

Dec. 4, 2017

Via Email: bjones@canadaenergypartners.com
Attention: Benjamin M. Jones, CEO
Canada Energy Partners Inc.
343 Third St., Suite 412
Baton Rouge, La. 70801

Dear Sir:

Re: Consideration of cancellation of well permit for WA#22031 (the Well Permit) pursuant to section 26 of the *Oil and Gas Activities Act*

I write regarding the BC Oil and Gas Commission's (Commission) consideration of whether the above noted Well Permit held by Canada Energy Partners Inc. (CEP) should be cancelled pursuant to section 26 of the *Oil and Gas Activities Act* (OGAA or the Act). WA#22031 (the Well) is a disposal well operated by CEP to inject waste water from oil and gas operations into a deep underground formation (called the Baldonnel formation).

I initiated this consideration on June 16, 2017 in relation to concerns that an induced seismic event from CEP's operations at the Well could generate peak ground accelerations sufficient to negatively impact the Peace Canyon Dam (PCD or the dam) that is owned and operated by BC Hydro. The dam is located approximately 3.3km away from the Well. As the Commissioner's delegate, I am authorized to make determinations under section 26(1) of the Act.

I have undertaken a careful review of this matter, including consideration of submissions made by CEP and by BC Hydro through the opportunity to be heard offered pursuant to section 26(6) of the OGAA. I appreciate this review has taken considerable time and effort and I am grateful for the input that has been provided. For the reasons outlined below, I have decided not to cancel the Well Permit.

Background

CEP is the current operator of the Well. CEP holds subsurface rights associated with the Well issued by the Province. CEP's disposal operation is also governed by the terms of a special project order (Order 08-02-008, as amended) that was originally issued by the Commission in 2008. CEP did not own the Well at the time the Well Permit and special project order were originally issued.

The Well was used for disposal of waste water (called produced water) into the Baldonnel formation from 2008 to 2010. At that time, the source of water for disposal was a byproduct of coal bed methane. Disposal rates ranged from 100 to 260m³/d. Disposal well depth was 1,514m. (Disposal wells in B.C. range from about 600m to approximately 2,000m in depth.) No induced seismic events were recorded on the Canadian National Seismograph Network (CNSN) during this period of disposal operations. I am aware the CNSN was not sufficient to record seismic events below local Magnitude 3.0 during this time frame.

In 2009 BC Hydro contacted the Commission to request information about the potential that oil and gas activities (including local well fracturing) in the area of the Peace Canyon Dam might impact BC Hydro's infrastructure. To assist in its response to BC Hydro's request for information, the Commission employed a consultant (Ryan) to produce a report, which identified little risk due to the ongoing hydraulic fracturing but recommended additional monitoring of disposal activities. The Commission shared the report prepared by Ryan with BC Hydro in 2010.

In March 2010, the Commission amended the Special Project Order to specify a maximum well injection pressure limit of 6,500 kPa, which was based on a formation fracture pressure of 22,000 kPa, below the estimated fracture pressure of 28,500 kPa.

The operator of the Well ceased disposal in April 2010. The Well was subsequently transferred to a new operator. On Mar. 3, 2014, the Commission further amended the Special Project Order. The Well was again transferred, this time to CEP. In 2016, CEP completed testing requirements and on Jan. 10, 2017 re-commenced disposal operations at the Well.

The CNSN was upgraded during the time when the CEP well was suspended. It is now sufficiently configured to record seismic events down to local Magnitude 2.0 in the Peace Canyon Dam area. No seismic events have been recorded on the CNSN network within 5 km of the CEP well since operations were recommenced in January 2017. The Baldonnel formation reservoir quality at this location is considered favourable for disposal purposes.

Faulting is known in the area of the CEP Well and the Peace Canyon Dam. The Well and the dam are located at the intersection of the structurally complicated disturbed belt and the Fort St. John graben complex (a subsurface structural feature). Not all faults are susceptible to failure, but there is insufficient information about the faults to conclusively evaluate the failure susceptibility of specific faults in the area of the dam.

