Transmittal Letter

North Dakota Industrial Commission
ATTN: Oil and Gas Research Program
State Capitol – Fourteenth Floor
600 East Boulevard
Bismarck, North Dakota 58505

Dear Sir:

Attached is a proposal, "Enhanced Oil Recovery from the Bakken Shale Using Surfactant Imbibition Coupled with Gravity Drainage" that we submit for your consideration and funding. This project will be performed at the PREEC (***Petroleum Research, Education and Entrepreneurship Center***) at the University of North Dakota at Grand Forks.

Dr. Dongmei Wang will be the principal investigation for this three-year research project. The project will investigate a new process that may dramatically increase oil recovery from the Bakken shale. The total budget for the project is $819,763.13. We are requesting 30% of this amount from your agency. The remaining 70% is being requested from RPSEA (the Research Partnership for a Secure America) under their "Small Producers" request for proposals that was recently issued. The University of North Dakota hereby commits to complete this project as described in the attached proposal.

If you have any questions, please contact me or Dr. Dongmei Wang at 701-777-6143, E-mail: dongmei.wang@und.edu.

Sincerely,

Barry Milavetz
264 Centennial Dr., Stop 7134
Grand Forks, ND 58202

Signature:

Date: 10/29/09

TITLE PAGE

PROJECT TITLE: Enhanced Oil Recovery from the Bakken Shale Using Surfactant Imbibition Coupled with Gravity Drainage

NAME OF APPLICANT: UNIVERSITY OF NORTH DAKOTA

PRINCIPAL INVESTIGATOR: DONGMEI WANG

ADDRESS: Grand Forks, ND 58202 USA

DUNS Number: 10 2280781

Employer Identification Number (EIN): 45-6002491

Date: October 30, 2009

Amount of Request: $245,928.94

Technical Contact:

Dongmei Wang
UND/GGE
81 Cornell St. Stop-8358
Grand Forks, ND 58202
PHONE: (701) 777 – 6143
FAX : (701) 777 – 4449
E-MAIL: Dongmei.Wang@und.edu

Administrative Contact:

Deborah.E.Hanson
UND/GGE
81 Cornell St. Stop-8358
Grand Forks,ND 58202
PHONE : (701) 777 – 1040
FAX : (701) 777 – 4449
E-MAIL: Deborah.E.Hanson@und.edu

Enhanced Oil Recovery from the Bakken Shale Using Surfactant Imbibition Coupled with Gravity Drainage

ABSTRACT

This three-year research project (with requesting $245,928.94 from NDOC – 30% of estimated total cost of $819,763.13) is proposed by the University of North Dakota. Dr. Dongmei Wang will be the principal investigator (PI) during the project. The objective of this project is to determine whether surfactant solutions can alter the wettability of the Bakken Shale (in North Dakota's Williston Basin), so that oil recovery can be enhanced by a mechanism involving imbibition and gravity drainage.

The naturally fractured Bakken Formation consists of thin shale and silty carbonate sequences, capable of producing oil at economic rates when completed using hydraulically fractured horizontal wells. With the low permeability and oil-wet character, using existing methods, oil recovery factors have only been around a few percent of original oil in place. This proposed project will investigate whether a new surfactant imbibition concept can significantly improve oil recovery from the Bakken shale. This concept involves formulating special surfactant solutions that will alter the wettability of the formation. This alteration should promote imbibition of a dilute aqueous surfactant solution and increase oil displacement from the shale. The concept also relies on exploitation of gravity for collection and recovery of the oil in the system of natural and hydraulic fractures that are connected to horizontal wells.

In this proposed project, we will test a number of surfactants to identify formulations that will promote maximum imbibition into and oil displacement from Bakken shale cores. Measurements of phase behavior, interfacial tension, surfactant adsorption, and imbibition will be an important part of this effort. Based on these laboratory results, we will produce a numerical model that incorporates the relevant physics of surfactant imbibition and oil displacement for the Bakken shale. This model will then be used to assess the potential of this surfactant imbibition process for existing completions within the Bakken shale. The model will also be used assess whether alternative well placement/well completion/fracture configurations might provide higher oil recoveries.

In the Bakken shale formation within the middle of the Williston Basin, an increase of 1% in recovery could lead to an increase of 2 - 4 billion barrels of domestic oil production.

A. PROJECT DESCRIPTION

A.1 Project Objective

The objective of this research project is to determine whether surfactant solutions can alter the wettability of the Bakken shale formation (in North Dakota's Williston Basin), so that oil recovery can be enhanced by a mechanism involving imbibition and gravity drainage. Considering the Bakken shale geological features, the proposed project will focus on two goals: (1) Formulate special surfactant solutions that will alter the wettability of the formation. This alteration should promote imbibitions of dilute aqueous surfactant solutions and increase oil displacement from the shale. (2) Exploit gravity for collection and recovery of the oil in the system of natural and hydraulic fractures that are connected to horizontal wells.

The proposed project objective is consistent with the several aspects of QGRC eligibility. First, it targets the goal of increasing the ultimate recovery of existing oil pools — the Bakken shale in North Dakota. Second, it targets the scope of eligibility that the techniques and methods have not been used in currently producing and inactive fields in North Dakota.

A.2 Proposed Technology/Methodology

A.2.1 Statement and Significance of the Problems

The Bakken Formation has long been considered an important source rock for the oils of the Williston Basin. As a thin, clastic unit, the Bakken Formation in North Dakota occurs solely in the subsurface and consists of three informal units which are named the lower, middle, and upper members. The formation reaches a maximum thickness of 46 m (150 ft) in the central portion of the basin. The middle Bakken member ranges from 40 to 70 ft in thickness. The upper member of the Bakken is lithologically similar to the lower member and consists of dark-gray to brownish-black to black, slightly calcareous, organic-rich shale.[1] The maximum thickness can reach 9 m (28 ft) for the upper member in North Dakota, and the lower member has a maximum thickness of 17m (55 ft) in North Dakota.[2] Both upper and lower shales have a low porosity with ultra low permeability.

