PETROLEUM TECHNOLOGY ALLIANCE CANADA

Proppant Surface Treatment and Well Stimulation for Tight Oil and Shale Gas Development

Final Report
March 31, 2016

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Disclaimer

Executive Summary

This final report summarizes outcomes for the project Proppant Surface Treatment and Well Stimulation for Tight Oil and Shale Gas Development undertaken by PTAC Petroleum Technology Alliance Canada (PTAC) in collaboration with 3M Canada and two senior oil and gas companies in Western Canada, from September 25, 2015 to March 31, 2016.

The project evaluated 2 new technologies for production of shale gas and tight oil using hydraulic fracturing. Despite being a successful production technology, hydraulic fracturing has raised concerns about environmental impact. In addition, the sustainability of current production methods has been in question particularly with respect to the rate of recovery, the rate of production decline and high costs.

The new Proppant Surface Treatment (PST) and Well Stimulation (WS) technologies investigated in this project offers the opportunity to improve the sustainability of production and to reduce the intensity of environmental impacts. PST and WS are based on a chemical treatment developed by 3M Canada that modifies the surface of sand to make it neutral wet, reducing surface tension and causing liquids, such as oil, condensate and water, not to cling to sand surfaces, and instead to flow more easily. In PST, ordinary sand proppant is replaced by treated sand and the completion program is otherwise unchanged. In WS, the wellbore and the fractures themselves are treated in a remedial operation applied to an existing well to remove accumulations of liquids in the fractures that would impede the flow of hydrocarbons. PST and WS increase the efficiency of hydrocarbon extraction. Therefore, water consumption intensity is reduced because more hydrocarbons are produced from the original water injection volume. There is no water directly required to implement the PST or WS technologies.

The objectives of the project were (1) to understand challenges and opportunities in the Duvernay Play, (2) to understand challenges and opportunities in the Bakken Play, (3) to perform a proof of concept well test of the WS technology in Western Canada, (4) to analyse the performance of PST trials in Western Canada, and (5) final reporting and dissemination of outcomes. The project met all objectives and delivered the following achievements:

1. The Duvernay Play was analysed and summarized for stakeholders; technology needs and opportunities were identified.
2. The Bakken Play was analysed and summarized.
3. The field demonstration of the WS technology successfully took place in a well operated by a Canadian oil and gas company and the results were analysed.
4. The field demonstration of the PST technology by a second oil and gas company in Western Canada was analysed.
5. The analysis of the WS and PST field trials were performed by 2 subject matter experts and concluded that the technologies resulted in increased condensate production which is beneficial from the point of view of economics and the environment. The results were disseminated in presentations at a PTAC workshop.

The benefits of the project were (1) the identification of technology opportunities for hydraulic fracturing in Western Canada, (2) the demonstration that the WS and PST technologies could be effectively implemented in the Western Canadian Sedimentary Basin, and (3) that both PST and WS resulted in higher condensate production which will improve production economics and lower the intensity of environmental impact.

The next application of the PST and WS technologies is recommended to be in unsaturated gas condensate or oil reservoirs.

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1 Introduction

This report provides a final account of the project *Proppant Surface Treatment and Well Stimulation for Tight Oil and Shale Gas Development* undertaken by PTAC Petroleum Technology Alliance Canada (PTAC) in collaboration with 3M Canada, and two senior oil and gas companies in Western Canada.

Production from shale gas and tight oil resources has surged in North America due to new hydraulic fracturing technologies and this development has profound implications for Canada. In Alberta, light oil production has increased due to contributions from tight zones in formations such as the Cardium and Viking; in addition, significant growth could take place if the Duvernay and Montney formations are found economic to develop. In Saskatchewan, tight oil production from the Bakken formation has been significant. In British Columbia, prolific production of shale gas has created new opportunities for export of Liquefied Natural Gas (LNG).

