# Production Optimization in a Marginal Field through Established Reservoir Management Techniques – A Case Study*

**Williams Toluse[1], Victor Okolo[1], and Amarquaye Martey[1]**

Search and Discovery Article #20381 (2017)**
Posted February 20, 2017

*Adapted from oral presentation given at AAPG/SPE Africa Energy and Technology Conference, Nairobi City, Kenya, December 5-7, 2016


[1]Petroleum Engineering, Midwestern Oil and Gas Company, Lagos, Nigeria (toluwilliams@midwesternog.com)

## Abstract

The Federal Government of Nigeria in a bid to promote indigenous companies participation in the oil and gas sector, and to grow the nation's production capacity passed legislation in 1999 to foster the exploitation of Marginal Oil Fields (MOFs). A MOF is one that is considered non-commercial as a result of strategic business development philosophy of the operator, often times large oil companies. Reservoir management is central to the effective exploitation of any hydrocarbon asset; this dependence is heightened for an undeveloped marginal field. There is no 'one-size fits all' approach to reservoir management; this article reviews some techniques adopted by Midwestern Oil and Gas Ltd in the development of the Umusadege Marginal Field.

These techniques fall under three categories: (1) subsurface study, (2) well placement and spacing, and (3) integrated surface production and optimization, in accordance with regulatory practices. The previously acquired 3D seismic data was reprocessed and interpretation of reservoir heterogeneities within the Umusadege Field concessionary boundary carried out form the basis of the initial field development plan. To optimize reservoir drainage, the general principles of non-interference well spacing were employed, and advanced well placement technology was deployed to guarantee optimum well placement within the reservoir for effective and efficient drainage. Subsequently, 14 vertical wells and 4 horizontal wells were drilled to effectively optimize recovery from the field. Prior to bringing these wells on-stream, clean-up and Maximum Efficiency Rate (MER) tests were conducted to determine the optimum choke settings, GOR and water-cut limits for all wells. An integrated approach

encompassing choke sizing, gas and water production management, vessel and line sizing were implemented on the Umusadege Field to maintain and optimize recovery. Crude custody transfer measurements and export were enabled by an optimized Group Gathering Facility (GGF). The above techniques combining new technologies, traditional reservoir and production strategies led to the successful development of the Umusadege Field, increasing daily oil production from 2,000 bbls/day from the first well re-entry to approximately 30,000 bbls/day over a 7-year period. This case study proves that with the correct implementation of the key elements of reservoir management the value of any hydrocarbon asset can be maximized in a cost-effective, safe and environmentally friendly manner.

AFRICAN ENERGY IN THE 21ST CENTURY
PAVING THE WAY FOR THE FUTURE
5-7 December 2016 | Safari Park Hotel | Nairobi, Kenya
Africa Energy and Technology Conference
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# PRODUCTION OPTIMIZATION IN A MARGINAL FIELD THROUGH ESTABLISHED RESERVOIR MANAGEMENT TECHNIQUES - A CASE STUDY

Williams Toluse, Victor Okolo, Amarquaye Martey
Midwestern Oil and Gas Company Nigeria Limited

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# Executive Summary

- Reservoir management in an oil field rely on a multidisciplinary team approach
- Geological and structural plays of a field are represented in detailed geological models
- Reservoir simulation models are built to understand the dynamics of major producing reservoirs
- Simulation results are employed to ensure quality forecasts and a field development plan put in place for optimum development
- Surveillance programs for reservoirs are planned to ensure optimum production and minimum deferrals
- The aforementioned procedures have been effectively implemented in Umusadege field from the first oil of about 2,000b/d (two thousand barrels per day) in 2008 to about 30,000b/d (thirty thousand barrels per day) in 2015.

# Executive Summary

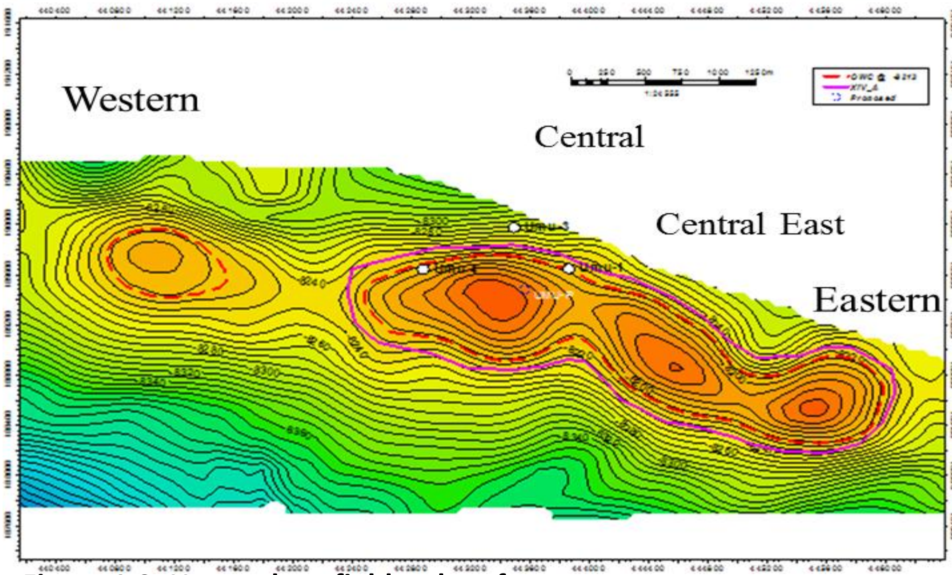



Figure 1.0: Umusadege field subsurface structure

Figure 1.1: Umusadege field central processing facility (CPF)

