Screening Criteria for Application of Carbon Dioxide Miscible Displacement in Waterflood Reservoirs Containing Light Oil

Subtask of 14960

"Post Waterflood CO_2 Miscible Flood in Light Oil Fluvial Dominated Deltaic Reservoir"

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by

Department of Petroleum Engineering
Louisiana State University

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Summary

In conjunction with a joint Texaco/DOE research project, the LSU Department of Petroleum Engineering developed an improved method of screening reservoirs for application of a carbon dioxide miscible enhanced oil recovery (EOR) process. This method, which can be applied to a large number of reservoirs, considers both the technical and economic feasibility of the EOR process.

The technical parameters of each reservoir are first compared to those of an "ideal" reservoir; and from that comparison, each reservoir is assigned a technical ranking. The technical ranking is used to estimate expected recovery. Key technical parameters used in the screening process are remaining oil in place, minimum miscibility pressure, reservoir depth, oil API gravity, and formation dip angle.

The reservoirs are subsequently screened for economic feasibility based on standardized capital costs and operation expenses that are representative of the reservoirs under consideration. The reservoirs are finally ranked based on the present worth value of revenues to costs ratio.

Using this method, we screened a database containing 197 light-oil waterflooded reservoirs in Louisiana. The database includes three reservoirs where CO_2 miscible floods are ongoing; these reservoirs ranked first, second and twelve. The high ranking of these reservoirs, which were selected based on detailed and comprehensive reservoir studies, validates the screening method.

Different implementation options in a specific reservoir can be screened if warranted, by using CO_2 - PROPHET, a PC compatible software. CO_2 -PROPHET is a relatively simple numerical model capable of simulating water and gas floods. An example of its application is included.

Introduction

In 1992 Texaco Exploration and Production Inc. (TEPI) and the U. S. Department of Energy (DOE) entered into a cost-sharing cooperative agreement to conduct an Enhanced Oil Recovery (EOR) demonstration at Port Neches field, Orange County, Texas. The agreement was formulated under DOE Class I Oil Program, which encourages the development of innovative technical approaches to enhanced oil recovery. The innovative aspect of this project is the application of CO_2 miscible flooding in waterflooded light-oil fluvial-dominated reservoirs. TEPI agreed to disseminate the lessons and the experience gained at Port Neches to other operators in the petroleum field.

Louisiana State University (LSU) has agreed to assist TEPI with technology transfer efforts. LSU's role was mainly to identify and rank waterflooded Louisiana reservoirs where the CO_2 EOR process is applicable. To achieve this goal, LSU needed to develop a screening process that could be applied to reservoirs listed in the Louisiana Office of Conservation database. To be meaningful to interested operators, the screening method had to consider both the technical and economic feasibility of the EOR process. Because economic feasibility depends highly on CO_2 availability, identifying CO_2 sources and their distance to prospective reservoirs was imperative.

Once a prospect is identified, management options need to be considered. This task requires a user friendly numerical simulator. The effect of reservoir heterogeneity and well locations which is not considered in the initial screening can be investigated when performing the numerical simulations.

Review of Past Field Applications

The oil industry has extensive experience in carbon dioxide miscible displacement for enhanced oil recovery.[1-7] Fundamentals of the behavior of oil in presence of carbon dioxide, its characteristics and potential have been discussed by several authors.[8-16] In the case considered in this study, that is, miscible displacement, relatively reliable correlations have been developed to determine the minimum miscibility pressure.[17-21] Accumulated knowledge ranges from successful field applications almost at the end of their application, to many projects currently under development.[22-44] Following are the synopses of the published field experiences in waterflooded sandstone reservoirs.

Recovery results are encouraging, even though it is difficult to quantify the final outcome because many projects are still in progress. The CO_2 process is applicable in waterflooded and primary depleted reservoirs regardless of the original oil-in-place (OOIP). However, the remaining oil saturation must be high enough to justify the cost of miscible displacement.

Recovery efficiencies ranged from 2 to 19% of OOIP, and the net amount of CO_2 required to recover an incremental barrel of oil varied from 3 to 13 thousand cubic feet (Mscf). The average recovery for documented cases is 10.8% of OOIP and the average utilization ratio is 7.2 Mscf of CO_2 per incremental barrel of oil. Data is scarce on CO_2 cost and estimates vary between 0.50 to 2.0 $/Mstb.

The most common spacing used was 40 acres per well, even though some applications, especially pilot tests, had spacings of 10 acres. The preferred configuration was the 5-spot pattern, sometimes combined with line drive patterns. The predominant injection mechanism was a 1:1 water alternating gas (WAG), with innovations such as hybrid injection and tapered injection. Injected carbon dioxide volumes varied between 19 and 60% of the hydrocarbon pore volume (HCPV) with an average of 36% HCPV. Reported reservoir dips varied between 4° and 30°, with a clear preference for reservoirs with a low dip angle. Several of the reservoirs had an initial gas cap.

The most common problems were corrosion which was reported in 58% of the cases reviewed, followed by low vertical sweep efficiency in 50% of the cases. Asphaltene or paraffin precipitation occurred in 30% of the cases. It was also evident that the industry has gained a lot of experience dealing with these problems and have found ways to prevent or minimize them.

Project economics were not always reported, but at least half of the documented cases were profitable. Carbon dioxide accounted for a large fraction of the project cost. Most of the reported sources of carbon dioxide were nearby industrial plants which allowed easy transport and processing of the CO_2. Using the average estimated CO_2 utilization and an assumed cost of $0.60/ Mscf of CO_2, the average cost per incremental barrel of oil is about $4.5.

During many of these projects, the process was modified to maximize recovery efficiency. It was necessary to have efficient monitoring and maintenance programs so that the process performance could be assessed as the project proceeded. It is apparent that additional research is needed in order to improve vertical sweep efficiency. It is necessary to improve reservoir characterization and correctly assess the problems of continuity and channeling.

Many field operations can be improved to reduce cost and enhance economics. These operations include optimized use of existing wells, improvements in sweep efficiency by using gels or polymers or selective injection, reutilization of existing facilities, optimization of the reservoir fill-up, CO_2 recycling; and the use of horizontal drilling technology. Use of sophisticated technology such as 4-D seismic, compositional simulation and geostatistics techniques could be economically feasible in certain large reservoirs.

Review of Screening Methods

Screening is usually performed following certain guidelines and criteria developed from laboratory tests and field experience. Screening methods include reservoir performance prediction, binary comparison and, parametric optimization. Klins[13] assembled a chronological list of available screening guides for the carbon dioxide miscible process.

As experience with carbon dioxide processes increases, the results of field applications are used to define ranges of operating and reservoir parameters needed for successful application of a given process. Binary screening methods have been frequently used as preliminary screening tools because they are easy to use.

Rivas *et. al.*[46] presented a screening method based on parametric optimization. Reservoir parameters examined were: temperature, pressure, porosity, permeability, dip, API gravity, oil saturation, net oil sand thickness, minimum miscibility pressure, saturation pressure, remaining oil-in-place, and reservoir depth. An arbitrary heuristic function, called the exponentially varying function, was used to rank the set of reservoirs. The function's value depends exponentially on the weighted differences between the properties characteristic of each reservoir and a set of optimum parameters obtained for an "ideal" reservoir using numerical simulation.

Recently, Chung *et. al*[48]., presented a novel approach to asses an EOR project performance which is based on the application of artificial intelligence in the form of a fuzzy expert system. The method incorporates experts' experience to screen EOR methods, estimate field performance and perform economic analysis. The method determines overall recovery efficiency as result of the fuzzy set arithmetic product of estimates of displacement efficiency and vertical sweep efficiency, which are treated as fuzzy variables. Economic analysis considers recovery efficiency, residual oil in place, oil price and operating costs.[48]

Some screening methods use estimated incremental oil recovery, CO_2 breakthrough, and project economics to estimate a value of after-tax profit. Normally this profit is expressed in terms of discounted cash flow (DCF) and rate of return (ROR).[13]

Several numerical simulators can predict the process performance. DOE CO_2 predictive model[52,54] and DOE CO_2 Prophet[53,54] are not suited to screen a large number of possible candidates because of the time required. Carbon Dioxide Predictive Model (CO_2PM) basically consists of a one - dimensional fractional flow model, which includes modifications to account for the effects of viscous fingering, reservoir heterogeneities, and gravity segregation. Areal sweep calculations generate production rates for oil, water, and CO_2.[55] The most restrictive characteristics of CO_2PM are the fixed five spot well configuration, the inability to simulate alternate injection schemes such as hybrid and tapered WAG, and the optimistic predictions of oil rate and recovery.[55]

PC Prophet[56], a water and gas flood prediction software was developed by Texaco with support of the U.S. Department of Energy (DOE), has been shown to be a good tool for screening, reservoir management and economic analysis. It is available to the industry with a detailed user manual. Ease of use and PC compatibility were emphasized in its development. It computes streamlines between injection and production wells to form streamtubes, making flow computations along them. It considers miscible flow and vertical heterogeneity.

Screening for Technical Feasibility

Reservoir performance prediction methods were excluded because of the relatively large number of reservoirs to be screened. Binary screening methods were also excluded because they do not account for the synergistic effects of reservoir parameters. For example, with the binary comparison method, a reservoir that has properties marginally within the recommended ranges would be selected over a reservoir that has very good values of all properties except one.

We opted for the parametric optimization method developed by Rivas *et al.*[46] Their screening method is based on determining for each property (j) of the reservoir (i) being ranked a corresponding normalized parameter $x_{i,j}$, defined by:

$$X_{i,j} = \frac{|P_{i,j} - P_{o,j}|}{|P_{w,j} - P_{o,j}|} \tag{1}$$

where $P_{o,j}$ is the magnitude of the property (j) in a fictitious reservoir called the optimum reservoir, which gives the best response ot CO_2 flooding. $P_{w,j}$, on the other hand, is the value of the property (j) in another ficitious reservoir, called the worst reservoir, which is not suited to CO_2 flooding. The variable $x_{i,j}$ varies linearly between 0 and 1.

Because an exponential function is more adequate than a linear function for comparing different elements within a set, the normalized linear parameter $x_{i,j}$, is transformed to exponential varying parameter $A_{i,j}$ using the following heuristic equation:[46]

$$A_{i,j} = 100e^{-4.6x_{i,j}^2} \tag{2}$$

$A_{i,j}$ range from a minimum of 1 to a maximum of 100. To take into account the relative importance, or weight, of each reservoir parameter, a weighted grading matrix $w_{i,j}$, is determined as follows:

$$w_{i,j} = A_{i,j} w_j \tag{3}$$

where w_j is the weight of property (j).

The reservoirs are then ranked using a ranking parameter, R_i, defined as:

$$R_i = 100 * \frac{\sum_{j=1}^{j} M_{i,j}}{\sum_{j=1}^{j} M_{1,j}} \tag{4}$$

where $M_{i,j}$ is the product of the weighted matrix $w_{i,j}$ by its transpose, $w_{j,i}$.

The parameters used in the parametric optimization screening are oil API gravity, reservoir temperature, saturation of oil before process application, porosity, permeability, ratio of reservoir pressure to CO_2 minimum miscibility pressure (MMP), net pay oil thickness, and reservoir dip. Other important parameters such as oil viscosity, gas to oil ratio, and bubble point pressure were excluded for simplicity purposes. These properties, however, correlate with oil gravity which is included in the screening.

The properties of the optimum reservoir $p_{o,j}$, used in equation 1 were obtained by performing numerical simulation on a base case to determine the set of parameters that optimized reservoir response to CO_2 flooding[46]. The relative importance or weight of each parameter on process performance was determined from the average normalized slopes of the reservoir performance around the optimum value of the parameter.[47] Optimum reservoir parameters and weighting factors are given in Table 1.

The properties of the worst reservoir $p_{w,j}$ are determined using the data of the reservoirs to be ranked. The value farthest away from the optimum is the worst value. It is conceivable to have two worst values, one lower and one higher than the optimum. Worst parameters of the reservoirs considered in this study are listed in Table 2.

TABLE 1: Optimum Reservoir Parameters and Weighting Factors.[46]

Parameter	Optimum	Weight
API Gravity	37	0.24
Oil saturation, %	60	0.20
Pressure/MMP	1.30	0.19
Temperature, °F	160	0.14
Net oil thickness, ft.	50	0.11
Permeability, md	300	0.07
DIP, °	20	0.03
Porosity, %	20	0.02

TABLE 2: Worst Parameters from Louisiana's Reservoir Database.

Parameter	Lower Limit	Upper Limit
API Gravity	24	48
Oil saturation, %	8	80
Pressure/MMP	0.10	1.47
Temperature, °F	80	276
Net oil thickness, ft	5	175
Permeability, md	17	3485
Dip, °	0.03	64
Porosity, %	17.6	34

CO_2 Sources and Providers in Louisiana

Critical to the economic feasibility of the process is the availability and location of CO_2 sources. A list of CO_2 industrial sources and providers was compiled through personal interviews and by reviewing a brochure published by the Louisiana Chemical Association.[57] Some potential commercial sources/ providers of CO_2 were also identified from a computer database compiled by Louisiana State University.[58] A complete list of CO_2 providers in Louisiana is given in Appendix A.

Naturally occurring CO_2 reservoirs are associated with the Jackson Dome geologic structure in Mississippi. Shell operates a pipeline that runs from Jackson Dome to Week's Island field. The pipeline has two sections: a 20 inch and a 10 inch. The 20-inch pipeline crosses from Mississippi into Louisiana in St. Helena Parish and continues across St. Helena, Livingston, East Baton Rouge, Ascension, and Iberville parishes. A site just northeast of Pierre Part serves as a pumping station where the 20-inch and 10-inch pipelines connect. The 10-inch pipeline, crosses Assumption, St. Martin, St. Mary, and Iberia parishes, and terminates at Week's Island field. The last 16 miles of this pipeline were leased and are temporarily being used for hydrocarbon transportation. The remaining northern portion is still used to transport a small amount of CO_2 to Shell projects. The pipeline is available for tap-ins. Figure 1 shows fields with at least one waterflooded reservoir, plant sources of CO_2, and the location of the Shell pipeline. Fields with at least one waterflooded reservoir are also listed alphabetically in Table 3.

History of CO_2 Use in Enhanced Oil Recovery Efforts in Louisiana

The Department of Natural Resources (DNR) provided information on 23 CO_2 recovery projects within Louisiana. Of these 23, Texaco has 11 in five fields, Shell has three in two fields, ARCO has two (both sold to TXO) in one field, Chevron has six (two sold to Greenhill Petroleum) in three

TABLE 3: Fields with at Least One Waterflooded Reservoir

Avery Island
Bancroft
Bay Marchand
Bay St. Elaine
Bayou Choctaw
Bayou des Glaise
Bayou Fordoche
Bayou Middle Fork
Bayou Sale
Belle Isle
Bellevue
Big Creek
Black Bayou
Bossier
Buckhorn
Bull Bayou
Bully Camp
Burrwood
Caddo (Jeems Bayou)
Caddo-Pine Island
Caillou Island
Carterville
Catahoula Lake
Cecelis
Chemard Lake
Clovelly
Cotton Valley
Cut Off
Dave Haas
Delhi
Delta Farms
Delta Duck Club
Deltabridge
DeSoto - Red River
DeSoto - Red River (Bull Bayou)
Dog Lake
Duck Lake
Dykesville
East Hackberry
East Larto Lake
East Longville
Erath
Eugene Island Block 18
Eugene Island Block 19
Frisco
Garden City
Garden Island Bay
Good Hope -
Grand Bay
Grand Isle Block 18
Grand Lake
Greenwood-Waskom
Grogan
Haynesville
Hester
Holly
Hurricane Creek
Iota
Iowa
Jefferson Davis
Jennings
Killens Ferry
Klondike
Lafitte
Lake Barre
Lake Enfermer
Lake Hatch
Lake Hermitage
Lake Mongulois
Lake Pelto
Lake Salvador
Lake Washington
Larose
Larto Lake
Leeville
Lisbon
Little Lake
Little Temple
Livingston
Livonia
Lockhart Crossing
Locust Ridge
Longville
Main Pass Block 35
Main Pass Block 41
Main Pass Block 69
Mamou
Manila Village
Mira
Naberton (Bull Bayou)
Napoleonville
Nebo-Hemphill
Newlight
North Burtville
North Cankton
North Missionary Lake
North Shongaloo-Red Rock
Northeast Lisbon
Olla
Opelousas
Opelousas
Ora
Panther Creek
Paradis
Patterson
Perry Point
Pine Island
Pleasant Hill
Plumb Bob
Port Barre
Potash
Quarantine Bay
Red River-Bull Bayou
Redland
Rodessa
S.E. Manila Village
Saline Lake
Section 28
Sentell Field
Shongaloo
Shongaloo-Pettet, W Seg
Siegen
Simpson Lake
South Bayou Mallet
South Black Bayou
South Pass Block 24
South Pass Block 27
Southeast Pass
Southeast Pass & S. Pass Blk. 6
Southwest Lisbon
Starks
Sulphur Mines
Ten Mile Bayou
Tepetate
Timbalier Bay
Valentine
Vatican
Venice
Ville Platte
West Bay
West Cote Blanche Bay
West Delta Block 83
West Delta Block 84
West Hackberry
West Lake Verret
West Lisbon
West Tepetate
West White Lake
White Castle

fields, all but one are in south Louisiana and Hunt has one in Olla field in LaSalle Parish. Not all of these projects are presently active. A list of the projects along with company ownerships and permit application dates is given in Table 4.

C.F. Industries (now operating as Cherokee Associates) of Baton Rouge, Louisiana, has provided and transported CO_2 in liquid form to eight of the 23 projects. C.F. Industries has two CO_2 plants in Louisiana. These two facilities recover CO_2 from flue gas and from other operations, such as ammonia. Cherokee Associates has operations close to Jackson Dome and owns part of the Choctaw pipeline. Liquid Carbonics company was listed as a commercial source of CO_2 for one of Chevron's projects in Timbalier Bay. For its project in Olla field, Hunt obtained CO_2 by unknown means from Black Lake field. Shell, for its project in Week's Island field, used CO_2 via pipeline from Jackson Dome.

Economic Screening

The proposed screening method considers the economic feasibility of the process. The economic screening was based on before-tax, present-worth benefit to cost ratio. The economic evaluation relied heavily on data and experience gained from similar projects. Data specific to the reservoir at hand was limited to initial oil in place, area, depth, number of wells, distance to the CO_2 source, and the ranking characteristic parameter calculated in the technical screening phase.

In determining the project's costs, it was assumed that the CO_2 project could take advantage of the existing infrastructure. It was also assumed that the operating cost is charged to the CO_2 project. This last assumption implies that production from the candidate reservoir is at or near the economic limit.

TABLE 4: CO_2 Projects Identified from Office of Conservation

Texaco:	Lake Barre (LB UP MS RD SU) - 3/84 West Cote Blanche Bay (W CBB 14 RBX SU) - 3/84 Bayou Sale (BS St. Mary RDS SU) - 3/84 Paradis (PAR Paradis'RTSU) - 3/84 Lafitte (LFT 8900 RMKA SU) - 5/84 Paradis (PAR LWR 9000 RM SU) - 1/80 Paradis (PAR 8 RA SU) - 1/80 Paradis (PAR 9500 RC7 SU) - 4/89 Paradis (16 SD RAB-1) - 2/89 Paradis (PAR PZ RU SU) - 5/90 Paradis (PAR 10000 RU SU) - 5/90
ARCO:	Jeanerette (JEN Q RA VU) - 7/84 Jeanerette (JEN UR RA VU) - 7/84
Shell:	White Castle (WC MW RA SU) - 3/86 Weeks Island (R RA SU) - 9/86 Weeks Island (S RA SU) - 9/86
Chevron:	Timbalier Bay (TB 4900 RBASU) - 1/87, [currently owned by Greenhill Petroleum] Quarantine Bay (QB 4 RC SU) - 8/81 Timbalier Bay (TB S-2B RA SU) - 9/83, [currently owned by Greenhill Petroleum] Bay Marchand Blk 2 (2500' A - 7/90 Bay Marchand Blk 2 (3150'-3200' A) - 7/90 Bay Marchand Blk 2 (3400' RB) - 3/91
Hunt	Olla (OL 2800 Wilcox RA SU) - 10/82

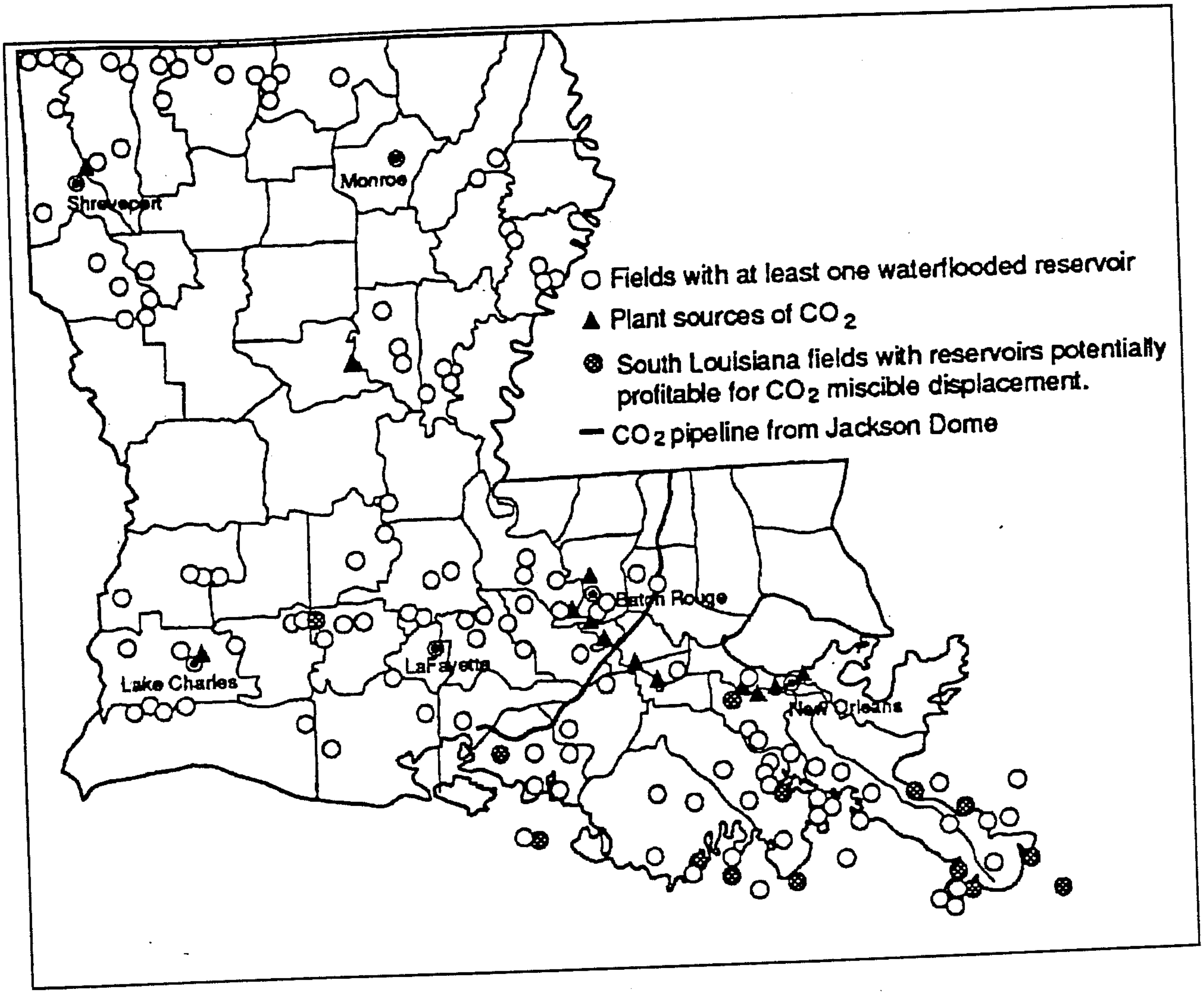

Figure 1. Potential candidates for CO_2 miscible displacement in Louisiana

Production Schedule. Studies[33,39,59-62] of several field-scale CO_2 projects concluded that vastly different projects exhibit similar production responses to CO_2. Based on these studies, the potential recovery of the CO_2 process when applied to an optimum reservoir is estimated to be 15% of the original oil in place, N. The potential recovery from the reservoirs in the database is obtained by multiplying 15% by the original oil in place, by the ranking parameter, R_i. This is expressed as:

$$N_{pi} = 0.15 * N * R_i \quad (5)$$

The potential recovery is produced according to the schedule shown in Figure 2. The expected life of the project is taken to be 15 years. The annual revenues are calculated using the schedule with the price of oil set at $17/STB.

