

TECHNICAL REVIEWERS' RATING SUMMARY

G015-A

Hydraulic Fracturing and Microseismic Monitoring Project – Bakken Research Consortium

Submitted by Headington Oil Company, L.P. on behalf of Continental Resources, Inc., Hess Corporation and Schlumberger Oilfield Services

Principal Investigators: Headington Oil Company

Request for \$750,000; Total Project Costs \$14,000,000

| Rating Category | Weighting Factor | Technical Reviewer | | | Average Weighted Score |
|--------------------------------------|-------------------------|---------------------------|---------------|---------------|-------------------------------|
| | | 15A-01 | 15A-02 | 15A-03 | |
| Objective | 9 | 2 | 5 | 5 | 36.0 |
| Availability | 9 | 3 | 4 | 5 | 36.0 |
| Methodology | 7 | 3 | 4 | 5 | 28.0 |
| Contribution | 7 | 4 | 4 | 5 | 30.3 |
| Awareness | 5 | 2 | 3 | 4 | 15.0 |
| Background | 5 | 2 | 5 | 5 | 20.0 |
| Project Management | 2 | 3 | 4 | 4 | 7.3 |
| Equipment Purchase | 2 | 5 | 5 | 5 | 10.0 |
| Facilities | 2 | 3 | 5 | 4 | 8.0 |
| Budget | 2 | 4 | 5 | 5 | 9.3 |
| Average Weighted Score | | 144 | 215 | 241 | 199.9 |
| Maximum Weighted Score | | | | | 250 |
| <u>OVERALL RECOMMENDATION</u> | | | | | |
| FUND | | X | X | X | |
| FUNDING TO BE CONSIDERED | | | | | |
| DO NOT FUND | | | | | |

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1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 015A-01 (Rating: 2)

The primary purpose of the proposed project is to use micro-seismic monitoring technology located in a central horizontal lateral to evaluate different fracturing designs performed on the outside laterals of three parallel horizontal laterals. The authors submit the data acquired will be useful to other operators attempting Bakken completions within North Dakota.

However, the azimuth of the three wells is not yet determined. Without a chosen azimuth, it is not clear how the data may be helpful for those who have completions with a significantly different horizontal lateral azimuth. Since the wells will all be parallel, that geometry will be constant with all treatments and potentially quite useful to those with a similar chosen azimuth. When fracture stimulating a horizontal lateral, the relationship of the horizontal lateral azimuth to the maximum principle horizontal stress direction is among the most important variables impacting the fracture stimulation design. Lateral orientation also appears to be a significant factor in the success of Bakken wells in North Dakota, although the exact reason may not be completely understood. Current operator tendencies for horizontal Bakken laterals drilled in North Dakota generally range from north to northwest (south to southeast) azimuths. If an azimuth significantly different is chosen for the three wells, it may limit the number of operators who can benefit from the results.

Additionally, while there appears to be a preferred azimuth tendency for better production from the Bakken formation, likely related to natural fracture orientation and the tendency for the Bakken to rely on natural fractures for a significant fraction of the reservoir system permeability, that same azimuth is likely to be unsatisfactory for some types of EOR due to inter-well communication. It seems unlikely that a single azimuth will provide optimal data for both research outcomes.

The differing types of completion techniques have also not been elaborated on in detail. Variations in diversion or wellbore isolation methods, fluid types, proppant types, treatment size, injection rate, etc., would require multiple projects of this type to fully evaluate so it should be a primary consideration that the chosen treatments provide useful information for the majority of North Dakota Bakken operators.

The use of the central horizontal lateral as a micro-seismic monitoring well should provide an improved opportunity to detect micro-seismic events along the entire length of the fracture stimulated laterals, something that has been difficult to achieve with out multiple vertical monitoring wells. Wells in new areas, similar to much of the North Dakota Bakken development, seldom have sufficient conveniently placed vertical wells available for that

purpose. Down-hole micro-seismic monitoring equipment should also provide better vertical fracture geometry resolution than can be obtained by surface tilt-meter or micro-seismic monitoring. Vertical fracture resolution is critical to determining the optimum drilling and fracturing practices needed to limit excessive vertical fracture growth out of the Bakken formation.