While a successful production technology, hydraulic fracturing has raised concerns about environmental impact, particularly concerning water, greenhouse gas (GHG) emissions, social impact from truck traffic and industrial activity, and the possibility of triggering earthquakes. In addition, the sustainability of current production methods has been in question particularly with respect to the rate of recovery, the rate of production decline and high costs.

- Low resource recovery. While unconventional resources are estimated to be very large, the economically recoverable amount based on current technologies is less than 10% and in some geological formations, less than 5%. New recovery technologies are required to maximize resource potential.
- High rates of production decline. While production rates are high initially, which provides the benefit of rapid payback, they decline rapidly and the production infrastructure becomes underutilized. Opportunities would exist to enhance production from existing assets from secondary or enhanced recovery schemes.
- High costs. Hydraulically fractured horizontal wells are very costly. Completions costs can also be very high due to the large water requirements. Well and fracture density may be high as a result of the low recovery factor. These characteristics and others offer many opportunities for reducing costs through technology development.

The new Proppant Surface Treatment (PST) and Well Stimulation (WS) technologies investigated in this project offers the opportunity to improve the sustainability of production and to reduce the intensity of environmental impacts.

2 Background

During hydraulic fracturing, a fluid, generally water or oil, is pumped into the reservoir at a high rate and at a pressure high enough to cause the reservoir rock to fracture. The purpose of fracturing the rock is to create channels to enhance the flow of oil and/or gas to the wellbore. When the injection of the fracturing fluid is stopped, the fractures will want to close due to the absence of hydraulic pressure. So, a proppant, typically fine sand with a uniform particle size distribution, is added to the fracturing fluid to keep the fractures open after the removal of hydraulic pressure and to permit free flow of the hydrocarbon resource being extracted.

Since oil and/or gas must flow through the fractures in order to be produced, methods to enhance flow through the fractures would directly result in higher production rates.

PST and WS technologies provide innovative new fracturing techniques for shale gas and tight oil. They are based on a chemical treatment developed by 3M Canada. The 3M chemical treatment modifies the surface of sand to make it neutral wet, reducing surface tension and causing liquids, such as oil, condensate and water, not to cling to sand surfaces, and instead to flow more easily. In PST, ordinary sand proppant is replaced by treated sand and the completion program is otherwise unchanged. In WS, the wellbore and the fractures themselves are treated in a remedial operation applied to an existing well to remove accumulations of liquids in the fractures that would impede the flow of hydrocarbons.

PST and WS increase the efficiency of hydrocarbon extraction. Therefore, water consumption intensity is reduced because more hydrocarbons are produced from the original water injection volume. There is no water directly required to implement the PST or WS technologies.

The project builds on previous work in which more than 9 field tests were conducted by 3M partners outside of Canada to assess the technology. In the last 2 years, PST was tried on a limited basis by 2 producers in western Canada with promising, but non-conclusive results. This prior development work resulted in a better understanding of how to apply the technology to oil and gas formations in Canada and this knowledge was applied to the well tests in this project.

3 Objectives

The objectives of this project are to understand how best to apply and to measure the performance of the 3M chemical treatment technology which is deployed through the PST and WS technologies, which are innovative new fracturing techniques for shale gas and tight oil. The project will provide a better understanding of the production and environmental benefits of the application of these technologies in western Canada.

3.1 Objective 1 – Technology Opportunities in the Duvernay Play

- The objective was to understand challenges and opportunities in order to maximize potential and returns, particularly to local communities and to identify technology development opportunities that would maximize benefits while minimizing environmental impact.
- The project was completed and the outcomes were captured in a final report and presentation at a stakeholders' workshop on February 22, 2016.

3.2 Objective 2 – Technology Opportunities in the Bakken Play – Phase 1

- The objective was to understand the opportunity presented by the Bakken formation based on its geology and the engineering technologies available to recover gas, condensate and oil from it.

- The project was completed and the outcomes were summarized in a final report and presentation, which took place at a PTAC workshop under the Tight Oil and Gas Innovation Network (TOGIN) on February 22, 2016.