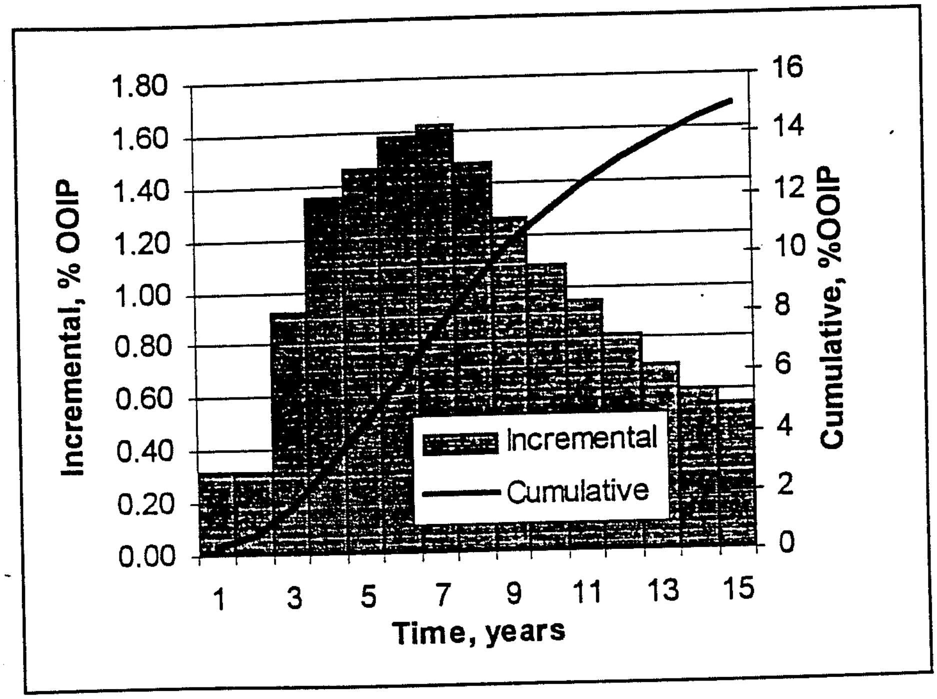

Figure 2. Typical production schedule for CO_2 miscible displacement

Capital Outlay. The capital needed to start a CO_2 project is field dependent. However, estimates using typical costs are acceptable for the purpose of screening. Capital outlay considered in this screening were of required new wells, pipeline to the CO_2 source, and injection and production equipment. Other equipment was assumed to be available as part of the existing infrastructure. Drilling and completion cost, c_d, was estimated using the following equation developed in a DOE study:[16,48]

$$\text{for onshore wells, } c_d = 30{,}430 * n * e^{0.00035D}, \tag{6}$$

$$\text{and for offshore wells, } c_d = 688{,}514 * n * e^{0.0001D} \tag{7}$$

where c_d is the drilling and completion cost, in U.S. dollars;

D is the formation depth in feet; and

n is the number of required new wells.

The number of required new wells depends on the optimum spacing and the number of active wells. It is estimated from:

$$n = \frac{A}{s} - n_a \tag{8}$$

where A is the reservoir area in acres;

n_a is the number of active wells, and

s is the optimum spacing.

For the purpose of screening s is assumed to be 40 acres for onshore reservoir and 80 acres for offshore reservoirs. The number of total wells, n_t, should not be less than two, an injector and a producer, or:

$$n_t = n + n_a \geq 2 \tag{9}$$

Injection and production equipment costs, c_{inj} and c_{pd} respectively, were estimated from the same DOE study using the equations:[16,48]

$$c_{inj} = 22{,}892 n_{inj} e^{0.00009D} \tag{10}$$

and

$$c_{pd} = 24{,}908 n_p e^{0.00014D} \tag{11}$$

where D is the formation depth in feet;

n_p is the number of producers; and

n_{inj} is the number of injection wells, which is taken to be half of the total number of wells.

CO_2 can be transported by tank truck, railcar, or pipeline. Transportation by pipeline is considered the least expensive of all these methods.[5] Depending on the pipeline pressure conditions, CO_2 can be transported either at subcritical or supercritical conditions or as a liquid. The supercritical CO_2 pipeline system is the most economical system for transporting the large quantities of CO_2 needed for enhanced oil recovery.[60] The following equation can be used to estimate the cost of pipeline:[16,48]

$$C_{pip} = (100{,}000 + 2{,}008\ q_{inj}^{0.834})\ d, \tag{12}$$

where C_{pip} is the pipeline cost in U.S. dollars;

d is the distance to the Shell pipeline, in miles; and

q_{inj} is the estimated CO_2 pipeline capacity, in MMSCF/D.

q_{inj} is estimated from the following correlation:[16,48]

$$q_{inj} = 2 * N_{pi} \tag{13}$$

where N_{pi} is the projected incremental oil in million STB estimated by Equation 5.

If more than one reservoir is located in the same field, the pipeline cost is shared. The pipeline capacity is calculated from Equation 13 using the incremental production from all the reservoirs to share the cost. The pipeline cost, c_{pip}, calculated from Equation 12 is then shared between the reservoirs on the basis of the individual incremental oil value.

All capital outlay is charged during the first year of the project.

CO_2 Cost. Published studies suggest that 6 MSCF per STB of incremental oil is a representative average value of CO_2 utilization.[59,61] The purchase of CO_2 is a major expense for miscible projects, especially if CO_2 is obtained from industrial sources. The CO_2 cost for the purpose of this screening was based on availability from natural sources via the Shell pipeline. The CO_2 cost was estimated at $0.60/MSCF and remained constant throughout the injection period. The CO_2 project was not burdened with separation and recycling costs. It is assumed that the value of produced natural gas would offset the cost of CO_2/natural gas separation.

Operating Costs. Operating costs are site and operator specific. The average annual operating cost, c_{op}, in U.S. dollars, however, can be predicted from the following equation:[13,54]

$$c_{op} = 13{,}298 n_t e^{0.0001D} \tag{14}$$

It is assumed that all wells will require future workovers at an average of 0.25 workovers per well per year.[60] The cost of a workover is estimated to be half the cost of the equipment. The annual workover cost, c_{wo}, can then be determined using the following equation:

$$c_{wo} = 0.25\left(\frac{n_t}{2}\right)\ (c_{inj} + c_{pd}), \qquad (15)$$

where c_{inj} and c_{pd} are expressed by equations 10 and 11, respectively.

Both the technical and economic screening algorithms were written in FORTRAN™ code. The economic screening may also be run on an electronic spreadsheet. The FORTRAN™ code and a user manual are in Appendix B.

Louisiana Waterflooded Reservoirs Database

The approach described in this paper was used to screen waterflooded reservoirs in Louisiana. These reservoirs are listed in a database available from the Louisiana Office of Conservation and Reserves. Initially, the database listed 499 reservoirs that were waterflooded. These reservoirs represented a total initial-oil-in-place of 5.289 billion STB, or an average of 10.6 million STB/reservoir.

Many reservoirs were eliminated in the initial stage of screening for various reasons. Because of the high cost of transporting CO_2, all of the 101 reservoirs located in North Louisiana were eliminated. An additional 188 reservoirs, mostly inactives were eliminated because current saturation and pressure data, two key screening parameters were unavailable. Inconsistent data also led us to eliminate 13 reservoirs, leaving 197 reservoirs for screening and ranking. A listing of these 197 reservoirs together with available data are given in Appendix C.

Screening Results

Table 5 lists Louisiana fields with reservoirs in the top 100 technical rank. Table 6 lists the 50 top economically ranked reservoirs and their relevant data. The reservoirs are ranked based on present worth benefit to cost ratio. The economic evaluation considered shared pipeline cost.

As expected, the final ranking did not correlate with the technical ranking parameter, R_i. Under the conditions established for the model, the majority of possible candidates are not economically suitable for CO_2 miscible displacement. Only 12% of the reservoirs in the database look economically attractive. Nevertheless, the potential incremental oil from these reservoirs is a significant 72.6 MMSTB of oil.

The validity of the screening approach is demonstrated by the fact that current CO_2 projects contained in the database are highly ranked. Texaco's Paradise Field projects in the Lower 9000 Sand and Main Pay RT-SU are ranked first and fifth respectively. Shell's project is the South Pass Block 27 field, "N46" RC SU, is ranked thirteenth. These cases were considered technically and economically feasible by the operator prior to the implementation of the process.

The process economics is dependent on are well spacing, oil price, CO_2 price, and discount rate. A sensitivity analysis was conducted. A summary of this analysis is given in Table 7.

TABLE 5: Fields with Reservoirs in Top 100 Technical Rank

Bay Marchand Block 2
Black Bayou
Bully Camp
Burrwood
Caillou Island
Clovelly
Dave Haas
Delta Duck Club
Dog Lake
Eugene Island Block 18
Frisco
Garden City
Garden Island Bay
Grand Bay
Hurricane Creek
Lake Barre
Lake Hatch
Leeville
Little Lake
Livingston
Livonia
Lockhart Crossing
Main Pass Block 69
Manila Village
Plumb Bob
Port Barre
Quarantine Bay
South Pass Block 24
South Pass Block 27
Southeast Pass
Tepetate
Timbalier Bay
Valentine
Vatican
Ville Platte
West Bay
West Cote Blanche
West Delta Block 83
West White Lake

TABLE 6. Potentially Profitable Reservoirs for CO_2 Miscible Displacement in Louisiana

Base case: 197 reservoirs with complete information

Prospect Identification			Reservoir Parameters				Screening Parameters								Tech.	Economic Parameters			Rank
Operator	Field	Reservoir	Depth Feet	EOOIP MMBbl	Recov. MMBbl	Area Acres	API	Temp o F	Perm, K, md	So %	P/MMP	Poros. %	H oil Feet	dip o	Rank	Wells Now	New Wells	Shared Dist, ml	40/80 15 %
Texaco	Paradise	Lower 9000 Sand RM	10450	13.5	1.7	235	35.7	193	515	62.0	0.909	28.8	45	8	85.04	6	0	1.0	1.14
Hassie	South Pass Block 24	8800' RD	8295	36.7	3.1	960	30.0	178	447	61.0	0.341	26.0	39	3	55.79	12	0	11.6	1.04
Shell	South Pass Block 27	"N1b" Reservoir F Sand unit	7300	3.7	0.2	70	28.0	165	537	43.5	0.478	30.0	35	7	42.99	1	0	1.4	0.96
Shell	Eugene Island Block 18	"O" Sand	10071	35.6	4.1	273	38.5	151	1000	31.3	1.866	32.0	80	4	76.50	3	0	59.0	0.95
Texaco	Paradise	Main Pay RT SU	10300	11.7	1.3	114	36.8	205	1910	51.7	0.752	27.5	51	10	74.25	2	1	1.0	0.93
Shell	South Pass Block 27	"M" RB SU	7500	7.4	0.7	150	32.4	178	200	47.5	0.465	30.0	40	9	60.03	3	0	3.9	0.89
Shell	South Pass Block 27	"N1b" Reservoir C Sand Unit	7450	9.2	0.6	211	32.0	168	300	22.9	0.616	33.0	28	5	44.22	3	0	3.5	0.82
Texaco	Caillou Island	Upper 8000 RA SU	7900	6.4	0.6	182	38.2	103	285	17.1	1.484	31.0	25	18	58.62	2	0	6.0	0.76
Shell	South Pass Block 27	"N1a" Reservoir C Sand unit	7350	14.4	1.1	328	32.0	168	300	36.9	0.340	33.0	27	5	49.67	6	0	6.2	0.72
Gulf	West Bay	Proposed WB6B (RG) Sand Unit	7419	49.7	3.6	530	31.3	80	470	38.4	1.306	32.6	41	5	48.52	5	2	29.9	0.71
Shell	South Pass Block 27	Proposed SPB 27 K RA SU	6200	4.1	0.3	174	27.5	160	500	54.4	0.484	28.0	17	10	48.61	2	0	1.7	0.69
Gulf	West Bay	5 A 'B"	7000	2.6	0.2	74.2	33.0	104	500	39.1	0.774	31.5	23	8	48.39	1	0	1.6	0.68
Shell	South Pass Block 27	"N4b" RC SU	7600	7.4	0.5	157	26.6	172	400	48.8	0.312	30.0	34	5	43.61	3	0	2.8	0.63
Shell	South Pass Block 27	"N1b" Reservoir D Sand Unit	7350	3.6	0.2	102	27.0	161	300	29.0	0.444	33.0	24	3	28.74	1	0	0.9	0.61
Shell	South Pass Block 24	Reservoir A, "Q" Sand	8125	17.0	1.7	516	39.5	186	500	21.5	1.161	32.0	24	2	66.09	5	1	6.4	0.61
Shell	South Pass Block 27	"M2" Reservoir A Sand Unit	6775	39.0	3.4	691	29.5	162	400	57.4	0.574	33.0	39	3	58.15	6	3	19.7	0.58
Shell	South Pass Block 27	"M6" Reservoir A Sand Unit	6750	22.9	1.2	360	27.0	159	600	33.9	0.479	33.0	41	4	34.24	9	0	6.8	0.52
Shell	South Pass Block 27	"N1b" Reservoir B Sand Unit	7550	3.5	0.1	116	26.8	168	300	26.7	0.329	33.0	22	2	26.03	1	0	0.8	0.48
Shell	South Pass Block 24	RA P-Q Sand	7860	44.2	3.8	1574	35.0	167	300	24.3	0.555	30.0	15	2	57.34	18	2	14.3	0.46
Shell	South Pass Block 27	"N1b" Reservoir E Sand Unit	7000	25.3	1.5	434	26.0	160	500	44.8	0.279	33.0	33	3	40.31	3	2	8.9	0.31
Shell	South Pass Block 24	8000' RS SU (Horstal "S")	8150	14.6	1.1	577	32.0	176	500	42.2	0.362	29.0	24	3	52.39	11	0	4.3	0.27
Gulf	Quarantine Bay	9BC, C2	9430	3.1	0.3	90	35.9	200	200	32.0	0.946	28.0	20	2	60.63	1	0	6.4	0.26
Chevron	Bay Marchand Blk 2	3650' Upper Block D, 3650' (U)	3850	26.8	0.8	167	24.0	136	570	11.4	0.352	32.0	78	17	18.99	2	0	24.0	0.24
Chevron	South Pass Block 24	8200' "T" Sand	8294	84.3	6.4	1456	32.0	104	325	43.2	0.819	31.8	45	2	50.98	9	9	24.2	0.24
Shell	South Pass Block 24	Res. A "T1a" Sand	8700	12.3	0.7	374	30.0	175	300	32.3	0.725	32.0	23	2	39.59	7	0	2.8	0.21
Shell	South Pass Block 27	"N2" Reservoir B Sand Unit	7500	2.4	0.1	119	27.0	94	380	41.4	0.667	29.0	18	6	25.98	1	0	0.5	0.20
Shell	South Pass Block 27	"N4b" Sand Reservoir B	7850	10.9	0.4	302	24.2	168	400	22.7	0.237	31.0	35	3	24.22	4	0	2.3	0.20
Texaco	West Cote Blanche Bay	Lower No. 11 Sand, Reservoir N3	8600	7.0	0.6	40	33.8	108	1200	36.4	1.495	33.0	84	27	59.13	1	1	1.2	0.14
Texaco	West Cote Blanche Bay	No. 17 Sand. Res. P-Q	7700	4.7	0.5	75	33.1	116	400	44.1	1.314	28.0	42	20	66.76	0	1	0.9	0.12
Texaco	Paradise	Paradis Zone, Seg. A-B	10000	119.0	14.6	2057	38.0	200	1348	60.0	0.872	26.2	55	4	81.73	8	43	1.0	0.10
Chevron	South Pass Block 24	8600' RA Sand Unit	8721	85.3	7.0	1496	32.4	179	500	35.7	0.734	31.0	43	2	54.95	7	12	26.5	0.09
Shell	South Pass Block 27	"N1a" Reservoir E Sand Unit	7000	21.2	0.9	529	26.0	160	500	31.5	0.391	33.0	22	3	28.49	6	1	5.3	0.08
Gulf	Grand Bay	GB 10B (FBB) RA SU	7870	7.7	0.7	440	35.3	98	300	23.9	1.402	32.6	11	2	56.17	6	0	10.5	0.05
Gulf	West Bay	11 Sand Fault Block B	10850	26.2	2.4	436	30.0	136	500	47.3	1.163	30.0	55	3	60.26	2	3	19.7	0.05
Shell	South Pass Block 27	"N1c" Reservoir E Sand Unit	7000	10.5	0.4	347	26.0	160	200	22.3	0.451	33.0	23	3	23.00	5	0	2.1	0.05
Texaco	Caillou Island	9400 ft Sand, RBB1C	10000	23.3	2.3	427	39.0	138	1900	17.3	1.113	30.0	44	12	64.42	2	3	23.8	0.03
Shell	South Pass Block 27	SPB27 L4 RD SU	7430	2.2	0.1	120	32.0	93	300	43.9	0.569	32.0	16	8	43.09	2	0	0.8	0.02
Gulf	Quarantine Bay	8 Sand, Reservoir "B"	8950	17.0	1.3	303	34.5	112	1669	22.1	1.102	32.0	28	3	50.43	3	1	29.0	0.01
Shell	South Pass Block 27	"M2" Reservoir B Sand Unit	6280	8.9	0.3	142	25.0	155	500	14.4	0.463	33.0	32	4	23.60	5	0	1.8	0.00
Shell	South Pass Block 27	Reservoir "A" "L2" Sand Unit	6420	30.2	1.1	992	25.6	153	500	20.1	0.324	33.4	33	3	24.01	18	0	6.3	-0.04

TABLE 7: Summary of the Sensitivity Analysis for Ranking of Candidate Reservoirs for CO_2 Miscible Displacement in Louisiana

Parameter	Spacing, Onshore/Offshore				Discount Rate			Oil Price, $/Bbl			CO2 Price, $/Mcf		
	20/40	40/40	40/80	80/160	12%	15%	20%	15	17	20	0.6	0.8	1.0
Attractive Reservoirs	5	8	39	73	41	39	27	28	39	47	39	32	27
Potential Oil, MMBbls	6.9	24.5	70.6	110.4	74.6	70.6	39.7	40.3	70.6	86.3	70.6	63.3	39.6

Specific Reservoir Performance

The objective of reservoirs screening and ranking is to attract the attention of operators to the potential of the miscible CO_2 EOR process in their own waterflooded reservoirs. Once this is accomplished, it is presumed that the operator will be interested in the absolute performance of a specific reservoir as opposed to its ranking relative to other reservoirs in the database. A user-friendly numerical simulator allows the screening of different implementation options. The effects of reservoir heterogeneity and well locations, which were not included in the initial screening, can be considered. Additional parameters can also be included in the simulation. CO_2-PROPHET software is selected to perform this task.[56]

CO_2-PROPHET, a water-and gas-flood prediction software product, has been developed by Texaco with support of the U.S. Department of Energy. CO_2-PROPHET has been shown to be a good tool for screening and reservoir management and is being released with a detailed user manual to the industry. The hardware required to run CO_2-PROPHET are an Intel® 386-based PC or better with at least 4 megabytes of RAM and 4 megabytes of free disk space. A math co-processor is required for 386 or 486SX systems.[56]

CO_2-PROPHET runs on PC compatible computers. Some of its features include: easy reservoir parameter input; several predefined patterns to simplify use; the ability to design patterns to fit most situations; fast computation; multiple flood regimes that model water, gas and miscible floods; output in surface units and dimensionless formats; and output designed for importing data into a spreadsheet.[56]

CO_2-PROPHET computes streamlines between injection and production wells to form stream tubes. It then makes flow computations along the stream tubes. It uses the Dykstra-Parsons coefficient to distribute the initial injection into a maximum of ten layers. A new case can be set up and run in a few minutes, making this program ideal for screening of EOR projects and pattern comparisons.