Reviewer 015A-02 (Rating: 5)

The objective of the proposal is clear and consistent with NDIC Oil and Gas Research Council. The proposing consortium has investigated implications other than the primary objective and intends to conduct studies of several factors which are of great importance for NDIC Oil and Gas Research Council.

Reviewer 015A-03 (Rating: 5)

High potential to bring in new O&G companies & investment—timing is right to conduct a Bakken study

High potential to create new O&G jobs and revenues—Optimum completion techniques may be the key to producing areas of the Williston Basin that currently appear to have marginal economic Bakken results

Release of confidential information at end of 2008 will provide educational opportunities for industry and the general public

Should increase the ultimate recovery from existing Bakken Pools since re-fracing of wells and drilling additional laterals will be studied

Will help preserve existing jobs and production levels—75% of rigs are currently drilling Bakken wells

Could reduce footprint since will study interference between horizontal wells

Could provide baseline information leading to other projects—hydraulic fracturing itself could lead to many different projects and processes, such as what frac fluid to use, what method to employ (i.e. swell packers), what type of proppant, etc.

Headington Oil Company's Response

On behalf of the Bakken Consortium, thanks to you and the Oil & Gas Research Council for the timely response to our application for grant support. The Technical Reviewers were very thorough in their assessment of the application, and I would like to provide some clarification regarding two key points that were addressed:

First, with regard to wellbore azimuth, the Consortium met in November 2007 to review 2D-seismic data in the immediate area and to discuss the structural implications for wellbore azimuth selection. Seismic data indicate that the local structural grain trends primarily north-south, and hence the decision was made to orient the three wellbores east-west in order to optimize intersection with potential local fractures. It is recognized that while fractures of more "regional" trend are also likely to exist in the area, participants agreed that the local structural setting was of greater significance. Moreover, since the project area was constrained to a 640-acre spacing unit because of microseismic monitoring limitations, other

azimuth choices normally afforded by 1280-acre spacing units were not available for consideration.

Second, with regard to completion designs for the initial two producers, the Consortium will be meeting in mid-January to finalize the plans for those wells. Discussions during the preliminary meeting last November concluded in all likelihood that one well would be completed with a pre-perforated, un-cemented liner using more standard diversion techniques, and the other would be fitted with external casing packers for a staged completion. Recent experiences by Consortium participants will likely play a significant role in the final completion designs.

It is hoped that these general clarifications are of some value, and that the Council remains supportive of this project.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 015A-01 (Rating: 3)

The proposed plan seems reasonable based on current drilling and completion practices. The operator has substantial experience in the area and access to well trained and experienced vendors.

Reviewer 015A-02 (Rating: 4)

The proposed approach seems to be adequate to the objectives of the proposal. However it is not quite clear what are the different designs which will be evaluated in the project.

Reviewer 015A-03 (Rating: 5)

The Consortium is currently following the timetable. The Industrial Commission approved their request to drill the three horizontal wells when it approved Order #11453 on November 20, 2007. A permit to drill the first well was also approved by the Oil and Gas Division on December 10, 2007. The Consortium currently operates 13 rigs drilling Bakken wells in the Williston Basin and should have no trouble contracting a rig to timely drill the three horizontal wells. The timetable is realistic and certainly achievable.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 015A-01 (Rating: 3)

The drilling, and micro-seismic monitoring aspects of the project appear to be at pace with accepted practices. However, the fracturing plans appear to be quite vague in regard to the many facets of that technology that can affect results. Some indications are given concerning fluid types and diversion methods, but these alone do not entirely define the full scope of the stimulation process. Many of the other available fracture stimulation technologies likely to be utilized can significantly impact the fracturing treatment results, particularly in regard to production. Failure to adequately define and address fluid composition and compatibility with the formation and reservoir fluids, gel breaker technology, proppant conductivity and stability, proppant transport, etc., in the fracture design could mask the effects the fracture placement and geometry, determined by the micro-seismic, ultimately have on both initial and long-term production results.

