



INSTYTUT NAFTY I GAZU
Państwowy Instytut Badawczy



MICROBIAL FLOODING INCREASES RECOVERY FACTOR OF DEPLETED PLAWOWICE OIL FIELD - FROM LAB TO THE FIELD

S. Falkowicz, R. Cicha-Szot

Polish Oil & Gas Institute
National Research Institute



P. Launt, S. Nelson

RAM Biochemicals, Inc



S. Dubiel

AGH-UST, Faculty of Drilling Oil and
Gas, Kraków



AGH

W. Wójcicki, M. Rogaliński

Polish Oil & Gas Company SA





- MEOR project design & development
- MEOR project implementation
- Project evaluation
- Project production results
- Project economics
- Conclusions



PRODUCER'S LIFE CYCLE

Discovery, Estimation, Development,

Primary recovery

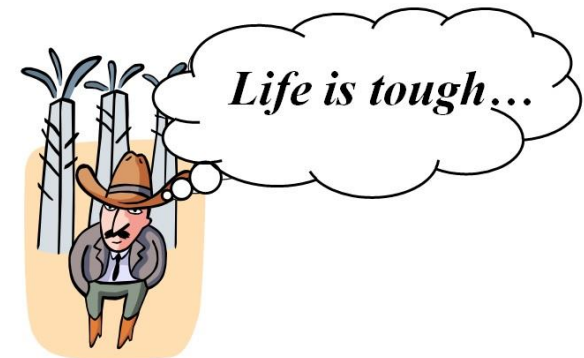
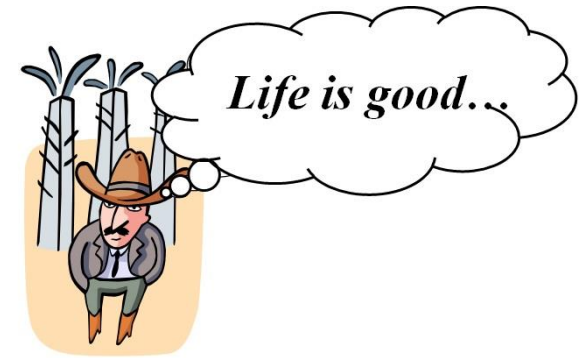
...doesn't

Secondary recovery

Battles physics and loses

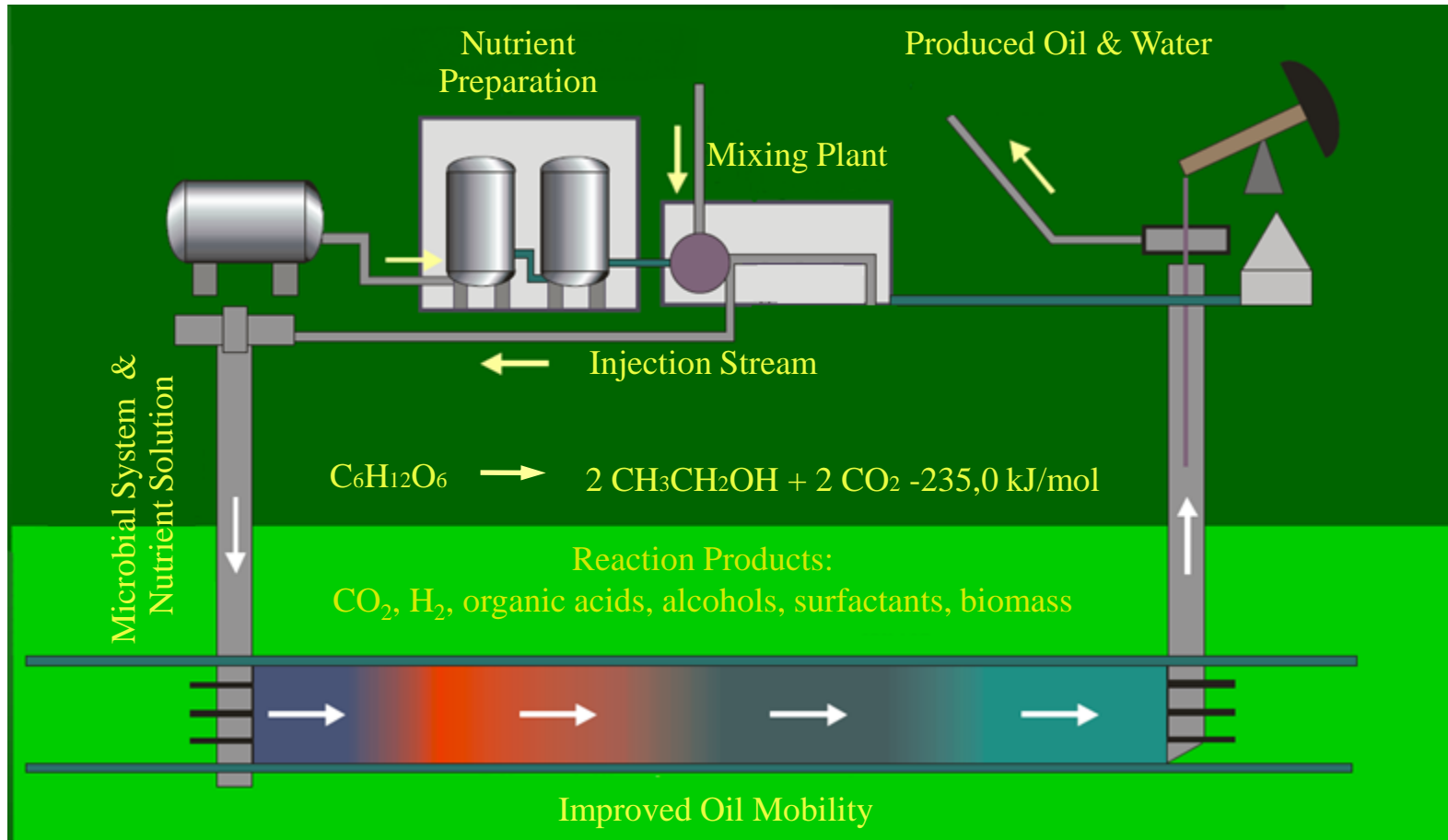
- poor sweep efficiency
- poor displacement efficiency