Although numerous studies have examined the geochemistry and hydrocarbon potential of the

Bakken shale, and capable of producing oil at economic rates when completed using hydraulically fractured horizontal wells. However, because of its low permeability and oil-wet character, using existing methods (hydraulic fracturing and horizontal wells), oil recovery amounts to a very small portion of original oil in place.[3-4] Various problems have been noted that contribute to the poor recovery factors:

(1) Natural fractures had poor flow connections with the vertical wells, so that although production was initially high, it rapidly dropped to low values. A number of vertical Bakken wells had decline rates between 15-17% with a range of 10-20%.[3] (2) Borehole instability related problems often arise when drilling weak, fissile shales.[5] (3) Wells completed in unconventional plays typically exhibited limited drainage areas and yielded a low oil recovery even though some of them were completed using horizontal wells and hydraulic fractures.[6]

A.2.2 Existing Technologies/Methodologies

It is vitally important to develop additional methods to increase oil recovery efficiency from the Bakken shale. A new method is currently being examined and tested in a sandstone reservoir,[7-8] in a low-permeability chalk reservoir in offshore Norway,[9] and in a low-permeability carbonate[10] reservoir in the United States. This new method involves coupling imbibition of aqueous surfactant solutions with gravity drainage. Similar to the Bakken shale, the target carbonate reservoirs are oil-wet and naturally fractured, with low matrix permeability and give very low oil recovery by water flooding. Most of the displacing fluid passes through the fractures without sweeping the oil-wet matrix. Based on a study by R. Guppa and K.K. Mohanty, [11] surfactant treatment for wettability alteration is one technique to recover oil from such a reservoir. Cationic, anionic, and nonionic surfactants have been identified that alter wettability of originally oil-wet carbonate rocks. Surfactants alter the wettability by solubilizing adsorbed hydrophobic components. More than 60% of the original oil can be recovered from initially oil-wet cores. In other studies, a series of long-term spontaneous imbibition tests were conducted with a temperature range from 40°C to 120°C on chalk cores representing different wetting conditions.[12] Based on this study, the aging time and reservoir temperature appeared to play a minor role. These results inspire us to explore the Bakken shale for the reservoir temperature range from 80°C to 120°C.

There is no literature reported yet for utilizing surfactant imbibition with gravity drainage to enhance oil recovery in shale reservoirs.

In this project, we will perform a number of laboratory experiments, combined with numerical simulations that will be directed at the following topics: (a) mechanism of oil recovery, (b) phase behavior, (c) oil/water interfacial tension (IFT), (d) wettability, (e) imbibitions, and (f) mathematical model employed in the numerical simulation.

A.2.3 Techniques Used and Facilities

Laboratory Research

Mechanism of oil recovery

The surfactant treatment of a fractured reservoir is very different from the traditional surfactant–alkaline or surfactant-alkaline-polymer (ASP) floods that need ultra low IFT.[13-14] For a surfactant-aided gravity drainage process in fractured reservoirs, the target oil recovery will be driven to a residual saturation value. Although this residual oil saturation may be much greater than in a traditional surfactant flood (i.e., near zero), it will still be a much lower value than if no aqueous fluid was imbibed. The IFT should be low enough so that the gravitational force allows sufficiently rapid oil drainage into the fracture system. The efficiency of this process is determined by a combination of capillary, gravity, and viscous forces.

For this proposed research, the following materials will be used:

Porous medium: cores from the Bakken shale in North Dakota will be used as the porous medium, the properties of the porous medium will be determined in our research. **Surfactants**: a number of surfactants will be selected for the work, and we will choose the one or two which should be looked promising at room temperature and that have high-temperature stability. **Oil**: oils with different AN (Acid number) will be used in experiments from the target Bakken formation. **Brines**: three different brines and local water will be used as imbibing fluids. **Na_2CO_3&NaCl**: these salts will be used to change salinity of the aqueous phase.

Surfactant Solution Formula Study

Previous research and the mineralogical analysis on core samples, as indicated in References 15-16, that formation damage from aqueous contact is a concern for Bakken shale. So, we wish to understand the clay chemistry and develop a surfactant formulation that enhances imbibition while causing minimum formation damage. One of the goals of this project is to identify a formulation that promotes imbibition while minimizing clay swelling and formation damage. Our first attempts toward this goal will involve balancing the salinity and divalent cation content of the injected aqueous fluid.

Phase behavior study

The purpose of the phase behavior study is to determine the surfactant composition and salinity that provides the lowest IFT. In this work, we observe changes in oil/water solubilization as a function of conditions, especially salinity. On the one hand, surfactants will be mixed with brine at various salinities ranging from 0 to 1M, and phase behavior will be observed at different temperatures from 20 to 120˚C. Na_2CO_3 and NaCl will be used to change salinity in different cases. On the other hand, a certain quantity of dilute surfactants will be prepared with varying concentrations of Na_2CO_3. These solutions will be equilibrated with equal volumes of oil on a tube shaker for a period of days and then left to settle for a time. The phase behavior will be studied to observe the change from Winsor type II^- to type of II^+ phase behavior with the increase in salinity of the solution.[16]

Interfacial Tension

IFT will be measured using a spinning drop interfacial tensiometer. In cases where a three phase micro-emulsion is found to exist, the oil phase is taken near the middle phase for accurate measurement of the IFT. Optimal salinity is taken as the salinity of the system which gives the least IFT between the oil and the aqueous phase. It is always near the salinity where the middle phase micro-emulsion is present in the phase behavior studies.

Wettability

Wettability is a key factor that affects the flow behavior in oil reservoir. It can be evaluated by measuring water-oil contact angles on mineral surface plates that is close to the composition of shale using a goniometer. The plates should be polished and equilibrated in NaCl brine for hours. Plates are then aged in oil to render the oil-wet. The experiments will be conducted at different temperatures from 20 to 120˚C. The evolution of contact angle is monitored with time for a period. Amott tests can also be used to assess wettability.

Imbibition

Spontaneous imbibition will be studied at a given temperature by using Amott cells. Brines with different sulfate contents will be used as imbibing fluids before the surfactant solution is used. A fixed imbibing period will be used before a new imbibing fluid is introduced. Some of the imbibition curves will be used during a study of the effect of acid number on imbibition. Using oils with different acid numbers, significant differences in both the imbibition rates and maximum recoveries should be observed during the period of application of the surfactant.

Surfactant imbibition and oil displacement simulation

As aforementioned, the surfactant-brine imbibition process can be effective in recovering oil from oil-wet fractured carbonates and chalk. Different parameters like water-oil ratio (WOR), IFT, wettability alteration, surfactant concentration, fracture dimensions, rock and fluid properties affect the amount and the rate of oil recovery. Using the equations which can descript the above mechanisms, a numerical model will be built and tested using results from laboratory. The simulation results should match the experimental data closely. For the simulation results, the change in wettability, the trends of imbibitions with increasing oil relative permeability, and enhancements in oil drainage will be demonstrated during the research.

Field predictions

A field-scale numerical model will be set up to estimate oil production in reservoir-scale matrix blocks. The wells to be tested will be selected in a pilot site and the reservoir dimensions will based on real data. The matrix will be assumed to be homogeneous. The surfactant solution is injected through a horizontal injector well at the bottom of the reservoir, and similarly, a horizontal producer well at the top of the reservoir is used to connect all the fractures and produce the oil. Fractures are assumed to be perpendicular to the horizontal wells. In the simulations, the fractures are assumed to be of infinite permeability and are always filled with surfactant solution. This is an ideal case, but can indicate the potential for scale-up of the laboratory results. The properties of the reservoir will be taken from the Bakken shale. The initial oil saturation inside the reservoir will be based on real field data.

