NIPER/BDM-0225
March 1996

Final Report

FEASIBILITY STUDY OF HEAVY OIL RECOVERY IN THE UNITED STATES

for

Management and Operating Contract for the Department of Energy's National Oil and Related Programs

Work Performed Under Contract No.
DE-AC22-94PC91008

Prepared for
Thomas B. Ried, Program Monitor
Thermal and Novel Technology
U.S. Department of Energy
Bartlesville Project Office

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

BDM-Oklahoma, Inc.
P.O. Box 2565
Bartlesville, Oklahoma 74005

ABSTRACT

A study was initiated in 1990 to evaluate the potential of increasing U.S. heavy oil production to lessen the U.S. domestic oil production decline. In California, heavy oil production was increased in the 1960s as light oil production declined to meet the petroleum demand, suggesting that similar trends are possible elsewhere. Changes in refining were made in accordance with the production trends. This study researches the U.S. petroleum industry to determine if it could undergo similar modifications. The U.S. heavy oil resource, production characteristics, and existing refining capacity were evaluated. The resource was comprised of a total 1,025 heavy oil reservoirs; 535 were characterized in more detail. Reliable information was not available for the other 490 reservoirs which include Alaskan heavy oil reservoirs. Heavy oil remaining in the 535 heavy oil reservoirs characterized was estimated to be 68.3 billion bbl.

As much as 18% of the 68 billion bbl, or 12 billion bbl may be recoverable using current technology. At the current oil price (projected flat price of $18/bbl for WTI), heavy oil production rates are expected to decline through the year 2010. An incentive of $2.90/bbl U.S. heavy oil would be needed to increase production over current levels by 300,000/day in the year 2010. U.S. refining capacity will need to be expanded to process the increased heavy oil production.

EXECUTIVE SUMMARY

This study was initiated in 1990 to evaluate the potential of increasing U.S. heavy oil production to impact U.S. domestic oil production decline. Precedence for such a change has already been demonstrated in the California petroleum market. As light oil reservoirs matured and production declined during the years 1955 to 1985, production of heavy oil gradually increased. The result was an increase in total oil production to meet demand. Refineries in California were upgraded to process the heavy ends as part of this transition. Currently, California produces more heavy oil than light oil.

This study evaluates the total U.S. heavy oil resource, estimates what is realistically recoverable from this resource and the feasibility of projected production increases. Heavy oil reservoirs were screened by individual regions (Midcontinent Region, Appalachian Basin, Black Warrior Basin, Illinois Basin, Michigan Basin, Permian Basin, Alaska, California, and Gulf Region) to identify obvious targets currently underdeveloped, and to recommend future technology improvements and field demonstrations. These recommendations are made to the U.S. Department of Energy (DOE) to direct their heavy oil program in the most advantageous way. Additional studies were conducted to evaluate the current U.S. refinery capacity to process heavy ends. Anticipated global market trend models were developed to estimate the impact of heavy oil production on refinery regions in the U.S. In addition to the originally proposed 930,000 bbl/D increase, an intermediate 300,000 bbl/D increase by the year 2010 was also considered. Market incentives for bringing about the proposed production increases were postulated.

The following were concluded from this study.

1. An estimated 68.3 billion bbl of heavy oil remains in 535 U.S. reservoirs. An undetermined additional amount remains in 490 less well documented U.S. reservoirs, including 25 to 40 billion bbl heavy oil in Alaska.
2. Most of the heavy oil (62.8 billion bbl) is located in California (half of which lies in seven fields), and 3.5 billion bbl is located in the Gulf Region (Alabama, Mississippi, Louisiana, Southern Arkansas, and Texas excluding the Permian Basin).
3. It was estimated that up to 4 billion bbl heavy oil could be recovered using waterflooding for low viscosity oils and up to 8 billion bbl heavy oil could be recovered using steam injection. Virtually all of this oil was in California.
4. Approximately 56 billion bbl of the oil left behind and another 5 to 40 billion bbl heavy oil in Alaska remain a production target for improved technology.
5. Based on the current oil prices (calculated on a flat rate of $18/bbl for WTI), heavy oil production rate is expected to decline through the year 2010. An estimated

$2.90/bbl incentive is needed to achieve heavy oil production increase of 300,000 bbl/D over current production levels by the year 2010.

6. Overall oil production rates are expected to decline in the U.S. by 2% annually, and petroleum product demand is expected to increase by 1% annually (through the year 2010). Increasing heavy oil production would require expansion in refinery capacity for processing heavy ends. The estimated plant utility costs associated with an increase of 300,000 bbl/D was $7 billion (no offsites included)
7. Moderate increases in heavy oil production from the Gulf Coast Region can be processed with existing refining capacity. However, production increases are most likely to come from California. Due to a perceived oil surplus market currently in California, it is uncertain what the actual impact of a U.S. heavy oil incentive would be on the overall oil industry.

It is recommended that future government programs, directed toward maximizing U.S. heavy oil production, consider the following observations.

1. Most of the U.S. heavy oil is likely to be produced from California where resource and production characteristics are more favorable. Any program effectively targeting heavy oil production is likely to impact California production operations.
2. The next largest heavy oil resource is in Alaska, although actual size of the resource is less certain. This is the only other large domestic heavy oil resource in the U.S. Heavy oil production is possible in Alaska if technological and economic challenges are met. However, the window of opportunity may quickly close if light oil production rates decline as projected. The Trans Alaskan Pipeline System (TAPS) may close before significant amounts of heavy oil can be produced (decisions driven by overall costs).
3. The Gulf Region is the third largest region in the U.S. with deposits of heavy oil. Existing refining capacity in this region can accommodate increased production making the economic adjustments more realizable. However, the thinner reservoirs in this region presents a production challenge.

ACKNOWLEDGMENTS

This work is sponsored by the U.S. Department of Energy under the Work Authorization Number AC/15054/BC/42, Rev. C. The author wishes to thank Thomas B. Reid of BPO for his support and encouragement; Arfon H. Jones of BDM-Oklahoma for his review and input; David Mitchell, CA District Engineer for his personal attention and information supplied to us at our request; and Herman Dykstra for his input and review of selected California reservoirs.

CONTENTS

1.0 INTRODUCTION 1

2.0 CHARACTERIZATION OF 3

2.1 Datafiles 4

2.2 Resource Estimate 12

2.3 Summary 16

3.0 U.S. HEAVY OIL RESOURCE, REGION STUDIES 17

3.1 Midcontinent Region (Kansas, Missouri, Oklahoma) (Olsen 1993, 1995) 17

3.2 Appalachian, Black Warrior, Illinois, and Michigan Basins (Olsen 1992) 19

3.3 Permian Basin (W. Texas, SE New Mexico) (Olsen and Johnson, 1993) 19

3.4 Alaska (Olsen, Taylor, and Mahmood 1992 20

3.5 California 21

3.6 Gulf Region (Sarkar and Sarathi 1992, Sarkar and Sarathi 1993) 30

3.7 Summary 32

4.0 IMPACT OF ACCELERATED 33

4.1 Accelerated Heavy Oil Production 33

4.2 Refining Capacity (Olsen, Ramzel, Strycker, Guariguata, and Salmen 1994) 38

4.3 Incentive Study (Pautz and Welch 1995) 47

4.4 Final Summary 48

5.0 CONCLUSIONS 51

6.0 REFERENCES 53

APPENDICES

A Heavy Oil Resource Tables 71

B Stratigraphic Maps of Major California Heavy Oil Fields 117

TABLES

2–1 Primary References and Estimation Methods for Data Elements in Table 7–1 5

2–2 Database Fields Sorted and Internal Checks Calculated to Identify and Correct Entry Errors in Table 7–1 (Appendix A) 11

2–3 Comparison of Screening Methods on Selected California Heavy Oil Reservoirs 13

2–4 Summary Estimate of U.S. Heavy Oil Resource Based on Reservoirs in Table 7–1 (Appendix A) 15

3–1 List of California Heavy Oil Fields Ranked by Heavy Oil Resource and Production 22

4–1 U.S. Refining Capacity by Region in 1990 (MB/SC) 36

4–2 Low Heavy Oil Production Rates Through 2010 37

4–3 Alternate High Heavy Oil Production Rates Through 2010 38

4–4 Crude Oil Prices from the Year 1983 to Year 2010 40

4–5 Projected U.S. Crude Oil Supply and Demand From 1990 to 2010, Mbbl/D 42

4–6 Projected U.S. Crude Oil Supply by Region From 1990 to 2010 42

4–7 Crude Representation for Regional LP Models, Base Case 1990 44

4–8 Heavy Crude Oil Production by Region Defined for Base Case, 1990 45

7–1 Reservoir Parameters for Heavy Oil reservoirs in the U.S. 71

7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study 95

7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters 105

FIGURES

3–1 California Heavy and Light Oil Production Since 1940 29

3–2 California Crude Oil Production by Region Since 1960 30

4–1 Historical U.S. Production and Consumption History of Crude Oil (API 1995) 34

4–2 Ten Defined Regions With Separate Linear Programming Models in DOE Refinery Feasibility Study 39

1.0 INTRODUCTION

The availability of heavy crude oil and the market economy for production, transportation, and refining has been the focus of many studies in recent years. A major shift in domestic oil production rates started in 1972 with the increase in imported crude oil. Many factors have influenced this shift, but the dominant reasons are the maturing of U.S. fields and the availability of cheap oil from other countries.

The state of California underwent a similar change (decline in light oil production with maturing fields) in the middle 1950s (Olsen et al. 1992). There was and still is an abundance of heavier crude oils in the state of California. Despite expensive production and refining, major oil companies found ways to produce and refine the heavier crude oil cost effectively. The result was a relatively seamless transition from predominantly light crude oil to predominantly heavy crude oil as the petroleum resource. The obvious question was whether a similar transition could take place in other parts of the U.S.

The purpose of this project was to determine if stimulating domestic heavy oil production is feasible in the U.S., to estimate the potential cost (qualitatively), and how much heavy oil production can be expected. First, an assessment of the U.S. heavy oil resource was made. This assessment included identifying the reservoirs, collecting reservoir rock and fluid information to assess how readily heavy oil production could be increased, and estimating the remaining oil. Second, evaluate the additional cost to achieve increases in U.S. heavy oil production. Third, review the transportation and refining limitations to increased heavy oil production.

This study had an advantage that the total number of heavy oil reservoirs was manageable and reasonably accurate data was available from the State of California where most of the heavy oil is located. Also, because of the historically successful production and refining of heavy oil grades in California, an estimate of refining capacity and cost limitations could be reasonably well benchmarked and projections reasonably determined.

The U.S. DOE definition of heavy crude oil is oil with API gravity between 10° and 20° inclusive at 60°F, or having a gas free viscosity > 100 cp and less than 10,000 cp inclusive at reservoir temperature. For purposes of simplicity, reservoirs were included in this study if the API gravity was between 10° and 20° inclusive with no consideration of viscosity. Viscosity values were obtained or estimated. A reservoir was considered if the average API gravity for the crude oil was in the defined heavy oil range. It is recognized that many productive zones have crude oils that range from heavy to light within the same reservoir; no attempt was made to estimate the heavy oil portion for these reservoirs. If the average or preponderance of oil produced was heavy, the reservoir was classified as heavy. Consequently, a reservoir producing predominantly light oil was considered a light oil reservoir, and one producing predominantly natural gas was considered a natural gas

reservoir, even if heavy oil is known to be produced also. Some sources have listed certain reservoirs as heavy oil reservoirs because the discovery well showed heavy oil. However, if the production wells flowed lighter gravity oil, the reservoirs were eliminated from further consideration. Within fields with multiple reservoirs, only heavy oil reservoirs were included in this study. Known API gravity ranges are listed in the report. Also, as with all studies of this type, the results are limited by what information is available. Engineering judgment was applied to determine the most reliable data where conflicting data exists.

Approximately 153,000 bbl/D of heavy oil is imported to U.S. refineries (Energy Information Agency 1992). Combined with estimated domestic heavy oil production of 750,000 bbl/D, a total of about 900,000 bbl/D heavy oil is going to U.S. refineries (Olsen 1993). It is suspected that more heavy oil produced by major importing countries reaches U.S. refineries as a medium gravity oil resulting from blending with light crude oil (Olsen et al. 1994). Regardless of what average density oil reaches the refinery, the heavy ends must still be processed and upgraded.

To increase the quality of hydrocarbons from heavy oil several processes may be implemented by the refinery: coking, flexicoking, hydrotreating, and resid hydrocracking. Delayed coking requires the lowest investment and is the most often used. The configuration of a given refinery limits the intake and throughput capacity of the heavy oil. Furthermore, more energy is required to upgrade lower quality crude oils and is the greater economic penalty to the refinery. Consequently, the refinery will adjust the offering price to the producer for the crude oil based on a number of factors including its quality, the available refining capacity to process, and the market price of other crude oils. Any consideration of increasing heavy oil production rates in the U.S. must review the impact to the refining capacity and the discounted prices the producer is likely to receive for the oil.

The first section of the report reviews the heavy oil resource, summarizes the methodology to develop datafiles, and discusses estimates made of the amount and location of heavy oil in the U.S. Reservoirs were screened, categorized by production methodology, prioritized from best to worst for advanced recovery processes, and reviewed for an estimate of producible heavy oil. The next section reviews the impact of accelerated heavy oil production scenarios. In evaluating the potential of heavy oil, the cost of increasing refining capacity for upgrading heavy oil must be added to the cost of production. Finally, an overall assessment is summarized.

2.0 CHARACTERIZATION OF U.S. HEAVY OIL RESOURCE

To target geographic regions or technology developments for stimulating heavy oil production, an assessment of the resource was performed. The intent was to get a reasonable estimate of the aggregate resource and sufficient detail to determine whether this oil was readily recoverable; the approach centered on self-consistency and traceability.

Differences will always exist between different sources reporting data. Self-consistency and traceability were considered key elements of the reservoir datafiles being constructed. A datafile of heavy oil reservoirs was generated with the ability to trace each data element to a specific reference source. This allows other users of the datafile to review the data and judge whether to accept it or revise it as needed depending on the data source and intended use. Sometimes values reported to the state and reproduced in state publications reflect discovery well data and are not always updated to reflect a better representation of the entire reservoir as the production operation expanded.

In addition, self-consistency was sought in generating the datafile. Self-consistency in methodology is needed to allow for meaningful comparisons from one reservoir to the next and to understand the limitations of the data and intended use. One objective was to create a spreadsheet type format that could be sorted easily to enable visual scanning of different reservoir properties. Such visual review of the reservoirs enables the user to utilize past experience to judge the relative value of the reported resource. Simply concluding that x amount of heavy oil remains unrecovered in the U.S. does not convey how much of that heavy oil is realistically recoverable in the future. Many studies rely on screening methods calibrated to past practices for making this estimate, but these screening methods have their own biases and assumptions. Visually screening the raw data in a convenient form enables the user with experience in heavy oil recovery to qualitatively assess the resource and the recoverable oil. State publications are often the best sources of information. Unfortunately, each state compiles different information, and the information is often collected in different ways. Engineering judgment was used to minimize these differences.

The following sections discuss the methodology for collecting information, how the information was compiled and reported, and an assessment of the potential recovery of heavy oil using current technology. Most of the heavy oil in the U.S. is located in California and Alaska. Some heavy oil is found in the Gulf Region. Due to the technical challenges of producing heavy oil in Alaska, very little of it is currently being produced and is a potentially large target for technology development. In the main file 535 heavy oil reservoirs are listed (excluding Alaska). Nearly half of this heavy oil resource can be found in seven fields located in California: Wilmington, Hondo Offshore, Point Pendernalas Offshore, Midway-Sunset, Cat Canyon, Santa Maria Valley, and Huntington Beach.

Therefore, any effort to substantially change U.S. heavy oil production for the purpose of reducing domestic production decline will need to consider these seven fields.

2.1 Datafiles

As previously stated, the primary purpose for creating a heavy oil database was to identify how much heavy oil is in the U.S., identify where it is located, and estimate from this data what is realistically recoverable. This information is to be used by the DOE to guide the development of future heavy oil programs. In addition to the reservoir data, a relational file was created to enable input of the information source for each data element. Because much of the available reservoir information is based on reports of other studies, the value of the data is a direct function of the source and methodology used. Any comparison of data for reliability must include a consideration of its source. Consequently, a separate datafile containing the source citation for each data element was considered just as important to this study as the data itself. Table 2–1 lists a cross reference table for the principal sources of the data in Table 7–1 (Appendix A). Additional references were used when available, such as specific publications on the respective reservoirs, individual geological survey reports, etc. When more than one reference was available and conflicting information was reported, the value defaulted to the primary reference unless a review of the particular situation indicated for specific reasons that other values were more accurate.

Heavy oil reservoirs were listed either in a primary or a secondary datafile (see Tables 7–1 and 7–2, Appendix A, respectively). Large heavy oil reservoirs with good data were listed in the primary file. This file was the basis of the U.S. heavy oil resource characterization. A number of other heavy oil reservoirs identified are listed in the secondary datafile. For this file, some of the key data elements may be missing or unreliable, the reservoir may be too small (< 1 MMbbl oil-in-place), or the field may be listed as abandoned. Resource characterization was not conducted on this datafile. However, a significant amount of oil may be contained in these reservoirs and they should be included in any future review of heavy oil resource.

A listing of reservoirs in the primary datafile required that certain key data elements be known. Basically, the data elements fall into three category types: key elements, secondary elements, and optional elements. The key elements include reservoir name, porosity, net pay, reservoir area, initial oil saturation, depth, API gravity, oil production, original-oil-in-place (OOIP), and current oil-in-place (OIP). If reservoir name, net pay, reservoir area, depth, API gravity or oil production could not be obtained, the reservoir was listed in the secondary file (see Table 7–2, Appendix A). The secondary or unconfirmed file was not considered a working file and was not rigorously reviewed or documented. It was useful for indicating the additional heavy oil resource not being evaluated in this study due to incomplete information. Evidence that the reservoir was a heavy oil reservoir was still needed.

Table 2–1 Primary References and Estimation Methods for Data Elements in Table 7–1

State	Field/Reservoir	API Gravity	Depth	Temp.	Visc.	Ann. Prod.	Cum. Prod.	Area	Porosity	Perm.	Gross Pay	Net Pay	S_{wi}	S_{oi}	Saturation bbl/acre*ft	Wells Total	Wells Prod.	Yr. Disc.	Geo Series	Lith.
Alabama	1,2	2,1	2,1	3	4	5	5	2	1		1,2	1,2		none	none	5	5	1,2	1	1
Arkansas	1,6	1,6	6,1	3	4,6	6	6	6	6	6	1	6	6	7	7	6	6	6,1	1	8,1
California	16	16	16	16	16,4	17	17	16,17	16	16,10	16,10	16,10	16	16	16	17	17	16	18	1
Kansas	1	1	1	3	4	5	5		1		1	1	none	none	none	none	none	1	1	1
Louisiana	1	1	1	3	4	5	5	9	1	10	9	9	none	10	none	5	5	1	1	1
Mississippi	1	1,11	1,5	3	4	5	5	1	1	1	1	1,5	none	none	none	5	5	1	1	1
Oklahoma	1	1	1	3	4	1,5	1,5	1	1	1	1,10	1,10	none	none	none	5	5	1	1	1
Texas	1	12,1	12,1	3	4	12	12	1	1	1	1	1	13	13	none	12	12	1	1	1
Wyoming	14,15	14,1	14,1	14,3	14,4	15	15	14,1	14	14	1,14	14,1	none	none	none	15	15	14,1	14,1	14,1
Other	1	1,5	1,5	3	4	5	5	1	1,5	1	1	1,5	none	none	none	5	5	1	1	1

References:

1 USGS 1885
2 1988 AL O&G Rpt. 3-L
3 temperature grad.; calc.
4 est. using method JPT 9/75 p. 1140; ass. dead oil
5 1991 Int. Oil Scouts V. 62
6 AR Ann. O&G Rpt., p. 28 (1990)
7 U.S. Bureau of Mines Cir. 8428, p. 8, 1969 (calc.)
8 DOE/ET/12380-1 (V. 2), 1981
9 *1978 LA Summ. Field Stats. & Drill Ops.*
10 technical papers
11 MS O&G Ann. Rpt. (1989)
12 1991 TX O&G Ann. Rpt. Vol. 1
13 Railroad Commission Applications
14 *WGA/Bighorn & Wind River* (1989)
15 WY O&G Stats (1989)
16 California Division of Oil & Gas, TR12 (1991)
17 California Division of Oil & Gas, PR06 (1991)
18 California Division of Oil & Gas, TR11 (1985)

An accepted methodology for estimating the key element values was followed. Both primary elements and secondary elements that helped the resource evaluation process were evaluated. Secondary elements include formation name, county, district, basin, reservoir temperature, reservoir viscosity, gross pay, permeability, salinity, number of wells, lithology, and depositional environment. If available, optional elements were added to the data elements. Optional elements include initial water saturation, initial gas saturation, formation volume factor, reservoir pressure, dip angle, geological series of formation, oil concentration (bbl/acre-ft), discovery well and date, Dykstra-Parsons Coefficient, primary recovery, secondary recovery, GOR, and amount of sulfur in oil. However, extensive effort was not directed toward obtaining this information, and if not found, the data elements were left blank (a value was entered into the database of "-1").

Because all the elements defining a reservoir are usually not known, estimates will always be required. The relative merit of an estimate is determined by the individual engineer's experience and availability to direct information. Recognizing this, greater value was placed on traceability. Use of the data must always be limited to the appropriate level of detail available. Data in Table 7–1 (Appendix A), for example, is not adequate for input to a simulator studying production processes.

The methodology for creating the datafiles and the degree of self-consistency in the datafiles help to define the end result. Thus, some care was taken to develop the methodology that would best provide consistency throughout the datafiles, and to enable the reviewer to evaluate each data element on its own merits (references for each data element would be made available). The following guidelines were followed in generating the datafiles.

(1) Reservoir delineation was by geological formations (defined by stratigraphic maps), as opposed to production pools. This delineation does not conform to production figures and associated nomenclature, often reported by pools.

(2) Because complete reservoir information is never known and multiple sources for a given reservoir often report different estimates, the basis of deciding which values are used (and associated assumptions) is important. Public documents were reviewed and used as primary sources. Where more than one source was available, a preferred source was selected and used unless mitigating circumstances suggested alternate values to be better. It is recognized that individual operating companies will have more accurate information, but using privately reported information prevents anyone else from identifying the methodology used in generating the numbers (often proprietary). In practice, the ideal was not fully achieved, but in principal this approach promotes an understanding of the limitations involved in the estimation process.

(3) Reservoirs containing certain key data elements that are unsubstantiated (cumulative production, area, net pay, API gravity, reservoir depth) by the primary information sources were listed in the secondary or unconfirmed file (Table 7–2, Appendix A) and were not used in the resource assessment

evaluation. These key elements were needed to delineate and estimate the heavy oil resource value. If the reservoir was determined to be heavy oil, but the resource estimate could not be reliably made, the reservoir was excluded from the primary file used to evaluate the U.S. heavy oil resource and was instead listed in an alternate file (secondary or unconfirmed file) to indicate an undefined potential. For the remaining key data elements, if reliable sources did not report these values selected methods of estimating the values were adopted and listed. If listed in the primary file, the method of estimating the value was inserted. Parameters often estimated include porosity (25% or formation average), oil saturation (60%), temperature (temperature gradient as a function of depth for the respective region), and viscosity (empirical calculation based on API gravity and temperature).

(4) When a range was given for depth, an average was taken. It was presumed if not stated that the depth value was that of the top of formation. For dipping reservoirs, depths vary making the average a poor representative of the overall reservoir. However, unless a weighted average was given in the literature, the average was taken as an acceptable approximation and no attempts were made to improve it.

(5) When permeability values were reported as a range, a geometric mean was entered, and the range was given in the reference file. This is an accepted practice by many engineers and is based on the observation that distribution of permeability values tend to conform to exponential rather than linear distributions.

(6) To minimize difficulties in selecting values between conflicting information sources, one or two principal reference sources were selected for each state. The principal references were considered the best sources, and the reported values from these sources were accepted in preference to other sources. Technical information from peer-reviewed journal publications on specific reservoirs or fields were considered more representative when available and applicable to the entire reservoir. In most cases, published journal publications were not available for specific reservoirs; state geological surveys were considered the next best choice.

(7) In publications by the State of California, initial oil saturations were reported both as percent saturation and as bbl/acre*ft (from which percent saturation could be calculated using reported porosities). However, it was found that the two values in the same publication gave different oil saturation values. In this study, both data elements were entered and reported in Table 7–1 (Appendix A). The percent oil saturation value was used in calculating original-oil-in-place. The reported bbl/acre*ft value was compared to identify potential outliers in the data.

(8) Often, initial oil saturation (S_{oi}) is determined by measuring water and gas saturation to obtain the oil saturation. Engineers often calculate S_{oi} of heavy oil by this approach. However, S_{oi} was not estimated by this method when only S_{wi} values were reported. Instead, an average value (S_{oi} = 60%) was considered a better estimate for the total resource. This situation occurred for 55 reservoirs in Table 7–1 (Appendix A).

(9) Original-oil-in-place (OOIP) was always calculated according to the formula: 7758.3678*porosity*area*net pay*S_{oi}. The primary purpose for uniformly using this equation was to maintain consistency throughout the datafile. OOIP was found to be statistically most sensitive to reservoir area.

(10) Reservoir thickness estimates vary depending on the methodology used. Gross pay was considered the entire production zone. Net pay was an estimate of total oil sands for a given production zone. When net and gross pay values were separately reported, they were similarly reported in the datafile. For those states reporting gross, net and average pay, the lower of net or average pay was entered as net pay. Generally, if one value was reported as the reservoir pay value, it was entered as net pay if consistent with other parameters. For the State of California, the most consistent value for net pay was determined from representative logs usually included with the principal information sources if values were not reported directly. In general, net pay values listed in Table 7–1 (Appendix A) tended to be larger than net pay values used in detailed steam simulation studies. Individual sands within the reservoir are likely to be thinner and have smaller net pay values.

(11) Reservoir acreage has the greatest influence in calculating oil-in-place. Refined estimates of reservoir acreage are highly variable since extrapolation is always required between wells. The greater the number of wells and the tighter the spacing, the better the refinement. This study estimates the full acreage of the reservoir with oil present, whether currently in production or not. Some maps indicated reservoirs to be much larger than is currently under production because values were revised upward to reflect perceived potential of the reservoir. In addition to all of these known situations, acreage for some reservoirs varied widely with no apparent or obvious reasons. Some situations of acreage conflicts were decided on a case-by-case basis.

(12) When reported salinities were not available, estimates were made based on typical formation salinities. In many cases, it was sufficient to determine whether it was low salinity (<100,000 ppm TDS) or high salinity (>100,000 ppm TDS). Salinity values were not listed in Table 7–1 (Appendix A) and did not impact directly the resource assessment discussed in this report. However, values were entered in the file and were available for reservoir review as needed.

(13) The heavy oil reservoirs listed in the secondary datafile were not used for estimating U.S. heavy oil resource. Included are reservoirs for which key parameters could not be verified (mentioned in paragraph three), small heavy oil reservoirs (OIP less than 10 MMbbl for California or less than 1 MMbbl for other states), and reservoirs in fields that have been abandoned and have no reported production wells (i.e., plugged). There still needed to be strong indication that API gravity was between 10° and 20° to be listed in the secondary file. Reservoirs with missing gravities were not listed in the secondary file unless a reference source specifically identified it as a heavy oil reservoir.

(14) Where annual production, cumulative production, number of production wells, and total number of wells are available for the entire field but not for the specific heavy oil reservoirs in the field, these values for heavy oil were spread over the entire field (light & heavy oil, no multiple completions of a given well) and proportioned to each reservoir OOIP.