Tertiary recovery – MEOR delivers
EOR performance at waterflood cost





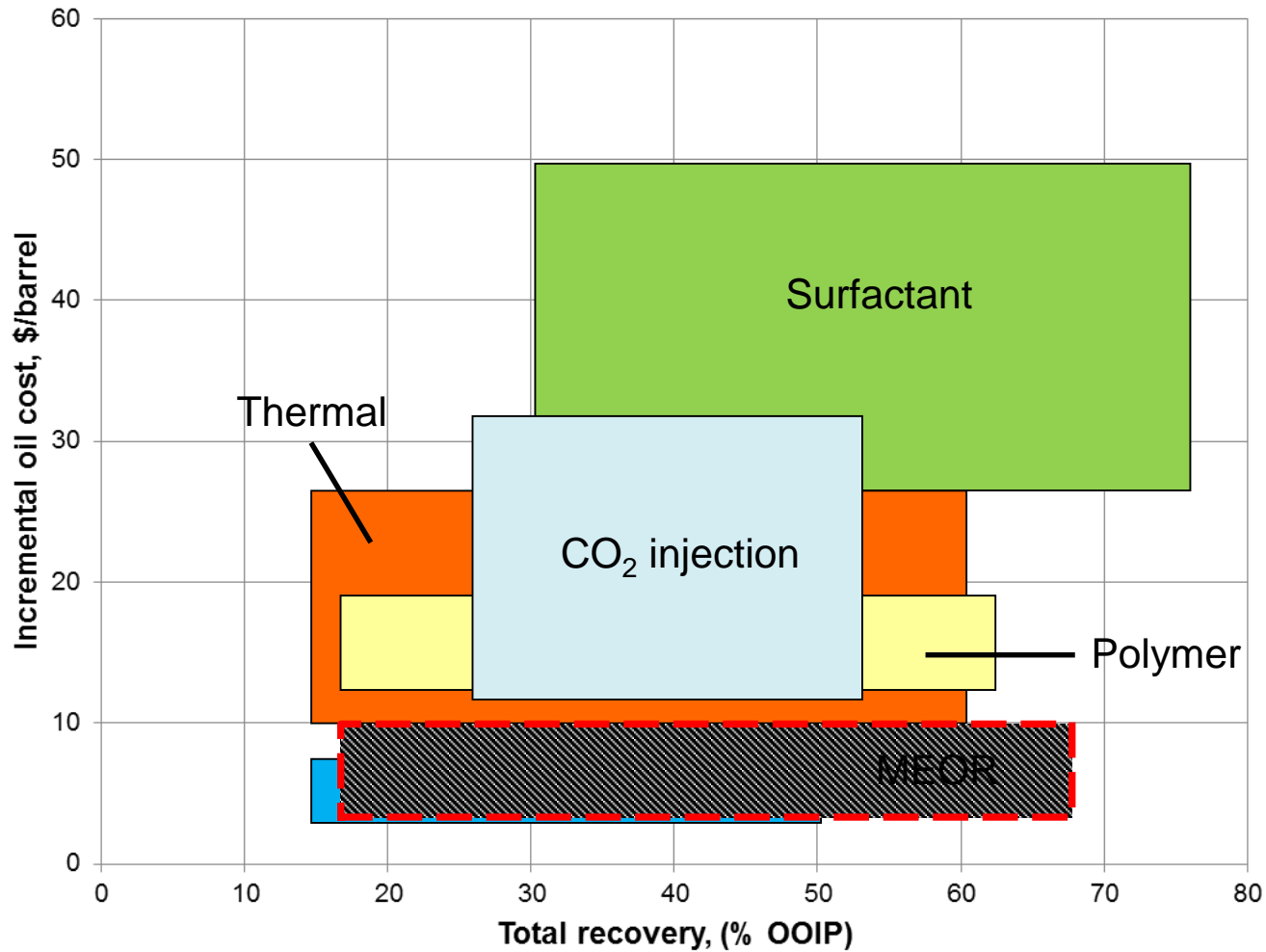
MICROBIAL ENHANCED WATERFLOOD PROCESS



Treatment process involves a specially selected Microbial System (MS) injection into the oil bearing formation, followed by regular / periodic nutrient injections. The Pławowice project used augmented beet molasses to sustain MS growth *in situ*. Other inexpensive nutrients can be used depending on the MS bacteria composition.



COSTS COMPARISON AND POTENTIAL OF VARIOUS EOR METHODS

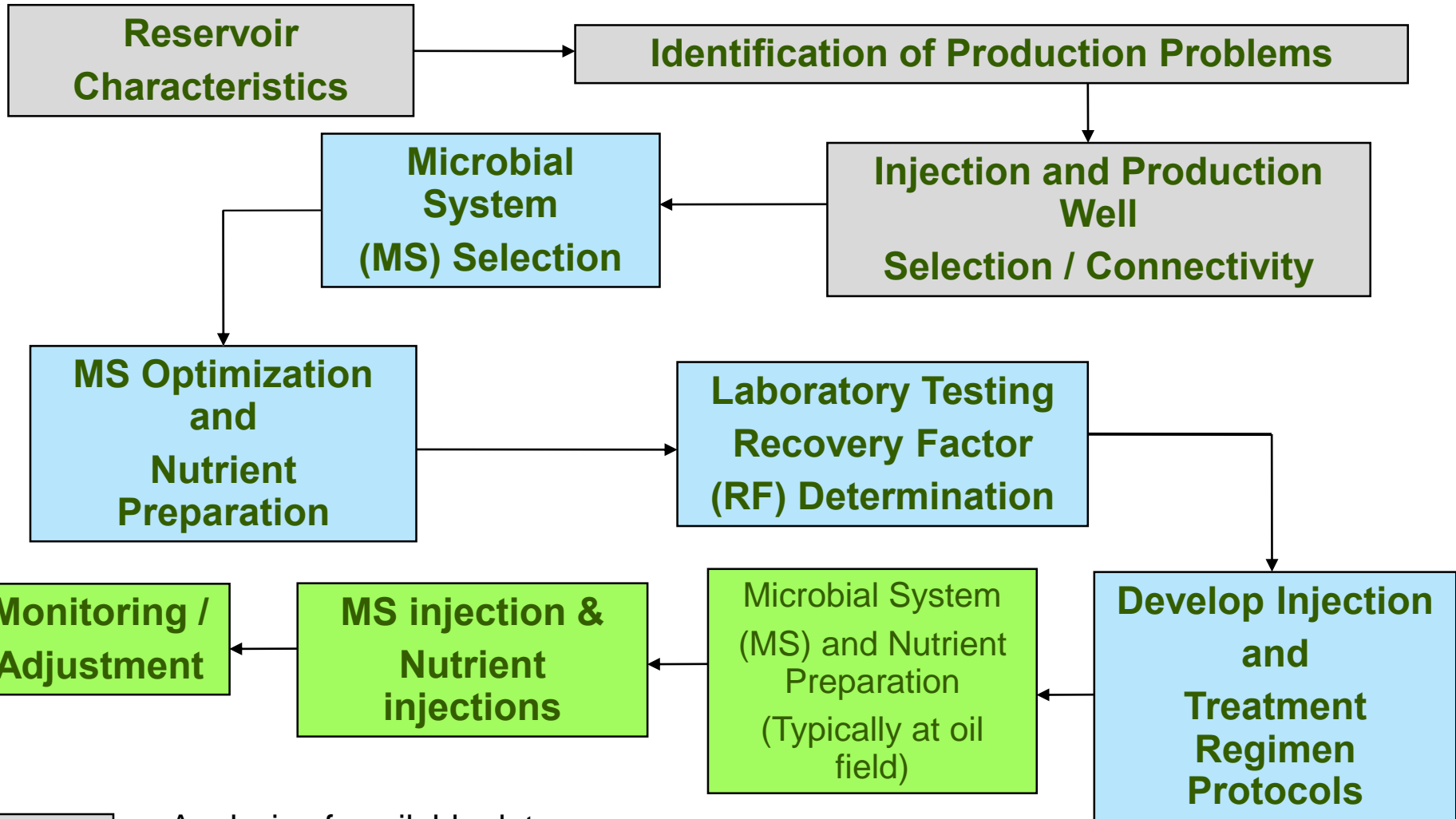


Comparison of various EOR process costs.

Ref: Simandoux *et al.* "Managing the Cost of Enhanced Oil Recovery." IFT Journal, vol 1.