Hydraulic fracturing and disposal activities have both been known to trigger movement of pre-existing faults resulting in induced events. Both types of activities have the potential to alter the existing stress field, increasing the risk of movement on susceptible faults in the vicinity. The nature of any impact in terms

of size and magnitude will depend on how the activity is designed and carried out (based, for example, on the volumes, rates and pressures used). There are some differences between impacts from fracturing and from disposal. In particular, one study, Atkinson, 2017¹, observes that for events triggered by fluid disposal, the maximum magnitude may be limited by the cumulative volume of fluid injected in the area. In these disposal situations, fluid is pumped in at low pressures and then dissipates in the formation. Where a pressure increase is observed, action may be taken. Dr. Atkinson also observes that “the hypothesis that magnitude is limited by the injected volume does not appear to hold for earthquakes triggered by hydraulic fracturing in Western Canada.” This is because during hydraulic fracturing, large amounts of fluid are pumped in short time frame at high pressures to fracture the formation.

Induced seismic events have been observed in association with high volume water disposal, including Baldonnel water disposal in the Altares area to the north of CEP’s Well. Increased cumulative volumes of disposal can increase the risk of seismic events where faults exist. However, the CEP disposal well is considered to exist in a separate Baldonnel structure. The reservoir quality is much better at the CEP well.

The Commission studies and monitors induced seismicity from oil and gas activities. The Commission initiated two studies into induced seismicity, which resulted in the publication of two reports that were subject to peer review prior to publication. It is a member of the B.C. Seismic Research Consortium, made up of federal and provincial government agencies, industry representatives and academic institutions. The Commission has also worked closely with the University of British Columbia in the study of causes and mitigation of induced seismic events.

It is the Commission’s role to provide in-depth regulatory oversight of disposal wells to ensure safe operation. As the body of information about induced seismicity has grown, the Commission has implemented regulatory updates, imposed additional operating and monitoring requirements in project approvals, and created conditions for the further collection and analysis of data.

Monitoring indicates most occurrences of induced seismicity in B.C. occur at depths greater than 1.5 kilometres below the surface and are of a low magnitude. Most events are not felt at surface. Felt events are usually of a short duration, and in all reported cases less than a few seconds long. The intensity of felt events has been measured as moderate and the associated vibrations are not expected to be great enough to cause damage. There have been no reports of injury or major structural damage related to induced seismic events in northeast B.C. However, there is no validated predictive model available that can predict the ground motions associated with all events.

¹ Atkinson GM 2017 *Strategies to prevent damage to critical infrastructure due to induced seismicity*, FACETS 2:374-394.

In March 2017, the Commission received new information from BC Hydro indicating the Peace Canyon Dam was particularly susceptible to low level ground motion. BC Hydro communicated that “due to foundational problems that were discovered during construction”, the Peace Canyon Dam may be more susceptible than other infrastructure built in or around the same time period, and that BC Hydro had been using “0.07g as its seismic withstand against damage/excessive leakage/gate problems etc.”

Based on this new information from BC Hydro regarding the particular susceptibility of the Peace Canyon Dam to low level seismicity, Lance Ollenberger, the Commission’s Vice-President, Compliance Operations and an official designated under the OGAA, determined it was necessary to suspend CEP’s operations at the Well pending the consideration of technical information. The Commission officer issued General Order 2017-008 requiring operations at the Well to be immediately suspended. The order was issued on the basis that the suspension was necessary to mitigate a risk to public safety or protect the environment while the Commission gathered and considered more information about the issue.

CEP suspended its operations in compliance with General Order 2017-008. CEP also appealed the Order to the Oil and Gas Appeal Tribunal. After conducting a hearing by way of written submission, the Tribunal dismissed the appeal. As of today’s date, General Order 2017-008 remains in place.

After receiving the information from BC Hydro in March 2017, the Commission initiated a review of Information about CEP’s operations at the Well and the potential for those operations to negatively impact the Peace Canyon Dam. As part of that work, the Commission received information from Commission staff, CEP and BC Hydro, including a technical meeting held in the Commission’s offices on Apr. 10, 2017. The Commission also received a report from an engineering consulting firm with particular expertise in civil engineering, Advisian. Information gathered through the review was shared with CEP and BC Hydro at the technical review meeting on Apr. 10, 2017 and by email on June 16, 2017.

Section 26 of OGAA

By my letter to CEP dated June 16, 2017, I initiated a consideration of whether CEP’s Well Permit should be cancelled pursuant to section 26 of the OGAA. In doing so, I communicated that while the information before the Commission demonstrated the potential for complete failure of the Peace Canyon Dam was extremely low, the damage potential from induced seismicity was more difficult to assess. I also communicated there were outstanding concerns an induced seismic event could generate peak ground accelerations sufficient to impact the Peace Canyon Dam.