Where productive acreage was known to be significantly different from reservoir acreage (Midway-Sunset, Tulare), productive acreage (published value) rather than reservoir acreage (reported value in our datafile based on isopach maps) was used to prorate the production between reservoirs. In prorating oil production between reservoirs of a field, if permeability and/or viscosity of a given reservoir appeared to have a significant impact on predicted prorated production (production verified from field engineers where possible), a revised basis of prorating production was used. Instead of OOIP, production was prorated on the basis of OOIP/viscosity or OOIP*sqrt(permeability)/viscosity. The preferred choice was to prorate on the basis of OOIP alone, unless introduction of viscosity or permeability substantially changed the overall result.

(15) For lithology, SS stands for consolidated sandstone matrix, UFS for friable or unconsolidated sandstone matrix, and others (marine, etc.) are for carbonate reservoirs. The assignment was based on knowledge of formations in the region when specific information was not available. Detailed references were not always available and in-depth studies were not conducted on a reservoir by reservoir basis. This qualification is particularly important for two reasons: (a) definition and characterization of reservoirs according to degree of consolidation is not well standardized, and these assignments, based on commonly available information, are not easily made; and (b) degree of consolidation is particularly important to the potential success of steam injection processes as a means of oil recovery.

(16) Some additional information not reproduced in this report in Table 7–1, Appendix A, was incorporated in the study as available. The primary and secondary datafiles were formatted into relational files for Macintosh FoxBase. The electronic file was developed with provisions for entering additional auxiliary data elements not discussed here including comments, notes, and multiple references related to each data element. Although not included in this

report, this additional information constituted a part of the study and was available for internal use on the project.

(17) For fractured shale reservoirs, permeabilities were not reported and a value of "-1" was entered into the datafile, even when reported permeability values were available.

(18) A key part to the development of any reservoir information file includes the procedures used for reviewing and checking entered information for errors. Errors are an inevitable part of the process.

Table 2–2 summarizes the individual review processes completed for the datafile listed in Table 7–1 (Appendix A). All text entries were reviewed for spelling errors and spelling consistencies. Since sorting is dependent on spelling, these errors are easily identified when sorting by columns and visually comparing by groupings. Slight differences in word orientation are also identified by this procedure and were corrected to enable more convenient sorting (i.e., South Belridge changed to Belridge, South so that Belridge, North and Belridge, South sorted together).

Numerical errors are easily spotted by downloading the file into spreadsheets and comparing entry values with calculated values. Differences are identified quickly with spreadsheet comparison commands. Self-consistency checks are more difficult and were based on engineering judgment. For example, when sorted by region and formation, a number of parameters will have similar values within certain variation limits. Depth, porosity, permeability, net pay, geological series, and depositional environment all will be somewhat similar within a given formation. Reservoir parameters falling outside the normal ranges for each of these formations were reviewed again for accuracy. Such a review included checking against the original source for possible entry error, directly contacting a representative such as the California District Engineers to double check the information with their sources, reviewing other sources not normally checked, and sometimes contacting the operators directly. If no additional information was available, no changes were made and the differences were accepted.

Self-consistency checks were performed comparing one number with another for a given reservoir. For example, reported cumulative production and OOIP are derived from separate data. Cumulative production should not exceed OOIP, and all reservoirs with remaining saturation values less than 20% or greater than 80% were reviewed. Acreage was checked by calculating spacing (acres/total wells) and comparing with reservoir viscosity and recovery. Extreme cases were reviewed. For example, 70% recovery is expected from 80 acre spacing pattern with reservoir oil viscosity at 5,000 cp and depth at 1,000 ft. Having no record of any steamflood operations would cast further doubt on the parameter values. For California, oil saturation values were reported separately as S_{oi} (percent) and S_{oi}

(bbl/acre*ft). Both values were compared after conversion. Estimates differing by more than 15% were reviewed for errors in porosity or initial oil saturation. When it was not possible to identify the better choices, the reported S_{oi} (percent) was accepted.

Table 2–2 Database Fields Sorted and Internal Checks Calculated to Identify and Correct Entry Errors in Table 7–1 (Appendix A)

	Field Sorted	Checks Made
State	State	spelling; state consistent with county, district, & basin
Field	Field	spelling
Reservoir	Reservoir	spelling
Formation	Formation	spelling; formation consistent with reservoir
County	County	spelling; county consistent with district
District	District	spelling; district consistent with county
Basin	Basin	spelling; basin consistent with district and state
Geo Series	Geo Series	spelling
Dep. Env.	Dep Env.	spelling
Lith	Lithology	spelling
Region	Region	spelling
Field	Field Code	field code consistent with field name
Field Code	Field	field name consistent with field code
Reservoir	Reservoir No.	reservoir number consistent with reservoir name
Reservoir No.	Reservoir	reservoir name consistent with reservoir number
Region	State	state consistent with region
Temp.	State	temperature consistent with temperature gradient
Salinity	State/formation	salinity consistent for formation group within reason
Geo Age	Geo Series	geological series should be consistent with geological age
Geo Series	Geo Age	geological age should be consistent with geological series
Geo Series	Formation	geological series should be consistent with depositional environment
Dep. Env.	Formation	depositional environment should be consistent with formation
Depth	Formation	depth consistent for formation group within reason
Porosity	Formation	porosity consistent for formation group within reason
Perm.	Formation	permeability consistent for formation group within reason
Net Pay	Formation	net pay consistent for formation group within reason
Permeability	Lithology	lithology should be consistent w/ permeability (fractured shale =-1, dolomite or limestone <200, etc.)
Viscosity	check	consistent with calculated number
Cum. Prod.	check	cumulative production should be <80% of OOIP
Cum. Prod.	check	if cumulative production is >60% of OOIP, review all data
OOIP	check	OOIP should equal 7758.3678*por*area*netpay*Soi
OIP	check	OIP should equal OOIP-Cum. Prod.
OIP	check	OIP should be <100% reservoir volume
OIP	check	OIP should be >20% reservoir volume
Recovery	check	should equal (cumulative production)/OOIP
Area	check	calculated well spacing (acres/tot. wells) should be consistent with viscosity & oil recovery
Gross Pay	check	gross pay should be > net pay
Net Pay	check	net pay should be consistent with representative logs
Swi	check	Soi+Swi=1 (some exceptions)
Soi	check	Soi should be less than 1
Soi	check	if Soi is >0.8, double check all values
Porosity	check	Soi should be ≈ Sat.(B/AF)/(porosity*units factor)
Soi	check	Soi should be ≈ Sat.(B/AF)/(porosity*units factor)
Sat. (B/AF)	check	Soi should be ≈ Sat.(B/AF)/(porosity*units factor)
Wells, Tot	check	calculated well spacing (acres/tot. wells) should be consistent with viscosity & oil recovery
Wells, Prod	check	# production wells should be 0 if annual production is 0
Wells, Prod	check	# production wells should be < # total wells
Lith	check	check inconsistencies (SS if porosity<21% & mD<500; UFS if por>27% & mD>1000)

In summary, the purpose of this data base was to estimate the heavy oil resource for the U.S., where the resource is located, and to estimate how difficult it will be to recover the heavy oil. The usefulness of the compiled reservoir information is a function of how easily this compiled information can be assessed (database format), consistency of the methodology for obtaining and compiling the information (consistent choices between conflicting information), how easily the methods and assumptions for deriving individual values can be identified for comparison with other reported or derived values (reference citations), and how thoroughly the data elements in the file have been reviewed for entry errors (self-consistency checks). All aspects of this process were incorporated.

As already discussed, one of the disadvantages of a single entry database is the inability to represent an irregularly shaped and variable property formation by individual numbers. As used in this datafile, reservoir volumetric parameters were calculated based on regular configurations. Anytime an average value is reported as a representation of an entire reservoir, the needed detail for assessing the economic prospects of production on a lease-by-lease basis is lost. Indeed, anyone familiar with the reservoir is likely to consider the reported values not representative, or simply, wrong. To mitigate this difficulty, ranges of values were also entered when known (see Table 7–3).

2.2 Resource Estimate

A method of screening the heavy oil reservoirs in the datafile was developed to provide estimates of heavy oil reservoir candidates for known recovery technologies. Robustness was built into the approach by developing a method of ranking the heavy oil reservoirs from best to worst, and grouping these reservoirs into three categories, i.e., favorable, marginally favorable and unfavorable. The purpose for the database was to guide DOE funding programs in developing the U.S. heavy oil resource and not to select individual heavy oil reservoirs for development. More importance was placed on aggregate resoure estimates than on individual reservoirs.

Screening Criteria

The first approach was to identify heavy oil reservoirs acceptable for thermal recovery based on screening criteria. To test this approach, California heavy oil reservoirs were first reviewed and prescreened. Those reservoirs missing permeability values were removed. Permeability is a critical variable in predicting the potential for steam injection. In addition, those reservoirs with viscosities less than 100 cp were removed. These reservoirs are often targets for waterflood recovery.

A screening criteria for steamflood recovery (Chu 1985) was applied to the remaining 119 candidate heavy oil reservoirs to separate the reservoirs into three groups: favorable, marginally favorable, and not favorable (see Table 2–3). All of the reservoirs identified as having successful thermal recovery projects (52 total) should be categorized as favorable or

marginally favorable. However, ten of the successful field projects (19% of total) were identified as not favorable by this approach as shown in Table 3–5. Furthermore, very little distinction was observed between the favorable by this approach as shown (21 successful field projects) and the marginally favorable (21 successful field projects) groups.

Table 2–3 Comparison of Screening Methods on Selected California Heavy Oil Reservoirs

	Steamflood Screening Crit. (No. Reservoirs)[1]	Chu SOR[5] (No. Reservoirs)[1]	Steam Injectivity[4] (No. Reservoirs)[1]	Total Reservoirs[2]
Favorable[3]	21	24	35	47
Marginally Favorable	21	16	13	42
Not Favorable	10	12	4	30
Total	52	52	52	119

1 Reservoirs where 1 or more thermal recovery projects lasted longer than 4 years.

2 California Heavy Oil Reservoirs: Permeability > 0 mD (excludes fractured shales); in situ viscosity >100 cP

3 Favorable: porosity*Soi>0.15; net pay>30 ft.; 500<depth≤3,000 ft.; permeability*net pay/viscosity>100
Marginally Favorable: Otherwise favorable reservoir, depth>3,000 ft. OR 400<depth<3,000 ft.; porosity*Soi>0.08; net pay>10 ft.; 400<depth<3,000 ft; permeability*net pay/viscosity>50
Not Favorable: The rest of the heavy oil reservoirs with viscosity >100 cp and permeability values known.

4 Defined as net pay*steam permeability/steam viscosity

5 Ref. Chu 1985.

One possible explanation for the discrepancies between performance and screening criteria is that successful field thermal projects have been operated in reservoirs with high oil viscosities (>3,000 cp), a limiting criteria in this screening approach. Canadian heavy oil and bitumen deposits, also with very high oil viscosities, have been successfully recovered. However, high oil viscosity values produce poor transmissibility values in screening criteria and do not reflect the successes just mentioned. This approach was not considered effective in separating favorable from unfavorable reservoirs for steamflood candidates.

Steam/Oil Ratio

Another approach was to estimate the required instantaneous steam/oil ratios (SOR) based on reservoir parameters. An empirical parameter set was developed based on 20 heavy oilfield projects (Chu 1985). Chu developed two empirical formulas for a range of SOR values. However, the equation for SOR≤5 was based on only eight reservoirs and was found to be unreliable for our dataset. Consequently, only the equation for SOR>5 was used in screening reservoirs even though some of the values exceeded the recommended SOR range. These formulas were applied to the same 119 reservoirs evaluated with the screening criteria discussed in the previous paragraph. The resulting reservoirs were ranked according to the steam/oil ratio and grouped by favorable, marginally favorable, not favorable and

were poorly predicted by this approach. As can be seen in Table 2–3, the results were very similar to that of the screening criteria. As before, 12 of the successful projects (23% of total) were in reservoirs identified as not favorable and were poorly predicted by this approach. Some distinction was observed between the favorable (24 successful projects) and the marginally favorable (16 successful projects) groups.

A major difference between the empirical SOR approach and the other two screening approaches (screening criteria, steam injectivity) is that the formula correlates increasing depth favorable to the SOR ratio criteria. This may be true up to about 3,000 ft (very few examples used by Chu were for depths >3,000 ft), but beyond 3,000 ft thermal efficiency decreases due to increased heat losses from the wellbore and decreased heat capacity of steam (overall higher temperatures). Reservoirs deeper than 3,000 ft appear more favorable and reservoirs less than 1,000 ft deep less favorable as compared to the other ranking methods. Although somewhat better, this approach was not considered very effective in separating favorable from non-favorable reservoirs for steamflood candidates.

Steam Injectivity

A third approach to screen reservoirs was developed based on steam injectivity. The idea was based on the principal that oil production is a function of the steam injected, and that reservoirs more favorable to steam injection would be successful. The same 119 California reservoirs were ranked from highest to lowest injectivity with respect to steam. The rankings were further grouped to favorable, marginally favorable, and not favorable. As can be seen in Table 2–3, this screening approach was more successful in ranking California reservoirs with successful field projects. Only four reservoirs considered successful were ranked in the not favorable category by this approach, one of which was a fireflood and not likely to be a successful steamflood due to the low permeability (200 md). Of the other four, two were low in permeability (<400 md) and two had a net pay of ≤50 ft. Therefore, this approach was accepted in this study as a first approximation to characterize the potential for oil recovery by thermal methods.

Resource Assessment

The steam injectivity screening method was applied to all reservoirs in the primary datafile. Reservoirs with unknown permeability values were removed. Waterflooding candidates (those with viscosity less than 100 cp) were analyzed separately. The remaining reservoirs were sorted by steam injectivity and categorized according to favorable, marginally favorable, or not favorable. Recovery factors were applied to these categories. The purpose was to estimate the total resource amenable to recovery, but not to vigorously determine heavy oil reserves for each reservoir.

For groups favorable to steamflooding, ultimate recovery for the entire reservoir was estimated at 50% of total OOIP less the cumulative production to date. For the marginally

favorable group, the ultimate recovery was estimated as 25% of total OOIP less the cumulative production to date. For the waterflood favorable group, estimated recovery was 35% of OOIP less the cumulative production to date. This is a bit high for waterflooding, but recovery was estimated high due to the application of advanced recovery processes. Estimates for steamflooding were a bit conservative and were arbitrarily selected. However, they are consistent with the upper limits found in the database.

As shown in Table 2–4, about 11 billion bbl of heavy oil have already been produced in the U.S., 9 billion bbl was produced from California reservoirs. About 68 billion bbl of heavy oil remain in the U.S., of which 63 billion bbl is located in California. Most of this heavy oil is not likely to be recovered applying current technology and economics (waterflooding, steamflooding). Approximately 4 billion bbl heavy oil (viscosity less than 100 cp) is candidate for waterflooding and nearly 8 billion bbl for steamflooding. Other known recovery methods including gas flooding and in situ combustion are expected to contribute, but are relatively small.

Not included in Table 2–4 is the Alaskan heavy oil, which could account for another 25 to 40 billion bbl. There are also a number of other reservoirs excluded accounting for potentially another 5 to 6 billion bbl heavy oil.

Finally, Table 2–4 also shows that a substantial amount of heavy oil is potentially recoverable if suitable technologies are developed. That is, much of the remaining heavy oil is not recovered with current steam and waterflooding technology. One of these targets is the Monterey formation in California with 21 billion bbl heavy oil, of which 17.5 billion bbl was excluded from thermal and waterflooding recoverable (fractured shale with unspecified reservoir permeability values).

Table 2–4 Summary Estimate of U.S. Heavy Oil Resource Based on Reservoirs in Table 7–1 (Appendix A)

	U.S., MMbbl	California, MMbbl	Other, MMbbl
Total Heavy Oil (OOIP)	79.1	71.6	7.6
Total Heavy Oil (OIP)	68.3	62.8	5.5
Recoverable Steam (Favorable)	6.8	6.8	0
Recoverable Steam (Marg. Favorable)	1.0	1.0	0.037
Recoverable Waterflood	4.2	4.0	0.18
Recoverable Total	12.0	11.8	0.22

2.3 Summary

Based on the data collected, 535 heavy oil reservoirs have been identified and were used to make resource estimates. It was estimated that 68.3 billion bbl heavy oil remain in these reservoirs in the U.S. Of the 68.3 billion bbl heavy oil, 62.8 billion bbl is located in California and half of this oil is located in seven fields. The Gulf Region has about 3.5 billion bbl heavy oil. An additional 490 heavy oil reservoirs have been identified including substantial deposits of heavy oil in Alaska. The deposits of West Sak and Ugnu in Alaska are potentially comparable with California deposits. Alaskan heavy oil-in-place is estimated to be 25 to 40 billion bbl. Unfortunately, technological and economic challenges prevent current production of West Sak and Ugnu.

A qualitative estimate was made of the total resource target based on current production technology. On this basis, about 12 billion bbl of the total 68.3 billion bbl may be recoverable—4 billion bbl by waterflooding and 8 billion bbl by steamflooding. Virtually all of this recoverable oil is in California. This suggests technology development is needed to have a significant impact on heavy oil production outside of California.

As part of this study, specific evaluations were conducted on different geographic regions to explore in more detail geological and reservoir characteristics of these heavy oil reservoirs. A brief discussion of these investigations is given in the next section, and are meant to add to the understanding of the reservoirs outlined in this section. The reader should refer to the individual reports for more detailed discussions.

3.0 U.S. HEAVY OIL RESOURCE, REGION STUDIES

The following sections are divided more or less by geographic region: Midcontinent Region, Appalachian Basin, Black Warrior Basin, Illinois Basin, Michigan Basin, Permian Basin, Alaska, California, and Gulf Region. The particular studies focused on a more detailed description of the reservoirs in the respective regions. Where available, documented information on successes and failures of advanced recovery processes were discussed. Estimated resource values reported elsewhere were also reviewed. Geological descriptions were also summarized or discussed as appropriate.

3.1 Midcontinent Region (Kansas, Missouri, Oklahoma) (Olsen 1993, 1995)

From the database, approximately 606 MMbbl of heavy oil remains in-place in Oklahoma, Kansas, and Missouri, most of which (584 MMbbl) is located in Oklahoma. There are a number of small carbonate reservoirs in Kansas containing heavy oil that are not included in the main file due to insufficient information. Production from these reservoirs has been very low both individually and collectively. The heavy oil in Missouri has been pretty much confined to the reservoirs listed in Table 7–1 (Appendix A). Several reservoirs in Oklahoma were excluded from the main file due to missing key information. Of these, the only one of potential significant size is Osage reservoir in the Carrier field. Acreage and porosity were not confirmed making resource estimates tentative.

Other estimates of total heavy oil resource for this region have been higher. For Kansas, Ebanks et al. estimates 225 MMbbl heavy oil in Cherokee, Crawford, and Bourbon counties (Ebanks et al. 1977). For Missouri, Heath estimated 1.4 to 1.9 billion bbl (Heath 1979). Bradshaw indicated there was 200 to 250 MMbbl of heavy oil in Missouri (Bradshaw 1985). Later estimates were much lower and total recoverable is estimated as being less than 5 MMbbl (Olsen 1993). For Oklahoma, Harrison estimated the resource at 800 MMbbl for the South-Central region of Oklahoma (Harrison 1982). Additional heavy oil has been reported in the Northeast section of Oklahoma, but firm numbers are elusive (Olsen 1993).

Of the total heavy oil resource, 45 MMbbl is estimated as recoverable—most from Oklahoma (Olsen 1993, 1995). The primary reason for low recoverables is attributed to the geology of the reservoirs. Most of the reservoirs are in consolidated or highly cemented rock formations. Although a number of recovery projects have been tried, the economic variables are not as favorable as for friable or unconsolidated formations more common in the younger rock formations of California.

Based on the screening procedures and the reservoir data in the datafile, 14 MMbbl of oil is potentially recoverable by thermal methods, and another 13 MMbbl is potentially

recoverable by waterflooding. All the oil identified as potentially recoverable is located in Oklahoma. These estimates are based on the lower permeabilities and thinner sands commonly found in the Midcontinent.

Projects have been successful in recovering heavy oil from the Midcontinent region, although details of the projects are lacking and economic failure was the norm (Olsen 1993). The projects found to be technically and economically successful were conducted in reservoirs with permeabilities > 500 md. The following is a listing of projects discussed in the DOE report (Olsen 1993).

- U.S. Department of Energy (1978-1981). Attempted in situ combustion projects in Labette County, Kansas. A sustained fire front was not obtained.
- Sun Oil Company (1965-1968). Attempted in situ combustion projects in Allen County, Kansas. Economics were not attractive due to required operating and capital investment costs associated with using old wells.
- Sinclair Research, Inc. (1956-1960). Attempted in situ combustion in Allen County, Kansas. Details are not available, but based on known information, production increases were marginal and economic values are expected to be unfavorable.
- Carmel Energy, Inc. (1976-1978). Attempted Vapor Therm process in Carlyle Pool, Allen County, Kansas. Additional oil was recovered.
- Survey of Kansas TEOR Projects (1966). A number of early thermal recovery projects are surveyed. Some additional oil was recovered, but in general, project expansions were not pursued. Heavy oil recovery did not appear to be economically viable.
- Phillips Petroleum Co. (1955-1958). Attempted in situ combustion in southwestern Missouri. Some additional oil was produced.
- Carter Oil Co. (1955- ca. 1959). Steam drive was attempted in Warner Formation, Missouri. Additional oil was recovered.
- Shell Oil Co. (1963-1966). Steam injection was attempted in Missouri. Additional oil was recovered.
- Henry Petroleum Co. (1965-1976). Little is known about this project.
- Dotson Oil Co. (1966-1980). An air injection process was tried in Missouri. Some 18,000 bbl of heavy oil was recovered.
- Benyon Energy Co. Conducted a carbon dioxide-steam project in Missouri.
- Jones-Blair Energy, Inc. (1982-1987). Conducted a carbon dioxide-steam project in Missouri. Some 133,000 bbl of heavy oil was recovered.
- Carmel Energy, Inc. (1978-1992). The Vapor-Therm recovery process was conducted in Missouri. Cumulative production exceeded 550,000 bbl, the largest production project from a field in Missouri.

- Mobil Oil Co. (1953). In situ combustion was successfully applied to a reservoir in southern Oklahoma. Approximately 25% of the pattern was swept by the combustion front.
- Shell Oil Co. (1964-1966). Shell Oil implemented a steam project in Oklahoma.
- Mobil Oil Co. (1962-1968). Mobil implemented a fireflood in Carter County, Oklahoma. Some oil was produced.
- Mobil Oil Co. (1986-1992). This steam project is still going in Carter County, Oklahoma. Of all the formations in Oklahoma, this one (Fourth Deese Sand in Sho-Vel-Tum field) was most like those found in California. The sands were friable to unconsolidated and relatively clean of swelling clays.

3.2 Appalachian, Black Warrior, Illinois, and Michigan Basins (Olsen 1992)

Heavy oil deposits in these basins constitute a negligible contribution to the total in the U.S. Approximately 12 MMbbl heavy oil is the estimated remaining resource in these basins. Using the screening method described earlier, none of the heavy oil is readily recoverable by waterflooding or thermal recovery methods. Some small amounts may be produced in isolated pools. A more detailed discussion of these areas is provided in a separate publication (Olsen 1992).

3.3 Permian Basin (W. Texas, SE New Mexico) (Olsen and Johnson, 1993)

This basin comprises reservoirs in West Texas and Southeast New Mexico. From the datafiles, the estimated resource for the Permian Basin is between 105 and 247 MMbbl remaining heavy oil in place. Although notable, it is not as large as that of the Midcontinent, and is certainly much smaller than that of California or Alaska. Only five reservoirs are listed in the primary datafile (estimated 105 MMbbl remaining OIP). Trinity reservoir in Toborg field, Texas, and all of the heavy oil reservoirs from New Mexico were listed in the secondary datafile due to uncertainties in key data elements.

The resource estimate is not well defined for several reasons. The largest heavy oil reservoir in this basin, Trinity in Toborg field, was estimated with 100 MMbbl OOIP. About 41 MMbbl of heavy oil has been reported as produced from this reservoir, which constitutes 39% recovery from primary and waterflooding processes. Some concerns on the accuracy of the reported production from this reservoir and associated API gravities (varies from 10° to 30°) are discussed in a separate report (Olsen and Johnson 1993). This reservoir was not included in the primary datafile because of these well known discrepancies.

In addition, a number of heavy oil reservoirs from this basin are located in New Mexico and were not included in the primary datafile due to unavailability of reliable information. As much as 52 MMbbl of heavy oil may remain in these reservoirs. Combined with that of Trinity (Toborg) and other reservoirs in West Texas, our basic estimate of 105 MMbbl heavy oil in the Permian Basin may be low by as much as 142 MMbbl, giving a total of 247 MMbbl OIP.

From the screening method described earlier (steam injectivity), none of the five reservoirs in the primary datafile were candidates for thermal recovery and an estimated 1 MMbbl may be recoverable by waterflooding in one reservoir, Wolfcamp (E. Blalock Lake Field in Texas).

A more detailed discussion of the geology and characteristics of reservoirs in the basin are given elsewhere (Olsen and Johnson 1993).

3.4 Alaska (Olsen, Taylor, and Mahmood 1992; Mahmood, Olsen and Thomas 1995)

Limited information on the heavy oil resource in Alaska has prevented its inclusion in the primary datafile. Estimates of OOIP vary from 25 to 40 billion bbl or more for the combined West Sak, Lower Ugnu, and Upper Ugnu formations. Estimates of heavy oil for other unexplored areas such as the Alaska National Wildlife Refuge (ANWR) are non-existent. West Sak formation underlies Kuparuk River and Milne Point operating units and is the deepest of the three major formations. The Ugnu sands lie above West Sak, and all formations slope downward to the North and East (Milne Point Unit area). More details of reservoir parameters and geology are discussed elsewhere (Olsen, Taylor, and Mahmood 1992; Mahmood, Olsen and Thomas 1995).

Current heavy oil production is minimal, and is only a fraction of the total production from Alaska (3,000 bbl/D from Schrader Bluff Pool, Milne Point unit). Because Schrader Bluff Pool is from the deepest section of the heavy oil formations (West Sak, Ugnu), viscosities are lower. Current declines in the major light oil reservoirs are causing producers to look for other attractive properties in Alaska to maintain the flow of oil through the Trans-Alaska Pipeline System (TAPS). Increasing production from these giant heavy oil reservoirs are seriously being considered (*Oil & Gas Journal* 1995).

Resource estimates from West Sak vary from 15 to 25 billion bbl OIP (Thomas, Allaire, Doughty, Faulder, Irving, Jamison, and White 1993; Werner 1984; Werner 1986). West Sak viscosities are generally lower than those found in the Ugnu sands. Resource estimates for Lower Ugnu range from 6 to 11 billion bbl and for Upper Ugnu range from 5 to 8 billion bbl (Werner 1984, Werner 1986). The state of Alaska has estimated technical recovery of 0.5 to 1 billion bbl from West Sak (Thomas, Allaire, Doughty, Faulder, Irving, Jamison, and White 1993). Atlantic Richfield Company (ARCO) has estimated 0.5 billion bbl recoverable

(Sullivan 1991). Technical issues need to be resolved pertaining to recovery techniques, environmental sensitivity and transportation/marketing of Alaska North Slope heavy oil.