MEOR PROJECT DESIGN & DEVELOPMENT



Analysis of available data



Laboratory tests

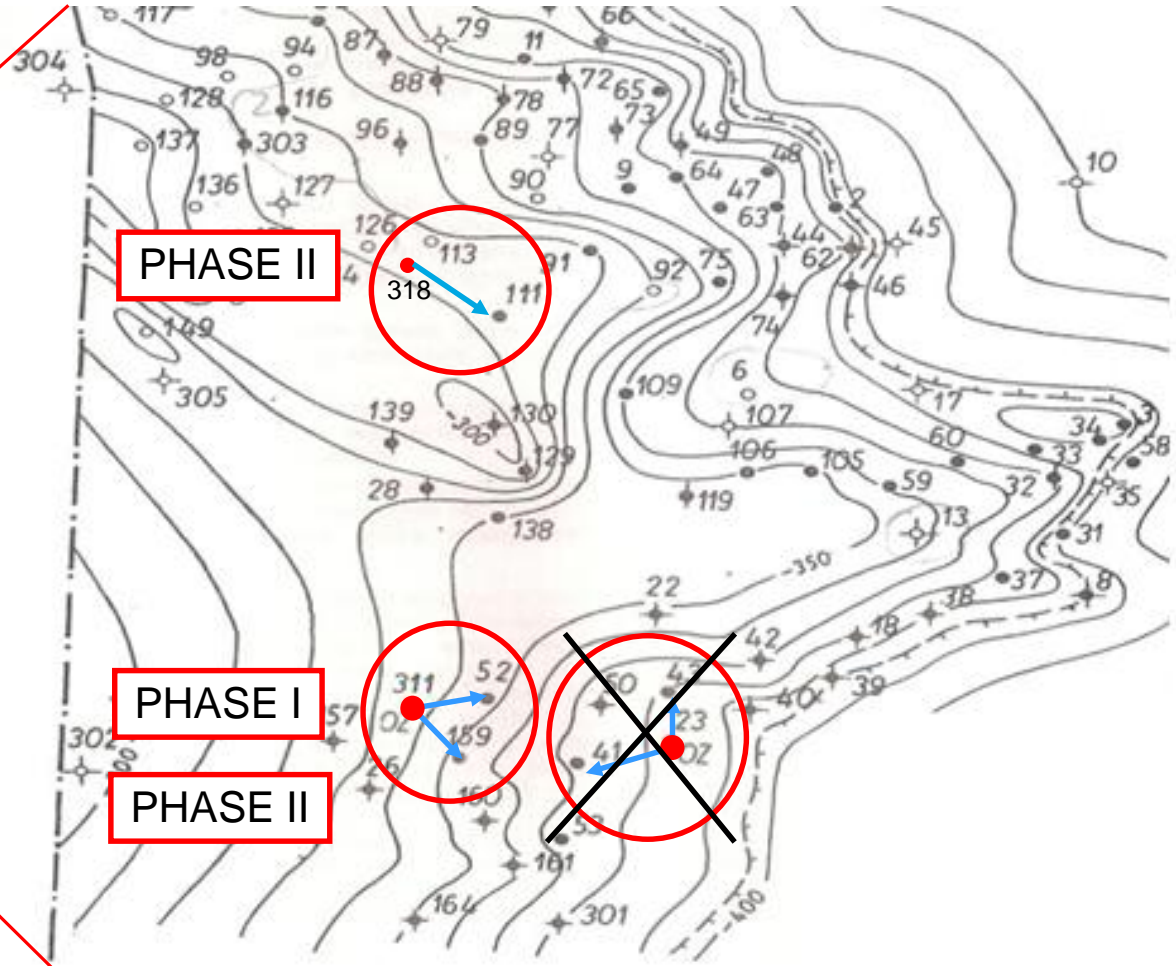
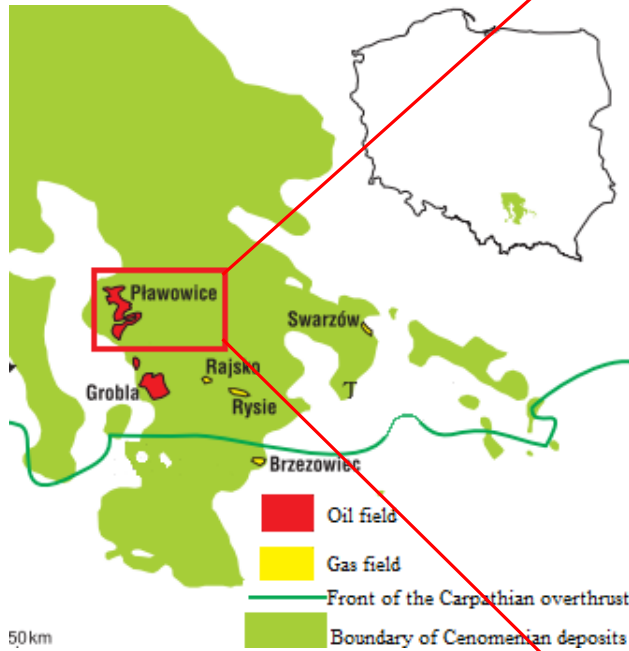


Project implementation



MEOR PROJECT DESIGN & DEVELOPMENT

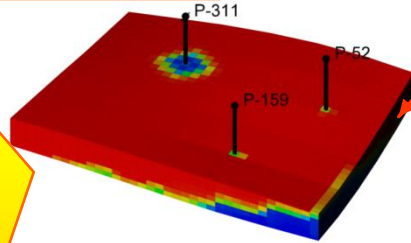
PLAWOWICE OIL FIELD



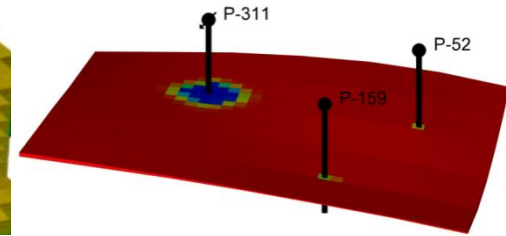


PLAWOWICE DEPOSIT - SIMULATION MODEL

Local model



Reservoir simulation

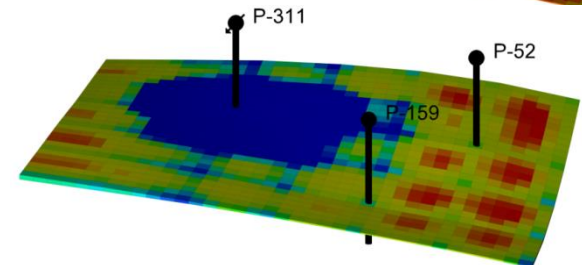
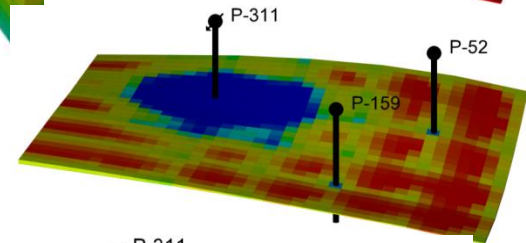


