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Knowledge Creation Process in an Upstream Oil and Gas Project:

A Nonakian View of a major Oil Sands Project

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Abstract

Just a couple of years ago things could not have been better for the oil industry. Per barrel oil prices were above USD100 and expensive to extract oil resources were then profitable to invest in. However, crude oil prices took a dive in mid-2014 and have been on a downward trajectory reaching record lows since 2003. This coupled with the recent commitment worldwide to a reduction in CO₂ levels in the atmosphere has taken its toll on the oil industry. More than ever, oil companies need to find more creative ways of extracting oil resources in a low oil price and low environmental carbon scenario. Knowledge has been known to be an asset that can create the competitive edge in industry and it is no exception in the oil and gas industry. Oil companies need to understand knowledge creation processes and tap into this asset to be able to find ways to weather the difficult environment in which they operate. This thesis takes a look at the SECI model and the spatial concept of ba developed by Nonaka Ikujiro and applies them to an upstream oil and gas project setting of a leading innovative oil and gas company in Alberta. I trace using the SECI model the knowledge creation process within the project through documentation spanning 12 years and then analyse the project “ba” and conclude that it is indeed possible to trace the knowledge creation process within a major oil and gas project as well as identify gaps in the knowledge creation process which I believe if solved can go a long way in creating valuable knowledge for a company.

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Ngatia, John Mugo

Glossary of Terms

BBL – Barrels

BBL/D – Barrels per Day

CL – Christina Lake

CSOR – Cumulative Steam to Oil Ratio

EPEA – Environmental Protection and Enhancement Act

ESP – Electrical Submersible Pump

FC – Foster Creek

FCCL – Foster Creek Christina Lake

FPSO – Floating Production, Storage and Offloading

GDP – Gross Domestic Product

GOR – Gas/Oil Ratio

ICT – Information Communication Technology

ISOR – Instantaneous Steam to Oil Ratio

IT – Information Technology

LTO – Low Temperature Oxygen

MARP – Measurement, Accounting, Reporting and Planning

SAGD – Steam Assisted Gravity Drainage

SOR – Steam to Oil Ratio

WHP – Wellhead Pressure

WTI – West Texas Intermediary

Table of Contents

Abstract	1
Acknowledgements	2
Glossary of Terms	3
Chapter 1: Contextual Background	5
A Snapshot of the Current Situation Global Oil Industry	5
Alberta Oil Sands Industry	6
Knowledge and the Oil and Gas Industry	9
Problem statement	9
Paper overview	10
Chapter 2: Literature Review	12
Knowledge	12
Knowledge Based View of the Firm	12
Knowledge Creation.....	13
The concept of ba	17
Chapter 3: Methodology.....	19
Theoretical Framework	19
The SECI Model.....	19
Key Assumption and Criticisms of the SECI model	21
Research Design	22
Cenovus Energy Christina Lake Oil Sands Project.....	24
Chapter 4: Research Findings	29
Presentation of Findings.....	29
SECI Element Socialisation	54
The project “Ba”.....	57
Chapter 5: Discussion of Findings and Proposal for Future Research.....	60
Discussion of findings	60
Implications for Management	63
Conclusion.....	64
Bibliography.....	68
Appendix 1 – Questionnaire sent to Cenovus Energy.....	72
Appendix 2 – List of Data Sources	76

Chapter 1: Contextual Background

A Snapshot of the Current Situation Global Oil Industry

Between 2011 and 2014, things could not have looked any brighter for the oil industry with per barrel crude oil prices at record highs of over \$100. This meant that hard to reach and expensive to extract oil reserves were then a profitable venture to invest in. US tight oil was attracting capital investments and US companies were selling their assets overseas to invest locally (EY, 2015) and in Canada, foreign direct investment in the energy industry was increasing and peaked at over \$180 billion in 2013 (Natural Resources Canada, 2014) just to mention a few cases. However, crude oil prices began to plunge from June 2014, crushing to a low of \$27 per barrel in January 2016 (CNBC, 2016). Furthermore, in December 2015, countries worldwide committed to a low carbon future and more efficient energy system in the COP21 talks in Paris (International Energy Agency, 2015). The low price scenario looking likely to continue into the foreseeable future and coupled with a low carbon future seems to be a new normal in the oil and gas industry. This situation has however not dampened crude production. According to statistics from the (TD Securities, 2015) report, 2 million barrels are being produced per day in excess of demand with the report further stating that OPEC has been producing 2 million barrels per day above its self-imposed quota. This has however created a situation where investments in the upstream oil and gas industry in the non-OPEC producer countries are not feasible as the current price levels are below project break-even prices in these countries (TD Securities, 2015). Furthermore, this has led to a fall in the number of operational rigs in non-OPEC countries with hardest hit US down 501 rigs in the last year while Canada is down 39 rigs in the last year. For the foreseeable future in this case, it seems that oil and gas companies will have to “make do with what they have at the moment” leaving the companies operating precariously, trying to maintain good performance

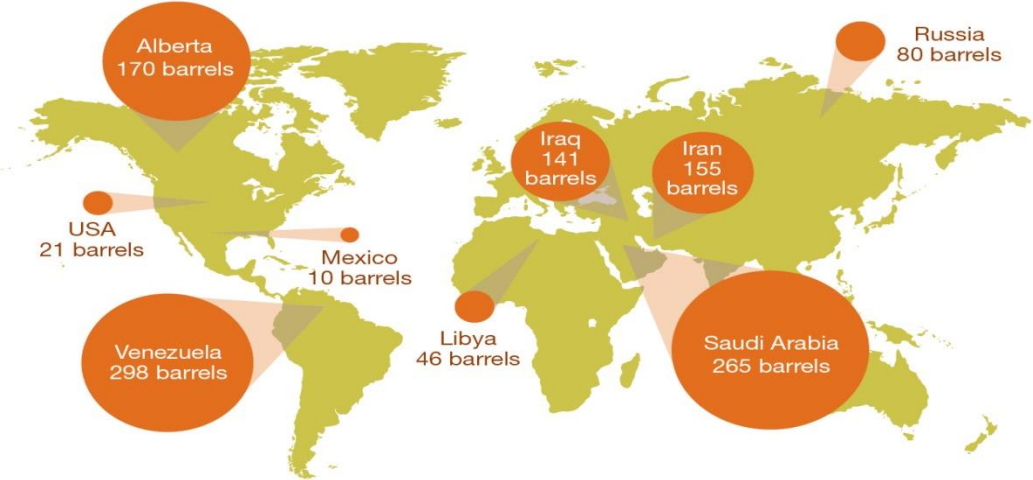
against a backdrop of low oil prices, low carbon commitment, limited capital expenditure and crude oil losing appeal to more greener forms of energy. With this in mind, I will now take a look at the Canadian oil industry in Alberta.



(Image from <http://www.infomine.com/investment/metal-prices/crude-oil/5-year/>)

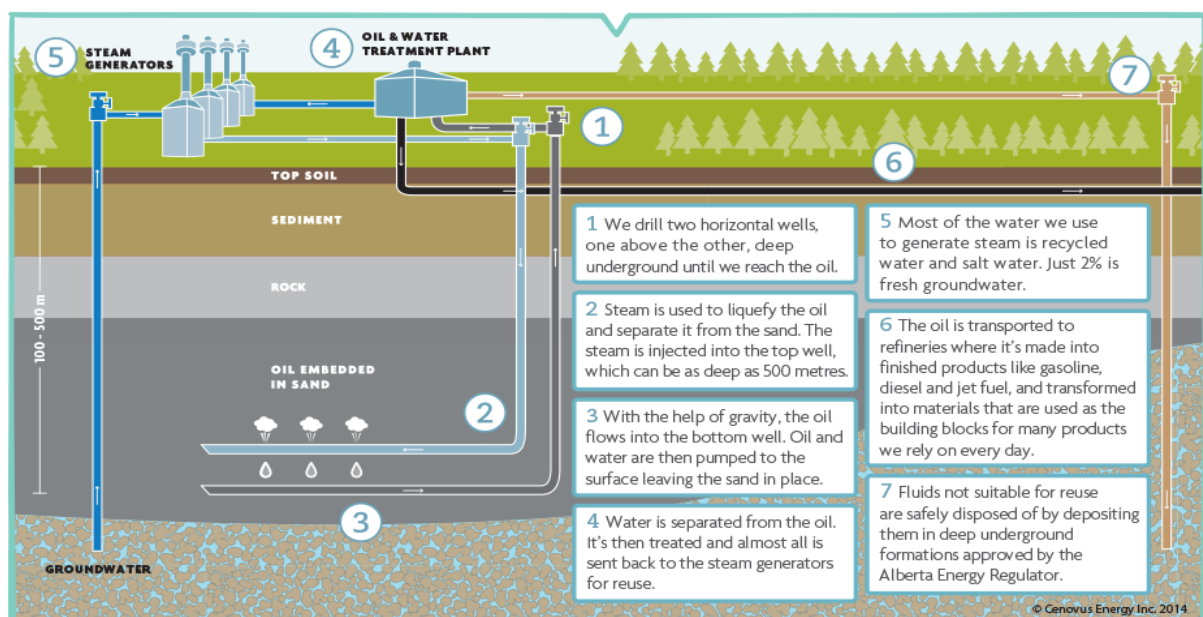
Alberta Oil Sands Industry

Comparative Oil Reserves (billions of barrels)
Source: Oil & Gas Journal, 2012



According to the (Government of Alberta) website, Alberta holds immense oil resource wealth holding the world's third-largest proven crude reserves after Saudi Arabia and Venezuela. Such an enormous oil resource has had a positive impact on the welfare of the inhabitants of Alberta Province. From statistics posted on the (Government of Alberta) website, in 2012, 121,500 people were employed in Alberta's upstream energy sector and the Government of Alberta received royalties amounting to \$3.56 billion. Together, oil and gas and mining accounted for over 22% of Alberta's GDP in 2012 and capital investments upward of \$207 billion were projected for the period 2013-2022 in the oil sands industry. The size of the resource and the scale of investment in the oil and gas industry in Alberta show without a doubt that the oil sands are key to the future prosperity of Alberta and how companies operate in the industry could play a vital role in securing that future. This bright outlook has however come under considerable pressure lately. The current low oil prices allow only 20-30 percent of Canadian oil production to generate positive cash flows with greenfield mines requiring around \$100 per barrel to break even and \$75 per barrel prices to break even for greenfield SAGD oil sands projects (Morgan, 2015). Further, when it comes to oil extraction techniques, the oil sands industry in Alberta has been the "bad kid on the block". Oil sands are recovered in two main ways: surface mining and in-situ technology. Surface mining requires the removal of forest and layers of overburden to expose the oil sands, which are then extracted and hauled to a processor although only 20% of Alberta's oil sands can be recovered through surface mining. Currently, Steam Assisted Gravity Drainage (SAGD) is the most commonly used in-situ process. Steam is injected into a well and this warms the oil sands and causes the bitumen to separate and flow into a parallel well where it is pumped to the surface for processing (Oil Sands Discovery Centre). Critics of the oil sands have expressed much concern over the environmental impact and resource intensiveness of the extraction processes in oil sands development. Oil sands extraction requires vast amounts

of water, about 2.5 barrels of new water for every 4.5 barrels of synthetic crude (Mech, 2011). The water used for the extraction of oil sands comes primarily from the Athabasca River which has seen a decline in average flows causing concerns as to whether the available water will be enough to sustain the projected increase in oil sands projects in Alberta. There is also intensive use of natural gas during oil sands extraction, with 700 to 1700 cubic feet used for the production of one barrel of oil sands crude (Mech, 2011). There are greenhouse gas emission concerns, production-related emissions, tailing ponds, air pollution concerns, minimal land reclamation, impact on aquatic life and land animals and the impact of oil sands development on the way of life of the First Nation People, which is in violation of Treaties 6 and 8 signed by First Nations People in 1876 and 1899 which surrendered vast amounts of land to the government in exchange for the guarantee that the First Nations would retain their traditional livelihood in perpetuity (Mech, 2011). With this repertoire of challenges to deal with, oil and gas companies in Alberta will need to come up with ever increasing means of extracting the abundant natural resources available while at the same time addressing the numerous issues facing them.