- **Producing Field:** 1
- **Oil Producers:** 16
- **Current av. production :** 25 kbopd
- **Oil Gravity:** 19-52 API
- **STOIIP:** 160.7 MMbbl
- **Remaining 2P Reserves (Sept . 2016):** 67.50 MMbbl
- **Cum. Prod. Oil (Sept. 2016)** 23.30 MMstb

## Infrastructure

- **Fixed Structures:**
  - CPF : 45 Mstb (Processing capacity)
  - GGF : 70 Mstb (Gathering and Export facility)

# Introduction

- Application of reservoir management principles presented in this paper would ensure that no damage is done to a reservoir while its reserves are efficiently, optimally and economically recovered

- Reservoir management strategies are as good as the data used in fashioning them

- Major data required for sound reservoir management are grouped as follows:

    - Geological
    - Petrophysical
    - Fluid properties
    - Pressure
    - Production data

# Introduction

- Legislation to provide for the award of marginal oil field (MOF) passed in 2003 by the Federal Government of Nigeria.

- Marginal Oil Field is generally defined as an oil field that does not produce enough net income to make it worth developing at a given time.

- Some characteristics of a MOF as specified by the Nigeria government include:

    - Geological, economic and technological constraints
    - Lack of nearby existing production facilities to put on stream
    - Unfavorable market and fiscal situations
    - Poor or unfavorable crude characteristics e.g. high crude viscosity
    - A field with few or one well undeveloped for about 10 years by the multinational oil company (MOC)
    - A field that may have low reserve and uneconomical for development by the MOC, and
    - A small field that may not produce up to 10,000bbls of oil per day

# Introduction

- Umusadege field in OML 56 originally operated by EPNL (Elf petroleum Nigeria limited), EPNL drilled a total of 3 wells between 1974 and 1978, proving the existence of oil in 13 Sands in the down thrown with a total estimated reserves of about 42MMbbls that was considered marginal and abandoned.

- The Field was awarded Midwestern Oil and Gas PLC (MWOG) -70% and SunTrust Int. – 30% in 2003, Midwestern re-entered Umu -1 in 2007/8 and completed the well in two sands XIIa and XIIb. Commenced production at about 2,000 bopd

- MWOG has drilled a total of 18 wells (including 4 horizontal wells and 2 water disposal wells) between 2007 to 2016 and proved the existence of oil in 26 Sands and gas condensate in 3 sands.

# Geology of Umusadege field

- The field is located onshore in the north central area of the Niger Delta Basin of Nigeria in OML 56. see figure 2.0
- The Umusadege field is part of the conventional Onshore Delta Play which is characterized by deltaic shallow marine shelf sands at intermediate depths in a growth fault settling. Traps are typically roll-over anticlines in front of growth faults.
- Umusadege field hydrocarbon reserves are contained within the Eocene, Agbada sandstones

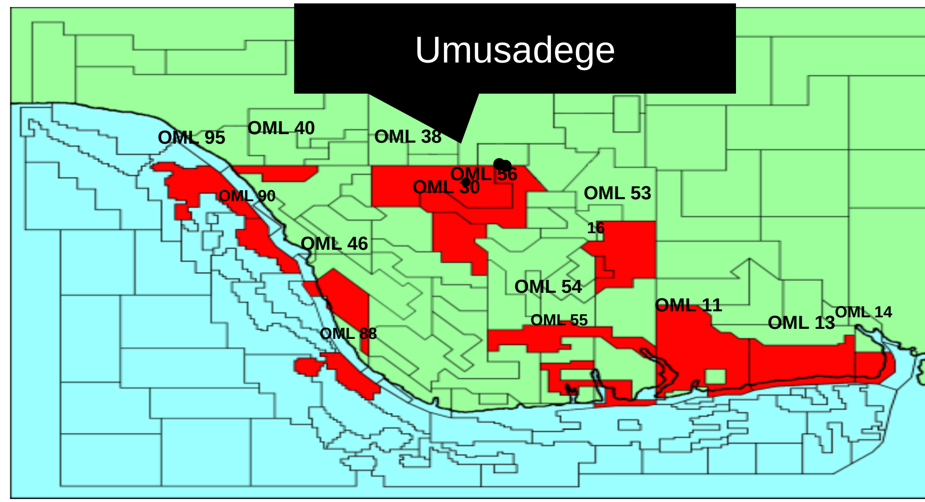



Figure 2.0: Umusadege field location

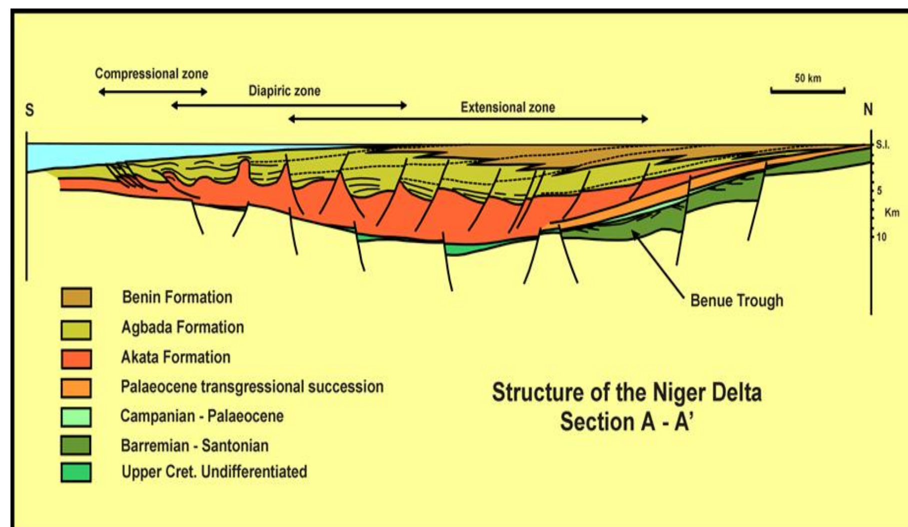



Figure 2.1: Niger delta depositional environment

# Umusadege field geological structure

- The Umusadege area is covered by 36 km2 of 3D seismic data, shot in the early 1980’s.