Local grid refinement

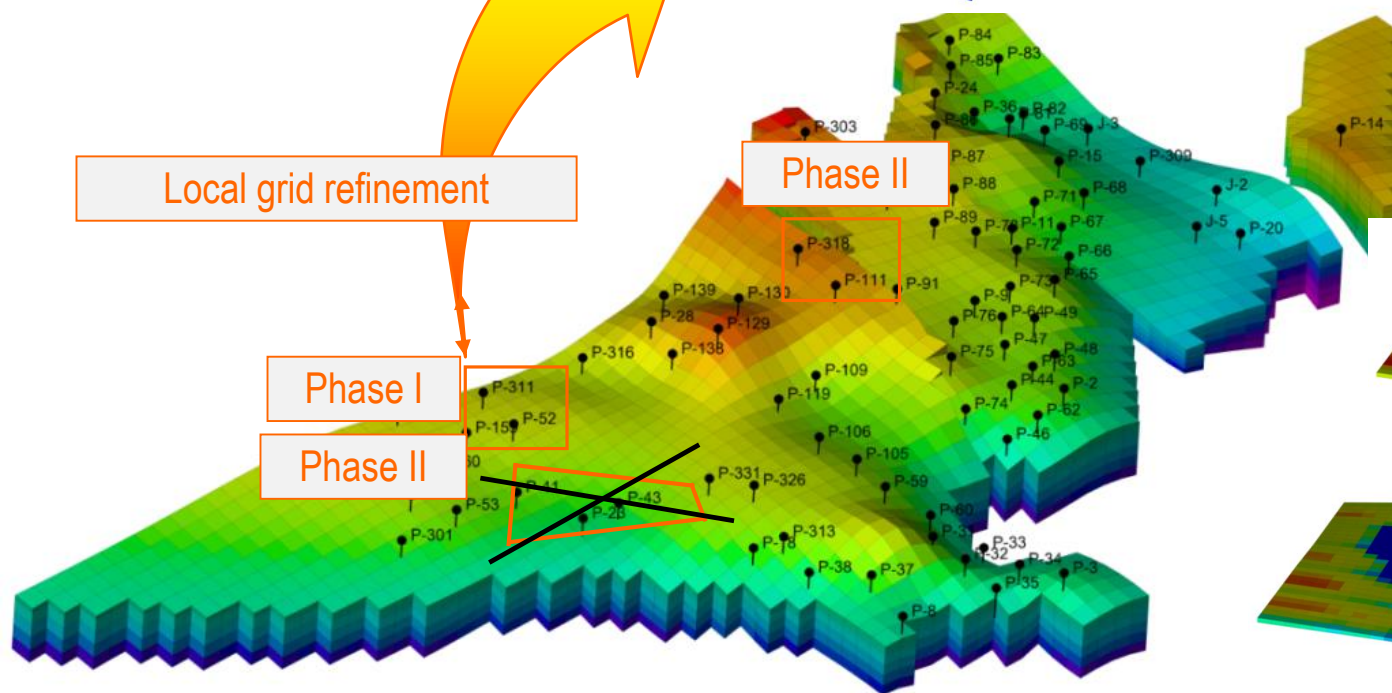
Phase I

Phase II

Phase II

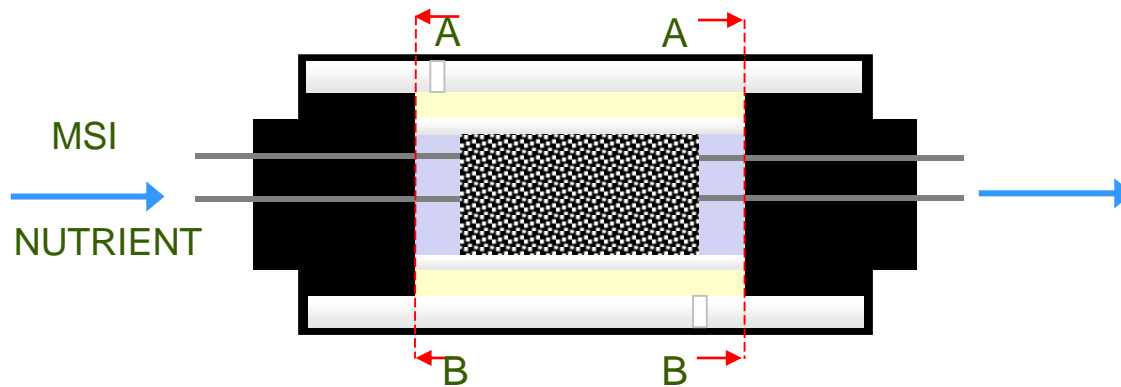


History matched global dual porosity model





CORE STUDY / RECOVERY FACTOR (RF) DETERMINATION



In 2011, INiG's petroleum engineering laboratory core studies were conducted to determine the recovery factors [RF] for the microbial system proposed by RAM Biochemicals, Inc.



CORE STUDY / RECOVERY FACTOR (RF) DETERMINATION

Core	Air permeability [mD]	Effective permeability S(or) [mD]	Core PV total [cm ³]	Amount of oil in core [cm ³]	Water flooding		
					Oil displaced [cm ³]	Oil remained [cm ³]	RFwf [%]
1- Control	267	4.1	4.36	3,0	1.0	2.0	33.3
2	295	1.82	4.30	2,8	1.1	1.7	39.3
3	424	5.64	4.15	2,6	1.1	1.5	42.3
4	344	5.4	4.17	2,6	1.2	1.4	46.2
5	335	4.3	4.21	2,2	1.3	0.9	59.1
14	81	0.73	6.54	3,8	0.9	2.9	23.7
15	97	0.85	6.52	4,3	0.9	3.4	20.9

$$E_{mwf} = RFR \cdot E_{mwf}$$

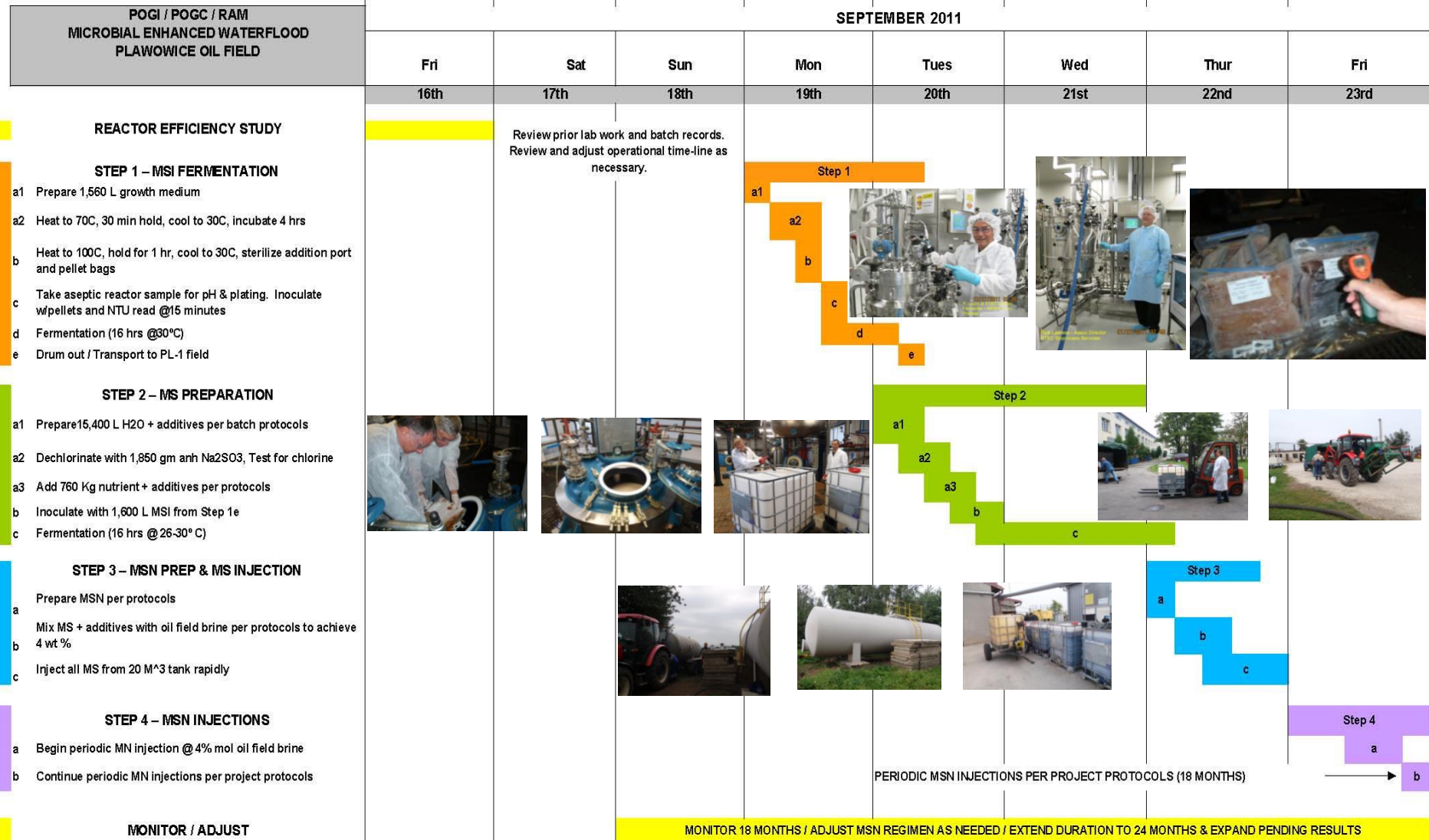
6,8%

Core	RFwf [%]	injected MS [PV]	Additional nutrient		Total time of incubation [days]	RFmwf [%]	Emwf [%]
			Amount of nutrient [PV]	Day of application			
1- Control	33.3	X	X	X	3	33.3	0.0
2	39.3	0.5	1	2	3	55.4	16.1
3	42.3	0.5	1	3	3	53.8	11.5
4	46.2	0.5	X	X	10	50.0	3.8
5	59.1	0.5	1	7	10	61.4	2.3
14	23.7	0.5	X	X	10	27.6	3.9
15	20.9	0.5	1	7	10	24.4	3.5



MEOR PROJECT IMPLEMENTATION – PHASE I

(Plawowice operational time-line / project implementation – initial 18 month project duration)