The goal of investigating the potential for re-fracture stimulation of horizontal laterals in the Bakken formation and using micro-seismic technology to monitor the new fracture locations and geometry has merit as well. However, care should be taken in the initial fracture designs to insure the need for re-stimulation is not related to a failure to address the previously mentioned factors, and instead, on changes related to fracture location and geometry needed to access additional reserves. Premature loss of proppant conductivity or insufficient initial conductivity, inadequate gelled fluid cleanup, fluid incompatibilities, and related initial treatment problems are preventable and should not be a factor in the need for re-fracture stimulation. Money spent to re-fracture a well for those reasons will have a negative effect on the economics of any well, potentially resulting in lost reserves.

Reviewer 015A-02 (Rating: 4)

It is desirable that the stimulation designs are described in greater details. It is mentioned in the proposal that one of the objectives is to assist operators in selecting optimum drilling locations. However, it is not quite clear which technique will assist in that.

Reviewer 015A-03 (Rating: 5)

Hydraulic fracturing of horizontal wells in the North Dakota portion of the Williston Basin is just coming out of its infancy—many operators are using slightly different techniques without the availability of monitoring their results with offset wells—this methodology is well above average.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 015A-01 (Rating: 4)

If the proposed data concerning fracture geometry relative to the horizontal well and the Bakken formation is determined with reasonable accuracy, that alone will be a significant scientific and technical contribution in regard to the NDIC OGRC goals. The proposed long-term re-fracturing and EOR data acquisition would be a bonus if it can be obtained by this same project.

Reviewer 015A-02 (Rating: 4)

The project intends to assess efficiency of several stimulation designs for well completed in the Bakken Formation and to define the most efficient design. This would benefit oil field operators and the State of North Dakota.

Reviewer 015A-03 (Rating: 5)

The potentially productive portion of the Bakken Pool underlies most of the oil producing lands in North Dakota. The scientific and technical contribution of the proposed work could have a great impact on future jobs and ultimate recoveries throughout the North, West, and Central portions of the Williston Basin. Under paragraph (1) reviewer has listed seven goals of the NDOGRC that are directly realized by this proposed project.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 015A-01 (Rating: 2)

While the three primary operators and the principle vendor listed are well established in the Williston Basin portion of North Dakota, it is not apparent outside of a generalized statement, who the individuals are that will be primarily allocated to this project from each contributor. No references to prior work are given in the project description outside of general statements of experience and proficiency.

Reviewer 015A-02 (Rating: 3)

It is indicated in the proposal that the consortium and the PI have experiences both with microseismic monitoring and with operating Bakken Formation reservoirs. More expertise in microseismic data utilization is desirable.

Reviewer 015A-03 (Rating: 4)

References to published research was not documented in the proposal, although reviewer is aware of papers published by Headington and Hess that address the technical nature of their proposed project. Many references are made to unpublished research, mainly that obtained by the Consortium from drilling and completing their own wells. All four companies in the Consortium have extensive knowledge in drilling and completing Bakken horizontal wells. Reviewer is convinced the principal investigator could have referenced literature the Consortium is responsible for publishing and received an “exceptional” rating on this question.

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 015A-01 (Rating: 2)

As stated above, no individual’s resume, in regard to the proposed work, is given in the proposal. Only generalized references to the overall experience of the technical staff of the three primary operators and the principle vendor are provided.

Reviewer 015A-02 (Rating: 5)

It can be suggested that combined efforts of three experienced operators and a leading provider of field services ensures that the working group has all the needed expertise to conduct the proposed work.

Reviewer 015A-03 (Rating: 5)

The Consortium has drilled and completed over 150 horizontal Bakken wells in the Williston Basin and currently operates 13 rigs drilling horizontal Bakken wells—it doesn’t get any better than that.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 015A-01 (Rating: 3)

A relatively detailed schedule is provided for major milestones in the project. Within the schedule are planned technical meetings for participating operators and the principle vendor and scheduled dates for completion of the interim and final data reports.