3.5 California

Remaining heavy oil in California is estimated at 62.8 billion bbl, and nearly 12 billion bbl of this may be recoverable economically with existing technology. One-half of this remaining oil lies in seven fields: Wilmington, Hondo Offshore, Point Pendernalas Offshore, Midway-Sunset, Cat Canyon, Santa Maria Valley, and Huntington Beach. Another one-fourth of this remaining oil lies in eight fields: Orcutt, San Ardo, Kern River, Coalinga, South Belridge, McKittrick, Poso Creek, and Mount Poso. A more detailed discussion is presented on some of these fields.

California reservoirs are listed in Table 7–1 (Appendix A). Information from a variety of sources reflect variations across the fields (see Table 3–1). Natural variation in depths, thickness, etc. are expected across the larger fields. For example, Monarch (Spellacy) reservoir (Midway-Sunset) is given as 1,300 ft deep, but depth ranges from 600 to 2,000 ft (Table 3–1). The following paragraphs discuss in more detail some of the more important characteristics of California's largest heavy oil fields.

Wilmington Field: Wilmington field (Appendix B) is the largest heavy oil field in California (see Table 3–1) with an estimated nearly 10 billion bbl heavy oil currently in place. It is also a major heavy oil producer (currently fourth largest in California) and is in a distinguished group of fields having produced over a billion bbl heavy oil to date.

This field is an asymmetrical anticline located in the southeast portion of Los Angeles County on the Orange County border, and inside and offshore of the City of Long Beach. This field is approximately 11 miles long and 3 miles wide covering a productive area of roughly 13,500 acres. Estimated heavy oil resource is 11 billion bbl OOIP. This field is the largest heavy oil reservoir in California and the Continental U.S.

Faulting contributes to the complexity of the Wilmington field. Most discussions show 10 major fault blocks trending north to northeast. On the flanks, the formation dip ranges from 20° in the north to 60° in the south. The Conservation Committee of California Oil & Gas Producers in their annual production report segregates production into 74 reservoir units, described by 19 fault blocks, four areas (Town Lot, Terminal, Harbor, and East), and eight production zones.

Included in the heavy oil producing zones are Ranger, Tar, and Upper Terminal. Light oil producing zones include Lower Terminal, Union Pacific, Ford, 237, and Schist. Production zones span a geographical region that includes both inland and California offshore properties. These reservoirs were split between onshore and offshore in this study, but

otherwise were combined by formation type. Other sources separate the isolated sections by fault blocks.

Midway-Sunset Field: Midway-Sunset (Appendix B) is the second largest heavy oil field in California. It is a major heavy oil producer (currently the largest producer in California). It has produced over 1.7 billion bbl heavy oil, using steam and in situ combustion processes.

Table 3–1 List of California Heavy Oil Fields Ranked by Heavy Oil Resource and Production

Field	OOIP, MMbbl	OOIP, rank	OIP, MMbbl	OIP, rank	Cum Prod, bbl	Cum Prod, rank	Ann Prod, bbl	Ann Prod, rank
Aliso Canyon	29.8	63	23.9	65	5,902,298	47	32,649	51
Ant Hill	51.3	52	44.6	52	6,763,188	46	51,352	42
Antelope Hills	80.3	50	64.6	50	15,711,710	38	239,195	32
Arroyo Grande	39.1	57	31.8	60	7,389,000	44	455,028	19
Barham Ranch	18.6	74	18.4	71	263,000	74	5,294	69
Belridge	2,353	9	1,710	12	643,273,000	4	43,431,397	3
Beta Offshore, Federal OCS	805	23	754	23	50,640,331	24	5,308,128	8
Blackwells Corner	21.1	69	20.3	68	812,760	67	14,375	59
Cascade	27.6	66	25.8	63	1,823,000	59	32,782	50
Casmalia	980	20	940	20	39,614,000	28	335,480	25
Castaic Junction	77.4	51	58.0	51	19,467,960	35	66,504	41
Cat Canyon	3,273	6	3,057	5	215,705,653	9	976,929	16
Chico-Martinez	14.5	76	14.0	76	470,778	69	2,651	73
Cienaga Canyon	17.2	75	16.9	75	324,900	71	19,166	58
Coalinga	2,013	11	1,795	11	217,957,988	8	3,244,582	11
Cymric	1,488	16	1,328	16	159,779,304	13	7,918,344	6
Devils Den	287	33	285	32	1,371,990	64	10,655	62
Edison	1,271	18	1,181	17	89,745,792	17	1,649,877	14
Fruitvale	1,105	19	1,028	19	76,573,869	21	315,412	26
Guadalupe	267	34	229	36	38,337,000	29	68,250	39
Hasley Canyon	20.1	71	17.9	72	2,198,000	56	120,791	34
Holser	42.6	54	42.6	54	500	80	196	76
Hondo Offshore, Fed.-OCS	6,284	2	6,177	2	106,998,039	14	8,211,684	5
Huasna	24.2	68	24.2	64	23,000	79	0	80
Hueneme, Fed.-OCS	31.0	62	23.7	66	7,261,000	45	422,478	20
Huntington Beach	3,421	5	2,851	7	569,266,366	5	1,726,614	13
Jasmin	89.4	49	86.0	49	3,393,000	52	66,614	40
Jesus Maria	35.5	58	35.2	57	285,000	73	0	78
Kern Bluff	112	45	100	46	11,928,000	39	5,724	68
Kern Front	1,330	17	1,153	18	177,148,000	12	2,332,029	12
Kern River	3,096	7	1,802	10	1,293,639,000	2	43,994,168	2
King City	19.7	72	17.8	73	1,845,000	57	3,802	71
Kreyenhagen	13.1	78	13.1	77	43,000	77	1,060	75
Las Posas	7.9	80	7.9	80	32,560	78	0	79
Lompoc	520	27	475	26	45,490,453	26	367,630	23
Los Angeles City	158	42	136	42	22,123,357	32	44,360	45
Lost Hills	366	30	268	33	98,603,000	15	249,957	31
McDonald Anticline	258	36	257	34	1,407,033	63	20,655	56
McKittrick	1,858	13	1,664	13	194,140,291	10	938,816	17
Midway-Sunset	6,159	3	4,374	4	1,785,047,734	1	52,842,903	1

Table 3–1 List of California Heavy Oil Fields Ranked by Heavy Oil Resource and Production (Cont.)

Field	OOIP, MMbbl	OOIP, rank	OIP, MMbbl	OIP, rank	Cum Prod, bbl	Cum Prod, rank	Ann Prod, bbl	Ann Prod, rank
Monroe Swell	33.6	60	33.3	59	295,001	72	3,779	72
Montalvo West	397	29	368	29	29,331,120	30	119,623	35
Montebello	545	25	446	27	98,420,536	16	280,591	29
Mount Poso	1,698	14	1,410	15	288,587,588	7	4,803,838	9
Newhall	39.5	56	37.1	56	2,388,000	54	6,943	66
Newport, West	260	35	251	35	9,294,000	41	411,055	21
Ojai, Sulphur Mountain	41.9	55	41.5	55	387,000	70	4,432	70
Olive	13.8	77	11.4	78	2,375,000	55	37,947	47
Orcutt	1,946	12	1946	8	183,810	75	8,157	64
Paris Valley	11.2	79	11.1	79	135,000	76	106	77
Placerita	306	32	286	31	20,503,887	34	303,483	27
Playa Del Rey, Venice	183	40	142	41	40,802,400	27	20,114	57
Pleito	32.6	61	30.8	61	1,828,260	58	6,274	67
Point Pendernales, Fed.-OCS	4,553	4	4,529	3	24,197,880	31	5,959,782	7
Poso Creek	1,542	15	1,463	14	78,467,103	20	388,449	22
Pyramid Hills	97.5	47	92.5	47	4,921,000	48	48,579	43
Railroad Gap	19.5	73	17.7	74	1,758,745	60	21,364	55
Raisin City	28.8	64	18.4	70	10,491,040	40	42,782	46
Ramona	95.9	48	87.6	48	8,269,716	43	34,895	49
Richfield	937	22	891	22	46,447,055	25	284,173	28
Rosedale Ranch	138	43	129	43	8,895,590	42	47,841	44
Round Mountain	488	28	407	28	81,678,190	19	259,222	30
Salt Lake	953	21	901	21	51,783,999	23	126,696	33
San Ardo	2,245	10	1,826	9	418,887,231	6	3,702,901	10
Sansinena	111	46	106	44	4,730,396	49	36,012	48
Santa Maria Valley	3,058	8	2,867	6	191,052,953	11	1,017,575	15
Simi, Canada De La Brea	171	41	169	39	2,425,385	53	24,748	54
Summerland	126	44	105	45	20,514,000	33	112,370	37
Tapia Oil Field	20.8	70	19.2	69	1,540,644	61	11,824	60
Tapo Canyon	25.6	67	21.6	67	3,957,619	50	28,798	52
Tapo, North	44.2	53	43.8	53	550,439	68	2,162	74
Tejon	541	26	523	25	18,259,078	36	80,557	38
Torrance	639	24	581	24	58,590,479	22	351,054	24
Union Avenue	28.7	65	27.2	62	1,514,000	62	9,321	63
West Mountain	318	31	314	30	3,950,000	51	27,865	53
Wheeler Ridge	34.6	59	33.3	58	1,314,000	65	7,251	65
White Wolf	207	39	206	38	1,147,000	66	10,981	61
Whittier	233	38	216	37	17,636,582	37	116,363	36
Wilmington	11,090	1	9,940	1	1,151,472,811	3	13,013,361	4
Yorba Linda	239	37	153	40	86,300,049	18	910,089	18

The Midway-Sunset field is a NW-SE trending field located on the west southwest edge of Kern County with a small portion in San Luis Obispo County. The field is approximately 25 miles long and three miles wide covering a productive area of approximately 25,000 acres. It lies to the south of the town of McKittrick, California, and runs between the towns of Maricopa on the southwest edge of the field and Taft on the northeast edge of the field. The field's name is derived from the Midway production area near Taft and the Sunset production area near Maricopa. The field is estimated to have had about 6.6 billion bbl OOIP

which includes 0.5 billion of light oil. It is currently the number one producing field in the state of California, with cumulative production in 1993 approaching 2.2 billion bbl. The three major producing zones are the Tulare, Potter (or Olig), and Monarch; all are extensively steamed.

The field generally dips 13° as it thickens to the east. To the extreme north, there is a nose-out area that in times past was called the Belgian Hills area. The Midway Valley Syncline lies on the northeast edge of the field. It starts one mile northwest of the Republic pools and cuts to the east of the northern Republic pools. The Spellacy Anticline runs through the southern Republic pools and cuts across the field to the southeast, exiting the northeast edge of the field 2.5 miles northeast of Maricopa.

Some confusion occurs when comparing names associated with production pools to names associated with vertically aligned formations. An example is Leutholtz (Metson) reservoir. Production numbers separate the reservoir into separate pools, Leutholz and, slightly to the southeast, Metson. Often, individual zones are combined differently making cross-referencing of production numbers to individual horizons nearly impossible. This is compounded by the "Others" production zone as reported by the Conservation Committee of California Oil and Gas Producers, which accounts for over 90% of the total field production. In the absence of clear assignment of production to individual formations, we were forced to artificially divide the production to individual reservoirs.

There are a number of oil-bearing zones in the Midway-Sunset Field. These include the following heavy oil producing zones: Calitroleum, Gusher, Kinsey, Leutholtz (Metson), Marvic, Moco, Monarch (Spellacy), Mya Tar, Obispo, Pacific, Potter, Republic, Top Oil, Tulare, Webster, and Wilhelm. Light oil zones include Lakeview, Sub-Lakeview, Antelope Shale, Pulv, and Pioneer. In addition to the reservoir data already discussed, specific points need to be mentioned that point out issues needing clarification critical to Midway-Sunset field analysis.

For Midway-Sunset, Tulare, the acreage is given as 5,000 acres in the literature (California Division of Oil and Gas 1985). However, isopach maps of Tulare indicate the reservoir to be much larger at 18,316 acres. The larger value was used in the original datafile. Unfortunately, isopach maps were not available for all of the reservoirs in Midway-Sunset field, and estimates of other reservoirs reported in the literature may be more conservative. This difference also impacts the estimate for reservoir production determined according to reservoir size (OOIP) which is a direct function of acreage. For this report the productive acres for Tulare was assumed to be 5,000 acres for the purposes of estimating individual reservoir production from field production, but reservoir acreage was listed as 18,316 acres in the database and the larger value was used in estimating the ultimate resource. Subparagraph 14 Subsection 2.1 of this report discusses this calculation method in more detail.

For Midway-Sunset, Potter (or Olig), the acreage is given as 3,000 acres in our datafile and is supported by documentation. However, other sources cite this reservoir with 320 acres, It

was determined that the 320 acres included only the Olig pool in the far northern section of the field, not the entire reservoir.

For Midway-Sunset, Republic, the acreage given by the California Division of Oil and Gas was
80 acres, but consultants to this project estimated this value to be higher. An intermediate value of 205 acres was selected.

Kern River Field: Kern River (Appendix B) is the seventh largest heavy oil field in California (including Federal OCS), and it is a major heavy oil producer (currently the second largest in California). It has produced over a billion bbl of heavy oil to date. An aggressive steam injection program in this field is the reason for strong production.

This field was discovered in 1899 when several wells were drilled to supply Bakersfield with lubricating oil. By 1904, the field was producing 17 MMbbl/yr. After this, production declined until World War II when increased drilling produced dramatic increases in production. Kern River field is located about five miles northeast of Bakersfield on the southeastern edge of the San Joaquin Valley. Estimates of productive acres range from 9,660 to 12,100. The structure of the field is a simple homocline that dips 3° to 6° to the southwest. The principal formation of the field is a braided alluvial system deposited by the westwardly-flowing Kern River. The trapping mechanism is predominantly stratigraphic with an updip tar seal and stratigraphic pinch outs. The productive Kern River Sand series consists of an alternating sequence of unconsolidated sands with considerable interbedded silts and clays. These sands consist of up to nine thick productive sand bodies varying from 30 to 100 ft thick, separated by mudstones averaging 20 ft in thickness. Ultimate recovery from the Kern River sands is estimated at 1.9 billion bbl (this would be about 60% of OOIP in Table 7–1, Appendix A).

The resource estimate of 1.9 billion bbl is by no means the highest. Other estimates include 4 billion bbl (Bursell et al. 1966), 4 billion bbl (Brelih 1990), and 3.6 billion bbl (Energy Development Consultants/Stone & Webster 1983). Acreages from these references are higher (11,000–12,000 acres) than the value accepted for this study. The reported porosities and net pay vary as shown in Table 7–3 (Appendix A). As stated earlier, the primary information sources accepted for California were those published by the California Division of Oil & Gas (DOG), unless specific information suggests more reliable parameters. The resource value in this study is based on volumetric calculations from DOG numbers and represents a reasonably conservative estimate.

South Belridge Field: Although Belridge (North and South, Appendix B) is the ninth largest of the heavy oil fields in California (including federal OCS), they are major heavy oil producers (currently the third largest producer in California). South Belridge is the dominant producer of the two Belridge fields, and an aggressive steam injection program in South Belridge has enabled it to be a major producer for the state of California.

South Belridge field is located on the western side of Kern County about 40 miles west of Bakersfield and 10 miles north of McKittrick. The field lies along a NW trending anticline and is ten miles long, NW to SE, and 1.5 miles wide, NE to SW. The field was discovered in 1911, and initial production was commingled with the Diatomite zone. The Tulare zone generally dips to the NE and varies from 0° to 3° at the crest and 15° at the edge. The average dip is 7° to 9°. Some E-W faults lie in the northern part of the field.

South Belridge Field contains the Tulare heavy oil zone. It also contains Antelope Shale and Diatomite light oil zones. The Tulare zone can be divided into three sections: (1) non-producing top zone, (2) Upper Tulare Oil Zone, and (3) Lower Tulare Oil Zone. The Lower Tulare Oil Zone pay covers 9,600 acres and is 75 ft thick (net). The Upper Tulare Oil Zone extends over 5,760 acres with a 90 ft net pay (Miller et al. 1990).

Federal Offshore Fields: Point Pendernalas and Hondo Offshore fields (Appendix B) are not officially considered part of California. Data reported on these fields are sparse. However, the size of the heavy oil reservoirs is substantial and deserves some mention. Furthermore, if combined with California proper, these fields rank fifth and seventh currently as heavy oil producers.

Point Pendernalas was discovered in 1982. Cumulative production from the heavy oil Monterey formation is still low (24 MMbbl). However, the potential is huge as indicated by the volumetric calculation in this study: 4.5 billion bbl OOIP in almost 20,000 acres. Because of the depth (6,600 ft) the reservoir temperature is relatively hot at 215°F, and the oil viscosity is low for heavy oil at 6 cp.

Hondo Offshore, Monterey formation, is very similar in characteristics to Point Pendernalas. Although the oil is considered heavy by density (17°API), it is deep (8,200 ft) and hot (210°F) resulting in a low viscosity of 9 cp. From a resource and refining viewpoint, this reservoir represents a very large heavy oil resource. This study estimated the OOIP to be 6.3 billion bbl.

Huntington Beach Field: Huntington Beach (Appendix B) ranks as the fifth largest heavy oil field in California (including federal OCS) with 3.4 billion bbl OOIP. It currently ranks 13th in heavy oil production, although cumulative production for Huntington Beach ranks it fifth, making it also a major heavy oil producer for California (see Table 3–1). Two-thirds of current production comes from the offshore area.

Huntington Beach has the sixth largest waterflood operation in California. Due to extensive waterflooding with fresh water sources, the salinity in parts of the field has dropped to 14,400 ppm vs. the original 30,000 ppm. Overall, the field produces oil ranging in gravity from 11° to 31°API. Productive reservoirs are in the Lower Pliocene Repetto and Upper Miocene Puente formations.

Huntington Beach field lies southeast of Wilmington field and the City of Long Beach, in Los Angeles County, California. The field lies both onshore and offshore. Maximum proved

acreage is 6,295 acres with 3,930 acres being onshore and 2,365 acres being offshore (California Division of Oil & Gas 1991). The proven productive areas are 2,385 acres for offshore and 1,163 acres for onshore.

Huntington Beach is highly faulted with numerous fault blocks onshore and offshore. The major Newport-Inglewood fault zone runs NW-SE for one mile away from and parallel to the shore line. Due to the highly faulted nature of the field, depth and dip of the reservoirs vary throughout the field. Dip is 30–40° near the Newport-Inglewood fault zone to the NE; 16–25° further away from the fault to the NE; 0–5° SW for the fault onshore and 16–25° offshore.

Cat Canyon Field: Cat Canyon field (Appendix B) ranks as the sixth largest heavy oil field in California (including federal OCS) with about 3.3 billion bbl OOIP and 3.0 billion bbl OIP. It currently ranks 16th in heavy oil production, although cumulative production for Cat Canyon ranks it ninth. Production has fallen considerably since 1981 (then at 5.1 MMbbl, annually) to current levels of near 1 MMbbl/annually.

Cat Canyon field is located in the Santa Maria Basin in Santa Barbara County, California, and lies southeast of Santa Maria Valley field and East of Orcutt field. The west area lies SW of the Sisquoc area to the extreme north. East, Central and Gato Ridge areas lie progressively further southeast of the Sisquoc area. The smaller Olivera Canyon and Tinaquaic areas lie to the extreme east of the field and have relatively little production. Estimated field reserves in 1993 stood at 25.7 MMbbl (California Division of Oil & Gas, PR06, 1994).

One major fault line in Cat Canyon field lies along the NE edge of the West area. This fault is downthrown to the SW, and dips towards the NW. This fault terminates in the Sisquoc S9-S10 sands, where it runs into another fault that cuts more to the center of the West area.

Another major fault line lies along the NE edge of the East and Central areas. This fault is downthrown to the SW. The East and Central areas to the SW of the fault dip towards the NW. East and Central areas to the NE of the fault dip towards the NE. This fault terminates in the Sisquoc S9-S10 sands. This fault continues in a SE direction along the SW edge of the upthrusted Gato Ridge area. Dip in the Gato Ridge area is to the east. Another downthrown block pinches out the Upper Monterey Brooks sand in the East area. Olivera Canyon and Tinaquaic areas are upthrusted areas like Gato Ridge, and the dip is to the North. Sisquoc area dip is to the NW.

The crude oil varies in gravity from 6° to 24°API. Production is primarily from below the S1B electric log marker in the Lower Pliocene Sisquoc formation and from fractured shale, sands, and cherty zones at the top of the Upper Miocene Monterey formation. The Los Flores cherty zone in the West area is intensively fractured (Huey 1954). Steamfloods were conducted in the East and Sisquoc areas between 1967 and 1990. Waterflooding was conducted in the Central area between 1965 and 1986. Gas injection was conducted in the West area between 1947 and 1955, and is currently being tried in the Gato Ridge area.

Santa Maria Valley Field: Santa Maria Valley field (Appendix B) ranks as the eighth largest heavy oil field in California (including federal OCS) with 3 billion bbl OOIP and 2.9 billion bbl OIP. It currently ranks 15th in heavy oil production, although cumulative production for Santa Maria Valley field ranks it 11th. Production has fallen since 1981 (then at 3 MMbbl, annually) to current levels of about one MMbbl annually. A majority of the heavy oil produced comes from the Bradley and Main areas of the field. Estimated field reserves in 1993 stood at about 16 MMbbl (California Division of Oil & Gas, PR06, 1994).

Santa Maria Valley Field is located in the Santa Maria Basin in Santa Barbara County, California to the northwest of Cat Canyon Field and north of Orcutt Field. The field trends from NW to SE. It is approximately 16 miles long and 0.5 to two miles wide. Field areas are non-continuous. The West area is to the extreme NW. The Bradley area lies in the SE part of the field and NW of the Clark area. All of these areas are considerably smaller than the Main area, which lies in the center of the NW-SE trend line. Most of the faults in Santa Maria Valley run NE to SW across the Main area, but three NW-SE faults run along the NE edges of the Main, Clark and Southeast areas. Dip in all areas is to the SW.

The crude oil varies in gravity from 7° to 19° API. Most of the production comes from basal sands in the Lower Pliocene Foxen and Sisquoc formations; from fractured shales, sands, and cherty zones in the Upper Miocene Monterey formation; and from sands in the Middle Miocene Point Sal formation. Currently, only waterflooding is being conducted in this field, primarily in the Bradley area, Basal Sisquoc formation.

San Ardo Field: San Ardo field (Appendix B) ranks as the tenth largest heavy oil field in California (including federal OCS) with 2.2 billion bbl OOIP and 1.8 billion bbl OIP. It currently ranks tenth in heavy oil production, although cumulative production for San Ardo field ranks it sixth. Production has fallen since 1981 (then at 10.2 MMbbl, annually) to current levels of about 3.7 MMbbl, annually. Production is currently on the rise from its lowest level reached in 1991.

San Ardo field is located in Monterey County in the Coastal Region of California. The small 70-acre North area, originally called the Lombardi or North Lombardi area was discovered in 1957 and abandoned in 1986. The large 4,320-acre, NW-SE trending Main area is about five miles long and two miles wide. Production in the Main area comes from the unconsolidated friable Middle Miocene Lombardi and Aurignac sands. The Los Lobos Thrust Fault cuts slightly across the extreme WNW corner of the San Ardo Field. The downthrust portion lies towards the field to the ENE. Dip of the field ranges from 0° to 5°. The dip is steepest on the SW and NE flanks, somewhat gentler in the NW part of the field and flatter to the SE.

The crude oil varies in gravity from 9° to 14°API. The shallower Lombardi is 2° or 3° heavier than the Aurignac. A majority of the oil has been produced from the Aurignac sands through most of the 1980's. However, in about 1989, production from Aurignac sands has decreased below that of Lombardi, which has continued to rise slowly since the middle 1980s. Estimated field reserves in 1993 stood at 101.2 MMbbl.

Total California Heavy Oil Production (Olsen, Ramzel, and Pendergrass II 1992)

As already discussed, most of the heavy oil in the U.S. is located in California. Furthermore, much of this resource has been developed, and because of the high viscosity of most heavy oils, California is also the largest producer of crude oil by enhanced oil recovery methods (EOR). Some method of EOR is usually needed to reduce the oil viscosity. Steam injection has been most successful because of favorable geology. Most of the reservoirs are less than 4,000 ft deep, permeabilities are high (>1,000 md), and the overall sand thicknesses exceed 50 ft in many of the reservoirs. All of these reservoir characteristics improve the economics of a steamflood operation. This has been the case in spite of the most stringent environmental regulations in the nation and deeply discounted heavy oil prices.

Figure 3–1 shows that historically dominantly lighter crude oils were produced during 1940 to 1960. However, since 1955, the production of light crude oil declined as the light oil reservoirs matured and heavy oil production increased. Heavy oil production was further stimulated by the Presidential Order (August 17, 1979) exempting most heavy crude oils from federal price controls. By 1985, production of heavy oil peaked in California, exceeding the production rate of light oil in 1950. Production of heavy oil was predominantly in three regions—San Joaquin Valley, Los Angeles Basin, and Coastal region. As can be seen in Figure 3–2 production within each of these regions increased and decreased as the reservoirs matured, each peaking at a different time. Currently, the San Joaquin Valley is the dominate heavy oil producing region of the state.

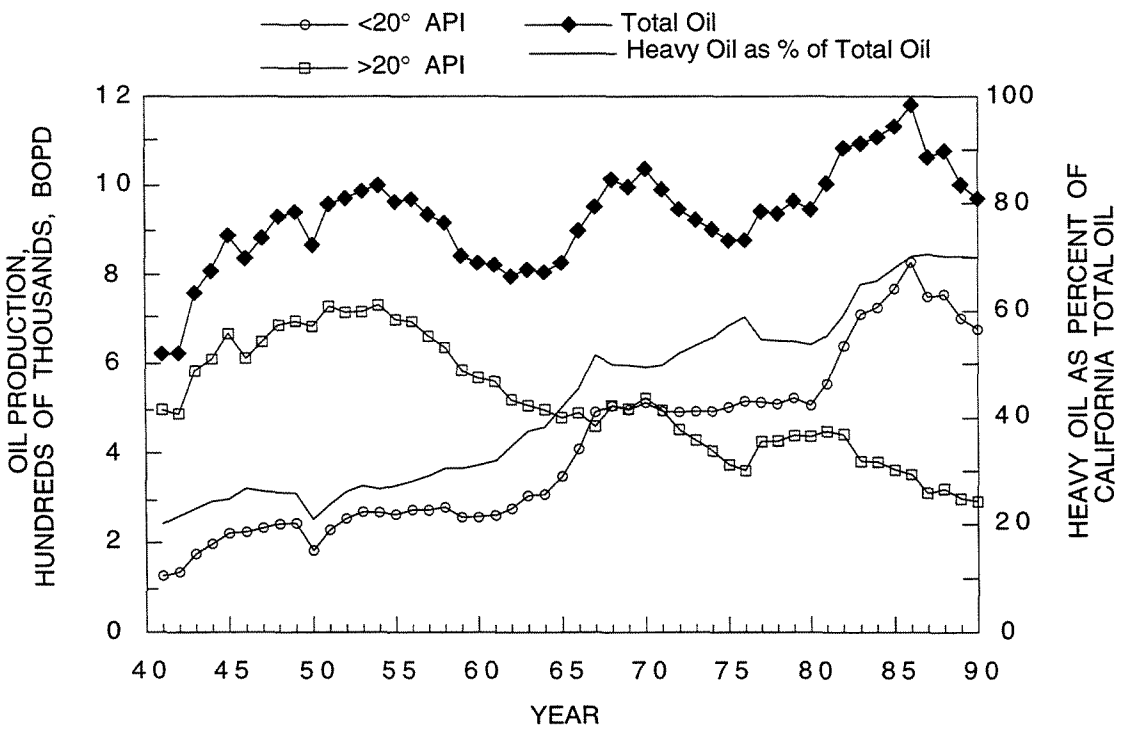


Figure 3–1 California Heavy and Light Oil Production Since 1940

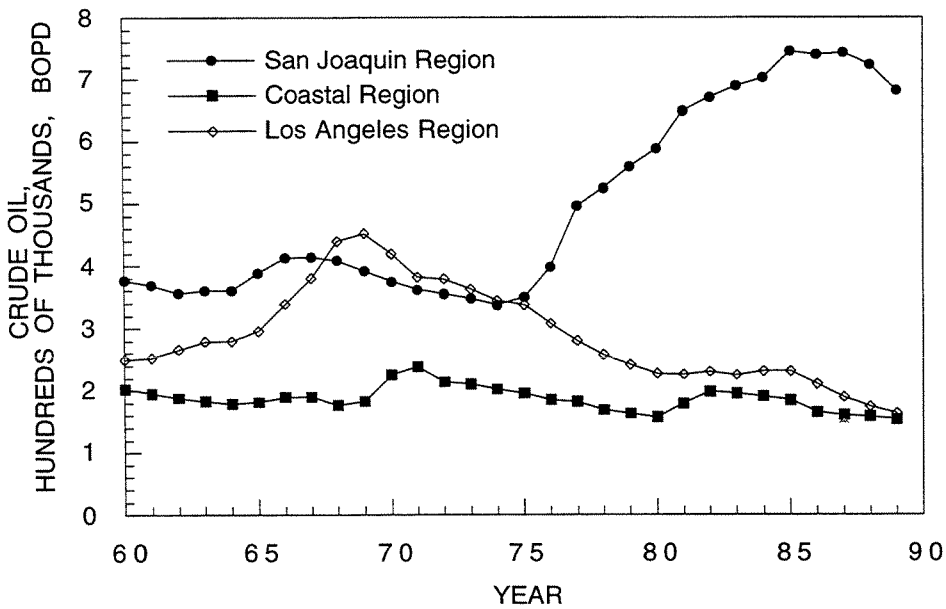


Figure 3–2 California Crude Oil Production by Region Since 1960

To process heavy oil at the refiner, increased resid hydrotreating and coking capacity is needed. Such increased refining capacity was also ideal for processing the medium gravity oil (27°API) produced from Alaska (started in 1977). Thus, the current oil supply to refiners in California is sufficient to satisfy product demand. Prices are not sufficiently high to encourage production of less economically favorable oil (Grigsby 1990). Total production of crude oil in California is 960,000 bbl/day (1991) or nearly 13% of the nation's total production, and California is the fourth largest producing state in the nation (Petroleum Producer 1992).

