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Options for Disposal of Shale Gas Formation Waters

This correspondence, on behalf of Elmworth Energy Corporation/Triangle Petroleum Corporation (Elmworth), addresses the potential use of deep well injection as a means of disposing brine rich water at two drill sites near Kennetcook West Hants Nova Scotia. At this point in time, Elmworth is preparing to undertake pilot testing to determine if the technology will work. If successful, approval to proceed with disposal in this manner will be sought from the Nova Scotia Environment (NSE). The intent of this report is to provide the Department with information that will assist in obtaining such approval if required. The remaining text includes:

- Relevant background information
- Issue at hand
- Review of disposal options
- Pilot test
- Closing statements

Background

In 2007 Elmworth began an exploration program to assess the feasibility of extracting gas from shale formations in Hants County, Nova Scotia. Of specific interest to this correspondence are two drill sites referred to as KC#1 and KC#2 in the Kennetcook Area. KC#1 and KC#2 were terminated at 1358 and 1920 meters (m) below surface (respectively) within the Horton Bluff Formation. Surface and production casings of both wells were cemented back to surface; and, therefore isolated from surface and groundwater. KC#1 is perforated between 1137 and 1326 m and KC#2 perforated between 1373 and 1896 m. KC#1 and KC#2 were determined unsuccessful with regards to shale gas production.

Two (one at each location) 10,000 m^3 capacity HPDE lined ponds were constructed to store water in preparation for fracture stimulating (frac) as well as storage of water collected from the wells during testing operations. Approximately 7,000 m^3 of fresh water was used to frac each well. The return formation water exhibited an exceptionally high concentration of total dissolved solids (primarily chloride) resulting in transformation of fresh water ponds to brine ponds.

At this time, drilling and support equipment have been removed from the sites, and both wells have been secured. The holding ponds are, however, still intact. A method of disposing of the water from these ponds has not been resolved. In the mean time, the ponds are regularly monitored to ensure adequate freeboard with excess water being trucked off-site on an as-need basis. The pond water has been tested on a number of occasions (**Attachment 1**). The most recent samples (September 2009) indicated TDS and chloride concentrations of 40,000 and 25,000 mg/L (respectively) in KC#1 and 13,000 and 7,800 mg/L in KC#2.

Issue

The issue at hand is finding a viable short-term solution to dispose of the water. Elmworth does not intend to reuse the ponds for storage of brine water, nor do they intend to construct additional ponds at other sites. Continued trucking of the water is not reasonable based on both the quantity involved, and the problem of finding an end receiver within reasonable proximity to Kennetcook. There is no on-site power supply. Furthermore the sites are situated on small parcels (~110 m^2) of leased property. Following removal of the brine water, the ponds will either be reclaimed or converted to fresh water storage only.

Issues associated with disposal of brine waters generated/accumulated during deep shale/coal gas drilling are not new to NS or to the industry in general. The challenge is finding a technology that is suitable for the specific site and circumstances. Significant factors influencing the decision making process include but are not limited to:

- Geology
- Well construction details
- Surrounding environment
- Climate
- Water quality
- Short-term vs. long-term requirements

Review of Disposal Options

Elmworth/Dillon reviewed the following options (additional detail provided in **Attachment 2**) presented in various documents, including Nova Scotia Environment's (NSE's) Best Management Practices for Formation Water and Alberta's Directive 51:

- Desalinization (including ion exchange, reverse osmosis (RO) and chemical oxidation combined with RO)
- Freeze/Thaw
- Evaporation (including vacuum distillation, crystallization and use of an evaporator)
- Constructed wetlands
- Deep Well Injection

- Off-site disposal (trucking)
- Brine salt use (i.e., de-icing and/or agriculture applications)
- Ocean dumping
- Salt mine disposal

Each option was evaluated (high medium or low) for the factors presented in the following **Table 1**.

