Reservoir Description and Management

For
PETR 471, 472 – Senior Design

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Summary

Objectives:
1. To integrate petroleum engineering principles for the evaluation of a comprehensive project.
2. To effectively communicate the results and investigations of this evaluation.
3. To promote teamwork within a multi-disciplinary project.

Student Outcomes:
1. Students will demonstrate the ability to apply the principles of petroleum engineering to an integrated project.
2. Students will learn to effectively communicate both in oral and written presentations.
3. Students will be capable of evaluating and designing projects.

Course Structure

The first semester is designed to apply previous knowledge of petroleum engineering principles to the evaluation of a field project. Emphasis will be on combining the various course components to evaluate the field performance and propose any improvements. Figures 1 and 2 illustrate the concept.

As a corollary, students will gain an initial awareness of the given reservoir in their project area, which will lay the framework for the second semester, where emphasis will be on reservoir management.
Geologic Description
Seismic
outcrop, sample, &
core analysis

Trapping mechanism,
depositional environment,
rock properties

Petrophysical Description
Well log
core
pressure testing

Logs - $\phi$, $S_w$, h, lithology
Cores - $\phi$, $S_w$, k, lithology
Special core - $P_c$, $k_c$
PTT - k, Skin, $P_f$

Fluid Description
$PVT$ Fluid sample or
API, $\gamma_g$, $T_f$, GOR

Reservoir fluid type,
Fluid properties, $B_o$,
$B_g$, $\mu$,...

Well Planning
$WOB$, $ROP$, mud type,
casing design,
bit design

Usable wellbore

Pressure losses in pipes
& completion,
decline curve analysis

Production Design
Production data,
completion type
facility data

Project Economics
Investment costs,
expenses,
target parameters

Cashflow and NPV,
risk and uncertainty,
viability

Figure 1
Figure 2

Reservoir Description and Evaluation
oil or gas-in-place reserves

Geologic Description
Petrophysical Description
Fluid Description

RESERVOIR MANAGEMENT

Well Performance
Optimization
Design

Well Planning
Project Economics
Production Design

Figure 2
**Reservoir Description**

The objective of reservoir description or characterization is to provide spatial and vertical variability to rock properties for the purpose of defining flow units within a reservoir. The intent of spatial variability is to describe properties from well-to-well or within the interwell area. In the case of vertical variability, the intent is to describe properties within a well for different layers. These variations can be used to delineate boundaries or define zones of common flow properties, which compose a single entity known as a *flow unit*.

Collection of data for reservoir description can be global or specialized. Global data provides information measured over a substantial portion of the reservoir, or is extrapolated to extend over the entire reservoir. An example of the former would be seismic data, of the latter, would be lithology. Specialized data is restricted to a given well; such as well log porosity or core permeability. Combining specialized data in an areal map, results in an upgrade to a global view of the reservoir.

The tools for providing the necessary information in reservoir description have been divided into three areas: geologic, petrophysical, and production. Each area has independent expertise; however, each area is dependent upon the other for success. Proper evaluation requires a multi-disciplinary team approach composed of geologists, geophysicists, petroleum engineers, and petrophysicists.

**Geologic Description**

The efforts of describing a reservoir are initially built upon the fundamental principles of the geosciences. Two key elements in the exploration stage of discovering oil or gas is the identification of the trapping mechanism and an understanding of the depositional environment of the target formations. For oil or gas to accumulate, a trap, either structural or stratigraphic, with a caprock, must be present. The storage and flow capacities of a formation are dependent upon the depositional environment of the sediments and the diagenesis which has altered these sediments throughout time. On a reservoir scale, seismic data and outcrop analysis provide useful information for the determination of the two before-mentioned elements. On a finer scale, analysis of drill cuttings, cores, and logs will provide evidence of rock types, porosity and other rock
properties. Over time, the acquisition of additional data will improve the quality of the geologic description and therefore benefit the reservoir management.

