalanced drilling and the frequency of gas migration, but there is no correlation between horizontal drilling and gas migration or other operational practices.

4.4.2 Other Areas

Data for the 19 GM wells that do not target the Jean Marie (Other Areas) are summarized in Table 2, below. Gas migration causes are defined as follows:

1. Biogenic gas – isotope analysis indicates that the gas source is a product of bacterial fermentation. There is an increased risk of GM in the presence of a shallow gas source due to poor cement to formation bond in unconsolidated zones and a limited ability to prevent gas influxes while cementing surface casing.
2. Shallow gas – isotope analysis indicates that the gas source is thermogenic and available data indicates that the gas source is shallower than the surface casing setting depth. There is an

increased risk of GM in the presence of a shallow gas source due to poor cement to formation bond in unconsolidated zones and a limited ability to prevent gas influxes while cementing surface casing.

3. Unknown – insufficient information available to determine the cause of gas migration.
4. Well problems – evidence that well problems other than cementing such as a casing failure or blowout caused the gas migration.

For the instances of Other Areas GM where a cause was identified, 77% (10 of 13) resulted from shallow gas (see Table 2).

During cementing, there is a period of time where the cement has set and no longer exerts any hydrostatic pressure on the formation, but has not built sufficient compressive strength to prevent gas from invading and channeling through the cement matrix. There are a variety of methods to prevent gas channeling including cement additives to reduce gas permeability, the use of "right angle" fast setting cements and by holding pressure on cement at surface. A variety of trade-offs must be considered in any cementing job as optimizing to prevent one problem such as gas invasion may cause other problems such as fracturing and loss of cement to a weak formation. When cementing surface casing, pressure cannot be applied at surface as there is no outer casing string to contain the pressure at surface.

With the development of shale gas in B.C., there has been a trend to use deeper surface casing setting depths, in some cases as deep as 1000 m. The use of deep surface casing is a cost-saving measure as well control can be achieved during drilling without setting intermediate casing. In effect, the surface casing becomes the intermediate casing and a shallow, ~200 m surface casing string is eliminated. A conservative estimate to set and cement shallow surface casing is $300/m, so a 200 m casing string might be expected to cost in the order of $60 000 per well.

The setting of very deep surface casing increases the probability that shallow gas zones are more likely to be above the surface casing shoe and lengthens the cemented interval, increasing the risk that cementing will be unsuccessful and gas migration will occur. Deep surface casing setting depth may be a factor in 5 of the 10 instances of gas migration resulting from shallow gas. The gas source for the remaining 5 instances of shallow gas migration is too shallow to be prevented by reducing the surface casing setting depth.

Mandating a shallow surface casing setting depth may prevent gas migration in some instances, however, it may come result in reduced drilling safety if intermediate casing is not installed or a significant additional cost per well if intermediate casing is installed.

Table 2: Summary of Other Areas Gas Migration

WA	Well Name	Objective	Cause	Notes
25046	STORM GAS RES GOTE D- 020-D/094-P-12	Muskwa	Biogenic gas	Isotope analysis indicates gas source is biogenic.
27790	SPK HZ TATTOO A-A086-B/094-O-15	Evie	Shallow gas	Shallow gas at 47 m. Attempted repair unsuccessful.
28221	PROGRESS HZ LILY A-052-K/094-G-02	Montney	Shallow gas	Gas source at 685 m above the surface casing shoe. Repaired.
25775	IMP SNAKE RIVER C- 049-C/094-O-02	Muskwa	Shallow gas	Isotope analysis suggests gas source is 500 m, above surface casing shoe 576 m.
25927	APACHE ETSHO C- 056-E/094-O-08	Muskwa	Shallow gas	Isotope analysis suggests gas source is 500 - 600 m, above surface casing shoe 692 m.
27689	SPK HZ TATTOO A- 086-B/094-O-15	Muskwa	Shallow gas	Shallow gas at 50 m based on kick while drilling.
28229	COPOL HZ WINDFLOWER D- 069-C/094-O-10	Muskwa	Shallow gas	Glacial channel from 5 - 120 m. Isotope analysis suggest gas is from Lower Cretaceous, 494 - 618 m. In either case, gas source is above the surface casing shoe at 785 m.
27876	PENN WEST HZ HELMET d-F55-A/94-P-10	Muskwa	Shallow gas	Logs suggest source is Spirit River at 300 m depth. Gas source is above the surface casing shoe at 435 m. Note: Isotope analysis suggests gas is from Jean Marie, which is unlikely.
24514	IMP KOMIE A-009-K/094-O-01	Muskwa	Shallow gas	Repaired - poor cement. Source depth was 149 m.
7209	BLZ ENERGY YOYO D- 011-L/094-I-14	Pine Point	Shallow gas	Suspect shallow gas. Drilling encountered 10 gpm water flow at 136 m.
8466	COPOL COMETRA HZ SAHTANEH C-A036-B/094-I-13	Pine Point	Shallow gas	Repaired. Multiple shallow sources between 33 and 200 m depth.
25769	HUSKY HZ KAHNTAH D-009-J/094-I-02	Kakiska	Unknown	Unknown. Isotope analysis indicates deep source. Repair planned for winter 2013.
28485	PROGRESS HZ POCKETKNIFE C-025-D/094-G-10	Montney	Unknown	Unknown. Need to sample next summer.
28818	PROGRESS HZ POCKETKNIFE C-A025-D/094-G-10	Montney	Unknown	Unknown. Need to sample next summer.
20890	CNRL HELMET A- 048-J/094-P-08	Pine Point	Unknown	Unknown. Isotope analysis indicates thermogenic gas, possibly from the Jean Marie. Interpretation is suspect.
8923	BLZ ENERGY ROMEO B- 064-B/094-I-14	Slave Point	Unknown	Unknown. Isotope analysis indicates gas may come from 600 m. Surface casing setting depth is 374 m
17290	HUSKY EKWAN D-100-F/094-I-10	Slave Point	Unknown	Plan to repair and abandon winter 2013 - 14. No info on source.
24268	COPOL HZ BRASSEY 08-30-077-20	Montney	Well problem	Blowout. Repair in progress fall 2013.
25792	SHELL HZ GROUNDBIRCH A04-18-078-18	Montney	Well problem	Casing leak at 2200 m. Repaired.