- The field has only one growth fault trending from WNW-ESE and a simple roll-over anticline structure, moving towards the growth fault

- The Umusadege field oil bearing sands were discovered in the down-thrown side of the fault, while the up-thrown are gas prone and over-pressured

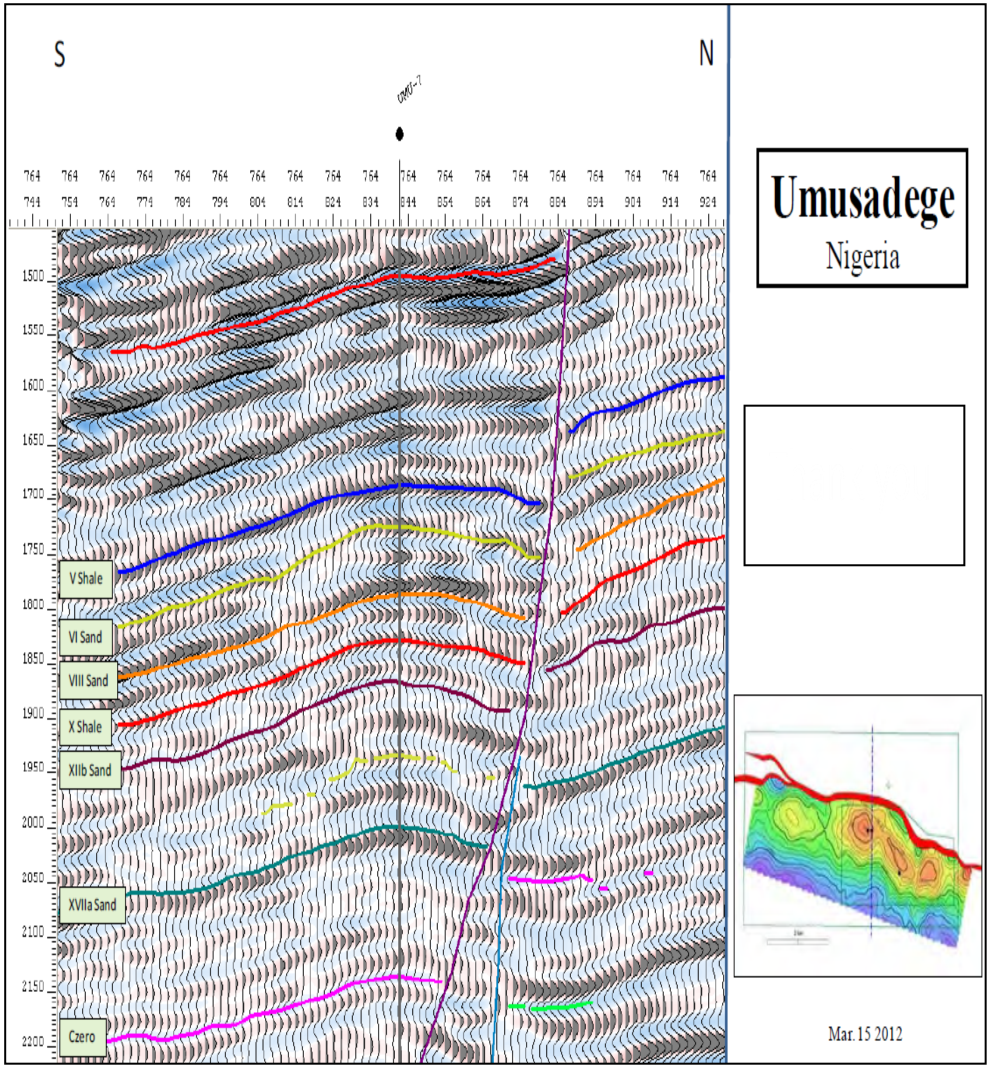



Figure 3.0 Umusadege seismic section

# Umusadege field geological structure

- These horizons have been interpreted on the seismic sections, and the horizons in time converted to depth.
- The surfaces have been matched to formation tops from well data. Representative cross sections showing the rollover structure at the west, central, central east and eastern culmination are depicted.
- The Umusadege structure is a rollover structure containing a sequence of vertically stacked sandstone oil reservoirs.