(SAGD Process Infographic)

Knowledge and the Oil and Gas Industry

Technological and market changes, rapid advancement in ICT development, scale of investments, and need for early identification and exploitation of opportunities have resulted in oil and gas companies being at the forefront of development and deployment of knowledge management techniques (Grant R. M., 2013) and (Bairi, Manohar, & Kundu, 2013). This is evidence of the premium that oil and gas companies have placed on knowledge as a primary asset. From development of simple rigs to extract oil in easy to reach resources at the beginning of the industry in the early 20th century to deep offshore rigs currently in use, to FPSO units, to highly complex performance monitoring systems the oil industry is evidently a knowledge-based industry and acquisition and creation of knowledge can indeed spell the difference between survival and exit of an oil and gas company.

Problem statement

Some lessons can be gleaned from the discussion above:

1. There is a lot of oil still available to be extracted and the demand for oil may increase (Finley, 2012) due to energy demand growth in the developing countries
2. Oil and gas companies are operating in an increasingly hostile environment characterised by constantly eroding share of oil in the energy mix, low commodity prices and worldwide commitments to a low greenhouse gas future.
3. Worldwide, stakeholder interests and the environment are taking centre stage and not just per barrel oil production. Carbon taxes, stakeholder empowerment, educated consumers, social media activism just to mention a few need to be addressed by companies operating in the oil and gas industry

4. Oil companies need now more than ever to gain new sources of competitive advantage to survive in the current oil and gas industry environment and knowledge is clearly an identifiable asset for competitive advantage.

In light of this characteristic of the modern day oil and gas industry, it is my argument in this thesis that knowledge is a competitive advantage that if fully utilised could go a long way in aiding oil companies weather the storm in the environment they currently operate in and emerge as better entities and therefore companies need to understand the knowledge creation process better and identify gaps in the knowledge creation process in their operations.

At the core of this thesis, the question that I seek to answer is:

“How does an oil company, within a project setting, create knowledge to improve its performance in an increasingly hostile environment?”

This question is aimed at identifying how knowledge is created within an upstream oil and gas project with a view of identifying knowledge creation opportunities as well as identify knowledge creation gaps in oil and gas projects therefore enabling oil and gas companies gain more competitive advantage by utilising more avenues of knowledge creation.

Paper overview

This thesis began in with a brief primer on the current state of the global oil and gas industry and introduced the oil and gas industry in Alberta, briefly describing how the resource is extracted and outlining a few of the criticisms facing the Alberta oil and gas industry. A brief overview of knowledge management in the oil and gas industry was presented and the problem statement was presented at the end of the chapter.

In chapter 2, I take a look at extant literature on the concept of knowledge. Of particular concern with regard to this thesis, I look at literature on the knowledge-based view of the firm and knowledge creation. Thereafter, I delve in-depth into the SECI model of knowledge creation and the spatial concept of ba that were developed by Nonaka Ikujiro and others. At the end of the chapter I present the research design of the study

In chapter 3, the theoretical framework and research design of the study are presented.

In chapter 4 I present the findings of the study. The findings are presented in tabulated form.

A short analysis of the data is presented at the end of each table.

Finally, in chapter 5 I present a discussion of the findings, the conclusion and a proposal for future research.

Chapter 2: Literature Review

Knowledge

Knowledge is defined in the Merriam-Webster Dictionary as “information, understanding or skill that you get from experience or education” that is, “the fact or condition of knowing something with familiarity gained through experience or association”. According to the American Heritage Dictionary, “knowledge can be defined as the state or fact of knowing; familiarity, awareness, or understanding gained through experience or study; and the sum or range of what has been perceived, discovered or learnt”. As quoted in (Cabrera-Suarez, Saa-Perez, & Garcia-Almeida, 2001), “knowledge can be defined as ‘information that is relevant, actionable, and based at least partially on experience’”

Knowledge Based View of the Firm

Organisations are operating in an ever increasingly “knowledge society” and changing environment and organisations that deal with such an environment ought not only to process information, as traditionally believed of organisations as information processing entities, but increasingly organisations are *nudged* into becoming information and knowledge creating entities (Nonaka I. , 1994), as aptly stated in (Nonaka , Toyama, & Konno, 2000), “Instead of merely solving problems, organisations create and define problems, develop and apply new knowledge to solve the problems, and then further develop new knowledge”. The knowledge based view of the firm is based on the resource based view of the firm. As quoted in (Spender, 1996), “the Resource Based View (RBV) of the firm, shaped by the suggestion that the strategic actions which reposition the firm, require it to possess very specific resources, competencies and capabilities and “those that lead to competitive advantage must, by definition, be scarce, valuable and reasonably durable and are unlikely to be available from others under terms that do not strip them of the net present value of the rent stream they are

capable of generating””. That is, according to (Hart, 1995), such resources must be valuable, non-substitutable, rare and/or specific to a given firm and difficult to replicate. The knowledge-based view of the firm views the firm as a knowledge-creating entity, and argues that knowledge and the capability to create and utilise such knowledge to uniquely add value to production processes are the most important source of a firm’s sustainable competitive advantage (Nonaka, Toyama, & Nagata, 2000) (Spender, 1996). The knowledge based view of an organisation therefore among other things tries to analyse how organisations create knowledge (Cabrera-Suarez, Saa-Perez, & Garcia-Almeida, 2001).

Knowledge Creation

There seems to be a glaring absence of literature on the concept of knowledge creation, as (Rich, 1991) puts it, “the field faces the following issues: a crisis of legitimacy, a lack of theory development, problems in measurement of the phenomena being explored and stalled development in terms of posing challenging questions”. Nonaka Ikujiro in (Nonaka I. , 1994) attempts to create a theory of knowledge creation. (Nonaka I. , 1994) Draws begins by drawing a distinction between two dimensions of knowledge;

a. Tacit knowledge

Tacit knowledge is described as “the personal knowledge used by members to perform their work and to make sense of their worlds” (Choo, 2000). Tacit knowledge is characterised by being action oriented and context specific (Nonaka I. , 1994); and highly personal and difficult to reduce to writing (Holste & Fields, 2010). It involves both cognitive and technical elements; cognitive elements being “mental models” in which human beings form working models, such as schemata, paradigms, beliefs and viewpoints, of the world by creating and manipulating analogies in their minds – this involving an individual’s images of reality and visions for the future, that is, what is

and what ought to be; and technical element which covers concrete know-how, crafts and skills that apply to specific contexts (Nonaka I. , 1994). Mostly, it is reduced to metaphor, narrative and personal strategy if ever expressed (Holste & Fields, 2010).

b. Explicit knowledge

This is described as formally expressed knowledge “using a system of symbols” and systematic language (Choo, 2000) (Nonaka I. , 1994). Explicit knowledge takes the form of artefacts such as product patents, databases, tools, and prototypes etc. and rules, routines and procedures (Choo, 2000)

(Nonaka & Noboru, 1998) In their paper define knowledge creation as “a spiralling process of interactions between explicit and tacit knowledge”, with interactions between these kinds of knowledge leading to the creation of new knowledge. The combination of tacit knowledge and explicit knowledge according to (Nonaka & Noboru, 1998) makes it possible to conceptualise four conversion patterns as follows:

i. Socialisation (Tacit to Tacit)

Socialisation occurs through physical proximity, direct observation, direct interaction and imitation (Choo, 2000) (Nonaka I. , 1994), usually involving joint activities rather than through written or verbal instructions, that is, through experience (Nonaka I. , 1994). From extant literature, several factors affect tacit knowledge sharing including: trust (Holste & Fields, 2010); relational embeddedness, cognitive embeddedness, absorptive capacity and motivation (Bakker, Cambre, Korlaar, & Raab, 2011); and organisation commitment (Lin, 2007).

ii. Externalisation (Tacit to Explicit)

This requires the expression of tacit knowledge and its translation into comprehensible forms that can be understood by others. Two key factors support externalisation:

- a. Articulation of tacit knowledge – conversion of tacit into explicit knowledge involving techniques that help to express one’s ideas or images as words, concepts, figurative language (such as metaphors, analogies or narratives) and visuals. Dialogue, that is, listening and contributing to the benefit of all participants, strongly supports externalisation.
- b. Translating the tacit knowledge into readily understandable forms requiring deductive/inductive reasoning or inference e.g. through use of knowledge transfer protocols (Herschel, Nemati, & Steiger, 2001).

During externalisation, knowledge becomes a basis for reflection and conscious action therefore explicit knowledge becomes a reflection of the tacit knowledge on which it is based (Nonaka & Krogh, 2009). Therefore knowledge is transferred as it changes form from tacit to explicit (Nonaka & Krogh, 2009).

iii. Combination (Explicit to Explicit)

It involves the conversion of explicit knowledge into more complex sets of explicit knowledge. Key issues in this stage are communication and diffusion processes and the systemisation of knowledge. This phase in practice relies on three processes, that is:

- I. Capturing and integrating new explicit knowledge – might involve collecting externalised knowledge e.g. public data from inside or outside the company and then combining such data

- II. Dissemination of explicit knowledge – based on the process of transferring this form of knowledge directly by using presentations or meetings
- III. Editing or processing of explicit knowledge – to make it more usable e.g. documents such as plans, reports or market data

In the combination phase, justification – the basis for agreement – takes place and allows the organisation to take practical concrete steps.

iv. Internalisation (Explicit to Tacit)

This involves conversion of explicit knowledge into an organisation's tacit knowledge. Internalisation relies on two dimensions:

- a. Explicit knowledge is embodied in action, that is, actualising concepts or methods about strategy, tactics, innovation, or improvement
- b. Embodying the explicit knowledge by using simulations or experiments to trigger learning by doing processes. New concepts or methods can thus be learned in virtual situations.

This therefore implies acting on knowledge acquired, that is, knowledge is gained through action, practice and reflection (Nonaka & Krogh, 2009).

The concept of ba

According to (Nonaka & Noboru, 1998), “ba” can be thought of as a shared space for emerging relationships. This space can be physical e.g. office, dispersed business space; virtual e.g. email, teleconferencing; mental e.g. shared experiences, ideas, ideals; or any combination of them. Ba therefore provides a platform for advancing individual and/or collective knowledge, that is, a shared space that serves as a foundation for knowledge creation (Nonaka & Noboru, 1998). Ba is the platform for the “resource concentration” of the organisation’s knowledge assets and intellectualising capabilities within knowledge creation processes, that is, ba collects the applied knowledge of an area and integrates it (Nonaka & Noboru, 1998). To shed more light on spatial thinking, (Graupe & Nonaka, 2010) make use of the notion of mental maps, that is, cognitive frameworks to guide and orient us in the complex reality of everyday economic phenomena. (Graupe & Nonaka, 2010) argue that not all mental maps depict reality from the same vantage point, neither are they simply objective representations of the world but rather they approach reality from certain perspectives, selecting particular perceptions while suppressing others thus constructing and editing reality. Further, according to (Graupe & Nonaka, 2010), scientists go about their projects in the world by means of a certain mental map only, without explicitly reflecting upon it or its possible alternatives, failing in the process to fully utilise the whole repertoire of mental maps that may be at their disposal as a source of creative thinking therefore management requires the broadening of its horizons, the development of a wider, more encompassing methodological framework capable of making explicit and incorporating different mental maps or cognitive frameworks concerning space.