The use of CO_2-PROPHET is demostrated in one of the top-ranked reservoirs, refered to as Eden. The Eden reservoir is located in a salt dome related structure. Its initial pressure in 1949, when commercial development was initiated, was 4500 psi. The reservoir had a large initial gas cap about 0.444 the size of the oil zone. The estimated original-oil-in-place was 11.7 million barrels of 35.2 API gravity oil. By 1972, the reservoir had produced 2.6 millions of barrels of oil, mostly due to gas cap expansion. In 1974, a waterflooding program was initiated to increase recovery. As of 1990, waterflooding resulted in the recovery of 4.3 millions barrels of oil.

The Eden reservoir was simulated using an option that allowes for the development of stream tube model which is stored for later investigation of implementation options. Figure 3 shows the stream tube model of the Eden reservoir and well locations. Table 8 lists the reservoir and simulation parameters for Eden. A summary of the main assumptions used in this study is presented in Table 9. Basically they consist of the limitations inherent in the model itself, the assumptions used for missing data, and economic assumptions necessary to evaluate the project.

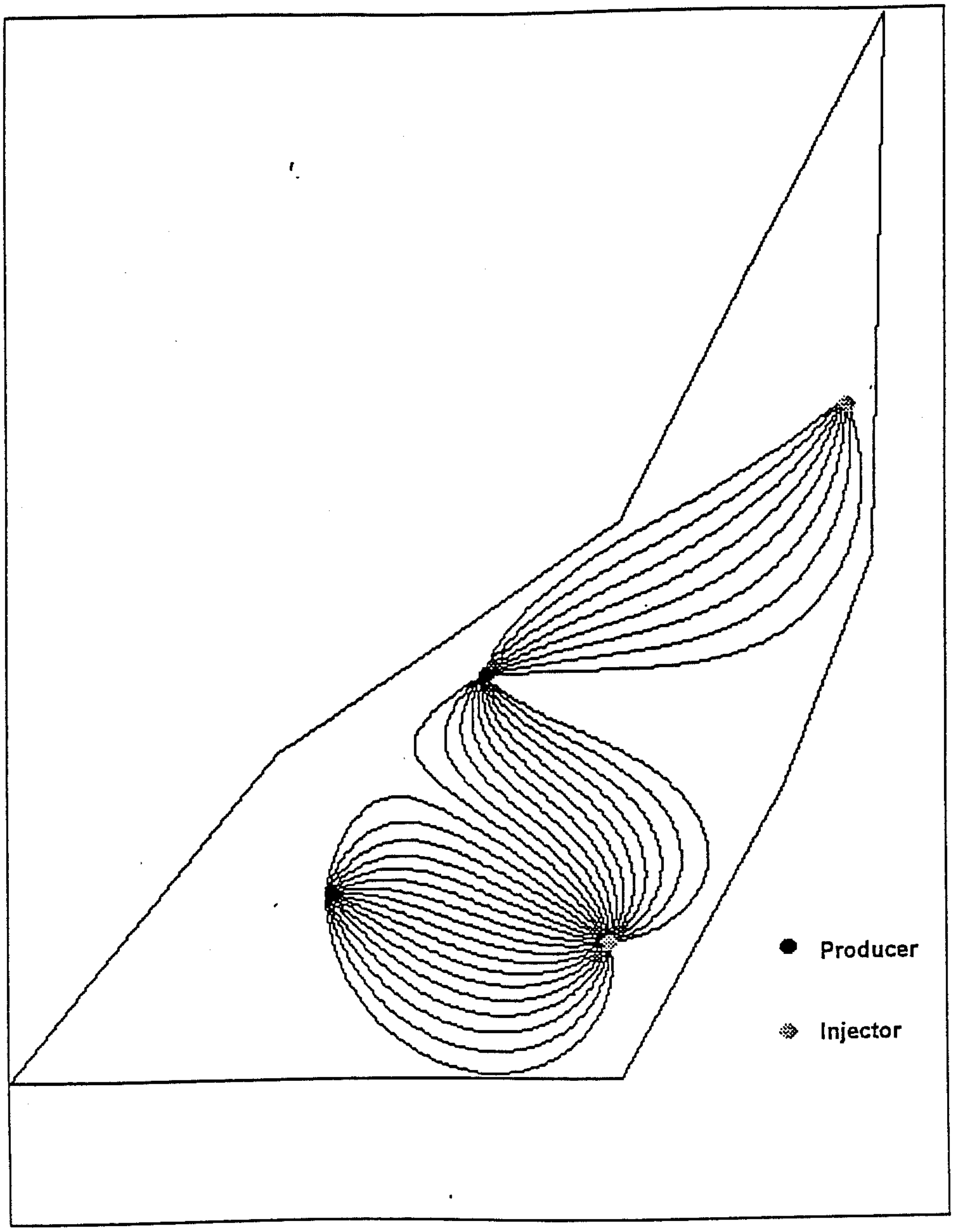

Figure 3. Streamline model for simulation of CO_2 miscible displacement at Eden reservoir.

TABLE 8: Reservoir and simulation parameters. Eden field

RESERVOIR PARAMETERS

OOIP, MMBls	11.723
Permeability, md	1910
Temperature, F	205
Dip angle, o	10
Gravity, API	35.2
MMP, psi	3500
Dykstra- Parsons	0.75
C5+ MW	230.3
Swc, %	14
Rs. scf/stb	900
Oil viscosity, cp	0.35
Bo, rb/stb	1.4
Gas gravity	0.7
Water viscosity, cp	0.8
Salinity, ppm	100000
Mixing Parameter	0.6666
Area, sf	3841632
Thickness, ft	139.5
Porosity, %	20
Kh/Kv	0.1

SIMULATION PARAMETERS RELATIVE PERMEABILITIES

Layers	3
Pattern	Custom
Krocw	1
Kwro	0.116
Krsmax	0.477
Krgcw	0.477
Nw	2
Now	2
Ns	2
Ng	2
Nog	2
Sorw	0.3
Sorg	0.3
Sorm	0.05
Sgr	0.3
Ssr	0.3

SIMULATION RUNS

WF & CO2 HYBRID

Pre- wf pres, psi	3335
Pre -wf So, %	0.517
Water inj, hcpv	0.7
CO2 slug, hcpv	0.125
WAG (CO2 hcpv)	0.3
WAG ratio (vol)	2
Chase water, hcpv	0.3
Qw inj. bpd/w	1000
QCO2, MMscf/d/w	6.2 & 8.0

WATERFLOODING

Pre- wf pres, psi	1484
Pre -wf So, %	0.517
Water inj, hcpv	1.25
Qw inj, bpd/well	1000

INITIAL CO2 HYBRID

Pre-co2 pres, psi	3335
Pre-co2 So, %	0.517

TABLE 9: Reservoir Assumptions for Paradis Main Pay RT-SU Reservoir.

MODEL ASSUMPTIONS	RESERVOIR ASSUMPTIONS	ECONOMIC ASSUMPTIONS
• Homogeneous formation • Dykstra Parsons = 0.7 • Kv/Kh = 0.1 • Mixing parameter = 0.6666 • Thickness & porosity adjusted to match estimated OOIP • No gravity effects.	• Relative permeability parameters. • Gas saturation negligible • Production & injection potentials constant. • No matching of previous performance attempted. • Initial conditions estimated from volumetrics. • Reservoir already pressured.	• Constant oil and CO_2 prices ($17 & $0.7). • Constant capital & operating costs. • Project's life 20 years • 100 % net revenue interest • Discount rate 12 %. • Gas severance tax 0.07 $/MCF • Oil severance tax 15 %

Two implementation options were investigated, waterflooding and waterflooding followed by hybrid CO_2 displacement. For the waterflooding option, the startup conditions were those existing in 1974 at the end of the primary recovery phase. A total of 1.25 pore volumes (P.V.) of water were injected in the waterflooding option.[63] The hybrid CO_2 process started after 0.7 P.V. of water was injected. The performances of the two options are compared in Table 10 and Figure 4.

Conclusions

A screening model was developed to rank a large number of potential reservoirs in a short period of time and with little effort. The model provides a rapid evaluation of both the technical and economic feasibility of the CO_2 miscible process. CO_2-PROPHET was found to be a user-friendly tool that can complement the screening model. CO_2-PROPHET can incorporate site-and operator-specific data that are not considered in the initial screening.

The results of this investigation are summarized in SPE 35431, a paper presented at the SPE Improved Oil Recovery Symposium held in Tulsa, OK, 21-24 April, 1996. A copy of the paper is appended.

TABLE 10: Comparison of Alternatives of Development for Eden Reservoir

ALTERNATIVE	WATERFLOOD	WATERFLOOD & CO_2 HYBRID
Total recovery time	27.1	36.9
HCPV injected	1.25	2.025
Recovery % OOIP	19.37	37.45
Oil recovery MMBls	2.27	4.39
HCPV injected at 20th year	0.92	1.03
Recovery at 20th year, %OOIP	17.75	26.96
NPV at 20th year, MM$	50.6	24.6
IRR	>1000	>1000
Benefit/Cost Ratio	12	17.43

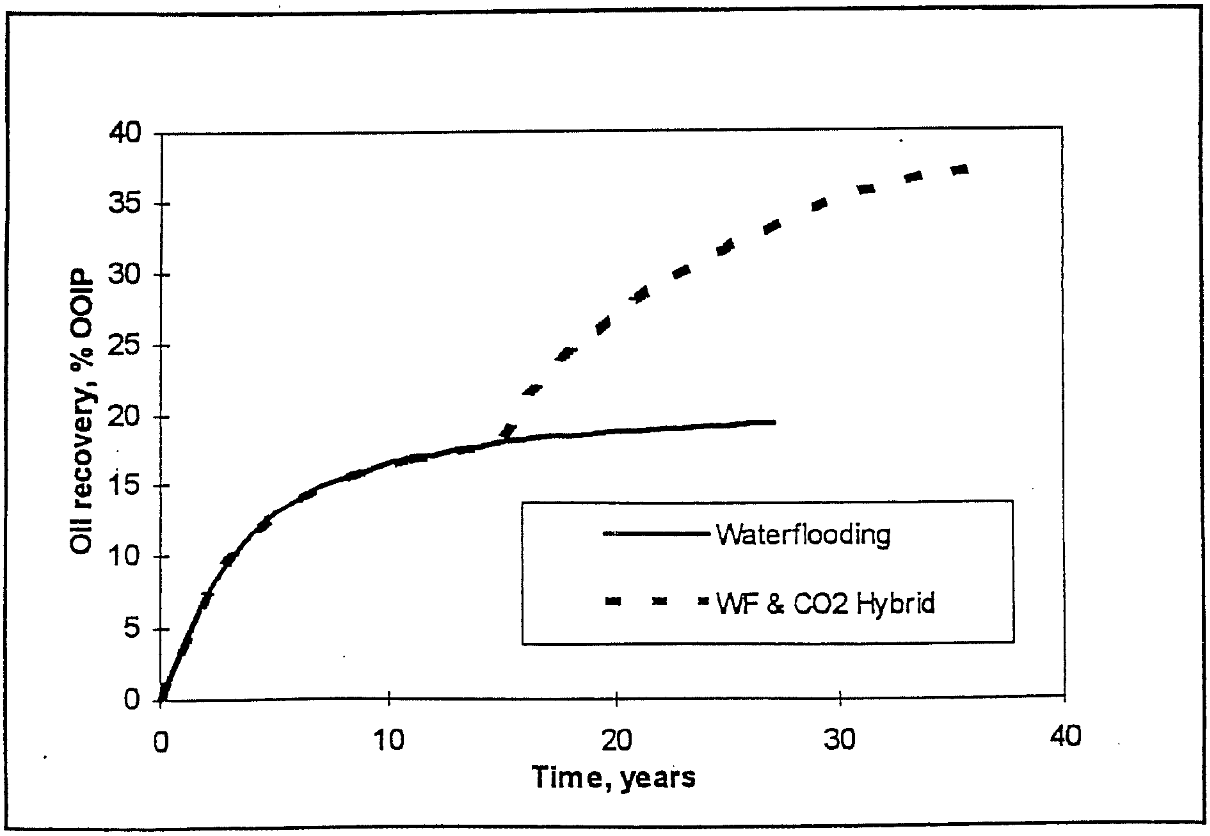

Figure 4. Comparison of alternatives of development for Eden reservoir

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APPENDIX A
CO_2 PROVIDERS IN LOUISIANA

AGRICO CHEMICAL COMPANY/FREEPORT-McMORAN
9959 La. 18
St. James, La. 70086
(504) 473-4271
Scott Shean
Chemicals manufactured: sulfuric acid, phosphoric acid, diammonium and monoammonium phosphates, urea.
Consumer uses: fertilizer.

AIR PRODUCTS AND CHEMICALS, INC.
14700 Intracoastal Drive
New Orleans, La. 70129
(504) 254-1590
William Greer
Chemicals Manufactured: Ammonia, carbon dioxide, hydrogen.
Consumer uses: fertilizer (urea products), dry ice, fuel for space shuttle program.

AMERICAN CYANAMID
10800 River Road
Westwego, La. 70094-2040
(504) 431-6436
Jim Dutcher
Chemicals Manufactured: acrylonitrile, aminonitrile, acrlamae, methylmethancralate, acetonitrile, melamine, sulfuric acid, ammonia.
Consumer uses: acrylite, synthetic fibers, ABS plastics.

AMPRO FERTILIZER INC.
P.O. Box 392
Donaldsonville, La. 70346
(504) 473-3976
Bobby K. Shackelford
Chemicals manufactured: anhydrous ammonia
Consumer uses: fertilizer

CF INDUSTRIES
P.O. Box 468
Donaldsonville, La. 70346
(504) 473-8291
Gene T. Lewis
Chemicals manufactured: ammonia, urea ammonia nitrate, urea.
Consumer uses: fertilizer.

DOW CHEMICAL USA
P.O. Box 150
Plaquemine, La. 70765-0150
(504) 389-8236
Chemicals manufactured: caustic, chlorine, chlor-alkali, cellulose, chlorinated methanes, chlorinated polyethylene/glycol ethers, glycol I and II, light hydrocarbon II and III, poly A & B, C, solvents/EDC, vinyl II (over 50 basic chemicals).
Consumer uses: soaps, bleaches, food additives, cosmetics, shampoos, pharmaceuticals, automotive hoses, roofing, brake fluid, antifreeze, adhesives, film, trash bags, Tupperware, pipe, diaper liners, wall paper, herbicides, aerosols, Teflon, solvents, silicones, detergents, milk carton coatings, Handi-wrap, Saran-wrap, ise bags, housewares, margarine tubs.

FARMLAND INDUSTRIES, INC.
P.O. Box 438
Pollock, La. 71467
(318) 765-3574
William White
Chemicals manufactured: anhydrous ammonia
Consumer uses: fertilizer

MONSANTO COMPANY
P.O. Box 174
Luling, La. 70070
(504) 785-3259
Tim Gustafson
Chemicals manufactured: ammonia, activated chlorine/cynauric (ACL/CYA), phosphorous trichloride (PCL3), disodiumiminodisidicacid (DSIDA), APAP (Acetaminophen), Glyphosate, herbicide.
Consumer uses: nylon, chlorine for swimming pools, bleaches, aspirin substitute, herbicides.

OCCIDENTAL CHEMICAL CORPORATION
7377 Hwy. 3214
Convent, La. 70723
(504) 562-9201
Chemicals manufactured: chlorine, caustic soda, ethylene dichlorides (EDC), hydrogen.
Consumer uses: PVC plastics - EDC, water purification, chlorine.

OLIN CORPORATION
P.O. Box 52137
Shreveport, La. 71135
(318) 797-2595
E.E. Warren
Chemicals manufactured: sulfuric acid.
Consumer uses: gasoline, paper, batteries, fertilizer, water purification.

PIONEER CHLOR ALKALI COMPANY INC.
P.O. Box 23
St. Gabriel, La. 70776
(504) 642-1882
Benny L. Bennett
Chemicals manufactured: chlorine, caustic, hydrogen.
Consumer uses: polyvinyl chloride, soap, bleach, pesticides, water treatment chemicals.

TRIAD CHEMICAL
P.O. Box 310
Donaldsonville, La. 70346
(504) 473-9231
Tomm Torr
Chemicals manufactured: ammonia, urea.
Consumer uses: fertilizers.

VULCAN CHEMICAL COMPANY
P.O. Box 227
Geismar, La. 70734
(504) 473-5003
John Waupsh
Chemicals manufactured: chlorine, caustic soda, methyl chloride, chloroform, carbon tetrachloride, perchloroethylene, EDC, methyl chloroform, muriatic acid, hydrogen.
Consumer uses: refrigerents, silicones, dry cleaning, equipment cleaning solvents, food industry (soda pop), pulp and paper.

CONVENT PLANT
Convent, La.

UNION CARBIDE CORP.
P.O. Box 50
Hahnville, La. 70057

INTERNATIONAL MINERALS & CHEMICAL CORP.
Sterlington, La. 71280

FORMOSA PLASTICS CORPORATION
P.O. Box 271
Baton Rouge, La. 70821
(504) 356-3341
Alden L. Andre
Chemicals manufactured: chlorine, caustic soda, ethylene dichlorides (EDC), vinyl chlorides monomer (VCM), polyvinyl chloride (PVC).
Consumer uses: PVC pipe, pool liners, pondliners, shower curtains, tablecloths, raincoats, book binders, air mattresses, waterbeds, etc.

PPG INDUSTRIES INC.
P.O. Box 15
Lake Charles, La. 70602
(318) 491-4500
Tom G. Brown
Chemicals manufactured: chlorine, caustic soda, vinyl chloride monomer, silicas products, chlorinated solvents.
Consumer uses: vinyl plastic, water treatment, paper, aluminum.

APPENDIX B

Screening Model for Application of Carbon Dioxide Miscible Displacement

- **User Manual**
- **Fortran™ Code**
- **Example Input File for the Screening Model**
- **Example Output File for the Screening Model**

CO29: RESERVOIR SCREENING MODEL FOR CO2 MISCIBLE DISPLACEMENT USER MANUAL

INTRODUCTION

The level of knowledge required to use this program is in the beginners to intermediate level. It demands to have basic knowledge about DOS™ particularly the Editor, some basics of FORTRAN™ and working experience with electronic spreadsheets such as MS EXCEL™ or QUATTRO PRO™.

COMPUTERIZED SCREENING MODEL

The computer program mentioned above was written in FORTRAN™, and is identified as CO29. The model screen technical and economic feasibility of a reservoir database for CO_2 miscible displacement. It basically consists of three files:

CO29.FOR: This is the source code file written in FORTRAN™ language. It is in ASCII format and contains the instructions given by the programmer. This file is known as the source code. In order to make changes in any part of the program, it has to be edited and compiled again.

CO29.OBJ: This is an intermediate file which is used in the preparation of the final executable program (CO29.EXE).

CO29.EXE: This is the program file itself. Just type CO29 and the program begins to work. (assuming required input file is complete and correct).

In order to use this program it is necessary for two data files to exist and be available for program's use in the same directory as CO29. EXE. These two are:

INPUTdb.DAT: Contains the input data for the program, it is prepared in an editor.

OUTPUTdb.DAT: Stores the results obtained from the program.

DATA FILES DESCRIPTION

The **first row** of INPUTdb.DAT file contains the values for the optimum reservoir.

The **second row** contains the values for the worst reservoir at the extreme right of optimum (upper limit), those values come from the database of reservoirs to rank.

The **third row** contains the weighting factor for each parameter.

The **fourth row** contains the values of expected recovery in terms of fraction of Original Oil in Place (OOIP) in a yearly basis for 15 years. It is used in estimating the expected yearly production.

The **fifth row** begins with the listing of reservoirs, first, the data for the ideal reservoir, followed by the listing of the candidate reservoirs to be ranked. It is important to preserve the order of the variables to be input, so the right values are used for each variable.

A description of the variables by columns, included from the fifth row to the end of the INPUTdb.DAT file.

First column: API gravity.

Second column: Temperature, in Fahrenheit degrees.

Third column: Permeability, in milidarcies.

Fourth column: Remaining Saturation of Oil, (as close as current situation as possible), in percentage.

Fifth column: Current pressure/ Minimum Miscibility Pressure ratio.

Sixth column: Porosity, in percentage.

Seventh column: Net oil thickness, in feet.

Eighth column: Dip.

Those are the variables used for the technical ranking. Immediately after the technical information, the economic variables appear as follows (in the case of the optimum reservoir fill these column with zeros):

Ninth column: Original Oil in Place, in Millions of Standard Tank Barrels.

Tenth column: Oil area, in acres.

Eleventh column: Number of active wells.

Twelfth column: Depth, in feet.

Thirteenth column: Distance to the CO_2 source in miles.

Fourteenth column: Location, put 0 for onshore reservoirs and 1 for offshore reservoirs. No specific format was used to read the INPUTdb.DAT file, because of this the order and completeness are critical. For most of the calculations, real numbers have been used, with significative figures depending on the magnitude of the variable. For guidance look at the example file attached.

The OUTPUTdb.DAT file contains the results from the model. It has three columns. The first one contains the technical ranking parameter, the second column shows the economic ranking parameter, and the third column contains the number of additional wells required to obtain the desired spacing.

RUNNING THE PROGRAM

To run the program, the user has to **open** the source code file (CO29.FOR), and input the number of reservoirs to be evaluated. In order to perform this step, the program has to be edited in the FORTRAN™ editor, DOS™ editor, or any other text editor for ASCII format. After the program is edited, go to line 5 and input the number of reservoirs to be ranked (including the optimum) plus

1, to make room for the worst reservoir parameters, which are found automatically by the computer from the data in the INPUTdb.DAT file.