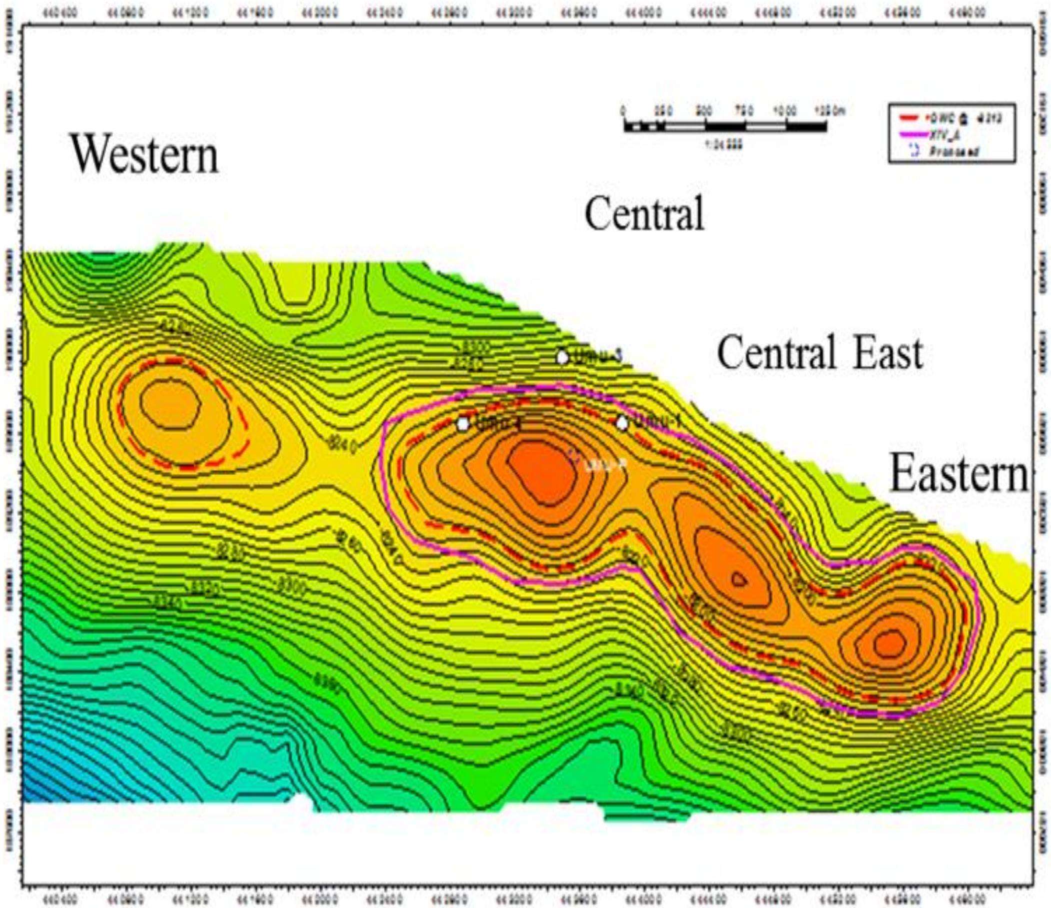



Figure 3.1: Umusadege subsurface structure

# Umusadege field development plan

- An initial FDP (based on available data obtained from ELPN) was submitted as one of the criteria for the MOF award. This has been updated twice in 2010 and 2013 from results of further reservoir studies carried out

- Umusadege field reservoir units consist primarily of stacked sandstones parasequences which are well sorted, highly porous and permeable with high net gross ratios.

- The second FDP update in 2013 recommend the drilling of three horizontal and three vertical wells to develop the central and central east culminations of the field. See Table 1.0

| Development Well | Reservoir Targets | Estimated Reserves (MMbbl) |
|---|---|---|
| UMU-Hz1 (UMU-4 st) | VI sand | 2.08 |
| UMU-Hz2 (UMU-3 st) | VII sand | 3.38 |
| UMU-Hz3 (new drill) | VIII sand | 3.27 |
| UMU-11 | XIIb, XIIc, XVIa, XVIb sands | 3.79 |
| UMU-C1 | XIIa, XIIb | 1.87 |
| UMU-CE1 | VI, VIII, IX | 4.24 |
| UMU-CE2 | VII, XVIIIb, XXa | 1.74 |
| S/T to Upper Zones | III, IV, V | 0.77 |
| **Total Future Wells** | | **21.13** |