Before making any decision under section 26 the Commission is required to provide a permit holder with an opportunity to be heard. I determined the

opportunity to be heard in this matter may be conducted by way of written submissions. I advised CEP that I would also consider the submissions and information previously provided to the Commission.

CEP made a submission to the Commission under the opportunity to be heard provisions. In that submission, CEP communicated, in part, that its operations are consistent with the Commission's mandate and regulatory regime and were unlikely to have a public safety impact on the Peace Canyon Dam. CEP also communicated that even if an event occurred that impacted the Peace Canyon Dam, the environmental impacts would be "transitory" (quoting from a summary from Commission staff) and, essentially, would be equivalent to BC Hydro's planned future work on the dam.

On June 26, 2017, BC Hydro made a brief submission in the opportunity to be heard provisions. In that submission BC Hydro requested that I consider BC Hydro's submissions and other materials provided to the Commission and set out its view regarding the scope and application of section 26 of the OGAA. I agree with BC Hydro's submission that all materials should be considered. I comment briefly on the Commission's power under section 26 below. I provided BC Hydro's letter to CEP and advised CEP that it could make a submission in reply. On June 28, 2017, CEP provided a reply submission.

I have reviewed and considered all of the submissions and information provided to the Commission. I will comment on only some of those submissions and information in this letter.

CEP has communicated it "does not believe that the OGC can site section 49(1)(b) in the Suspension Order and then claim the Well Permit cancellation was under another provision of OGAA." General Order 2017-008 was made by the Commission official very shortly after the Commission received new information from BC Hydro that the seismic withstand of the Peace Canyon Dam could be exceeded by ground motions at levels that have been previously recorded in association with induced seismicity in other areas of northeast B.C. Little information was available to assess this information, evaluate the likely outcome of any exceedance. Further, additional time would be required to gather and assess available data and information to consider potential impacts relating to CEP's operations. In making the order, the official communicated his view that it was necessary to immediately suspend operations at the Well pending a review of additional technical information. Section 49 allows the Commission to require immediate actions to be taken to address non-compliances or where such action is necessary to address a risk to public safety, protect the environment or to ensure conservation of the resource.

Where the Commission contemplates more permanent action – such as the suspension or cancellation of a permit – it may act under section 26 of OGAA. The actions taken by the Commission under section 49 and the action that I have considered under section 26 are not incompatible. Section 26 is the only

statutory provision in the OGAA that allows a permit to be amended, suspended or cancelled at the Commission's initiative (rather than through an application made by a permit holder through, for example section 31 or 33 of OGAA). Section 26 actions are not limited to the circumstances set out in section 49(1)(a) and (b). A broader range of circumstances may be considered to ensure oil and gas activities are regulated in a manner consistent with the purposes of the Commission identified in section 4 of the OGAA. For clarity, the Commission's authority to act under section 26 is not limited to the circumstances set out in 26(2). As communicated in BC Hydro's submission, section 26(2) specifies "without limiting the authority of the Commission", the Commission may take action under section 26 in specific circumstances. None of the circumstances listed in section 26(2) were relevant to my consideration as to whether CEP's Well Permit should be cancelled at this time.

Consideration

As outlined above, the Peace Canyon Dam lies at the intersection of two major structural terrains in northeast British Columbia; the foothills disturbed belt and the Fort St. John graben complex. The CEP well depth is within the foothills disturbed belt thrust faulting, not the graben structure.

A subset of the thrust faults within the foothill settings may generate induced events from disposal activity, if they are oriented in a direction favorable to retaining tectonic strain, as observed in similar structural settings in northeast B.C. There is insufficient well control and seismic information in the area to adequately characterize the geo-mechanical properties of the area. As with other areas of northeast B.C., existing faults cannot always be mapped and known, even after available seismic data is collected and analyzed.

Based on my review, I find the likelihood of a damaging event resulting from water disposal operations is very low. While I have reached this conclusion, I acknowledge there is uncertainty regarding the ability to predict an induced seismic event. Such uncertainty is inherent where there is no reliable predictive model.

In that context, Dr. Atkinson's 2017 paper, covers extensive induced seismic history in a range of circumstances and identifies both avoidance and mitigation strategies to reduce hazards. In doing so, she emphasizes that in each case, a combination of factors will determine risks. For example, the likelihood of damaging motions will depend on a number of different factors, including event initiation, characteristics of event sequences, ground motion characteristics, and the response characteristics of the structure. In turn, the damage potential of motion will depend on amplitude, frequency content, and duration. Dr. Atkinson's work suggests that site specific information is likely the best source of information for decision making.