A.2.4 Environmental Impact and Risks

In this proposed project, very small quantities of surfactant that exhibit no chemical toxicity will be used. They will be disposed of using UND's established and approved environment and safety procedures. If the surfactant solution with Na_2CO_3 is injected into the formation, the alkaline solution can cause scale formation, and the surfactant also can create emulsions. These are small risks, and the problems are manageable using existing technologies.

B STANDARDS OF SUCCESS

B.1 Expected Impacts and Benefits

Currently, surfactant costs 0.5 to $1/lb, and the surfactant solution typically contains 0.1% surfactant. That means a barrel of surfactant solution might cost $0.35. We anticipate that 0.5 to 1 bbl of oil might be displaced for every barrel of surfactant solution injected. If the oil price is $20, the process could (very conservatively) yield more than $5 for each dollar invested.

In the oil-wet Bakken Formation within the middle of the Williston Basin, very little oil is currently recovered. If the proposed project is successful, our new technology can substantially expand the reserves that can be economically produced from the Bakken formation. Each 1% OOIP increase in recovery could result in an additional 2-4 billion barrels of oil.

B.2 Applicability

Because of low permeability and oil-wet character, existing methods (hydraulic fracturing and horizontal wells) provide very low oil recovery factors when applied in the Bakken shale. The technology developed during this project should have applicability to any shale reservoir with natural fractures. Our technology will be directly applicable to and substantially improve oil recovery from the Bakken shale.

C BACKGROUND/QUALIFICATIONS

C.1 Organizational Capabilities and Experience

The University of North Dakota (UND) is the state's most comprehensive research university and the primary center for professional education and training. For research and entrepreneurism, the UND has established an international reputation for research and scholarship and has received $647.2 million for sponsored programs from internal and external sources. The ***Petroleum Research, Education and Entrepreneurship Center (PREEC*****)** is a team within the **School of Engineering and Mines,** which located the **Department of Geology and Geological Engineering (GGE)** at UND. It addresses several geological engineering characteristics of the Williston Basin, including (1) the role of in-situ stress fields and fracturing in the Bakken Formation and (2) enhanced oil recovery. **Dr. Dongmei Wang** is a member of PREEC and will be the principal investigator (PI). She has 22 years of experience in EOR (Enhanced Oil Recovery) project planning, laboratory experiments, numerical reservoir simulation, and economic evaluation. The project will also involve four senior faculty members (as described in section C.2) at the PREEC, a laboratory assistant, and two graduate students.

Additionally, we have three high-quality, suitable laboratories that will support the proposed project research. They are the Petroleum Engineering Laboratory, the Mining Engineering Laboratory, and the Environmental Analytical Research Laboratory.

C.2 Qualifications of Key Personnel

Dr. Dongmei Wang joined the Department of Geology and Geological Engineering (GGE) at the UND in July 2009. She has been involved with 40 projects related to reservoir engineering, production, and case design of the Daqing and five other oilfields in China, as well the oil field development case designs for Sudan, Kazakhstan, and Indonesia. She won 14 awards for outstanding achievement in implementing new concepts and developing innovative pilot tests for several enhanced oil recovery processes at Daqing. In this proposed project, Dr. Wang will contribute 80% of her time (1664 hours per year) in this project, and be in charge of project planning and management, numerical simulation, and field-scale prediction. **Dr. William D. Gosnold** is the Project Director of PREEC and a Professor and Chairman of the GGE at UND. He has conducted research on a variety of thermal properties of sedimentary basins including geothermal resources, heat advection in fluids, and kerogen maturation since 1979. Dr. Gosnold will be a Co-PI of this project and will contribute 10% of his time (108 hours per year) in charge of project technical and management support. **Dr. Raymond D. Butler** is a Research Associate in the GGE at the UND. He has over 30 years experience in industry and research, covering numerous geologic and hydrogeological projects in the Williston Basin and northern plains, and petroleum exploration in Montana and offshore Gulf of Mexico. Dr. Butler will contribute 10% (108 hours per year) of his time in charge of project cooperation with the industry, including obtaining Bakken core, oil, and water samples. **Dr. Michael Mann** is a Professor and Chairman of the Chemical Engineering Department at the UND. His specialty areas include renewable and sustainable energy systems with a focus on integration of fuel cells with renewable resources and production of fuel and specialty chemicals from crop oils. Dr. Mann will contribute 10% (108 hours per year) of his time in this project and be in charge of surfactant-product optimization and other questions related chemical engineering consultation. **Dr. Richard D. LeFever** is an Associate Professor in the GGE at UND. He has conducted extensive research on the petroleum geology of the Williston Basin for the past 27 years. Dr. LeFever will contribute 10% (108 hours per year) of his time in charge of project geological analysis in the Bakken shale.

D TECHNICAL MANAGEMENT

The project will be supervised by the project supporting office and reviewed periodically. The project implementation and planning will be made by the project PIs at the beginning of each project year. This project will consist of five senior members of PREEC, two graduate students and one lab associate. In the first year, a part of the time will be used for laboratory equipment preparation and surfactant product selection. Testing of various surfactant formulations and initiation of core floods will begin in the first project year and will proceed throughout the second project year. Beginning in the second project year (and continuing through to the end of the project) numerical simulation models will be set up to verify the core flooding results, and expanded to field-scale prediction of oil recovery from application of the process in the Bakken Formation.

E PROJECT SCHEDULE AND MILESTONES

This proposed project will plan to start in April 2010 and end in March 2013. During this three-year project, six tasks should be implemented, including: **(1)** technical management and planning, **(2)** technology status assessment, **(3)** technology transfer, **(4)** surfactant formulation evaluation and laboratory tests, **(5)** numerical simulation modeling of imbibition and gravity drainage study, and **(6)** the project summary. We shall submit periodic, topical, and final reports in accordance with the instructions accompanying the checklist and final research report. The detail labor hours are provided by Table 1.

Table 1 Project Schedule and Milestones

Year	Task \ Time		1st Quarter			2nd Quarter			3rd Quarter			4th Quarter		
1st year			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Task1	Name/hrs				W./440, G./72								
	Task2	Name/hrs				W./280, R./72, M./72, B./108								
	Task3	Name/hrs							W/168, LA./480					
	Task4	Name/hrs										W./440,LA./640, S./480		
	Task5	Name/hrs												
	Task6	Name/hrs					S./256 LA./224	W./144		S./128 LA./388	W./72		G./36 M./36 R./36	W./120
2nd year	Task \ Time		1st Quarter			2nd Quarter			3rd Quarter			4th Quarter		
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Task1	Name/hrs	W./320, G./72,LA./160											
	Task2	Name/hrs				M./72, R./72								
	Task3	Name/hrs							W./80					
	Task4	Name/hrs	W./432, ,B./108, S./1440, LA./1772											
	Task5	Name/hrs										W./496		
	Task6	Name/hrs		S./128 LA./144	W./72		S./128 LA./144	W./72		S./128 LA./144	W./72		G./36 M./36 R./36	W./120
3rd year	Task \ Time		1st Quarter			2nd Quarter			3rd Quarter			4th Quarter to next 1st Quarter		
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Task1	Name/hrs	W./320, G./36, LA./320											
	Task2	Name/hrs				B./108								
	Task3	Name/hrs					W./200							
	Task4	Name/hrs	LA./264			LA./264			LA./264			LA./264		
	Task5	Name/hrs	W./720,S./720											
	Task6	Name/hrs		S./128 LA./264	W./72		S./128 LA./264	W./72		S./128 LA./264	W./72	W./288, G./72,M./108,R./108		

Here, B.: Butler, G.: Will Gosnold, M.: Mike Mann, R.: Richard LeFever, W.: Dongmei Wang, S.: Graduate student (student, 20% hourly rate), LA.: Lab. Assistant (100% hourly rate).