Example: You want to rank 350 reservoirs, including the optimum reservoir will give 351 reservoirs, so you have to put N2=352. The number of reservoirs to be ranked, including the optimum plus the worst.

Line 5 originally: PARAMETER (M = 8, N2 = 199)

so changing 199 for 352 the line should read:

PARAMETER (M = 8, N2 = 352)

It is absolutely necessary for the INPUTdb.DAT to be complete. Once the program is run, it automatically calculates the technical ranking value. For the economic ranking part, the CO29 asks the user for the parameters used in the sensitivity analysis. These data are oil price, maximum recovery factor (15% is suggested), spacing, and CO_2 cost. Once those parameters are input in the model, it automatically calculates the correspondent economic ranking for each reservoir. At the end it asks if you want to run the program again with different values or exit.

HANDLING THE INPUTdb.DAT AND THE OUTPUTdb.DAT FILES

An easy way to prepare the input data necessary to run the program is to prepare the data in a spreadsheet, and then save it with the extension .txt. This file can be easily opened in dos™ and saved with the extension .dat.

In order to retrieve the results, the OUTPUTdb.DAT file can be saved with the extension TXT, using a conventional editor. Once in this format, the file can be imported into any spreadsheet, keeping the values in different columns. The economic part of the program can be easily programmed in a spreadsheet, and thus, sensitivity analysis results are directly accessible in the spreadsheet. Once the results are in spreadsheet form, it is possible to sort the reservoirs in order of suitability by simply using a sorting option from the spreadsheet program. Care should be taken to match the information and parameters from each reservoir with its correspondent ranking values.

ASSUMPTIONS AND LIMITATIONS OF THE ECONOMIC SCREENING

In order to rank the reservoirs, it is necessary to have a parameter that can be easily used for comparison of all of the possible candidates, and benefit/ cost ratio is suitable for this purpose. Due to the difficulty of predicting the expected performance of a reservoir without simulation, some assumptions are required to make the model work. The major assumptions are:

- The maximum expected recovery of the process is 15% of the OOIP.
- Economic evaluation uses an assumed interest rate. Evaluation considers that the project extends for only 15 years.
- Correlations used for the economic calculations of cost are estimates and depend on location.
- The desired spacing is used to calculate if additional wells need to be drilled. Spacing is a user set value which is dependent on factors such as reservoir heterogeneity, shape and size, dip, economics, and previous displacement efficiency.
- Operating costs are assumed constant, and are estimated on an annual basis.
- A gross CO_2 utilization ratio of 10 Mscf/ Bbl (6 Mscf/Bbl, net), and a value of 40% for the CO_2 recycling were used.
- The benefit-cost ratio used as an additional ranking parameter in the economic screening. It has to be higher than 0, to represent potential interest.

CO29.FOR

```
$DEBUG
* PROGRAM TO RANK RESERVOIRS FOR CO2 MISCIBLE DISPLACEMENT
      DIMENSION RES(550,14)
      INTEGER I,J,M,N1,K,N2
* "REMEMBER PUT RESERVOIR NUMBER (N1) PLUS ONE IN N2"
      PARAMETER (M = 8, N2 = 199)
      REAL OPTM(M),WRTL(M),WRTR(m),WFAC(m),WORST(m),
     & WT(m,n2),A(n2,m),X(n2,m),SUM3(n2),R(n2),NWELL(N2),
     & W(n2,m),V(n2,n2),TEMP,OPRIC,SPAC,SPACE,SPACE1,SPACE2,
     & NW(N2),COSNW,COSINJ,COSPROD,COSEQP,PIPCAP,COSPIP,COSWK,
     & OPCOS,CO2COS,TOTCOS,NREV,RATRC(n2),SMALL,PERCENT(15),
     & CO2,RF,IRATE,YEAR,BTNPV,PCOST,YREV,TWELL
      N1=N2-1
      OPEN (5,FILE='INPUTdb.DAT')
      READ (5,*) (OPTM(J),J=1,8)
      READ (5,*) (WRTR(J),J=1,8)
      READ (5,*) (WFAC(J),J=1,8)
      READ (5,*) (PERCENT(J),J=1,15)
      READ (5,*) ((RES(I,J),J=1,14),I=1,N1)
      CLOSE (5)
      OPEN (6,FILE='OUTPUTdb.DAT')
* CALCULATION OF WRTL & WORST FICTICIOUS RESERVOIR
      DO 7 J=1,8
      SMALL=1E20
      DO 8 I=2,N1
      SMALL=MIN(SMALL,RES(I,J))
 8     CONTINUE
      WRTL(J)=SMALL
      RES(N2,J)=SMALL
 7     CONTINUE
* SELECTION OF WORST PARAMETER
      DO 5,I=1,N2
      DO 10,J=1,8
      IF(RES(I,J) .GT. WRTR(J)) THEN
      RES(I,J)=WRTR(J)
      ELSE
      ENDIF
      IF(RES(I,J) .LE. OPTM(J)) THEN
       WORST(J)=WRTL(J)
      ELSE
       WORST(J)=WRTR(J)
```

```
      ENDIF
* CALCULATION OF NORMALIZED PARAMETER
      TEMP=ABS(WORST(J)-OPTM(J))
      X(I,J)=(ABS(RES(I,J)-OPTM(J))/ABS(WORST(J)-OPTM(J)))
* CALCULATION OF EXPONENTIAL FUNCTION
      A(I,J)=100*EXP(-4.6*(X(I,J)**2))
* CALCULATION OF THE WEIGTHED MATRIX
      W(I,J)=A(I,J)*WFAC(J)
 10   CONTINUE
 5    CONTINUE
* CALCULATION OF THE TRANSPOSED WEIGTHED MATRIX
      DO15,I=1,N2
      DO20,J=1,8
      WT(J,I)=W(I,J)
 20   CONTINUE
 15   CONTINUE
* CALCULATION OF THE PRODUCT MATRIX
      DO25,I=1,N2
      DO30,K=1,N2
      SUM1=0
      DO40,J=1,8
      SUM1=SUM1+W(I,J)*WT(J,K)
 40   CONTINUE
      V(I,K)=SUM1
 30   CONTINUE
 25   CONTINUE
* CALCULATION OF OPTIMUM CHARACTERISTIC PARAMETER
      I=1
      SUM2=0
      DO80,J=1,N2
      SUM2=SUM2+V(I,J)
 80   CONTINUE
      RO=SUM2
* CALCULATION OF THE CHARACTERISTIC PARAMETERS
      DO90,I=1,N2
      SUM3(I)=0
      DO100,J=1,N2
      SUM3(I)=SUM3(I)+V(I,J)
 100  CONTINUE
      R(I)=(100*SUM3(I))/RO
 90   CONTINUE
* END OF TECHNICAL RANKING - BEGINNING ECONOMIC RANKING
      PRINT *,'TECHNICAL SCREENING READY'
```

```
      PRINT *,'CONTINUE WITH ECONOMICAL SCREENING? YES=1, NO=0'
      READ *,EE
      IF (EE.EQ.0) THEN
      PRINT 1010,(R(I),I=1,N2)
      WRITE (6,1010)(R(I),I=1,N2)
      GO TO 120
      ELSE
      CONTINUE
      ENDIF
* ECONOMICAL EVALUATION
 105  PRINT *,'DISCOUNT RATE (fraction)=?'
      READ *,IRATE
      PRINT *,'OIL PRICE ($/Bbl)=?'
      READ *,OPRIC
      PRINT *,'RECOVERY FACTOR (fraction)=?'
      READ *,RF
      PRINT *,'SPACE ONSHORE (acres/well)=?'
      READ *,SPACE1
      PRINT *,'SPACE OFFSHORE (acres/well)=?'
      READ *,SPACE2
      PRINT *,'CO2 COST ($/MSCF)=?'
      READ *,CO2
* CAPITAL COSTS
* 1.DRILLING
      DO 110,I=2,N1
      IF (RES(I,14).EQ.0) THEN
      SPACE=SPACE1
      ENDIF
      IF (RES(I,14).EQ.1) THEN
      SPACE=SPACE2
      ENDIF
      IF (RES(I,11).NE.0) SPAC = (RES(I,10)/RES(I,11))
      IF (SPAC.LE.SPACE) THEN
      NW(I)=0
      ELSE
      ENDIF
      TWELL=(RES(I,10)/SPACE)
      IF (RES(I,11).GE.TWELL)THEN
      NW(I)=0
      ELSE
      NW(I)=TWELL-RES(I,11)
      ENDIF
      IF (RES(I,10).LE.60.AND.RES(I,11).EQ.0) THEN
```

```
      NW(I)=2
      ELSE
      ENDIF
      IF (RES(I,10).LE.60.AND.RES(I,11).EQ.1) THEN
      NW(I)=1
      ENDIF
      IF (RES(I,10).LE.60.AND.RES(I,11).EQ.2) THEN
      NW(I)=0
      ENDIF
      NWELL(I) = NINT(NW(I))
      IF (RES(I,14).EQ.0) THEN
      COSNW=30430*EXP(0.00035*RES(I,12))*NWELL(I)
      ENDIF
      IF (RES(I,14).EQ.1) THEN
      COSNW=688514*EXP(0.00011*RES(I,12))*NWELL(I)
      ENDIF
* 2.EQUIPMENT
      COSINJ=22892*EXP(0.00009*RES(I,12))
      COSPROD=24908*EXP(0.00014*RES(I,12))
      COSEQP=((COSINJ+COSPROD)/2)*(RES(I,11)+NWELL(I))
* 3.PIPELINE
      PIPCAP=(RES(I,9)*R(I)*RF/100)*2
      COSPIP=(100000+2008*((PIPCAP)**0.834))*RES(I,13)
*     PRINT *,COSEQP,COSPIP,COSNW
* 4.TIME DEPENDENT ECONOMICS
      PCOST = 0
      YEAR = 0
      SUM5 = 0
      DO 125 J=1,15
      YEAR =YEAR+1
* 4.1 YEARLY OIL RECOVERY
      YREC= RES(I,9)*R(I)*1.0E04*PERCENT(J)
* 4.2 OPERATION COSTS
      OPCOS=13298*EXP(0.00011*RES(I,12))*(RES(I,11)+NWELL(I))
* 4.3 CO2 PURCHASE COSTS
      CO2COS=YREC*6*CO2
* 4,4 WORKOVER COST
      COSWK=0.25*COSEQP
* 4.5 YEARLY GROSS REVENUE
      YREV=(YREC*OPRIC)/((1+IRATE)**YEAR)
* 4.6 NPV OF TIME DEPENDENT COSTS
      SUM4=(OPCOS+CO2COS+COSWK)/((1+IRATE)**YEAR)
* 4.7 BEFORE TAXES NPV OF NET INCOME
```

```
      SUM5=YREV+SUM5
      PCOST=PCOST+SUM4
 125  CONTINUE
      BTNPV=SUM5-PCOST
* 5 TOTAL COSTS
      TOTCOS=COSNW+COSEQP+COSPIP+PCOST
* 6 NET REVENUE
      NREV=BTNPV-COSNW-COSEQP-COSPIP
* 7 BENEFIT/COST RATIO
      RATRC(I)=NREV/TOTCOS
 110  CONTINUE
      PRINT 1000,(R(J),RATRC(J),NWELL(J),J=1,N2)
      WRITE (6,1000)(R(J),RATRC(J),NWELL(J),J=1,N2)
      PRINT *,'CHANGE ECONOMICAL PARAMETERS? YES=1, NO=0'
      READ *,EC
      IF (EC.EQ.1) THEN
      GO TO 105
      ELSE
      CONTINUE
      ENDIF
 1000 FORMAT (1X,F6.2,2X,F6.3,2X,F4.0)
 1010 FORMAT (1X,F6.2)
 120  END
```

INPUTDB.DAT

37	160	300	60	1.3	20	50	20							
70	250	2500	92	1.3	33	180	20							
0.24	0.14	0.07	0.2	0.19	0.02	0.1	0.03							
0.0032	0.0032	0.0092	0.0136	0.0146	0.0158	0.0162	0.0147	0.0126	0.0108	0.0094	0.0082	0.0070	0.0060	0.0055
37	160	300	60	1.3	20	50	20	0	0	0	0	0	0	
24.0	136	570.0	11.43	0.352	32.0	78	16.5	26.795	167	2	3850	24.0	1	
35.5	155	362.0	16.51	0.389	29.7	28	16.0	6.371	168	0	5132	17.0	1	
37.0	158	330.0	25.29	0.436	33.0	32	20.0	13.966	390	1	5500	41.0	1	
29.5	100	2500.0	64.17	0.393	29.0	28	6.0	2.200	47	1	8200	3.6	1	
29.5	101	2300.0	16.16	0.449	28.0	31	6.0	2.300	45	1	8067	1.4	1	
32.5	246	292.0	41.38	0.725	28.2	62	14.0	30.604	386	3	13000	53.0	1	
35.0	167	200.0	68.79	0.376	33.0	73	60.0	0.900	9	0	6400	8.1	0	
37.0	174	350.0	80.79	0.103	33.0	45	45.0	1.250	14	0	7800	9.6	0	
36.7	175	1000.0	81.99	0.495	30.0	105	60.0	1.180	8	0	7200	8.6	0	
36.0	171	200.0	64.20	0.591	33.0	83	60.0	1.800	16	0	6600	18.2	0	
40.6	160	200.0	78.26	0.235	32.0	60	40.0	0.315	4	0	6680	2.4	0	
37.5	180	200.0	48.15	0.197	30.0	85	55.0	6.300	61	0	7600	58.1	0	
34.7	206	111.0	34.47	1.247	24.5	40	30.0	17.436	473	3	10150	32.0	0	
36.1	213	100.0	44.86	0.629	28.0	29	4.5	47.000	1865	6	10000	79.0	1	
39.0	138	1900.0	17.31	1.113	30.0	44	12.0	23.310	427	2	10000	23.8	1	
36.6	162	500.0	36.69	0.692	25.2	40	8.0	35.266	1109	0	12400	41.2	1	
38.2	103	285.0	17.14	1.484	31.0	25	18.0	6.420	182	2	7900	6.0	1	
28.0	218	200.0	55.42	0.566	20.0	26	16.0	2.174	122	0	11389	5.7	0	
31.6	155	317.4	16.50	1.231	23.0	42	12.5	6.272	124	2	12700	23.9	0	
32.2	160	317.4	50.50	1.303	23.0	50	19.0	7.071	97	2	12200	39.4	0	
34.5	113	59.4	21.30	0.428	21.3	11	3.0	5.040	660	7	7500	7.9	0	
45.6	127	196.9	52.90	2.267	21.2	69	3.0	21.550	830	5	8500	69.1	0	
31.8	164	633.0	43.90	0.285	27.6	14	2.0	9.609	545	3	6365	80.5	0	
26.7	168	588.0	38.29	0.415	28.8	44	5.0	8.590	144	1	6350	49.5	0	
34.3	80	2295.0	39.04	1.471	32.9	113	45.0	3.888	19	2	4700	51.0	0	
28.0	200	500.0	34.49	0.653	30.5	8	5.0	2.952	286	0	10000	32.0	1	
38.5	151	1000.0	31.27	1.866	32.0	80	4.0	35.600	273	3	10071	59.0	1	
38.0	231	17.0	52.48	0.339	17.6	28	2.0	23.718	1883	14	11213	18.0	0	
35.0	255.5	180.0	69.96	0.533	22.0	36	5.0	13.017	473	0	13650	4.0	0	
37.5	170.5	751.0	50.10	0.491	30.5	74	15.0	5.105	54	1	8382	100.1	1	
26.0	140	915.0	33.69	0.147	30.0	17	20.0	0.938	46	0	6246	5.5	1	

30.5	162	1287.0	33.31	0.643	31.9	35	30.0	1.707	28	0	6600	17.3	1
32.0	142	250.0	25.62	0.113	29.7	48	31.0	1.481	20	0	4100	15.0	1
35.0	177	300.0	20.97	0.755	33.0	28	3.0	16.800	384	2	7850	23.9	1
36.4	206	484.0	44.53	0.794	27.6	35	2.0	27.256	788	7	10400	46.7	1
37.4	195	382.0	53.86	1.060	28.0	10	2.5	9.165	861	3	9860	18.7	1
30.1	83	250.0	40.94	0.893	29.1	10	2.0	9.023	661	5	6610	7.9	1
33.0	165	250.0	39.27	0.619	29.8	11	2.7	6.682	476	1	7150	9.4	1
35.3	98	300.0	23.93	1.402	32.6	11	2.0	7.734	440	6	7870	10.5	1
30.4	196	300.0	47.74	0.645	23.1	10	3.8	4.399	468	2	9550	4.9	1
36.0	223	200.0	56.12	0.225	22.0	18	7.3	2.000	348	2	11147	8.0	0
48.0	190	73.0	54.89	0.516	28.0	17	5.0	30.000	2277	10	8100	99.0	0
32.0	189	333.0	72.22	0.538	20.0	11	14.0	3.511	306	0	10200	77.0	0
30.0	276	75.0	57.27	0.461	22.0	41	21.0	33.459	1059	0	15000	26.3	1
30.0	276	75.0	44.39	0.496	22.0	56	21.0	41.268	976	5	15000	26.5	1
33.0	168	305.0	29.06	0.750	27.2	63	24.0	12.762	151	0	12800	14.1	1
37.0	188	789.0	49.94	1.546	30.0	18	2.5	4.768	220	1	9850	32.0	0
38.0	153	155.0	54.81	1.089	25.7	99	15.0	7.646	77	1	12250	43.5	0
37.5	232	187.0	49.63	0.224	25.8	81	17.0	7.792	48	0	12650	31.5	0
35.0	201	420.8	24.60	1.533	25.7	28	2.4	26.405	998	3	10890	28.0	0
38.0	215	30.0	34.19	0.857	19.0	22	1.5	30.000	3124	18	9960	0.0	0
38.3	202	65.0	44.91	0.588	23.2	7	1.0	6.245	1266	0	9800	18.0	0
41.0	215	40.0	40.89	1.333	20.0	26	1.5	46.000	3398	0	10100	6.0	0
29.0	151	500.0	20.38	0.579	34.0	19	0.5	20.420	640	0	6640	51.0	1
31.0	101	1000.0	20.75	1.078	30.0	44	5.0	29.000	486	3	8100	48.0	1
33.0	94	500.0	56.65	0.741	30.0	15	2.0	5.850	277	0	7500	16.3	1
35.2	120	500.0	39.86	0.760	30.0	33	5.0	2.534	103	3	7730	7.5	1
28.0	170	500.0	31.06	0.548	32.5	16	4.0	10.030	465	7	7450	14.8	1
29.0	174	500.0	46.85	0.666	32.0	15	4.0	11.000	550	6	7900	24.5	1
36.0	182	300.0	35.05	0.469	32.0	15	4.0	9.203	397	4	8450	27.0	1
33.8	191	300.0	63.58	0.894	28.0	27	6.0	4.227	129	4	10630	32.0	0
47.4	80	591.0	14.85	4.587	28.0	6	1.6	2.129	387	5	9650	6.0	0
36.5	198	300.0	57.00	0.904	27.2	21	9.5	9.286	416	2	11425	1.0	0
35.7	193	515.0	62.00	0.909	28.8	45	8.0	13.453	235	6	10450	1.0	0
36.8	205	1910.0	51.70	0.752	27.5	51	10.0	11.723	114	2	10300	1.0	0
38.0	200	1348.0	60.00	0.872	26.2	55	4.0	119.02	2057	8	10000	1.0	0
33.5	181	200.0	62.76	0.892	31.3	9	5.0	11.547	1096	5	10000	59.0	0

28.1	142	300.0	48.42	0.642	26.0	22	26.0	1.794	69	0	9250	13.0	0
32.1	157	277.0	56.48	0.135	29.2	18	17.0	2.054	89	0	10200	21.0	0
39.0	123	1173.0	64.37	0.120	31.0	30	50.0	3.200	74	3	5886	41.0	0
33.2	80	220.0	50.75	1.999	27.4	25	4.0	17.256	635	1	8200	38.1	1
27.2	185	375.0	48.90	0.551	30.0	9	0.0	6.014	615	0	8540	8.4	1
34.5	112	1669.0	22.12	1.102	32.0	28	3.0	16.954	303	3	8950	29.0	1
34.7	190	500.0	22.12	0.565	30.0	13	3.0	2.941	179	0	9406	5.0	1
35.8	118	400.0	46.77	1.053	28.0	22	5.0	7.874	332	1	9450	20.1	1
35.9	200	200.0	31.95	0.946	28.0	20	2.0	3.100	90	1	9430	6.4	1
32.0	251	30.0	67.03	0.634	18.0	15	10.0	4.300	360	4	13250	32.0	0
47.0	83	400.0	29.04	3.805	29.0	20	5.0	1.575	100	3	10050	8.0	0
47.0	198	40.0	26.25	1.127	25.2	26	6.0	2.876	411	0	10225	24.0	0
32.0	104	325.0	43.20	0.819	31.8	45	2.0	84.298	1456	9	8294	24.2	1
30.3	177	500.0	43.19	0.638	27.8	36	3.0	44.700	1284	4	8472	12.6	1
32.4	179	500.0	35.66	0.734	31.0	43	1.7	85.250	1496	7	8721	26.5	1
29.4	164	338.0	38.77	0.437	29.8	18	4.0	26.546	1135	5	7275	6.1	1
33.0	180	100.0	45.32	0.492	29.5	14	3.0	19.227	1014	29	8600	6.1	1
30.0	178	447.0	61.02	0.341	26.0	39	3.0	36.700	960	12	8295	11.6	1
26.0	172	300.0	28.11	0.281	32.0	18	2.0	9.070	374	2	8020	1.3	1
28.9	167	400.0	22.58	0.662	32.0	23	7.0	37.500	1182	11	8725	6.8	1
32.0	182	200.0	40.87	0.746	31.0	6	2.5	4.700	702	0	8485	1.4	1
35.0	184	400.0	34.51	0.371	30.6	13	1.5	5.370	374	3	9025	1.8	1
36.0	184	400.0	15.26	0.744	31.0	20	1.5	12.700	528	3	9200	4.1	1
35.0	200	200.0	68.01	0.832	30.0	10	13.0	2.140	242	1	10150	0.8	1
39.0	186	200.0	27.46	0.649	30.0	30	5.0	4.100	330	0	9450	1.3	1
34.2	111	100.0	22.88	1.103	31.0	9	1.0	3.096	295	0	8900	0.8	1
32.0	176	500.0	42.19	0.362	29.0	24	3.0	14.600	577	11	8150	4.3	1
26.0	164	200.0	37.31	0.260	30.0	8	2.0	3.286	378	1	7350	0.6	1
30.0	89	200.0	38.31	0.579	29.0	6	1.4	2.500	333	4	7100	0.4	1
25.0	166	500.0	57.17	0.262	32.0	22	1.3	5.378	166	1	7750	1.4	1
25.0	153	200.0	27.95	0.277	34.0	15	1.0	19.250	870	10	6650	2.5	1
31.1	163	200.0	26.21	0.323	31.8	13	2.5	12.717	804	6	7550	2.6	1
35.0	167	300.0	24.26	0.555	30.0	15	1.5	44.159	1574	18	7860	14.3	1
30.0	106	300.0	19.98	0.382	32.0	43	2.0	27.800	460	18	8450	3.5	1
30.0	175	300.0	32.26	0.725	32.0	23	2.0	12.300	374	7	8700	2.8	1
39.5	186	500.0	21.46	1.161	32.0	24	2.0	17.000	516	5	8125	6.4	1

