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APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT AND RESERVOIR CHARACTERIZATION TO OPTIMIZE INFILL DRILLING

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FINA OIL AND CHEMICAL COMPANY

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Reporting Period: March 13, 1995 - June 12, 1995

QUARTERLY TECHNICAL PROGRESS REPORT

"APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT AND RESERVOIR CHARACTERIZATION TO OPTIMIZE INFILL DRILLING"

INSTRUMENT NO. DE-FC22-94BC14989

NORTH ROBERTSON UNIT DEPARTMENT OF ENERGY CLASS II OIL PROGRAM PROJECT

REPORTING PERIOD: 3/13/95 TO 6/12/95

This Quarterly Progress Report summarizes the technical progress of the project from 3/13/95 to 6/12/95. Project work planned for the next Quarter is also summarized.

ACTIVITY I.1 - MANAGEMENT AND ADMINISTRATION

PROJECT MANAGEMENT AND ADMINISTRATION - *TASK I.1.1*

The project is on track for accomplishing objectives, goals, and milestones. Work assignments have been progressing smoothly for all team members.

The third Technical Committee Meeting for the project was held on March 30, 1995 at Fina's Dallas office. The next Technical Committee meeting will be scheduled during late summer after further progress has been made on the geostatistics and reservoir simulation tasks.

ACTIVITY I.2 - RESERVOIR CHARACTERIZATION AND ANALYSIS

GEOLOGICAL ANALYSIS - *TASK I.2.1*

Mapping of porosity thickness, permeability thickness, hydrocarbon pore volume, and rock type occurrence of the primary, secondary and non-pays is in progress at David K. Davies and Associates. These maps are being generated for all of the flow units and also the cross-flow barriers. Mapping of cross-flow barriers is required since the sealing quality of the barriers change throughout the unit. Cross-flow barriers also have the potential to have some pay rock.

The mapping work will be used to quantify volumetrics which can be compared with derived volumetrics from the material balance type curve analysis.

The maps are also used for the geostatistical work. The rock type images generated from geostatistics are being compared with the mapped rock type frequency to check for reasonableness of the geostatistical methods employed.

RESERVOIR PERFORMANCE ANALYSIS - *TASK I.2.4*

Production data for the North Robertson Unit has been analyzed using Material Balance Decline Type Curve Analysis. All primary (40-acre) and secondary (20-acre) producing wells have been analyzed to determine total/movable volumes and formation flow characteristics (permeability and skin factor) based on individual well performance. Maps of OOIP, kh, and estimated ultimate recovery (EUR) using primary production data, and maps of kh and EUR using secondary production data have been generated for comparison with the geological interpretation.

Decline type curve and waterflood performance analyses indicate that the NRU is not performing as well as expected under secondary recovery operations. This indicates the need for a complete review of the fluid flow behavior in the reservoir (required for reservoir simulation), and the completion/stimulation procedures used in the past. This work is critical for determining the placement of the 10-acre infill wells, and for optimization of future completion and stimulation practices. In addition, a new waterflood/water influx performance type curve is being formulated to more accurately monitor the performance of individual wells and patterns. These studies will be performed during the next Quarter.

Pressure transient (buildup and falloff) data are being used to estimate reservoir pressure and formation flow characteristics. The estimated bottomhole pressures from buildup surveys conducted during 1987-1991 and the present pressure falloff tests have been tabulated for use in the geostatistics and reservoir simulation. The analyses of the buildup tests indicate that the hydraulic fracture treatments were ineffective (short fracture half-lengths) in creating good pressure sinks at the wellbore due to the presence of large, discontinuous gross pay intervals containing many individual layers, and possessing no effective barriers to vertical fracture propagation.

INTEGRATED RESERVOIR DESCRIPTION - *TASK I.2.5*

The stratigraphic and flow unit zonation of the Unit has been completed and is being used for the deterministic and geostatistical reservoir description. The work has been reviewed with the University of Tulsa for use in the geostatistics and reservoir flow simulation.

GEOSTATISTICAL ANALYSIS - *TASK I.2.6*

The geostatistical reservoir description being generated for the first modeling area utilizes a stepwise approach which includes the following sequence:

- Rock Type Simulation
- Porosity Simulation
- Permeability Simulation
- Upscaling of Petrophysical Properties

The methodology is detailed below:

Rock Type Simulation: The first step in the geostatistical reservoir description is to simulate the underlying rock types which determine the petrophysical properties. The rock type data are first transformed into categorical variables (may be represented mathematically in a "binary" type format). Isotropic and anisotropic variograms describing the spatial relationships are then generated. The anisotropic variograms provide information on the direction of maximum or minimum continuity and anisotropy ratio. Sequential gaussian simulation is then used to estimate rock type values at specific points. This involves defining a search neighborhood around sampled locations.