3.6 Gulf Region (Sarkar and Sarathi 1992, Sarkar and Sarathi 1993)

Outside of California only Alaska and the Gulf Coast Region have sizable heavy oil deposits. Only about 3.5 billion bbl was identified in 190 reservoirs in the Gulf Coast Region. A more detailed study was conducted to evaluate the reservoirs in the Gulf Coast Region to determine the feasibility of increasing heavy oil production. Indeed, over 30 thermal recovery projects in the Gulf Coast Region have been conducted and documented, and at least half of these were considered successful and profitable by the operators (Sarkar 1994). The best reservoirs were studied in detail using simulation tools.

The first group of reservoirs considered were in the Nacatoch formation of southern Arkansas and northern Louisiana. Reservoirs were screened based on established steamflood screening tools (published screening criteria, prediction models) to narrow the selection. Additional information was obtained directly from the operators including well logs, production history, geologic characterization, fluid properties, etc. The reservoir parameters listed in Table 7–1 (Appendix A) were then modified based on the detailed information received to reflect the better sections of the field and were studied in more detail using CMG's STARS simulation software. Because the reservoir parameters in Table 7–1 (Appendix A) are fieldwide average values, they did not accurately represent the selected sections from within the reservoirs better suited for thermal recovery processes, nor were they suitable for detailed simulation studies.

Thirty-one heavy oil reservoirs were initially identified. Of the 31, five reservoirs were identified as promising for steamflood. Using predictive models (SUPRI, GOMAA, Jones, and Intercomp), the three best Nacatoch reservoirs were Chavirari Creek, Irma, and Troy. The Nacatoch formation in the Chavirari Creek field was selected for more detailed study. As compared to California heavy oil reservoirs, it was relatively thin (23 ft), low permeability (186 md), with an average oil saturation (44% oil) and moderate viscosity (180 cp at reservoir conditions).

Detailed simulation studies determined that cyclic steam injection was ineffective due to the lack of strong gravity drainage (formation was thin and flat). Economics of continuous injection benefited from higher injection rates. Due to the low permeability and relatively thin formation, use of horizontal wells with steamflooding was found to be beneficial. Unfortunately, current oil market prices would provide only marginal profits at best.

A similar study was conducted of 73 reservoirs in Texas (Districts 1 through 4). Of the 73 reservoirs, 16 were found promising. Because of the typical reservoir characteristics and the availability of detailed reservoir data, Taylor-Ina field, Navarro formation was selected for detailed study. A pilot cyclic steam injection project was conducted in 1966 in the Hutzler "A" lease and would serve as a useful comparison to simulation results for other parts of the field. As with many of the Texas heavy oil reservoirs, the formation was relatively thin (18 ft), permeability was low (50 to 240 md), but the oil saturation was good (46 to 62% oil). The sand was poorly consolidated and the large field (7,700 acres) suggested a significant potential if found to be economic.

As with the Charivari Creek field, cyclic steam process simulation results were not encouraging and considered uneconomic at current conditions. Use of horizontal wells with steamfloods improved the steam injectivity and overall oil recovery. However, overall economics remained only marginally favorable in even the best cases. Simulation of the in situ combustion recovery processes were not conducted due to the limitations of the software and hardware. However, the thinner and less permeable formations are amenable to injected gases such as air. Recommendations to further study this approach were made.

3.7 Summary

It is fortunate that most of the heavy oil in the U.S. is also located in formations that are relatively thick and unconsolidated (California). Thick and unconsolidated formations enable efficient injection of steam for viscosity reduction and efficient production of the oil. Steam injection projects have been tried in other regions of the U.S., including the Midcontinent, Permian, and Gulf Coast Regions. Many of these projects have successfully recovered heavy oil. However, economic success has generally been limited to the thick unconsolidated sands in California. Alaska has the next largest deposits of heavy oil outside of California. However, the deep permafrost, the transportation costs to California refineries, and the environmental challenges associated with production operations appear to be too costly for the current oil market. As a result, very little of the heavy oil resource is currently under development. Only a limited amount of heavy oil was located in the Gulf Coast Region. Simulation and economic studies showed that the better reservoirs had only marginal potential.

4.0 IMPACT OF ACCELERATED PRODUCTION ON U.S. REFINING

As previously mentioned, the purpose of this overall project was to determine if stimulating domestic heavy oil production is feasible and at what cost, and to determine to what extent increased heavy oil production could lessen the decline of domestic crude oil production. Previous sections of this report estimated the heavy oil resource in the U.S. and a fraction of the total that is potentially recovered. Knowing these values provides an understanding of how big an impact an accelerated heavy oil production program might have on the domestic production decline.

In addition to considering production potential, the impact to refining capacity was also considered. Upgrading processes are required in the refinery to convert the heavy ends of a crude oil into usable petroleum products, and because heavy oil has substantially more heavy ends, the cost associated with its conversion is higher. Unfortunately, this cost translates into less value to the oil producer in a competitive market. Artificially increasing the heavy oil supply to the refiner by incentive programs may saturate the U.S. refineries and artificially lower the spot oil price. The result would be counter productive in the short-term without balanced incentives for refining with appropriate timing.

The following study was initiated to evaluate the impact of accelerated heavy oil production to the current U.S. refinery capacity. If additional refining capacity was needed to process the additional heavy oil, an estimate of the additional costs were made. This study was later expanded to include an estimate of the level of incentives needed by the government to support expansion to the proposed production levels, because the original study predicted that projected open market prices were too low to support proposed expansions.

The first phase of the evaluation required that an initial market analysis of the global oil supply/demand trends be developed along with projected changes through the period being studied (years 1990 through 2010). These figures were calibrated to known values in the year 1990. The bulk of the projections and expansion cost estimates were developed in 1992. The expanded incentive evaluation was somewhat delayed, but was completed in 1995.

4.1 Accelerated Heavy Oil Production

U.S. domestic oil production continues to decline (see Fig. 4–1), and any resource evaluation of this type must pose the question of whether accelerated production of heavy oil could make a favorable impact to the overall industry. Because heavy oil requires additional refining, the most logical choice between cheap light crude oil and the more expensive to produce and refine heavy crude oil is the light crude oil—even if imported. The production and refining of heavy oil in California represents an excellent example of domestic heavy oil replacing domestic light oil as resources are depleted (see Fig. 3–1).

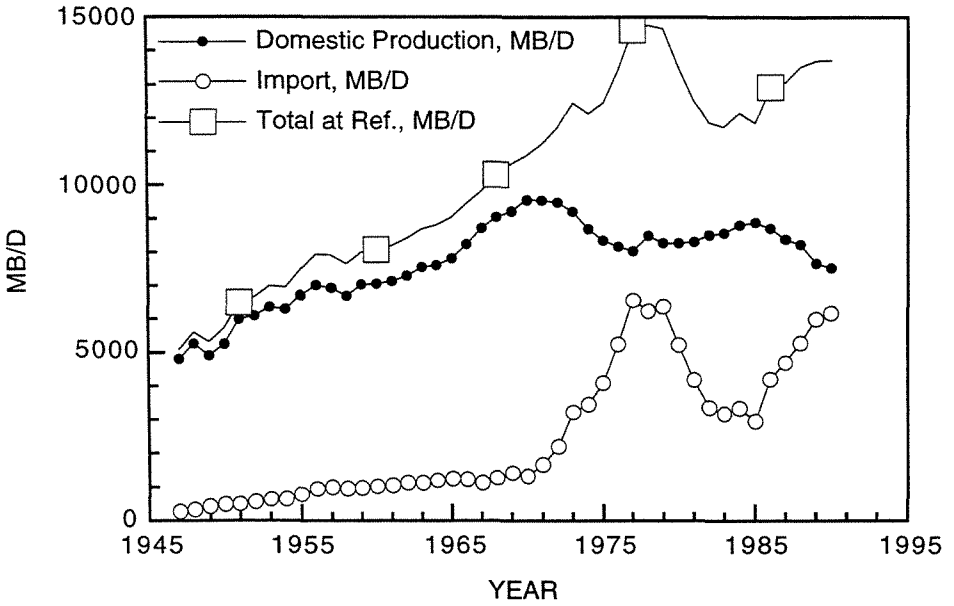


Figure 4–1 Historical U.S. Production and Consumption History of Crude Oil (API 1995)

In California, production of lighter crude oil peaked in the 1950s but have declined since then (Olsen, Ramzel, and Pendergrass II 1992). At the same time, production of heavier crude oil increased and peaked in the mid-1980s. The subsequent decline was in part due to the decrease in the worldwide oil price. These trends underlie the increases in crude production for the State of California during the same time period. This increase in heavy oil production was made possible by the presence of large heavy crude oil deposits with relatively favorable depositional environments. Steamflooding, the primary method of choice for heavy oil, was discovered to be a successful process (late 1950s to early 1960s).

A related question is the impact to existing refining capacity associated with a major shift in refinery feedstock composition. The industry in the State of California was able to justify long lead times and high capital investments to add capacity in the 1960s. A cost is associated with this change. Could the current industry justify increasing heavy oil production? If refiners are not willing to buy the oil at a reasonable price, producers are not going to produce it regardless of how much remains in the reservoir.

Based on preliminary information, two production rate increases were hypothesized: 300 Mbbl/D and 900 Mbbl/D by the year 2010. A more detailed discussion of how these production increases were assigned to various regions of the U.S. is given in a separate report (Olsen, 1993). The higher value was selected based on a separate study for U.S. heavy oil production (Brashear et al. 1991, National Energy Strategy 1991). The lower value was considered because the proposed increase of 900,000 bbl/D in less than 20 years was unprecedented and inconsistent with known required lead times to make major

expansions. The objectives were to determine from which regions of the country incremental heavy oil production would occur, determine the required adjustments to local refineries to accommodate such production increases, and determine what costs would be associated with the expansion of existing capacity.

Based on the heavy oil resource assessment in previous sections of this report, a determination was made as to which regions could accommodate accelerated production rates. The options available included California where most of the heavy oil is currently being produced, Alaska with the next largest heavy oil resource, and the Gulf Region with a limited but producible quantity of heavy oil.

Production increase was to happen within a 20-year period. Given the time frame and known locations of heavy oil deposits, it was argued that Alaska would not see such large heavy oil production increases. In fact, as will be described in the following section, a preliminary economic assessment of the industry worldwide indicated that oil production from Alaska would see a substantial production decline through this 20-year period and would not be a major producer from the year 2010 and beyond. Considering the added costs and technical challenges of producing heavy oil in Alaska's severe environment and the costs of transporting Alaskan heavy oil to California for processing, it was argued that heavy oil production increases in California would likely occur before substantial production of heavy oil occurred in Alaska. A significant technological breakthrough would be needed to make the Alaska heavy oil resource a serious consideration prior to the year 2010. The export of Alaskan North Slope (ANS) crude oil to other countries was not considered.

Increased production rates are feasible in California given that the market price to the producer is adequately high. However, California is a closed market from the refining standpoint. That is, most of the fuel products from refineries in California are consumed on the west coast. The current refineries are operating near capacity with existing local heavy oil production and the large volume of medium gravity oil being shipped from Alaska. To accommodate increased production, the oil would either have to be shipped or pipelined to another region, such as the Gulf Coast, or the refinery capacity would need to be increased beyond what is currently required. In either case, the market price to the producer is likely to decrease. It would appear that a major change in the overall California market would be required before any proposed increases in heavy oil production would result. Again, the impact of exported ANS crude oil to other countries was not addressed by these studies.

The Gulf Region has a much larger refining capacity (see Table 4–1) and a less restrictive product market. The impact of increased heavy oil production would be less; the penalty to the producer will be less; and the market price is more likely to support the proposed accelerated production. Unfortunately, the Gulf Region has only a limited heavy oil resource of about 3.5 billion bbl. Furthermore, the oil in the Gulf Region is primarily located in thinner and less permeable reservoirs. Such reservoirs are not as economically suitable for steamflooding, and acceptable alternatives are not readily available. From a production perspective, a major technological change is needed before any proposed increases in heavy oil production from the Gulf Region can occur.

TABLE 4–1 U.S. Refining Capacity by Region in 1990 (MB/SC)

	Charge Capacity								Production Capacity								
						.....Hydro Process											
DOE Region	CRD[1]	VAC[2]	THRM[3]	FCC[4]	REF[5]	CRK[6]	REFINE[7]	TRT[8]	ALK[9]	POLY[10]	ISOM[11]	AROM[12]	LUBES	ASPH[13]	DEASP[14]	H_2 MMcf/SD	COKE MT/SD
Region 1	1,391.9	630.2	76.3	529.6	310.2	50.7	96.3	727.7	77.0	13.5	38.0	15.9	29.1	146.5	9.5	92.9	3.7
Region 2	2,467.4	1,020.2	255.5	832.3	664.2	109.9	264.3	1,175.2	182.2	10.8	114.8	61.0	17.6	228.1	12.2	142.9	11.2
Region 3	722.4	244.5	61.6	225.9	175.8	5.9	63.0	294.1	62.6	5.0	61.7	4.9	9.0	19.1	14.7	9.0	3.0
Region 4	1,232.8	719.6	196.1	321.1	306.5	235.4	258.8	488.7	63.0	8.5	10.5	–	18.3	48.7	49.1	537.3	8.3
Region 5	6,059.7	2,512.3	780.0	2,144.1	1,615.9	380.5	1,194.4	3,099.2	473.5	36.1	213.9	199.8	120.2	176.2	166.9	912.7	29.8
Region 6	485.7	183.2	17.7	159.8	115.8	7.1	45.1	203.3	30.7	6.8	15.7	–	–	46.8	14.9	22.8	0.9
Region 7	343.3	65.6	37.0	17.2	22.5	22.0	–	23.9	4.1	1.0	5.0	2.3	–	10.4	–	29.6	–
Region 8	8.7	6.6	–	–	–	–	–	–	–	–	–	–	–	6.8	–	–	–
Region 9	1,111.4	598.1	314.0	346.5	276.3	131.1	266.9	512.1	72.2	2.7	9.5	–	–	47.2	–	463.9	13.7
Region 10	108.7	46.0	20.6	--	23.9	11.6	14.9	17.5	--	--	--	--	8.2	9.0	--	18.9	0.6
	13,932.0	6,026.4	1,758.8	4,576.6	3,510.9	954.0	2,203.6	6,541.7	965.2	84.3	468.9	283.8	202.2	748.7	267.0	2,229.9	71.3

1 = Crude Distillation; 2 = Vacuum Distillation; 3 = Thermal Processing; 4 = Fluid Catalytic Cracking; 5 = Catalytic Reforming; 6 = Catalytic Hydrocracking; 7 = Catalytic Hydrorefining; 8 = Catalytic Hydrotreating; 9 = Alkalation; 10 = Polymerization; 11 = Isomerization; 12 = Aromatics; 13 = Asphalt; 14 = Deasphalting.

This study assumed proposed increases in heavy oil production for the purpose of evaluating the impact to the refining capacity. An assignment of production on a regional basis was required to evaluate refining issues. Therefore, production was primarily assigned to be California and the Gulf Region, but a greater increased production was assigned to the Gulf Region temporarily (through year 2010). It was expected that production rates would soon thereafter decrease in the Gulf Region as reservoirs matured and increased production rates would come from California.

The details of the production increases by region for hypothesized production targets are given in Tables 4–2 and 4–3, and discussed in separate reports (Olsen 1993; Olsen, Ramzel, Strycker, Guariguata, and Salmen 1994). The discussion summarizes the impact to existing refining capacity should the proposed heavy oil production increases occur. Unfortunately, both this study (base case) and a subsequent related incentive study have determined that neither proposed increase (300,000 B/D, 900,000 B/D) is likely to occur in the foreseeable future without a major change in current petroleum market forces.

Table 4–2 Low Heavy Oil Production Rates Through 2010

		DOE Estimates of Incremental Domestic Heavy Oil Production				
Proposed Region	General Location	Mbbl/D As of 1990	Mbbl/D As of 1995	Mbbl/D As of 2000	Mbbl/D As of 2005	Mbbl/D As of 2010
1	East Coast	0	0	0	0	0
	Incremental Production Rate	--	0	0	0	0
2	Upper Midwest	0.25	0.25	0.25	0.25	0.25
	Incremental Production Rate	--	0	0	0	0
3	Midwest (OK, KS, MS)	4.18	5.18	6.18	7.18	9.18
	Incremental Production Rate	--	1.00	1.00	1.00	2.00
4	West Coast (except Regions 8, 9, 10)	0.25	0.25	0.25	0.25	0.25
	Incremental Production Rate	--	0	0	0	0
5	Gulf States	63.96	74.96	108.96	159.96	260.96
	Incremental Production Rate	--	11.00	34.00	51.00	101.00
6	Rocky Mt. Region	20.25	21.25	25.25	28.25	28.25
	Incremental Production Rate	--	1.00	4.00	3.00	0
7	Alaska	0	0	0	1.00	5.00
	Incremental Production Rate	--	0	0	1.00	4.00
8	California Coastal Region	63.80	93.80	113.80	113.80	93.80
	Incremental Production Rate	--	30.00	20.00	0	-20.00
9	Los Angeles Basin	89.90	84.90	79.90	74.90	69.90
	Incremental Production Rate	--	-5.00	-5.00	-5.00	-5.00
10	San Joaquin Valley	500.60	525.60	550.60	563.60	575.60
	Incremental Production Rate	--	25.00	25.00	13.00	12.00
	Total Production Rate	743.19	806.19	885.19	949.19	1,043.19
	Total Incremental Production Rate	0	63.00	142.00	206.00	300.00

Table 4–3 Alternate High Heavy Oil Production Rates Through 2010

Proposed Region	General Location	Mbbl/D As of 1990	DOE Estimates of Incremental Domestic Heavy Oil Production Mbbl/D As of 1995	Mbbl/D As of 2000	Mbbl/D As of 2005	Mbbl/D As of 2010
1	East Coast	0	0	0	0	0
	Incremental Production Rate	--	0	0	0	0
2	Upper Midwest	0.25	0.25	0.35	0.75	1.25
	Incremental Production Rate	--	0	0.10	0.40	0.50
3	Midwest (OK, KS, MS)	4.18	5.18	6.18	7.18	9.18
	Incremental Production Rate	--	1.00	1.00	1.00	2.00
4	West Coast (except Regions 8, 9, 10)	0.25	0.25	0.25	0.25	0.25
	Incremental Production Rate	--	0	0	0	0
5	Gulf States	63.96	75.96	120.46	262.46	618.96
	Incremental Production Rate	--	12.00	44.50	142.00	356.50
6	Rocky Mt. Region	20.25	21.25	30.25	40.25	60.25
	Incremental Production Rate	--	1.00	9.00	10.00	20.00
7	Alaska	0	0	1.00	5.00	30.00
	Incremental Production Rate	--	0	1.00	4.00	25.00
8	California Coastal Region	63.80	93.80	113.80	138.80	163.80
	Incremental Production Rate	--	30.00	20.00	25.00	25.00
9	Los Angeles Basin	89.90	84.90	79.90	87.90	88.90
	Incremental Production Rate	--	-5.00	-5.00	8.00	1.00
10	San Joaquin Valley	500.60	525.60	550.60	600.60	700.60
	Incremental Production Rate	--	25.00	25.00	50.00	100.00
	Total Production Rate	743.19	807.19	902.79	1,143.19	1,673.19
	Total Incremental Production Rate	0	64.00	159.60	400.00	930.00

4.2 Refining Capacity (Olsen, Ramzel, Strycker, Guariguata, and Salmen 1994)

The objective was to determine costs associated with the expansion of existing capacity to accommodate the hypothesized production rate increases. A number of assertions were made in developing this study for the base case (no proposed production increases).

1. The U.S. was divided into ten homogenous regions (see Fig. 4–2). Within each region, the crude oil input, product output, and refinery capacity were assigned average values.
2. EPA does not regulate oil field produced water or oil as hazardous waste.
3. There are no additional government restrictions or fees on importing crude oil. The refining industry operates in a free world market economy.

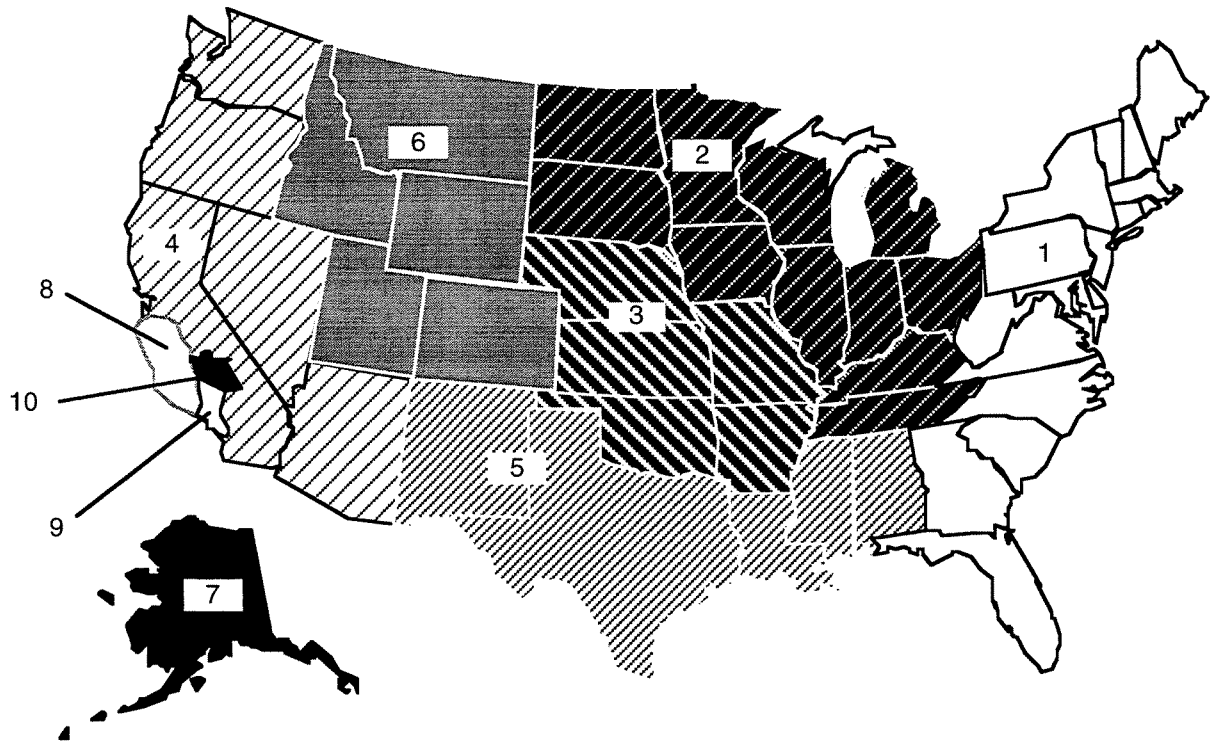


Figure 4–2 Ten Defined Regions With Separate Linear Programming Models in DOE Refinery Feasibility Study

4. There is no government incentive program to stimulate heavy oil production.
5. Environmental and economic restrictions continue to prevent the construction of new grass root heavy oil refineries.
6. The trends in Los Angeles and Coastal Range basins continue to follow the decline established over the past few years.
7. Continued environmental pressure keeps the Los Angeles refineries from expanding, but allows them to operate within the Los Angeles Basin at the current processing levels.
8. Nationalized state oil companies, or major international companies, do not make a major push to take their crude to dedicated refineries so they can corner the market in a given area.

U.S. Market Outlook (1990)

The petroleum products were expected to grow a modest 1% yearly throughout the 20-year period. Most of the product categories were expected to remain flat. Growth was expected for jet fuels and automotive diesel supplies. Fuel efficiency of automobiles was expected to compensate for population growth and keep the demand for this fuel sector flat.

Domestic production was expected to decline 2% yearly. This was due largely to the decline in production of Alaska North Slope (ANS) crude oil. Other domestic crude oil was expected to decline moderately. The difference in crude oil volume was to be made up by imported crude oil, primarily from the Middle East. The over the 50% import dependency threshold was projected to occur on or before 1996.

Based on world supply/demand of crude oil, prices were forecasted to increase in constant 1990 dollars, although only at modest rates (see Table 4–4). A spike is expected in 1998 due to a temporary high utilization capacity in OPEC. Price/capacity would self-correct and make the spike short lived. U.S. refining margins are expected to average about $2.00 /bbl.