32.0	167	400.0	39.85	0.754	31.0	30	2.0	35.900	1028	3	9530	11.6	1
36.0	184	600.0	32.09	0.452	31.0	12	2.0	10.900	762	0	9050	3.6	1
33.0	187	200.0	38.91	0.409	30.7	13	2.0	9.365	714	2	8750	2.6	1
32.4	178	200.0	47.52	0.465	30.0	40	9.0	7.440	150	3	7500	3.9	1
32.8	175	500.0	36.18	0.328	32.0	24	5.5	1.380	37	3	7450	0.6	1
29.5	162	400.0	57.45	0.574	33.0	39	2.5	39.000	691	6	6775	19.7	1
25.0	155	500.0	14.43	0.463	33.0	32	4.0	8.860	142	5	6280	1.8	1
31.5	170	1000.0	31.59	0.401	32.0	26	7.0	6.079	170	1	7500	2.2	1
27.0	159	600.0	33.89	0.479	33.0	41	4.0	22.920	360	9	6750	6.8	1
26.8	168	300.0	48.84	0.521	33.0	19	1.5	10.720	359	0	7500	4.1	1
32.0	168	300.0	44.83	0.420	33.0	17	4.5	10.419	381	2	7400	5.1	1
27.0	161	300.0	26.33	0.490	32.9	10	2.5	3.706	273	3	7300	0.9	1
26.0	160	200.0	21.86	0.480	33.0	11	2.5	9.570	557	9	7000	1.9	1
27.0	165	550.0	50.19	0.407	31.0	26	7.0	2.755	65	0	7250	1.1	1
26.8	168	300.0	38.75	0.432	33.0	26	1.5	10.077	270	0	7520	3.1	1
32.0	168	300.0	36.93	0.340	33.0	27	4.5	14.387	328	6	7350	6.2	1
27.0	161	300.0	28.42	0.438	33.0	21	2.5	6.238	201	1	7450	1.5	1
26.0	160	500.0	31.54	0.391	33.0	22	2.5	21.170	529	6	7000	5.3	1
26.8	168	300.0	26.69	0.329	33.0	22	1.5	3.458	116	1	7550	0.8	1
32.0	168	300.0	22.94	0.616	33.0	28	4.5	9.173	211	3	7450	3.5	1
27.0	161	300.0	28.96	0.444	33.0	24	2.5	3.589	102	1	7350	0.9	1
28.0	165	537.0	43.45	0.478	30.0	35	7.0	3.692	70	1	7300	1.4	1
26.0	160	500.0	44.78	0.279	33.0	33	2.5	25.320	434	3	7000	8.9	1
26.0	160	200.0	22.28	0.451	33.0	23	2.5	10.480	347	5	7000	2.1	1
27.0	94	380.0	41.39	0.667	29.0	18	6.0	2.400	119	1	7500	0.5	1
27.0	171	144.0	45.92	0.188	29.0	12	8.0	0.879	69	0	7600	0.3	1
24.2	168	400.0	29.31	0.444	31.5	20	2.5	54.170	1765	14	7800	12.3	1
27.5	170	400.0	39.21	0.441	31.0	24	9.0	3.120	77	3	7700	1.0	1
36.0	190	700.0	39.55	0.699	31.0	26	7.5	8.433	208	1	8650	4.9	1
24.2	168	400.0	8.01	0.752	31.0	20	2.5	2.840	136	3	7800	0.6	1
24.2	168	400.0	23.11	0.511	32.0	28	2.5	16.610	466	3	7800	3.6	1
24.2	168	400.0	30.28	0.431	31.0	8	2.5	4.910	593	0	7875	1.1	1
26.6	172	400.0	48.83	0.312	30.0	34	5.0	7.444	157	3	7600	2.8	1
24.2	168	400.0	22.71	0.237	31.0	35	2.5	10.890	302	4	7850	2.3	1
26.8	168	300.0	39.07	0.405	33.0	12	1.5	5.236	367	1	7470	1.6	1
32.0	168	300.0	35.91	0.364	32.2	11	4.5	3.441	276	1	7550	1.4	1

27.0	161	300.0	34.66	0.361	31.7	10	2.5	5.132	393	0	7650	1.4	1
26.0	160	100.0	31.39	0.401	33.0	8	2.5	5.980	675	3	7000	1.3	1
35.0	188	700.0	62.31	0.104	32.0	17	7.5	3.614	134	0	8100	2.2	1
30.0	190	500.0	69.37	0.234	31.0	26	6.0	1.209	36	0	8650	0.4	1
35.0	191	500.0	51.47	0.731	31.0	16	6.0	1.903	102	0	8750	1.2	1
31.0	191	500.0	40.07	0.458	31.0	13	6.0	0.458	27	0	8750	0.2	1
32.0	177	300.0	44.85	0.696	30.0	25	7.5	0.985	53	2	8100	0.5	1
27.5	160	500.0	54.36	0.484	28.0	17	10.0	4.080	174	2	6200	1.7	1
27.5	160	500.0	24.51	0.765	32.0	13	6.0	1.038	54	2	6300	0.3	1
32.0	175	500.0	58.10	0.371	32.0	11	7.0	2.888	181	5	7530	1.6	1
31.0	191	500.0	53.06	0.656	31.0	11	10.0	0.228	18	0	8660	0.1	1
25.6	153	500.0	20.11	0.324	33.4	33	3.0	30.180	992	18	6420	6.3	1
29.0	165	500.0	54.06	0.418	33.0	7	7.5	1.152	120	1	7350	0.5	1
31.0	80	300.0	57.62	1.152	30.0	14	3.0	2.589	158	1	7200	1.3	1
32.0	93	300.0	43.91	0.569	32.0	16	7.5	2.240	120	2	7430	0.8	1
37.3	172	1329.0	60.93	0.598	30.2	15	2.7	11.596	541	5	7665	58.5	1
33.9	178	1368.0	38.84	0.791	29.6	34	3.5	22.404	430	4	8040	87.5	1
38.5	154	3485.0	49.72	0.671	31.6	18	5.0	47.848	1500	9	8300	37.0	0
32.1	211	180.0	31.33	0.980	25.5	39	8.0	2.412	60	0	11400	6.1	1
33.0	106	400.0	31.33	1.013	29.0	35	14.5	2.696	58	0	8450	7.7	1
32.5	112	245.0	46.87	0.678	28.0	38	12.0	20.175	501	1	8987	62.5	1
29.0	175	300.0	56.01	0.272	26.0	30	10.0	1.604	41	0	6850	4.7	1
37.0	104	39.6	61.97	0.583	30.9	25	33.0	4.169	112	0	8300	25.9	0
39.5	103	373.0	53.04	0.485	32.9	30	33.0	3.948	80	0	8276	25.1	0
37.0	205	316.0	34.76	0.758	28.0	7	4.0	3.170	429	5	10800	38.7	0
32.0	185	66.0	64.47	0.389	23.2	10	5.0	2.420	224	2	8030	21.3	0
32.3	185	66.0	62.72	0.666	24.6	7	5.0	1.430	168	1	8000	13.9	0
37.4	185	38.0	57.13	0.731	28.5	5	5.0	2.516	448	2	7833	31.8	0
30.0	136	500.0	47.26	1.163	30.0	55	3.0	26.200	436	2	10850	19.7	1
30.0	80	100.0	56.45	0.620	32.4	14	6.0	2.629	153	1	6300	1.3	1
36.9	166	500.0	39.93	0.256	32.9	29	9.0	1.203	29	1	7270	1.1	1
33.0	104	500.0	39.07	0.774	31.5	23	8.0	2.592	74	1	7000	1.6	1
34.0	115	228.0	54.48	0.789	28.4	23	3.2	29.041	1032	0	9235	24.1	1
35.0	182	380.0	82.00	0.590	30.6	12	1.4	18.689	1461	0	9100	12.7	1
31.3	80	470.0	38.43	1.306	32.6	41	4.5	49.700	530	5	7419	29.9	1
30.0	80	500.0	32.21	1.054	34.0	14	3.0	12.800	547	2	6180	5.2	1

33.4	101	500.0	57.94	0.465	30.0	52	4.6	4.439	59	0	8070	3.4	1
31.2	212	579.0	60.80	0.816	29.9	11	4.3	1.867	141	0	10280	1.3	1
27.2	206	594.0	29.74	0.722	30.8	21	4.1	18.269	683	0	10473	5.0	1
27.8	212	719.0	59.11	0.211	29.7	14	3.6	13.110	724	1	10289	6.0	1
28.4	208	636.0	48.51	0.156	30.6	13	3.3	3.672	225	1	10393	1.5	1
28.5	192	1180.0	60.80	0.665	29.1	21	3.3	13.280	466	5	9490	7.5	1
28.0	207	400.0	57.66	0.426	28.0	16	6.0	2.542	131	0	9841	1.3	1
30.0	220	400.0	35.41	0.509	29.0	25	5.0	9.034	290	2	9133	3.2	1
31.8	170	500.0	35.41	0.987	33.0	30	4.3	1.875	40	0	7100	1.3	1
33.3	128	600.0	56.22	0.354	30.4	16	23.0	1.447	57	0	8500	0.3	1
33.8	108	1200.0	36.45	1.495	33.0	84	27.0	6.960	40	1	8600	1.2	1
30.9	126	1058.0	58.07	0.827	29.0	31	31.0	2.232	54	0	8400	0.4	1
32.0	128	305.0	40.09	0.671	29.0	78	20.0	4.433	27	0	8500	0.7	1
33.1	116	400.0	44.10	1.314	28.0	42	20.0	4.651	75	0	7700	0.9	1
30.3	180	64.0	44.10	0.186	25.0	24	22.0	3.932	146	0	12011	0.5	1
32.0	124	360.0	40.09	1.326	26.0	39	16.0	0.894	19	0	8278	0.2	1
35.5	196	200.0	40.44	0.611	28.0	20	2.0	60.505	2417	0	10100	83.0	1
27.4	154	212.0	46.37	0.335	29.6	43	64.0	2.208	36	0	6500	23.3	0
28.1	176	800.0	29.00	0.303	28.4	100	55.0	10.982	87	0	7875	75.7	0
37.0	160	200.0	59.00	0.458	26.0	7	5.0	13.380	3040	12	7050	24.3	1
37.0	160	200.0	46.87	0.548	26.0	7	5.0	13.380	3040	23	7050	22.7	1
30.0	109	200.0	16.78	0.286	30.0	175	53.0	0.500	2	0	5000	8.0	0

OUTPUTDB.DAT

100.00	.000	0.
18.99	.830	0.
57.16	-.046	2.
62.80	.000	4.
35.34	-.623	1.
13.45	-.829	1.
49.04	.211	2.
72.81	-.556	2.
62.45	-.595	2.
59.28	-.585	2.
82.01	-.374	2.
62.52	-.814	2.
74.86	-.211	2.
62.66	-.243	9.
61.75	-.314	17.
64.42	.521	3.
73.43	-.341	14.
58.62	1.593	0.
37.46	-.839	3.
53.86	-.362	1.
79.11	.253	0.
37.73	-.752	10.
77.31	-.157	16.
53.55	-.556	11.
36.77	-.417	3.
58.15	-.477	0.
26.45	-.917	4.
76.50	1.867	0.
63.12	-.732	33.
56.46	-.805	12.
81.52	-.566	1.
24.26	-.917	2.
41.96	-.810	2.
42.10	-.792	2.
58.60	.255	3.
70.91	.367	3.
84.34	-.553	8.
36.22	-.427	3.
57.86	-.511	5.

56.17	.547	0.
46.34	-.743	4.
65.92	-.884	7.
58.14	-.577	47.
47.93	-.883	8.
40.74	-.690	13.
33.25	-.514	7.
56.94	.052	2.
85.71	-.494	5.
91.19	.064	1.
64.99	-.321	2.
61.32	-.528	22.
55.81	-.754	60.
62.56	-.880	32.
66.01	-.676	85.
29.43	-.581	8.
35.22	.014	3.
59.36	-.390	3.
63.15	.091	0.
30.97	.004	0.
47.13	-.032	1.
62.21	.081	1.
74.57	-.225	0.
42.22	-.864	5.
81.95	-.462	8.
85.04	2.148	0.
74.25	1.845	1.
81.73	.615	43.
73.46	-.712	22.
45.29	-.699	2.
64.18	-.657	2.
69.68	-.418	0.
65.17	-.243	7.
40.67	-.812	8.
50.43	.486	1.
49.90	-.622	2.
75.17	-.221	3.
60.63	.856	0.
43.20	-.895	5.
48.13	-.524	0.
48.14	-.891	10.
50.98	.821	9.
49.54	-.041	12.

54.95	.605	12.
40.30	-.280	9.
55.83	.134	0.
55.79	1.998	0.
24.80	-.564	3.
31.79	.061	4.
51.38	-.826	9.
57.67	-.321	2.
57.39	-.157	4.
67.93	-.651	2.
58.25	-.663	4.
47.59	-.774	4.
52.39	.862	0.
29.68	-.828	4.
26.83	-.324	0.
45.94	.195	1.
22.65	.067	1.
35.96	-.399	4.
57.34	1.143	2.
22.20	.083	0.
39.59	.785	0.
66.09	1.365	1.
57.22	-.044	10.
58.96	-.624	10.
49.45	-.619	7.
60.03	1.779	0.
51.41	-.137	0.
58.15	1.323	3.
23.60	.476	0.
41.57	.210	1.
34.24	1.239	0.
44.05	-.255	4.
56.22	.039	3.
27.08	.148	0.
22.46	-.095	0.
45.18	-.203	1.
35.06	-.258	3.
49.67	1.531	0.
28.14	-.460	2.
28.49	.583	1.
26.03	1.170	0.
44.22	1.678	0.
28.74	1.367	0.

42.99	1.883	0.
40.31	.922	2.
23.00	.536	0.
25.98	.770	0.
36.12	-.777	1.
26.02	-.186	8.
36.03	.209	0.
66.65	.258	2.
25.03	-.163	0.
24.76	-.280	3.
26.02	-.873	7.
43.61	1.390	0.
24.22	.770	0.
34.21	-.698	4.
47.87	-.495	2.
31.12	-.776	5.
24.04	-.803	5.
72.01	-.234	2.
41.66	-.840	2.
73.84	-.231	1.
41.36	-.939	2.
58.33	-.050	0.
48.61	1.483	0.
30.85	-.308	0.
62.53	.193	0.
54.23	-.960	2.
24.01	.417	0.
50.73	-.648	1.
56.99	-.190	1.
43.09	.494	0.
80.83	-.021	2.
62.46	.271	1.
76.76	.259	29.
43.93	-.775	2.
49.63	-.640	2.
54.06	-.243	5.
51.13	-.722	2.
67.79	-.327	3.
69.06	-.216	2.
60.14	-.846	6.
53.90	-.716	4.
59.58	-.728	3.
77.64	-.761	9.

60.26	.538	3.
38.90	-.365	1.
70.53	-.509	1.
48.39	1.463	0.
66.82	-.247	13.
54.49	-.674	18.
48.52	1.514	2.
32.60	-.417	5.
62.53	-.207	2.
54.37	-.739	2.
21.94	-.774	9.
36.86	-.699	8.
33.86	-.711	2.
45.59	.340	1.
39.69	-.728	2.
28.07	-.418	2.
56.74	-.621	2.
63.05	-.710	2.
59.13	.679	1.
56.78	-.600	2.
50.72	-.332	2.
66.76	.650	1.
41.01	-.656	2.
59.13	-.824	2.
61.23	-.436	30.
43.58	-.633	2.
28.43	-.558	2.
81.36	-.722	26.
75.68	-.628	15.
16.41	-.930	2.
1.01	.000	0.

List of the Ranked 197 Louisiana Waterflooded Reservoirs

APPENDIX C

Base Case: 197 reservoirs with complete information

operator	b-codes	field	reservoir	ID #	API	Temp (f)	Perm md	So %	P/MMP	poro. %	net pay feet	Dip deg	EOOIP MMBbl	area oil acres	wells present	depth feet	Dist miles
Chevron	B-0264	Bay Marchand Blk 2	3650' Upper Block D, 3650' (U) RD Sand	6	24	138	570.0	88	0.352	32.0	78	16.5	26.785	167	6	3850	87
Chevron	B-0406	Bay Marchand Blk 2	4400' "G"	7	35.5	155	362.0	65	0.389	29.7	28	18	6.371	168	0	5132	87
Chevron	B-0040	Bay Marchand Blk 2	4600 A-B Sand	8	37	158	330.0	43	0.436	33.0	32	20	13.968	390	10	5500	87
Chevron	B-0483	Bay Marchand Blk 2	8350 "NN"	11	29.5	100	2500.0	77.5	0.393	29.0	28	6	2.200	47	3	8200	87
Chevron	B-0484	Bay Marchand Blk 2	8400' "NN"	12	29.5	101	2300.0	77.5	0.449	28.0	31	6	2.300	45	2	8067	87
Texaco	B-0192	Bay St. Elaine	13600 - Ft. Sand, Seg. C & C-1	14	32.5	246	292.0	52	0.725	28.2	62	14	30.604	386	5	13000	61
Shell	B-0349	Black Bayou	"T" Sand Reservoir "M"	29	35	167	200.0	61	0.376	33.0	73	60	0.900	9	1	6400	105
Shell	B-0394	Black Bayou	"T" Sand	30	37	174	350.0	65	0.103	33.0	45	45	1.250	14	0	7800	105
Shell	B-0379	Black Bayou	"T" Sand Reservoir O	31	36.7	175	1000.0	65	0.495	30.0	105	60	1.180	8	0	7200	105
Shell	B-0350	Black Bayou	"T2" Sand, Reservoir "F"	32	36	171	200.0	57	0.591	33.0	83	65	1.800	16	1	6600	105
Shell	B-0439	Black Bayou	BB O RF SU	35	40.6	160	200.0	68.9	0.235	32.0	60	40	0.315	4	1	6680	105
Shell	B-0330	Black Bayou	Frio Sand, reservoir A	38	37.5	180	200.0	36	0.197	30.0	85	55	6.300	61	3	7600	105
Exxon	B-0409	Bully Camp	Textularia, RL	44	34.7	208	111.0	59	1.247	24.5	40	30	17.436	473	4	10150	61
Chevron	B-0265	Burrwood	"T" Res A	45	36.1	213	100.0	43	0.629	28.0	29	4.5	47.000	1865	16	10000	130
Texaco	B-0334	Caillou Island	9400 ft Sand, RBB1C	66	39	138	1900.0	17.3	1.113	30.0	44	12	23.310	427	2	10000	71
Texaco		Caillou Island	Caillou Island 53-C RA SU	68	36.8	162	200.0	36.69	0.692	25.2	40	8	35.266	1109	5	12400	71
Texaco	B-0308	Caillou Island	Upper 8000 RA SU	75	38.2	103	285.0	17.14	1.484	31.0	25	18	6.420	182	2-	7900	71
Superior	B-0149	Clovelly	No. 37 Sand Fault Block VII	84	28	218	200.0	50.4	0.566	20.0	26	16	2.174	122	1	11389	69
Superior Oil Co.	B-0059	Clovelly	No. 50 Sand, Fault Block VI	85	31.8	155	317.4	70.34	1.231	23.0	42	12.5	6.272	124	5	12700	69
Superior Oil Co.	B-0058	Clovelly	No. 50 Sand, Fault Block VII	88	32.2	160	317.4	59.7	1.303	23.0	50	19	7.071	97	2	12200	69
Atlantic Refinin	B-0060	Dave Haas	Sparta	92	34.5	113	59.4	37.5	0.428	21.3	11	3	5.040	660	4	7500	77
Atlantic Refinin	B-0003	Dave Haas	Wilcox Sand	93	45.6	127	196.9	49	2.267	21.2	69	3	21.550	830	11	8500	77
Texaco	B-0311	Delta Duck Club	Lower 6300' Sand, Seg A	97	31.8	164	633.0	46.9	0.285	27.6	14	2	9.609	545	5	6365	130
Texaco	B-0166	Delta Duck Club	Lower 6300' Sand, Seg. B	98	26.7	168	588.0	67.2	0.415	28.8	44	5	8.590	144	3	6350	130
Texaco	B-0220	Dog Lake	DGL CC RU SU (Revision)	109	34.3	80	2295.0	22.2	1.471	32.9	113	45	3.888	19	3	4700	53
Shell	B-0352	Eugene Island Block	P' RB SU	138	28	200	500.0	35.9	0.653	30.5	8	5	2.952	286	3	10000	32
Shell	B-0105	Eugene Island Block	"O" Sand	139	38.5	151	1000.0	82	1.866	32.0	80	4	35.600	273	7	10071	30
American Tradl	B-0491	Frisco	Upper Wilcox Zone Reservoir A	140	38	231	17.0	52	0.339	17.6	28	2	23.718	1883	14	11213	40
Quintana Petrol	B-0397	Garden City	13600' Operc. 9 Sand	141	35	255.5	180.0	70	0.533	22.0	36	5	13.017	473	5	13650	4
Texaco	B-0384	Garden Island Bay	189 RB SU	144	37.5	170.5	751.0	41.75	0.491	30.5	74	15	5.105	54	1	8382	138
Texaco	B-0445	Garden Island Bay	248-B Sand, Seg D-1	145	26	140	915.0	37.9	0.147	30.0	17	20	0.938	46	1	6246	138
Texaco	B-0382	Garden Island Bay	G-1 Sand, Seg C-2	151	30.5	162	1287.0	43.9	0.643	31.9	35	30	1.707	28	1	6600	138
Texaco	B-0446	Garden Island Bay	G-2 Sand, Segment H-4	152	32	142	250.0	41.5	0.113	29.7	48	31	1.481	20	0	4100	138
Gulf	B-0320	Grand Bay	10B Sand, Fault Block "A-1"	154	35	177	300.0	47	0.755	33.0	28	3	16.600	384	7	7850	122
Gulf	B-0078	Grand Bay	21 Sand, Fault Block "B"	156	36.4	206	484.0	64.6	0.794	27.6	35	2	27.258	788	23	10400	122
Gulf	B-0077	Grand Bay	31 Marker Sand, Fault Block "A"	157	37.4	195	382.0	62.4	1.06	28.0	10	2.3	9.165	861	14	9860	122
Gulf	B-0340	Grand Bay	4 sd. Fault Block "C"	158	30.1	83	250.0	59.4	0.893	29.1	10	2	9.023	661	6	6610	122
Gulf	B-0200	Grand Bay	6-B Sand, Fault Block "C", Res. "A"	159	33	165	250.0	47	0.619	29.8	11	2.7	6.682	476	5	7150	122
Gulf	B-0229	Grand Bay	GB 10B (FBB) RA SU	160	35.3	88	300.0	35.4	1.402	32.6	11	3.2	7.734	440	11	7870	122
Gulf	B-0341	Grand Bay	20 Sand , Fault Block "A"	161	30.4	196	300.0	55.3	0.645	23.1	10	3.8	4.399	468	5	9550	122
Concord Operat	B-0507	Hester	D3 RC SU	171	36	223	200.0	43	0.225	22.0	18	7.3	2.000	348	2	11147	22
Socony Mobil O	B-0108	Hurricane Creek	Doombos Sand	173	48	190	73.0	40	0.516	28.0	17	5	30.000	2277	17	8100	99
Texaco	B-0499	Lafitte	Lwr. St. Dennis Sd., Seg H	180	32	189	333.0	0.48	0.538	0.2	11	14	3.511	306	6	10200	77
Texaco	B-0126	Lake Barre	LB LM1 SU	181	30	278	75.0	68	0.461	22.0	41	21	33.459	1059	9	15000	67
Texaco	B-0127	Lake Barre	LB LM2 SU	182	30	276	75.0	64	0.496	22.0	58	21	41.268	976	13	15000	67
Texaco		Lake Barre	Unit B Upper M-1 Sand	193	33	168	305.0	79	0.75	27.2	63	23	12.762	151	3	12800	67
Union	B-0230	Lake Hatch	9850 ft	201	37	188	789.0	75	1.546	30.0	18	2.5	4.768	220	3	9850	38
Texaco	B-0413	Leeville	95 Sand, Seg B	219	38	153	155.0	57.2	1.089	25.7	99	15	7.646	77	4	12250	75
Texaco	B-0414	Leeville	96 Sand, Seg B	221	37.5	232	187.0	50.2	0.224	25.8	81	17	7.792	48	6	12650	75
Humble	B-0083	Little Lake	E-4 Sand, Res. A	226	35	201	420.8	72	1.533	25.7	28	3	26.405	998	25	10890	65
Amoco	B-0480	Livingston	LVG WX 1 RA SU	231	38	215	30.0	43	0.857	19.0	22	1.5	30.000	3124	18	8960	0
Sun	B-0236	Livonia	Cockfield	232	38.3	202	65.0	53.9	0.588	23.2	7	1	6.245	1268	12	9800	37