The “Nonakaian” view of the firm borrows from Japanese philosophy of topological space (Graupe & Nonaka, 2010). In the logic of this philosophy, the world is viewed as actuality, that is, as a field of activity out of which both the whole and the part (the one and the many)

as subjects in process are continually and mutually created, therefore, space itself thus becomes understood as a ‘magma of processes’, that is, it is productive activity and engagement and can only be expressed in terms of activity (Graupe & Nonaka, 2010). In this view of space according to (Graupe & Nonaka, 2010), we cannot relate to it from the outside as observers, but only be “indwelling” and experiencing it, that is, participant observers, thus the actual rather than the conceptual counts. Thus “the world comes to be seen in a verbal sense as the activity of individuals – or their “here-now-relationships in action” – interacting and mutually determining one another, that is, it becomes ‘pure activity’, an open process which is not causally attributable to any substantial “prime mover”, neither the one nor the many, the whole, nor the parts” (Graupe & Nonaka, 2010). Therefore, the process of actualisation, not some substance that actualises, is what becomes manifest in the theory of topological space, that is, space is to be seen as a living, dynamic nexus made up of activities and processes (Graupe & Nonaka, 2010). In this view, individuals do not simply devote themselves to *basho* (topological space) but rather see themselves as active parts of it, and as such they create social structures out of their interactivity (Graupe & Nonaka, 2010), therefore neither subject nor world, neither individuals nor social structures can be seen as pre-existing ‘lumps’ in the process but rather they emerge as such in the process itself. (Graupe & Nonaka, 2010) State:

“The knowledge creation view is of the firm as *ba*, which means a shared situation or time-space nexus where the various subjective and historical dimensions of its members intersect and their heterogeneous experiences interact. Here the ‘interaction’ does not denote a relationship external to autonomous subjects, but a context of shared, direct experience, in which individuals co-creatively and dynamically create themselves as well as their environment”

Chapter 3: Methodology

Theoretical Framework

The SECI Model

The SECI (Socialisation, Externalisation, Combination, and Integration) model was developed by Nonaka Ikujiro as a paradigm for the management of the dynamic aspects of organisational knowledge. In the SECI model according to (Nonaka & Noboru, 1998) knowledge creation is a spiralling process of interactions between explicit and tacit knowledge. The combination of the two categories makes it possible to conceptualise four conversion patterns, that is; socialisation, externalisation, combination and internalisation.

SECI Element	Key Elements
Socialising	Capturing knowledge through physical proximity e.g. direct interaction and

	<p>observation and disseminating Knowledge that is, transferring of one's ideas or images directly. From (Bakker, Cambre, Korlaar, & Raab, 2011);</p> <ol style="list-style-type: none"> a. Relational embeddedness – strength of the relation between two or more organisational actors. b. Cognitive embeddedness – extent to which the relation between the parent organisation and the project venture is characterised by “shared representations, interpretations, and systems of meaning” c. Absorptive capacity – refers to the organisation's ability to recognise the value of new, external information, assimilate it, and apply it for competitive advantage. d. Motivation - this is the willingness to share knowledge. A higher motivation to transfer knowledge is likely to result in more successful knowledge transfer.
Externalisation	Articulation of tacit knowledge i.e. conversion of tacit knowledge into explicit knowledge – techniques to express one's ideas or images as words, concepts, figurative language (metaphors, analogies or narratives) and visuals
Combination	<p>Capturing and integrating new explicit knowledge – involves collecting externalised knowledge e.g. public data from inside and outside the company</p> <p>Dissemination of explicit knowledge – e.g. presentations and meetings</p> <p>Editing or processing of explicit knowledge to make it more usable e.g. documents, plans, reports, market data</p>
Internalisation	<p>Explicit knowledge embodied into action or practice</p> <p>Embodying explicit knowledge by using simulation or experiments to trigger learning by doing processes</p>

In (Nonaka & Noboru, 1998), there are four types of ba that correspond to the four stages of the SECI model, that is; originating ba, interacting ba, cyber ba and exercising ba:

Ba Element	Key Elements
Originating ba	Physical, face-to-face experiences, open organisational structures,

	knowledge vision and culture
Interacting/Dialoguing ba	Selecting people with the right mix of specific knowledge and capabilities for a project team then individuals share the mental model of others and reflect on and analyse their own mental models Dialog is key as interacting ba is where tacit knowledge is made explicit
Cyber/Systemising ba	Combination of explicit knowledge most efficiently supported in collaborative environments utilising information technology e.g. online networks, group-ware, documentations and database
Exercising ba	Internalisation of knowledge continuously enhanced by the use of formal knowledge (explicit) in real life or simulated applications

Key Assumption and Criticisms of the SECI model

In the SECI model, it is assumed that knowledge is created and improved as it flows through different levels of the organisation and between individuals and groups thus knowledge value is created through synergies between knowledge holders (both individual and group) within a supportive and developmental organisational context (Rice & Rice, 2002) in a spiral manner going from tacit to tacit, tacit to explicit, explicit to explicit, and explicit to tacit knowledge.

However, this model has had some criticisms as pointed out in (Gourlay, 2006):

- i. Subjectivism in the model tends towards dangerous relativism because justification is made a matter of managerial authority and how scientific criteria relate to corporate knowledge is neglected. Further,
- ii. The theory fails to recognise the commitment of various groups to their ideas and the resulting need to resolve this conflict by managerial authority cannot bode good for creativity and innovation
- iii. The theory overlooks learning theory with misreading important organisational writers and not using better accounts of western philosophy

- iv. The model does not explain how new ideas are produced nor how depth of understanding (necessary for expertise) develops
- v. Collaborative work is made a mystery

Research Design

This thesis will take a critical realism approach and a case study research design.

Critical Realism

According to (Easterby-Smith, Thorpe, & Jackson, 2012), critical realism provides a compromise position between stronger versions of positivism and constructionism. Starting with a realist ontology, critical realism recognises social conditions as having real consequences whether or not they are observed and then incorporates a relativist thread which recognises that social life is both generated by the actions of individuals, and also has an external impact on them (Easterby-Smith, Thorpe, & Jackson, 2012). (Easterby-Smith, Thorpe, & Jackson, 2012) Point out certain features of critical realism:

1. Its 'structured ontology', which differentiates between three domains, that is:
 - a. Empirical Domain – comprising of experiences and perceptions that people have
 - b. Actual Domain – comprising of events and actions that take place whether they are observed or detected
 - c. Real Domain – comprising of causal powers and mechanisms that cannot be detected directly but which have real consequences for people and society
2. Causality exists as potential rather than automatic correlation of events. However, (Easton, 2010) argues that critical realists should use causality with thinking, that is, critical realism justifies the study of any situation, regardless of the number of

numbers of research units involved but only if the process involves thoughtful in-depth research with the objective of understanding why things are as they are.

Case Study Method

Case study method can be described as a study method with a sample of one (Easton, 2010). It allows investigators to focus on a 'case' and retain a holistic and real world perspective – such as organisational and managerial practices (Yin, 2014) thus allowing the study of phenomena in their context rather than independent of context (Gibbert, Ruigrok, & Wicki, 2008). In (Gibbert, Ruigrok, & Wicki, 2008), four validity and reliability criteria are provided to gauge the quality of the case study research:

- a. Internal validity (logical validity) – causal relationships between variables and results.
- b. Construct validity – quality of the conceptualisation or operationalisation of the relevant concept.
- c. External validity (generalisability) – grounded in the intuitive belief that theories must be shown to account for phenomena not only in the setting in which they are studied but also in other settings. Researchers should also provide a clear rationale for the case study selection and ample details on the case study context to allow the reader to appreciate the researcher's sampling choices.
- d. Reliability – absence of random error, enabling subsequent researchers to arrive at the same insights if they conduct the study along the same steps again.

Following the five components of case study research design as presented in (Yin, 2014), the study question in this thesis as presented in chapter 1 is "how knowledge is created in an upstream oil and gas project". My proposition in this thesis is that knowledge is created in a project setting and it is possible to identify the knowledge creation process. The unit of analysis in this thesis will therefore be knowledge, both tacit and explicit. The SECI model will be applied to the data being analysed and different scripts relating to the four elements of the SECI model will be sought. The results will then be interpreted to show that as the SECI model proposes, knowledge is created in a spiral fashion as tacit knowledge is converted to tacit knowledge, then the tacit knowledge is converted to explicit knowledge, then the explicit knowledge is converted to more explicit knowledge and finally that explicit knowledge is converted to tacit knowledge.

Cenovus Energy Christina Lake Oil Sands Project

Cenovus Energy began independent operations on 1st December 2009 when the Encana Corporation split into two distinct companies, an oil company (Cenovus) and a gas company (Encana). Cenovus holds vast oil sands resources in north Alberta as well as conventional oil and natural gas production in Alberta and Saskatchewan and 50% ownership in two U.S. refineries.

The Cenovus Energy Christina Lake oil sands project is located in Northeast Alberta, about 150km south of Fort McMurray. It is a 50% ownership with ConocoPhillips. The pilot project began in 2000 and the first production began in 2002 and has an anticipated lifespan of 30 years. Cenovus Energy's Christina Lake operations boasts one of the lowest steam to oil (SOR) ratios in the industry at about 1.8 (the number of barrels of steam it takes to produce one barrel of oil). The project has five stages of growth, with phases A through E in operation

currently and construction of phase G on hold due to low oil prices while an application for phase H is currently under regulatory review. The project currently produces about 150,000 gross barrels of crude per day with a projected production of approximately 310,000 barrels per day with future optimisation.

The primary technology used at the Cenovus Energy Christina Lake is the Steam Assisted Gravity Drainage (SAGD) method where two horizontal wells are drilled, one above the other about five meters apart. Salt water from deep underground is heated to create steam, which is then continuously injected into the upper well. As the formation is heated, it softens the oil, allowing it to flow more freely. The oil then drains into the lower well where it is pumped to the surface. Majority of the water used is recycled and reused to generate steam. Other technologies in use are Solvent Aided Process (SAP) where solvents such as butane are injected along with the steam to help the oil move more easily to the surface thereby reducing the amount of water and natural gas required to produce a barrel of oil and fewer emissions. Cenovus Energy also use their SkyStrat™ drilling rig that is smaller and lighter and transportable by helicopter reducing the need for access roads as well as Wedge Well™ technology where horizontal wells are drilled in the ‘wedge’ region between two well pairs to recover oil that wouldn’t be recovered otherwise.

The research involved analysing scripts from the Encana/Cenovus annual presentations to the EUB/ERCB updating the regulator on the progress of their SAGD operations at Christina Lake. Presentations analysed were from the year 2003 to 2015. A few scripts representing various SECI model elements were identifiable from the documents analysed.



Cenovus Christina Lake Project Layout

Data Sources

Data used in this thesis was the Encana/Cenovus Christina Lake annual progress reports presented to the Alberta Energy and Utilities Board (AEUB) which later became the Alberta Energy Regulator (AER). These presentations are held once a year to give progress of the oil sands projects in Alberta province. The reports used were for the years 2003 through 2015. They were sourced from the AER website archives and they are publicly available.

Method

The data was analysed by comparing scripts in the documents analysed to the various SECI model elements. For the socialising element of the SECI model, scripts regarding direct observation of phenomena were sought, that is, personal sharing of experiences regarding the Christina Lake oil sands project. For the externalisation element, scripts regarding narration

on different phenomena in the Christina Lake project were sought. These were mostly scripts regarding happenings at the Christina Lake project. For the combination element, scripts regarding planning, reporting, and monitoring were sought. For the internalisation element of the SECI model, scripts regarding tests, pilots, experiments, and application of learnings were sought.

Limitations and assumptions of the Study

Due to time and budgetary constraints during the writing of this thesis, the study was done with the following limitations:

- a. A key assumption in this study was taking Cenovus Energy as an “individual”, that is, Cenovus was viewed as a “learning organisation” that is, as quoted in (Grugulis, 2003), “an intelligent, non-human species at an early stage of their development”. An organisation can be viewed as “an identifiable social entity” (Zelaya-Zamora & Senoo, 2013) capable of learning to do what it does (Cook & Yanow, 2011). This means that aspects in the SECI model which view interactions between individuals were mapped onto an organisation.
- b. It was not possible to go into depth with regard to the ba concept and assumptions were made with regard to this.
- c. Only key concepts behind the elements of the SECI model were used in analysing scripts from the documents analysed. For the externalisation element, the key concept analysed was narration and therefore scripts regarding narration of phenomena at the project site were sought from the documents analysed. For the combination element, the key element sought was collection of explicit knowledge both internally and externally. Therefore I sought scripts regarding monitoring programs, studies, planning exercises and monitoring systems.