F COST SUMMARY

Table 2 shows estimated costs for the project. The total estimate project cost is $819,763.13. Of this value, we are requesting 30% ($245,928.94) of this amount from your agency. The remaining 70% is being requested from RPSEA under their "Small Producers" request for proposals that was recently issued. Additional, justifications for the costs are included in the detail budget. We have requested the minimum amount of equipment and supplies to make this project work. If less money is available than our request, we will need to cut staff for the project. That will make the project less efficient. Additionally, the personnel budget is estimated by the actual personnel salaries multiplied by their fractional project contribution. Five percent increases are included for each subsequent year. The travel budgets are estimated based on costs for attendance of specific conferences and workshops, and project reviews. The communications-phone costs are for long distance calls for the technical discussions, and the postage to transmit materials to the relative technical departments. The office supplies are for paper, pens, pencils, etc. The supply/materials-professional costs are for the core samples and lab ware consumables such as beakers, test tubes, flasks, tubing, etc.

Table 2 Cost Summary

BUDGET OUTLINE	F&A (INDIRECT COST) RATE FOR PROPOSAL =			35.00%
DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	TOTAL
Salary - Wang	15,600.00	16,380.00	17,199.00	49,179.00
Salary - Gosnold	2,631.31	2,762.88	2,901.02	8,295.20
Salary - Mann	3,027.72	3,179.11	3,338.06	9,544.89
Salary - LeFever	2,519.43	2,645.40	2,777.67	7,942.50
Salary - Butler	1,950.00	2,047.50	2,149.88	6,147.38
Salary - Lab Associate	10,650.00	11,182.50	11,741.63	33,574.13
SALARIES - Graduate Students(2)	8,164.80	8,573.04	9,001.69	25,739.53
FRINGE BENEFITS	6,570.00	6,898.50	7,243.43	20,711.93
TOTAL PERSONNEL	51,113.26	53,668.92	56,352.37	161,134.55
TRAVEL	2,400.00	2,250.00	1,800.00	6,450.00
COMMUNICATIONS-PHONE	75.00	75.00	75.00	225.00
COMMUNICATIONS-POSTAGE	60.00	60.00	60.00	180.00
INSURANCE	0.00	0.00	0.00	0.00
RENTS/LEASES-EQUIPMENT & OTHER	0.00	0.00	0.00	0.00
RENTS/LEASES-BUILDING/LAND	0.00	0.00	0.00	0.00
OFFICE SUPPLIES	225.00	225.00	225.00	675.00
PRINTING-COPIES, DUPLICATING	0.00	0.00	0.00	0.00
REPAIRS	0.00	0.00	0.00	0.00
UTILITIES	0.00	0.00	0.00	0.00
SUPPLIES-IT SOFTWARE	0.00	0.00	0.00	0.00
SUPPLY/MATERIALS-PROFESSIONAL	3,000.00	3,000.00	3,000.00	9,000.00
SUPPLIES-MISCELLANEOUS	30.00	30.00	0.00	60.00
IT EQUIPMENT <$5,000	0.00	0.00	0.00	0.00
OTHER EQUIPMENT <$5,000	0.00	0.00	0.00	0.00
FEES-OPERATING FEES & SERVICES	0.00	0.00	0.00	0.00
FEES-PROFESSIONAL FEES & SERVICES	0.00	0.00	0.00	0.00
FEES-SUBCONTRACTS (see Note 1 below)	0.00	0.00	0.00	0.00
PROFESSIONAL DEVELOPMENT	0.00	0.00	0.00	0.00
FOOD AND CLOTHING	0.00	0.00	0.00	0.00
WAIVERS/SCHOLARSHPS/FELLOWSHPS	0.00	0.00	0.00	0.00
TOTAL OPERATING	5,790.00	5,640.00	5,160.00	16,590.00
EQUIPMENT >$5,000	6,000.00	0.00	0.00	6,000.00
IT EQUIPMENT >$5,000	0.00	0.00	0.00	0.00
TOTAL EQUIPMENT	6,000.00	0.00	0.00	6,000.00
TOTAL DIRECT COST	62,903.26	59,308.92	61,512.37	183,724.55
F&A (INDIRECT COST) *	19,916.14	20,758.12	21,529.33	62,203.59
TOTAL COST	82,819.40	80,067.05	83,041.70	245,928.15

REFERENCES

1. LeFever, J.A., Martiniuk, C.D., Dancsok, E.F.R., *et al.*: “Petroleum Potential of the Middle Member of Bakken Formation,” *Sixth International Willinston Basin Symposium*, pp. 74-95,1991.

2. LeFever, J.A. , Helms. L.: “ Bakken Formation reserve estimates.” North Dakota Geological Survey, Bismarck, ND. 2006.

3. Reisz, M.R: “Reservoir Evaluation of Horizontal Bakken Well Performance on the Southwest Flank of the Williston Basin,” SPE 22389 presented at the SPE International Meeting on Petroleum Engineering, Beijing, China. Mar. 24-27, 1992.

4. Breit, V.S., Streight D.H. and Dozzo, J.A.: “Reservoir Characterization of the Bakken Shale from Modeling of Horizontal Well Production Interference Data,” SPE Rocky Mountain Regional Meeting, held in Casper, WY. May 18-21, 1992.

5. McLellan, P.J. , Cormier, K.: “ Borehole Instability in Fissile, Dipping Shales, Northeastern British Columbia,” SPE 35634 presented at the Gas technology Conferenc held in Calgary, Alberta, Canada, 28 Apr. -1 May. 1996

6. Stuart, A.C, David, M.C., Ken D., et al. :” Unconventional Resource Play Evaluation: A Look at the Bakken Shale Play of North Dakota,” SPE 114171 presented at the SPE Unconventional Reservoirs Conference held in Keystone, Colorado, U. S.A, 10-12 Feb. 2008.

7. J.Chen, H.Tang, X.Xu, *et al*: “Analysis of the Inhibition displacement Effect Influenced by the Surface Active Agent in Low Permeability Fractured Sandstone Reservoir,” *Offshore Oil*:, Vol.28(1), pp. 51-55,2008.