**Petrophysical Description**

The basis of petrophysical description is the evaluation of individual well data. The three primary sources of this data are well logs, cores, and pressure transient tests. Well logs provide a vertical variation of rock properties as a function with depth. Porosity, shale content, water saturation and lithology are determined by interpretation of well logs. Conventional core data provides porosity, permeability and saturation data for potential reservoir rock, also as a function of depth. Furthermore, special core analysis can result in capillary pressure and relative permeability data, both important parameters to reservoir simulation and estimates of improved recovery. Conventional well tests such as drawdowns and buildups are essential for estimating permeability, skin factor, and average reservoir pressure.

The wealth of data can be extremely inconsistent. This is in part due to measurement errors and unknowns in the procedures, but is predominately due the difference in scale of the various methods. On average, the radial investigation of cores, logs and welltests are .33, 3, and 30 to 300 ft., respectively. Subsequently, each method is averaging over its respective volume.

Techniques to assemble this individual well data into a reservoir picture have been applied for years. Initially, mapping techniques such as isopachs provided an areal view of the reservoir quality. Today, sophisticated geostatistical techniques are employed to develop realizations, which honor the data points but provide a detailed interwell picture of the reservoir. Furthermore, advances in seismic processing and acquisition have become a component of this work.

**Production Description**

Another component necessary for many reservoir calculations is fluid property analysis. Typically, a PVT fluid sample or data such as oil and gas gravities and formation temperature are collected to describe the pressure and temperature dependency of the reservoir fluid. Furthermore, analyzing the fluids provides important information pertaining to the identification of the reservoir type; i.e., black oil, volatile oil, retrograde
condensate, wet gas or dry gas. Knowing reservoir fluid type benefits by the mechanisms of depletion and displacement. A final property of reservoirs, which is frequently not included in reservoir description is production data. That is, reported production rate over time for an individual well. Production decline analysis can be useful in estimating ultimate hydrocarbon recovery, drainage volume, and possible drive mechanism.

Reservoir Evaluation
Before any project can be proposed, a thorough understanding of the reservoir must be obtained. Most notably is defining the storage and flow properties for the reservoir. The key of reservoir evaluation is the scale. Instead of defining properties in a well, we are combining well properties to describe pressure and production behavior on the reservoir scale. Therefore, information from reservoir description will be applied to determine this reservoir behavior. In turn, reservoir evaluation will identify areas of deficiency in reservoir description which need to be addressed to enhance the management of the reservoir.

To efficiently manage the reservoir it is desired to be able to quantify the volume of hydrocarbons available. Reservoir evaluation will provide the hydrocarbons-in-place and reserve estimates for the producing horizons. Two methods of accomplishing these goals are material balance calculations and volumetric analysis. The material balance requires pressure – time – production data to determine the volume of hydrocarbons and recovery. Volumetrics relies on petrophysical data to determine the hydrocarbon pore volume in a reservoir.

Well Performance
A second aspect important to well development and ultimately reservoir management is well performance. The objective is to optimize production from the reservoir to the stock tanks on the surface. Furthermore, this concept can be expanded to optimize the network of wells comprising the entire field development. For example, balancing water injection and fluid withdrawals in a waterflood project, or the gathering of various oils through flowlines and surface equipment.
A common component of well performance is design. The planning and drilling of a well is designed; or the well completion and surface facilities are designed. These topics will be elaborated on later.

The final test of any project is the cost/benefit ratio. That is, for any costs incurred for a given project what are the associated benefits? Typically, this is measured and thus evaluated in terms of money; subsequently economics plays an important role in the success of a project.

**Project Design**

An important aspect of reservoir management is oriented towards engineering projects such as drilling new wells, recompletions of existing wells, or injection facilities for secondary recovery projects. These investments require proper engineering design to safely and efficiently accomplish the tasks. For example, *well planning* is a key area for drilling engineers. By gathering information from all sources a detailed design of a well can be achieved. For example, the rate of penetration and trajectory of a well is dependent upon geologic information such as the types and structure of the formations to be penetrated. Or other information such as pore pressure and fracture pressure would improve the drilling of the well. Well planning is a broad topic composed of various design aspects; e.g., bit, mud, hydraulic, and casing/cement are all design components.