3.3 Objective 3 – Perform Proof of Concept Well Test of WS Technology in Western Canada

- The objective was to test the WS technology on an existing well.
- The well trial was successfully performed between in October 2015 in a well in the Cardium formation in north western Alberta. This trial constituted the first test of WS in Western Canada.
- Analysis of the trial results indicated that the WS treatment resulted in higher production of condensate which will have beneficial economic and environmental impacts.

3.4 Objective 4 – Analyse the Performance of PST Trials in Western Canada

- The objective was to test the PST technology on an existing well.
- A senior oil and gas company had trialled the PST technology in three vertical wells and one horizontal well in Western Canada. This data set was acquired and analysed by the project.
- Analysis of trial results indicated that the PST treatment resulted in higher production of condensate which will have beneficial economic and environmental impacts.

3.5 Objective 5 – Final Reporting and Dissemination of Outcomes

- The objective was to analyse and report on trials of the WS and PST technologies.
- Detailed confidential technical reports were produced by expert reservoir engineering firms.
- The technical reports confirm the higher production of condensate resulting from the application of the WS and PST technologies.

4 Results of Project

4.1 Project Achievements

4.1.1 Achievement 1 - Understanding of the Duvernay Play

The analysis of the Duvernay Play resulted in 4 reports as follows:

- Phase I – Duvernay Backgrounder Report - Mapping Existing Resources and Activities in the Duvernay Play;
- Phase II - Technology Needs Assessment and Gap Identification; and
- Phase III - Technology Development Opportunities

- Phase IV - Final report and workshop with stakeholders

In addition, a workshop was held in Whitecourt, Alberta on September 16, 2015 to present information about the Duvernay Play to stakeholders such as local businesses and government authorities in the region where the hydraulic fracturing developments are taking place. Presentations were also offered to interested producers. An article “Technology Opportunities in the Duvernay” was prepared for publication in an industry journal or publication.

4.1.2 Achievement 2 - Understanding of the Bakken Play

The final report about understanding the Balkan Play was prepared by the Saskatchewan Research Council and a summary of the findings were shared in a workshop organized by PTAC on February 22, 2016.

4.1.3 Achievement 3 - Field demonstration of the WS Technology

The WS technology was injected as a workover in a well in the Alberta Cardium formation in October 2015. The well was pre-flushed with solvent and treated with the chemistry from 3M Canada. After an overnight period to allow completion of the chemical treatment, the well was successfully placed back into production. This trial demonstrated that the WS technology can be implemented at wellsites in Western Canada.

4.1.4 Achievement 4 - Field demonstration of the PST Technology

The project was successful in securing a rich data set from a senior oil and gas company. It concerned 4 wells (3 verticals and 1 horizontal) tested with PST in 2012-13, as well as data for offset wells used as comparators. The data set provided approximately 3 years of production history and was obtained at no cash cost to the project. These trials confirm that the PST technology can be successfully deployed in Western Canada.

4.1.5 Achievement 5 - Analysis and Reporting of WS and PST Trials

The analysis of the WS trial was completed by 2 subject matter expert consulting firms specialized in reservoir engineering. The analysis confirmed a significant increase in condensate production and productivity. The next steps are to wait for at least one year of production data to determine if the improvement is sustained. This sustainability is required for the economics to be acceptable in a low oil price context.

The analysis of the PST well trials was completed by 1 subject matter expert consulting firm. Results also indicated higher condensate productivity in the horizontal well trial. The vertical well trials, however, appeared to have suffered operational difficulties unrelated to the technology that, in some cases, overwhelmed the benefits of the technology; thus no improvement in productivity could be proven in the vertical well data set.

Finally, PTAC organized a well-attended workshop on sustainable production from tight oil and shale gas during which preliminary results of the project were shared with the audience.