- d. It was not possible to differentiate the socialisation scripts from the externalisation scripts therefore all narration scripts were classified as externalisation.

Chapter 4: Research Findings

Presentation of Findings

2003

Externalisation

In 2003, certain scripts relating to the SECI element externalisation were identified. One of the scripts identified was:

“Alternate water treating technologies identified but with setbacks”

This is a narrative describing seeking of new alternative technologies to use on site but they had certain limitations. A narrative of full compliance with commitments made during the application for the project was also identified:

“Facility operations in full compliance and in accordance with commitments made in application”

Scripts narrating learning in the project was also identified in the documents analysed:

“New flare meter installed in October may have caused an increase in reported flared gas”

A script narrating finding of minor deficiencies in the project and that they were addressed was identified:

“Several minor deficiencies identified during audit of facility operations addressed”

Combination

Here, scripts relating to reporting were identified related to the following:

Internal compliance tracking

“Internal compliance tracking reports no EUB non-compliance reported in 2002”

Self-disclosure of issues with the project to the energy regulator

“Self-disclosure of pressure exceedance for disposal well but later corrected”

Reporting as required by an energy regulator directive

“Submitted annual resource management report as per EUB decision”

Internalisation

Internalisation scripts indicate the a correction of an exceedance not permitted by regulations, the conducting of a pilot for a new technology on the project site and incorporation of learnings from the first phase of the project as well as learnings from a similar project in a different site

SECI Element	Scripts Identified
Internalisation	“corrected...exceedance” “SAP pilot” “Alternative strong acid cation resin being tested for use with brackish water” “Incorporate learnings of phase 1 and foster creek”

2004

Combination

SECI Element	Scripts Identified
Combination	“Conducted an internal safety, environment and regulatory facility inspection” “EUB conducted oil facility inspection/operational audit of Christina Lake facility... audit concluded that Encana was in compliance with EUB regulations”

In 2004, combination scripts that were identified are an internal inspection that was carried out by Encana as well as an audit of the facilities that was conducted by the EUB

Internalisation

SECI Element	Scripts Identified
Internalisation	“Limited pump test – one deviated and one vertical well drilled off disposal pad, respectable deliverability but had issues with gas coning” “converted A3 to electrical submersible pump (ESP) – first test at Christina Lake”

In 2004, Encana conducted a limited pump test and converted a well at the site to ESP, a pilot at the project site

2005

Externalisation

SECI Element	Scripts Identified
Externalisation	“2003/2004: One deviated and one vertical well were drilled off 03-16 disposal pad. Respectable deliverability but had some issues with gas coning”

In 2005, there was narration of a well that was drilled on the project site but had some technical challenges.

Combination

SECI Element	Scripts Identified
Combination	<p>“Submitting semi-annual well operations reports”</p> <p>“Encana conducted an internal safety, environment and regulatory facility inspection”</p> <p>“The EUB conducted an oil facility inspection/operational audit of the Christina Lake facility”</p>

In 2005 Encana submitted semi-annual well operation reports, conducted an internal inspection, and the EUB conducted an audit of the Encana Christina Lake facility

Internalisation

SECI Element	Scripts Identified
Internalisation	<p>“applied learnings from 2004 horizontal well to effectively expand brackish WSW system”</p> <p>“Injectivity test with natural gas done June 2005 on two wells”</p>

In 2005, Encana applied learnings from the well drilled in 2004 to a different operation and conducted a natural gas injectivity test on two wells

2006

Externalisation

SECI Element	
Externalisation	“While not measurable from the experiment, it is believed, based on previous

	experience and the previous conclusion, that low levels of oxygen uptake would occur at reservoir conditions”
	“Methane co-injection experience – demonstrated in field to consistently improve SOR, higher percentage of injected methane appears to get produced preventing excessive accumulation in steam chamber. Mechanism not well understood and is not accounted for in simulators which predict accumulation of methane leading to a dramatic reduction in steam chamber growth rate hence oil production”
	“In some cases oil production is observed, likely from improved drainage of accumulated fluid and enhanced drainage from HIS above steam chamber”
	“have not achieved anticipated emulsion rates from B02-1 and B02-2 due to ESP limitations (gas handling issues) – currently reviewing limitation”
	“Impact of Low Temp Oxygen (LTO) in top gas zone. Oil reaction six-month tests show that the impact to the oil is not significant under LTO”
	“long term oxidation – coke production did not occur in the timeframe of the experiment, apparent increase in asphaltenes content for all cases attributed to an initial loss of volatile materials from the reactors”

In 2006, the above are a sample of the scripts that were identified where Encana articulated tacit knowledge from the project into narratives. Some of the scripts show an understanding of phenomena occurring in the project based on previous experience, articulation of experience gained by a new technology introduced in the project and challenges to fully understanding that new technology, experience from ongoing operations in the project and experience from an experiment.

SECI Element	Scripts Identified
Combination	“planning pad-wide methane co-injection test at A-pad – expected to reduce SOR, prolong steaming and increase recovery”

In 2006, Encana was involved in planning a pad-wide methane co-injection test that was expected to reduce SOR, prolong steaming and increase oil recovery.

SECI Element	Scripts Identified
Internalisation	“11-16 results – re-pressuring of gas pools possible for SAGD, air injection is cost effective and operationally superior to other gases, no detrimental impacts on air observed to date. Results of 11-16 used as basis for phase II section 15 – re-pressuring of a gas over bitumen zone”
	“Corrosion long-term testing underway to understand corrosion rates under combusted gases and high temperature”
	“Water re-use initiatives – blowdown water re-use study completed – direct treatment preferred”
	“McMurray water source study completed – option to blend some volumes”

In 2006, Encana used the results of a previous test as the basis for similar operations in a different phase of the project. Encana also undertook a long-term test to understand a phenomenon in the project as well as chose alternatives to operations in the project based on studies conducted by the company.

2007/2008

SECI Element	Scripts Identified
Externalisation	“New pump technology deployed in A0-2 without success”
	“Gas lift (B02-3, B02-4) – no temperature limitations. ESP (A01-1 through A01-6, B02-1, B02-2) currently limited by bottom-hole temperature and gas handling issues”
	“Have removed wellhead temperature limitation – everywhere but A01-5 can now operate at 210”

	“Lift performance review – A pad gas-lift worked well at high pressures but not expected to work efficiently at 2500kPa future target pressure. A3 ESP replaced in January 2007 after 653 days of run time. B-pad gas-lift working well at high pressures but not expected to work efficiently at 2500kPa future steam chamber target pressure. ESP installations planned for September turnaround”
	“On December 17 2007 WHP at 7-16 breached the maximum wellhead pressure of 6000kPa ”

In 2007/2008, Encana articulated that a new technology had been deployed in the project without success, a technology deployed in the project had certain limitations, reviewed a technology’s performance and could predict its performance in different conditions and articulated an incidence that occurred in the project.

SECI Element	Scripts Identified
Combination	“MARP(Directive 42)sulphur recovery facility amendment – Amine Claus process selected for SRF and design details being finalised”
	“CD Disposal amendment studies underway to verify the 16-15 location is suitable for CD disposal; Rate rise control pilot-variation of methane co-injection scheme in well B01-7 – application to be filed in Q4 2008; SAP test with synthetic solvent under gas cap – application to be filed in 2009”

In 2007/2008, Encana, as per a regulatory directive, was finalising plans for a sulphur recovery facility. Encana was also undertaking studies to identify a disposal.

SECI Element	Scripts Identified
Internalisation	“Issues resolved due to MARP directive 42 – co-injection and produced gas measurement (GOR basis), salt cavern inventories, database set-up and testing (rebuild PVR and testing), steam prorating, estimated flows, new meter installation requirements, applicable meter checks”
	“New start-up initiatives on B01 pad B01-3 reverse gradient circulation – start-up flow is with gravity instead of against gravity, fluid/steam front may be more stable and continuous moving downwards rather than potentially having fingers of communication moving upwards, goal is to speed up the ramp-up phase of SAGD operations – Encana’s circulation technique involves a conductive and convective component”

In 2007/2008, Encana was able to resolve some issues based on a regulatory directive and started new a new operational process in the project.

2008/2009

SECI Element	Scripts Identified
Externalisation	“B01-4 was performing poorly with ESP (~100m ³ /day oil) currently working to raise chamber pressure (potentially sacrificing pump), may be put back to gas lift if pump fails”
	“A01-3 toe producer produced well initially (100-150m ³ /day oil), then became very gassy and pump limited (50m ³ /day oil)” A01-3 toe producer turned off co-injection gas from A01-3 reduced steam to toe, has since turned around, re-achieving 100-150m ³ /day
	“not meeting production capacity amount because-approval based on 12 well pairs for phase 1b currently have nine, only using ~90% steam

	capacity”
	“Individual well pairs have not been able to achieve our predicted rates- lower pressure ESP operations yield better SOR but lower rates, most ESPs are unable to operate at full speed due to-temperature limitations, amp draw fluctuations from produced gas at the pump so will be converting B01-4 back to gas lift from ESP and running pressure to see if well turns around”
	“Tracer test 1- test confirmed that methane injected into the SAGD chamber returned quickly, over 87% of the tracer returned within two weeks of the initial injection, well was operating on gas lift; Tracer test 2- second - purpose of test was to identify any changes in methane gas production, first test was completed while A4 was on gas lift, the well is now on artificial lift, some tracer did return quickly, total volume of tracer returned is not comparable to the first test”
	“Key learnings at Christina Lake for 2008-intersection of steam chamber with gas does not impact the SAGD process, gas composition of produced gas changes-allowing steam chamber to intersect with gas cap at high pressure appears to be more effective than reducing pressure using ESP; reverse circulation does not appear to be any more beneficial than the standard circulation; converting to ESP right after circulation (B01-4) does not appear beneficial, high pressure gas lift may develop the steam chamber more evenly than low pressure ESP operations during rise; increase recovery and reduce environmental footprint”

In 2008/2009, articulation narratives identified showed that a well was performing poorly with a new technology and could be reverted back to a previous technology; a new technology at another well began producing well but production abruptly went down, conditions were changed in the well and production picked up again; current production in the project was not meeting anticipated production and causes were identified; individual wellpairs were not

operating as expected; results of a test were articulated; and a new technique that was tried out did not show any benefit to the current technique in use in the project

SECI Element	Scripts Identified
Internalisation	“On May 12, 2009 Encana conducted a mini-fractest on well 100/071707606W4 – primary objectives of tests was to assess the in-situ stress conditions within both the reservoir and various cap rock intervals”
	“leverage FC success and learnings at CL”
	“Q1 2008 performed pulse tests to confirm injectivity and pool connectivity, total gas volume injected ~1538 Se ³ m ³ ; new piezometers installed for gas cap pressure monitoring; Q4 2008 performed second pulse test for pressure transient analysis, total gas volume injected 1288 Se ³ m ³ ”

In 2008/2009, Encana conducted a mini-test on a well to assess well conditions, combined learnings of two similar projects at different sites and conducted two pressure tests, the second after installation of new monitoring equipment to confirm “injectivity and pool connectivity”.

2009/2010

SECI Element	Scripts Identified
Externalisation	“Re-converting inefficiently operating ESP well to high pressure gas lift greatly accelerates production and steam chamber development during rise phase-higher production rates, 4d seismic; sustained production under top gas cap is achievable as long as there is a pressure balance e.g. B02-1 and B02-2; co-injection does not negatively affect rate of resource recovery-improves SOR, does not appear to affect ultimate recovery, require blow-down

	operations to confirm above point”
	“All three steam generators at Christina Lake have been operated above nameplate design (over firing)-this test has been online for several months, over firing includes higher fuel rates and boiler feed water rates for an increase in steam production of ~10%”
	“Static/passive air monitoring-2008/2009 monitoring and reporting satisfactory; no criteria exceedances were noted in either monitoring program”

Articulation narratives in 2009/2010 include articulation of tacit knowledge gained by adopting a different technique in the well that doing so increased production and chamber development; experience gained by over-firing steam generators; and articulation of satisfactory static/passive air monitoring.