Table 1.0: Umusadege field development plan

# Umusadege field development plan

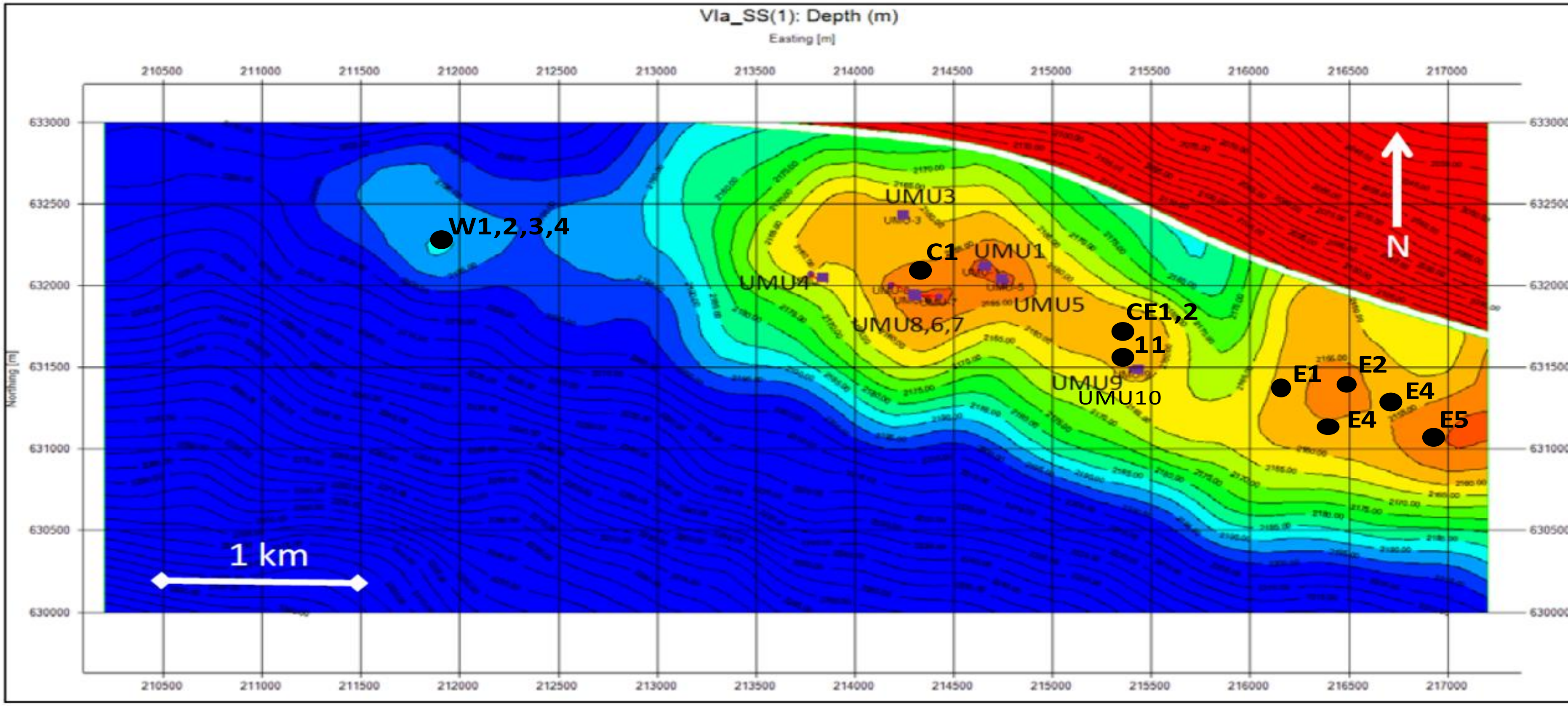
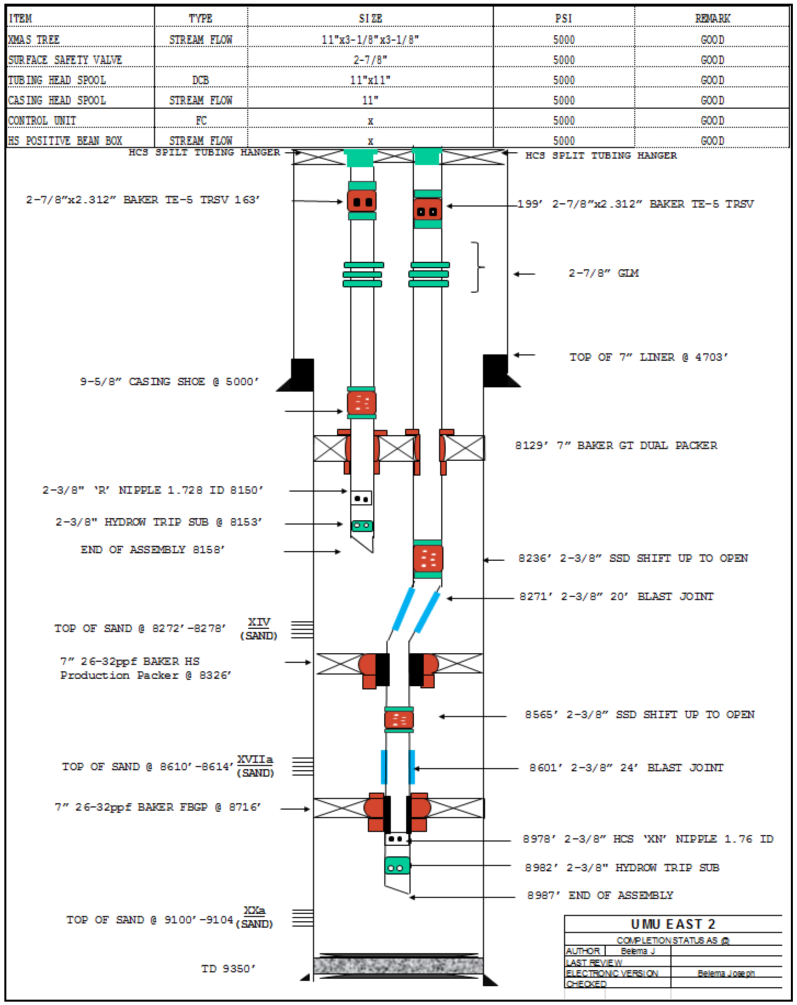



Figure 4.0: Umusadege subsurface well location

## Well Placement and Spacing

- The drilling and completion schedule, the number and placement of wells drilled so far in Umusadege field are a function of several factors:
    - Number of wells and rates as defined from the reservoir study that culminate in the field depletion plan
    - The installed facility capacity; individual well capacities with the tubulars, completion techniques, and artificial lift planned; and any regulatory limits on spacing and/or producing rates
    - Location of the wells for efficient drainage, that is, spaced evenly to contact portions of the reservoir or targeted to specific areas because of reservoir geometry, quality variations, or invading water or gas
    - Four horizontal wells have been drilled to date in Umusadege to:
        - Expose the well to more lateral extent of the reservoir
        - Achieve higher rates with fewer wells
        - Minimize coning of gas and/or water