Table 4–4 Crude Oil Prices from the Year 1983 to Year 2010

Year	Inflation (%/yr)	Crude Oil Prices ($/bbl) (Constant 1990 Dollars) US Ave. Acq. Cost	WTI Spot	OPEC Basket	Brent	Dubai	Maya (US)
1983	3.82	36.7	38.57		37.61	35.67	
1984	3.68	34.95	35.89		35.06	33.52	
1985	2.97	31.71	33.17		32.56	31.09	
1986	2.73	16.93	17.32		16.38	14.9	14.71
1987	3.09	20.01	21.41		20.59	18.9	14.18
1988	3.26	15.96	17.3		16.2	14.27	12.17
1989	4.69	18.69	20.44	18.06	18.89	16.28	15.29
1990	4.08	22.35	24.45	22.34	23.7	20.39	17.15
1991	3.5	18.89	20.95	17.67	19.55	16.15	12.42
1992	4.04	19.83	21.69	19.5	20.39	17.51	15.97
1993	4.49	20.18	22	19.86	20.71	17.91	16.31
1994	4.2	20.68	22.18	19.83	20.73	18.13	16.38
1995	4	20.59	22.14	19.68	20.67	18.04	16.16
1996	4	20.66	22.28	19.72	20.78	17.98	16.01
1997	4.6	21.3	22.99	20.36	21.45	18.66	16.44
1998	6	25.53	27.38	23.93	25.71	22.12	19.1
1999	5	20.73	22.35	19.78	20.8	17.51	15.55
2000	4.5	21	22.69	20.09	21.13	18.12	15.95
2005	4	22.24	23.98	21.23	22.43	18.91	16.22
2010	4	22.57	24.08	21.85	23.2	20.71	15.76

Industry Profile

The most important market-driven events to impact U.S. refineries to date, have been the motor gasoline lead phasedown and the need to accommodate declining consumption of residual fuels for electric power generation. Significant investments took place for the production of high octane components, to replace lead quality stabilization, and "bottom of

the barrel conversion" to increase volume of higher value products. As a result, the thermal conversion to distillation capacity ratio was nearly doubled, providing the industry with the necessary operational flexibility to address the demand within the prevailing regulatory constraints in a profitable manner.

During 1990, the refining industry responded to mounting environmental concerns, and earmarked significant investments to meet reduced emission motor gasoline specifications before the end of 1992. Capacities of primary downstream refining processes, which yield gasoline and diesel, logged gains, while processes that treat feeds for the secondary units increased because of feed requirements for acceptable quality conversion and light fuels.

The industry accommodated itself to meet the increasingly stringent air quality regulations which require higher oxygen content gasolines in winter and less volatile gasolines in the summer.

Forecasted Crude Oil Supplies

A forecasted U.S. crude demand and supply balance shows moderate increases in crude requirements for refinery runs from 1990 to 2010 (Table 4–5). The domestic oil production decline averages 2% yearly, most of it from ANS decline production (Table 4–6). Domestic heavy oil production in 1990 was about 750 Mbbl/D (Olsen 1993). Despite all efforts by producing countries to increase their crude production capabilities, the incremental production of import crude oil will come from the Middle East.

Projection Scenarios

The following ten regions were defined:

1. East Coast: Florida, Georgia, S. Carolina, N. Carolina, Virginia, W. Virginia Pennsylvania, and New York
2. Upper Midwest: Tennessee, Kentucky, Ohio, Indiana, Illinois, Iowa, Michigan, Wisconsin, Minnesota, N. Dakota, S. Dakota
3. Midwest: Oklahoma, Kansas, Missouri, Arkansas, Nebraska
4. West Coast: Washington, Oregon, California (excluding regions 8, 9, 10), Arizona
5. Gulf States: New Mexico, Texas, Louisiana, Arkansas (several southernmost counties), Mississippi, Alabama
6. Rocky Mt.: Idaho, Montana, Nevada, Utah, Colorado, Wyoming
7. Alaska
8. California: Southern Coastal
9. California: Los Angeles Basin
10. California: San Joaquin Valley

Table 4–5 Projected U.S. Crude Oil Supply and Demand From 1990 to 2010, Mbbl/D

		Supply	
	Demand	Domestic	Foreign
1990	13231	7356	5867
1991	13235	7339	5889
1992	13174	7230	5955
1993	13107	7050	6087
1994	13226	6930	6298
1995	13246	6757	6499
1996	13380	6588	6802
1997	13514	6423	7100
1998	13632	6263	7361
1999	13522	6106	7418
2000	13551	5953	7603
2050	13917	5114	8814
2010	14292	4509	9793

Table 4–6 Projected U.S. Crude Oil Supply by Region From 1990 to 2010

		Total	DOE Regions									
Year		x10E-3 bbl/D	1	2	3	4	5	6	7	8	9	10
1990	Domestic Produced	7,543	30	337	529	6	3340	585	1773	48	223	672
	Domestic Refined	7,543	13	1443	648	1101	2745	405	217	8	855	108
	Total Refined	13,410	1285	2330	682	1194	6060	460	237	8	1046	108
1995	Domestic Produced	6,918	20	289	466	6	3144	521	1490	51	239	692
	Domestic Refined	6,918	9	1315	587	970	2590	363	182	9	785	108
	Total Refined	13,416	1286	2332	682	1194	6061	461	237	9	1046	108
2000	Domestic Produced	6,118	10	249	415	5	2884	472	1070	54	252	707
	Domestic Refined	6,118	4	1186	512	791	2363	336	131	9	678	108
	Total Refined	13,724	1316	2386	699	1221	6201	471	242	9	1071	108
2005	Domestic Produced	5,272	0	210	365	5	2598	422	660	55	254	703
	Domestic Refined	5,272	0	1049	432	603	2104	299	81	9	581	114
	Total Refined	14,089	1350	2449	717	1254	6367	481	249	9	1099	114
2010	Domestic Produced	4,669	0	165	308	5	2435	360	400	54	251	691
	Domestic Refined	4,669	0	938	367	475	1932	262	49	9	521	116
	Total Refined	14,463	1386	2516	735	1287	6533	497	256	9	1128	116

These regions were divided approximately according to Petroleum Administration for Defense Districts (PADD), but adjusted based on a preliminary assessment of heavy oil production and refining characteristics. The intent was to ensure the most realistic homogeneity for each region with respect to production and refining characteristics, and to minimize crude oil transport between regions. As the study progressed, obvious deviations from this intent were observed, most particularly in regions 8, 9, and 10. Regions 8, 9, and 10 were defined primarily based on known production trends. However, most of the heavy oil produced in region 10 is transported to region 9 or to San Francisco in region 4 to be refined. Refining capacity in region 10 was only sufficient to support product demand in the local area. Also, refining capacity in region 8 was very low and as with region 10, most of the production was transported to other regions. These regions (8 and 10) were eventually combined in the study. Similarly, regions 2 and 3 were later combined.

A base case was calculated based on projected increases in demand, projected decreases in domestic crude oil supply, and prevailing economic projections as outlined previously. No incremental heavy oil production was added in this case and the results were used to validate the models to 1990 data, which is known. The supply mix was divided into 18 crude oils (11 domestic and 7 foreign). Table 4–7 lists these oils and shows daily production by region for the year 1990. Of the domestic crude oils, the heavy oil was represented by four average oils: Midwest Heavy (18.8° API), Rocky Mountain Heavy (19.8°API), Gulf Coast Heavy (19.5°API), and California Heavy (13.1° API). As can be seen in Table 4–8, most of the heavy oil production is California Heavy. Total heavy oil production was 734,000 bbl/D, of which 654,000 bbl/D was produced from California.

Low Incremental Heavy Oil Proposed Scenario

Over the time period of 1990 to 2010, the total heavy oil production was increased by 300,000 bbl/D, and to balance the input/output equations, foreign supply was reduced. Tables similar to Table 4–7 were constructed for 1995, 2000, 2005, and 2010. The increased production volume from California was 90,000 bbl/D, and 197,000 bbl/D was from the Gulf Coast Region. The data was then processed with the Linear Programming Models developed for each region, and the refining process optimization of total input was calculated to determine the required refining capacity.

Table 4–7 Crude Representation for Regional LP Models, Base Case 1990

Region	MB/D	Vol. Frac	API	%S	Proposed DOE Region 1	2	3	4	5	6	7	8	9	10	Total
Eat Light	30	0.002	51.6	0.26	13	2	0	0	15	0	0	0	0	0	30
Cushing Sweet	1155	0.086	39.4	0.42	0	465	141	0	297	253	0	0	0	0	1155
Mid West Sour	247	0.018	25.1	2.55	0	115	0	0	0	132	0	0	0	0	247
Mid West Hvy	4	0.000	18.8	1.98	0	0	4	0	0	0	0	0	0	0	4
Rocky Mt Hvy	20	0.001	19.8	2.30	0	0	0	0	0	20	0	0	0	0	20
West Texas Int.	1169	0.087	40.5	0.35	0	298	219	0	652	0	0	0	0	0	1169
Louisianan Sweet	2107	0.157	35.8	0.36	0	531	183	0	1393	0	0	0	0	0	2107
Gulf C Heavy	64	0.005	19.5	0.63	0	15	0	0	49	0	0	0	0	0	64
Alaska No Slope	1773	0.132	27.7	1.12	0	17	101	733	339	0	217	0	366	0	1773
California Med	319	0.024	28.7	0.68	0	0	0	41	0	0	0	0	203	75	319
California Hvy	654	0.049	13.1	1.21	0	0	0	327	0	0	0	8	286	33	654
Canada Blend	643	0.048	29.8	1.29	60	511	0	10	7	55	0	0	0	0	643
So America Med	1413	0.105	24.8	1.85	345	0	0	25	1042	0	0	0	1	0	1413
So America Hvy	211	0.016	16.5	2.40	100	0	0	1	110	0	0	0	0	0	211
Middle East	1863	0.139	32.9	1.80	266	199	16	24	1358	0	0	0	0	0	1863
Africa	1205	0.090	35.4	0.17	401	143	0	0	660	0	0	0	1	0	1205
Europe	251	0.019	37.6	0.40	66	27	18	0	138	0	0	0	0	0	251
Asia	281	0.021	39.5	0.10	32	7	0	33	0	0	20	0	189	0	281
Total	13409	1.000			1285	2330	682	1194	6060	460	237	8	1046	108	13409
			Target Supply		1285	2330	682	1194	6060	460	237	8	1046	108	13409

Table 4–8 Heavy Crude Oil Production by Region Defined for Base Case, 1990

Crude Oil	API	Production Mbbl/D	Region 1	2	3	4	5	6	7	8	9	10
Midwest Heavy	18.8	4	0	0	0	4	0	0	0	0	0	0
Rocky Mt. Heavy	19.8	20	0	0	0	0	0	20	0	0	0	0
Gulf Coast Heavy	19.5	64	0	15	0	0	49	0	0	0	0	0
California Heavy	13.1	646	0	0	0	327	0	0	0	0	286	33
South American Heavy	16.5	211	100	0	0	1	110	0	0	0	0	0
Total U.S.		734	0	15	0	331	49	20	0	0	286	33
Total		945	100	15	0	332	159	20	0	0	286	33

Region 1 had no domestic heavy oil production, and was heavily dependent on foreign imported crude oil to meet product demand. This region was not affected by factors tested in this study.

Regions 2 and 3 were combined for several reasons. Very little oil is produced in Region 2, and much of the petroleum needs in this region are provided by surplus production from Region 3 through crude oil pipelines. Heavy oil production increases in these regions were very small, and increased bottoms conversion capacity was needed.

Region 4 processed an additional 45,000 bbl/D heavy oil in the year 2010, nearly all of it coming from regions 8, 9, and 10. Refineries in this region are specifically designed to efficiently handle heavy crudes, and existing capacity is sufficient to process this crude oil. The investment costs specifically for the heavy crude oil was expected to be negligible.

Region 5 is the largest producer of crude oil in the U.S. (light and heavy oil, 44% of total domestic production) and has the largest refining capacity concentration (43% of primary distillation). Even so, imports made up almost 55% of the total crude oil processed in 1990. Heavy oil production amounted to only 64 Mbbl/D during 1990 (less than 2% of total region production). Although proposed increases of heavy oil production is substantially higher, existing processing capacity was adequate until about the year 2005. Investment dollar increases were about $2 billion, approximately the same as that of Region 9.

Region 6 was unusual in that the existing refining capacity is relatively isolated and self-contained. Furthermore, much of the oil currently processed in this region comes from Canadian fields nearby. The small demand for fuel oil created an unusual supply/demand balance in this region that required additional bottoms conversion capacity in each of the years 1995 through 2010 to process the proposed modest increases.

Regions 8 and 10 were combined because of their geographical proximity, their significant heavy oil production, and their limited refining capacity. Most of the produced oil is transported to region 9 or region 4 for processing. Thus, the refining capacity is limited to

supplying local demand and includes no catalytic crackers for processing heavy oil. No refining capacity upgrading was assigned to these regions.

Region 9 contains a substantial capacity to process heavy oil. Because of an anticipated decline in heavy oil production in region 9, no need was identified for increasing capacity for heavy oil processing (bottoms conversion). However, overall capacity expansion and upgrading was indicated (distillation and motor fuel quality), and the facility costs are estimated at near $2 billion.

In summary, this study indicated a need for increasing the conversion capacity by 230,000 bbl/D over the 20-year period. This expansion incorporated increased domestic heavy oil production and increased imported crude oil needed to accommodate the increasing product demand. The cost associated with this expansion was estimated to be $7 billion dollars (plant utility costs, no offsites included). Regions 2, 3, 5, and 9 accounted for about $5 billion of this total.

High Incremental Heavy Oil Proposed Scenario

An additional study was made to determine what difference resulted from increasing heavy oil production by 930,000 bbl/D instead of 300,000 bbl/D as discussed in the previous scenario. The production increase assigned to California was 249,000 bbl/D, and to the Gulf Coast Region 544,000 bbl/D. As before, the data was processed with the Linear Programming Models developed for each region, and the total production was used to determine the required refining capacity.

Results from the models indicated a need for refinery expansion of 310,000 bbl/D. This is 80,000 bbl/D higher than that for the low incremental heavy oil scenario. Although heavy oil production was increased by 630,000 bbl/D, most of that crude simply displaced other foreign crude. The additional 80,000 bbl/D capacity represents the increase of bottoms conversion capacity needed over the low incremental heavy oil scenario. Also, since most of the increased oil production occurred in region 5, 75% of the total increased capacity was in that region. Since this increase is small relative to the total refining capacity for the region, the facility capacity requirements incurred a modest additional $200 million price tag over the investments required to meet the low oil scenario. In summary, the investment costs for upgrading the refining capacity sufficiently to process the incremental heavy oil crude volumes specified in the two scenarios is small relative to the total upgrade requirements. Price penalties from the refiner to the producer will largely be determined by the processing costs and should not differ significantly from what they are currently.

One very important consideration in this study was that the greatest percentage heavy oil production increase came from the Gulf Region where actual supplies are limited. Because of the limited supply in this region, such increased production rates could not be sustained, and based on the review of estimated recoverable oil outlined in the previous sections, such production increases would require large price incentives and development of cost effective

production methods for heavy oil in thin reservoirs. Additional sensitivity runs may need to be conducted to assess the impact if most of the increased production levels came from California or Alaska where most of the resource is located.

4.3 Incentive Study (Pautz and Welch 1995)

The previous section concluded that if heavy oil production was increased in the U.S., capital investment in refining would be necessary. What the previous study did not determine was the incentive levels required to compensate producers and refiners to bring about the proposed heavy oil production increases. Current trends indicated production levels are likely to decrease rather than increase.

An incentive evaluation study was conducted based on the same economic projections outlined in the previous section. However, the source of the heavy oil production was not constrained to the regions previously defined. California and Gulf Coast regions were analyzed separately to determine the effects of four scenarios: base case or no incentive, $1.50/bbl, $3.00/bbl, and $4.50/bbl for produced heavy crude oil. These incentives were restricted to heavy oil production projects started between the years 1994 and 2010. Several approaches were investigated, but a cash-flow model was the only method found to give plausible results.

A spreadsheet model was developed that used cash flow as a means of measuring the industry's willingness to initiate new thermal recovery projects. Income from ongoing projects and added incentives were combined to cover cash outlays (capital outlays, operation, return on investments, etc.) and for investing toward new development. The reservoir locations and oil resource potential were evaluated using a steamflood predictive model.

Results indicated that to achieve a 300,000 bbl/D increase in production of heavy oil (compared to 1993 production) by the year 2010, a $2.10/bbl incentive would be needed. To achieve the 900,000 bbl/D increase, an incentive of about $4.25/bbl would be needed. This presumes that all of the incentive is directed to newly started projects and that existing projects operate without incentives. Furthermore, this is based on an economic projection of $20–24/bbl projected market price for WTI with suitable discounts for heavy oil during this time period. This price projection has turned out to be optimistic for the period 1993 through 1995.

Consequently, a second market price projection of crude oil was analyzed (flat $18/bbl for WTI). The models indicated that current heavy oil production would decline. To achieve the proposed production increase scenarios, an incentive of about $3.00/bbl would be needed to achieve the 300,000 bbl/D increase by the year 2010, and an incentive much higher than $4.50/bbl would be needed to achieve the 900,000 bbl/D incremental increase in heavy oil production. An estimated $0.50 to $2.20/bbl portion of the incentive would be needed by

the refiners to justify capacity expansion sufficient for the increased production scenarios. Natural open market forces would allocate incentives between producers and refiners so that distinctions would get blurred. Early incentives to refiners is desirable to encourage capacity. Incentives to producers would favor domestically produced heavy oil over imported oil.

As stated, California and the Gulf Coast were evaluated separately. Results indicated that nearly all of the increased production would come from California. It was concluded that existing technologies were not economically competitive in the Gulf region and that development of new technologies are needed to significantly impact Gulf region production. Heavy oil production in Alaska was not considered in the proposed scenario.

4.4 Final Summary

U.S. domestic oil production is expected to continue to decline. This study investigated the feasibility of increasing domestic heavy oil production to mitigate the decline rate. Two incremental oil production scenarios were evaluated: 300,000 bbl/D and 930,000 bbl/D increases by the year 2010. The objectives were to determine from which regions of the U.S. the incremental heavy oil production would occur, to determine the required adjustments to regional refining capacity to accommodate such production increases, and to determine what costs would be associated with expansion.

Most of the domestic heavy oil is located in principally three regions: California, Alaska, and the Gulf Coast Region. For the purposes of this study, heavy oil deposits in Alaska were not considered even though by size the heavy oil resource is potentially nearly equal to that of California. The Alaskan oil was assumed to be refined in California. Because of the additional economic penalties associated with the harsh environment in Alaska, increases in heavy oil production were expected to occur preferentially in California. Proposed increases were assigned to both California and the Gulf Region. However, more production was assigned to the Gulf Region initially (1990–2010) due to the more favorable refining capacity. Greater increases from California would occur later (beyond 2010). However, most of the economics show this to be unreasonable and that technical improvements are needed for production from thinner, tighter heavy oil reservoirs.

The U.S. petroleum products demand is expected to grow a modest 1% annually between the years 1990 and 2010. Domestic production is expected to decline 2% annually, most of the decline coming in production of Alaska North Slope crude oil. The difference was made up with imported Middle East crude oil. Expansion of refining capacity was expected for the period studied, principally in the Gulf Region, in the Los Angeles Basin, and to a smaller degree in the Midwest and Upper Midwest. Total projected costs associated with the expansion was about $7 billion (plant utility costs, no offsites included).

Some of this expansion is a direct result of projected increases in heavy oil production. The increased conversion capacity needed was 230,000 bbl/D at 300,000 bbl/D incremental heavy oil production and 310,000 bbl/D at 930,000 bbl/D incremental heavy oil production. Because much of the increased heavy oil production was assigned to the Gulf Region refineries, existing refinery capacity was able to process most of the oil.

Based on the original projected market oil price, the incentive level required to support an increase of 300,000 bbl/D heavy oil was estimated at $2.10/bbl, and for an increase of 930,000 bbl/D heavy oil was estimated at $4.25/bbl. Unfortunately, the technical challenges facing production in the Gulf Region led to the conclusion that projected heavy oil production increases would have to come from California even if the production is refined in the Gulf Region. An additional $0.50 to $2.20/bbl incentive is needed for refinery modifications.

Since the original study was conducted, a lower more conservative oil price trend has been evident. Based on a projected flat $18/bbl, current heavy oil production rates are expected to decline rather than remain flat as expected at the higher prices forcing the incentives higher for the scenarios studied. The incentive level required to support a 300,000 bbl/D increase would be $2.90/bbl. The projected incentive for a 930,000 bbl/D increase was well above $4.50/bbl and was not considered a reasonable target. The same incentive is needed by the refiners to justify capacity modifications.

It was clear from these studies that additional developments in production technology are needed to competitively produce the substantial amounts of heavy oil located in Alaska and Gulf Region. Higher market prices and financial incentives would stimulate additional domestic heavy oil production.

5.0 CONCLUSIONS

The objective of this project was to assess the potential of increased U.S. heavy oil production as a means of reducing the domestic oil production decline rate. An assessment of the U.S. heavy oil resource was made. The heavy oil reservoirs were screened to estimate the recoverable oil. Additional studies were conducted in individual regions (Midcontinent Region, Appalachian Basin, Black Warrior Basin, Illinois Basin, Michigan Basin, Permian Basin, Alaska, California, and Gulf Region) to further clarify these estimates, identify obvious targets currently underdeveloped, and recommend those areas appropriate for future development, for technology improvements, and for field demonstrations. These recommendations are to be made to the U.S. Department of Energy (DOE) to direct their heavy oil program in the most advantageous way for the U.S. The following conclusions were made from this study.

1. An estimated 68.3 billion bbl of heavy oil remains in 535 U.S. reservoirs that were well defined in this study. An undetermined additional amount remains in 490 less well documented U.S. reservoirs, including 25 to 40 billion bbl heavy oil in Alaska.
2. Most of the defined heavy oil (62.8 billion bbl) is located in California (half of which lies in seven fields), and 3.5 billion bbl is located in the Gulf Region (Alabama, Mississippi, Louisiana, Southern Arkansas, and Texas excluding Permian Basin).
3. It was estimated that up to 4 billion bbl heavy oil could be recovered using waterflooding for low viscosity oils and up to 8 billion bbl heavy oil could be recovered using steam injection. Virtually all of this oil is in California.
4. Approximately 56 billion bbl of the oil left behind and another 5 to 40 billion bbl heavy oil in Alaska remain a production target for improved technology.
5. Based on the current oil prices (calculated on a flat rate of $18/bbl for WTI), the heavy oil production rate is expected to decline through the year 2010. An estimated $2.90/bbl incentive is needed to achieve a heavy oil production increase of 300,000 bbl/D over current production levels by the year 2010. An additional $0.50 to $2.20/bbl incentive is needed to encourage refiners to invest in equipment to process heavy oil into marketable transportation fuels.
6. Overall, oil production rates are expected to decline in the U.S. by 2% annually and petroleum product demand is expected to increase by 1% annually (through the year 2010). Increasing heavy oil production would require expansion in refinery capacity for processing heavy ends. The estimated plant utility costs associated with an increase of 300,000 bbl/D was $7 billion (no offsites included)

7. Moderate increases in heavy oil production from the Gulf Coast Region can be processed with existing refining capacity. However, production increases are most likely to come from California. Due to a perceived oil surplus market currently in California, it is uncertain what the actual impact of a U.S. heavy oil incentive would be on the overall oil industry.

It is recommended that future government programs, directed toward maximizing U.S. heavy oil production, consider the following observations.

1. U.S. heavy oil is likely to be produced from California where resource and production characteristics are more favorable. Any program effectively targeting heavy oil production is likely to impact California production operations.
2. The next largest heavy oil resource is in Alaska, although actual size of the resource is less certain. This is the only other large domestic heavy oil resource in the U.S. Heavy oil production is possible in Alaska if technological and economic challenges are met. However, the window of opportunity may quickly close if light oil production rates decline as projected. The TAPS may close before significant amounts of heavy oil can be produced.
3. The Gulf Region is the third largest region in the U.S. with deposits of heavy oil. Existing refining capacity in this region can accommodate increased production making the economic adjustments more realizable. However, the thinner reservoirs in this region present a production technology challenge. Development of new production technologies is needed before any sizable production is economically possible.

6.0 REFERENCES

Aalund, L. R. 1988. Annual Production Report. *Oil and Gas Journal*, pp. 33-73 (April 18).

Adamson, Gary R. and Edward J. Hanzlik. 1979. Steamflood Demonstration Pilot Williams Holding Lease, Cat Canyon Field, Santa Barbara County, California. Presented paper at 5th Annual DOE Symposium, Tulsa, OK, August 22-24.

Alfred, W. O. 1985. *The "200" Sand Steamflood Demonstration Project, Seventh Annual Report for June 1982 -June 1983*. U.S. Dept. of Energy, Fossil Energy Report DOE/ET/12059-7 (October).

American Petroleum Institute 1995. *Basic Petroleum Data Book.* Petroleum Industry Statistics, Vol. XV(1), January.

Arkansas Oil and Gas Commission. 1986. *Annual Oil & Gas Report.* El Dorado, AR: State of Arkansas Oil and Gas Commission.

Arkansas Oil and Gas Commission. 1988. *Annual Oil & Gas Report.* El Dorado, AR: State of Arkansas Oil and Gas Commission.

Arkansas Oil and Gas Commission. 1989. *Annual Oil & Gas Report.* El Dorado, AR: State of Arkansas Oil and Gas Commission.

Arkansas Oil and Gas Commission. 1990. *Annual Oil & Gas Report.* El Dorado, AR: State of Arkansas Oil and Gas Commission.

Arkansas Oil and Gas Commission. 1991. *Annual Oil & Gas Report.* El Dorado, AR: State of Arkansas Oil and Gas Commission.

Armstrong, Ted A. 1968. "East Wilmington comes alive." *Oil and Gas Journal,* pp. 75–78 (January 29).

Armstrong, Ted. 1967. First Automated Field 5 Years Old and Going Strong. *Oil and Gas Journal*, p. 73, (July 24).

Barger, R. M. and J. L. Zulberti. 1948 and 1949. San Ardo Oil Field. *Summary of Operations, California Oil Fields*, Vol. 34(1), p. 15, 1948 and Vol. 35(2), p. 15, 1949 (same article).

Barger, R. M. 1958. South Belridge Thermal Recovery Experiment. *Summary of Operations, California Oil Fields,* Vol. 44(2):21.

Barnes, J. A. 1966. Main Area of Edison Oil Field. *Summary of Operations, California Oil Fields,* Vol. 52(2)-Part 2:31.

Barrett, M. L. and R. W. Mathias. 1992. Sediment Alteration and Fines Migration in Enhanced Recovery Operations, Tertiary Heavy Oil Fields, California. SPE paper 23782 presented at the SPE International Symposium on Formation Damage Control, Lafayette, LA, February 26-27.

Bates, R. D. 1979. *Summary of Field Statistics and Drilling Operations, Louisiana, 1978*. Baton Rouge, LA: Department of Natural Resources, State of Louisiana, Geological Oil and Gas Division.

Beggs, H. D. and J. R. Robinson. 1975. Estimating the Viscosity of Crude Oil Systems. *J. Pet.* Technology, 1140 (September).

Bennett, S. 1985. "Bowes Dome Field." Oil and Gas Fields Symposium, Montana Geological Society, Vol. 1.

Bertholf, Harold W. 1962. Northeast Area of McKittrick Oil Field. *Summary of Operations, California Oil Fields*, Vol. 48(1): 63.

Beyer, L. A (United States Geological Survey). 1987. Porosity of Unconsolidated Sand, Diatomite, and Fractured Shale Reservoirs, South Belridge and West Cat Canyon Oil Fields, California. In *Exploration for Heavy Crude Oil and Natural Bitumen Reservoirs,* American Association of Petroleum Geologists Geological Study No. 25, pp. 395–413.

Bolin, David E., S. D. Mann, D. Burroughs, H. E. Moore, Jr., and T. J. Powers. Petroleum Atlas of Southwestern Alabama: Geological Survey of Alabama Atlas 23. Tuscaloosa, AL: Geological Survey of Alabama, Energy and Coastal Geology Division, 1989.

Bilden, D. M., F. P. Efthin, J. J. Garner, T. C. Pence, and S. T. Kovacevich. 1990. Evaluation and Treatment of Organic and Inorganic Deposition in the Midway Sunset Field, Kern County, California. SPE paper 20073 presented at the 60th California Regional Meeting of the Society of Petroleum Engineers, Ventura, CA, April 4–6.