MS = MICROBIAL SYSTEM
 MSI = MICROBIAL SYSTEM INOCULUM
 MSN = MICROBIAL SYSTEM NUTRIENT

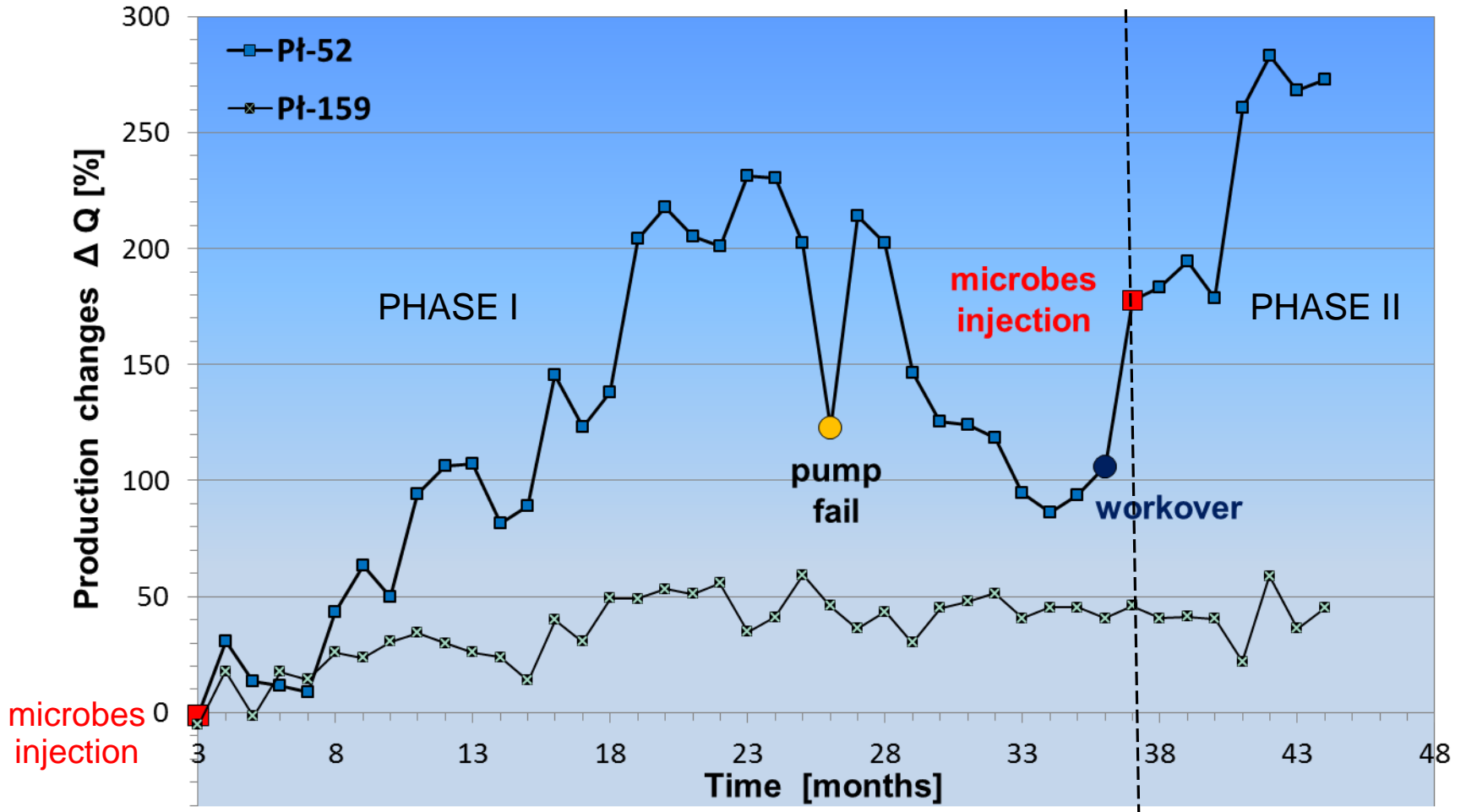


MEOR PROJECT IMPLEMENTATION – PHASE II





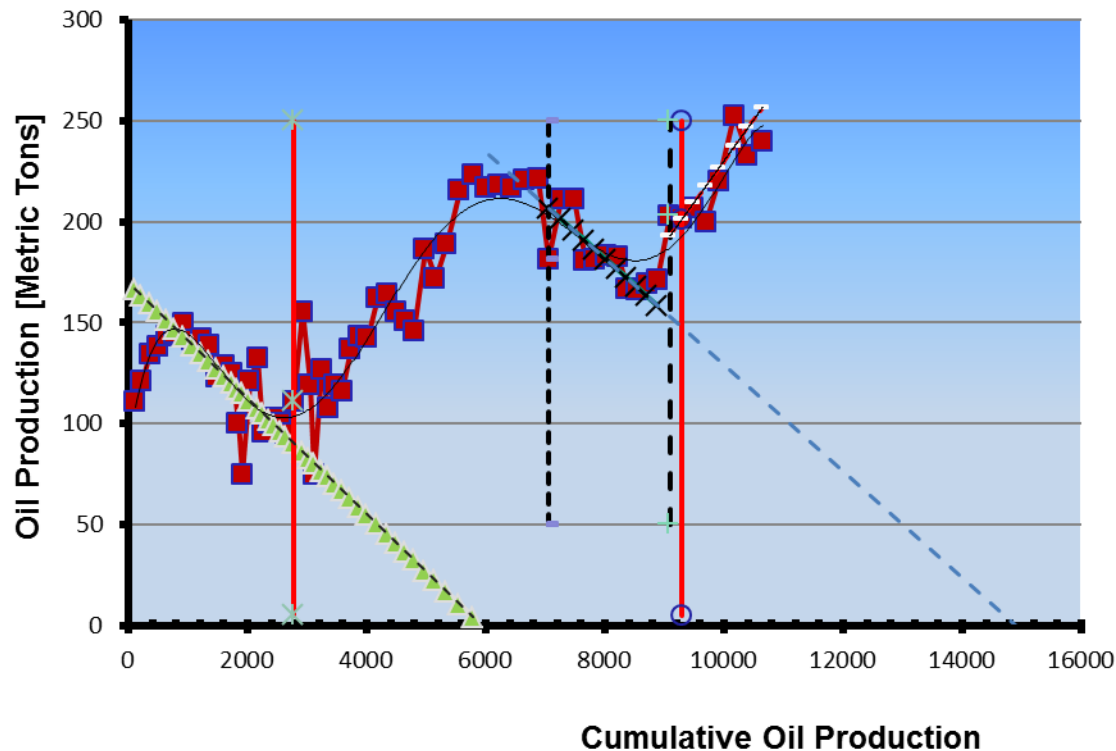
MEOR PROJECT DESIGN & DEVELOPMENT





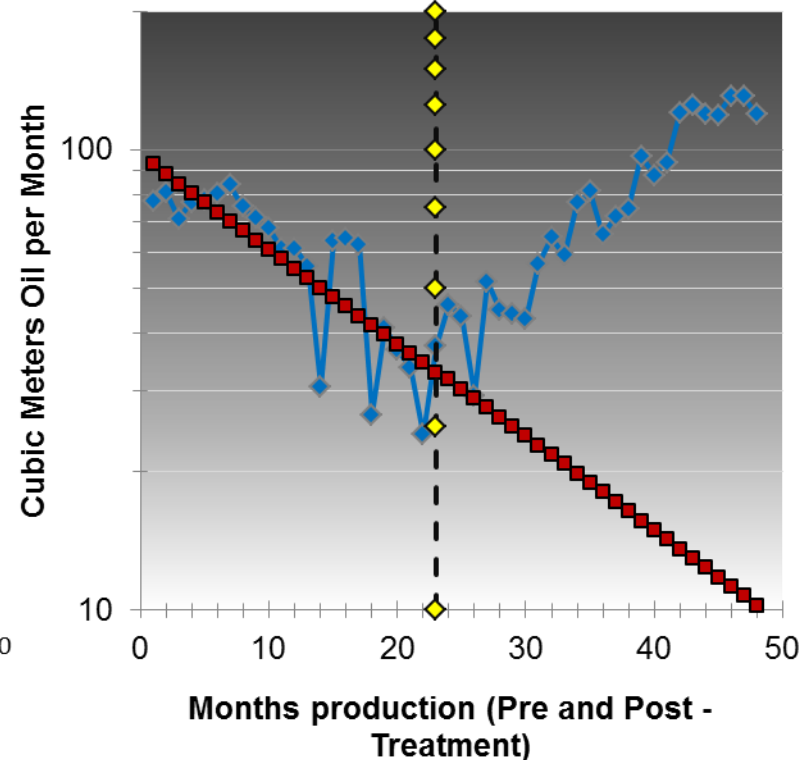
PLAWOWICE MICROBIAL EOR – ECONOMIC EVALUATION

PL-52+PL-159 Metric Tons / Month



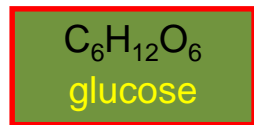
- q(Oil)
- × Phase I MEOR
- PumpFail
- Liniowy (PreTrend)
- ▲ PreTrend
- Phase II MEOR
- PIII Trend
- Liniowy (PostTrend)
- × PostTrend
- Workover
- Wielob. (q(Oil))
- Wielob. (PIII Trend)