4.2 Benefits

4.2.1 Benefit 1 - Identification of knowledge gap and technology opportunities in hydraulic fracturing plays in Western Canada

The benefits of the studies of knowledge gaps and technology opportunities in the Duvernay and Bok and Plays were:

- To identify technology opportunities for solving challenges in unconventional hydraulic fracturing plays;
- To scope technology projects and funding for technology innovators interested in pursuing innovation based opportunities;
- To provide opportunities for technology transfer;
- To provide stakeholders, including government, with accurate and up to date information about technology and economic prospects, based on available public information, applicable to hydraulic fracturing in the major formations in Western Canada.

4.2.2 Benefit 2 - Demonstration of the effective implementation of the WS and PST technologies

Before this project, the WS and PST technologies had been trialled overseas in different oil and gas formations with good success, and the results of these trials had been reported in technical literature. However, successful implementation in geological formations specific to Western Canada had not occurred for the WS technology and had locally been done, but without engineering analysis for the PST technology.

The project confirmed that the WS and the PST technologies could be implemented without expensive retooling by existing service companies and oil and gas operators in Western Canada. This demonstration opens the door for additional implementation of the technology as implementation methodologies have now been proven effective.

4.2.3 Benefit 3 - Demonstration of the economic and environmental benefits of the WS and PST technologies

In western Canada, the vast majority of water for hydraulic fracturing is supplied from fresh water sources such as rivers and lakes. Two of the major environmental concerns with hydraulic fracturing are consumption of this fresh water and disposal of contaminated flowback water. One of the aims of this project is reducing both concerns by demonstrating effective technologies that:

- Re-establish past production levels production from damaged wells (WS technology) and thus avoid the fracturing of new well for producing the gas resource. This benefit will produce more hydrocarbons from the same amount of water and energy used to initially fracture the well.
- Allow newly fractured wells to produce longer at higher rates as the PST technology facilitates the flow of liquids such as condensates through the fractures. Thus, the environmental intensity of hydrocarbon production from hydraulic fracturing is reduced as more hydrocarbon volumes are produced from the same initial water requirement.

Additional benefits to Canada and the hydraulic fracturing sector will be the availability of a new effective technologies that will increase production and reduce unit costs from the same initial investment in well drilling and completion.

PTAC Petroleum Technology Alliance Canada (PTAC) is a not-for-profit organization that facilitates collaborative research and technology development to improve the financial, environmental and safety performance of the Canadian hydrocarbon energy industry. PTAC facilitated this Project through its network of oil and gas operators. The project assisted PTAC in fulfilling its mission and vision which are:

- PTAC's mission is to facilitate innovation, collaborative research and technology development, demonstration and deployment for a responsible Canadian hydrocarbon energy industry.
- PTAC's vision is to help Canada become a global hydrocarbon energy technology leader.

4.3 Technology/Knowledge Development Objectives

4.3.1 Understanding the Duvernay Play

Duvernay Characteristics

Key characteristics of the Duvernay Play were reported as follows:

- **Stage of Development -** Even though the Duvernay may contain extremely large volumes of oil, NGLs and gas, so far there has mainly only been exploration activity. Based on the Alberta Geologic Survey two other shale/siltstone formations (Montney and Muskwa) contain more resources than the Duvernay, and the Montney is already in commercial development, while the exploration activities in the Muskwa (also known as the Northern Duvernay) have not yet begun.
- **Economics Compared to Other Resources -** The stand-alone economics of Duvernay production are poor compared to other formations and resources in the U.S. and Western Canada and only liquids production made them somewhat attractive. With the recent, (2014) drop in oil prices, the Duvernay may still be relatively uneconomic compared to other formations, even as drilling and completion costs are dropping. Duvernay wells are more expensive to drill, require 5 to 20 times more water for fracturing and are generally less productive than shallower formations such as the Montney in Alberta and British Columbia.
- **Motivation of Active Players -** The largest active developers are mainly focused on resource tenure, investment recovery through farm-ins or integrated economics with other projects.
- **Uncertainties Clouding Development -** There are many uncertainties related to costs, economics, water impacts, seismic impacts and other facets of the Duvernay development. All of these factors are more severe for the Duvernay than for the other shallower formations in the region, which are easier and cheaper to access.
- **No Reserves Assigned** – To be classified as "Reserves" hydrocarbons must be both technically and economically recoverable. To date production from the Duvernay has not demonstrated either of these traits on a consistent basis, and the 2014 drop in prices for oil and liquids has

reduced the potential for any reserves which might have been developed. As a result there are no reserves assigned to these formations except for production already in the tank or pipeline.