8. T.Babadgli: “Analysis of Oil recovery by Spontaneous Imbibition of Surfactant Solution,” paper SPE 84866 presented at the SPE Improved Oil recovery Conference in Asia Pacific held in Kuala Lumpur, Malaysia. Oct. 20-21, 2003.

9. P.Zhang and T. Austad: “Waterflooding in Chalk: Relationship Between Oil Recovery, New Wettability Index, Brine Composition and Cationic Wettability Modifier,” paper SPE 94209 presented at the SPE Europe/EAGE Annual Conference held in Madrid, Spain. Jun. 13-16, 2005.

10. R. Gupta, K.K. Mohanty: “Wettability Alteration of Fractured Carbonate Reservoirs,” paper SPE 113470 presented at the SPE/DOE Symposium on Improved Oil Recovery, 20-23 April 2008, Tulsa, Oklahoma, USA.
Surfactant,” PETROLEUM EXPLORATION & DEVELOPMENT, Beijing. June, 2008.

11. B. Adibhatla, K.K.Mohanty: “Oil Recovery from Fractured Carbonates by Surfactant-Aided Gravity Drainage: Laboratory Experiments and Mechanistic Simulations,” SPE 99773 presented at SPE/DOE Symposium on Improvement Oil Recovery held in Tulsa, OK. Apr. 22-26, 2006.

12. R. Gupta, K.K. Mohanty: “Temperture Effects on Surfactant-Aided Imbibition Into Fractured Carbonates,” paper SPE 110204 presented at the SPE Annual Technical Conference and Exhibition, 11-14 Nov. 2007, Anaheim, CA, USA.

13. Dongmei W.,Dakuang H. and Guanli X, et al.:“HPAM Affecting Foam Capability with α-Olefin Sulfonate

14. https://www.dmr.nd.gov/oilgas/FeeServices/wfiles/15/W15722.pdf

15. Cramer, D.D.: “Reservoir Characteristics and Stimulation Techniques in the Bakken Formation and Adjacent Beds, Billings Nose Area, Willinston Basin,” SPE 15166 presented at the Rocky Mountain Regional Meeting of the Society of Petroleum held in Billings, MT, May 19-21, 1986.

16. Winsor, P.A.: Solvent Properties of Amphiphilic Compounds, London, Butterworths, 1954.

(USE THIS FORM FOR ALL EXTERNAL FUNDING PROPOSALS)

☐ Earmark ☒ Competitive Proposal ☐ Noncompetitive Proposal ☐ Preproposal ☐ Fellowship ☒ Appendix Attached (e.g. Matching Funds Form, MOU)

UNIVERSITY OF NORTH DAKOTA
Proposal Transmittal Form

Submit 2 copies of signed proposal in **FINAL** form no fewer than **5 working days** prior to proposal deadline to *RD&C , Box 7134, 105 Twamley Hall*

TITLE: (30 Characters or Less) Enhanced Oil Recovery from the Bakken Shale Using Surfactant Imbibition Coupled with Gravity Drainage

FUNDING AGENCY/RFP: North Dakota Industrial Commission Oil and Gas Research Council

PRINCIPAL INVESTIGATOR(S): Dongmei Wang, Research Associate **DEPT #:** GGE **PHONE:** 701-777-6143
(Name, Title, Department)

PRINCIPAL INVESTIGATOR(S): Will Gosnold, Chairman of Department **DEPT #:** GGE **PHONE:** 701-777-2631
(Name, Title, Department)

PROPOSAL DEADLINE DATE: Nov.1, 2009 **PROPOSED PROJECT PERIOD:** Apr. 2010 To: Mar. 2013

TOTAL FUNDS REQUESTED: 245,928.939 **TOTAL DIRECT COSTS:** 183,725.142 **TOTAL F & A:** 62,203.00

Check if your project involves any of the following (review and approval of a proposal may be required by the appropriate committee):

☐ Animals (Institutional Animal Care Committee)
☐ Biohazards or Recombinant DNA (Institutional Biosafety Committee)
☐ Human Subjects (Institutional Review Board)
☐ Radioactive Materials (Radiation Safety & Hazardous Materials Committee)
☐ Controlled Substances/DEA License Required

RECEIVED
OCT 23 2009
UND GRANTS & CONTRACTS

☐ **UNIVERSITY COMMITMENTS**

If University Commitments is checked, check corresponding commitment on right and please explain.

☐ Faculty Release Time beyond Current Allocation
☐ Office/Lab Space beyond Current Allocation
☐ Support Staff
☒ Graduate Student Tuition Waivers
☐ Matching Funds
☐ Other

If the response to any of the following is "Yes," please attach documentation.

	Yes	No
Has lobbying occurred with respect to this proposal? (Required for Federal projects only)	☐	☒
Does this proposal require modification to existing building utilities, construction of new space, or impact the existing operation of building components?	☐	☒
Does the project have a confidentiality agreement, proprietary information or a material transfer agreement?	☐	☒
Does this proposal involve interdisciplinary or multidisciplinary research?	☐	☒
Will this proposal use resources in the High Performance Computer Center?	☐	☒
Did this proposal result from a Faculty Research Seed Money (FRSM) grant?	☐	☒

If so, date of FRSM award:

Conflict of Interest: I have filed with the Dean of my college appropriate, up-to-date Financial Interest Disclosure forms that relate to the University of North Dakota. I understand that these forms indicate that I will cooperate in the development of a Memorandum of Understanding that constitutes a conflict of interest "resolution plan" if a conflict of interest or potential conflict of interest is found to exist that relates to this proposal, and to comply with any conditions or restrictions imposed by the University to manage, reduce or eliminate actual or potential conflicts of interest or forfeit the award.

Dongmei Wang 10-23-09 W.D. Gosnold 10-23-09

Principal Investigator(s) Date Principal Investigator(s) Date

APPROVALS:

W.D. Gosnold 10-23-09

Department Chairperson(s) Date

Other Date

School/College - Administration & Finance (as appropriate) Date

10/29/09

Grants & Contracts Administration (G&C) Date

Richard K. Schultz 10/23/2009

Principal Investigator's Dean for Hesham El-Rewini Date

[signature] 10/28/09

Research Development and Compliance (RD&C) Date

Dean of Graduate School (if graduate students are included) Date

Revised 11/14/2006

BUDGET OUTLINE — F&A (INDIRECT COST) RATE FOR PROPOSAL = 35.00%

DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	TOTAL
Salary - Wang	15,600.00	16,380.00	17,199.00	0.00	49,179.00
Salary - Gosnold	2,631.31	2,762.88	2,901.02	0.00	8,295.20
Salary - Mann	3,027.72	3,179.11	3,338.06	0.00	9,544.89
Salary - LeFever	2,519.43	2,645.40	2,777.67	0.00	7,942.50
Salary - Butler	1,950.00	2,047.50	2,149.88	0.00	6,147.38
Salary - Lab Associate	10,650.00	11,182.50	11,741.63	0.00	33,574.13
SALARIES - Graduate Students(2)	8,164.80	8,573.04	9,001.69	0.00	25,739.53
FRINGE BENEFITS	6,570.00	6,898.50	7,243.43	0.00	20,711.93
TOTAL PERSONNEL	51,113.26	53,668.92	56,352.37	0.00	161,134.55
TRAVEL	2,400.00	2,250.00	1,800.00	0.00	6,450.00
COMMUNICATIONS-PHONE	75.00	75.00	75.00	0.00	225.00
COMMUNICATIONS-POSTAGE	60.00	60.00	60.00	0.00	180.00
INSURANCE	0.00	0.00	0.00	0.00	0.00
RENTS/LEASES-EQUIPMENT & OTHER	0.00	0.00	0.00	0.00	0.00
RENTS/LEASES-BUILDING/LAND	0.00	0.00	0.00	0.00	0.00
OFFICE SUPPLIES	225.00	225.00	225.00	0.00	675.00
PRINTING-COPIES, DUPLICATING	0.00	0.00	0.00	0.00	0.00
REPAIRS	0.00	0.00	0.00	0.00	0.00
UTILITIES	0.00	0.00	0.00	0.00	0.00
SUPPLIES-IT SOFTWARE	0.00	0.00	0.00	0.00	0.00
SUPPLY/MATERIALS-PROFESSIONAL	3,000.00	3,000.00	3,000.00	0.00	9,000.00
SUPPLIES-MISCELLANEOUS	30.00	30.00	0.00	0.00	60.00
IT EQUIPMENT <$5,000	0.00	0.00	0.00	0.00	0.00
OTHER EQUIPMENT <$5,000	0.00	0.00	0.00	0.00	0.00
FEES-OPERATING FEES & SERVICES	0.00	0.00	0.00	0.00	0.00
FEES-PROFESSIONAL FEES & SERVICES	0.00	0.00	0.00	0.00	0.00
FEES-SUBCONTRACTS (see Note 1 below)	0.00	0.00	0.00	0.00	0.00
PROFESSIONAL DEVELOPMENT	0.00	0.00	0.00	0.00	0.00
FOOD AND CLOTHING	0.00	0.00	0.00	0.00	0.00
WAIVERS/SCHOLARSHPS/FELLOWSHPS	0.00	0.00	0.00	0.00	0.00
TOTAL OPERATING	5,790.00	5,640.00	5,160.00	0.00	16,590.00
EQUIPMENT >$5,000	6,000.00	0.00	0.00	0.00	6,000.00
IT EQUIPMENT >$5,000	0.00	0.00	0.00	0.00	0.00
TOTAL EQUIPMENT	6,000.00	0.00	0.00	0.00	6,000.00
TOTAL DIRECT COST	62,903.26	59,308.92	61,512.37	0.00	183,724.55
F&A (INDIRECT COST) *	19,916.14	20,758.12	21,529.33	0.00	62,203.59
TOTAL COST	82,819.40	80,067.05	83,041.70	0.00	245,928.15

* F&A is applied to modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or

---

Note (1)

Complete this Subcontract information section so that an accurate MTDC can be calculated:

F&A is applicable only to the first $25,000 of each subcontract, regardless of how many years a subcontract lasts.

Subcontract Amounts of $25,000 or less	YEAR 1	YEAR 2	YEAR 3	YEAR 4
Subcontract 1	0.00	0.00	0.00	0.00
Subcontract 2	0.00	0.00	0.00	0.00
Subcontract 3	0.00	0.00	0.00	0.00
Subcontract 4	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00

Example	*YEAR 1*	*YEAR 2*	*Notes*
ABC Corp.	*25,000.00*	*0.00*	*The subcontract with ABC is for $100,000 and is for 2 years. F&A will only be applied to first $25,000.*
XYZ, Inc.	*16,000.00*	*0.00*	*The subcontract with XYZ is for $16,000 and is for 1 year. F&A will be applied to the entire $16,000.*
Acme Co.	*19,000.00*	*6,000.00*	*The subcontract with Acme is for $50,000 and is for 2 years. Anticipate paying only $19,000 the first year and the rest the 2nd year. Only $6,000 will have F&A applied the 2nd year.*
Total amount that F&A can be applied to	*60,000.00*	*6,000.00*	

BUDGET OUTLINE

F&A (INDIRECT COST) RATE FOR PROPOSAL = 35.00%

DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	TOTAL
Salary - Wang	52,000.00	54,600.00	57,330.00	0.00	163,930.00
Salary - Gosnold	8,771.04	9,209.59	9,670.07	0.00	27,650.70
Salary - Mann	10,092.40	10,597.02	11,126.87	0.00	31,816.29
Salary - LeFever	8,398.10	8,818.01	9,258.91	0.00	26,475.01
Salary - Butler	6,500.00	6,825.00	7,166.25	0.00	20,491.25
Salary - Lab Associate	35,500.00	37,275.00	39,138.75	0.00	111,913.75
SALARIES - Graduate Students(2)	27,216.00	28,576.80	30,005.64	0.00	85,798.44
FRINGE BENEFITS	21,900.62	22,995.65	24,145.43	0.00	69,041.69
TOTAL PERSONNEL	170,378.16	178,897.06	187,841.92	0.00	537,117.14
TRAVEL	8,000.00	7,500.00	6,000.00	0.00	21,500.00
COMMUNICATIONS-PHONE	250.00	250.00	250.00	0.00	750.00
COMMUNICATIONS-POSTAGE	200.00	200.00	200.00	0.00	600.00
INSURANCE	0.00	0.00	0.00	0.00	0.00
RENTS/LEASES-EQUIPMENT & OTHER	0.00	0.00	0.00	0.00	0.00
RENTS/LEASES-BUILDING/LAND	0.00	0.00	0.00	0.00	0.00
OFFICE SUPPLIES	750.00	750.00	750.00	0.00	2,250.00
PRINTING-COPIES, DUPLICATING	0.00	0.00	0.00	0.00	0.00
REPAIRS	0.00	0.00	0.00	0.00	0.00
UTILITIES	0.00	0.00	0.00	0.00	0.00
SUPPLIES-IT SOFTWARE	0.00	0.00	0.00	0.00	0.00
SUPPLY/MATERIALS-PROFESSIONAL	10,000.00	10,000.00	10,000.00	0.00	30,000.00
SUPPLIES-MISCELLANEOUS	100.00	100.00	0.00	0.00	200.00
IT EQUIPMENT <$5,000	0.00	0.00	0.00	0.00	0.00
OTHER EQUIPMENT <$5,000	0.00	0.00	0.00	0.00	0.00
FEES-OPERATING FEES & SERVICES	0.00	0.00	0.00	0.00	0.00
FEES-PROFESSIONAL FEES & SERVICES	0.00	0.00	0.00	0.00	0.00
FEES-SUBCONTRACTS (see Note 1 below)	0.00	0.00	0.00	0.00	0.00
PROFESSIONAL DEVELOPMENT	0.00	0.00	0.00	0.00	0.00
FOOD AND CLOTHING	0.00	0.00	0.00	0.00	0.00
WAIVERS/SCHOLARSHPS/FELLOWSHPS	0.00	0.00	0.00	0.00	0.00
TOTAL OPERATING	19,300.00	18,800.00	17,200.00	0.00	55,300.00
EQUIPMENT >$5,000	20,000.00	0.00	0.00	0.00	20,000.00
IT EQUIPMENT >$5,000	0.00	0.00	0.00	0.00	0.00
TOTAL EQUIPMENT	20,000.00	0.00	0.00	0.00	20,000.00
TOTAL DIRECT COST	209,678.16	197,697.06	205,041.92	0.00	612,417.14
F&A (INDIRECT COST) *	66,387.35	69,193.97	71,764.67	0.00	207,346.00
TOTAL COST	276,065.51	266,891.04	276,806.59	0.00	819,763.13