Bleakley, W. B. 1968. THUMS-Here's how four-island project taps East Wilmington. *Oil and Gas Journal,* pp. 88-107 (January 29).

Blevins, T. R. and R. H. Billingsley. 1985. The Ten-Pattern Steamflood, Kern River Field, California, in SPE Reprint Series No. 7—*Thermal Recovery Processes of the Society of Petroleum Engineers*, pp. 203–210, Richardson, TX, 1985. Also in *J. Pet. Technology*, pp. 1505–1514 (December 1975) .

Bradford, W. C. and E. D. Lawrence. 1956. San Ardo Oil Field. *Summary of Operations, California Oil Fields*, Vol. 42(2):27.

Bradley, W. A. et al., Eds. 1979. *Symposium: Wyoming Oil and Gas Fields, Greater Green River Basin, Vol. 1 & 2.* Casper, WY: Wyoming Geological Association.

Bradshaw, D. T. 1985. *Geologic Variables Influencing Production in Eastburn Field, Vernon County, Missouri.* Master's thesis, Colorado State University.

Brashear, J., M. Godec and B. Wood. 1991. Incremental Oil Production Attributed to the Oil Research Program. Memorandum to Robert Folstein (U.S. Dept. of Energy) from *ICF Resources Inc.*, May 3.

Brelih, D. A. and E. J. Kodl. 1990. Detailed Mapping of Fluvial Sand Bodies Improves Perforating Strategy at Kern River Field. SPE paper 20080 presented at the 60th California Regional Meeting of the Society of Petroleum Engineers, Ventura, CA, (April 4–6).

Buller, S. M. 1992. Evaluation of Horizontal, Radial, and Vertical Injection Wells in a Pilot Steamflood. SPE paper 24630 presented at 67th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Washington, D.C. (October 4-7).

Bursell, C. G., H. J. Taggert, and H. A. DeMirjian. 1966. Thermal Displacement Tests and Results, Kern River Field, California. *Producers Monthly*, pp. 18–21 (September).

Bursell, C. G. 1970. Steam Displacement—Kern River Field. *J. Pet. Technology*, pp. 1225-1231 (October).

Bursell, C. G. and G. M. Pittman. 1985. Performance of Steam Displacement in the Kern River Field, in SPE Reprint Series No. 7—*Thermal Recovery Processes of the Society of Petroleum Engineers*, pp. 195-202, Richardson, TX. Also in *J. Pet. Technology*, pp. 997-1004 (August 1975).

Byars, Carlos. 1970. Fireflood Blossoms in North Louisiana. *Oil and Gas Journal*, pp. 58–62 (August 3).

California Division of Oil & Gas. 1984. *California Oil & Gas Fields: Southern, Central Coastal, & Offshore California*. Publ. TR12, Vol. 2, Sacramento: California Department of Conservation, Div. of Oil & Gas, 2nd Edition 1974, Reprinted 1984.

California Division of Oil & Gas. 1991. *California Oil & Gas Fields: Southern, Central Coastal, & Offshore California*. Publ. TR12, Vol. 2, Sacramento: California Department of Conservation, Div. of Oil & Gas, 3rd Edition, 1991.

California Division of Oil & Gas. 1985. *71st Annual Report of the State Oil & Gas Supervisor.* Publ. PR06, Sacramento: California Department of Conservation, Div. of Oil & Gas.

California Division of Oil & Gas. 1986. *72nd Annual Report of the State Oil & Gas Supervisor*. Publ. PR06, Sacramento: California Department of Conservation, Div. of Oil & Gas.

California Division of Oil & Gas. 1990. *76th Annual Report of the State Oil & Gas Supervisor*. Publ. PR06, Sacramento: California Department of Conservation, Div. of Oil & Gas.

California Division of Oil & Gas. 1991. *77th Annual Report of the State Oil & Gas Supervisor*. Publ. PR06, Sacramento: California Department of Conservation, Div. of Oil & Gas.

California Division of Oil & Gas. 1985. *California Oil & Gas Fields: Central California.* Publ. TR11, Vol. 1, Sacramento, CA: California Department of Conservation, Div. of Oil & Gas, 3rd Edition.

California Division of Oil & Gas. 1985. Lost Hills Oil Field, South Salt Lake Oil Field. Publ. TR32, Sacramento, CA: California Department of Conservation, Div. of Oil & Gas.

Cardinal, Donald F., T. Miller, W. W. Stewart, and J. F. Trotter, Eds. 1989. *Symposium: Wyoming Oil and Gas Fields, Bighorn and Wind River Basins.* Casper, WY: Wyoming Geological Association.

Cato, B. W and W. A. Frnka. 1967. "Results of an In Situ Combustion Pilot Project." Interstate Oil Compact Commission Bulletin Vol. 9(2) (December).

Chiou, R. C. S. and T. S. Murer. 1989. Cyclic Steam Pilot in Gravity Drainage Reservoir. SPE paper 19659 presented at 64th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, San Antonio, TX, pp. 319–332 (October 8–11) .

Chiou, R. C. S., T. L. Kirst, and C. W. Kiven. 1990. Reservoir Description and Steamflood Development in Lost Hills Field. SPE paper 20727 presented at 65th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, New Orleans, LA, (September 23–26).

Chiou, R. C. S., H. G. Weinstein, R. C. Smith, R. A. Barrett, and D. P. DuBois. 1992. South Belridge Tulare Simulation Study: Steamflood in a Heterogeneous Stratified Reservoir. SPE paper 24633 presented at 67th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Washington, D.C. (October 4–7).

Chu, Chieh. 1985. State-of-the-Art Review of Steamflood Field Projects. *J. Pet. Tech*. 37(11) 1887-1902, October.

Chu, C. 1985. State-of-the-Art Review of Fireflood Field Projects, in SPE Reprint Series No. 7—*Thermal Recovery Processes of the Society of Petroleum Engineers*, pp. 402-419, Richardson, TX, 1985. Also in *J. Pet. Technology*, pp. 19–36, January 1982 with Discussion in *J. Pet. Technology*, pp. 861–862 (April 1982).

Chu, C. 1985. State-of-the-Art Review of Steamflood Field Projects, in SPE Reprint Series No. 7—*Thermal Recovery Processes of the Society of Petroleum Engineers*, pp. 256-282, Richardson, TX. Also in *J. Pet. Technology*, pp. 1887–1902 (October 1985) and presented as SPE paper 11733 at California Regional Meeting of the Society of Petroleum Engineers, Ventura, CA (March 6–8, 1983).

Cities Service Company, Energy Resources Group, Tulsa, OK. 1977. *Bodcau In Situ Combustion Project: First Annual Report.* U. S. Department of Energy Report SAN-1189-2, (September).

Clampitt, R. L., R. L. Eson, and R. W. Cooke. 1991. Applying a Novel Steam-CO_2 Combination Process in Heavy Oil and Tar Sands. SPE paper 21547 presented at the International Thermal Operations Symposium of the Society of Petroleum Engineers, Bakersfield, CA, (February 7–8).

Conservation Committee of California Oil and Gas Producers. 1991. *1990 Annual Review of California Oil and Gas Production*. Los Angeles, CA: Conservation Committee of California Oil and Gas Producers.

Conservation Committee of California Oil and Gas Producers. 1992. *1991 Annual Review of California Oil and Gas Production*. Los Angeles, CA: Conservation Committee of California Oil and Gas Producers.

Conservation Committee of California Oil and Gas Producers. 1993. *1992 Annual Review of California Oil and Gas Production*. Los Angeles, CA: Conservation Committee of California Oil and Gas Producers.

Crowder, Robert. 1978. Polymer Flooding in Wilmington Oil Field, Ranger Zone, Fault Block 5. In Publ. TR 22, Sacramento, CA: California Department of Conservation, Division of Oil & Gas (originally published August 1974, revised 1977).

Crown, Walter J. 1941. *Wilmington Oil Field. Summary of Operations, California Oil Fields*, Vol. 26, pp. 5–11.

Crysdale, B. L and Schenk, C. J. 1990. *Heavy Oil Resources of the United States.* United States Geological Survey Bulletin 1885.

Dietzman, W. D., M. J. Carrales, and C. J. Jirik. 1965. *Heavy Crude Oil Reservoirs in the United States: A Survey*. United States Department of the Interior, Bureau of Mines, Information Circular No. 8263.

Dietrich, James K. 1990. Steamflooding in a Waterdrive Reservoir: Upper Tulare Sands, South Belridge Field. SPE paper 17453 presented at California Regional Meeting of the Society of Petroleum Engineers, Long Beach, CA, March 23-25, 1988, pp. 479-494. Revised version in SPE *Reservoir Engineering*, Vol. 5(3):275–284.

Djabbarah, N. F., S. L. Weber, D. C. Freeman, J. A. Muscatello, J. P. Ashbaugh, and T. E. Covington. 1990. Laboratory Design and Field Demonstration of Steam Diversion with Foam. SPE paper 20067 presented at the 60th California Regional Meeting of the Society of Petroleum Engineers, Ventura, CA (April 4-6).

Dowd, W. Timothy, V. A. Kuuskraa, and M. L. Godec. 1988. *A Technical and Economic Assessment of Domestic Heavy Oil—Final Report.* U. S. Department of Energy Report DOE/BC/10840-1, (January).

Earlougher, R. C. and Harrison L. Staub. 1979. Residual Oil Saturation Determination Wilmington Micellar-Polymer Project October 1978-May 1979. In Vol 2. of the 5th Annual DOE Symposium on Enhanced Oil and Gas Recovery and Improved Drilling Technology, Tulsa, OK, August 22–24.

Ebanks, W. J., G. W. James and N. D. Livingston. 1977. *Evaluation of Heavy Oil and Tar Sands in Bourbon, Crawford, and Cherokee Counties, Kansas*. U.S. Dept. of Energy Report No. BERC/RI-77/20, December.

Energy Development Consultants/Stone & Webster Engineering Corporation. 1983. *An Evaluation of Heavy Oil Mining: Final Report.* U.S. Dept. of Energy Report No. DOE/PC/30259-1, Vol. 1: 112-120, March.

Energy Information Agency. 1992. *Petroleum Marketing Annual, 1991*. U.S. Dept. of Energy Report No. DOE/EIA 0487(91), August.

Emmett, W. R. 1971. "Reservoir Properties Control Recovery" *Oil and Gas Journal,* Vol. 69(39):85–90 (September 27).

Eson, Rodney L., Jon P. Fitch, and Albert M. Shannon. 1981. North Kern Front Steam Drive with Ancillary Materials. SPE/DOE paper 9778 presented at SPE/DOE Second Joint Symposium on Enhanced Oil Recovery of the Society of Petroleum Engineers, Tulsa , OK, (April 5–8).

Eson, Rod L. and Stephen K. O'Nesky. 1982. Evaluation of a Conventional Steam Drive with Ancillary Materials: North Kern Front Field. SPE paper 10775 presented at the 1982 California Regional Meeting of the Society of Petroleum Engineers, San Francisco, CA (March 24–26).

Fancher, George H. and Donald K. Mackay. 1946. *Secondary Recovery of Petroleum in Arkansas—A Survey*. El Dorado, AR: State of Arkansas Oil and Gas Commission, El Dorado, AR.

Farouq Ali, S. M. and R. F. Meldau. 1979. Current Steamflood Technology. *J. Pet. Technology*, Vol. 31(10):1332–1342 (October).

Fireflood Peps Up Old Arkansas Field. 1965. *Oil and Gas Journal*, Vol. 63(41):100–101 (October 11).

Frame, R. G. 1957. A Review of Water Flooding in the Wilmington Oil Field. *Summary of Operations, California Oil Fields*, Vol. 43(1):59.

Gates, C. F. and S. W. Brewer. 1974. Steam Injection into the D and E Zone, Tulare Formation, South Belridge Field, Kern County, CA. SPE paper 4760 presented at Symposium on Improved Oil Recovery of the Society of Petroleum Engineers of AIME, Tulsa, OK, April 22-24, pp. 271–282. Also in *J. Pet. Technology*, p. 343 (March 1975).

Gomaa, E. E., J. H. Duerksen, and P. T. Woo. 1985. Designing a Steamflood Pilot in the Thick Monarch Sand of the Midway-Sunset Field, in SPE Reprint Series No. 7—*Thermal Recovery Processes of the Society of Petroleum Engineers*, pp. 246-255, Richardson, TX. Also in *J. Pet. Technology*, pp. 1559–1568 (December 1977).

Greaser, Gary R. and R. A. Shore. 1980. Steamflood Performance in the Kern River Field. SPE/DOE paper 8834 presented at First Joint SPE/DOE Symposium on Enhanced Oil Recovery of the Society of Petroleum Engineers, Tulsa, OK, April 20–23.

Grigsby, E. 1990. Paper and Pencil Exercise or Treble Damages in Kern County by D. Gill. *Oil & Gas Investor*, p. 19, August.

Hall, A. L. and R. W. Bowman. 1973. Operation and Performance of the Slocum Thermal Recovery Project. *J. Pet. Technology*, pp. 402–408 (April).

Hanzlik, Edward J. and B. Frank Birdwell. 1976. Steamflood of Heavy Oil Cat Canyon Field. Presented paper at ERDA Symposium on Enhanced Oil Recovery, Tulsa, OK, Sept. 9-10.

Harrigal, R. L. and C. A. Clayton. 1992. Comparison of Conventional Cyclic Steaming and Steamflooding in a Massive, Dipping, Midway Sunset Reservoir. SPE/DOE paper 24197 presented at SPE/DOE Eighth Symposium on Enhanced Oil Recovery, Tulsa, OK (April 22–24).

Harrison, W. E. 1982. Tar Sand Resource Appraisal in South-Central Oklahoma. Paper presented at National Tar Sands (Heavy Oil) Symposium, Lexington, Kentucky, pp. 110-128.

Harrison, W. E. and M. R. Burchfield. 1984. Tar-Sand Potential of Selected Areas in Carter and Murray Counties, South-Central Oklahoma. U.S. Department of Energy Report No. DOE/LC/10730-T1.

Harrison, W. E. and D. L. Routh. 1981. Reservoir and Fluid Characteristics of Selected Oil Fields in Oklahoma. Special Publication No. 81-1, Oklahoma Geological Survey.

Hazenbush, George C. and Dennis R. Allen. 1958. Huntington Beach Oil Field. *Summary of Operations, California Oil Fields*, Vol. 44(1):13.

Himmelblau, David M. 1974. *Basic Principles and Calculations in Chemical Engineering.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc., Table E.1 of Appendix E.

Hollis, Stephen H. and Eric C. Potter, Eds. 1984. *Symposium: S. E. Wyoming Oil and Gas Fields, Laramie, Hanna and D-J Basins.* Casper, WY: Wyoming Geological Association.

Hunter, A. L., W. C. Bradford, and D. R. Allen. 1955. Huntington Beach Oil Field, Southeast Extension of Townlot Area. *Summary of Operations, California Oil Fields*, Vol. 41(1): 61–68.

Huey, W. F. 1954. West Cat Canyon Area of Cat Canyon Field. *Summary of Operations, California Oil Fields.* California Department of Natural Resources, Division of Oil and Gas, Vol 40(1).

Independent Producers Association of America. 1992. The Oil & Natural Gas Producing Industry in Your State. *Petroleum Independent*, 62(7): 84, September.

Interstate Oil Compact Commission. 1984. *Major Tar Sand and Heavy Oil Deposits of the United States.* Oklahoma City, Oklahoma: Interstate Oil Compact Commission.

Jensen, Trond B., M. P. Sharma and H. Gordon Harris. 1991. An Improved Evaluation Model for Steam-Drive Projects. *J. Pet. Sci. & Eng.*, Vol. 5: 309-322.

Jensen, Trond B., M. P. Sharma, and H. Gordon Harris. 1990. A critical evaluation of preliminary design techniques for steam drive projects. *Journal of Petroleum Science and Engineering*, Vol. 5: 67–85.

Jones, Jeff and J. Cawthon. 1990. Sequential Steam: An Engineered Cyclic Steaming Method. *J. Pet. Technology*, Vol. 42(7):848 (July).

Jones, J. 1981. Steam Drive Model for Hand-Held Programmable Calculators. *J. Pet. Technology*, pp. 1583-1598, September.

Joseph, Conrad, Charley B. Jay, Eric V. Eslinger, and Charles J. Mundis. 1982. Evaluation of an In-situ Combustion Process by Post Burn Core and Log Analysis. SPE paper 10766 presented at 1982 California Regional Meeting of the Society of Petroleum Engineers, San Francisco, CA (March 24-26).

Kaplow, E. J. 1945. Coalinga Oil Field. *Summary of Operations, California Oil Fields*, Vol. 31(2):5–22.

Kasline, Fred E. 1941. Edison Oil Field. *Summary of Operations, California Oil Fields*, Vol. 26: 12–18.

Krebs, H. J. 1976. Wilmington Field, California, Polymer Flood: A Case History. SPE paper 5828 presented at Symposium on Improved Oil Recovery of the Society of Petroleum Engineers of AIME, Tulsa, OK, March 22-24, pp. 389-402, 1976. Also in *J. Pet. Technology*, pp. 1473–1480 (December 1976).

Kujawa, Patrick. 1981. *Heavy Oil Reservoirs Recoverable By Thermal Technology* . U.S. Dept. of Energy Report DOE/ET/12380-1, Vol. 1, 2 & 3 (February).

Lawyer, G., J. Newcomer, and C. Eger. 1981. *Symposium: Oil and Gas Fields, Powder River Basin,* Vol. 1 & 2. Casper, WY: Wyoming Geological Association.

Lennon, R. B. Geological Factors in Steam-Soak Projects on the West Side of the San Joaquin Basin, in SPE Reprint Series No. 7—Thermal Recovery Processes of the Society of Petroleum Engineers, pp. 238-245, Richardson, TX, 1985. Also in *J. Pet. Technology,* pp. 741–748 (July 1985).

Leonard, Jim. 1986. Annual Production Report. *Oil and Gas Journal*, pp. 71–101 (April 14).

Leonard, Jim. 1984. Annual Production Report: EOR set to make significant contribution. *Oil and Gas Journal,* Vol. 82(14):83–105 (April 2).

Long, Ralph E. and Mark F. Nuar. 1982. A Study of Getty Oil Co.'s Successful In-Situ Combustion Project in the Bellevue Field. SPE/DOE paper 10708 presented at SPE/DOE Third Joint Symposium on Enhanced Oil Recovery of the Society of Petroleum Engineers, Tulsa, OK, pp. 481–486 (April 4-7).

Luebking, G. A. 1985. Soap Creek Field. Oil and Gas Fields Symposium, Montana Geological Society, Vol. 2.

Mahmood, S. M., D. K. Olsen and C. P. Thomas. 1995. Heavy Oil Production from Alaska. Paper 112 pres. at Sixth UNITAR International Conference on Heavy Crude and Tar Sands, Houston, February 12-17.

Mancini, Ernest A. and John H. Masingill, et al. 1988. *The Petroleum Industry in Alabama, 1988: Oil and Gas Report 3-L.* Tuscaloosa, AL: Geological Survey of Alabama for the State Oil and Gas Board.

Matthews, John F., Jr. 1955. Edison Groves Area of Edison Oil Field. *Summary of Operations, California Oil Fields*, Vol. 41(2):11–18.

Matthews, John F., Jr. 1956. Portals Fairfax Area of Edison Oil Field. *Summary of Operations, California Oil Fields*, Vol. 42(2):33–36.

Mayuga, M. N. 1968. Geology and Development of California's Giant—Wilmington Oil Field. In *Geology of Giant Petroleum Fields,* Association of American Petroleum Geologists.

Melancon, L. J. 1976. *Louisiana Annual Oil and Gas Report.* Baton Rouge, LA: Department of Natural Resources, State of Louisiana.

Mississippi State Oil and Gas Board. 1960. *Annual Report: Oil and Gas Reservoirs of Mississippi for the Year Ending December 31, 1959*. Mississippi State Oil and Gas Bulletin, Vol. 60(5), July 1960. Jackson, MS: Mississippi State Oil and Gas Board.

Mobil will kick off giant thermal project in Arkansas. 1967. *Oil and Gas Journal*, Vol. 65(35):30–31 (August 28).

Mohammadi, S. S. and J. R. Tenzer. 1990. Steam-Foam Pilot Project at Dome-Tumbador, Midway Sunset Field: Part 2. SPE/DOE paper 20201 presented at SPE/DOE Seventh Symposium on Enhanced Oil Recovery, Tulsa, OK (April 22–25).

Moritis, Gruntis. 1990. Annual Production Report: CO_2 and HC injection lead EOR production increase. *Oil and Gas Journal*, Vol. 88(17):49–82 (April 23).

Miller, Donald D., John G. McPherson, & Thomas E. Covington 1990. Fluviodeltaic Reservoir, South Belridge Field, San Joaquin Valley, California. *Sandstone Petroleum Reservoirs.* Chapter 5, p. 109-130; edited by J. H. Barwis, McPherson, and Studlick, New York: Springer-Verlag.

Mississippi State Oil and Gas Board 1989. *Mississippi Oil and Gas Production Annual Report.* Jackson, Mississippi: Mississippi State Oil and Gas Board, December 31.

Moritis, Gruntis. 1992. Annual Production Report. *Oil and Gas Journal*, pp. 51-79 (April 20).

Moritis, Gruntis. 1994. Annual Production Report. *Oil and Gas Journal*, pp. 51-79 (September 26).

Murray-Aaron, Eugene R. 1947. Tidelands Pool of Huntington Beach Oil Field. *Summary of Operations, California Oil Fields*, Vol. 33(1):3–11.

National Energy Strategy 1991. *Powerful Ideas for America*. First Edition, Washington, D.C.: U.S. Dept. of Energy, February.

Netzler, Bruce W. 1990. Heavy Oil Resource Potential of Southwest Missouri. Missouri Department of Natural Resources, Open File Report Series, OFR- 90-80-OG (January).

New steam generator uses brackish water. 1966. *Oil and Gas Journal*, Vol. 64(24): 54–55 (June 13).

Nichols, Earl A. 1946. Geothermal Gradients in Mid-Continent and Gulf Coast Oil Fields. AIME Tech. Publ. 2114, in *Petroleum Technology*, p 44 (November).

Oil and Gas Journal. 1995. North Slope Operators Pressing Marginal Oil Field Development. *Oil and Gas Journal*, pp. 31–36 (May 1).

Olenick, Steve, F. A. Schroeder, H. K. Haines, and T. G. Monger-McClure. 1992. Cyclic CO_2 Injection For Heavy-Oil Recovery in Halfmoon Field: Laboratory Evaluation and Pilot Performance. SPE paper 24645 presented at 67th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Washington, D.C. (October 4–7).

Olsen, D. K., V. Rawn-Schatzinger, and E. B. Ramzel. 1992. *Feasibility Study of Heavy Oil Recovery in the Appalachian, Black Warrior, Illinois, and Michigan Basins.* U.S. Dept. of Energy Report NIPER-584 (June).

Olsen, D. K. 1993. *Estimates of Future Regional Heavy Oil Production at Three Production Rates—Background Information for Assessing Effects on the U.S. Refining Industry*. U.S. Dept. of Energy Report NIPER-606, April.

Olsen, D. K. and W. I. Johnson. 1993. *Feasibility Study of Heavy Oil Recovery in the Midcontinent Region*. U.S. Dept. of Energy Report NIPER-560, April.

Olsen, D. K. and W. I. Johnson. 1993. *Feasibility Study of Heavy Oil Recovery in the Permian Basin (Texas and New Mexico).* U.S. Dept. of Energy Report NIPER-578, May.

Olsen, David K. and William I. Johnson 1995. *Feasibility of Heavy Oil Recovery in the U.S. Midcontinent (Kansas, Missouri, Oklahoma).* Paper 110 pres. at Sixth UNITAR International Conference on Heavy Crude and Tar Sands, Houston, February 12-17.

Olsen, D. K., E. B. Ramzel, and R. A. Pendergrass II. 1992. *Trends in Heavy Oil Production and Refining in California.* U.S. Dept. of Energy Report NIPER-587, May.

Olsen, D. K., E. B. Ramzel, A. R. Strycker, G. Guariguata, and F. G. Salmen. 1994. *Projections of the Impact of Expansion of Domestic Heavy Oil Production on the U.S. Refining Industry from 1990 to 2010.* U.S. Dept. of Energy Report NIPER-620, December.

Olsen, D. K., E. C. Taylor, and S. M. Mahmood. 1992. *Feasibility Study of Heavy Oil Recovery--Production, Marketing, Transportation, and Refining Constraints to Increasing Heavy Oil Production in Alaska.* U.S. Dept. of Energy Report NIPER-610, December.

Olson, L. J. 1978. Shallow Aquifers and Surface Casing Requirements for Wilmington and Belmont Offshore Oil Fields. In Publ. TR 22, Sacramento, CA: California Department of Conservation, Div. of Oil & Gas.

Park, W. G., S. O. Wood, and M. Carrales, Jr. 1969. *Heavy Oil Reservoirs in Arkansas*. United States Department of the Interior, Bureau of Mines, Information Circular 8428.

Park, W. H. 1965. Kern Front Oil Field. *Summary of Operations, California Oil Fields*, Vol. 51(1):13–22.

Pautz, J. F., C. A. Sellers, C. Nautiyal, and E. Allison. 1992. *Enhanced Oil Recovery Projects Data Base.* U.S. Dept. of Energy Report No. NIPER-583, April.

Pautz, James F. and Robert A. Welch. 1995. *Level of Incentives Required for Large-Scale Development of the Nation's Heavy Oil Resources*. U.S. Dept. of Energy Report NIPER/BDM-146, May.

Pierce, G. G. 1947. Cymric Oil Field. *Summary of Operations, California Oil Fields,* Vol. 33(2):7–15.

Piper, Edward M., Adam W. Riddell, and Robert H. Trent. 1983. *An Evaluation of Heavy Oil Mining: Final Report*. Vol. 1 & 2, U.S. Dept. of Energy Report No. DOE/PC/30259-1 (March).

Powers, M. L., C. J. Dodson, F. Ghassemi, and J. S. Moore. 1984. "Commercial Application of Steamflooding in an Oil Field Comprised of Multiple Thin-Sand Reservoirs." SPE paper 13035 presented at 1984 Annual SPE Technical Conference, Houston, TX (September 16–19).

Pyle, C. A. 1988. *Typical Oil and Gas Fields of South Texas*. Corpus Christi, TX: Corpus Christi Geological Society, Vol. II.

Railroad Commission of Texas, Oil and Gas Division. 1980. *A Survey of Secondary and Enhanced Recovery Operations in Texas to 1980, Bulletin No. 80*. Austin, TX: Railroad Commission of Texas, Oil and Gas Division.

Railroad Commission of Texas, Oil and Gas Division. 1982. *A Survey of Secondary and Enhanced Recovery Operations in Texas to 1982, Bulletin No. 82*. Austin, TX: Railroad Commission of Texas, Oil and Gas Division.

Railroad Commission of Texas, Oil and Gas Division. 1990. *1989 Oil and Gas Annual Report, Vol. 1*. Austin, TX: Railroad Commission of Texas, Oil and Gas Division, (June 15).

Railroad Commission of Texas, Oil and Gas Division. 1992. *1991 Oil and Gas Annual Report, Vol. 1*. Austin, TX: Railroad Commission of Texas, Oil and Gas Division.

Ramey, Jr., H. J., V. W. Stamp, F. N. Pebdani, and J. E. Mallinson. 1992. Case History of South Belridge, California, In-Situ Combustion Oil Recovery. SPE/DOE paper 24200 presented at SPE/DOE Eighth Symposium on Enhanced Oil Recovery, Tulsa, OK (April 22–24).