Key Challenges

The key needs for enhancing development of the Duvernay Play were reported as follows:

- **Best Practices** – for transfer to other producers. Assisting smaller or less involved producers with Duvernay assets with suggested best practices to avoid any problems or pitfalls already encountered and resolved by the lead producers in the play. These might also be input for potential Duvernay Regulatory Pilot standards.
- **Enhance Competitiveness** – of Duvernay compared to other oil and gas resources. The Duvernay is at a disadvantage compared to similar resources in shallower and more extensively developed plays in Western Canada, such as the Montney, Cardium, etc. and is also at a disadvantage compared to the Eagle Ford, Bakken and some other shale resources which have already been more extensively developed and which have competitive advantages over the Duvernay due to their geographic locations.

Technology Opportunities

The four major areas for technology opportunities are listed below:

1. **Methods to Slow production Rate Declines -** The rapid drop in initial production rates necessitates continuous drilling in shale formations. A way to extend the well life, perhaps via artificial lift or choking initial rates, could ease the burden on drilling programs, as well as increasing EUR.
2. **Selecting Wells for Re-fracturing -** Selecting wells to re-fracture is a time and personnel intensive process. The treatment for each well should be individually tailored, depending on how each stage performs, to get the most out of a refracture job. The identification of well selection criteria, which allows for efficient screening of wells and therefore provides the best re-fracturing candidates, will increase the speed of this process and help keep costs down while increasing recovery.
3. **Understanding of Fracture Behaviours Under Production -** To help design refracture treatments or other stimulation programs to extend the life of a multistage hydraulically fractured horizontal shale well, an understanding of how fractures and stresses behave in the reservoir as the well is produced. Ideally, a model of the reservoir which could predict the changes in stress orientations due to the drop in pore pressure as production proceeds, would help optimize any late-life treatments, and even help predict the effect of neighboring wells on production performance.
4. **Non-restrictive Completion Systems -** The development of a completion system that allows easy access to the wellbore via an unrestricted inner diameter, without compromising the logistical advantages of a ball-activated system, would help when refracturing the multi-well pads. Multi-well pads have the most to gain from the ability to re-enter and re-fracture individual wells, as pad development reduces recompletion costs and saves time.

4.3.2 Understanding the Bakken Play

Bakken Characteristics

The Bakken Formation, with at least 16 billion m^3 (100 billion barrels) of hydrocarbon resources, is one of the largest continuous oil deposits discovered in North America since the 1950s. The 520,000-km^2 formation lies underneath southeast Saskatchewan and southwest Manitoba in Canada, and North Dakota and Montana in the United States. The Bakken, considered "thermally mature" by geologists, produces high-quality light and sweet oil with a typical API gravity of 41 to 45°. Reservoirs in the Bakken Formation are characterized as "tight," with extremely low permeability and porosity. While primary oil production can be economic and only because of natural fractures creating flow pathways, most Bakken reservoirs have experienced uneconomic production since the resource's discovery more than half a century ago.

In the early years, Saskatchewan's Bakken oil production was limited to several pools such as the Rocanville-Welwyn, Viewfield, Ceylon, Hummingbird, and Roncott pools. Primary production is often related to natural fractures. Oil flow during primary production is dependent on the transmissibility and connectivity of these natural fractures that intersect with production wells. In general, the Bakken production was considered uneconomic until the introduction and application of innovative drilling and completion technologies since 2004. In recent years, drilling activities have been focused on the Viewfield–Midale region and have spread to other fields.