* F&A is applied to modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or

---

Note (1)

Complete this Subcontract information section so that an accurate MTDC can be calculated:

F&A is applicable only to the first $25,000 of each subcontract, regardless of how many years a subcontract lasts.

Subcontract Amounts of $25,000 or less	YEAR 1	YEAR 2	YEAR 3	YEAR 4
Subcontract 1	0.00	0.00	0.00	0.00
Subcontract 2	0.00	0.00	0.00	0.00
Subcontract 3	0.00	0.00	0.00	0.00
Subcontract 4	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00

Example	*YEAR 1*	*YEAR 2*	*Notes*
ABC Corp.	*25,000.00*	*0.00*	*The subcontract with ABC is for $100,000 and is for 2 years. F&A will only be applied to first $25,000.*
XYZ, Inc.	*16,000.00*	*0.00*	*The subcontract with XYZ is for $16,000 and is for 1 year. F&A will be applied to the entire $16,000.*
Acme Co.	*19,000.00*	*6,000.00*	*The subcontract with Acme is for $50,000 and is for 2 years. Anticipate paying only $19,000 the first year and the rest the 2nd year. Only $6,000 will have F&A applied the 2nd year.*
Total amount that F&A can be applied to	*60,000.00*	*6,000.00*	

APPENDIX **A. RESUMES**

Dongmei Wang , Department of Geology & Geological Engineering, University of North Dakota/
81 Cornell St. Stop 8358, Grand Forks, 58202, (701)666-6143 (Office), (701)777-4449(Fax),
Dongmei.Wang@und.edu (email)

EDUCATION:

2007: PhD of Engineering, Oil & Gas Development Engineering, Research Institute Petroleum Exploration & Development, Beijing, China.

2004: Master of Engineering, Oil & Gas Development Engineering, Research Institute Petroleum Exploration & Development, Beijing, China.

1999: B.Sc. Computer Science, Changchun Science & Technology University. Changchun, China.

1987: Sc. Computer Program Design, Daqing Petroleum University, Daqing, China.

Professional Experience

July 2009 - Present: Research Associate in Department of Geology & Geological Engineering, University of North Dakota/

July 2008 - July 2009: Director of *Potential Assessment of Overseas Oil Projects* Department, Chief Engineer of *EOR* Department,

June 2002- 2008: Chief Engineer of the Department, Senior Reservoir engineer, Supervisor of Projects & Manager of Employee Training, EOR Lab. of DPRI (Exploration & Development Research Institute of Daqing Oil Field).

1998-2001: Pilot Test Case Design, Polymer Flooding Research Department of DPRI, Head of Projects.

1987-1997: Reservoir Numerical Simulation Development and Application and Unix Operation System Administration, EOR Department of DPRI, Head of projects.

PROJECT / WORK EXPERIENCE:

1987-1989, participated:

1. “POLYMER Flooding” Numerical Module Development, 1987-1989.
2. In charge of the project: Solution Techniques for Parameters in Chemical Flooding Numerical Simulation Software, 1987-1988.

1990-1994, key technical person:

3. “SURFPOL” Numerical Module Development, 1990-1992.
4. Study of the Pilot Test for Injection of Natural Gas to Enhance Oil Recovery from the Fault East of the First North, 1993-1995.

5. Study of Pilot Test of WAG (water alternating gas) to Improve Oil Recovery for Shanshan Oil Field in XinJiang, 1993.

6. Numerical Simulation Study of Injection of Natural Gas to Enhance Oil Recovery for Eastern Beier, 1994.

***1995-2001, Head of Project*:**

7. Polymer Flooding Numerical Module Development and Application, 1991-1995

8. Development of Pre & Post Flood Software for Polymer Flooding Numerical Module, 1991-1995.

9. Second Evaluation and Layout for EOR Potential in Daqing, 1996-1998.

10. Reservoir Optimization and Development for ASP Flooding in Daqing, 1997-1998.

11. Polymer Flood Design for Western 3rd Site of North Daqing, 1998-1998.

12. Re-programming ASP Flood Numerical Simulation Software, 1999.

13. Polymer Flood Design for Eastern of Central Area in Daqing, 2001.

***2002-2006, supervisor of projects & the head of projects*:**

14. Polymer Flooding Design for Eastern of Central of Saertu in Daqing, 2002.

15. Polymer Flooding Development Case Design Optimize, 2003.

16. Pilot Test Research of Thermal Method to Enhance Oil Recover After Polymer Drive, 2003.

17. The EOR Database for the Daqing Oil Field, 2003.

18. Improvement of Polymer Flooding Technical Effectiveness, 2004.

19. Patent on "A Numerical Simulator Integrating Lower Concentrations of Surfactant with the Other Phases in ASP Flooding", Patent Number: **200310101815.0**. Authorization: Feb. 28th, 2007.

20. Analysis of Polymer Flooding Techniques for the Main Oil Strata in Daqing, 2005.

21. Feasibility Study of Injection Nitrogen Gas to Improve Oil Recovery for 32-6 Well Pattern in Qinhuangdao, 2004.

22. Economical Evaluation of Chemical Flooding in 12 Pilot Sites in the Daqing and Kalamayi Oil Fields.

23. The Criteria Establishing "Terms of Oil/Gas Reservoir Engineering", 2004-2005.

24. The Criteria Establishing "Technical Requirements for Development and Project Design for Polymer Flooding", Criteria Number: SY/T 6683-2007. Implement Date: March 1st, 2007. **(This is now the standard for polymer flood design throughout China.)**

25. Injection Profile Reversals during Polymer Floods: Characteristics and Counter-measures, 2005-2007.

26. Study of Polymer Flooding Effectiveness for Secondary & Tertiary Oil Strata, 2004-2005.

27. Study of Profile Modification Technique, 2004-2005.

28. Study of Option & Evaluation Techniques for New Polymer, 2004-2005.

29. Feasibility Study for Changing the Direction of Liquid Flow to Explore the Remained Oil near the Areas of the Distribution Lines, 2006.