Amoco	B-0475	Lockhart Crossing	LKHT 1 st WX RA SU	233	41	215	40.0	53	1.333	20.0	26	1.5	48.000	3398	29	10100	6
Shell	B-0323	Main Pass Block 35	"G2" Reservoir A Sand Unit	236	29	151	500.0	47	0.579	34.0	19	0.5	20.420	640	16	6640	110
Chevron	B-0049	Main Pass Block 69	8150 B-C Sand	244	31	101	1000.0	48.9	1.078	30.0	44	5	29.000	486	22	8100	138.1
Chevron	B-0388	Main Pass Block 69	8400' Sand- Reservoir C	245	33	84	500.0	57	0.741	30.0	15	2	5.850	277	5	7500	138.1
Shell	B-0458	Main Pass Block 69	"bQ" Resrvoir A Sand Unit	246	35.2	120	200.0	38	76	30.0	33	5	2.534	103	3	7730	138.1
Shell	B-0084	Main Pass Block 69	Res. A, "Q" Sand	248	28	170	500.0	65	0.548	32.5	16	4	10.030	465	10	7450	138.1
Shell	B-0138	Main Pass Block 69	Reservoir B "Q2" Sand	249	29	174	500.0	65	0.666	32.0	15	4	11.000	550	9	7900	138.1
Shell	B-0472	Main Pass Block 69	T1 Reservoir B Sand Unit	250	36	182	200.0	35.05	0.469	32.0	15	4	9.203	397	6	8450	138.1
Louisiana Land	B-0506	Manila Village	29 Sand	252	33.8	191	300.0	75	4.587	28.0	27	6	4.227	129	3	10630	79
DeNovo Oil & G	B-0500	North Burtville	9650' Reservoir A	261	47.4	80	591.0	14.85	0.904	28.0	6	1.6	2.129	387	4	9650	10
Texaco		Paradis	10000 ft Sand, Reservoir M	274	36.5	211	300.0	73	0.909	27.2	21	9.5	9.288	416	12	11425	45
Texaco		Paradis	Lower 9000 Ft Sand RM	275	35.7	193	515.0	80.5	0.752	28.8	45	8	13.453	235	6	10450	45
Texaco		Paradis	Main Pay Sand, Seg. T	276	36.8	80	2440.0	51.7	0.872	27.5	74	10	11.040	114	3	10260	45
Texaco		Paradis	Paradis Zone, Seg A-B	277	38	185	1348.0	60	0.892	26.2	55	4	119.021	2057	60	10000	45
Charles B. Wrig	B-0371	Perry Point	Third Alliance (Miocene)	279	33.5	181	200.0	28	0.642	31.3	9	5	11.547	1096	21	10000	34
Texaco	B-0177	Plumb Bob	10300 ft Sd- Seg. D	283	28.1	142	300.0	73	0.135	26.0	22	26	1.794	69	1	9250	34
Texaco		Plumb Bob	10300' Sand R-I	284	32.1	157	277.0	45.7	0.12	29.2	18	17	2.054	89	2	10200	34
Energy Service	B-0343	Port Barre	Futral Sand, Res A	285	39	123	1173.0	64.37	1.999	31.0	30	50	3.200	74	3	5886	55
Gulf	B-0454	Quarantine Bay	3 sand, Reservoir B	291	33.2	80	220.0	51	0.551	27.4	25	4	17.256	635	5	8200	107
Gulf	B-0389	Quarantine Bay	5 Sand, (REF)	292	27.2	185	375.0	53	1.102	30.0	9	0	6.014	615	5	8540	107
Gulf	B-0178	Quarantine Bay	8 Sand, Reservoir "B"	293	34.5	112	1669.0	49.1	0.565	32.0	28	3	16.954	303	15	8950	107
Gulf		Quarantine Bay	8F Sand Fault Block "B"	294	34.7	190	500.0	70	1.053	30.0	13	3	2.941	179	5	9406	107
Gulf	B-0153	Quarantine Bay	9A Sand, Fault Block "C"	295	35.8	118	400.0	51.8	0.946	28.0	22	5	7.874	332	9	9450	107
Gulf	B-0390	Quarantine Bay	9BC, C2	296	35.9	200	200.0	48.1	0.634	28.0	20	2	3.100	80	2	9430	107
Amoco	B-0489	Section 28	2nd Hackberry-Reservoir D	310	32	251	30.0	45	3.805	18.0	15	10	4.300	360	3	13250	37
DeNovo Oil & G	B-0481	Siegen	NS-3	317	47	83	400.0	29.04	1.127	29.0	20	5	1.575	100	4	10050	12
Amoco		South Black Bayou	Camerina B	321	47	198	40.0	43	0.819	25.2	26	6	2.876	411	4	10225	109
Chevron	B-0030	South Pass Block 24	8200' "T" Sand	322	32	104	325.0	67.8	0.638	31.8	45	2	84.298	1456	21	8294	162
Chevron	B-0324	South Pass Block 24	8400 RA Sand Unit	323	30.3	177	500.0	34.1	0.734	27.8	36	3	44.700	1284	55	8472	162
Chevron	B-0246	South Pass Block 24	8600' RA Sand Unit	324	32.4	179	500.0	48	0.437	31.0	43	1.7	85.250	1496	49	8721	162
Gulf	B-0244	South Pass Block 24	4-Sand, Fault Block B	325	29.4	164	338.0	62	0.492	29.8	18	4	26.546	1135	28	7275	162
Gulf	B-0419	South Pass Block 24	8 Sand, Reservoir B	326	33	180	100.0	0.56	0.341	0.3	14	3	19.227	1014	22	8600	162
Hassie Hunt Tr	B-0247	South Pass Block 24	8800' RD	327	30	178	447.0	42.7	0.281	26.0	39	3	36.700	960	34	8295	162
Shell	B-0357	South Pass Block 24	"Q" RE SU	329	26	172	300.0	35	0.662	32.0	18	2	9.070	374	4	8020	162
Shell	B-0282	South Pass Block 24	"Q" Sand Reservoir "C"	330	28.9	167	400.0	47.6	0.746	32.0	23	7	37.500	1182	37	8725	162
Shell	B-0156	South Pass Block 24	"R2" Reservoir A Sand Unit	331	32	182	200.0	44	0.371	31.0	6	2.5	4.700	702	5	8485	162
Shell	B-0091	South Pass Block 24	"S" Sand (Proposed Unit "A")	332	35	184	400.0	62	0.744	30.6	13	1.5	5.370	374	7	9025	162
Shell	B-0092	South Pass Block 24	"T" Sand (Proposed Unit "A")	333	38	184	400.0	68.7	0.832	31.0	20	1.5	12.700	528	12	9200	162
Shell	B-0095	South Pass Block 24	"T1" Sand (Proposed Unit "B")	335	35	200	200.0	70	0.649	30.0	10	13	2.140	242	3	10150	162
Shell		South Pass Block 24	"T1" Sand, F-1 down.	336	39	188	200.0	27.46	1.103	30.0	30	5	4.100	330	6	9450	162
Shell	B-0180	South Pass Block 24	"T1a" Reservoir B Sand Unit	337	34.2	111	100.0	44	0.362	31.0	9	1	3.096	295	6	8900	162
Shell	B-0402	South Pass Block 24	8000' RS SU (Horstal "S")	338	32	176	500.0	46	0.26	29.0	24	3	14.600	577	11	8150	162
Shell	B-0400	South Pass Block 24	M7 RA SU	339	26	164	200.0	38	0.579	30.0	8	2	3.286	378	4	7350	162
Shell	B-0373	South Pass Block 24	N2 RA SU	340	30	89	200.0	49	0.262	29.0	6	1.4	2.500	333	1	7100	162
Shell	B-0401	South Pass Block 24	R RA SU	341	25	166	500.0	44	0.277	32.0	22	1.3	5.378	166	2	7750	162
Shell	B-0090	South Pass Block 24	RA "M2" SU	342	25	153	200.0	63	0.323	34.0	15	1	19.250	870	11	6650	162
Shell	B-0111	South Pass Block 24	RA "O2" Sand	343	31.1	163	200.0	51.5	0.555	31.8	13	2.5	12.717	804	13	7550	162
Shell	B-0112	South Pass Block 24	RA P-Q Sand	344	35	167	300.0	54.5	0.382	30.0	15	1.5	44.159	1574	27	7860	162
Shell		South Pass Block 24	Res. "C" "T" Sand	346	30	106	300.0	58.5	0.725	32.0	43	2	27.800	460	22	8450	162
Shell		South Pass Block 24	Res. A "T1a" Sand	347	30	175	300.0	60.7	1.161	32.0	23	2	12.300	374	9	8700	162
Shell	B-0097	South Pass Block 24	Reservoir A, "Q" Sand	348	39.5	188	500.0	67.8	0.754	32.0	24	2	17.000	516	9	8125	162
Shell	B-0096	South Pass Block 24	Reservoir A, "U2" Sand	349	32	167	400.0	72	0.452	31.0	30	2	35.900	1028	28	9530	162
Shell	B-0094	South Pass Block 24	Reservoir D, "T" Sand	350	36	184	600.0	42.7	0.409	31.0	12	2	10.900	762	5	9050	162
Shell	B-0141	South Pass Block 24	Rreservoir C "S" Sand	351	33	187	200.0	51.7	0.894	30.7	13	2	9.365	714	11	8750	162
Shell	B-0358	South Pass Block 27	"M" RB SU	353	32.4	178	200.0	65	0.465	30.0	40	9	7.440	150	3	7500	134
Shell	B-0449	South Pass Block 27	"M" Reservoir C Sand Unit	354	32.8	175	500.0	36.18	0.328	32.0	24	4	1.380	37	1	7450	134
Shell	B-0248	South Pass Block 27	"M2" Reservoir A Sand Unit	355	29.5	162	400.0	61	0.574	33.0	39	2.5	39.000	691	17	6775	134
Shell	B-0283	South Pass Block 27	"M2" Reservoir B Sand Unit	358	25	155	500.0	70	0.463	33.0	32	4	8.860	142	5	6280	134

Shell	B-0450	South Pass Block 27	"M2" Reservoir D Sand Unit	357	31.5	170	1000.0	31.59	0.401	32.0	26	7	6.079	170	4	7500	134
Shell	B-0284	South Pass Block 27	"M6" Reservoir A Sand Unit	358	27	159	600.0	59	0.479	33.0	41	4	22.920	360	12	6750	134
Shell	B-0181	South Pass Block 27	"N" Reservoir B Sand Unit	359	26.8	168	300.0	49	0.521	33.0	19	1.5	10.720	359	11	7500	134
Shell	B-0249	South Pass Block 27	"N" Reservoir C Sand Unit	360	32	168	300.0	51	0.42	33.0	17	4.5	10.419	381	9	7400	134
Shell	B-0250	South Pass Block 27	"N" Reservoir D Sand Unit	361	27	161	300.0	47	0.49	32.9	10	2.5	3.706	273	4	7300	134
Shell	B-0285	South Pass Block 27	"N" Reservoir E Sand Unit	362	26	160	200.0	56	0.48	33.0	11	2.5	9.570	557	8	7000	134
Shell	B-0432	South Pass Block 27	"N1a" Reservoir F sand unit	363	27	165	550.0	46	0.407	31.0	26	7	2.755	65	2	7250	134
Shell	B-0182	South Pass Block 27	"N1a" Reservoir B sand Unit	364	26.8	168	300.0	56	0.432	33.0	26	1.5	10.077	270	8	7520	134
Shell	B-0251	South Pass Block 27	"N1a" Reservoir C Sand unit	365	32	168	300.0	64	0.34	33.0	27	4.5	14.387	328	9	7350	134
Shell	B-0252	South Pass Block 27	"N1a" Reservoir D Sand Unit	366	27	161	300.0	51	0.438	33.0	21	2.5	6.238	201	4	7450	134
Shell	B-0286	South Pass Block 27	"N1a" Reservoir E Sand Unit	367	26	160	500.0	64	0.391	33.0	22	5	21.170	529	5	7000	134
Shell	B-0183	South Pass Block 27	"N1b" Reservoir B Sand Unit	368	26.8	168	300.0	27	0.329	33.0	22	1.5	3.458	116	2	7550	134
Shell	B-0253	South Pass Block 27	"N1b" Reservoir C Sand Unit	369	32	168	300.0	52	0.616	33.0	28	4.5	9.173	211	6	7450	134
Shell	B-0254	South Pass Block 27	"N1b" Reservoir D Sand Unit	370	27	161	300.0	57	0.444	33.0	24	2.5	3.589	102	2	7350	134
Shell	B-0433	South Pass Block 27	"N1b" Reservoir F Sand unit	371	28	165	537.0	46	0.478	30.0	35	7	3.692	70	2	7300	134
Shell	B-0287	South Pass Block 27	"N1b" Reservoir E Sand Unit	372	26	160	500.0	45	0.279	33.0	33	2.5	25.320	434	3	7000	134
Shell	B-0288	South Pass Block 27	"N1c" Reservoir E Sand Unit	373	26	160	200.0	44	0.451	33.0	23	2.5	10.480	347	4	7000	134
Shell	B-0403	South Pass Block 27	"N2" Reservoir B Sand Unit	375	27	94	380.0	46	0.667	29.0	18	6	2.400	119	4	7500	134
Shell	B-0435	South Pass Block 27	"N2" Reservoir C Sand unit	376	27	171	144.0	42	0.188	29.0	12	8	0.879	69	2	7600	134
Shell	B-0157	South Pass Block 27	"N4 " Sand, Reservoir "B"	377	24.2	168	400.0	62	0.444	31.5	20	2.5	54.170	1765	47	7800	134
Shell	B-0391	South Pass Block 27	"N4" Reservoir C Sand Unit	379	27.5	170	400.0	78	0.441	31.0	24	9	3.120	77	2	7700	134
Shell	B-0143	South Pass Block 27	"N4" Sand Unit Reservoir A	380	36	190	700.0	65	0.699	31.0	26	7.5	8.433	208	5	8650	134
Shell	B-0158	South Pass Block 27	"N4A" Sand Reservoir A	381	24.2	98	400.0	50.5	0.752	31.0	20	2.5	2.840	136	3	7800	134
Shell	B-0159	South Pass Block 27	"N4a" Sand Reservoir B	382	24.2	168	400.0	59.3	0.511	32.0	28	2.5	16.610	466	11	7800	134
Shell		South Pass Block 27	"N4a" Sand Resevoir A	383	24.2	168	400.0	56.8	0.431	31.0	8	2.5	4.910	593	5	7875	134
Shell	B-0346	South Pass Block 27	"N4b" RC SU	384	26.6	172	200.0	55	0.312	30.0	34	5	7.444	157	7	7600	134
Shell	B-0161	South Pass Block 27	"N4b" Sand Reservoir B	385	24.2	168	400.0	42.4	0.237	31.0	35	2.5	10.890	302	6	7850	134
Shell	B-0184	South Pass Block 27	"No" Reservoir B Sand Unit	386	26.8	168	300.0	39	0.405	33.0	12	1.5	5.236	367	4	7470	134
Shell	B-0256	South Pass Block 27	"No" Reservoir C Sand Unit	387	32	168	300.0	59	0.364	32.2	11	4.5	3.441	276	1	7550	134
Shell	B-0257	South Pass Block 27	"No" Reservoir D Sand Unit	388	27	161	300.0	50	0.361	31.7	10	2.5	5.132	393	8	7650	134
Shell	B-0289	South Pass Block 27	"No" Reservoir E Sand Unit	389	26	160	100.0	50	0.401	33.0	8	2.5	5.980	675	3	7000	134
Shell		South Pass Block 27	"No" sand Reservoir A	390	35	188	700.0	71	0.104	32.0	17	7.5	3.614	134	4	8100	134
Shell	B-0420	South Pass Block 27	Proposed "N2" RE SU	393	30	190	500.0	70	0.234	31.0	26	6	1.209	36	0	8650	134
Shell		South Pass Block 27	Proposed "N2" RG SU	394	35	191	500.0	48	0.731	31.0	16	6	1.903	102	1	8750	134
Shell	B-0422	South Pass Block 27	Proposed 'N4" RI SU	395	31	191	500.0	70	0.458	31.0	13	6	0.458	27	1	8750	134
Shell	B-0498	South Pass Block 27	Proposed 01 RH SU	396	32	177	300.0	44.85	0.696	30.0	25	7.5	0.985	53	1	8100	134
Shell	B-0436	South Pass Block 27	Proposed SPB 27 K RA SU	397	27.5	160	500.0	57	0.484	28.0	17	10	4.080	174	2	6200	134
Shell	B-0437	South Pass Block 27	Proposed SPB 27 K RB SU	398	27.5	160	500.0	43	0.765	32.0	13	6	1.038	54	1	6300	134
Shell	B-0434	South Pass Block 27	Proposed SPB 27 M RD SU	399	32	175	500.0	58.1	0.371	32.0	11	7	2.888	181	5	7530	134
Shell	B-0431	South Pass Block 27	Proposed SPB 27 N4 RD SU	400	31	191	500.0	46	0.656	31.0	11	10	0.228	18	1	8660	134
Shell	B-0115	South Pass Block 27	Reservoir "A" "L2" Sand Unit	401	25.6	153	200.0	60.4	0.324	33.4	33	3	30.180	992	25	6420	134
Shell	B-0496	South Pass Block 27	SPB27 L2 RC SU	402	29	165	500.0	42	0.418	33.0	7	7.5	1.152	120	3	7350	134
Shell	B-0504	South Pass Block 27	SPB27 L2 RE SU	403	31	80	300.0	57.62	1.152	30.0	14	3	2.589	158	3	7200	134
Shell	B-0497	South Pass Block 27	SPB27 L4 RD SU	404	32	93	300.0	35	0.569	32.0	16	7.5	2.240	120	2	7430	134
Exxon	B-0359	Southeast Pass	J-5 Sand RA	405	37.3	172	1329.0	70	0.598	30.2	15	2.7	11.596	541	9	7665	146
Humble	B-0098	Southeast Pass	K Sand, Reservoir C	406	33.9	178	1368.0	87	0.791	29.6	34	3.5	22.404	430	13	8040	146
Conoco	B-0212	Tepetate	Ortego "A"	416	38.5	154	3485.0	49.72	0.671	31.6	18	5	47.848	1500	12	8300	63
Gulf	B-0147	Timballer Bay	D-14 Sand, "G" Fault Block	418	32.1	211	180.0	54.8	0.98	25.5	39	8	2.412	60	3	11400	81
Gulf		Timballer Bay	D-3-4 Sand, Reservoir A	420	33	106	400.0	44	1.013	29.0	35	14.5	2.696	58	1	8450	81
Gulf	B-0325	Timballer Bay	D-5 Sand, Reservoir B	422	32.5	112	245.0	59.6	0.678	28.0	38	12	20.175	501	20	8987	81
Gulf	B-0378	Timballer Bay	S-1D Sand, Res BA	427	29	175	300.0	46.2	0.272	26.0	30	10	1.604	41	2	6850	81
General Americ	B-0117	Valentine	"N" Sand Reservoir A	430	37	104	39.6	50.3	0.583	30.9	25	33	4.169	112	3	8300	51
General Americ	B-0443	Valentine	Val "N" RC SU	431	39.5	103	373.0	40.9	0.485	32.9	30	33	3.848	80	1	8276	51
Texaco	B-0393	Vallcan	Bol Mex Reservoir B	432	37	205	316.0	45.1	0.758	28.0	7	4	3.170	429	4	10800	38.7
Conoco	B-0476	Ville Platte	Basal Cockfield RI	435	32	185	66.0	68	0.389	23.2	10	5	2.420	224	2	8030	67
Conoco	B-0469	Ville Platte	Basal Cockfield RD	436	32.3	185	66.0	69.3	0.666	24.6	7	5	1.430	168	1	8000	67
Conoco	B-0468	Ville Platte	Middle Cockfield RA	437	37.4	185	38.0	60.5	0.731	28.5	5	5	2.516	448	1	7833	67