In considering data regarding seismic events, it is important to understand the conditions under which seismicity was induced. For example, comparisons of

disposal operations in B.C. to those in Oklahoma USA (which have been associated with a magnitude 5.7 seismic event that has been noted by both CEP and BC Hydro), are not practical. Northeast B.C. and Oklahoma are associated with very different geological settings and fault characteristics. Potentially even more important is the fact that disposal operations are monitored and regulated very differently in each jurisdiction. At the time of the Oklahoma event, that jurisdiction did not monitor ground motion or seismic activity, did not monitor disposal pressures, did not monitor reservoir pressures, and did not take action after smaller pre-cursor events were measured. In contrast, disposal in British Columbia is highly regulated and monitored.

For example, in British Columbia reservoir pressure testing is required annually for disposal wells. This test is not required in many other jurisdictions. Reservoir pressure will build up at the disposal well and will dissipate with distance from the well into the point in time when all available pore space is occupied. This is when the pressure is considered to have contacted a boundary in the reservoir and the pressure will build throughout the reservoir. Testing has proven to be an effective way to monitor the build-up of formation pressure, which is a key cause of induced seismicity.

While complete geo-mechanical data is not available, due to monitoring activity, data regarding volumes, pressures, ground motion detection specific to the CEP Well (and to other northeast B.C. operations) is available and continues to be gathered, analyzed and acted upon. I am of the view that additional operating conditions and monitoring and response requirements are available that would further mitigate against the likelihood that induced seismic activity would occur or would have the potential to impact the Peace Canyon Dam. Many of these mitigations are not expressly considered in Dr. Atkinson's paper, and indeed many involve reservoir engineering. Dr. Atkinson does indicate hazard reduction strategies, including mitigation measures, will change as knowledge of the processes that control hazards associated with induced seismicity improve.

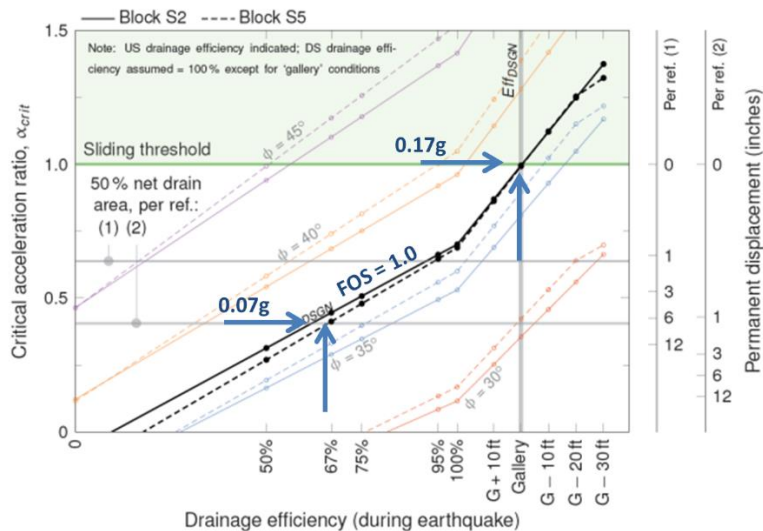
In British Columbia, 100 per cent of disposal induced events have exhibited smaller precursor events prior to any Magnitude 3+ event and have not demonstrated repeated events in a short (less than six hour) time span. Considering the CEP Well, I find additional monitoring of disposal activities and other operating requirements would mitigate risks associated with a series of events that could reduce the Peace Canyon dam's ability to withstand further seismic events.

The evidence indicates the most severe potential consequences (such as a complete failure of the dam) from an induced seismic event are extremely unlikely. BC Hydro has indicated that when the dam was built, the design was for a factor of safety of 1.5, but the dam's seismic withstand is extra sensitive to the effective operation of its drainage systems and other factors. I accept the information from BC Hydro's documents and representatives indicating the Peace Canyon Dam is susceptible to relatively low peak ground accelerations

(0.07 -0.2g). While ground motions of that intensity could be generated by induced seismic events, the low end peak ground accelerations are only of concern when the dam is operating with water levels above the gallery level, which is not the current standard operating practice.