SECI Element	Scripts Identified
Combination	“Special core vertical perm study-objective of the study was to ascertain the vertical permeability character of provided full diameter core samples that had been cleaned of all bitumen and water content and to ascertain the effect of vertical permeability barriers/baffles thought to exist in the formation”
	“Wildlife & biodiversity monitoring completed in 2009, wildlife mitigation monitoring completed in 2009, wetland monitoring completed in 2009; Maintains and tracks compliance through our ORIS database, Incident Management System (IMS), routine inspections and dedicated regulatory and environment staff”
	“non-compliance-ERCB-self disclosure D56 SAP HVP pipeline, AENV-two releases of reportable volume occurred in 2009-clean-up of released materials complete; Cenovus was in non-compliance scenario with the currently regulated water recycle calculation”

In 2009/2010, a study was conducted to ascertain certain properties of the project geology; wildlife and biodiversity monitoring and wetland monitoring was conducted as well as regular

monitoring through a database, incidence management system, routine inspections and environmental staff; and reporting of non-compliance to the industry regulator.

SECI Element	Scripts Identified
Internalisation	“B01-4 conversion from ESP to gas lift in Q2 2009; Steam+air injection test-B01-5 and B01-6 well pairs; engineering on scavenger unit started”
	“continue to incorporate lessons learned into future development”
	“continue with steam circulation, gas lift, ESP, blow-down strategy, continue Wedge Well and SAP pilots; Butane SAP -in operation; produced gas re-injection-process under review”
	“MARPs-meter calibration/inspection frequencies improved by use of ultrasonic meters and borescope; overall water balance closure monitored on a monthly basis, source and disposal are measured at wellhead with individual metering with meters calibrated as per MARP directive, produced water meters verified as per MARP, utilising strap-on ultrasonic”

In 2009/2010, internalisation scripts identified include conversion of well technology back to a previous technology; incorporation of lessons learnt during the project; continuation of pilot technologies in the project; and improved monitoring by use of new technology as required by a regulatory directive.

2010/2011

SECI Element	Scripts Identified
Externalisation	“Generally stable and predictable plant performance; minor issues-cooling at high flow rates, handling production swings; minor issues with bitumen treatment due to-production swings, high rates restricting hydraulics, cooling

	capacity at high rates”
	“co-injection experience to date-co-injection has not demonstrated a negative impact on production or recovery, CSOR appears steady, and in most cases decreasing with time”
	“Steam dilation, modified injector completion successful on B01-5, B01-6 first pilot well with water dilation-communicated with bottom water zone, converted early to ESP to maintain pressure balance with bottom-water, important to monitor fluid losses to understand how dilation zone is being developed, monitor fluid losses to determine when dilation start-up will be stopped; optimising injector hydraulics helps improve steam chamber development; starting to understand gas movement in reservoir further; A01pad bottom water influx via increased gas injection into pad-gas injection has helped increase bitumen recovery from pad”

Articulation scripts identified in 2010/2011 include narration of generally stable and predictable plant performance with minor issues; experience with a technique which over time has been beneficial to project performance; and learning from successful implementation of a new technique and experience in operations using that new technique.

SECI Element	Scripts Identified
Combination	“2010 non-compliance ERCB-self-disclosure on co-injection A01 pad; AENV-measuring free chlorine instead of total chlorine residual at WTP, not documenting daily dosage of chemicals added to WTP, raw wastewater samples analysed for CBOD not BOD5, shut down WTP, WWTP stopped discharging treatment effluent at the discharge point, chlorine pump at WTP shut down, missed daily analysis for TSS and CBOD from WTP; phase h application will continue to look for improvements to plant design or water treatment strategy that was proposed in the EFG application”

Combination scripts show that Cenovus self-disclosed non-compliance issues to the energy regulator.

SECI Element	Scripts Identified
Internalisation	“Minimum of 4 tests per well per month; minimum 48hrs of test time per well per month; starting to understand how gas behaves in reservoir, simulations being conducted to investigate how gas is moved around in the chamber; simulation work being conducted to test out our ideas, will provide further information to ERCB once conclusions are drawn”
	“New techniques employed in an attempt to accelerate reclamation; interim reclamation and erosion control is ongoing”

Internalisation scripts identified in 2010/2011 show that Cenovus continued to conduct tests in all wells in the project and the results were an understanding of well conditions as well as conducted simulations to understand the wells better and test out ideas to provide information to the regulator; new techniques were also employed in an attempt to accelerate land reclamation.

2011/2012

SECI Element	Scripts Identified
Externalisation	“Phase c had excellent operational success, no major commissioning/start-up problems, ramped up to nameplate capacity in ~6 months; phase c success attributed to-superior reserve quality, high plant availability and experienced operations, intelligent drilling, completion and start up practices; minor issues with vapour cooling at high flow rates, oil treating issues at high flow rates”
	“Have consistently achieved rates in excess of 55000bbl/day-minor issues with treating due to-production swings, high rates restricting hydraulics; water treatment-de-oiling-minor issues in de-oiling are water cooling at high flow rates, fouling of heat exchangers”
	“Sulphur recovery challenges-scavenger started on January 31-only ran 2/3 months in quarter, would require 100% uptime and 100% removal efficiency to reach 67% on quarter average, Initial chemical was tri-ethylene glycol based-chemical was switched in April to improve performance, encountered

	solids plugging, Plant upset in March; Sulphur recovery summary-Emissions are still below the average 2.0t/d as regulated before scavenger start-up, emissions are still below the 1.67t/d as regulated after scavenger start-up, Christina Lake had difficulty meeting the 67% recovery rate for Q1 2012 due to commissioning/operational challenges; Christina Lake expects to be compliant for all future operations”
	“Patented WedgeWell Technology-start up time affected mainly by facility restraints, rather than start up technology used; WedgeWell performance-not enough data yet to make any conclusions regarding incremental production”
	“Early conversion from high pressure operations to low pressure operations- has been successful in the field, allowed to produce accumulated fluids with minimal steam usage; steam rates restored to normal rates once accumulated fluids produced; SOR improves dramatically-some wells have CSOR close to 2 after less than 1 yr in operation; gas cap re-pressurisation- currently on track at being target pressure by end of year, results from wells operating at chamber pressures lower than 2000kPag has been positive, have seen SOR improvements and will continue to monitor performance of these wells”

Articulation scripts identified in 2011/2012 include a successfully started new phase, desirable plant performance with minimal issues, challenges with a new technology recently set up in the project, review of a patented new technology developed by the company, review of an operational technique done in the project

SECI Element	Scripts Identified
Combination	“have a multi-phase flow metering trial occurring in Q2 this year (Schlumberger and AGAR); investigating water cut meters other than AGAR (red eye, delta V, NMR)”

Combination scripts identified in 2011/2012 include a planned trial occurring later in the year

SECI Element	Scripts Identified
Internalisation	“well converted to water production well-well started in July 2011,

	successfully working on locally reducing pressure in the bottom water zone”
	“Conducting simulation analysis to further understand and investigate drainage from I.H.S.-intend to present results of a simulation study (with gas) to ERCB once complete”
	“CL CondenSAP pilot-using condensate mix as solvent-B01-6 CondenSAP, SAGD on well pair began in June 2010, currently on ESP (low pressure), solvent injection started in mid-March, B01-7 CondenSAP, well pair currently under circulation, start solvent injection within 3 months after converting the well pair to gas lift”

Internalisation scripts for 2011/2012 include a conversion of a well to water production, a simulation to understand a phenomenon in the project and a pilot to improve project performance.

2012/2013

SECI Element	Scripts Identified
Externalisation	“Integrated InSAR (Synthetic Aperture Radar) Land Deformation monitoring took place between March-October 2012 - the over pressure can be explained-by the thermal pore pressure mechanism, due to more thermally expandable fluid than rock matrix, and low effective reservoir mobility, the simulations show no failure in Clearwater caprock; even when the thermal pore pressure occurs-simulations did not account for potential lateral and vertical variation, thus recommend production from WBSK soon-to reduce impact on Clearwater caprock”
	“current start-up methods-currently have three main start-up methods-dilation*, solvent soak*, circulation-success of each method is reservoir dependent (*-patent pending)”
	“Key learnings at Christina Lake for 2012-phase ABCD nameplate oil (98000bbl/d)-achieved Q1 2013 (after 6 months oil production)-fast ramp-up achieved due to successful start-up strategy, optimised steam injection design and superior reservoir quality; start-up technology-still evaluating

	<p>the different technologies, start-up technology used on a pad will be determined on a pad-to-pad basis, areas with bottom water will revert to circulation or solvent soak in injectors, early conversion from high pressure operations to low pressure operations, has been successful on the field, SOR improves, some wells have CSOR close to 2 after less than 1 year in operation, oil rate and steam chamber conformance is affected”</p>
	<p>“WedgeWell performance-results from B01 WedgeWell promising, not enough data yet to make any conclusions regarding incremental production bottom water, high pressure operation when in direct contact with bottom water can negatively impact oil production rates (in addition to SOR), by carefully using downhole instrumentation to manage water influx, have achieved production rates at B06 pad in line with standard wells in CL, despite bottom water contact A01 pad-co-injection continues to show positive results, pad at 70% recovery on a POIP basis”</p>
	<p>“Steam generation-have achieved rates in excess of design capacity, working with OTSG vendor to prove high quality operation with no increased scaling and no loss of tube wall wetting, no significant scaling increase or increased tube wall temperature noted to date, rigorous monitoring program including NDT, DT and continuous boiler performance monitoring in place”</p>

Articulation scripts in 2012/2013 show narratives about identifying an issue with a phenomenon in the project site; a review of techniques in use at the project site two of which are patented by Cenovus; narration of desirable project performance and reasons identified for the performance; narration concerning the performance of a patented technology in use at the project site; and desirable performance of a section of the project

SECI Element	Scripts Identified
Combination	<p>“Ambient air quality monitoring-passive air monitoring, four passive station locations for the 2012 calendar year, gathered and reported data on calculated sulphur dioxide and calculated hydrogen sulphide, continuous ambient monitoring -2012 monitoring and reporting satisfactory, no criteria</p>

	exceedances were noted in either monitoring program”
	“environmental monitoring programs-wildlife mitigation program, in compliance, wildlife monitoring program, in compliance, caribou mitigation and monitoring program, in compliance”
	“wetlands monitoring program proposal submitted June 2012, SIRs received December 2012, resubmitted May 2013 (approval pending), voluntary monitoring of water quality at Sunday and Monday Creeks, ongoing monitoring planned for 2013; reclamation-annual conservation and reclamation report, commercial footprinting-560ha, focus on reuse of existing disturbances and reduced footprint; wetland reclamation trial program-submitted April 2013(approval pending), reclamation monitoring program, no reclamation opportunities available, extension authorised until December 2014”

Combination scripts identified in 2012/2013 include continued air quality monitoring, environmental monitoring and wetlands monitoring.

SECI Element	Scripts Identified
Internalisation	“bottom water pressure influence-historical disposal into the local bottom aquifer caused high bottom water pressure-what are we doing now-moved disposal to remote location and saw immediate and significant drop in aquifer pressure”
	“MARP – new measurement technology-Delta C installed on B04 pad (February 2012), B02 pad (September 2012)-typically within 10% of incumbent AGAR and Redeye and generally reliable; AGAR installed on B05 pad (April 2013)”
	“additional monitoring wells installed in December 2012 to include EFG footprint, thermal mobilisation of naturally occurring metals in shallow groundwater systems, pilot implemented at FCTP 2011/12”
	“MARP (directive 42)-addressed SIRs received in June 2012, fixed two formulas, add air injection meters to schematic and meter list; proration factors-overall water balance closure monitored on a monthly basis, some higher proration occurred after start-up/commissioning, meters need to be

	calibrated and some logic checked, some months have higher proration error due to production cutbacks due to central processing facility upsets; MARP new measurement technology install nuclear magnetic resonance (NMR) on B05 pad in ~Q4 2013, install Schlumberger on B05 pad in Q3 2013”
	“key changes to monitoring program—logical framework and measurable indicators, alignment with COMS (follows the PERI model), objectives align with impacts identified in EIA”

Internalisation scripts identified in 2013/2014 period include changing of location of a disposal well after learning of a phenomenon occurring at the project site, installation of new technology as directed by the energy regulator, additional monitoring wells drilled to gain more insight into a phenomenon at the project site, correction of techniques in use in the project as per a directive from the operator and changes to a monitoring program in accordance with learnings from an impact assessment study.