The boom in Saskatchewan Bakken production activity generally started in mid-2000, and was triggered by application of long horizontal wells, which allow maximum exposure to the reservoir, and new conceptual stackfrac techniques, which allow fracturing of siltstone along the extent of the wellbore. At the largest Viewfield field in the Saskatchewan Bakken, the average true vertical depth (TVD) is 1,500 m and lateral length is 1,600 m. The average estimated ultimate recovery (EUR) is 110,000 barrels of oil equivalent (BOE). Saskatchewan Bakken production has climbed sharply since 2005 and peaked in October 2012 at 70,000 bbl/d. Cumulative total production to date is about 160 million bbl.

According to a recent report published by Saskatchewan Ministry of the Economy and the National Energy Board, about 1.4 billion bbl of oil and 2.9 trillion cubic feet of natural gas are economically recoverable from the Canadian Bakken. With cumulative production of 160 million barrels up to the end of 2014, there are still 1.24 billion barrels of recoverable oil remaining based on today's technology. History always proves that advancements in drilling, completion, and completion technologies will further add to these reserves.

Technology Opportunities

Key challenges and opportunities for new technologies were reported as follows:

- Reservoir Characterization
  - Reservoir Fluid Properties
  - Petrophysical Properties
  - Geomechanical Properties
- Drilling and Completion Technologies

    - Drilling Technologies
    - Drilling/Fracking Fluid and Proppant Design
    - Completion Technologies
- Production Optimization and Stimulation Technologies
    - Production Optimization
    - Refracking Technologies
- Enhanced Oil Recovery Technologies
    - (Enhanced) Waterflooding
    - Gas Flooding
- Numerical Simulation
    - Reservoir Modeling
    - Geological/Geomechanical Modeling
    - Production/Decline Analysis
    - Economic Analysis
- Produced Water Recycling
- Bakken Oil Processing and Transportation
- Produced Gas Utilization

4.3.3 Demonstration of the WS Technology

The well was treated during a workover in October 2015 using 3M's WS-1200 chemical technology with a solvent. The work over was completed as per the trial plan without any significant issues. The well was placed back on production and after an adjustment period, stable production resulted. After 6 months of production, the pilot well's gas production returned to what it was before the workover, with an increase in condensate to gas ratio.

The increased condensate rate and ratio seems to indicate that the chemical product performed as intended, although it is possible that the increase in condensate ratio may have come from the solvent wash and not necessarily from the WS-1200. Economically, the treatment did not give the absolute production increase needed to justify the cost. Future technology developments would be required to significantly reduce the cost of the chemical and solvent mixture required. It is worth noting that it could be possible that the test well was too greatly depleted to give the WS-1200 technology a fair chance to prove its productivity increase. Future consideration of additional use of the WS-1200 chemical would depend on future technology developments to reduce the cost of the chemical / solvent mixture.

4.3.4 Demonstration of the PST Technology

The benefit of altering wettability using the 3M chemical treatment is to reduce capillary pressure, increase the mobility of liquids, and thus increase gas, condensate, and liquids relative permeability and production. In certain circumstances, liquids may be retained by capillary forces on sand surfaces in the narrow confines of fractures and pore throats. Accumulations of liquids restrict flow of gas and mobile liquids, thus reducing production, sometimes dramatically so. Treating proppant particles will reduce the amount of liquids accumulation in fractures, allowing mobile fluids to be produced faster.

A senior oil and gas company tested the PST technology in three vertical wells and one horizontal well in the 2012-13 timeframe for the purpose of determining if the new technology would lead to improved production over time. The availability of approximately three years of production data from multiple wells provided the opportunity to analyse the performance of the PST technology using advanced reservoir engineering methodologies. The project retained a reservoir engineering firm specialized in hydraulic fracturing well analysis to perform a detailed analysis of the trial data set. The outcome was a confidential specialized detailed analysis report. However, the principle conclusions are summarized as follows.