The budget provided is very vague concerning the cost of the individual components of the project for each of the three wells. No detailed cost estimates from the major vendors were

provided to document the estimated cost given in the proposal. The principle vendor is indicated to be providing \$2 million of product discounts and services. The three primary operators will share the remaining costs, less any outside funding.

Reviewer 015A-02 (Rating: 4)

The project management plan is well thought over and seems to be reasonable.

Reviewer 015A-03 (Rating: 4)

The proposal has a very realistic timeframe and financial outline. The Consortium's expertise in drilling and completing horizontal Bakken wells is invaluable in seeing the outline to fruition.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 015A-01 (Rating: 5)

No special equipment will be purchased for this project.

Reviewer 015A-02 (Rating: 5)

No equipment to be purchased.

Reviewer 015A-03 (Rating: 5)

The proposed equipment to purchase includes that necessary to drill and complete a well, plus conduct a hydraulic frac and monitor the results. The purchase is absolutely necessary.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 015A-01 (Rating: 3)

All resources for this project should be adequate and available.

Reviewer 015A-02 (Rating: 5)

The field service provider for this project is one of the leading service companies. It can be expected that the most current technologies and equipment will be employed in the project.

Reviewer 015A-03 (Rating: 4)

The proposal did not list the facilities and equipment in detail, but production facilities will be necessary and the Consortium plans to meter or test each producing well independent of the other, which is critical to obtain accurate information to perform the necessary research. Reviewer is convinced the Consortium will use “state of the art” equipment and facilities, but was unwilling to rate “exceptionally good” due to the lack of documentation.

10. The proposed budget “value”¹ relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 015A-01 (Rating: 4)

If the fracture geometry's relationship to treatment design and completion method is the only result obtained from this project, the investment will be very reasonable. However, if the other potential goals regarding, re-fracturing, EOR potential, and carbon dioxide sequestration are even partially attained, it will be a highly successful and cost effective outcome.

The financial commitment from other sources is substantially greater than the program funding requested.

Reviewer 015A-02 (Rating: 5)

The majority of the costs involved in the project completion will be paid by the Consortium.

Reviewer 015A-03 (Rating: 5)

The grant request of \$750,000 is only 5.4% of the total cost of the \$14 million project. The total cost includes approximately \$2 million of product discounts and services provided by Schlumberger Oilfield Services, a present leader in horizontal and hydraulic fracturing technology.

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 015A-01 (Fund)

Overall, this appears to be a very worthwhile project with lofty goals, some of which are likely achievable in whole and some in part. Some of the potential selling points like EOR and carbon dioxide sequestration may have conflicting requirements with the goal of maximizing production capacity that are related to optimum lateral orientation, but that is a point that cannot be argued with certainty at this time. It is likely that even a failure in those aspects would still provide useful information to build upon in future projects. I would recommend funding this project.

I would have preferred to see more details in regard to the qualifications of those who will be the primary project contacts within the primary operators and principle vendor. A project of this magnitude will need substantial leadership by qualified individuals who fully grasp the larger picture of how each component of the project influences and interacts with other components. Continuity of at least some core individuals throughout the entire project will be important to keeping the other intermittent contributors directed toward the same originally defined goals.

Reviewer 015A-02 (Fund)

The proposal addresses important problem of Bakken Shale development, namely testing different completion designs. Unfortunately it is not evident what exact designs will be tested. If successful the project will benefit the State of North Dakota. I suggest funding the project.

Reviewer 015A-03 (Fund)

Reviewer is convinced the research project would proceed without the grant money provided by the NDOGRC. The grant money provided by the NDOGRC will allow a great many persons and companies to benefit from this research study. The state of North Dakota and the Consortium should be commended for providing the funding that will bring this project to fruition so all can benefit from it.

Reviewer is concerned that granting \$750,000 will exhaust the NDOGRC's fund prematurely. The NDOGRC should use their expertise to evaluate the need for the entire \$750,000. The largest amount awarded by the NDOGRC has been \$500,000 and it is suggested to consider equaling that amount.