

Technical Reviewers' Rating Summary

Proposal Number	G-53-01	Application Title	Creedence Energy Services	Submitted By	
Creedence Energy Services/	Request For	\$205,750.00	Total Project Costs		

Section A. Scoring

Statement	Weighting Factor	G-53-01A	G-53-01B	G-53-01C	Average Weighted Score
1. Objectives	9	4	4	4	36
2. Achievability	7	4	3	3	21
3. Methodology	8	3	2	3	16
4. Contribution	8	3	4	3	24
5. Awareness / Background	5	2	2	2	10
6. Project Management	3	3	3	3	9
7. Equipment / Facilities	2	4	2	2	4
8. Value / Industry - Budget	4	4	4	4	16
9. Financial Match - Budget	4	3	4	3	12
Average Weighted Score		167	160	156	161

Total: 50

250 possible points

OVERALL RECOMMENDATION

FUND

FUNDING TO BE CONSIDERED

X

X

X

DO NOT FUND

Section B. Ratings and Comments

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:

The applicants have indicated a multi-tiered set of goals that would provide escalating levels of economic benefit if the technology is proven viable. First level would involve increasing production from existing candidate wells, primarily legacy and early unconventional completions to help reduce the decline in statewide oil and gas production. Second level would involve incorporation of the technology in new completions to enhance oil and gas recovery. Third level would involve construction of a commercial chemical manufacturing facility within North Dakota to supply demand for the technology by processing of existing North Dakota agricultural products as the inputs.

- Reviewer: G-53-01A

- Rating: 4

The objectives and goals of the proposed project are consistent with the OGRC goals and purposes in that the project seeks to maximize the potential recovery and marketability of oil and gas resources, promote job growth and further innovation and economic development of natural resources.

- Reviewer: G-53-01B

- Rating: 4

The description of the technology, applicability to the Williston Basin, plan for demonstration and how the technology will be deployed if the technology impact is as the requestor anticipates are all clearly stated. What is not clear is the percentage of wells in general are candidates. It also does not state an expectation of success of re-application of the treatment, since the effects only last a year or two. Both need to be addressed to assess the potential impact of the technology.

- Reviewer: G-53-01C

- Rating: 4

Candidate wells include vertical/horizontal oil/gas wells in North Dakota. Generally, horizontal wells with oil production rates greater than 10 bopd and vertical wells with production rates greater than 2 bopd offer better economics for the operator. Oil cut (oil/total fluid) ratios of greater than 5% and gas-oil ratio (scfg/bo) less than 50,000 are preferred. While we have limited case histories with re-application, wells that have been re-treated with biosurfactant have shown equivalent or greater production response. Re-treatment is often delayed because of the length of the positive production response, in some cases lasting more than 1-year.

- Applicant

2. With the approach suggested and time and budget available, the objectives are:

Applicant indicates a 6 to 18 month period for the project. Variance in time frame relates to expected treatment evaluation period required to monitor the effectiveness of the chemical and the persistence of the physical properties produced from the chemical interaction with the formation and produced fluids. An additional variable is timely identification availability of suitable candidate wells.

- Reviewer: G-53-01A

- Rating: 4

Budget and timing appear to be adequate for a short-term treatment cycle. More clarity and gauging of the willingness and availability of cost-share industry partners for testing would help to satisfy the notion that the time frames and budgets are appropriate.

- Reviewer: G-53-01B

- Rating: 3

I do feel three field demonstrations of each of three application types are likely to provide discernable results for an indication of success. However, I feel selecting two of the three proposed applications and doing five tests of each would provide a more definitive result within a similar timeframe and budget.

- Reviewer: G-53-01C

- Rating: 3

As a whole, the producers we have spoken to acknowledge the need for our type of EOR application and have welcome further discussion. With over 40 MSAs in the Williston Basin, including 19 of the top 20 producers in North Dakota, Creedence has access to a multitude of prospective operators. Several have already been approached and are in the final stages of candidate well selection. Hunt Oil Company formalized their support via their letter. Cobra Oil and Gas and Oasis Petroleum have demonstrated strong interest in participating in trials by providing well candidates and associated information. This technology has also been presented to engineers and geologists from Continental Resources and Whiting Oil and Gas. Creedence is open to optimizing the well candidate pool and criteria based on feedback from

the state and OGRC.