# Well Placement and Spacing



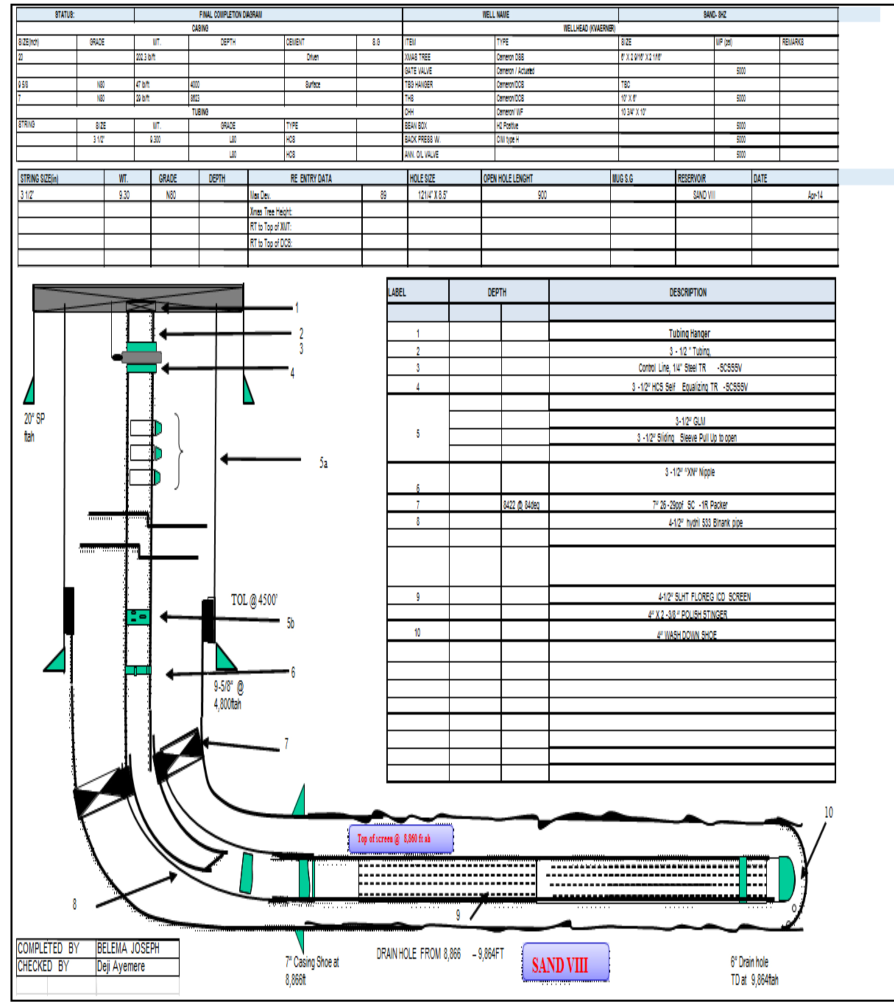




**Figure 5.0: Umusadege vertical well compl.**

**Figure 5.1: Umusadege Horizontal well compl.**

# Umusadege field production forecast

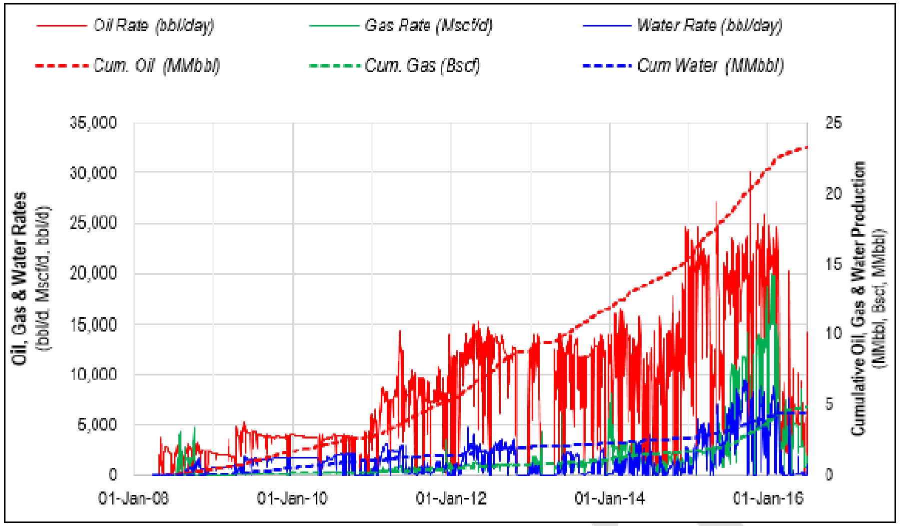



**Figure 6.0 : Umusadege field total field production rates profile**

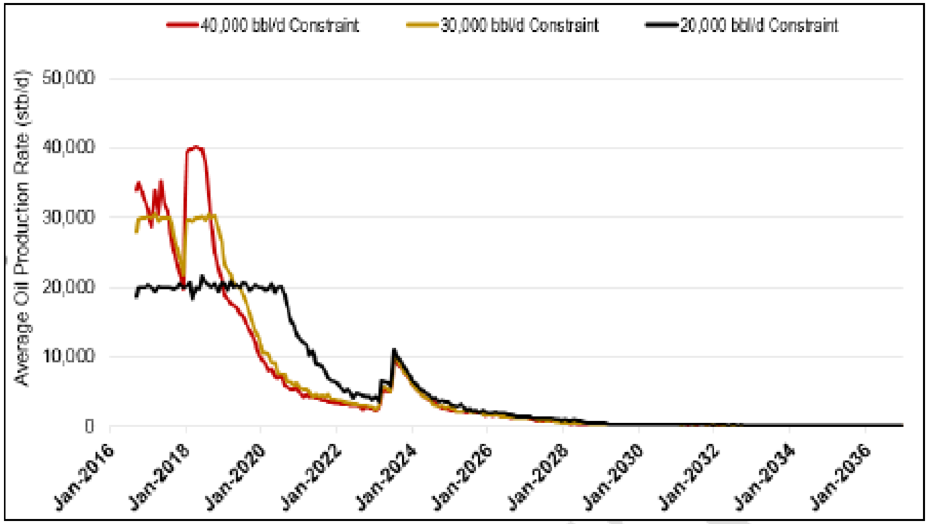



**Figure 6.1: Umusadege field total field oil production rates forecast**

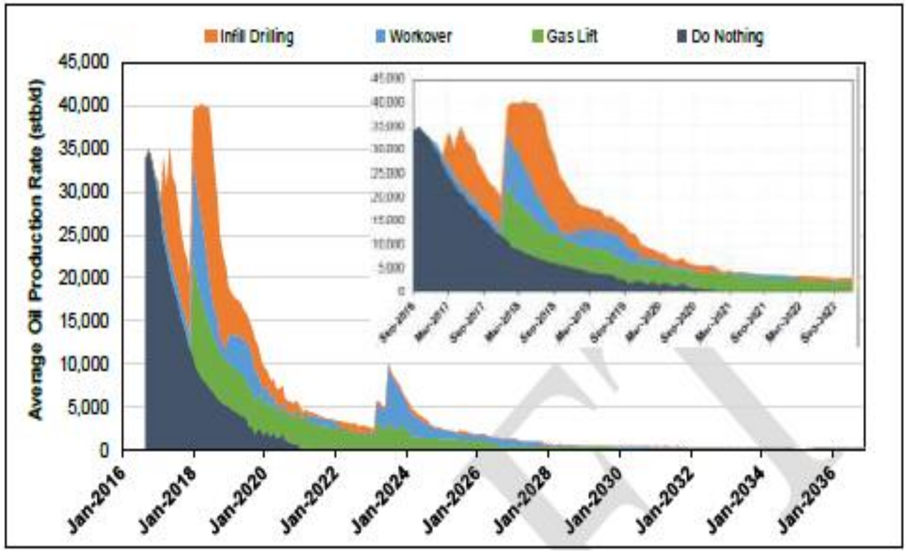



**Fig. 6.2: Umu. field total field oil prod. rates forecast with devel plan**

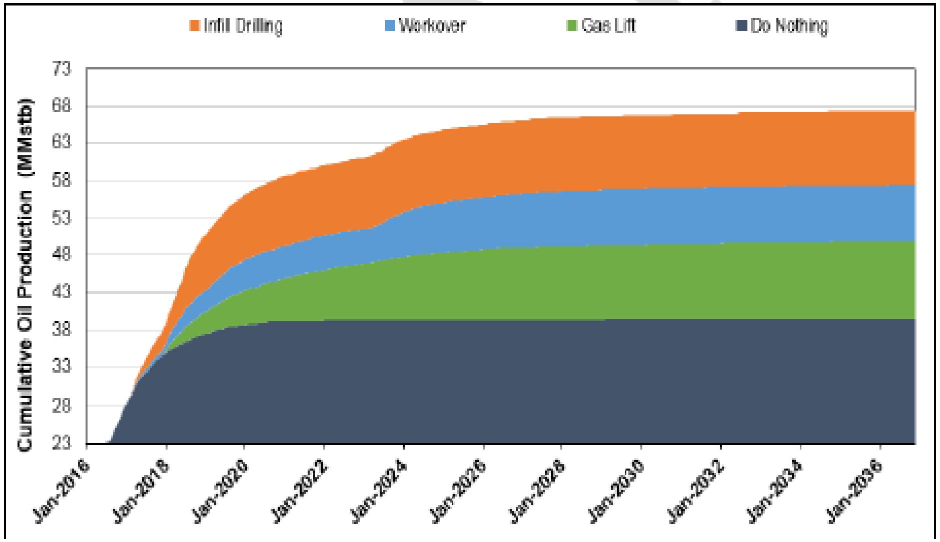



**Fig.6.3: Umu. field total field cum oil prod with dev. plan**

# Reservoir Monitoring and production optimization

- Maximum efficient rate test (MER) and bottom-hole flowing/ build-up surveys are conducted immediately after well completion, and furthermore when required in order to investigate changes to reservoir conditions, well productivity, and increase general understanding of the field.