Reid, T. B. and H. J. Robinson. 1981. Lick Creek Meakin Sand Unit. Immiscible CO_2—Waterflood Project. SPE/DOE Paper 9795 presented at SPE/DOE Symposium on Enhanced Oil Recovery, Tulsa (April 5–8).

Restine, J. L. 1991. On the Effect of Viscosity and Sand Thickness on Kern River Field, Single-Zone, Steamflood Performance. SPE paper 21526 presented at the International Thermal Operations Symposium of the Society of Petroleum Engineers, Bakersfield, CA (February 7–8).

Robertson, Jack A., Jeffery A. Blesener, and Samuel Soo Hoo. 1987. Subzone Redevelopment of the Long Beach Unit, Wilmington Oil Field: A Case Study. *J. Pet. Technology*, p. 1229 (October).

Roux, C., W. H. Fertl, E. Frost, D. Stedman, and D. Elliot. 1981. Well logs evaluate and monitor heavy oil steamflood in Kern County, California. *Oil and Gas Journal*, p. 184 (August 17).

Sankur, Vega, J. L. Creek, S. S. DiJulio, and A. S. Emanuel. 1986. A Laboratory Study of Wilmington Tar Zone CO_2 Injection Project. SPE paper 12751 presented at California Regional Meeting of the Society of Petroleum Engineers of AIME, Long Beach, CA, April 11-13, 1984. Revised version in *SPE Reservoir Engineering*, Vol. 1:95–104.

Sarkar, A. K. and P. S. Sarathi. 1992. *Feasibility of Steam Injection Process in a Thin, Low-Permeability Heavy Oil Reservoir of Arkansas—A Numerical Simulation Study.* U.S. Dept. of Energy Report NIPER-661, December.

Sarkar, A. K. and P. S. Sarathi. 1993. *Thermal Processes for Heavy Oil Recovery.* U.S. Dept. of Energy Report NIPER-722, September.

Sarkar, A. K. 1994. *Thermal Recovery in the Gulf Coast Region: Past Performances and Future Potentials.* U.S. Dept. of Energy Report NIPER/BDM-101, December.

Shah, Raj P., Elmer E. Wittmeyer, Stephen D. Sharp, and Raymond W Griep. 1979. *A Study of CO_2 Recovery and Tertiary Oil Production Enhancement in the Los Angeles Basin: Final Report—September 1978*. U.S. Department of Energy Publ. SAN/1582-1 (January).

Shea, D. N. 1965. West Area of Edison Oil Field. *Summary of Operations, California Oil Fields*, Vol. 51(1):23–27.

Smith, R. V., A. F. Bertuzzi, E. E. Templeton, and R. L. Clampitt. 1973. "Recovery of Oil by Steam Injection In The Smackover Field, Arkansas." *J. Pet. Technology*, pp. 883–889 (August).

Spivak, Allan and C. M. Chima. 1984. Mechanisms of Immiscible CO_2 Injection in Heavy Oil Reservoirs, Wilmington Field, CA. SPE paper 12667 presented at the California Regional Meeting of the Society of Petroleum Engineers, Long Beach, CA (April 11–13).

Spivak, Allan, William H. Garrison, and John P. Nguyen. 1988. Review of an Immiscible CO_2 Project, Tar Zone, Fault Block V, Wilmington Field, California. SPE paper 17407 presented at California Regional Meeting of the Society of Petroleum Engineers, Long Beach, CA (March 23-25).

Stalkup, F. I., S. Atkinson, D. B. Burnett, S. A. Chung, R. I. Hawes, P. L. McGuire, M. J. Pitts, A. G. Putz and M. Sugioka. 1992. Enhanced Oil Recovery Field Reports. Vol. 17(2). Richardson, TX: Society of Petroleum Engineers, Enhanced Oil Recovery Field Reports Committee.

Staub, Harrison L. and Wayne R. Hause. 1979. Micellar-Polymer Joint Demonstration Project, Wilmington Field, California (June, 1978 through April, 1979). Vol. 1 of the 5th Annual DOE Symposium on Enhanced Oil and Gas Recovery and Improved Drilling Technology, Tulsa, OK (August 22–24).

Stevenson, V. M. and C. E. Mullen. 1991. Evaluation of a Successful Steamdrive in a Geologically Complex, Steeply Dipping Reservoir at South Casper Creek, WY. SPE paper 21528 presented at the International Thermal Operations Symposium of the Society of Petroleum Engineers, Bakersfield, CA (February 7–8).

Sullivan, John C. 1955. Race Track Hill Area of Edison Oil Field. *Summary of Operations, California Oil Fields*, Vol. 41(2):19–23.

Sullivan, A. 1991. One Field Environmentalists Want. *Wall Street Journal*, Section B1, December 31.

Thomas, C. P., R. B. Allaire, T. C. Doughty, D. D. Faulder, J. S. Irving, H. C. Jamison, and G. J. White. 1993. *Alaska North Slope National Energy Strategy Initiative: Analysis of Five Undeveloped Fields.* U. S. Dept. of Energy Report DOE/ID/01570-T164, Idaho National Engineering Laboratory, May.

Updike, F. H. 1939. Premier Area of the Poso Creek Oil Field. *Summary of Operations, California Oil Fields*, Vol. 24(4):23.

Van Orstrand, C. E. 1935. Normal Geothermal Gradient in United States. American Association of Petroleum Geologists Bull., Vol. 19(1):78 (January).

Weddle, James R. 1966. Northeast Area of McKittrick Oil Field. *Summary of Operations, California Oil Fields*, Vol. 51(2):5.

Wells, Margie and Marilyn Lay, Eds. 1988. *International Oil and Gas Development Yearbook (Review of 1986), Part 2: Production, V. 57*. Austin, TX: Mason Map Service, Inc. and International Oil Scouts Association.

Wells, Margie and Marilyn Lay, Eds. 1989. *International Oil and Gas Development Yearbook (Review of 1987), Part 2: Production, V. 58*. Austin, TX: Mason Map Service, Inc. and International Oil Scouts Association.

Wells, Margie and Marilyn Lay, Eds. 1990. *International Oil and Gas Development Yearbook (Review of 1988), Part 2: Production, V. 59*. Austin, TX: Mason Map Service, Inc. and International Oil Scouts Association.

Wells, Margie and Marilyn Lay, Eds. 1993. *International Oil and Gas Development Yearbook (Review of 1991), Part 2: Production, Vol. 62*. Austin, TX: Mason Map Service, Inc. and International Oil Scouts Association.

Wells, J. S., and L. J. Heath. 1979. *Inventory of Heavy Oil in Western Missouri: Final Report.* U.S. Dept. of Energy Report No. BETC-1808-1.

Wells, J. S., W. J. Ebanks, Jr., and J. F. Roberts. 1982. *Heavy Oil Resources of Kansas-Missouri-Oklahoma*. Energy Research and Development Administration.

Werner, M. R. 1984. Tertiary and Upper Cretaceous Heavy Oil Sands, Kuparuk River Unit Area, North Slope Alaska. In *Exploration for Heavy Crude Oil and Natural Bitumen.* AAPG Studies in Geology No. 25, pp. 537-547, edited by R. F. Meyer, October/November.

Werner, M. R. 1986. *West Sak and Ugnu Sands: Low Gravity Oil Zones of the Kuparuk River Area, Alaskan North Slope.* Interstate Oil Compact Commission Committee Bulletin, Vol. XXVIII (1): 76-84, June.

White, J. Lloyd. 1955. "Edison Oil Field." *Summary of Operations, California Oil Fields,* Vol. 41(2):5–9.

Williams, R. L., J. A. Jones, and T. M. Counihan. 1987. Expansion of a Successful In-Situ Combustion Pilot in Midway Sunset Field. SPE paper 16873 presented at 62nd Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Dallas , TX (September 27–30).

Wooten, Robert Walter. 1978. Case History of a Successful Steamflood Project—Loco Field. SPE paper 7548 presented at 1978 Annual Conference of Soc. Pet. Eng., Houston, TX (Oct. 1–3).

Wyoming Oil and Gas Conservation Commission. 1990. *Wyoming Oil and Gas Statistics, 1989.* Casper, WY: Wyoming Oil and Gas Conservation Commission.

Wyoming Oil and Gas Conservation Commission. 1992. *Wyoming Oil and Gas Statistics, 1991.* Casper, WY: Wyoming Oil and Gas Conservation Commission.

Ybarra R. A. and A. D. Stockton. 1964. Ford Pool of Fault Block I, Wilmington Oil Field. *Summary of Operations, California Oil Fields,* Vol. 50(1):69–75.

Zulberti, John L. 1956. McKittrick Oil Field. *Summary of Operations, California Oil Fields*, Vol. 42(1):49–59.

APPENDIX A
HEAVY OIL RESOURCE TABLES

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
3												
4	AL	Carlton, South	Tuscaloosa Massive, Lower	Tuscaloosa	Gulf C	15	5424	161	28	46,130	1,800,025	1991
5	AL	Carlton, South	Tuscaloosa Pilot, Lower	Tuscaloosa	Gulf C	15	5272	159	29	161,281	5,232,232	1991
6	AL	Gilbertown	Eutaw, Lower	Eutaw	Gulf C	19	3204	125	40	66,032	6,064,455	1991
7	AL	Gilbertown	Eutaw, Upper	Eutaw	Gulf C	19	3188	125	41	44,971	5,885,980	1991
8	AL	Gilbertown	Selma Chalk	Selma Chalk	Gulf C	19	2580	115	59	5,827	1,791,957	1991
9	AL	Latham	Dantzler	Dantzler	Gulf C	16	7086	187	14	0	14,347	1991
10	AL	Melvin	Smackover	Smackover	Gulf C	18	11176	253	5	0	42,412	1986
11	AL	Toxey	Smackover	Smackover	Gulf C	19	10470	242	5	23,668	1,720,349	1991
12	AR	Artesian	Meakin	Meakin	Arkla	17	2560	120	72	9,703	797,935	1990
13	AR	Benjamin Lake	Meakin	Meakin	Arkla	18	2550	120	59	7,395	363,292	1990
14	AR	Boyd Hill	Smackover	Smackover	Arkla	11	6622	193	25	0	7,475	1990
15	AR	Buena Vista	Nacatoch	Nacatoch	Arkla	14	1270	98	520	786	217,553	1990
16	AR	Calion	Graves	Graves	Arkla	15	2490	119	115	4,879	287,494	1990
17	AR	Careyville Landing	Cotton Valley	Cotton Valley	Arkla	19	3379	135	29	8,315	1,010,199	1990
18	AR	Champagnolle Landing	Graves/Baker	Baker	Arkla	16	2602	121	475	31,875	2,799,613	1990
19	AR	Charivari Creek	Nacatoch	Nacatoch	Arkla	19	2380	117	55	31,875	475,147	1990
20	AR	Cross Country Slough	Baker	Baker	Arkla	16	2570	120	88	8,599	1,068,215	1990
21	AR	Crossett	Cotton Valley	Cotton Valley	Arkla	18	3726	141	29	10,872	96,457	1990
22	AR	El Dorado, East	Nacatoch (Old)	Nacatoch	Arkla	20	2170	113	67	23,966	12,273,127	1990
23	AR	Elliot, South	Nacatoch	Nacatoch	Arkla	16	1858	107	165	937	7,609	1990
24	AR	Falcon	Nacatoch	Nacatoch	Arkla	14	1180	95	635	2,031	1,034,166	1990
25	AR	Gum Creek	Blossom	Blossom	Arkla	20	2255	115	50	727	6,253	1990
26	AR	Gum Creek	Nacatoch	Nacatoch	Arkla	17	1590	103	380	6,494	1,314,896	1990
27	AR	Gum Creek	Tokio	Tokio	Arkla	17	2470	119	380	4,536	373,634	1990
28	AR	Hampton	Meakin	Meakin	Arkla	14	2480	119	1550	3,620	815,299	1990
29	AR	Irma	Nacatoch	Nacatoch	Arkla	14	1150	88	377	69,222	11,807,303	1990
30	AR	Lewisville	Tokio	Tokio	Arkla	19	2290	115	59	2,385	509,150	1990
31	AR	Lewisville, West	Tokio	Tokio	Arkla	19	2450	118	280	16,624	2,237,210	1990
32	AR	Lewisville, West	Tuscaloosa	Tuscaloosa	Arkla	19	2850	125	40	1,671	50,895	1990
33	AR	Lick Creek	Meakin	Meakin	Arkla	17	2545	118	160	26,417	6,890,831	1990
34	AR	Lloyd Creek	Nacatoch	Nacatoch	Arkla	17	2340	118	41	1,817	62,240	1990
35	AR	Mayton	Paluxy (Williams Sand)	Paluxy	Arkla	16	3620	139	43	7,838	551,675	1990
36	AR	Midway, East	Tokio	Tokio	Arkla	18	2185	113	79	6,417	253,375	1990
37	AR	Mud Lake	Graves/Baker	Baker	Arkla	16	2560	120	88	22,026	1,391,056	1990
38	AR	Pigeon Hill	Cotton Valley	Cotton Valley	Arkla	15	4287	151	36	3,249	235,915	1990
39	AR	Ritchie	Baker	Ozan	Arkla	16	2606	121	470	6,965	1,187,567	1990
40	AR	Sandy Bend	Nacatoch	Nacatoch	Arkla	19	2270	115	12	86,537	12,404,284	1990
41	AR	Smackover	Blossom	Brownstown	Arkla	19	2583	121	71	522,974	126,801,077	1990
42	AR	Smackover	Graves	Ozan	Arkla	20	2380	117	56	611,181	148,187,927	1990
43	AR	Smackover	Meakin	Ozan	Arkla	19	2230	114	62	67,596	16,389,448	1990
44	AR	Smackover	Nacatoch	Nacatoch	Arkla	19	1920	110	75	991,265	240,343,808	1990
45	AR	Smackover	Tokio	Tokio	Arkla	19	2640	122	46	101,292	24,559,340	1990
46	AR	Spirit Lake	Tokio	Tokio	Arkla	18	2702	123	53	2,133	21,365	1990
47	AR	Stamps	Tokio	Tokio	Arkla	16	2350	116	105	17,968	2,148,013	1990
48	AR	Stamps	Tuscaloosa	Tuscaloosa	Arkla	20	2600	121	40	2,182	309,280	1990
49	AR	Stamps, NW	Tokio	Tokio	Arkla	15	2295	115	140	7,908	460,477	1990
50	AR	Stephens	Nacatoch	Nacatoch	Arkla	17	1402	99	425	22,266	586,807	1990

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
3																		
4	AL	9	7	21	600	31	325	10	10	50	-1	-1	-1	16	1991	1950	Cretaceous	SS
5	AL	44	39	12	4365	31	325	-1	7	50	-1	-1	-1	57	1991	1951	Cretaceous	UFS
6	AL	30	24	20	880	29	500	32	25	38	-1	-1	-1	13	1990	1944	Cretaceous	SS
7	AL	61	55	10	1800	29	500	32	25	38	-1	-1	-1	28	1990	1944	Cretaceous	SS
8	AL	7	5	26	520	29	-1	-1	10	38	-1	-1	-1	13	1991	1944	Cretaceous	Chalk-fract
9	AL	2	2	1	120	20	275	-1	14	32	-1	-1	3	0	1991	1987	Cretaceous	SS
10	AL	3	2	2	188	22	100	15	13	28	-1	-1	2	0	1991	1977	Jurassic	LS
11	AL	6	5	27	307	22	33	36	20	46	-1	-1	7	7	1991	1967	Jurassic	LS
12	AR	4	3	20	430	25	235	-1	9	38	-1	1037	-1	34	1990	1952	Cretaceous	UFS
13	AR	2	2	18	240	25	235	-1	8	40	-1	1058	9	9	1990	1959	Cretaceous	UFS
14	AR	3	3	0	320	18	73	-1	12	34	-1	-1	2	0	1990	1984	Jurassic	LS
15	AR	3	3	7	315	25	-1	-1	9	40	-1	-1	58	58	1990	1956	Cretaceous, Upper	UFS
16	AR	2	2	14	180	33	2140	-1	8	40	-1	1396	9	9	1990	1952	Cretaceous	UFS
17	AR	2	1	48	240	27	333	-1	7	40	-1	-1	8	8	1990	1960	Jurassic	SS
18	AR	11	9	25	1120	31	4865	-1	7	30	-1	1451	29	29	1990	1958	Cretaceous	UFS
19	AR	16	16	3	549	29	65	-1	22	35	-1	1329	22	22	1990	1963	Cretaceous	UFS
20	AR	3	2	34	420	34	1835	-1	5	35	-1	1491	17	16	1990	1959	Cretaceous	UFS
21	AR	2	2	5	240	21	59	-1	8	56	-1	-1	6	5	1990	1980	Jurassic	SS
22	AR	21	9	58	3088	25	1700	51	6	35	-1	1146	-1	-1	-1	1922	Cretaceous	UFS
23	AR	4	4	0	320	37	2200	-1	7	-1	-1	-1	3	2	1990	1982	Cretaceous	UFS
24	AR	2	1	50	150	25	1700	-1	12	35	-1	1146	41	30	1990	1938	Cretaceous	UFS
25	AR	5	5	0	200	30	1400	-1	17	35	-1	1398	3	3	1990	1945	Cretaceous	SS
26	AR	6	4	23	280	30	490	-1	15	35	-1	1361	4	4	1990	1941	Cretaceous	UFS
27	AR	3	3	11	200	26	798	-1	14	35	-1	1174	4	4	1990	1945	Cretaceous	UFS
28	AR	4	3	20	160	25	1500	-1	24	38	-1	1093	12	12	1990	1943	Cretaceous	UFS
29	AR	47	35	25	2200	35	2500	31	13	40	-1	-1	-1	-1	-1	1920	Cretaceous	UFS
30	AR	2	2	25	120	31	2285	-1	9	18	-1	1915	-1	1	1990	1939	Cretaceous	UFS
31	AR	5	2	48	267	31	480	-1	12	30	-1	1478	14	14	1990	1947	Cretaceous	UFS
32	AR	1	1	5	80	20	650	-1	14	30	-1	906	4	3	1990	1980	Cretaceous	UFS
33	AR	26	19	27	1640	33	1200	-1	12	32	68	1405	39	39	1990	1957	Cretaceous	UFS
34	AR	1	1	6	200	36	620	-1	3	45	-1	-1	5	5	1990	1968	Cretaceous	UFS
35	AR	3	2	21	180	26	540	16	12	35	-1	-1	8	8	1990	1967	Cretaceous	SS
36	AR	1	1	18	200	25	940	-1	6	35	-1	1146	10	10	1990	1958	Cretaceous	UFS
37	AR	7	5	20	760	34	1600	-1	6	35	-1	1491	19	19	1990	1959	Cretaceous	UFS
38	AR	2	1	15	120	23	330	-1	13	30	-1	1041	3	3	1990	1953	Jurassic	SS
39	AR	6	4	21	550	31	2754	-1	7	20	-1	1451	16	16	1990	1963	Cretaceous	UFS
40	AR	163	150	8	5330	25	1700	-1	35	50	-1	882	506	506	1990	1947	Cretaceous	UFS
41	AR	214	87	59	12190	29	1500	-1	13	25	-1	-1	-1	-1	-1	1922	Cretaceous	UFS
42	AR	250	102	59	10233	25	1000	-1	21	25	-1	-1	-1	-1	-1	1922	Cretaceous	UFS
43	AR	28	11	59	3000	22	2400	-1	9	35	-1	-1	-1	-1	-1	1922	Cretaceous	UFS
44	AR	405	165	59	16980	27	2000	-1	19	25	-1	-1	-1	-1	-1	1922	Cretaceous	UFS
45	AR	41	17	59	2967	25	2000	-1	12	35	-1	-1	-1	-1	-1	1922	Cretaceous	UFS
46	AR	1	1	2	20	33	300	-1	34	35	-1	-1	1	1	1990	1980	Cretaceous	UFS
47	AR	10	8	21	760	33	939	-1	12	50	-1	1123	28	28	1990	1955	Cretaceous	UFS
48	AR	1	1	22	220	25	812	-1	7	47	-1	936	5	4	1990	1955	Cretaceous	UFS
49	AR	2	2	21	200	28	940	-1	8	35	-1	1371	11	11	1990	1956	Cretaceous	UFS
50	AR	3	3	18	870	20	1700	-1	4	45	-1	-1	51	51	1990	1971	Cretaceous	UFS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
51	AR	Troy	Nacatoch	Nacatoch	Arkla	18	1220	96	1260	68,644	9,900,237	1990
52	AR	Troy	Tokio	Tokio	Arkla	18	2150	113	75	13,851	3,476,591	1990
53	AR	Wesson	Nacatoch	Nacatoch	Arkla	15	1500	101	315	18,238	1,216,323	1990
54	AR	Willisville	Nacatoch	Nacatoch	Arkla	14	1211	96	610	35,908	461,837	1990
55	AR	Willisville, SW	Blossom	Blossom	Arkla	18	1980	110	94	7,878	276,014	1990
56	AR	Willisville, SW	Nacatoch	Nacatoch	Arkla	14	1140	95	1000	66,147	3,957,343	1990
57	AR	Willisville, West	Nacatoch	Nacatoch	Arkla	15	1200	96	460	4,198	448,099	1990
58	AR	Winchester	Meakin	Meakin	Arkla	20	2635	121	65	3,393	1,027,329	1990
59	AR	Woodley	Nacatoch	Nacatoch	Arkla	20	1925	109	67	4,253	416,260	1990
60	CA	Aliso Canyon	Aliso	Pico	Coastal	15	4150	130	69	32,649	5,902,298	1990
61	CA	Ant Hill	Olcese	Olcese	San Joaquin	14	2300	90	330	51,352	6,763,188	1990
62	CA	Antelope Hills, North	Agua	Temblor	San Joaquin	15	2380	117	130	84,011	3,043,800	1990
63	CA	Antelope Hills, North	Point of Rocks	Kreyenhagen	San Joaquin	16	1545	96	340	135,502	5,082,030	1990
64	CA	Antelope Hills, Williams Area	Agua	Temblor	San Joaquin	18	2300	140	350	19,682	7,585,880	1990
65	CA	Arroyo Grande, Tiber Area	Dollie	Pismo	Coastal	14	750	95	1050	455,028	7,389,000	1990
66	CA	Barham Ranch, Old Area	Monterey	Monterey	Coastal	14	2800	100	435	2,647	131,500	1990
67	CA	Barham Ranch, Old Area	Sisquoc, Basal	Sisquoc	Coastal	15	1400	85	1130	2,647	131,500	1990
68	CA	Belridge, North	Tulare, Etchegoin	Tulare/Etchegoin	San Joaquin	13	600	100	1080	982,830	13,158,000	1990
69	CA	Belridge, South	Tulare	Tulare	San Joaquin	13	400	91	510	42,448,567	630,115,000	1990
70	CA	Beta Offshore, Federal OCS	Delmontian	Delmontian	Los Angeles	16	3900	140	105	5,308,128	50,640,331	1990
71	CA	Blackwells Corner	Agua	Temblor	San Joaquin	14	1300	76	1000	14,375	812,760	1990
72	CA	Cascade	Cascade	Saugus	Coastal	19	2733	94	180	32,782	1,823,000	1990
73	CA	Casmalia	Monterey	Monterey	Coastal	16	2038	140	12	335,480	39,614,000	1990
74	CA	Castaic Junction	10-A	Modelo	Coastal	14	8400	208	12	66,504	19,467,960	1990
75	CA	Cat Canyon, Central	Sisquoc	Sisquoc	Coastal	11	2800	103	880	162,255	19,652,246	1990
76	CA	Cat Canyon, East	Sisquoc	Sisquoc	Coastal	14	3000	125	3200	320,021	84,508,786	1990
77	CA	Cat Canyon, Gato Ridge	Monterey	Monterey	Coastal	12	3800	135	1100	70,434	15,883,022	1990
78	CA	Cat Canyon, Gato Ridge	Sisquoc	Sisquoc	Coastal	13	2210	110	305	68,920	15,541,451	1990
79	CA	Cat Canyon, West Area	Los Flores	Monterey	Coastal	17	6000	188	900	342,127	77,149,931	1990
80	CA	Cat Canyon, West Area	Sisquoc	Sisquoc	Coastal	15	2800	105	3100	13,172	2,970,217	1990
81	CA	Chico-Martinez	Etchegoin	Etchegoin	San Joaquin	12	900	75	11600	2,651	470,778	1990
82	CA	Cienaga Canyon	Temblor "A"	Temblor	San Joaquin	20	2000	100	100	19,166	324,900	1990
83	CA	Coalinga, Westside Area	Etchegoin-Temblor	Etchegoin/Temblor	San Joaquin	15	2000	110	1000	3,244,582	217,957,988	1990
84	CA	Cymric, Salt Creek Main Area	Carneros Unit	Temblor	San Joaquin	20	1950	132	22	71,833	25,840,304	1990
85	CA	Cymric, Sheep Springs Area	Etchegoin "54-21"	Etchegoin	San Joaquin	16	2450	97	94	26,778	3,926,000	1990
86	CA	Cymric, Sheep Springs Area	Tulare	Tulare	San Joaquin	12	1420	103	645	1,384	67,000	1990
87	CA	Cymric, Welport Area	Tulare (Amnicola)	Tulare	San Joaquin	13	1000	100	3000	7,818,349	129,946,000	1990
88	CA	Devils Den, Alferitz Area	Carneros-Agua	Temblor	San Joaquin	15	1350	115	120	4,029	689,981	1990
89	CA	Devils Den, Alferitz Area	Escudo	Monterey	San Joaquin	15	1100	94	20000	2,301	394,009	1990
90	CA	Devils Den, Old Area	Cymric (Salt Creek)	Temblor	San Joaquin	19	200	74	975	1,689	112,457	1990
91	CA	Devils Den, Old Area	Point of Rocks	Kreyenhagen	San Joaquin	18	600	81	620	899	59,858	1990
92	CA	Devils Den, Old Area	Santos	Temblor	San Joaquin	14	200	74	5900	760	50,606	1990
93	CA	Devils Den, Old Area	Wagonwheel (Tumey)	Wagonwheel	San Joaquin	16	500	80	1420	977	65,079	1990
94	CA	Edison, Groves Area	Kern River - Chanac	Kern River/Chanac	San Joaquin	15	1150	78	740	34,402	2,265,353	1990
95	CA	Edison, Groves Area	Olcese	Olcese	San Joaquin	13	3450	106	390	26,085	1,717,647	1990
96	CA	Edison, Jeppi Area	Santa Margarita	Santa Margarita	San Joaquin	20	3500	104	81	5,967	1,902,943	1990
97	CA	Edison, Main Area	Kern River - Chanac	Kern River/Chanac	San Joaquin	18	2475	103	300	1,306,552	39,938,832	1990
98	CA	Edison, Main Area	Schist	Basement	San Joaquin	19	2850	108	20	66,506	20,330,309	1990