- Applicant

3. The quality of the methodology displayed in the proposal is:

Applicant has shown a testing procedure using physical properties of surface tension, interfacial tension, and contact angle as methods of evaluating the performance of the surfactant in oil, gas, and water situations. Additional testing for relative imbibition of treated fluid and displacement of hydrocarbons is also mentioned. No mention is made of whether the testing equipment can simulate reservoir conditions. The Williston Basin has several reservoirs that approach or exceed 300F. This can impact the performance of surfactants, especially solubility, in the presence of divalent cations like magnesium, calcium, and ferrous iron.

- Reviewer: G-53-01A

- Rating: 3

The quality of the methodology displayed in the proposal is somewhat lacking in terms of laboratory testing techniques. The proposed laboratory testing focuses heavily on drill cuttings which do not accurately reflect the interconnection of porosity systems or provide a basis for observed oil-water interaction at pore-throat scale. Ideally, laboratory procedures utilizing whole-core would provide a better means of simulating results in the field. Technical paper references to the success of this type of treatment in fracture-stimulated reservoirs versus traditional conventional reservoirs would be encouraging.

- Reviewer: G-53-01B

- Rating: 2

The general methodology is adequate. However, it does not appear the applicant has done any initial feasibility lab testing to determine if the technology application in the Bakken is promising. Nor do they state what the success criteria of the proposed core tests is to proceed to field testing. I think it would be reasonable to either do this prior to grant award or make successful bench testing a go/no-go criteria.

- Reviewer: G-53-01C

- Rating: 3

Preliminary work has been completed with drill cuttings of diverse mineralogy from sandstone and carbonates to Utica, Wolfcamp and Bone Spring Shales that show promising results in column recovery tests and Amott cell spontaneous imbibition testing for recovery of oil and suitability with dominant mineralogy of the Bakken formation. Laboratory work has been completed with core and cuttings of the Utica Shale (carbonate mudstone) in Ohio and Bone Spring (calcareous, siliceous mudstone) in Texas, which offer some comparisons with other fracture-stimulated reservoirs. Interfacial tension reduction has been demonstrated with Bakken crude and produced water with TDS of 290,000 to 350,000 ppm. Contact angle measurements showed biosurfactants were able to change an oil-wet surface to water-wet even at low concentrations that simulating flowback conditions. Data collected from the test methodologies used in prior evaluation has been able to be correlated with field performance data of prior applications. Biosurfactant stability has been tested in produced water with high salinity - high divalent ions. Our experimental data has been collected for heavy brines from TDS of 200,000 – 300,000. Surface and interfacial tensions were measured before and after samples aged for 1 – 7 days showing biosurfactant performance in these brines is nearly equivalent to that in freshwater aged for same period. Field applications have been done on other shale basins with formation brines with TDS up to 220,000.

- Applicant

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:

Although the use of surfactants to alter the imbibition and wetting characteristics of formations to enhance oil and gas recovery is well studied, this application will likely expand the range of formation types and environments where they can be utilized, if the technology is determined to be viable in the Williston Basin. The Williston Basin is known for its harsh downhole reservoir conditions, particularly the highly saturated salt brines with abundant divalent cations, as well as elevated temperatures and sour gas conditions. The possibility of manufacturing the surfactant locally, using North Dakota agricultural products, will also contribute scientific and technical knowledge to that sector.

- Reviewer: G-53-01A

- Rating: 3

The technical contribution of this study will likely be significant either as an application to fracture stimulated reservoirs or conventional reservoirs. In addition to technical advantages to be gained in the Bakken/Three Forks system, the Williston basin contains a significant number of conventional fields facing a lack of positive cash flow. A simple EOR treatment such as this will hopefully allow many of these operators to remain active while producing additional revenue for the state of North Dakota.

- Reviewer: G-53-01B

- Rating: 4

Yes, if the technology is capable of increasing production 25% after one treatment for 1-2 years and is applicable to the three well types and to a high percentage of all Bakken wells, the the technology will have a significant impact. Considering the low per well treatment costs, these results will sustain a healthy service delivery market and potentially provide the economic justification to build the referenced manufacturing facility. If subsequent results of repeat applications (not contemplated in this grant application) were to be successful, the impact would be very significant.

- Reviewer: G-53-01C

- Rating: 3

Stability of these biosurfactant has been tested in produced water with high salinity - high divalent ions. Our experimental data has been collected for heavy brines from TDS of 200,000 – 300,000. Surface and interfacial tensions were measured before and after samples aged for 1 – 7 days showing biosurfactant performance in these brines is nearly equivalent to that in freshwater aged for same period. Field applications have been done on other shale basins with formation brines with TDS up to 220,000. The overall availability of data collected repeat applications is currently limited, somewhat in part due to the long-term response of initial jobs. However, the data that is currently available has been favorable, as the repeat jobs often have as good, or greater production response.