PL-52 Production

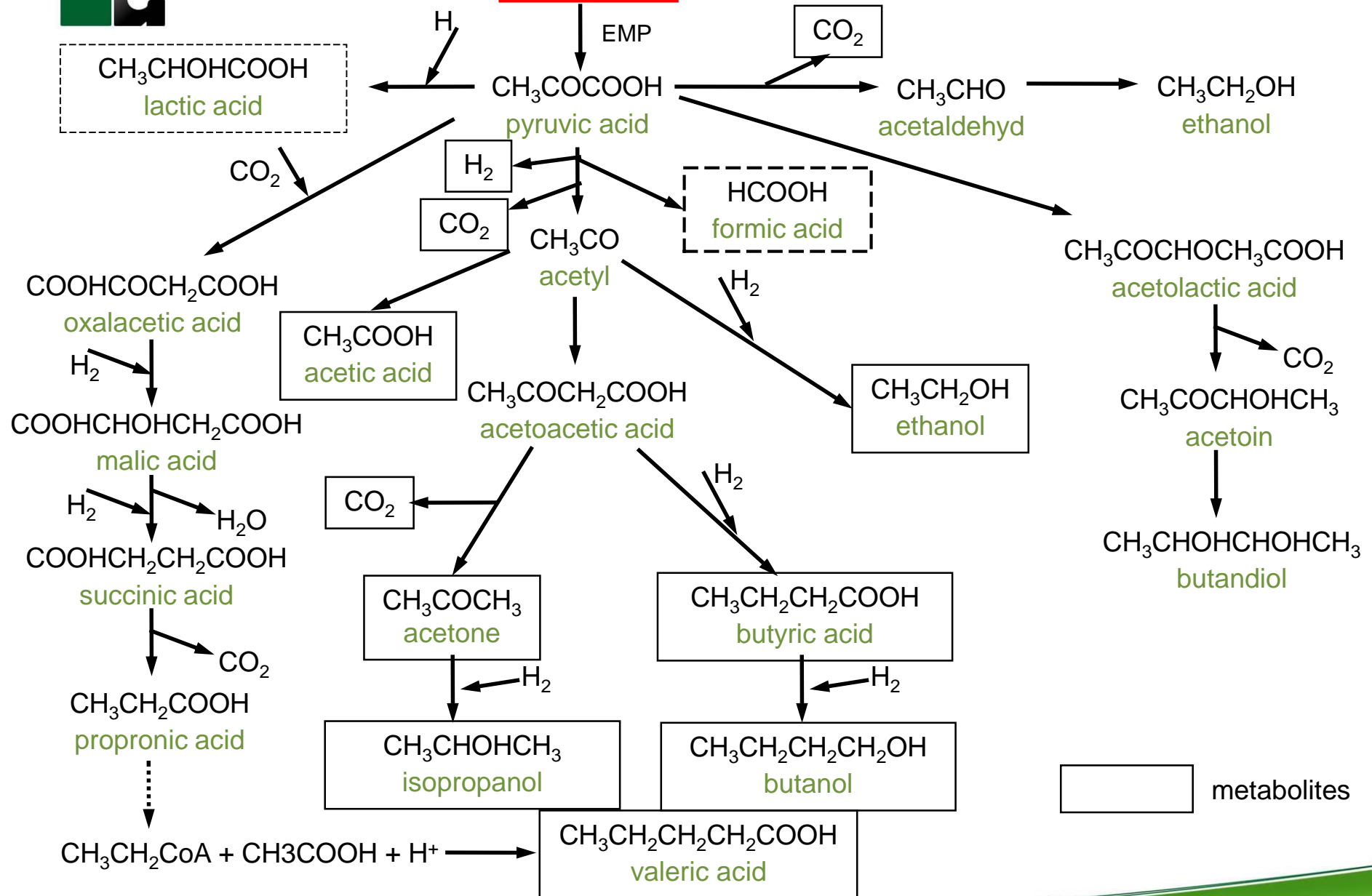


- ◆ PL-52
- Decline
- ◆ MEOR Treatment

NOTE: The Decline Curve Analysis (DCA) approach and methods used by RAM Biochemicals conform with SPE guidelines and industry's best practices. References are available which include; multiple papers on DCA by J.J. Arps and others, plus personal communications with Dr. Steve L. Bryant, Department of Petroleum and Geosystems Engineering, University of Texas at Austin, and Dr. Larry Lake, Endowed Chair in Petroleum and Geosystems Engineering, University of Texas at Austin.