Porosity Simulation: For the porosity simulation only the points that have the same rock type as the unsampled points are used in the simulation process. As with the rock type simulation, spatial analysis using variograms are performed. This is followed by sequential gaussian simulation to assign porosity values as a function of rock type at unsampled locations.

Permeability Simulation: The conditional permeability distribution for each rock type is generated by plotting permeability and porosity. These permeability data are then divided into several porosity classes. For each porosity class, the cumulative conditional distribution (ccdf) of the permeability is then generated. Finally, knowing the porosity and rock type of a grid node, the ccdf plot is used to assign a random permeability to a specific grid node. In this way, all permeability data will be honored, including extreme values (i.e., high permeability streaks) that may affect reservoir performance.

Upscaling of Petrophysical Properties: Upscaling is required to assign grid block permeabilities and porosities since rock type, porosity and permeability data are generated geostatistically on a very fine grid with one foot vertical intervals. This is accomplished using a tensor method.

RESERVOIR SIMULATION - *TASK I.2.7*

Both deterministic and geostatistical reservoir simulation are being conducted in the first modeling area, Section 329. The goal is to ascertain the advantages and/or disadvantages of the deterministic vs. the geostatistical techniques. Although it is more time consuming to obtain the reservoir description for geostatistical simulation it may be much easier to obtain a history match, as the geostatistical simulation is expected to better represent the heterogeneities and compartmentalization which are present. Differences are expected in the predictive mode for simulations considering different geologically targeted infill drilling options, since many options may have equal or similar probabilities of success.

Subsequent simulations in the other model areas may only be conducted geostatistically. This decision, however, will be made after considering the results from the Section 329 simulation. The second simulation area is expected to be in Section 5. This area, like Section 329 is also an area with good potential for infill drilling.

The initialization for the deterministic model has been completed. Two PVT regions are being used, one for the Glorieta and Upper and Lower Clearfork; and the second region for the Lower Clearfork. Available steady-state and unsteady state relative permeability data are being used primarily to define displacement endpoints. Historical oil and water production data are also being used as relative permeability data for the history match. Initial water saturations will be obtained using well log data from the 20-acre infill wells (which were drilled after unitization, 1987).

The history match of the deterministic model is proceeding well. The primary depletion phase has been matched. The match is now being extended to include the waterflood displacement after 1987. At this point, predictive runs for infill drilling options will be considered, and the geostatistical model for Section 329 will be initialized and run.

ACTIVITY I.3 - INTEGRATED RESERVOIR MANAGEMENT

INTEGRATED RESERVOIR MANAGEMENT - *TASK I.3.1*

Well Deepenings: Twenty-two well deepening candidates have been identified (10 producing wells and 12 injectors). The overall rate increase projected from this deepening work is approximately 290-445 BOPD and represents approximately 10% of existing unit production. A field implementation strategy for the deepenings has been developed and is being implemented.

INTEGRATED RESERVOIR MANAGEMENT - *TASK I.3.1 - Continued*

Additional Completions: Wells with additional completion potential in the Lower Clearfork have been identified. A ranking process is being developed to rank the best wells for additional completion. Field implementation for additional completions is expected during the next quarter.

Pressure Falloff Tests: Nine tests have been completed and one test is in progress using surface pressure data acquisition. Initial results show that the current reservoir pressure in areas around the injection wells is between 3000 and 4000 psia. All of the injection wells analyzed appear to be well stimulated, however, this is most likely the result of extensive fracture propagation due to continuous injection at or near the fracture pressure of the formation. A few tests indicate that offset injection wells may be in contact with each other via hydraulic fractures. Falloff data acquisition will continue in order to get as much usable data as possible for simulation history matching and subsequent infill drilling.

Pressure Build-Up Tests: Additional bottomhole pressure buildup surveys are presently being recorded throughout the Unit to confirm the results of the pressure falloff program (which utilizes surface pressure data acquisition) to provide further data for pressure matching during reservoir simulation, and to locate areas of the reservoir (if any) which have not been effectively repressured. A new pressure data acquisition technique will be utilized for several of the tests in which data is sent uphole real-time using radio signals via the casing string. It is felt that the use of this emerging technology is in keeping with the goals of this project for the identification of such techniques. While the cost of the survey is only slightly more than the usual pressure buildup test, this method allows pressures to be monitored real-time at surface to determine how a test is proceeding and when it may be terminated.

In addition, both surface and downhole pressure acquisition techniques will be used in order to compare the relative data quality from both test types. By measuring the surface pressure and monitoring fluid level height during the test, a buildup can be performed without the cost associated with pulling a well to run downhole shut-in devices. However, due to the low reservoir permeability of the Clearfork/Glorieta in this area, if a well is not shut-in downhole, extremely long wellbore storage periods result, and it is often difficult to obtain quality test results.