- Applicant

5. The background of the principal investigator and the 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:

Applicant has not produced any referenced research papers. Comments on anecdotal results of this technology from other formations and basins has been noted. The applicant partner, Locus BioEnergy, is active in the Permian and Appalachian basins, with over 4 years of experience using the technology. Technical data is limited due to the proprietary nature of the chemistry, limiting available public data. Creedence Energy Services is an established Williston Basin service company and can bring local knowledge to the project, along with fluid pumping technology.

- Reviewer: G-53-01A

- Rating: 2

The background of the principle investigator is adequate in practical experience but limited in the technical realm. There is no doubt that Creedence Energy Services has much in the way of application experience to this type of project, though the lack of references to peer-reviewed technical papers and proposed laboratory testing techniques show a deficit in technical understanding and experience.

- Reviewer: G-53-01B

- Rating: 2

Very little information regarding the background of the principle investigators, past research experience, published results of previous applications in other basins is provided.

Additionally, the two success stories referenced in the application did not provide sufficient detail to fully determine the magnitude of success at all. Only an indication of some level of success in two instances. Overall market success in another similar basin would be much more compelling.

- Reviewer: G-53-01C

- Rating: 2

Use of microbial surfactants (Biosurfactants) for bioremediation and cleaning oil spills have been reported in literature from 1990s. Application of biosurfactants as ex-situ Microbial Enhanced Oil Recovery has been reported since 2000 and recent trends in use of renewable and biodegradable materials attracted more attentions to biosurfactants. Two publications describing results for these EOR applications are currently in preparation, SPE-204370-MS and SPE-204278-MS. This document will describe EOR production response results of application of biosurfactant in a field of 70+ wells over the course of 3.5 years and application of microbial surfactants and bio-based nanomaterials for increasing oil & gas production in the Permian Basin. Related to EOR, Amir Mahmoudkhani, Director of Technology for Locus Bio-Energy, has two relevant publications on the topic of EOR chemical applications, SPE-173729-MS and SPE-181290-MS. These publications, in process papers, are listed along, below, with publications regarding other applications of this technology. Locus Published Papers: SPE-195379-MS A Novel Biochemical-Based Paraffin Wax Removal Program Providing Revenue Generation and Asset Enhancement. OTC-30673-MS The Assessment of Microbial Surfactants as Asphaltene Dispersants: Sophorolipids vs Dodecylbenzenesulfonic Acid. OTC-30695-MS Impact of Solvent Treatments for Asphaltenes on Wax Deposition and an Efficient Alternative with Green Surfactants. SPE-201297-MS. Can Paraffin Wax Deposit Above Wax Appearance Temperature? A Detailed Experimental Study. In Preparation Documents (Accepted for Presentation at the 2021 SPE International Conference on Oilfield Chemistry): SPE-204315-MS Uncovering Mysteries of Waxphaltenes: Meticulous Experimental Studies of Field and Lab Deposits Unveil Nature of Wax-Asphaltene Intermolecular Interactions. SPE-204366-MS A Comprehensive Validation Methodology for Benchmarking Polymeric Chemistries for Controlling and Inhibiting C60+ Paraffin Waxes in Shale Oils. SPE-204357-MS Ultra-Low Dose Asphaltene Inhibitors for Offshore Applications: Myth or Reality. SPE-204278-MS Application of Microbial Surfactants and Bio-based Nanomaterials for Increasing Oil and Gas Production: Learnings from Producing Wells in the Permian Basin. SPE-204370-MS Green Well-Stimulation Fluids for Enhanced Oil Recovery from Tight Sand Formations: Field Wide 70+ Wells Study over 3.5 Years. Relevant Publications of Director of Technology, Amir Mahmoudkhani: SPE-173729-MS Microemulsions as Flowback Aids for Enhanced Oil and Gas Recovery after Fracturing, Myth or Reality: A Turnkey Study to Determine the Features and Benefits. SPE-181290-MS A New Class of Renewable Surfactants for Chemical Enhanced Oil Recovery.

- Applicant

6. 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:

Applicant will rely heavily on accurate information from operators concerning production as well as prompt notification of any significant changes that could impact production, either positively or negatively. It appears that performance rating will be primarily determined by raw production numbers. A more accurate PI determination would provide better normalization of the data, but may be difficult to obtain, from most operators, due to the cost of acquiring BHP data concurrent with the measured production.

- Reviewer: G-53-01A

- Rating: 3

The project management plan adequately outlines the testing timeframe and hours needed for subcontractor work. The project title lists an 18 month timeframe for the project duration, though the application and treatment times are listed at 6 months. Presumably this 12 month gap is needed to find operators willing to use the proposed treatment?