The hypothesis analysed was that the 3M treatment would allow liquids to move more freely through the propped fracture as a result of wettability reduction of the proppant from the chemical treatment. Therefore, evidence that the 3M chemical treatment resulted in the intended benefit would be seen in improved liquid yields associated with increased relative permeability to hydrocarbon liquids flowing in the proppant pack. This would be evidenced by comparing produced volumes of gas and liquids between treated and untreated wells in comparable geological settings. The benefit could also manifest itself as higher apparent fracture conductivity from the higher mobility of liquids. In this manifestation, the Rate Transient Analysis (RTA) and the Pressure Transient Analysis (PTA) would show a smaller skin and/or greater effective fracture lengths and production forecast resulting from the analysis would show better expected ultimate recoveries for the treated wells.

The analysis methodology included RTA and PTA to establish baseline reservoir and completion characteristics for each of the six wells analysed. Specialized plots and production forecasts were developed for all wells. These included type curve analysis (Blasingame, Wattenbarger and Compound Linear flow type curves) to obtain estimates of fracture half-length and permeability, Linear Flow specialized plots used to analyse early linear flow signal and obtain independent estimates of fracture half-length and permeability, Flowing Material Balance used to understand the contacted drainage areas, and Analytical Modelling also used to estimate the fracture half lengths and permeability. The RTA and PTA results were compared for treated and untreated wells.

Results indicated a higher condensate productivity. However, the vertical wells appear to have suffered operational difficulties unrelated to the technology that, in some cases, overwhelmed the benefits of the technology.

4.4 Challenges and Barriers

4.4.1 Barrier/Challenge 1 - Access to test sites for demonstration trials

Deployment or field testing is a necessary step in moving new innovative technologies from prototype to commercialization. It can be extremely difficult for technology innovators to secure funding and sites for field pilot testing. There is a large gap between the expectations of oil and gas exploration and producer companies and typical offerings by technology innovators. Oil and gas operations are capital intensive and under intense public scrutiny, resulting in a very conservative approach to technology risk. By contrast, technology innovators may try to build their business from limited technology development work and may offer products with uncertainties and risks beyond the tolerance of conservative operating companies. PTAC has a long and deep experience in operating in this chasm, helping to identify industry needs and to assist end user operating companies to source innovation, while managing risk through consortium technology demonstration projects.

In this project, PTAC was successful in securing a test site for the WS technology, as well as access to a rich data sets of four well trials for the PST technology.

4.4.2 Barrier/Challenge 2 - Need for better understanding of the fundamental effects of the 3M chemical treatment on hydrocarbon flow in the reservoir

Scientific questions remain to be explored about the detailed mechanisms by which the 3M chemical treatment affects the flow of hydrocarbons at reservoir scale. To improve this understanding, 3M has supported research at the University of Alberta. This work is in progress and should elucidate some of the key variables and offer new directions on how best to apply the technology to maximize effectiveness.

5 Conclusion and Follow-up

The project was a multifaceted investigation in demonstration of a new technology to improve the economics and to reduce the environmental impact of hydraulic fracturing in Western Canada. The outcome was the identification of challenges and opportunities in major Western Canadian plays which should provide a blueprint for innovators. The project also clearly demonstrated that the WS and PST technologies from 3M Canada could be implemented by existing service companies and operators in Western Canada. The results of the trials analysed in this project indicated early results of higher condensate production which could be beneficial to future operations.

5.1 Next Steps

Two next steps were identified at the conclusion of the project:

More time is required to validate the durability of the chemical treatment and to firmly establish the value of the condensate production increases. The trials analysed during the project will continue to be monitored accordingly.

The cost of the treatment needs to be reduced. Cost reduction is paramount in the current economic situation caused by low oil and natural gas prices. Thus, all aspects of the implementation methodology will need to be reviewed for potential improvements in efficiency and reduction of costs.