I find while impacts to the dam infrastructure, operations, the environment, surrounding area and the public are possible, they are greatly reduced due to the safety factors BC Hydro employs in the daily operation of the Peace Canyon Dam, along with redundancies to prevent any reduction in safety factors. In particular, the dam’s drainage system includes galleries and pumps that work to maintain water levels in the structure. These systems provide high drainage efficiency, and allow BC Hydro to achieve “acceptable” levels of stability. BC Hydro has indicated “[u]nder current conditions of uplift, we likely have a seismic withstand sliding threshold of about 0.2g, however this could be significantly reduced through a temporary loss of the pumping wells. With a loss of about half of the existing drainage efficiency due to any cause, the seismic withstand for the sliding threshold reduces to about 0.07g. This is likely somewhat conservative, due to assumptions of limited support being provided by the rock mass downstream of the dam.”

BC Hydro provided this helpful representation of drainage efficiency of the dam:



While not impossible, it is unlikely that PCD’s two pumps and a dedicated back up pump, being designed specifically to mitigate structural shortcomings, would lose pumping capability at the same time. Nevertheless, the risk associated with such an event could be mitigated, in part, by a requirement that activities at the Well be suspended in the event the PCD’s factor of safety falls below 1.5. Such a step would create an added measure of safety during times when the dam may be more vulnerable to impacts from ground motion.

I accept BC Hydro's submissions that in the event of damage to the dam, impacts could include increased seepage which in turn could require a drawdown of the Dinosaur lake reservoir to assess damage, with resulting impacts for some time, including impacts to electrical generation, water turbidity, risk of erosion, and fish mortality due to increase water discharge rates. As the Peace Canyon Dam has been an important part of B.C.'s hydroelectric power infrastructure for decades, I consider it to be in the public interest to avoid potential damage to this infrastructure and associated possible impacts to the environment.

I accept Advisian's finding that they did not identify any compelling reason for induced seismicity to result in significant damage to or an outright failure of the Peace Canyon Dam. However I acknowledge this conclusion was qualified by the scope of Advisian's review.

Atkinson, 2017, states that:

Numerous authors have noted that, in general, PGA tends to be well correlated with felt effects (and lower MMI levels), whereas peak ground velocity (PGV) tends to be well correlated with damage (and higher MMI levels) (e.g., Worden et al. 2012).

Atkinson, 2017 also states that:

There is no single definitive measure of what makes ground-motion damaging. In general, the damage potential of ground motion depends on a combination of factors including amplitude, frequency content, and duration. Small-to-moderate events tend to be of short duration and are rich in high frequency content (at close distances), whereas larger events are longer in duration and have significant energy at longer periods.

While, the Commission has measured ground motions that exceed 5%g and 10%g, which may be considered at or approaching the damage threshold, solely using PGA (%g) is not a conclusive measure. In two cases in British Columbia where we have measured ground motions, the event that had an 11.4%g (PGA) had a corresponding PGV of 0.73cm/s PGV, and the 5.4%g measured event had a PGV of 0.89 cm/s. Atkinson considered many sources and concluded:

Considering this range of estimates, a value of PGV = 10 cm/s was adopted as the damage threshold for induced earthquakes.

Given this determination, it has been demonstrated that solely relying on PGA is not a sufficient indicator of potential damage and PGV must be taken into account. When this is done, it shows the PGVs that have so far been measured in B.C. are well below the damage threshold outlined by Atkinson and the paper further qualifies that PGV is a better indicator of damage. Atkinson, 2017 does not consider duration in detail, but the duration for measured ground motions that the Commission has collected demonstrates if a ground motion exceeds 1, 5 or

10%g, it does so for a fraction of a second. The result of this very brief acceleration is that the ground motions do not have sufficient time, or duration, to reach a damaging velocity.

Finally, I find increased monitoring would mitigate the risk of induced seismicity from disposal operations. The possibility that a large magnitude (greater than local Magnitude 4.0) event could occur without smaller precursor events under the proposed monitoring regime is extremely unlikely. Such an event, sufficient to impact important infrastructure and trigger significant impacts to BC Hydro's operations, has not been observed either in the Altares Baldonnell disposal well (analog) or in other portions of the disturbed belt with seismicity related to disposal. The immediate curtailment of disposal might not prevent additional, possibly damaging events from occurring, however, Appendix A outlines potential operating conditions designed to effectively mitigate over-pressured reservoir occurrences and enhance the ability of the reservoir to dissipate reservoir pressures due to disposal volumes well in advance of any such incident.

Conclusion

Based on the above, I have decided not to cancel the Well permit. That decision is based on my view that with certain identified operating restrictions in place, the disposal activities at this particular location and to this formation location can proceed safely and without impact to the Peace Canyon dam.