Gulf		West Bay	11 Sand Fault Block B	439	30	136	500.0	70	1.163	30.0	55	3	26.200	436	19	10850	126
Gulf		West Bay	16A Marker Sand FB "J-D-D2" Proposed (RA) Sa	440	30	80	100.0	68	0.62	32.4	14	6	2.629	153	2	6300	126
Gulf	B-0466	West Bay	5 (RD) SU	441	36.9	166	500.0	40	0.256	32.9	29	9	1.203	29	1	7270	126
Gulf	B-0424	West Bay	5 A 'B"	442	33	104	500.0	40	0.774	31.5	23	8	2.592	74	3	7000	126
Gulf		West Bay	8 A Sand Fault Block A	445	34	115	228.0	72	0.789	28.4	23	3.2	29.041	1032	20	9235	126
Gulf	B-0262	West Bay	8 AL Sand	446	35	182	380.0	82	0.59	30.6	12	1.4	18.689	1461	26	9100	126
Gulf		West Bay	Proposed WB6B (RG) Sand Unit	449	31.3	80	470.0	58	1.306	32.6	41	4.5	49.700	530	21	7419	126
Gulf	B-0185	West Bay	WB 1 (FBA) SU	450	30	80	500.0	75	1.054	34.0	14	3	12.800	547	18	6180	126
Gulf		West Bay	WB 7 RD SU	453	33.4	101	500.0	37.9	0.465	30.0	52	4.6	4.439	59	3	8070	126
Pennzoil Producing Co		West Bay	X-11 Sand (Reservoir C)	454	31.2	212	579.0	51.7	0.816	29.9	11	4.3	1.867	141	2	10280	126
Pennzoil Produ	B-0186	West Bay	11 Sand (Reservoir A)	455	27.2	206	594.0	58.6	0.722	30.8	21	4.1	18.269	683	14	10473	126
Pennzoil Produ	B-0297	West Bay	X-11 (Reservoir A)	457	27.8	212	719.0	64	0.211	29.7	14	3.6	13.110	724	8	10289	126
Pennzoil Produ	B-0298	West Bay	X-11 (Reservoir B)	458	28.4	208	636.0	53.3	0.156	30.6	13	3.3	3.672	225	1	10393	126
Pennzoil Produ	B-0296	West Bay	X-9 A Sand (Reservoir A)	459	28.5	192	1180.0	69.4	0.665	29.1	21	3.3	13.280	466	9	9490	126
Gulf	B-0465	West Bay	10 Sand, Reservoir 'A'	460	28	207	200.0	48.04	0.426	28.0	16	6	2.542	131	5	9841	126
Gulf	B-0462	West Bay	9 Sand, Res 'A'	462	30	220	200.0	24.7	0.509	29.0	25	5	9.034	290	19	9133	126
Gulf		West Bay	WB 3A (FBB) S U	463	31.8	170	500.0	55	0.987	33.0	30	4.3	1.875	40	1	7100	126
Texaco	B-0427	West Cote Blanche B	8100' Sand, Res N, N3, N4	467	33.3	128	600.0	49.4	0.354	30.4	16	23	1.447	57	0	8500	4
Texaco	B-0301	West Cote Blanche B	Lower No. 11 Sand, Reservoir N3	468	33.8	108	1200.0	81	1.495	33.0	84	27	6.960	40	1	8600	4
Texaco		West Cote Blanche B	Lwr 8 R G-R	470	30.9	126	1058.0	43.1	0.827	29.0	31	31	2.232	54	11	8400	4
Texaco		West Cote Blanche B	No. 11 Sand, Seg Q-U	472	32	128	305.0	75	0.671	29.0	78	20	4.433	27	4	8500	4
Texaco	B-0195	West Cote Blanche B	No. 17 Sand. Res. P-Q	475	33.1	116	400.0	57	1.314	28.0	42	20	4.651	75	1	7700	4
Texaco		West Cote Blanche B	No. 38 Sand, Seg. E2	479	30.3	180	64.0	82	0.186	25.0	24	22	3.932	146	5	12011	4
Texaco		West Cote Blanche B	Upper 11 Sand, Reservoir C	483	32	124	360.0	60.2	1.326	26.0	39	16	0.894	19	1	8278	4
Chevron	B-0118	West Delta Block 83	10100' C Sand	487	35.5	196	200.0	62	0.611	28.0	20	2	60.505	2417	50	10100	130
Michel T. Halbo	B-0321	West Hackberry	2nd Cameron	490	27.4	154	212.0	71	0.335	29.6	43	64	2.208	36	1	6500	99
Pan American	B-0274	West Hackberry	Camerina C Sand - FB 5	491	28.1	176	800.0	74	0.303	28.4	100	55	10.982	87	8	7875	99
Amoco	B-0492	West White Lake	Big (3)-2, RE, RC	498	37	160	200.0	57	0.458	26.0	7	5	13.380	3040	39	7050	47
Amoco	B-0501	West White Lake	Big(3)-2 RE, RC	499	37	160	200.0	57	0.548	26.0	7	5	13.380	3040	39	7050	47
Shell	B-0485	White Castle	"O1" RF SU	500	30	109	200.0	65	0.286	30.0	175	53	0.500	2	1	5000	8

APPENDIX D

SPE 35431

Screening Criteria for Application of Carbon Dioxide Miscible Displacement in Waterflooded Reservoirs Containing Light Oil

Daniel Díaz, SPE, Zaki Bassiouni, SPE, William Kimbrell, SPE, and Joanne Wolcott, SPE,
Louisiana State University

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Abstract

In conjunction with a joint Texaco/DOE research project, the LSU Department of Petroleum Engineering developed an improved method of screening reservoirs for the application of the carbon dioxide miscible enhanced oil recovery (EOR) process. This method, which can be applied to a large number of reservoirs, considers both the technical and economic feasibility of the EOR process.

The technical parameters of each reservoir are first compared to those of an "ideal" reservoir; and from that comparison, each reservoir is assigned a technical ranking. The technical ranking is used to estimate expected recovery. Key technical parameters used in the screening process are remaining oil in place, minimum miscibility pressure, reservoir depth, oil API gravity, and formation dip angle.

The reservoirs are subsequently screened for economic feasibility based on standardized capital costs and operation expenses that are representative of the reservoirs under consideration. The reservoirs are finally ranked based on the present worth value of revenues to costs ratio.

Using this method, we screened a database containing 197 light-oil reservoirs in Louisiana. The database includes three reservoirs where CO_2 miscible floods are ongoing; these reservoirs ranked first, fifth, and thirtieth. The high ranking of these reservoirs, which were identified based on detailed and comprehensive reservoir studies, validates the screening method.

Different application options in a specific reservoir can be screened, if warranted, by using CO_2 -PROPHET, a PC compatible software. CO_2 -PROPHET is a relatively simple numerical model capable of simulating water and gas floods. An example of its application is included.

Introduction

In 1992, Texaco Exploration and Production Inc. (TEPI) and the U. S. Department of Energy (DOE) entered into a cost-sharing cooperative agreement to conduct an enhanced oil recovery demonstration at Port Neches field, Orange County, Texas. The agreement was formulated under the DOE Class I oil program, which encourages the development of innovative technical approaches to enhanced oil recovery. The innovative aspect of this project is the application of CO_2 miscible flooding in waterflooded light-oil fluvial-dominated reservoirs. TEPI agreed to disseminate the knowledge and the experience gained at Port Neches to other operators in the petroleum field.

Louisiana State University (LSU) has agreed to assist TEPI with technology transfer efforts. LSU's role was mainly to identify and rank waterflooded Louisiana reservoirs where the CO_2 EOR process may be used. To achieve this goal, LSU needed to develop a screening process that could be applied to reservoirs listed in the Louisiana Office of Conservation database. To be meaningful to interested operators, the screening method had to consider both the technical and economic feasibility of the EOR process. Because economic feasibility depends highly on CO_2 availability, identifying CO_2 sources and their distances to prospective reservoirs was imperative.

Once a prospect is identified, management options need to be considered. This task requires a user friendly numerical simulator. The effect of reservoir heterogeneity and well locations which is not considered in the initial screening can be investigated during the numerical simulations.

Screening for Technical Feasibility

Screening is usually performed following certain guidelines and criteria developed from laboratory tests and field experience. Screening methods include reservoir performance prediction, binary comparison, and parametric optimization. Reservoir performance prediction was excluded because of the relatively large number of reservoirs screened.

Binary comparison is easy to perform; it involves comparing a candidate reservoir's parameters against established ranges. The binary screening method does not, however, account for the synergistic effects of reservoir parameters. For example, with the binary comparison method, a reservoir that has properties marginally within the recommended ranges would be selected over a reservoir that has very good values of all properties except one.

We used a parametric optimization method developed by Rivas *et al.*[1] Their screening method is based on determining for each property (j) of the reservoir (i) being ranked a corresponding normalized parameter, $X_{i,j}$, defined by:

$$X_{i,j} = \frac{|P_{i,j} - P_{o,j}|}{|P_{w,j} - P_{o,j}|} \quad \text{.......... (1)}$$

where $P_{o,j}$ is the magnitude of the property (j) in a fictitious reservoir called the optimum reservoir, which gives the best response to CO_2 flooding. $P_{w,j}$, on the other hand, is the value of the property (j) in another fictitious reservoir, called the worst reservoir, which is not suited to CO_2 flooding. The variable $X_{i,j}$ varies linearly between 0 and 1.

Because an exponential function is more adequate than a linear function for comparing different elements within a set, the normalized linear parameter, $X_{i,j}$, is transformed to exponential varying parameter, $A_{i,j}$ using the following heuristic equation:[1]

$$A_{i,j} = 100\, e^{-4.6 X_{i,j}^2} \quad \text{.......... (2)}$$

$A_{i,j}$ ranges from a minimum of 1 to a maximum of 100.

To take into account the relative importance, or weight, of each reservoir parameter, a weighted grading matrix, $W_{i,j}$, is determined as follows:

$$W_{i,j} = A_{i,j} w_j, \quad \text{.......... (3)}$$

where w_j is the weight of property (j).

The reservoirs are then ranked using a ranking parameter, R_i, defined as:

$$R_i = 100 * \frac{\sum_{j=1}^{j} M_{i,j}}{\sum_{j=1}^{j} M_{1,j}}, \quad \text{.......... (4)}$$

where $M_{i,j}$ is the product of the weighted matrix $W_{i,j}$ by its transpose, $W_{j,i}$.

The parameters used in the parametric optimization screening are oil API gravity, reservoir temperature, saturation of oil before the process application, porosity, permeability, ratio of reservoir pressure to CO_2 minimum miscibility pressure, net pay oil thickness, and reservoir dip. Other important parameters such as oil viscosity, gas to oil ratio, and bubble-point pressure were excluded for simplicity purposes. These properties, however, correlate with oil gravity, which is included in the screening.

The properties of the optimum reservoir, $P_{o,j}$, used in equation 1 were obtained by performing numerical simulation on a base case to determine the set of parameters that optimized reservoir response to CO_2 flooding. The relative importance or weight of each parameter on process performance was determined from the average normalized slopes of the reservoir performance around the optimum value of the parameter.[1] Optimum reservoir parameters and weighting factors are given in Table 1.

The properties of the worst reservoir, $P_{w,j}$, are determined using the data of the reservoirs to be ranked. The value farthest away from the optimum is the worst value. It is conceivable to have two worst values, one lower and one higher than the optimum. Worst parameters of the reservoirs considered in this study are listed in Table 2.

CO_2 Sources and Providers in Louisiana

Critical to the economic feasibility of the process is the availability and location of CO_2 sources. A list of CO_2 industrial sources and providers was compiled through personal interviews and by reviewing a brochure published by the Louisiana Chemical Association.[2] Some potential commercial sources/providers of CO_2 were also identified from a computer database compiled by Louisiana State University.[3]

Naturally occurring CO_2 reservoirs are associated with the Jackson Dome geologic structure in Mississippi. Shell operates a pipeline that runs from Jackson Dome to Week's Island field. The pipeline has two sections: a 20 inch and a 10 inch. The 20-inch pipeline crosses from Mississippi into Louisiana in St. Helena Parish and continues across St. Helena, Livingston, East Baton Rouge, Ascension, and Iberville parishes. A site just northeast of Pierre Part serves as a pumping station where the 20-inch and 10-inch pipelines connect. The 10-inch pipeline crosses Assumption, St. Martin, St. Mary, and Iberia parishes, and terminates at Week's Island field. The last 16 miles of this pipeline were leased and are temporarily being used for hydrocarbon transportation. The remaining northern portion is still used to transport a small amount of CO_2 to Shell projects. The pipeline is available for tap-ins. Figure 1 shows fields with at least one waterflooded reservoir, plant sources of CO_2, and the location of the Shell pipeline.

Economic Screening

To be practical, the screening method considers the economic feasibility of the process. The economic screening was based on before-tax, present-worth, benefit-to-cost ratio. The economic evaluation relied heavily on data and experience gained from similar projects. Data specific to the reservoir at hand was limited to initial oil in place, area, depth, number of wells, distance to the CO_2 source, and the ranking characteristic parameter calculated in the technical screening phase.

In determining the project's cost, it was assumed that the CO_2 project could take advantage of the existing infrastructure. It was also assumed that the operating cost is charged to the CO_2 project. This last assumption implies that production from the candidate reservoir is at or near the economic limit.

Production Schedule. Recent studies[4,5] of many field-scale CO_2 projects concluded that vastly different projects exhibit similar production responses to CO_2. Based on these studies, the estimated potential recovery of the CO_2 process when applied to an optimum reservoir is 15% of the original oil in place, N. The potential recovery from the reservoirs in the database is obtained by multiplying the optimum recovery by the ranking parameter, R_i. This is expressed by:

$$N_{pi} = 0.15 * N * R_i \quad \text{.......... (5)}$$

The potential recovery is produced according to the schedule shown in Figure 2. The expected life of the project is 15 years. The annual revenues are calculated using the schedule with the price of oil set at $17/STB in the base case.

Capital Outlay. The capital needed to start a CO_2 project is field dependent. However, estimates using typical costs are acceptable for the purpose of screening. Capital outlay considered in this screening accounted for costs of new wells, pipeline to the CO_2 source, and injection and production equipment. Other equipment was assumed to be available as part of the existing infrastructure.

Drilling and completion cost, C_d, was estimated using the following equation developed in a DOE study:[6]

$$\text{for onshore wells, } C_d = 30{,}430 * n * e^{0.00035D}, \quad \text{.......... (6)}$$

$$\text{and for offshore wells, } C_d = 688{,}514 * n * e^{0.00011D}, \quad \text{.......(7)}$$

where C_d is the drilling and completion cost, in U.S. dollars;
D is the formation depth in feet; and
n is the number of required new wells.

The number of required new wells depends on the optimum spacing and the number of active wells. It is estimated from:

$$n = \frac{A}{S} - n_a \quad \text{.......... (8)}$$

where A is the reservoir area in acres;
n_a is the number of active wells; and
S is the optimum spacing.

For the purpose of screening, S is assumed in the base case to be 40 acres for onshore reservoirs and 80 acres for offshore reservoirs. The number of total wells, n_t, should not be less than two, an injector and a producer, or:

$$n_t = n + n_a \geq 2 \quad \text{.......... (9)}$$

Injection and production equipment costs, C_{inj} and C_{pd} respectively, were estimated from the same DOE study using the equations:[6]

$$C_{inj} = 22{,}892\, n_{inj}\, e^{0.00009D} \quad \text{.......... (10)}$$

$$\text{and } C_{pd} = 24{,}908\, n_p\, e^{0.00014D}, \quad \text{.......... (11)}$$

where D is the formation depth in feet;
n_p is the number of producers; and
n_{inj} is the number of injection wells, which is taken to be half of the total number of wells.

For projects requiring CO_2 injection, CO_2 can be transported by tank truck, railcar, or pipeline. Transportation by pipeline is considered the least expensive of all these methods.[5] Depending on the pipeline pressure conditions, CO_2 can be transported either at subcritical or supercritical conditions or as a liquid. The supercritical CO_2 pipeline system is the most economical system for transporting the large quantities of CO_2 needed for enhanced oil recovery.[7] The following equation can be used to estimate the cost of the pipeline:[6]

$$C_{pip} = (100{,}000 + 2{,}008\, q_{inj}^{0.834})\, d, \quad \text{.......... (12)}$$

where C_{pip} is the pipeline cost in U.S. dollars;
d is the distance to the Shell pipeline, in miles; and
q_{inj} is the estimated CO_2 pipeline capacity, in MMSCF/D.

q_{inj} is estimated from the following correlation:[6]

$$q_{inj} = 2 * N_{pi}, \quad \text{.......... (13)}$$

where N_{pi} is the projected incremental oil in million barrels estimated by Equation 5, in STB.

If more than one reservoir is located in the same field, the pipeline cost is shared by the reservoirs. The pipeline capacity is calculated from Equation 13 using the incremental production from all the reservoirs to share the cost. The pipeline cost, C_{pip}, calculated from Equation 12 is then shared between the reservoirs on the basis of the individual incremental oil value. All capital outlay is charged during the first year of the project.

CO_2 Cost. Published studies suggest that 6 MSCF per one STB of incremental oil is a representative average value of CO_2 utilization.[4,8] The purchase of CO_2 is a major expense for miscible projects, especially if CO_2 is obtained from industrial sources. The CO_2 cost for the purpose of this screening was based on availability from natural sources via the Shell pipeline. The CO_2 cost was estimated at $0.60/MSCF and remained constant throughout the injection period. The CO_2 project was not burdened with separation and recycling costs.

It was assumed that the value of produced natural gas would offset the cost of CO_2/natural gas separation.

Operating costs. Operating costs are site and operator specific. The average annual operating cost, C_{op}, in U.S. dollars, however, can be predicted from the following equation:[6]

$$C_{op} = 13{,}298\, n_t e^{0.00011D} \qquad (14)$$

It is assumed that all wells will require future workovers at an average of 0.25 workovers per well per year. The cost of a workover is estimated to be half the cost of the equipment. The annual workover cost, C_{wo}, can then be determined using the following equation:

$$C_{wo} = 0.25\left(\frac{n_t}{2}\right)\left(C_{inj} + C_{pd}\right) \qquad (15)$$

where C_{inj} and C_{pd} are expressed by equations 10 and 11, respectively.

Both the technical and economic screening algorithms were written in FORTRAN™ code. The economic screening may also be run on an electronic spreadsheet.

Louisiana Waterflooded Reservoirs Database

The approach described in this paper was used to screen waterflooded reservoirs in Louisiana. These reservoirs are listed in a database available from the Louisiana Office of Conservation and Reserves. Initially, the database listed 499 reservoirs that were waterflooded. These reservoirs represented a total original-oil-in-place of 5.289 billion STB, or an average of 10.6 million STB/reservoir.

Many reservoirs were eliminated in the initial stage of screening for various reasons. Because of the high cost of transporting CO_2, all of the 101 reservoirs located in North Louisiana were eliminated. An additional 188 reservoirs, mostly inactives, were eliminated because current saturation and pressure data, two key screening parameters were unavailable. Inconsistent data also led us to eliminate 13 reservoirs, leaving 197 reservoirs for screening and ranking.

Screening Results. Table 3 lists the 40 top ranked reservoirs and their relevant data. The reservoirs are ranked based on before-tax, present-worth, benefit-to-cost ratio. The economic evaluation considered shared pipeline cost. A discount rate of 15% was used in the base case. A positive value of the benefit-to-cost ratio indicates profitability.