2013/2014

SECI Element	Scripts Identified
Externalisation	“geomechanical and surface heave-Integrated InSAR land deformation monitoring took place between March-October 2013 - measurements were successfully made on 62 active corner reflector (CR) locations installed since April 2008; Wabiskaw pressure at CL.- upon retrieving a steam core from a well, an overpressured zone within the sandy tidal flat interval of the Wabiskaw was encountered causing bitumen to flow back through the well bore to the surface, overpressured zone is a result of conductive heating from the underlying steam chamber, the original pressure within the zone increased from 2000kPa to 6500kPa, due to the encounter the coring operations were halted and the well was cased and completed in order to produce the well and depressurise the zone; Cenovus will continue to monitor the wells as one well continues to produce and take necessary action by either recompleting proximal wells to produce and/or

	<p>drill more observation wells for monitoring purposes”</p>
	<p>“methane co-injection experience-co-injection of methane with steam in SAGD has been demonstrated in the field to improve SOR, high percentage of injected methane appears to get produced preventing excessive accumulation in the steam chamber, good understanding of how gas behaves in reservoir, allowed for increased understanding of drainage from I.H.S., co-injection has not demonstrated a negative impact on production and recovery, elevation regional bottom water pressure caused influx of water into A01 pad impacting oil rates and recovery negatively, after first phase of co-injection (shut in in Dec 2006 steam only SAGD operations resumed with no negative impacts, second phase of co-injection is proceeding, CSOR has increased from 2.37 to 2.49 in March 2014, ISOR as of March 2014 is >7.00, need to consider full blowdown of pad, increased gas rates will help reduce bottom water influx issues, rate of recovery is about 0.20% POIP per month; ramp-down/blowdown test plan-conduct a temporary wind-down test on B01 and B02 pads”</p>
	<p>“CL Rise Rate Pilot - location of rise rate was moved to B05-8, modifications to the design were required in order to make the compressor system operational, intent of the pilot was to inject air and steam during the chamber rise phase, monitor if/how the shape of the chamber differs from regular SAGD as it grows vertically, monitor changes in the rate of steam rise, B05-8 steam chamber has connected to gas cap under regular SAGD ops, rise rate control opportunity missed on B05-8, will look for another location in the future”</p>
	<p>“key learnings at CL for 2013-phases ABCDE nameplate oil (138800bbl/day cumulative capacity) achieved Q1 2014 after 6-9 months of oil production, fast ramp-up achieved due to successful start-up strategy, optimised steam injection design, superior reservoir quality; still evaluating different start-up technologies; results from B01 and B02 WedgeWell technology promising”</p>
	<p>“Sulphur Recovery Challenges - Plugging issues - • High temperature excursions during ramp up caused fouling of chemical in contactor and inlet distributor • Spent chemical carry over condensed at downstream pressure control valve and caused plugging issues Preventative Measures • Chemical injection was switched to counter current injection October 2013 to prevent fouling of internal distributor • Three</p>

	<p>additional produced gas aerial coolers were added in May 2013 to maintain inlet air temp < 40°C • Downstream valve trim upsized to prevent condensation / fouling of spent chemical in valve</p> <ul style="list-style-type: none"> • Each train is on a 6 month PM to be cleaned (contactor, internal distributor, outlet separator demister inspected)”
	<p>“Steam Generation Steam generation via 15 OTSGs• Design capacity of 39,523 m3/d CWE dry steam• Have achieved rates in excess of 41,300 m3/d CWE dry steam• Typical operation: 80 to 85% quality, but have tested a single unit at >90% qualities• Working with OTSG vendor to prove high quality operation with no increased scaling and no loss of tube wall wetting • No significant scaling increase or increased tube wall temperature noted to date • Rigorous monitoring program including NDT, DT, and continuous boiler performance monitoring in place”</p>
	<p>A02-2 Isolated SAP test-inject solvent along with steam, solvents aid in reducing the viscosity of the oil, benefits of SAP-reduced CSOR, improved oil recovery, improved oil quality, possibility of wider well spacing, solvent is produced from production well and can be recycled and re-injected, several SAP pilots have been tested by Cenovus</p>
	<p>Surfactant Steam Process (SSP)-pilot description-SSP co-inject surfactant at 0.30%wt%of steam rate, the pilot needs to be operated for longer period in order to have a more meaningful evaluation of the SSP process</p>

Articulation scripts identified in 2013/2014 learnings from a monitoring exercise, narration of experience to date with a technique in use at the project site, change of site of a project technique in review to a different location within the project, review of project performance that showed desirable performance, narration of challenges in operating a new technology in the project site and learnings from use of various technologies within the project.

SECI Element	Scripts Identified
Combination	“Environmental Monitoring Programs: Wildlife: Wildlife Mitigation Program, Wildlife Monitoring Program, Caribou Mitigation and Monitoring Program Soil -

	<p>Soil Monitoring Program completed in 2008 – no industrial impacts - Soil Monitoring Program to be implemented in the summer of 2014 Groundwater - Annual groundwater monitoring – no material changes”</p>
	<p>“information requested from AER May 13 2014-follow up and B02 bottom water influx-bottom water influx due to regionally elevated bottom water pressure, risk of flooding B01, B02 chambers similar to challenges on A01 pad, large developed steam chamber therefore re-pressurisation with steam would not be sufficient, able to inject natural gas into gas cap to support chamber pressures and bring us in balance with bottom water pressure, path forward continue to inject natural gas into gas cap until bottom water pressure reached, once 2700kPag is reached transition to ramp-down/blowdown phase on B02-1 through B02-4 and B01-1 through B01-4”</p>
	<p>“Ambient Air Quality Monitoring - Passive Exposure Monitoring - Passive exposure monitoring was conducted for SO₂ and H₂S at the AESRD approved passive monitoring locations from January through December, 2013 The passive monitoring results in 2013 did not identify any significant air quality issues related to Plant operations • The continuous ambient air quality monitoring in 2013 did not identify any significant air quality issues related to Plant operations. No criteria exceedances were noted in either monitoring program”</p>
	<p>“In 2013, continuous air quality monitoring was conducted from July 1 to December 31 by Maxxam Analytics. The continuous ambient air monitoring station is located approximately at 03-16-076-06-W4M. This location is the same as the passive monitoring station C10. Parameters measured were SO₂, H₂S, NO₂, wind speed and direction. There were no operational issues relating to the ambient air monitoring equipment during the monitoring period”</p>

Combination scripts identified in 2013/2014 show a continued monitoring and reporting of impacts to the environment by the project, additional information requested by the regulator regarding phenomena at a location in the project site and a separate monitoring exercise that was conducted by an outside party and revealed the same results as the internal monitoring program

SECI Element	Scripts Identified
Internalisation	<p>Slop Treatment – Hydro cyclone • Hydro cyclone equipment installed to concentrate high BS&W slop oil feed to crude flash unit; water phase recycled to skim tank</p> <ul style="list-style-type: none"> • Commercial installation not tested due to feedstock availability, however pilot demonstration showed concentration of BS&W from 80% to 50%
	<p>MARP – New Measurement Technology - Water cut meters:</p> <ul style="list-style-type: none"> • Delta C installed on B04 pad (February 2012), B02 pad (September 2012) – Installing data logger and sampling system on B04 pad to collect raw data for improved calibration. Multi-Phase flow meters: • AGAR MPFM-50 installed on B05 pad Aug 2012 and trialed until Oct 2013. • Still plan on using test separator for well testing. Reviewing MPFM technology for future trials and where it could be applicable in well testing.

In the 2013/2014 period, internalisation scripts identified include installation of operational equipment after a pilot test and installation of new technology after a directive from the regulator

2014/2015

SECI Element	Scripts Identified
Externalisation	<p>“SAGD Well Pressure Instrumentation - At Christina Lake all production and injector wells are equipped with bubble tubes to measure downhole pressures - Currently there are 2 sizes of bubbles tubes - 38/inch and 12/inch - We are replacing all 38/inch bubble tubes with 12/inch to increase reliability. Fibre pressure gauges have been trialed with poor results. Moving forward bubble tubes will continue to be the pressure instrumentation of choice at Christina</p>

	Lake”
	<p>“B02-1 iSOR in 2014 - Why is B02P01 iSOR so high in 2014? Declining production rates – has been declining since 2010 - Has produced over 2,700,000 bbl. of oil - Recovery rates of 76% - Decline further accelerated by the B02W03 and B02W06 start-ups - Continue to maintain steam rates for B02 pad pressure support and blowdown trial baseline - B02 Pad is operated on a pad level – not overly concerned with an individual well having a high iSOR on this pad”</p>
	<p>“Methane co-injection experience (2007 - 2014) - Co-injection of methane with steam in SAGD has been demonstrated in the field to improve SOR - High percentage of injected methane appears to get produced preventing excessive accumulation in the steam chamber - Good understanding of how gas behaves in reservoir - allow for increased understanding of drainage from I.H.S - Pad partial/full blowdown as of November 2014 - Steam shut-in and chamber pressure being increased through methane injection in order to mitigate bottom water influx Pad partial/full blowdown as of November 2014 - November 2014: steam ramp down began on the entire pad - February 2015: full steam shut-in to all wells on the pad. Pressure maintenance continued through natural gas injection - current chamber average operating pressure ~ 2100 kPag - so far no negative impact has been observed with the pad operations as a result of full methane injection. It’s too early to comment on the trial performance - average concentration for Nov 2014 – March 2015 - average methane injection rate 16 e3m3/d - CSOR has been maintained at 2.53 from November 2014 to March 2015 following a steady increase prior to steam ramp down”</p>
	<p>“Current A02-2 pilot - Currently in low pressure ESP phase - Injector BHP avg 2325 kPa - Recycled butane injection only, no make-up butane at this time - Will transfer butane injection over to A02-1 - Received blowdown approval on A02-2 - A02-2 Conclusions - We believe SAP has resulted in lower than usual SOR - We believe SAP has resulted in faster steam chamber lateral growth that could affect future well spacing - Current butane recovery is 65% and will increase during blowdown (we do not believe that we have lost much butane to thief zones) - We believe that SAP has not resulted in dramatically higher rates due to geology and well profile”</p>
	<p>“SSP pilot description - Surfactant steam process (SSP) - Co-inject surfactant at</p>

	<p><0.30 wt% of steam rate - SSP well operation overview - July 2013 – First Steam - August 2013 – Conversion to gas lift - November 2013 – HP ESP (4000 kPa BHP) - January 2014 – Surfactant-steam co-injection begins Surfactant-1 à B11-10 Surfactant-2 à B11-11 - June 2014- Present – LP ESP (2800 kPa BHP) - Results are promising, however steam chambers have communicated with neighbouring wells and the overlaying gas cap, therefore more results are required - Plan to continue the pilot to the end of 2015”</p>
	<p>CondensSAP pilot – CondensSAP - Using condensate mix as solvent B01-7 CondensSAP -Well pair currently operating on ESP, Solvent injection: December 2012 to December 2013, Currently bringing pressure in balance with gas cap, B01 CondensSAP conclusions - Relatively poor geology and facility issues have not allowed steady operation nor steady injection of condensate, Pressure readings suggest that we have connected to the neighbouring gas cap, This would explain the low solvent recovery, We do not have conclusive results from this pilot and it may have to be repeated.”</p>

Articulation scripts in 2014/2015 include change in equipment in use at the project site to improve pressure measurement reliability, narration indicating concern of increasing SOR and declining production at a production pad at the project site, narration of experience in using a technique for a period of seven years between 2007-2014 and the learnings accrued and narration regarding pilot exercises currently underway at the project site.