A second topic in design is to apply optimization methods to improve well performance through *production design*. Systems analysis is a comprehensive method to optimize production. Development of inflow and outflow relationships combine aspects of reservoir and production engineering to provide the best solution for the given conditions. Wellbore design and surface facility design are components of this routine, such as tubing configuration or flowline sizing, etc. Also included are the effect of completion design (openhole, perforated or gravel pack) and stimulation on the well productivity.

**Economics**

Economic principles govern business decisions. Any investment project must meet certain target economic criteria set by the company to be viable. Such parameters as rate-of-return on investment, profit-to-investment ratio and/or payout are key issues to
be investigated for success. Others are cashflow and net present value. Some parameters are not controllable, e.g., oil and gas price, others are more flexible such as minimizing investment costs. Many projects are based on sound engineering and geological judgement; however, to proceed they meet the prescribed economic guidelines. It is this requirement which makes economics a vital component of reservoir management.

**Reservoir Management**

The objective of reservoir management is to optimize production in an effort to maximize profit. It relies on information and analysis from reservoir description to make critical decisions on achieving this goal. A common example is well spacing. A single well in a reservoir provides minimal information on the number of wells to efficiently drain a reservoir. After several wells are drilled and completed the information gathered can be useful in estimating the optimum spacing. Too few wells and portions of the reservoir are undrained. Too many wells and the profit margin decreases due to the lower recovery per well. It also relies on successful drilling and production optimization. In summary, reservoir management and reservoir description form a continuous cycle of change and improvement. The goals of reservoir management are continuously being updated to reflect the improved reservoir description obtained through acquiring additional information. The acquiring of additional information provides vital material for better informed decision-making.

The role of reservoir management has become a popular topic of discussion within the recent years. References 1 thru 4 provide a summary on reservoir management. An example of reservoir management practices to the Rhourde El Baguel Field in Algeria is discussed in reference 7. Several common themes are present in these works. First, reservoir management is a continuous process from discovery to abandonment. Along this timeline, data is continuously collected, analyzed and reservoir description improved. In response to this improvement, reservoir management strategies can be altered accordingly. Second, emphasis is on defining clear objectives, which are measureable and achievable. Furthermore, as eluded to in the first theme, the objectives maybe revised as additional data is gathered and interpreted.
For example a clean, oil-bearing sandstone is discovered to be highly productive. Early development plans locate the wells on 40-acre spacing. Information gathered suggests infill drilling to 20 acres could be technically achieved and would be profitable. Unfortunately, the infill wells were poor performers and the results were devastating. Further investigations by the reservoir management team, shows the oil sand to have excellent secondary potential to waterflooding. Subsequent development of a waterflood pattern results in substantial oil recovery.

In this example the objectives were modified to reflect the additional data. It could be argued that early during the discovery, the team should have foreseen and predicted this type of response. However, there does exist some risk and uncertainty in reservoir management.

This example leads to a third and final theme of reservoir management; i.e., teamwork. An extreme value is placed on multi-disciplinary teams working cooperatively to attain the objectives of the project or asset. This concept extends beyond engineers and geoscientists to include management, legal, accounting and field personnel. Commitment by all parties will lead to success both for the company and for the team. The team needs to realize its strength and weaknesses. If expertise in a particular area is needed, they need to request key personnel who are knowledgeable in that area.

Technology Transfer
In the first semester the goal is to prepare a written feasibility report of the evaluation of the project and the proposed work to improve production. This report should mention work which has been accomplished, work which is currently in progress, and work proposed for the next semester.

A traditional technical report has the following components:

1. Title page
2. Executive Summary
3. Table of Contents
4. Body
5. References
6. Appendices
In preparing any document, it is of concern to know the audience. You should ask several questions: Who will read the report? What will the reader want to know? What is the purpose of the document? For example, a researcher would like to know technical data and derivations while a business manager would like to here more on the milestones and costs.

1. **Title page**
The goal of the title page is to inform the reader of the topic covered and the person or persons who performed the work. Typical title pages include the title (usually emphasized by larger type or different font), author’s name(s), name to whom report was prepared, date, and in some cases, project or contract numbers. This page should be arranged in logical sequence for clarity and not appear cluttered.