5.0 Regulatory Issues

Under the *Oil and Gas Activities Act* (OGAA), natural gas escaping or leaking from a well is defined as spillage. Section 37 of OGAA requires a permit holder to promptly remedy the cause of spillage. GM meets the definition of spillage under OGAA.

Prior to August 2012, the Drilling and Production Regulation (DPR) required permit holders to investigate and report gas migration. In August 2012, the DPR was amended so that a permit holder is required to promptly eliminate gas migration. The intent of the August 2012 DPR amendment was to improve the reporting of surface casing vent flows. At that time, there was no intent to require the immediate repair of GM and industry was not consulted on the change.

Commission policy is for permit holders to report gas migration and to evaluate each occurrence for risk to safety and the environment. If no risk is identified, the permit holder is allowed to defer repair until the time of well abandonment. Deferral of repair until the time of well abandonment maximizes recovery of the resource as repair work may damage the integrity of the well, making it unusable. Additionally, repair at the time of abandonment results in significant cost savings as equipment mobilization/site access costs are reduced and the well does not need to be restored to a productive state (cement plugs drilled out and tubing reinstalled). As most cases of GM have been in remote areas, far from domestic water wells, most GM risk assessments have been cursory. The Commission does not have access to good research related to the effect of GM on aquifers in order to inform decision making.

At the present time, Commission policy is not aligned with regulation. Changes to regulation and/or policy are required so that they are aligned and adequately manage the risks associated with GM.

6.0 Conclusions and Recommendations

At the present time, there are 47 confirmed instances of GM in B.C. and there may be as many as 900 instances of GM in the north zone. Major risk factors associated with the occurrence of GM are as follows:

1. Geology – the presence of gas deposits at or above the surface casing shoe appears to be a major risk factor in the occurrence of gas migration.

2. Underbalanced drilling – the use of underbalanced drilling appears to increase the frequency of gas migration.

There is still significant uncertainty regarding the frequency at which GM occurs. The only reliable method of GM detection at the present time is by observation of bubbling in standing water around the wellhead. Observing for evidence of vegetation damage or the use of a portable gas detector was ineffective. Soil vapour surveys may also be used, in unsaturated soil conditions. The Commission should consider conducting additional GM monitoring in the summer of 2014 with an improved detection methodology. The project should be expanded to consider a representative sample of wells outside of the north zone.

While gas isotope analysis is effective at distinguishing between biogenic and thermogenic gas sources, there is reason to believe that the depth interpretation for thermogenic gas sources is inaccurate due to a lack of background data to compare to. An accurate database of gas isotope profiles would be valuable for the management of surface casing vent flows, gas migration and for conducting groundwater investigations. Detailed profiles of gas isotope values with depth can be collected by sampling the drilling fluid while drilling a well. The Commission should consider implementing regulatory provisions for the mandatory collection and submission of this information from a representative number of wells.

The Commission does not have any information on the effect that GM may have on groundwater aquifers. As groundwater contamination is the primary concern related to GM, this information is critical in order to adequately manage GM. The Commission should promote additional research in this area.

There are inconsistencies between the Commission's regulations and current policy with respect to GM. In particular, the provisions respecting "spillage" under *OGAA* imply that GM must be repaired immediately. In most cases, current practice is to defer GM repair until the time of well abandonment. The Commission should ensure that policy and regulation are aligned.

At the present time, there is no timeline to abandon an inactive well, allowing wells with GM or surface casing vent flows to be suspended indefinitely. The Commission should consider prioritizing the abandonment of wells with GM or surface casing vent flows.

The Commission should continue to support research and the development of industry standards related to cementing practices and well integrity. The Commission is currently supporting cementing research by UBC , participating in the development of an Industry Recommended Practice for cementing and a CSA standard for well construction.