Four pressure buildup tests have been completed, and two are currently in progress. Initial results indicate that the average reservoir pressure in the areas surrounding the producing wells is between 1600 and 2100 psia. Further analyses verify that well stimulation and hydraulic fracturing are still major concerns on the newer (1987 - 1991) producers, and these problems are currently being addressed by utilizing cased-hole dipole sonic logs to find untreated intervals, estimate fracture height growth from the initial stimulations, and to compile data on rock

INTEGRATED RESERVOIR MANAGEMENT - *TASK I.3.1 - Continued*

mechanical properties that have been estimated in the past. New stimulation/fracturing techniques will be utilized on the well deepenings and some recompletions will be attempted on existing wells in an attempt to find optimum methods for completion and stimulation prior to drilling 10-acre infill wells. A stimulation database will be set up to determine which stimulation methods, fluids, and volumes produce the best completions.

Conformance Control Workovers: These workovers are being considered to address communication problems. These phenomena are typical of waterfloods in low permeability carbonate formations, and result in early water breakthrough and poor sweep efficiency. Results from the rock-log model analyses and geostatistical simulation will be used to target only zones which contribute significantly to production. By producing from (and injecting into) only the major pay intervals, well conformance should improve significantly.

Step Rate Test Data: Available step-rate data have been tabulated to determine the net increase in the required injection pressure/rate over time and to help identify workover candidates. It has been determined that additional tests cannot be accurately performed using surface (instead of bottomhole) gauges. It has also been determined that after the reservoir fill-up stage of the waterflood, the utilization of step-rate data to set individual well surface injection pressure limits should be discouraged since results no longer show the true fracture pressure of the reservoir due to pore pressure increases.

TDT Logging: The evaluation of the current water saturation profile throughout the unit will be done using Thermal Decay Time (TDT) logs. The new data can be compared with original water saturation data for reservoir surveillance purposes, and can be used as an additional history match parameter for reservoir simulation. In addition, by-passed pay intervals have been identified that will be completed in the near future. Four surveys have been completed to date, and several more will be completed during the next Quarter.

The TDT will also be used in conjunction with a production logging survey to identify zones which contribute most to production, and to verify previous conceptions regarding the relative contributions of the Glorieta, Upper/Middle/Lower Clearfork. Since these wells do not produce naturally (pumping wells), flow will be induced by injecting nitrogen to create an artificial pressure drop in the area of a downhole packer-type flowmeter tool. Production rate and fluid density will be measured. This work will be extremely valuable when well deepenings, re-completions, and infill drilling are performed.

ACTIVITY I.5 - TECHNOLOGY TRANSFER

NEWSLETTERS - *TASK I.5.2*

A Project Newsletter is being developed.

PUBLICATIONS AND PRESENTATIONS - *TASK I.5.3*

Technology transfer activities for the project this Quarter were:

- **Published Papers and Professional Meeting Presentations:**

  - SPE Rocky Mountain Regional Meeting and Low Permeability Reservoirs Symposium, March 20-22, 1995, Denver, CO.

    SPE 29594, *"An Integrated Geologic and Engineering Reservoir Characterization of the North Robertson (Clearfork Unit), Permian Basin, West Texas - A Case Study."*

  - Southwestern Petroleum Short Course, April 19-20, 1995, Lubbock, TX.

    "An Integrated Geologic and Engineering Reservoir Characterization of the North Robertson (Clearfork Unit), Permian Basin, West Texas - A Case Study."

  Also, a presentation on the project was made to Shell Development, Houston during May, 1995. Shell had expressed interest in the project and has done reservoir characterization studies on their operated Clearfork properties. Feedback was provided on the methodologies employed on the project.

- **Presentations Scheduled For Next Quarter are at several SPE, SEG, and DOE Forums and Conferences:**

PUBLICATIONS AND PRESENTATIONS - *TASK I.5.3*

- SEG Development and Production Forum, June 11-16, 1995, Snowmass, Colorado

  "Cooperative Projects to Improve Reservoir Management" To be attended by Louis Doublet, Texas A&M University.

- SPE Forum Series In North America, Snowmass, Colorado

  "Risk and Confidence In Reserves Evaluation", July 30 to August 4, 1995, To be attended by Tom Blasingame, Texas A&M University.

  "Multidisciplined Analysis and Solutions to Rejuvenating Old or Marginal Fields", August 6-11, 1995, To be attended by Louis Doublet & Tom Blasingame, Texas A&M University, and Paul Hunt, Mobil.

- DOE Contractor Review Conference, Coordinated by Bartlesville Project Office June 25-29, 1995.