2. **Executive Summary**
The purpose of the summary is to permit busy managers to obtain the significant information from the report in a short period of time. Therefore the summary must be self-sufficient, and must also be written after the main body has been completed. In writing the summary, I suggest the writer answer the following questions in sequence; What is the News? Why is it important? How did you attain this conclusion? What is next?  

3. **Table of Contents**
The table of contents not only provides the reader with the location of the page numbers, but also provides an outline of the report. It furnishes the reader with the framework to which he can comprehend the sequence of the report. In fact the table of contents is compiled from the headings in the report. Any document over five pages long should have a table of contents.

4. **Body**
The body of the report performs several functions and thus is typically subdivided into sections. It is the longest and most important section of the report, and contains some or all of the following:
• Purpose of the investigation and sufficient background material to inform the reader. (introduction)
• How was it accomplished (description)
• What was determined from this work (results and discussion)
• What are the outcomes (conclusions and recommendations)

It must be emphasized that these are functions and not mandatory sections!
The body should be written in a natural, logical and efficient manner.

Introduction – orients the reader to the topic and report. Can include any of the following:
• The purpose of the investigation
• A description of the basic procedures or methods used
• A definition of the scope of the study
• A description of the organization of the report

Description – is an elaboration of the procedures or methods involved, which lead to the results that follow. The key to this section is to determine the importance of these procedures to the overall report. Consider, if a new method or process has been developed and thus is an essential component of the main theme of the report. Then a detailed description can be at the beginning of the report or interspersed among related topics within the body. However, if the primary purpose is to present the results of an investigation, and the methods are familiar, then the detailed description should be in an appendix or omitted completely. If the methods and equipment are well known to the reader then it may be sufficient to omit the detailed descriptions.

Results and Discussion – contains evidence of the actual data collected and analyzed. The discussion explains and elucidates the results. It investigates the significance of the results, identifies any limitations or strengths, and any unexpected behavior. Sample calculations and most important graphs should be imbedded in this section. The tedious or routine material should be left for an appendix.
Conclusions and Recommendations – Conclusions are logical decisions or judgements based on the evidence presented in the previous sections. Recommendations direct attention to areas of improvement needed within the study, or to work that should be initiated because of the study.

5. References
Detailed guidelines for the correct writing of references can be found in the SPE Author Guide on the SPE website. For reports, two methods are commonly employed: (1) in citation order or (2) in alphabetical order. In the first, the references are listed sequentially by number in the order they are cited in the text. This document is an example of such a system. The alternative is to list the references in alphabetical order by author’s name. Subsequently, within the text the reference would list the name and date of the reference. For example, [Thakur, 1996] would be inserted in the appropriate location in the text. This method is commonly named a Bibliography.

6. Appendices
The appendix is the location to insert any material that needs to be included in the report but is not essential to the main theme. Thus it is possible to maintain important detailed information for record purposes or for those who desire to read it. Each section of an appendix should be referenced within the text. This allows the reader to follow up on pertinent information while reading the document. Also, if it is not worth mentioning then it is not worth putting in the report. The appendices should be arranged in a rational order, frequently following the sequence in which they were referred to in the text. Several suggestions for appendix material are: tables and graphs of repeating components, tabulations of data that are presented as graphs, detailed descriptions of equipment or methods, sample forms, derivations, copies of other documents cited in the text, or any other material deemed important.
In some cases it is desired to write a published work in the form of a technical paper. These are frequently shorter in length and directed to an audience who are extremely familiar with the work you have accomplished. The Society of Petroleum Engineers (SPE) provides helpful guidelines on how to write and prepare a technical paper. These guidelines can be found on the SPE website.

An oral presentation is frequently required of your technical report or paper. This presentation should describe the objectives of the project, the engineering analysis, and the results, conclusions and recommendations. The concept is to inform and promote the idea to management, investors, or others. Therefore the presenters should be positive and active, make use of interesting and useful graphics (not distracting or overwhelming), and get their ideas across to the audience clearly and concisely, within 20 minutes. The SPE Visual Aids Guide is a useful reference for planning a presentation.

References
1. Thakur, G.C.:”What is Reservoir Management”, JPT June, 1996, 520-525