- Static bottom-hole-pressure surveys on each production interval at least once yearly

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FIELD COPY

MIDWESTERN OIL & GAS
UMU-15 SS SAND XIV
Multi-Rate Test Report Summary

Multi-rate rest summary from 17/12/2015 to 18/12/2015

| Choke size (/64ths) | Total Flow Duration (hrs:mins) | WHP (psi) | WHT (degF) | DSP (psi) | WH BS&W (%) | Liquid Rate (BLPD) | STOil Rate (BOPD) | STOil Cumm (bbls) | API @ 60degF | Water Rate (BWPD) | Water Cumm (bbls) | Sep. Press (psig) | Gas Rate (mmscf/d) | Gas Cumm (mmscf) | sand lb/1000gm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 6:00 | 488 | 93 | 246 | 0.0 | 1670 | 1647 | 412 | 44.2 | 0 | 0 | 242 | 0.090 | 0.023 | 0 |
| 28 | 6:04 | 455 | 96 | 272 | 0.0 | 1832 | 1804 | 456 | 44.2 | 0 | 0 | 269 | 0.083 | 0.021 | 0 |
| 32 | 9:05 | 416 | 99 | 308 | 0.4 | 1996 | 1954 | 740 | 44.2 | 8 | 3 | 304 | 0.072 | 0.027 | 0 |
| 36 | 6:00 | 412 | 102 | 346 | 1.3 | 1971 | 1908 | 477 | 44.2 | 26 | 7 | 341 | 0.054 | 0.014 | 0 |