- Reviewer: G-53-01B

- Rating: 3

The project management plan, schedule, financial plan, and plan for communications among the investigators and subcontractors is adequate. The application does lack a well-defined milestone chart and clearly stated criteria of success of the prior lab testing or field test results. It should also provide statistics regarding the number (or percentage) of promising candidates per the number of wells reviewed to be able to better judge the potential market.

- Reviewer: G-53-01C

- Rating: 3

The 18-month timeline was selected for two primary reasons. First, to allow initial testing to be concluded, determine a 'best candidate' trial well, and pump the job. We do not expect this to extend past Q1 2021. Second, many of the applications production responses have extended past 1 year and approached 600 days. We wanted to allow for continued data collection if interfacial testing and production volumes indicated a continued effect past the 1-year mark. Without providing a specific number or percentage of wells, the general guidelines of a favorable well, horizontal wells with oil production rates greater than 10 bopd and vertical wells with production rates greater than 2 bopd offer better economics for the operator, oil cut (oil/total fluid) ratios of greater than 5%, and gas-oil ratio (scfg/bo) less than 50,000, should provide a wide range of potential initial applications. Candidate wells will be selected with consideration of historical production characteristics. Decline curve analysis will be used to characterize the reservoir and to forecast future production. Wells with irregular production characteristics will not be selected. Biosurfactant formulation/selection will be based upon screening completed in the laboratory using core, drill cuttings, and produced fluids. Surface tension, interfacial tension, and contact angle with reservoir materials will be measured with potential biosurfactant blends. These results, along with data collected from Amott cell imbibition testing and column recovery testing will be considered in determining the most likely successful biosurfactant blend to be used. These efforts are already underway. These screenings and evaluations start with ensuring salinity tolerance and thermal stability properties. Prior work has demonstrated that the described laboratory results are predictive of field performance. In performance monitoring, and success determination, positive production response above forecast production rates will be the key performance indicator for the program. Economics of the application will be monitored to establish payback times and return on investment to the operator at commercial rates. In addition to the production response, fluid characteristics will be monitored after treatment to determine persistence and activity of biosurfactant in the reservoir. A successful program will be defined as providing reasonable economic returns for each application.

- Applicant

7. The proposed purchase of equipment and the facilities available is:

Testing equipment for determining physical properties of produced fluids, at a field location, is well justified. The availability of these tests in the field will allow shorter turnaround of testing results and faster optimization of chemical treatment design.

- Reviewer: G-53-01A

- Rating: 4

There are no major purchases listed outside a laboratory setting. The purchase of equipment for laboratory purposes is subject to the revision of Amott cell imbibition of drill cuttings as an adequate means of testing reservoir response to surfactant treatments. Without specific technical references to the success of this type of testing in similar reservoirs, the purchase is poorly justified.

- Reviewer: G-53-01B

- Rating: 2

I do not feel it is necessary to do the initial lab core testing in North Dakota. The additional expense of transporting the core samples for testing at a lab that already has the test apparatus is modest. This is assuming the applicant has capability to do the core testing described elsewhere. At minimum, the applicability to the Bakken should be confirmed prior to the capital expenditure of the lab instruments for the North Dakota facility in support of the field demonstrations.

- Reviewer: G-53-01C

- Rating: 2

Our laboratory work dealing biosurfactants for Bakken shale formation and fluids has just been started recently through technical collaboration between Creedence and Locus BE. However, a significant progress has been made over the last 18 months on other unconventional plays including Permian and Appalachia. We have streamlined our lab process to quickly screen various biosurfactants and formulations to select the best candidates for which we utilize ST, IFT, CA, oil recovery and spontaneous imbibition tests. We have established an empirical correlation between lab and field performance data. Applicability of biosurfactant technology to fracture-stimulated reservoirs looks very promising. We have also generated more in-depth analysis using nanofluidics methodology to demonstrate efficacy of biosurfactants at nano-sized channels and pores level. Initial third-party testing with micro-chip technology (pore throats 110 nm) shows excellent performance for enhancing oil recovery. We have also another ongoing project with a 3rd party lab looking at shale core plugs wettability and to visualize the fluids in small pores using low field nuclear magnetic resonance (NMR) technique and correlation with Amott Cell Spontaneous Imbibition test. In another independent project, we are conducting screening biosurfactants with core-flood experiments on tight sandstone formation at a 3rd party laboratory. Above projects are expected to be completed by end of Q1 2021. Initial testing for suitability of the biosurfactant formulations with the mineralogy, reservoir conditions and fluid properties of the Bakken/Three Forks is currently in progress. First results show a good correlation of biosurfactants performance and fluid compatibility in extremely high TDS systems. The lab work will be completed prior to capital expenditures to equip a laboratory in North Dakota. We are trying to acquire core plugs from Bakken from potential operators interested to try a new low-cost green technology. To be clear, core testing within North Dakota, initial or otherwise, is not currently in plan. The proposed North Dakota laboratory testing capabilities planned for is limited to surface tension, interfacial tension, contact angle, spontaneous imbibition, and column oil recovery tests. The first three measurements are critical for assessing system response to the biosurfactant. Interfacial tension is used to correlate at which point in the life cycle of the application the well is currently in, as the chemistry cannot be directly measured itself. The aim in bringing these capabilities in-state, is to be as responsive as possible to the operator trialing the chemistry.