MOLASSES

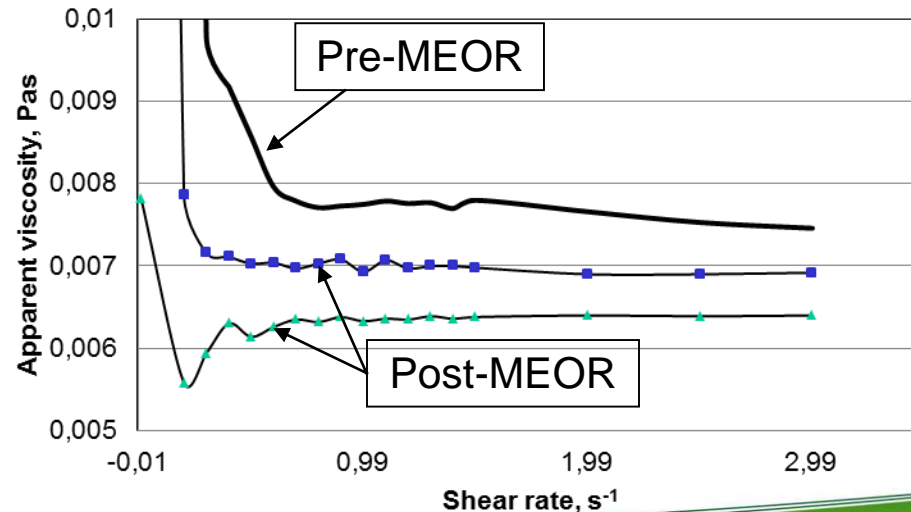




MEOR PROJECT EVALUATION

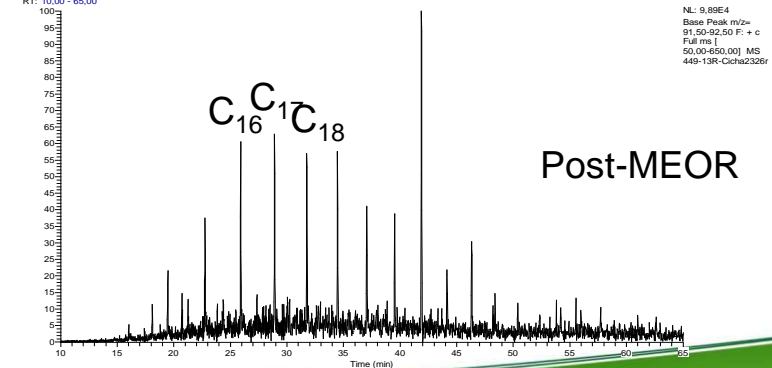
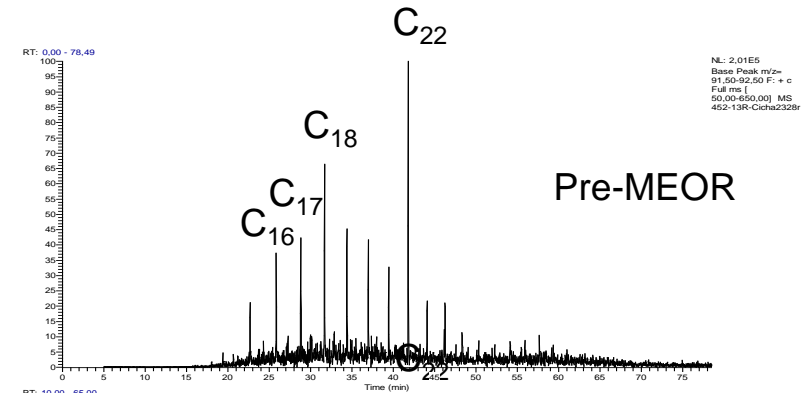
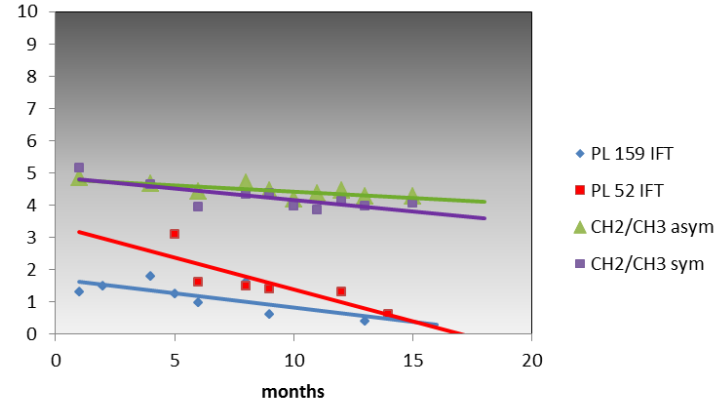
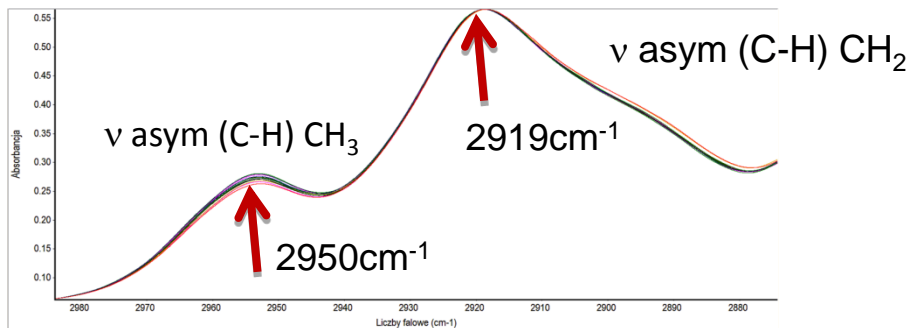
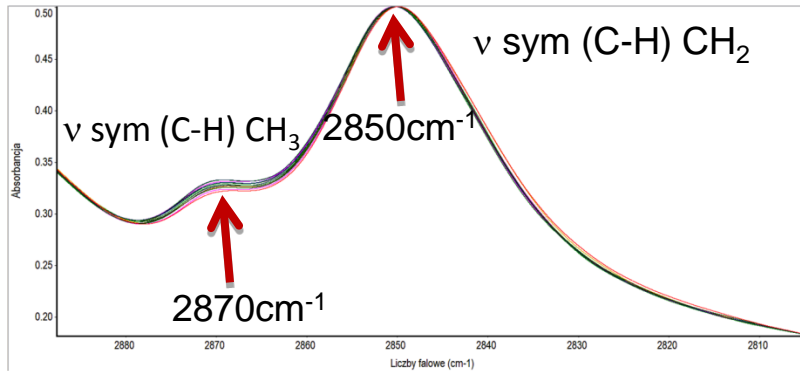
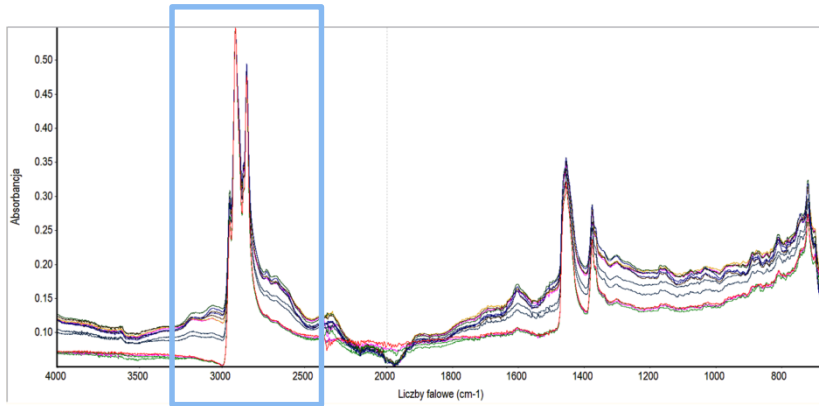
MEOR's long-term distinctive response is to increase net oil rate and simultaneously to reduce Water Cut. This typical duality in MEOR response is explained by the change in apparent oil and water mobilities in the colonized portion of the reservoir, the bioreactor.

well	Viscosity Pre-MEOR mPas	Viscosity Post-MEOR mPas	Density Pre-MEOR °API	Density Post-MEOR °API	Temperature °C / F
PL - 52	14.74	9.52	32.5	36.0	20/68
PL - 159	14.96	9.79	32.5	35.9	20/68





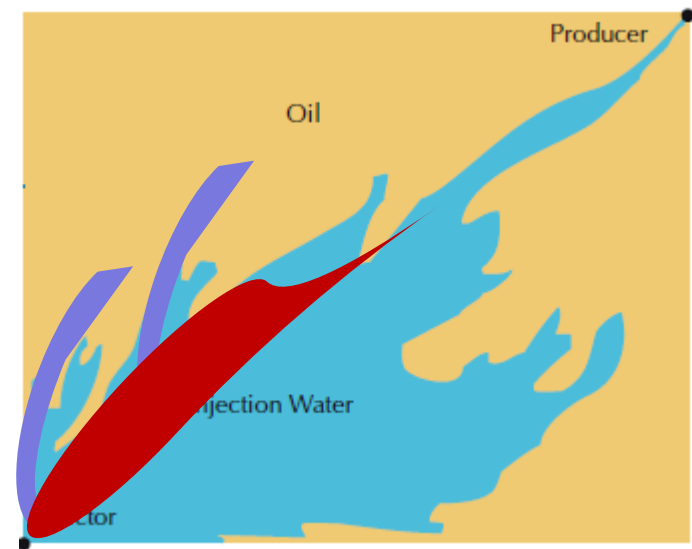
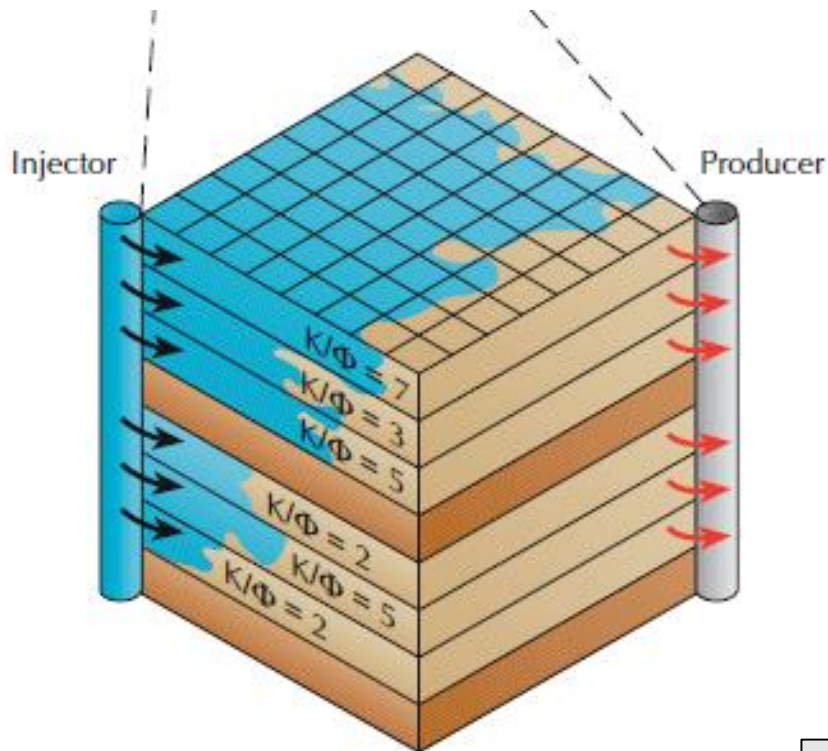
MEOR PROJECT EVALUATION