SECI Element	Scripts Identified
Internalisation	<p>“What is SAP? - Solvent-aided process is a technological enhancement applied to our SAGD operations that helps us maximize the amount of oil recovered. Small amounts of solvent such as light alkanes (e.g. butane) or natural gas liquids are co-injected with steam to enhance the oil recovery process and improve associated project economics. Solvents primarily decrease SOR, thereby reducing the water usage. Reduction in water usage means lower CAPEX and OPEX required to process the water. Reduced water usage leads to fewer GHG emissions, and smaller footprint. Solvents accelerate the oil</p>

	production rate and reduce the steam usage, leading to a lower SOR, increased revenue and increased reserves. A02-2 SAP at CL : 30% SOR reduction and 20% increase in production - Co-injection of light alkanes along with steam allows for wider well spacing, which leads to smaller footprint, lower capital cost and higher revenue”
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An internalisation script identified in 2014/2015 shows a description of a technique that was piloted at the project site and after use and review certain learnings were gleaned and articulated by the company.

SECI Element Socialisation

As is evidenced from the data above, the SECI element of socialisation could not be identified in the documents analysed. As a result of this, a questionnaire was developed to fill this gap in the model. The questionnaire was developed to find out:

Sources of knowledge regarding the project

From preliminary data in the documents analysed, certain sources of knowledge could be identified namely: the Alberta Energy Regulator (AER), the Alberta Environment and Parks (AEP), experimentation, prior experience, internal studies, external studies, incidences, public consultations and other sources. The questions were posed in the form of a Likert scale from 1 meaning least likely to have gained knowledge from those sources to 5 meaning most likely to have gained knowledge from those sources. The results are summarised in the following table:

How likely is it that Cenovus has gained knowledge from the following: AER, AEP, experimentation, prior experience,	Most likely
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internal studies, external studies, incidences, public consultations	
Please state if and how Cenovus has gained knowledge from other sources regarding the Christina Lake project	Entrepreneurs, venture capitalists, NGO, Government

Impact of knowledge gained from various sources on the project

The impact of knowledge gained from various sources was put on a Likert scale from 1 being least likely that knowledge gained from a source had an impact on the Cenovus Christina Lake project to 5 being most likely that knowledge from a given source had an impact on the project. The sources identified from various data sources were: AER, AEP, public consultations, consultations with indigenous people, academic institutions, media, internal studies, external studies and reports, reportable incidents, experimentation and complaints received. On all data sources, all were marked as most likely. This indicates that knowledge from all the sources mentioned could have had an impact on the Christina Lake project.

Relational embeddedness, cognitive embeddedness, absorptive capacity and motivation

As derived from (Bakker, Cambre, Korlaar, & Raab, 2011), relational embeddedness, cognitive embeddedness, absorptive capacity and motivation were measured as factors that may influence the transfer of knowledge from one source to another. The sources identified were – AER, AEP, academic institutions in Alberta, other research institutions, residents, indigenous people and the media. The factors were measured as perception of the strength of the relationship between Cenovus and the different actors, strength of shared interests, value

of knowledge and perceived willingness of actors to share knowledge regarding the project.

The results are summarised in the table below:

Relational embeddedness	On this question, the relationships between Cenovus and AER, AEP, residents, and indigenous people were ranked 5 while the relationships between Cenovus and academic institutions, other research institutions, and the media were ranked 4
Cognitive embeddedness	On this question, the perceived shared interests between Cenovus and AER, AEP, academic institutions in Alberta, other research institutions, residents, indigenous peoples and media were all ranked 5
Absorptive capacity	<p>This factor was covered by two questions:</p> <ul style="list-style-type: none"> a. Knowledge from AER, AEP, academic institutions in Alberta, other research institutions, residents, indigenous peoples and media were all ranked 5 as being perceived as valuable by Cenovus b. Likelihood of knowledge from the above mentioned actors to be incorporated into the Christina Lake project was ranked 5 for AER, AEP, academic institutions in Alberta, residents and indigenous people and was ranked 4 for other research institutions and media
Motivation	The perceived willingness of AER, AEP, academic institutions in Alberta, other research institutions, residents, indigenous peoples and the media were all ranked 5

The project “Ba”

As interaction is a key concept in understanding ba (Umemoto), I sought to identify locales or spaces where individuals interacted between each other or between them and their environments in the Christina Lake project.

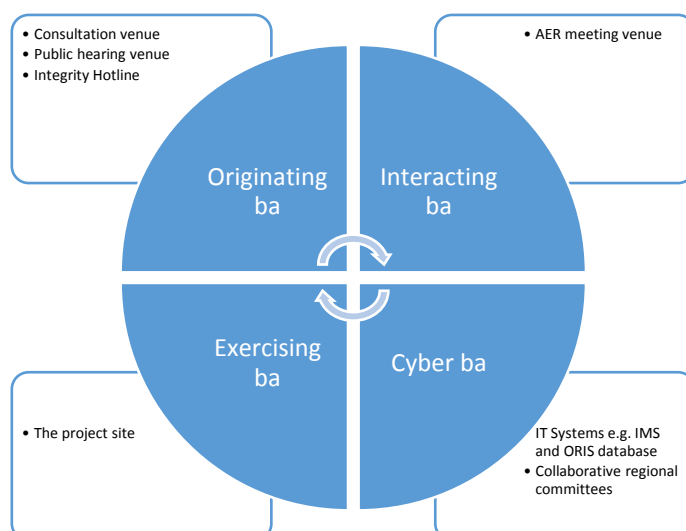
1. Originating Ba – this should be a locale where individuals can share feelings, emotions, experiences and perceptual models (Rice & Rice, 2002). Originating ba in the Cenovus Christina Lake project includes:
 - a. Consultation venue: This was the venue of the consultation exercise that was held as a requirement by regulatory directives. However, due to time constraints during the writing of this thesis, it was not possible to ascertain the location of the consultation meeting.
 - b. Public hearing venue: This was the venue for the public hearing exercise that was held before commencement of the project. Due to time constraints during writing of this thesis, details of the public hearing could not be retrieved; neither could the venue of the public hearing be ascertained.
 - c. Externally, Cenovus has provided an integrity hotline where concerned stakeholders can let the company know about any issues and how the company’s operations are conducted
2. Interacting Ba – this should be a space where tacit knowledge is transferred and documented to explicit form, key factors being through dialogue and metaphor creation (Rice & Rice, 2002). Ideally, the creative development of systems to facilitate the transfer of newly categorised knowledge into a form that will be of use to groups beyond the creators of the knowledge (Rice & Rice, 2002). Examples include
 - a. AER annual presentation meetings

3. Cyber/Systemising Ba – this should be a virtual space where IT facilitates the recombination of existing explicit knowledge to form a new explicit knowledge (Rice & Rice, 2002). Emphasis should be on collaborative efforts to develop and share newly aggregated learning, often employing IT to facilitate asynchronous learning and the contribution of various groups and constituencies in the development of an organisational knowledge asset. Cenovus energy had created various platforms for knowledge sharing within the Christina Lake project:
 - a. IT systems in place for monitoring were identified. These were the Incidence Management System and the ORIS database for monitoring phenomena within the project
 - b. Cenovus was involved in several collaborative regional committees which included members of industry and the indigenous communities. These committees include:
 - i. Regional hydrogeology committee – purpose of hydrogeology committee is to share hydrogeology information among regional SAGD producers and arrive at one regional hydrogeology model
 - ii. Regional Environmental Monitoring Association – regional focus group which will provide monitoring of wildlife, water, air and wetland at a regional scale. The committee is an industry committee with community representatives committed to developing collecting, analysing and communicating environmental monitoring data from the Southern Athabasca region.
 - iii. Alberta Biodiversity Monitoring Institute (ABMI)
 - iv. Wood Buffalo Environmental Association (WEBA)
 - v. Regional Aquatics Monitoring Program (RAMP)

4. Exercising Ba – a space where explicit knowledge is converted to tacit knowledge (Rice & Rice, 2002). Focus here is on the transfer and internalisation of shared organisational knowledge back to individual workers’ knowledge and routines (Rice & Rice, 2002).
 - a. The Cenovus Christina Lake project site which is an avenue for transferring explicit knowledge to tacit knowledge through application of the explicit knowledge in the real world

Chapter Summary

I have gone through the various stages of analysing the Cenovus presentation reports using the SECI model. This has revealed that knowledge creation can be viewed as a spiral process of conversion from tacit knowledge to explicit knowledge. I applied the SECI model simplistically to the data and the results show that the knowledge creation process spiral was evident at the Cenovus Christina Lake project. There was evidence of tacit knowledge from the previous year being used as a basis for explicit knowledge in the following year, tacit knowledge gained from experimentation being articulated and converted to explicit knowledge, and constant monitoring which resulted in more explicit knowledge within the project. Various ba were also identified as well within the project. These ba were the platforms for knowledge transfer and could be mapped onto the SECI model



Chapter 5: Discussion of Findings and Proposal for Future Research

Discussion of findings

Knowledge creation in the SECI model takes the form of a spiral in which knowledge converts from tacit to tacit, tacit to explicit, explicit to explicit and explicit to tacit. Once the spiral is complete, this new tacit knowledge forms the basis for the next cycle of knowledge creation. Although this makes it impractical to quantitatively analyse data derived by use of the SECI model, the model does offer beneficial learnings from data. A close analysis of the data reveals the following regarding the Cenovus Christina Lake project:

1. Cenovus has a wide range of knowledge sources. Knowledge sources identified include

a. Regulatory authorities such as the AER and the AEP

The regulatory authorities played an important part in knowledge creation within the project. They would act as a standard enforcer through annual audits of operations in the project site. They would give a vote of confidence in the project when the audits showed the operations were being conducted according to directives issued and in case of infractions they would point them out and Cenovus would correct the mistakes. This enabled Cenovus know more about the project and areas that they may improve within the project. The regulatory authorities would require regular reports regarding the project such as environmental monitoring reports. This would encourage Cenovus to gather knowledge through constant monitoring of the project and its impacts on the environment

b. From experimentation

An analysis of the data reveals that during the period between 2003 and 2015, Cenovus would conduct various experiments to understand more about the project. These experiments include the SAP tests and the WedgeWell tests that would

eventually lead to the patenting of the WedgeWell technology. Putting explicit knowledge to practice through experimentation enabled Cenovus to gather more knowledge regarding phenomenon within the project, improve operational processes, develop new processes and technology and learn about the use of that new technology and its impacts on the project.

c. From prior experience

During the project, Cenovus would apply learnings from their other SAGD project which is located in Foster Creek to the project in Christina Lake.

d. From internal studies

In the project documents analysed, Cenovus conducted a number of internal studies such as the water re-use study, McMurray water source study, core vertical perm study and geology study to understand the project phenomena better.

e. From external studies

Cenovus was involved in a number of regional committees whose task was to gather information on various phenomena around the Christina Lake area where similar projects were taking place.

f. From new technologies

Cenovus applied new technologies in the project site and articulated knowledge gathered by application of the new technologies. This included installation of new meters for measurement of gas flaring volumes, chamber pressure and water usage. From the data analysed, the technology was adopted either as a result of regulatory directives or as a result of Cenovus constantly looking for alternative technologies in the market

g. From Incidents

A number of incidences were self-reported by Cenovus to the regulator and corrections were made. Some incidences were minor such as contracted driver disposing cement wrongly while others were major such as overpressure in the SAGD chamber.