30. Development of Numerical Simulation Software on Polymer Multi-Molecule Weight Injection and Profile Modification, 2004-2006.

31. Study of the Approach to Enhance Oil Recovery Further After Polymer Flooding, 2004-2007.

32. Study of the Approach to Enhance Oil Recovery Further After Polymer Flooding, 2008

33. Study of Effects of Fractures on Sweep Improvement for Polymer Flooding of Eastern Berxi in Daqing, 2005.

34. Investigated Sweep Improvement Options for the Daqing Oil Field (including more concentrated polymers, new polymers, gel treatments, colloidal dispersion gels, foams, as well as others), 2005-2006.

2007, at Saudi Aramco and Kuwait KOC:

35. Introduced EOR Technology Being Performed at Daqing.

36. Prepared a “PRE-QUALIFICATION DOCUMENT” that initiated collaborative projects between PetroChina, Saudi Aramco, and the Kuwait Oil Company in the areas of EOR, Drilling, and Workovers.

2008, in charge of :

37. Development Case Design of 1/24 of Greater Unity Field in Sudan.

38. Development Case Design of 17 of Greater Unity Field in Sudan.

39. Evaluation the Feasibility of EOR method for Heglig Oil Field in Sudan.

40. Training of polymer flooding technology for KNOC (Korea National Oil Company).

41. Suitable Reservoir Condition Study of Polymer Flooding with High Concentration.

AWARDS/HONORS:

AWARDS:

1. “Polymer Flooding” Numerical Module Development. Award for Technology Progress from Daqing, 1989.

2. “SURFPO” Numerical Module Development. Award for Technology Progress from Heilongjiang Province, 1992.

3. Development of the Pilot Test for Injection Natural Gas to Enhance Oil Recovery from the Fault East of the First North. Award for Technology Progress from Daqing, 1995.

4. Development of the Polymer Flooding Numerical Module Application. Award for Technology Progress from Daqing, 1995.

5. Development of Pre & Post Flooding Software for Polymer Flooding Numerical Module. Award for Technology Progress from Daqing, 1995.

6. Second Evaluation and Layout for EOR Potential in Daqing. Award for Technology Progress from Daqing, 1998.

7. Measuring Parameters for Numerical Simulation Module for ASP Flooding. Award for Technology Innovation from DPRI, 2000.

8. Re-programming the ASP Flooding Numerical Simulation Software. Award for Technology Innovation from Daqing, 2001.

9. Polymer Flooding Development for Eastern of Central Area. Award for Outstanding Production Project from DPRI, 2001.

10. Polymer Flooding Design Optimization. Award for Outstanding Production Project from DPRI, 2002.

11. Evaluation of Polymer Flooding for Western 3rd Site of North in Daqing. Award for Outstanding Technology Work from DPRI, 2004.

12. Further Enhance Oil Recovery by Polymer Flooding for 1st Class Oil Strata in Daqing. Award for Special Grade Technology Innovation of "11^{th}-5 Years Strategically" from Daqing Oil Company, 2005.

13. Sweep Improvement Technologies by Polymer Flooding for 1st Class Oil Strata in Daqing. Award for Outstanding Research Team from DPRI, 2006.

14. Sweep Improvement Technologies by Polymer Flooding for 1st Class Oil Strata in Daqing. Award for Outstanding Production Project from DPRI, 2007.

HONORS:

1. Outstanding employee of DPRI & backbone of the EOR numerical simulation field, from 1988 to 2001.

2. Outstanding promising scientist nomination of top ten in DPRI, 2002.

3. Outstanding woman scientist of top ten in DPRI, 2003.

4. Outstanding woman scientist in Daqing Oil Field Company, 2004.

5. The academic key leader of Polymer flooding technology in EDRI, 2002 to 2006.

Selected Publications

1**.** "Review of Practical Experience by Polymer Flooding at Daqing", ***SPE Reservoir Evaluation and Engineering*，** June 2008.

2**.** "Key Aspects of Project Design for Polymer Flooding", ***SPE Reservoir Evaluation and Engineering*，** December 2008.

3. "Sweep Improvement Options for the Daqing Oil Field," ***SPE Reservoir Evaluation and Engineering*，** February 2008, 18-26.

4. "Review of Practical Experience & Management by Polymer Flooding at Daqing", Keynote paper IOR SPE-114342, presented at the 2008 ***SPE Symposium on Improved Oil Recovery, Tulsa, OK,*** April 19-23.

5. "Key Aspects of Project Design for Polymer Flooding", paper ATCE SPE-109682-PP, 2007 ***SPE Annual Technical Conference and Exhibition, Anaheim, California, USA,*** November 11-14.

6. "Sweep Improvement Options for the Daqing Oil Field," paper SPE 99441 presented at the ***2006 SPE Symposium on Improved Oil Recovery, Tulsa, OK,*** April 22-26.

7. “HPAM Affecting Foam Capability with α-Olefin Sulfonate Surfactant”, ***PETROLEUM EXPLORATION & DEVELOPMENT, Bejing*** (June, 2008).

8. “Factors Affecting Follow-up Water Drive During Polymer Flooding”, ***JOURNAL OF DAQING PETROLEUM INSTITUTE, Daqing, Helongjiang,*** Apri.2007.

9. “The Types and Changing Laws on the Profile Reversal During the Period of Polymer Flooding”, ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Aug.2007.

10. “Study of the Possibility of Fractures occurring Within a Polymer Flood”, ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Oct. 2007.

11. “Evaluation of Numerical Simulation Matching Study on the ASP Field Tests in Daqing Oilfield”. ***THE INTERNATIONAL SYMPOSIUM OF THE EFFICIENT PRODUCTION OF OIL AND GAS FIELDS, Beijing,*** Oct. 2003

12. “Evaluation of Numerical Simulation Matching Study on the ASP Field Tests in Xingerxi Test Site”. ***THE XINJIANG-DAQING SYMPOSIUM OF THE IMPROVING OIL RECOVERY, KunMing,*** May, 2002.

13. “Evaluation of Polymer Flooding Potential for Daqing Oil Field”. ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Feb. 2001.

14. “The Methods of Inputting Files in the ASP Flooding Reservoir Simulator”. ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Feb. 2001.

15. “Study of the Reasonable Well-Pattern and Well-Distance for ASP Flooding”. ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Jun. 1999.

16. “Study of Numerical Simulation for Natural Gas Injection to Enhance Oil Recovery”. ***PETROLEUM GEOLOGY & OILFIELD DEVELOPMENT IN DAQING,*** Aug. 1994.