MEOR PROJECT EVALUATION

The influence of reservoir anisotropy on waterflooding efficiency

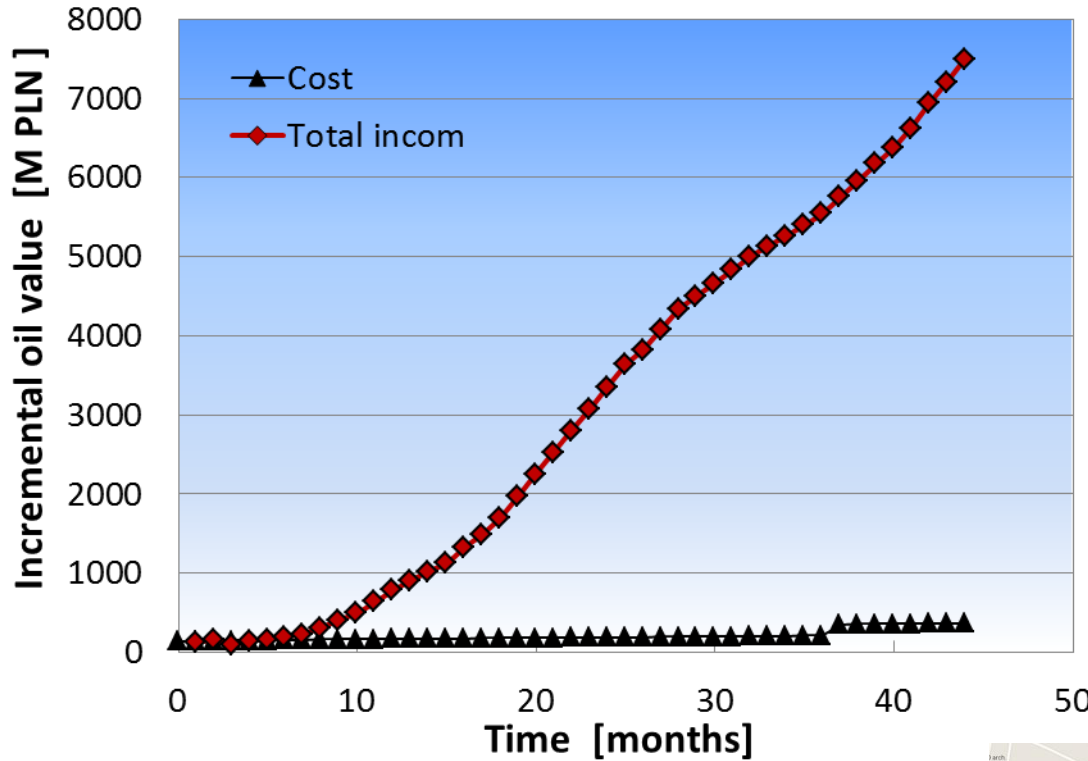


Plugging of highly permeable zones

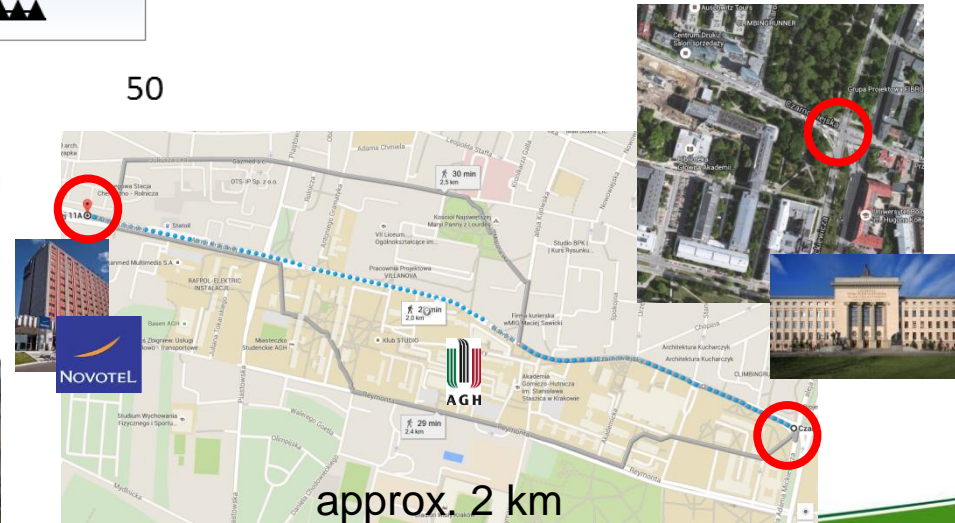


MEOR PROJECT PRODUCTION RESULTS

Pł-52 + Pł-159 (MT/month)



Incremental oil - 3339 tons
139 of 24 tons tracks





- **Proven cost effective even at small scale**
- **Utilizes waste production brine for injection**
- **Phase I and II have produced additional oil over projected declines in pre treatment phase**
- **Substantial and sustained production increases**
- **Economic productive life extended**
- **Easy to implement and scale up**
- **Limited risk - built in go / no-go decision points**
- **Environmentally responsible**
- **No labor at 311 injector well**



ADDITIONAL PROJECT BENEFITS

Since October 2nd, 2014

184 Downloads and over 90 views

5,3 downloads per week

31 Downloads and over 140 views

3,8 views per week

Since June 5th, 2015

9 Downloads and over 5 views



Presentation No. 2253

Microbially Enhanced Oil Recovery Field Pilot at Plawowice, Poland
Validation of MEOR for Smaller Scale Projects through Proper Design, Development, Implementation and Monitoring

NAFTA-GAZ maj 2013 ROK LXIX

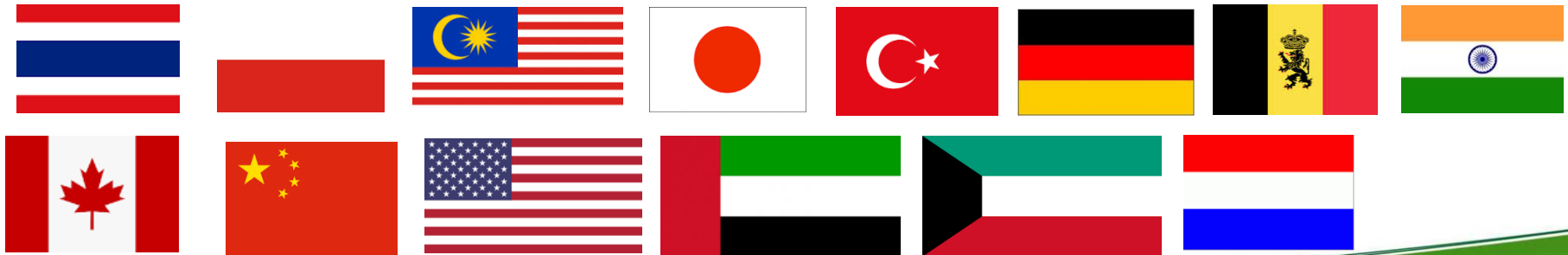
Slawomir Falkowicz, Renata Cicha-Szot
Instytut Nafty i Gazu Kraków

Nawadnianie mikrobiologiczne jako sposób zwiększenia stopnia sczerpania starych złóż ropy naftowej na przykładzie złoża Plawowice. Część I

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<http://dx.doi.org/10.7494/drill.2015.32.2.345>

Slawomir Falkowicz*, Renata Cicha-Szot*, Stanislaw Dubiel**,
Phillip Launt***, Sidney Nelson***, Witold Wójcicki****,
Marcin Rogaliński****

MICROBIAL FLOODING INCREASES RECOVERY FACTOR
OF DEPLETED PLAWOWICE OIL FIELD –
FROM LAB TO THE FIELD*****





NEW CHALLENGES

Ongoing project: GROBLA oil field

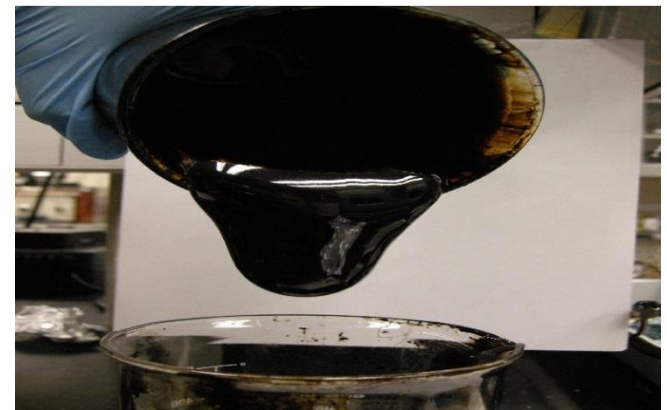
Planned implementation of MS on September 2015

H₂S mitigation by microbial out competition
of indigenous SRB

SRB inhibition by bacteriophage introduction
redox inhibition of SRB (SO₄⁴⁻ to S⁼) by NO₃³⁻, NO₂²⁻, Mo

Planned project: Heavy oil

Microbial flooding – special procedures





Thank you for Your attention

Sławomir Falkowicz
Instytutu Nafty i Gazu PIB
Department of Petroleum Engineering
e-mail: falkowicz@inig.pl



INSTYTUT NAFTY I GAZU
Państwowy Instytut Badawczy
ul. Lubicz 25 A, 31-503 Kraków

www.inig.pl
office@inig.pl