I find allowing the activity to continue under strict circumstances is consistent with the Commission's purpose to regulate oil and gas activities for the benefit of British Columbians, having regard to fostering a healthy environment, a sound economy and social well-being. I note not all of the operating restrictions I have identified in this decision and Appendix A are currently in place at the Well. General Order 2017-008 remains in place until it is terminated by the Commission.

I have asked Richard Slocumb, the Commission's Vice President, Reservoir, Field Engineering & Technical Services to contact you to discuss CEP's special project order and the operating and monitoring requirements identified in Appendix A.

I recognize this decision will have some impacts on CEP's business due to the operating conditions outlined in Appendix A, however these conditions are consistent with operating conditions imposed on disposal wells in B.C. I want to recognize my appreciation for CEP and BC Hydro's participation in the process to evaluate these issues and for the work done to effectively communicate each party's perspective.

This decision is a "determination" as that term is defined in section 69 of the OGAA and so pursuant to Part 6 of the OGAA, CEP has an opportunity to

request a review of the decision to a Commission review official or initiate an appeal of the decision to the Oil and Gas Appeal Tribunal.

Yours Sincerely,

A handwritten signature in black ink, appearing to be 'M. Kennedy', written in a cursive style.

Mayka Kennedy, P.Eng.
Executive Vice President, Chief Engineer
Oil and Gas Commission
mayka.kennedy@bcogc.ca

cc: Attention: Shawn M. Munro
Bennett Jones
munros@bennettjones.com

[Attention: Jeff Christian](#)
[Lawson Lundell](#)
jchristian@lawsonlundell.com

Appendix A

Conditions for operation of CEP Well (WA#22031):

- a) Inject produced water, including well flowback completion fluids, only into the well CE Portage a-20-D/094-A-04 (Well Permit # 22031), Baldonnel formation (1520.0 mKB to 1574.5 mKB).
- b) Not exceed an injection pressure, measured at the wellhead on the subject well, of 6,200 kPag or the pressure required to fracture the formation, whichever is lesser.
- c) Not exceed an injection rate of 200 m³/d.
- d) Inject only through tubing.
- e) Continually measure and record the wellhead casing and tubing pressures.
- f) Cease injection and notify the Commission immediately if hydraulic isolation is lost in the wellbore or formation.
- g) Submit the annual packer isolation test report to the Commission within 30 days of the completion of the test.
- h) Include the disposal operating hours and the maximum injection pressure values on the monthly disposal statement.
- i) Cease injection upon reaching a maximum formation pressure of 18,000 kPaa, measured at mid point perms (1547.3 mKB).
- j) Conduct a reservoir pressure test on the Baldonnel formation in the subject well within 6 months of recommencement of disposal and then each 6 months thereafter, with a shut-in period of sufficient length to provide data for calculation of the reservoir pressure, and submit a report of the test within 60 days of the end of the test.
- k) Perform a casing inspection log on the subject well and submit results to the Commission within 30 days of the completion of logging, at an interval of not more than every 10 years, commencing from the original date of initial disposal.
- l) Perform a hydraulic isolation log on the subject well within 60 days of the date of recommencement of produced water disposal and submit results to the Commission within 30 days of the completion of logging, and thereafter at an interval of not more than every 5 years, commencing from the date of recommencement of disposal.
- m) Not conduct hydraulic fracture stimulation on any formation in the subject well without prior Commission approval.

- n) Before recommencing disposal operations, install and fully activate a monitoring program to observe and record seismic events within a 5 km radius of the well; WA #22031, that:
 - i. is capable of real-time monitoring;
 - ii. has a magnitude detection of 1.5Mw and greater;
 - iii. has hypocenter accuracy to within ± 500 metres;

- o) Before recommencing disposal operations, install and fully activate an accelerometer within 1 km of the wellsite able to record three components of ground acceleration with a minimum detectability of 0.005g and a dynamic range of +/- 2g.

- p) Report the results of seismicity monitoring in items n) and o), including date, time, location, magnitude, ground acceleration and depth of seismic events, to the Oil and Gas Commission (Commission) via email to reservoir@bcogc.ca, at 1 month intervals, commencing one month from the date that monitoring begins, or upon request. The Commission may request full SEED data for any significant seismic event and will make any event equal to or exceeding local Magnitude 3.0 available in the public domain.

- q) Cease injection upon receiving notification from BC Hydro that the Peace Canyon dam factor of safety has fallen below 1.5. Injection operations may only resume upon notification from the Commission.