- Applicant

8. The proposed budget “value”¹ relative to the outlined work and the commitment from other sources is of:

This is a relatively low cost project, but has potential for significant long term economical benefits, if fully successful. Of notable economical potential is the possible synergy of the petroleum and agricultural sectors of North Dakota.

- Reviewer: G-53-01A

- Rating: 4

The proposed budget is very good in relative value as it aims to provide a cost-effective means of immediately increasing production and revenues for both operators and the state of North Dakota if successful. Further upside in the application beyond well-to-well scale is also possible for a relatively low budget.

- Reviewer: G-53-01B

- Rating: 4

I do feel the estimated field delivery cost and labor costs to perform the core testing, candidate search and analysis of results are all reasonable.

- Reviewer: G-53-01C

- Rating: 4

9. The “financial commitment”² from other sources in terms of “match funding” have been identified:

Applicant matching share includes a combination of cash and in-kind contributions that equal or exceed 50% of the total project cost.

- Reviewer: G-53-01A

- Rating: 3

Financial commitments of matching funds are of high value in that the majority of matching funds are coming from the applicant and their partner company. Commitments from current operators to adhere to the proposed assumption of additional costs associated with increased pumping would increase confidence.

- Reviewer: G-53-01B

- Rating: 4

Yes, the financial commitment and detail of matching funds is sufficient and reasonable. This includes the value of the projected work and technical outcome for the budgeted amount of the project. The financial commitment of 50% as outlined appears to be adequately supported. The anticipated support from an additional industry partner is a reasonable expectation, but already having this contributor identified would justify a high value rating.

- Reviewer: G-53-01C

- Rating: 3

Hunt Oil Company has signed a formal letter of support for this project, and several other operators are in the process of identifying well candidates. This grant application is another key step in validating the potential of the technology to other operators and stakeholders.

- Applicant

¹ “value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar. A commitment of support from industry partners equates to a higher value.

² “financial commitment” from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application; industry partnerships equates to increased favorability.

General Comments

Overall, this is a relatively low cost experiment and should be funded. The primary difficulties will be simulating the extreme downhole environmental conditions in some of the HTHP regions of the Williston Basin, and normalizing the raw production data to reduce external impacts to the production, unrelated to the surfactant treatment. Efficient communication and cooperation between the experimenter and the oil and gas operators will be essential. If an operator were willing to step up and commit to providing BHP data, during the monitored production period, for estimating changes in the PI of the completion, that would greatly enhance the rigor of the results.

- Reviewer: G-53-01A

The proposed EOR methodology has tremendous potential in both conventional and unconventional reservoirs in the Williston Basin. The introduction of a low-cost EOR treatment during a time of industry downturn would help to enhance production and cashflow from existing wells at higher rates of return without large capital commitments. Areas of concern include the inadequate testing of reservoir lithologies with respect to biosurfactants. In addition, no published technical references or data was presented illustrating the efficacy of the proposed treatment, especially in fracture stimulated reservoirs. However, excluding technical details, the upside in testing the application of this low cost treatment far outweighs the cost borne by the OGRC as a whole.

- Reviewer: G-53-01B

Overall, I do feel this nano biosurfactant technology has the potential to have a significant impact on well productivity, add a new service delivery market, add a new market for North Dakota ag-based raw materials and justify the construction and operation of a local manufacturing facility. However, I also feel the application itself is a little less than convincing and should have provided additional support of it's success in the Permian Basin in particular. The fact that there are numerous typographical errors brings into question the attention to detail necessary to deliver excellence in research documentation. That being said, my overall assessment is the application has sufficient merit to justify an award depending how it stacks up against the other grant requests.

- Reviewer: G-53-01C