- Pressure, temperature, BS&W, and flowrates correspond to average values over the flow durations

**Table 2.0: Maximum efficiency rate (MER) test result**

## Reservoir Monitoring and production optimization

- An Integrated Production Model (IPM) for the Umusadege field validated with the field actual production data, for the purpose of field production optimization

- The Petroleum Experts Nodal analysis package, PROSPER (Production System PERformance and optimisation tool), was used for evaluating the well performance and calibrated to measured field data. The required inputs: PVT, VLP and IPR data were modelled

- Surface network was modelled with GAP package based on pipeline lengths and diameter obtained from the surface schematic.

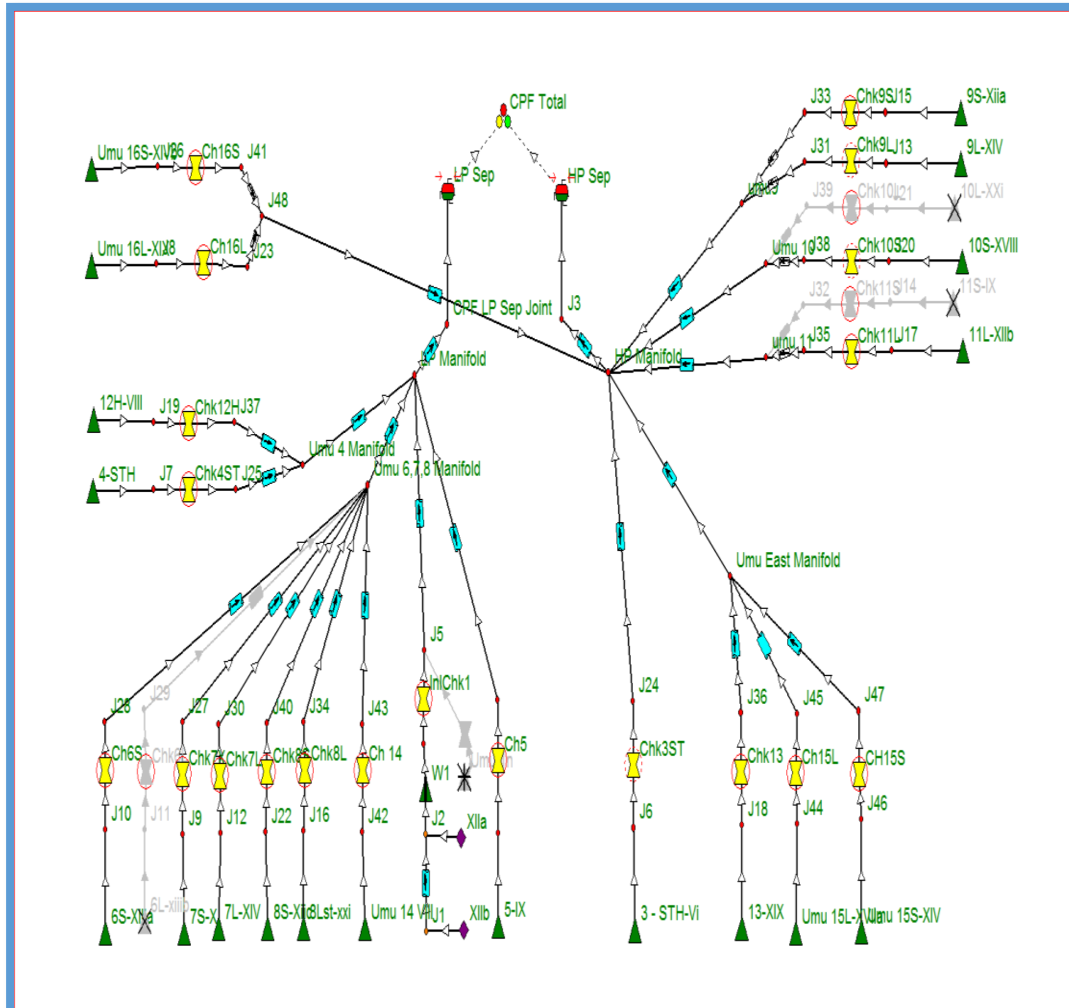


Figure 6.4: Umusadege production optimization GAP model

# Discussions and Conclusions

- The main drive mechanism in Umusadege field is active water and solution gas drive. This understanding has been the determining factor in selecting the depletion strategy and predicting the following:
  - Oil-, gas-, and water-producing rates
  - Reservoir pressure trends and
  - Field ultimate recovery
- An on-going reservoir study to update static/dynamic reservoir simulation models to improve reservoir understanding and performance prediction, update production forecasts, and to identify further development opportunities will be concluded by the end of this year.
- In conclusion the aforementioned procedures have been effectively implemented in Umusadege field from the first oil of about 2,000b/d (two thousand barrels per day) in 2007 to about 30,000b/d(thirty thousand barrels per day) in 2015 year end.