Table 1
Screening Factors

Factor	High	Medium	Low
Output water quality/residues	Meets Canadian Environmental Quality Guidelines	Suitable for agricultural use; may result in residue requiring further treatment	Suitable for agricultural use; will result in residue requiring further treatment
Proven technology	Established state of art technology	Technology with short track record	Emerging technology
Implementation practicality	Applicable to condition(s)	Requires some minor infrastructure	Requires significant infrastructure
Long-term liability	Potential low to none	Potential low to moderate	Potential moderate to high
Short term liability	Potential low to none	Potential low to moderate	Potential moderate to high
Environmental impact	Potential low to none	Potential low to moderate	Potential moderate to high
Health and Safety implications	Potential low to none	Potential low to moderate	Potential moderate to high
Timeframe	<1 year	2-4 years	>4 years
Viable as a short term solution	Viable	Possible	Not realistic
Cost – capital	Lowest	Moderate	Highest
Cost – operational	Lowest	Moderate	Highest

The evaluation (**Table 2**) reflects a balance of technical feasibility, suitable endpoint quality and costs. While some technologies may be suitable if Elmworth were actually producing shale gas, few (if any), are practical as a short-term solution during the exploration phase of a project.

As indicated in the table, desalination, evaporation and wetland construction are not considered viable as short-term solutions. With regards to potential short-term solutions (freeze-thaw deep well injection, trucking to an approved off-site facility, ocean dumping and salt mine disposal), there are also a number of uncertainties. For instance, the timing for freeze-thaw would be severely restricted. Aside from the vast number of trips required

to transport of this quantity of water, acceptance at off-site facilities is not guaranteed. Ocean disposal not only with requires transport of the material, but federal approvals. Without pilot testing, the viability of deep well injection is also not certain.

Table 2
Screening of Applicability of Potential Produced Water Disposal Methods for Elmworth Pond Water

Score (No. of highs)	Technology	Output Water Quality	Proven Technology	Implementation Practicality	Long-term Liability	Environmental Impact	H&S	Timeframe	Cost	Solution Timeframe
	Desalination									
2	Ion Exchange	M	L	L	H	M	H	M	M	L
5	Reverse Osmosis (RO)	H	H	L	H	H	H	M	M	L
3	Chemical Oxidation & RO	H	M	M	H	M	H	M	L	L
	Freeze-thaw									
2	Freeze-thaw	M	H	L	M	L	H	M	M	M
	Evaporation									
3	Vacuum Distillation	H	M	M	H	M	H	M	L	L
6	Crystalization	H	H	H	H	H	H	M	L	L
5	Evaporator	H	H	M	H	H	H	M	M	L
	Wetland Treatment									
3	Constructed Wetland	M	M	L	M	H	H	L	L-H	L
	Other Disposal									
7	Deep Well Injection	Na	H	H	L	H	H	H	H	H
4	Truck off-site	Na	H	M	H	H	M	M	M	H
2	Brine Salt Use	Na	L	L	U	U	M	H	U	H
1	Ocean Dumping	Na	L	L	U	U	M	H	U	H
1	Salt Mine Disposal	Na	L	L	U	U	M	H	U	M

*na not applicable U Unknown

Pilot Test

The pilot test is tentatively scheduled for June 2010 (pending availability of equipment). The test will initially involve injection of water for four hours per site, to establish a rate versus pressure relationship (estimated 100 m^3 per test maximum). Pressure, rate and

volume will be measured throughout the test, ensuring that the injection odours below fracture pressure.

Closing Statements

At this time, Elmworth only proposes to determine the feasibility of re-injecting the water back into the reservoir from whence it came. The results of the pilot test will be presented to NSE. If considered to be an effective means for disposing of the water in the two ponds, Elmworth will seek formal approval with additional methodology detail.

We trust that this information will be useful to the Department and help facilitate an approval to re-inject should this occur. We also, trust that this information along the results of the pilot test will be beneficial to the Department as on-shore oil and gas development moves forward in the province of Nova Scotia.

Please do not hesitate to contact the undersigned should you have any questions or require additional information. In the meantime, we will keep the Department informed of a tentative date for the test.

Yours truly,

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