- h. From the questionnaire sent to Cenovus, other sources of knowledge identified were NGOs, venture capitalists, and the government
2. Although Cenovus has taken various steps to create platforms or ba for interaction, there remains areas for improvement in some cases:
- a. Originating ba can be closely mapped onto the socialisation stage in the SECI model. From the data analysed, with the exception of an integrity helpline, there is no evident platform for sharing of knowledge among different actors in the case of the Christina Lake project.
 - b. Interacting ba can be closely mapped onto the externalisation phase in the SECI model. With the exception of the AER meetings where the presentations are made by Cenovus, there is no evident platform where various actors can share narratives and metaphors regarding the project.
 - c. Cyber/Systemising ba is evident in the committees Cenovus is engaged in and chairing regarding oil sands development in the region. The focus here is a platform for collaboration and sharing of newly learned knowledge and it can be seen that Cenovus, through the various collaborative committees provided a platform for knowledge sharing among industry competitors and community representatives. Cenovus also maintains an Incidence Management System (IMS) as well as the ORIS database.
 - d. Practicing ba – the project site is the most evident practicing platform where Cenovus conducted various tests and experiments during the period 2003-2015

Implications for Management

1. Cenovus maintains a large source of knowledge sources for the Christina Lake project. At least 10 knowledge sources are identified in the study. Maintaining this large repertoire of knowledge sources allows Cenovus to maintain a large database of knowledge from which to tap from unique knowledge to aid in the development of new processes and technologies. Project managers should seek to have as large a number of knowledge sources as possible.
2. Cenovus conducts studies that go beyond the realm of operations in the project such as Chipewyan Prairie First Nations Traditional Food Study. These studies although outside of the realm of operations in the project help better understand the project stakeholders and bring Cenovus to a point where they better understand the concerns of the indigenous peoples. This allows for easier exchange of tacit knowledge between Cenovus and the indigenous people and helps convert some of their tacit knowledge to explicit knowledge. This implies that project managers should seek to understand fully the impacts of the projects they manage and should seek information and knowledge beyond the realm of the project that they are managing.
3. Do not be afraid to experiment. Cenovus conducted and continues to conduct multiple experiments on the project site some with success such as the WedgeWell which was later patented and some fail to produce desirable results such as the reverse gravity circulation technique which was tried but did not show any improvement as compared to the ordinary circulation technique. Where possible, project managers should encourage experimentation as it is a beneficial source of tacit knowledge which may lead to creation of new techniques and technologies.
4. Constant monitoring throughout the period covered in the documents studied, Cenovus maintained constant monitoring of different phenomena within the project. Although some of the monitoring was mandatory as per energy regulatory directives, there was voluntary

monitoring carried out by Cenovus such as water quality monitoring of the Sunday and Monday Creek. Cenovus also maintains an incidence management system as well as the ORIS database for monitoring the project. This implies that project managers should set up monitoring systems as soon as the project commences and should also monitor impacts of the projects they manage and where possible beyond the realm of what is required by regulation.

5. Collaborative knowledge creation platforms – with relation to the spatial concept of ba, it is seen that with the exception of the interacting ba, Cenovus had provided collaborative platforms where knowledge could be exchanged in all phases of the SECI model. The concept of ba allow project managers to identify gaps in knowledge creation opportunities in the project setting thereby enabling them to put up platforms to capture knowledge within the project setting
6. The project setting as a learning space. This study has shown that a project setting can be a valuable learning space for a company. This knowledge can become a unique asset to the company and enable it to apply it to new projects to great success.

Conclusion

This thesis adapted the SECI knowledge creation spiral to a major upstream oil project. From an analysis of various documents, different aspects of the SECI model were identified throughout a duration of 12 years from 2003-2015. From analysis of the data using the SECI model, different sources of knowledge were identified throughout the period. The questionnaire revealed different sources of knowledge that Cenovus tapped into during the years analysed, how they perceived these sources of knowledge in terms of their relational embeddedness, cognitive embeddedness, absorptive capacity and motivation. Although Cenovus perceives itself to value the strength of relationships, to share interests with, to value

the knowledge gained from various actors, there was evident failure in creating platforms where various actors could share knowledge with the company regarding the Christina Lake project yet the perception of the company was that various actors were willing to contribute knowledge with regard to the project. In the externalisation phase of the SECI model as evidenced from the data on the Christina Lake project, there were numerous narratives from the company regarding the project but there was a lack of evidence of a platform where such narratives could be shared. The AER meeting proceedings, from which the data analysed in this thesis was derived, is the only evident platform which enabled sharing of narratives and metaphors regarding the Christina Lake project. In the combination phase of the SECI model, it was evident from the data that Cenovus was engaged in constant monitoring of the project as well as the impacts of the project on the environment and surrounding communities. This maps well onto the combination phase as it is where explicit knowledge is combined with more explicit knowledge to form new knowledge. Finally the internalisation phase of the model was evident by the number of trials, tests and experiments that Cenovus conducted on the project site and the various patented technologies that resulted from knowledge gained from those experiments. Although the thesis took a simplified view of the SECI model and adapted it to a project setting, it is believed by this author that it provided intuitive insights into knowledge creation in project settings that can benefit companies undertaking projects to view them as knowledge generating ventures.

Proposed Areas of Research

<i>Ba</i> SECI	Originating	Interacting/ Dialoguing	Cyber/ Systemising	Exercising
Socialisation	1	2	3	4
Externalisation	5	6	7	8
Combination	9	10	11	12
Internalisation	13	14	15	16

Literature exists regarding areas marked 1, 6, 11, 16 from (Nonaka I. , 1994), (Nonaka & Noboru, 1998) among others. However, I propose a model that includes all ba in the various phases of the SECI model as shown above:

- a. Incorporate interacting, cyber/systemising and exercising ba into the socialisation phase of the SECI model – interacting ba is the platform where narratives and metaphors are shared among different actors, cyber ba is where collaboration among different actors occurs through the use of IT, exercising ba is where explicit knowledge is put into practice. The model proposed by this author is one where during the socialisation phase of the SECI model, platforms are put in place to support the different ba elements. This could be a collaborative platform that allows for different narratives and metaphors to be shared among different actors through the use of IT and allow for some form of trying out the combined knowledge through simulation or testing in the real world. This is represented by gaps 2, 3, and 4 in the table above
- b. Incorporate originating, cyber/systemising and exercising ba into the externalisation phase of the SECI model – this author proposes that a platform for socialising to share experiences and tacit knowledge, a collaborative platform through the use of IT and an

exercising platform be available during the externalisation phase of the SECI model represented by gaps 5,7, and 8

- c. Incorporate originating, interacting and exercising ba into the combination phase of the SECI model – this author proposes that a platform for sharing experiences and tacit knowledge, sharing metaphors and narratives and putting into practice newly gained tacit knowledge be made available during the combination phase of the SECI model, represented by gaps 9,10, and 12 in the table above
- d. Incorporate originating, interacting and cyber ba into the internalisation phase of the SECI model – this author proposes that there be incorporated a platform for sharing tacit knowledge, sharing metaphors and narratives and collaborating different explicit knowledge during the internalisation phase of the SECI model, represented by gaps 13, 14 and 15 above.

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Appendix 1 – Questionnaire sent to Cenovus Energy

4/26/2016

Cenovus Energy Questionnaire

Cenovus Energy Questionnaire

Dear Sir/Madam

Thank you for agreeing to participate in this survey. This questionnaire is part of a case study research for the completion of a Master of Science Energy Management thesis. The research seeks to analyse how knowledge flows among different actors within a project setting and how this in turn affects the project. The questions are kept as short and simple as possible and this exercise will only take a few minutes to complete. By completing this questionnaire you agree that the information provided will be treated with utmost confidentiality.

* Required

1. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from the Alberta Energy Regulator (AER) regarding the Christina Lake oil sands project *

Mark only one oval.

	1	2	3	4	5	
Least Likely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Most likely

2. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from the Alberta Environment and Parks (AEP) regarding the Christina Lake oil sands project *

Mark only one oval.

	1	2	3	4	5	
Least Likely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Most likely

3. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from experimentation at the Christina Lake oil sands project? *

Mark only one oval.

	1	2	3	4	5	
Least Likely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Most likely

4. On a scale of 1 through 5, please indicate how likely it is that Cenovus has knowledge from prior experience at the Christina Lake oil sands project? *

Mark only one oval.

	1	2	3	4	5	
Least Likely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Most likely

5. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from internal studies (research initiated from within the company) at the Christina Lake oil sands project? *

Mark only one oval.

1 2 3 4 5

Least Likely Most likely

6. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from external studies (research initiated from outside the company) at the Christina Lake oil sands project? *

Mark only one oval.

1 2 3 4 5

Least Likely Most likely

7. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from incidents that occur at the Christina Lake oil sands project? *

Mark only one oval.

1 2 3 4 5

Least Likely Most likely

8. On a scale of 1 through 5, please indicate how likely it is that Cenovus has gained knowledge from public consultations regarding the Christina Lake oil sands project? *

Mark only one oval.

1 2 3 4 5

Least Likely Most likely

9. Please state if and how Cenovus has gained knowledge from other sources regarding the Christina Lake oil sands project? *

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10. On a scale of 1 through 5 (one being the least impact and 5 being the most impact), please indicate the degree to which knowledge gained from the following has impacted the Christina Lake project *

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Public Consultations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consultations with Indigenous Peoples	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Internal Studies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
External Studies and Reports	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reportable Incidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Experimentation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Complaints Received	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. On a scale of 1 through 5 (1 being weakest and 5 being strongest), please rate the strength of the relationship between Cenovus and the following actors with regard to the Christina Lake Project

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions in Alberta	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Residents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous people (First Nations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

12. On a scale of 1 through 5 (1 being weakest and 5 being strongest), please rate the strength of shared interests between Cenovus and the following actors with regard to the Christina Lake Project

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions in Alberta	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Residents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous people (First Nations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. On a scale of 1 through 5 (1 being lowest and 5 being highest), please rate the value of knowledge gained from the following actors with regard to the Christina Lake Project

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions in Alberta	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Residents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous people (First Nations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. On a scale of 1 through 5 (1 being weakest and 5 being strongest), please rate the perceived willingness of the following actors to share knowledge with Cenovus with regard to the Christina Lake Project

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions in Alberta	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Residents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous people (First Nations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. On a scale of 1 through 5 (1 being lowest and 5 being highest), please indicate Cenovus' likelihood to incorporate knowledge received from the following actors into the Christina Lake project

Mark only one oval per row.

	1	2	3	4	5
Alberta Energy Regulator (AER)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alberta Environment and Parks (AEP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Institutions in Alberta	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Residents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous people (First Nations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Appendix 2 – List of Data Sources

These were accessed from the Alberta Energy Regulator (AER) website. They are publicly accessible via the public archives

1. 2003 Athabasca EnCana Christina Lake SAGD 8591 – Christina Lake Thermal Project EUB Presentation – May 6th 2003
2. 2004 Athabasca EnCana Christina Lake SAGD 8591 – EnCana – AEUB In Situ update – May 4th 2004
3. 2005 Athabasca EnCana Christina Lake SAGD 8591 – 2005 In Situ Update
4. 2006 Athabasca EnCana Christina Lake SAGD 8591 – EnCana Christina Lake In Situ Oil Sands Scheme 2006 Update – May 25th 2006
5. 2007 Athabasca EnCana Christina Lake SAGD 8591 – EnCana Christina Lake In Situ Oil Sands Scheme 2007 Update – June 8th 2007
6. 2008 Athabasca EnCana Christina Lake SAGD 8591 – EnCana Christina Lake In Situ Oil Sands Scheme 2008 Update – June 27th 2008
7. 2009 Athabasca EnCana Christina Lake SAGD 8591 – EnCana Christina Lake In Situ Oil Sands Scheme 2009 Update – June 12th 2009
8. 2010 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2010 Update – June 8th 2010
9. 2011 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2011 Update – June 16th 2011
10. 2012 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2011-2012 Update – June 21st 2012
11. 2013 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2012-2013 Update – June 19th 2013
12. 2014 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2013 Update – June 4th 2014
13. 2015 Athabasca Cenovus Christina Lake SAGD 8591 – Cenovus Christina Lake In Situ Oil Sands Scheme 2015 update – June 24th 2015