As expected, the final ranking did not correlate with the technical ranking parameter, R_i. Under the conditions established for the model, the majority of the possible candidates are not economically suitable for miscible displacement with CO_2. Only 20% of the reservoirs in the database look economically attractive. Nevertheless, the potential incremental oil from these reservoirs is a significant 70.6 MMSTB of oil. The economic potential of CO_2 depends on the well spacing, CO_2 price, oil price, and discount factor.

The ranking shown in Table 3 was for a base case in which a 40-and 80-acre spacing were used for onshore and offshore reservoirs, respectively. The base case used 0.6\$/Mcf, 17\$/STB and 15% for CO_2 price, oil price, and discount factor. Sensitivity of the CO_2 performance to these parameters is shown in Table 4.

The validity of the screening approach is demonstrated by the fact that of the CO_2 projects contained in the database are highly ranked. These cases were considered to be profitable by the individual operator prior to the implementation of the process.

Specific Reservoir Performance

The objective of the reservoir screening and ranking is to attract the attention of operators to the potential of the miscible CO_2 EOR process in waterflooded reservoirs. Once this is accomplished, it is presumed that the operator will be interested in the absolute performance of a specific reservoir as opposed to its ranking relative to other reservoirs in the database. A user-friendly numerical simulator allows the screening of different implementation options. The effects of reservoir heterogeneity and well locations, which were not included in the initial screening, can be considered. Additional parameters can also be included in the simulation. CO_2-PROPHET™ software was recommended to perform this task.[8]

CO_2-PROPHET, a water-and gas-flood prediction software, was developed by Texaco with support of the U.S. Department of Energy. The simulator has been shown to be a good tool for screening and reservoir management and is being released with a detailed user manual to the industry. The hardware required to run CO_2-PROPHET includes an Intel® 386-based PC or better with at least 4 megabytes of RAM and 4 megabytes of free disk space. A math coprocessor is required for the 386 or the 486SX systems.[8]

This software runs on PC compatible computers. Some of its features include: easy reservoir parameter input; several predefined patterns to simplify use; the ability to design patterns to fit most situations; fast computation; multiple flood regimes that model water, gas, and miscible floods; output in surface units and dimensionless formats; and output designed for importing data into a spreadsheet.[8]

CO_2-PROPHET computes streamlines between injection and production wells to form stream tubes. It then makes flow computations along the stream tubes. It uses the Dykstra-Parsons coefficient to distribute the initial injection into a maximum of ten layers. A new case can be set up and run in a few minutes, making this program ideal for screening of EOR projects and pattern comparisons.

The use of CO_2-PROPHET is demonstrated with one of the top-ranked reservoirs, fictitiously named Eden. The Eden reservoir is located in a salt dome related structure. Its initial pressure in 1949, when commercial development began, was 4500 psi. The reservoir had a large initial gas cap about 0.444

the size of the oil zone. The estimated original-oil-in-place was 11.7 million barrels of 35.2 API gravity oil. By 1972, the reservoir had produced 2.6 millions of barrels of oil, mostly due to gas cap expansion. In 1974, a waterflooding program was initiated to increase recovery. As of 1990, waterflooding had resulted in the recovery of 4.3 millions barrels of oil.

The Eden reservoir was simulated using an option that allowed for the development of a stream tube model which was stored for later investigation of implementation options. Figure 3 shows the stream tube model of the Eden reservoir and the well locations.

Two implementation options were investigated: waterflooding and waterflooding followed by hybrid CO_2 displacement. For the waterflooding option, the startup conditions were those existing in 1974 at the end of the primary recovery phase. A total of 1.25 pore volumes (P.V.) of water was injected in the waterflooding option. The hybrid CO_2 process started after 0.7 P.V. of water was injected. The two options are compared in Table 4 and Figure 4. Figure 4 shows the expected cumulative oil recovery versus time. These data can be imported to a spreadsheet for site and operator specific economic evaluation.

Conclusions and Recommendations

A screening model was developed to rank a large number of potential reservoirs in a short period of time and with little effort. The model provides for rapid evaluation of both the technical and economic feasibility of the CO_2 miscible process. Of the 197 waterflooded reservoirs screened in this project, 39 looked economically attractive. The potential incremental recovery from these reservoirs is 70.6 million STB. To complement the screening model, CO_2-PROPHET numerical sumulator was used. This software allowed to incorporate site- and operator-specific data that are not considered in the initial screening.

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SI Metric Conversion Factors

acre × 4.046 873	E+03	= m^2
°API 141.5/(131.5+°API)		= g/cm^3
bbl × 1.589 873	E-01	= m^3
cp × 1.0*	E-03	= Pa-s
ft × 3.048*	E-01	= m
ft^3 × 2.831 685	E-02	= m^3
°F × (°F-32)/1.8		= °C
mile × 1.609 344*	E+00	= km
psi × 6.894 757	E+00	= kPa

* Conversion factor is exact

Table 1: Optimum Reservoir Parameters and Weighting Factors.[1]

Parameter	Optimum	Weight
API Gravity	37	0.24
Oil saturation, %	60	0.20
Pressure/ MMP	1.30	0.19
Temperature, °F	160	0.14
Net oil thickness, ft	50	0.11
Permeability, md	300	0.07
Dip, °	20	0.03
Porosity, %	20	0.02

Table 2: Worst Parameters from Louisiana's Reservoir Database.

Parameter	Lower Limit	Upper Limit
API Gravity	24	48
Oil saturation, %	8	80
Pressure/ MMP	0.10	1.47
Temperature, °F	80	276
Net oil thickness, ft	5	175
Permeability, md	17	3485
Dip, °	0.03	64
Porosity, %	17.6	34

Table 3: Potentially profitable reservoirs for CO2 miscible displacement in Louisiana

Base case: 197 reservoirs with complete information

Prospect Identification			Reservoir Parameters				Screening Parameters								Tech.	Economic Parameters			Rank
Operator	Field	Reservoir	Depth Feet	EOOIP MMBbl	Recov. MMBbl	Area Acres	API	Temp o F	Perm, K, md	So %	P/MMP	Poros. %	H oil Feet.	dip o	Rank	Wells Now	New Wells	Shared Dist, mi	40/80 15 %
Texaco	Paradise	Lower 9000 Sand RM	10450	13.5	1.7	235	35.7	193	515	62.0	0.909	28.8	45	8	85.04	6	0	1.0	1.14
Hassie	South Pass Block 24	8800' RD	8295	38.7	3.1	960	30.0	178	447	61.0	0.341	26.0	39	3	55.79	12	0	11.6	1.04
Shell	South Pass Block 27	"N1b" Reservoir F Sand unit	7300	3.7	0.2	70	28.0	165	537	43.5	0.478	30.0	35	7	42.99	1	0	1.4	0.96
Shell	Eugene Island Block 18	"O" Sand	10071	35.6	4.1	273	38.5	151	1000	31.3	1.866	32.0	80	4	76.50	3	0	59.0	0.95
Texaco	Paradise	Main Pay RT SU	10300	11.7	1.3	114	36.8	205	1910	51.7	0.752	27.5	51	10	74.25	2	1	1.0	0.93
Shell	South Pass Block 27	"M" RB SU	7500	7.4	0.7	150	32.4	178	200	47.5	0.465	30.0	40	9	60.03	3	0	3.9	0.89
Shell	South Pass Block 27	"N1b" Reservoir C Sand Unit	7450	9.2	0.6	211	32.0	168	300	22.9	0.616	33.0	28	5	44.22	3	0	3.5	0.82
Texaco	Caillou Island	Upper 8000 RA SU	7900	6.4	0.6	182	38.2	103	285	17.1	1.484	31.0	25	18	58.62	2	0	6.0	0.76
Shell	South Pass Block 27	"N1a" Reservoir C Sand unit	7350	14.4	1.1	328	32.0	168	300	36.9	0.340	33.0	27	5	49.67	6	0	6.2	0.72
Gulf	West Bay	Proposed WB6B (RG) Sand Unit	7419	49.7	3.6	530	31.3	80	470	38.4	1.306	32.6	41	5	48.52	5	2	29.9	0.71
Shell	South Pass Block 27	Proposed SPB 27 K RA SU	6200	4.1	0.3	174	27.5	160	500	54.4	0.484	28.0	17	10	48.61	2	0	1.7	0.69
Gulf	West Bay	5 A 'B"	7000	2.8	0.2	74.2	33.0	104	500	39.1	0.774	31.5	23	8	48.39	1	0	1.6	0.68
Shell	South Pass Block 27	"N4b" RC SU	7600	7.4	0.5	157	26.6	172	400	48.8	0.312	30.0	34	5	43.61	3	0	2.8	0.63
Shell	South Pass Block 27	"N1b" Reservoir D Sand Unit	7350	3.6	0.2	102	27.0	161	300	29.0	0.444	33.0	24	3	28.74	1	0	0.9	0.61
Shell	South Pass Block 24	Reservoir A, "Q" Sand	8125	17.0	1.7	516	39.5	186	500	21.5	1.161	32.0	24	2	66.09	5	1	6.4	0.61
Shell	South Pass Block 27	"M2" Reservoir A Sand Unit	6775	39.0	3.4	691	29.5	162	400	57.4	0.574	33.0	39	3	58.15	6	3	19.7	0.58
Shell	South Pass Block 27	"M6" Reservoir A Sand Unit	6750	22.9	1.2	360	27.0	159	600	33.9	0.479	33.0	41	4	34.24	9	0	6.8	0.52
Shell	South Pass Block 27	"N1b" Reservoir B Sand Unit	7550	3.5	0.1	116	26.8	168	300	26.7	0.329	33.0	22	2	26.03	1	0	0.8	0.48
Shell	South Pass Block 24	RA P-Q Sand	7860	44.2	3.8	1574	35.0	167	300	24.3	0.555	30.0	15	2	57.34	18	2	14.3	0.46
Shell	South Pass Block 27	"N1b" Reservoir E Sand Unit	7000	25.3	1.5	434	26.0	160	500	44.8	0.279	33.0	33	3	40.31	3	2	8.9	0.31
Shell	South Pass Block 24	8000' RS SU (Horstal "S")	8150	14.6	1.1	577	32.0	176	500	42.2	0.362	29.0	24	3	52.39	11	0	4.3	0.27
Gulf	Quarantine Bay	9BC, C2	9430	3.1	0.3	90	35.9	200	200	32.0	0.946	28.0	20	2	60.63	1	0	6.4	0.26
Chevron	Bay Marchand Blk 2	3650' Upper Block D, 3650' (U)	3850	26.8	0.8	167	24.0	136	570	11.4	0.352	32.0	78	17	18.99	2	0	24.0	0.24
Chevron	South Pass Block 24	8200' "T" Sand	8294	84.3	6.4	1456	32.0	104	325	43.2	0.819	31.8	45	2	50.98	9	9	24.2	0.24
Shell	South Pass Block 24	Res. A "T1a" Sand	8700	12.3	0.7	374	30.0	175	300	32.3	0.725	32.0	23	2	39.59	7	0	2.8	0.21
Shell	South Pass Block 27	"N2" Reservoir B Sand Unit	7500	2.4	0.1	119	27.0	94	380	41.4	0.667	29.0	18	6	25.98	1	0	0.5	0.20
Shell	South Pass Block 27	"N4b" Sand Reservoir B	7850	10.9	0.4	302	24.2	168	400	22.7	0.237	31.0	35	3	24.22	4	0	2.3	0.20
Texaco	West Cote Blanche Bay	Lower No. 11 Sand, Reservoir N3	8600	7.0	0.6	40	33.8	108	1200	36.4	1.495	33.0	84	27	59.13	1	1	1.2	0.14
Texaco	West Cote Blanche Bay	No. 17 Sand. Res. P-Q	7700	4.7	0.5	75	33.1	116	400	44.1	1.314	28.0	42	20	66.76	0	1	0.9	0.12
Texaco	Paradise	Paradis Zone, Seg. A-B	10000	119.0	14.6	2057	38.0	200	1348	60.0	0.872	26.2	55	4	81.73	8	43	1.0	0.10
Chevron	South Pass Block 24	8600' RA Sand Unit	8721	85.3	7.0	1496	32.4	179	500	35.7	0.734	31.0	43	2	54.95	7	12	26.5	0.09
Shell	South Pass Block 27	"N1a" Reservoir E Sand Unit	7000	21.2	0.9	529	26.0	160	500	31.5	0.391	33.0	22	3	28.49	6	1	5.3	0.08
Gulf	Grand Bay	GB 10B (FBB) RA SU	7870	7.7	0.7	440	35.3	98	300	23.9	1.402	32.6	11	2	56.17	6	0	10.5	0.05
Gulf	West Bay	11 Sand Fault Block B	10850	26.2	2.4	436	30.0	136	500	47.3	1.163	30.0	55	3	60.26	2	3	19.7	0.05
Shell	South Pass Block 27	"N1c" Reservoir E Sand Unit	7000	10.5	0.4	347	26.0	160	200	22.3	0.451	33.0	23	3	23.00	5	0	2.1	0.05
Texaco	Caillou Island	9400 ft Sand, RBB1C	10000	23.3	2.3	427	39.0	138	1900	17.3	1.113	30.0	44	12	64.42	2	3	23.8	0.03
Shell	South Pass Block 27	SPB27 L4 RD SU	7430	2.2	0.1	120	32.0	93	300	43.9	0.569	32.0	16	8	43.09	2	0	0.8	0.02
Gulf	Quarantine Bay	8 Sand, Reservoir "B"	8950	17.0	1.3	303	34.5	112	1669	22.1	1.102	32.0	28	3	50.43	3	1	29.0	0.01
Shell	South Pass Block 27	"M2" Reservoir B Sand Unit	6280	8.9	0.3	142	25.0	155	500	14.4	0.463	33.0	32	4	23.60	5	0	1.8	0.00
Shell	South Pass Block 27	Reservoir "A" "L2" Sand Unit	6420	30.2	1.1	992	25.6	153	500	20.1	0.324	33.4	33	3	24.01	18	0	6.3	-0.04

Table 4: Summary of the sensitivity analysis for ranking of candidate reservoirs for CO2 miscible displacement in Louisiana

Parameter	Spacing, Onshore/Offshore				Discount Rate			Oil Price, $/Bbl			CO2 Price, $/Mcf		
	20/40	40/40	40/80	80/160	12%	15%	20%	15	17	20	0.6	0.8	1.0
Attractive Reservoirs	5	8	39	73	41	39	27	28	39	47	39	32	27
Potential Oil, MMBbls	6.9	24.5	70.6	110.4	74.6	70.6	39.7	40.3	70.6	86.3	70.6	63.3	39.6

Table 5: Reservoir and simulation parameters. Eden field

RESERVOIR PARAMETERS

OOIP, MMBls	11.723
Permeability, md	1910
Temperature, F	205
Dip angle, o	10
Gravity, API	35.2
MMP, psi	3500
Dykstra- Parsons	0.75
C5+ MW	230.3
Swc, %	14
Rs, scf/stb	900
Oil viscosity, cp	0.35
Bo, rb/stb	1.4
Gas gravity	0.7
Water viscosity, cp	0.8
Salinity, ppm	100000
Mixing Parameter	0.6666
Area, sf	3841632
Thickness, ft	139.5
Porosity, %	20
Kh/Kv	0.1

SIMULATION PARAMETERS

RELATIVE PERMEABILITIES

Layers	3
Pattern	Custom
Krocw	1
Kwro	0.116
Krsmax	0.477
Krgcw	0.477
Nw	2
Now	2
Ns	2
Ng	2
Nog	2
Sorw	0.3
Sorg	0.3
Sorm	0.05
Sgr	0.3
Ssr	0.3

SIMULATION RUNS

WF & CO2 HYBRID

Pre- wf pres, psi	3335
Pre -wf So, %	0.517
Water inj, hcpv	0.7
CO2 slug, hcpv	0.125
WAG (CO2 hcpv)	0.3
WAG ratio (vol)	2
Chase water, hcpv	0.3
Qw inj. bpd/w	1000
QCO2, MMscf/d/w	6.2 & 8.0

WATERFLOODING

Pre- wf pres, psi	1484
Pre -wf So, %	0.517
Water inj, hcpv	1.25
Qw inj, bpd/well	1000

INITIAL CO2 HYBRID

Pre-co2 pres, psi	3335
Pre-co2 So, %	0.517

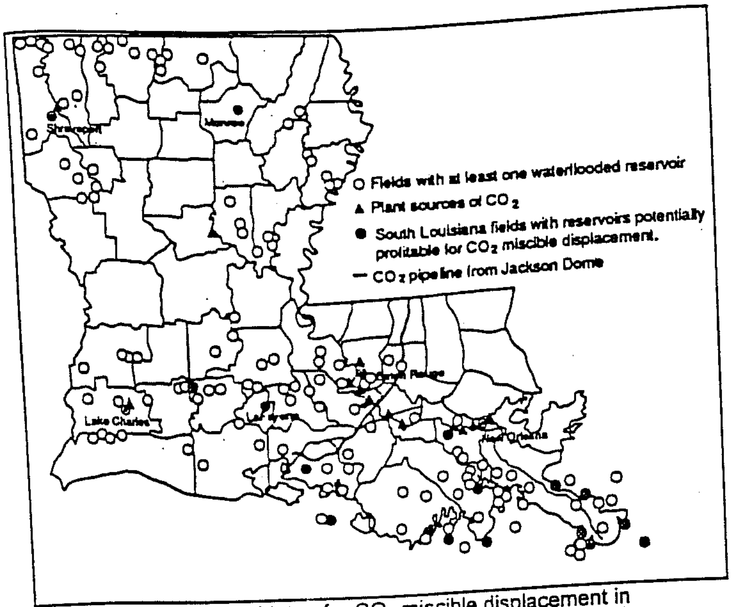

Figure 1. Potential candidates for CO_2 miscible displacement in Louisiana

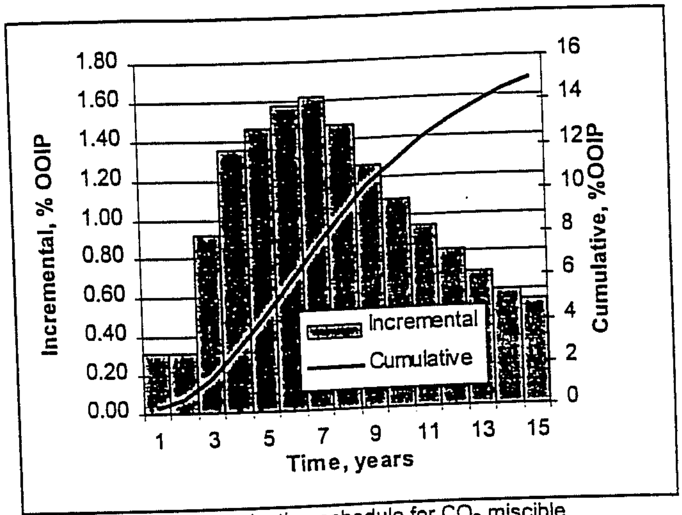

Figure 2. Typical production schedule for CO_2 miscible displacement

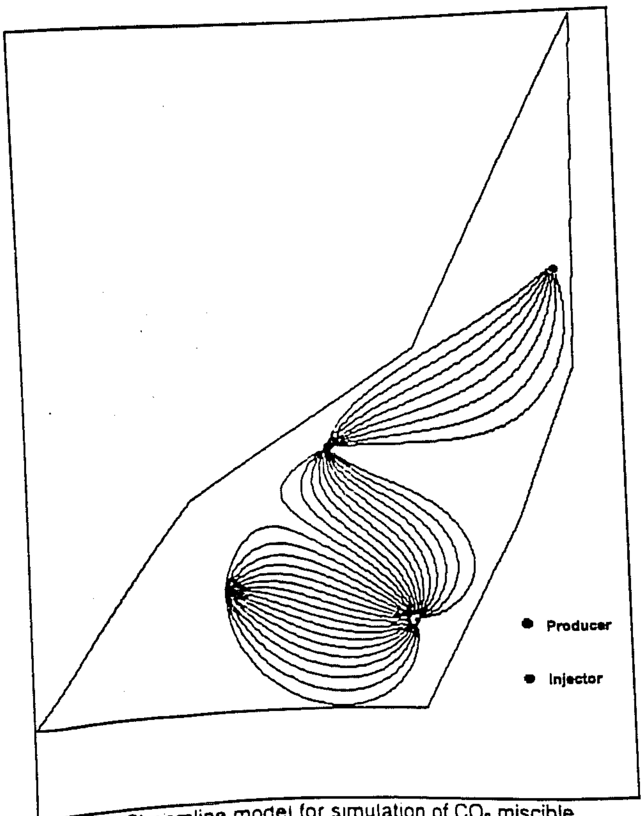

Figure 3. Streamline model for simulation of CO_2 miscible displacement at Eden reservoir

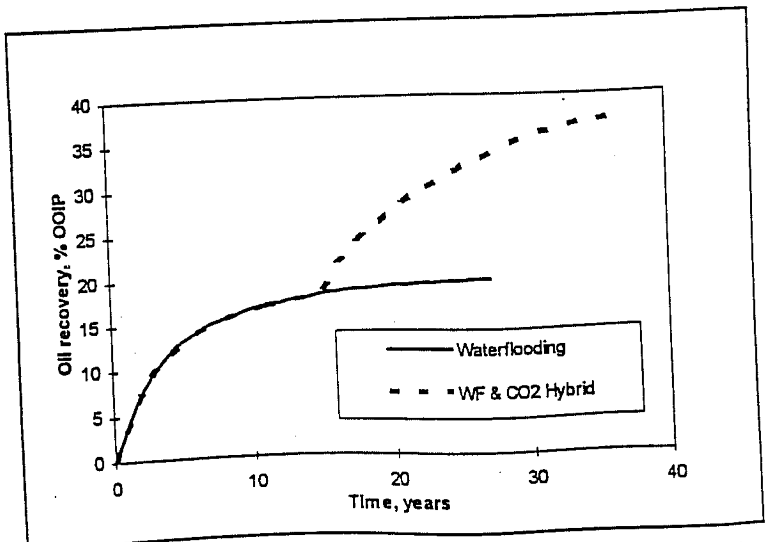

Figure 4. Comparison of alternatives of development for Eden reservoir