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
51	AR	25	15	40	997	40	3000	18	13	33	-1	1890	50	50	1990	1936	Cretaceous	UFS
52	AR	12	9	29	642	32	1919	18	13	33	-1	1444	10	10	1990	1936	Cretaceous	UFS
53	AR	2	1	50	280	30	1700	-1	6	35	-1	1441	16	15	1990	1946	Cretaceous	UFS
54	AR	5	5	9	250	35	2000	-1	14	45	-1	1552	30	30	1990	1951	Cretaceous	UFS
55	AR	3	3	10	220	28	500	-1	10	30	-1	-1	11	11	1990	1970	Cretaceous	UFS
56	AR	8	4	51	460	35	1700	-1	11	40	-1	1552	47	30	1990	1956	Cretaceous	UFS
57	AR	3	2	16	100	26	1700	-1	25	40	-1	1100	8	7	1990	1957	Cretaceous	UFS
58	AR	4	3	26	360	28	709	-1	10	40	-1	1095	10	10	1990	1956	Cretaceous	UFS
59	AR	7	7	6	744	25	1700	210	8	35	-1	1201	-1	-1	-1	1922	Cretaceous	UFS
60	CA	30	24	20	270	25	770	148	89	36	64	1206	20	9	1990	1950	Pliocene, Upper	UFS
61	CA	51	45	13	875	31	530	150	40	39	61	1680	33	17	1990	1944	Miocene	UFS
62	CA	34	31	9	235	30	500	185	100	37	63	1369	10	7	1990	1950	Oligocene	UFS
63	CA	13	8	38	300	32	100	65	30	-1	-1	-1	53	53	1990	1965	Eocene	UFS
64	CA	32	25	23	190	33	400	125	101	-1	66	1609	22	9	1990	1942	Oligocene	UFS
65	CA	39	32	19	530	28	870	400	100	66	34	-1	160	58	1990	1906	Pliocene/Miocene	UFS
66	CA	9	9	1	40	25	-1	400	300	-1	40	-1	2	2	1990	1943	Miocene, Upper	SH-fract
67	CA	9	9	1	40	25	400	-1	300	60	40	-1	2	2	1990	1945	Pliocene/Miocene	SS
68	CA	442	429	3	2265	37	2500	-1	100	32	68	1850	327	249	1990	1917	Pleistocene/Pliocene	UFS
69	CA	1,911	1,281	33	10753	35	3000	400	85	20	77	2050	5557	3950	1990	1911	Pleistocene	UFS
70	CA	805	754	6	1900	26	100	390	350	40	60	1000	78	72	1990	1976	Miocene, Upper	SS
71	CA	21	20	4	250	32	670	-1	85	60	40	984	7	3	1990	1943	Oligocene	UFS
72	CA	28	26	7	60	25	-1	500	395	-1	-1	-1	10	10	1990	1954	Pliocene/Miocene	UFS
73	CA	980	940	4	2350	25	-1	1000	500	-1	43	400	196	125	1990	1905	Miocene, Upper	SH-fract
74	CA	77	58	25	600	13	60	-1	200	36	64	-1	21	7	1990	1950	Miocene	SS
75	CA	49	30	40	620	35	1000	100	45	35	65	1600	91	43	1990	1956	Pliocene	UFS
76	CA	820	735	10	1970	33	1500	800	250	35	65	1600	391	83	1990	1953	Pliocene, Lower	UFS
77	CA	199	183	8	690	25	-1	-1	248	-1	-1	-1	45	25	1990	1915	Miocene, Upper	SH-fract
78	CA	195	179	8	690	28	2000	-1	200	35	65	-1	45	25	1990	1937	Pliocene, Lower	UFS/SH
79	CA	1,936	1,858	4	2880	25	-1	1500	550	-1	63	1164	218	113	1990	1938	Miocene, Upper	SH-fract
80	CA	75	72	4	300	29	270	-1	160	31	69	1700	8	4	1990	1908	Pliocene	UFS
81	CA	15	14	3	360	33	900	85	35	55	45	1200	37	6	1990	1927	Pliocene	UFS
82	CA	17	17	2	95	28	700	300	170	-1	49	1300	13	13	1990	1978	Miocene, Lower	UFS
83	CA	2,013	1,795	11	9608	30	2000	600	200	48	45	1114	972	658	1990	1900	Pliocene/Miocene	UFS
84	CA	83	57	31	310	33	240	165	150	28	70	1604	70	22	1990	1946	Pliocene, Lower	UFS
85	CA	24	20	17	170	35	480	105	75	-1	68	1707	114	62	1990	1929	Pliocene, Lower	UFS
86	CA	14	14	0	140	31	800	-1	65	35	65	1350	11	4	1990	1948	Pleistocene	UFS
87	CA	1,367	1,237	10	9050	34	700	450	83	31	69	1527	1418	918	1990	1916	Pleistocene	UFS
88	CA	114	113	1	495	33	300	-1	150	40	60	1400	17	4	1990	1938	Miocene/Oligocene	UFS
89	CA	65	65	1	495	32	1600	-1	100	47	53	870	10	3	1990	1952	Miocene	UFS
90	CA	42	42	0	167	27	250	-1	200	-1	-1	-1	44	16	1990	-1	Oligocene	SS
91	CA	22	22	0	100	24	250	-1	200	-1	-1	-1	23	9	1990	-1	Eocene	SS
92	CA	19	19	0	167	27	250	-1	90	-1	-1	-1	20	7	1990	-1	Miocene/Oligocene	SS
93	CA	24	24	0	167	25	200	300	125	-1	-1	-1	26	9	1990	-1	Eocene	SS
94	CA	31	29	7	645	26	960	70	43	45	55	1110	111	76	1990	1950	Miocene, Lower	UFS
95	CA	23	22	7	179	28	1400	-1	100	40	60	1000	84	58	1990	1950	Miocene, Lower	UFS
96	CA	31	29	6	680	30	1800	-1	30	35	65	1350	7	5	1990	1948	Miocene	UFS
97	CA	215	175	19	1850	30	1700	360	100	47	50	1065	247	171	1990	1932	Pliocene/Miocene	UFS
98	CA	85	64	24	1119	25	-1	2207	60	-1	65	-1	125	87	1990	1945	Cretaceous/Jurassic	Xln

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
99	CA	Edison, Main Area	Walker	Walker	San Joaquin	18	2900	109	97	2,333	713,125	1990
100	CA	Edison, Main Area	Wicker	Fruitvale	San Joaquin	16	2000	96	339	880	268,902	1990
101	CA	Edison, Portals-Fairfax Area	Nozu	Round Mountain	San Joaquin	15	4100	121	500	21,855	1,985,000	1990
102	CA	Edison, Portals-Fairfax Area	Wicker	Fruitvale	San Joaquin	19	4200	122	500	30,596	2,779,000	1990
103	CA	Edison, Race Track Hill Area	Kern River-Chanac	Chanac	San Joaquin	15	1070	90	720	90,955	4,513,517	1990
104	CA	Edison, Race Track Hill Area	Nozu	Round Mountain	San Joaquin	16	3260	110	145	5,141	255,112	1990
105	CA	Edison, Race Track Hill Area	Santa Margarita	Santa Margarita	San Joaquin	13	1830	97	750	7,846	389,340	1990
106	CA	Edison, Race Track Hill Area	Wicker	Fruitvale	San Joaquin	14	3200	109	250	3,076	152,631	1990
107	CA	Edison, West Area	Chanac	Chanac	San Joaquin	20	3200	101	95	36,370	9,560,226	1990
108	CA	Edison, West Area	Nozu	Round Mountain	San Joaquin	20	4500	116	48	2,554	671,382	1990
109	CA	Edison, West Area	Porter	Olcese	San Joaquin	20	4400	115	49	1,165	306,298	1990
110	CA	Edison, West Area	Santa Margarita	Santa Margarita	San Joaquin	15	4000	111	175	7,594	1,996,175	1990
111	CA	Fruitvale, Main Area	Fairhaven	Etchegoin	San Joaquin	17	3000	118	115	33,960	8,244,627	1990
112	CA	Fruitvale, Main Area	Kernco	Chanac	San Joaquin	19	3600	130	340	174,657	42,402,230	1990
113	CA	Fruitvale, Main Area	Mason-Parker	Chanac	San Joaquin	18	3100	119	85	103,206	25,055,760	1990
114	CA	Fruitvale, Main Area	Santa Margarita	Santa Margarita	San Joaquin	18	4500	133	165	3,589	871,252	1990
115	CA	Guadalupe	Monterey	Monterey	Coastal	12	3000	127	180	8,747	337,000	1990
116	CA	Guadalupe	Sisquoc	Sisquoc	Coastal	11	2700	155	300	59,503	38,000,000	1990
117	CA	Hasley Canyon	Val Verda	Modelo	Coastal	16	5063	165	23	120,791	2,198,000	1990
118	CA	Holser	Conglomerate	Modelo	Coastal	17	1000	92	350	196	500	1990
119	CA	Hondo Offshore, Federal-OCS	Monterey	Monterey	Coastal	17	8200	210	9	8,211,684	106,998,039	1990
120	CA	Huasna-Lavoie-Hadley Area	Santa Margarita	Santa Margarita	Coastal	10	1155	95	2450	0	23,000	1987
121	CA	Hueneme, Federal-OCS	Hueneme	-1	Coastal	15	5160	168	23	312,634	5,373,140	1990
122	CA	Hueneme, Federal-OCS	Sespe	Sespe	Coastal	14	5520	173	24	109,844	1,887,860	1990
123	CA	Huntington Beach, Offshore Area	AA	Repetto	Los Angeles	15	1510	105	244	71,517	15,437,438	1990
124	CA	Huntington Beach, Offshore Area	Jones, Lower	Puente	Los Angeles	16	2850	142	31	281,266	60,713,486	1990
125	CA	Huntington Beach, Offshore Area	Jones, Upper	Puente	Los Angeles	18	2400	132	42	229,369	49,511,103	1990
126	CA	Huntington Beach, Offshore Area	TM	Puente	Los Angeles	12	2200	128	135	97,156	20,971,896	1990
127	CA	Huntington Beach, Onshore Area	Bolsa, Lower (Lower Tar)	Repetto	Los Angeles	18	2300	125	3600	32,252	13,014,973	1990
128	CA	Huntington Beach, Onshore Area	Bolsa, Middle (Upper Tar)	Repetto	Los Angeles	18	2200	122	940	48,378	19,522,459	1990
129	CA	Huntington Beach, Onshore Area	Bolsa, Upper (Garfield)	Repetto	Los Angeles	18	1800	126	50	79,905	32,244,888	1990
130	CA	Huntington Beach, Onshore Area	Jones, Lower	Puente	Los Angeles	17	4600	150	27	243,000	98,060,864	1990
131	CA	Huntington Beach, Onshore Area	Jones, Upper	Puente	Los Angeles	17	4300	150	26	446,354	180,123,063	1990
132	CA	Huntington Beach, Onshore Area	Main	Puente	Los Angeles	19	4300	170	13	197,417	79,666,196	1990
133	CA	Jasmin	Cantleberry Sand	Vedder	San Joaquin	14	2750	112	300	66,503	3,391,000	1990
134	CA	Jasmin	Pyramid Hill	Jewett	San Joaquin	14	1705	98	515	111	2,000	1990
135	CA	Jesus Maria, Main Area	Monterey	Monterey	Coastal	10	2750	110	2600	0	285,000	1985
136	CA	Kern Bluff	Santa Margarita	Santa Margarita	San Joaquin	14	950	84	1000	2,862	5,964,000	1990
137	CA	Kern Bluff	Transition	Transition	San Joaquin	14	1045	84	1000	2,862	5,964,000	1990
138	CA	Kern Front	Etchegoin-Chanac	Etchegoin/Chanac	San Joaquin	14	2290	102	4150	2,332,029	177,148,000	1990
139	CA	Kern River	Kern River	Kern River	San Joaquin	13	850	80	5600	43,994,168	1,293,639,000	1990
140	CA	King City, Doud Area	Thorup	Monterey	Coastal	15	2000	108	200	3,802	1,845,000	1990
141	CA	Kreyenhagen	Temblor	Monterey & Temblor	San Joaquin	16	450	90	1300	1,060	43,000	1990
142	CA	Las Posas	Sespe Eocene	Sespe-Llajas	Coastal	15	4600	156	30	0	32,560	1990
143	CA	Lompoc, Main Area	Monterey	Monterey	Coastal	20	2500	170	11	192,925	44,409,000	1990
144	CA	Lompoc, Northwest Area	Monterey	Monterey	Coastal	18	2700	150	10	174,705	1,081,453	1990
145	CA	Los Angeles City	First Sand	Puente	Los Angeles	19	900	88	310	35,060	17,485,182	1990
146	CA	Los Angeles City	Second Sand	Puente	Los Angeles	14	1100	94	700	9,300	4,638,175	1990

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
99	CA	5	4	14	180	26	675	84	25	-1	57	1050	4	3	1990	1934	Oligocene	UFS
100	CA	4	4	7	60	26	2000	60	52	-1	62	1150	2	1	1990	1945	Miocene, Upper	UFS
101	CA	42	40	5	690	24	1200	80	50	35	65	1150	29	25	1990	1928	Miocene, Middle	UFS
102	CA	58	56	5	690	35	2500	120	60	48	52	1350	40	36	1990	1934	Miocene, Upper	UFS
103	CA	96	91	5	456	30	1000	-1	150	40	60	1800	48	31	1990	1954	Miocene, Upper	UFS
104	CA	78	78	0	860	30	1800	440	60	35	65	1350	3	2	1990	1947	Miocene, Middle	UFS
105	CA	105	105	0	1520	36	1600	-1	40	38	62	1000	4	3	1990	1953	Miocene, Upper	UFS
106	CA	26	26	1	320	30	2000	130	50	30	70	1500	2	1	1990	1952	Miocene, Upper	UFS
107	CA	360	350	3	1545	25	3000	460	200	40	60	1050	71	44	1990	1935	Miocene, Upper	UFS
108	CA	25	25	3	350	20	250	-1	75	38	62	850	5	3	1990	1935	Miocene, Middle	SS
109	CA	12	11	3	110	30	150	100	75	40	60	1200	2	1	1990	1951	Miocene, Lower	UFS
110	CA	75	73	3	1545	27	550	50	40	42	58	1150	15	9	1990	1937	Miocene, Upper	UFS
111	CA	119	111	7	1460	30	1000	80	50	30	70	1500	32	19	1990	1936	Pliocene, Lower	UFS
112	CA	612	569	7	3800	28	820	380	130	43	57	1100	164	99	1990	1928	Miocene, Upper	UFS
113	CA	361	336	7	1500	29	1200	230	170	37	63	1300	97	59	1990	1928	Pliocene/Miocene	UFS
114	CA	13	12	7	120	30	1200	260	75	40	60	-1	4	2	1990	1929	Miocene, Upper	UFS
115	CA	28	28	1	200	25	-1	265	120	40	60	-1	5	5	1990	1955	Miocene, Upper	SS
116	CA	239	201	16	2090	36	1250	120	65	37	63	-1	209	128	1990	1948	Pliocene, Lower	UFS
117	CA	20	18	11	190	25	-1	150	88	-1	62	-1	24	23	1990	1944	Miocene	SS
118	CA	43	43	0	130	14	-1	890	450	-1	67	-1	1	1	1990	1954	Miocene	SS
119	CA	6,284	6,177	2	3600	30	-1	-1	1250	-1	-1	-1	24	22	1990	1968	Miocene	S
120	CA	24	24	0	40	25	-1	1300	520	-1	-1	-1	5	0	1987	1965	Pliocene, Lower	UFS
121	CA	19	14	28	220	32	2200	-1	105	32	33	-1	5	5	1990	1969	Miocene	UFS
122	CA	12	10	16	346	30	260	-1	25	52	17	-1	2	2	1990	1969	Oligocene	SS
123	CA	449	434	3	2365	34	1000	-1	90	20	80	-1	13	6	1990	1964	Pliocene, Lower	UFS
124	CA	290	229	21	1950	28	600	-1	120	43	57	-1	53	21	1990	1933	Miocene, Upper	UFS
125	CA	453	403	11	1890	25	300	-1	190	35	65	-1	43	17	1990	1933	Miocene, Upper	UFS
126	CA	338	317	6	2365	32	1000	-1	125	54	46	-1	18	7	1990	1964	Miocene, Upper	UFS
127	CA	58	45	22	350	33	2300	230	100	35	65	1800	15	12	1990	1920	Miocene, Upper	UFS
128	CA	87	68	22	350	33	2300	155	150	35	65	1800	22	19	1990	1920	Miocene, Upper	UFS
129	CA	144	112	22	800	31	1500	130	100	25	75	-1	36	30	1990	1926	Miocene, Upper	UFS
130	CA	439	341	22	2514	25	-1	270	150	40	60	-1	111	92	1990	-1	Miocene, Upper	UFS
131	CA	806	626	22	3252	30	550	500	142	-1	75	1751	204	169	1990	1926	Miocene, Upper	UFS
132	CA	357	277	22	790	30	1000	-1	277	30	70	-1	91	75	1990	1926	Miocene, Upper	UFS
133	CA	16	13	21	120	40	1300	80	62	30	70	1700	71	41	1990	1946	Oligocene	UFS
134	CA	73	73	0	590	37	1125	130	92	53	47	1200	7	7	1990	1964	Miocene, Lower	UFS
135	CA	35	35	1	100	25	-1	500	305	-1	-1	-1	4	0	1985	1948	Miocene	SH-fract
136	CA	56	50	11	715	27	3500	110	55	32	68	1400	77	34	1990	1947	Miocene, Upper	UFS
137	CA	56	50	11	715	27	3500	80	55	32	68	1400	71	31	1990	1944	Miocene, Upper	UFS
138	CA	1,330	1,153	13	5495	32	1400	490	150	35	65	1500	1456	947	1990	1912	Pliocene/Miocene	UFS
139	CA	3,096	1,802	42	10270	37	3000	500	150	30	70	1950	8781	7269	1990	1899	Pleistocene/Pliocene	UFS
140	CA	20	18	9	110	32	-1	-1	100	28	72	1702	41	7	1990	1959	Miocene	UFS
141	CA	13	13	0	95	24	60	300	130	43	57	1336	21	12	1990	1949	Miocene, Middle	UFS
142	CA	8	8	0	20	25	-1	2000	340	-1	-1	-1	2	0	1990	1966	Miocene	UFS
143	CA	488	443	9	2290	25	-1	500	183	-1	-1	-1	117	67	1990	1903	Miocene, Upper	SH-fract/STS
144	CA	33	32	3	100	25	-1	-1	280	-1	-1	-1	11	10	1990	1983	Miocene, Upper	STS
145	CA	125	108	14	760	34	-1	-1	125	-1	50	-1	48	47	1990	1890	Miocene, Upper	UFS
146	CA	33	29	14	700	34	-1	40	30	-1	-1	-1	11	11	1990	-1	Miocene, Upper	UFS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
147	CA	Lost Hills	Tulare	Tulare	San Joaquin	15	275	78	1200	246,870	98,543,000	1990
148	CA	Lost Hills, Northwest	Antelope	Monterey	San Joaquin	20	3800	91	170	3,087	60,000	1990
149	CA	McDonald Anticline, Bacon Hills Area	Antelope	Monterey	San Joaquin	13	500	82	3140	7,016	53,682	1990
150	CA	McDonald Anticline, Layman Area	D-1	Monterey	San Joaquin	19	1200	110	440	0	53,150	1990
151	CA	McDonald Anticline, Layman Area	Layman 101	Monterey	San Joaquin	19	1400	80	610	0	69,853	1990
152	CA	McDonald Anticline, Layman Area	Phacoides	Temblor	San Joaquin	20	1300	130	29	7,728	655,967	1990
153	CA	McDonald Anticline, Layman Area	Tolco (7th Devilwater)	Monterey	San Joaquin	20	2600	96	125	5,911	501,742	1990
154	CA	McDonald Anticline, Layman Area	Tulare	Tulare	San Joaquin	20	550	70	1080	0	72,639	1990
155	CA	McKittrick, Main Area	Olig	Reef Ridge	San Joaquin	14	800	100	2000	473,336	128,631,995	1990
156	CA	McKittrick, Main Area	Reef Ridge, Basal	Reef Ridge	San Joaquin	17	1500	115	1670	12,171	3,307,680	1990
157	CA	McKittrick, Main Area	Tulare-San Joaquin	Tulare-San Joaquin	San Joaquin	16	750	98	4500	120,916	32,859,732	1990
158	CA	McKittrick, Northeast Area	Tulare (Amnicola)	Tulare	San Joaquin	18	650	97	6500	332,393	29,340,884	1990
159	CA	Midway-Sunset	Calitroleum	Etchegoin	San Joaquin	20	3000	115	20	6,373,938	215,313,381	1990
160	CA	Midway-Sunset	Gusher	Etchegoin	San Joaquin	20	2500	108	8	1,793,714	60,592,141	1990
161	CA	Midway-Sunset	Kinsey	Etchegoin	San Joaquin	20	2800	128	20	579,416	19,572,845	1990
162	CA	Midway-Sunset	Leutholtz (Metson)	Monterey	San Joaquin	16	2200	108	4900	754,390	25,483,509	1990
163	CA	Midway-Sunset	Marvic	Monterey	San Joaquin	13	1000	105	3000	645,714	21,812,389	1990
164	CA	Midway-Sunset	Moco	Monterey	San Joaquin	15	2400	125	110	954,114	32,230,246	1990
165	CA	Midway-Sunset	Monarch (Spellacy)	Monterey	San Joaquin	15	1300	95	1600	11,751,859	396,981,011	1990
166	CA	Midway-Sunset	Mya Tar	San Joaquin	San Joaquin	14	1100	108	1500	630,516	21,299,003	1990
167	CA	Midway-Sunset	Obispo	Monterey	San Joaquin	20	3600	132	27	543,539	18,360,911	1990
168	CA	Midway-Sunset	Pacific	Monterey	San Joaquin	16	3700	136	48	176,147	5,950,295	1990
169	CA	Midway-Sunset	Potter	Reef Ridge	San Joaquin	13	1350	98	1475	18,734,640	632,861,254	1990
170	CA	Midway-Sunset	Republic	Monterey	San Joaquin	18	3100	142	200	342,622	11,573,849	1990
171	CA	Midway-Sunset	Top Oil	San Joaquin	San Joaquin	19	1500	108	32	683,858	23,100,896	1990
172	CA	Midway-Sunset	Tulare	Tulare	San Joaquin	11	800	101	3500	6,823,828	230,510,774	1990
173	CA	Midway-Sunset	Webster	Monterey	San Joaquin	14	1650	112	600	404,263	13,656,131	1990
174	CA	Midway-Sunset	Wilhelm	Etchegoin	San Joaquin	20	2800	128	31	1,650,345	55,749,099	1990
175	CA	Monroe Swell, Old Area	44	Monterey	Coastal	19	2000	110	75	1,374	107,273	1990
176	CA	Monroe Swell, Old Area	Beedy	Monterey	Coastal	17	3200	104	160	1,031	80,455	1990
177	CA	Monroe Swell, Old Area	Doud	Monterey	Coastal	19	2900	109	78	1,374	107,273	1990
178	CA	Montalvo West, Onshore Area	Colonia	Sespe	Coastal	16	11000	230	12	119,623	29,331,120	1990
179	CA	Montebello	First Sand	Repetto	Los Angeles	20	2200	110	50	149,862	52,565,759	1990
180	CA	Montebello	Fourth Sand	Repetto	Los Angeles	20	4800	160	13	130,729	45,854,777	1990
181	CA	Mount Poso, Dominion Area	Pyramid Hill	Freeman-Jewett	San Joaquin	13	1140	92	1140	0	1,000	1986
182	CA	Mount Poso, Dominion Area	Vedder	Vedder	San Joaquin	15	1560	98	490	158,377	8,613,000	1990
183	CA	Mount Poso, Dorsey Area	Vedder	Vedder	San Joaquin	15	1500	99	470	50,411	5,850,000	1990
184	CA	Mount Poso, Main Area	Pyramid Hill	Freeman-Jewett	San Joaquin	15	1600	100	340	220,541	13,156,676	1990
185	CA	Mount Poso, Main Area	Vedder	Vedder	San Joaquin	15	1750	110	280	4,374,509	260,966,912	1988
186	CA	Newhall, Towsley Canyon Area	Unnamed	Modelo	Coastal	20	1482	98	110	0	85,000	1986
187	CA	Newhall, Tunnel	Modelo	Modelo	Coastal	17	1581	103	165	6,943	2,303,000	1990
188	CA	Newport, West, Offshore Area	Newport	Puente	Los Angeles	19	3750	140	25	53,120	4,908,000	1990
189	CA	Newport, West, Onshore	B Sand	Puente	Los Angeles	18	2850	110	550	357,935	4,386,000	1990
190	CA	Ojai, Sulphur Mountain	Miocene	Monterey	Coastal	16	1861	105	185	4,432	387,000	1990
191	CA	Olive	Dinkler	Repetto	Los Angeles	14	4900	122	125	37,947	2,375,000	1990
192	CA	Orcutt, Main Area	Monterey	Monterey	Coastal	16	1700	140	89	8,157	183,810	1990
193	CA	Paris Valley, Main Area	Ansberry, Basal	Monterey	Coastal	11	1090	87	23000	106	135,000	1990
194	CA	Placerita	Kraft, Upper	Pico	Coastal	12	1000	90	1000	243,247	16,434,220	1990

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
147	CA	358	259	28	2560	40	1700	450	75	40	60	1850	1685	678	1990	1915	Pleistocene	UFS
148	CA	9	9	1	20	25	-1	800	380	-1	-1	-1	3	3	1990	1954	Miocene	SLT/SS
149	CA	19	19	0	20	20	-1	-1	1000	-1	-1	-1	6	6	1990	1953	Miocene, Upper	SH-fract
150	CA	23	23	0	285	29	390	-1	60	40	60	1300	-1	0	1990	1951	Miocene	UFS
151	CA	37	37	0	285	28	500	-1	100	40	60	1250	-1	0	1990	1951	Miocene	UFS
152	CA	30	30	2	590	21	150	-1	50	37	63	905	3	3	1990	1945	Oligocene	SS
153	CA	41	40	1	285	32	900	90	80	28	72	2071	3	2	1990	1951	Miocene, Middle	UFS
154	CA	108	108	0	590	25	200	350	150	35	63	1200	-1	0	1990	1954	Pleistocene	UFS
155	CA	1,303	1,175	10	1400	30	3000	-1	500	20	80	1600	730	413	1990	1896	Miocene	UFS
156	CA	34	30	10	60	30	1580	-1	400	40	60	1300	19	11	1990	1944	Miocene	UFS
157	CA	333	300	10	1100	34	1200	500	153	-1	75	2000	186	105	1990	1887	Pleistocene/Pliocene	UFS
158	CA	188	159	16	2100	33	2500	200	50	30	70	1600	239	119	1990	1948	Pleistocene	UFS
159	CA	805	590	27	9534	28	230	450	67	-1	58	1180	1444	952	1990	1922	Pliocene, Lower	UFS
160	CA	172	111	35	1360	38	1000	75	63	-1	68	2090	406	268	1990	1909	Pliocene, Lower	UFS
161	CA	65	46	30	458	32	450	175	90	36	64	1458	131	87	1990	-1	Pliocene, Lower	UFS
162	CA	61	36	41	150	32	1900	400	220	25	75	1660	171	113	1990	1945	Miocene, Upper	UFS
163	CA	67	45	33	200	28	700	270	200	-1	-1	1645	147	96	1990	1941	Miocene, Upper	UFS
164	CA	82	49	39	150	36	1575	450	260	25	75	1980	217	143	1990	1957	Miocene, Upper	UFS
165	CA	1,028	631	39	4964	31	1450	400	123	30	70	1550	2663	1756	1990	1900	Miocene, Upper	UFS
166	CA	61	40	35	300	35	950	-1	150	50	50	1160	143	94	1990	1920	Pliocene	UFS
167	CA	47	29	39	150	25	-1	1500	270	-1	-1	-1	123	81	1990	1925	Miocene, Upper	SH-fract
168	CA	15	9	39	175	15	-1	300	125	-1	-1	-1	40	26	1990	1947	Miocene, Upper	SH-fract
169	CA	1,548	916	41	3000	33	1800	500	280	28	72	1725	4245	2799	1990	1910	Miocene, Upper	UFS
170	CA	46	34	25	205	31	150	240	150	30	-1	1500	78	51	1990	1928	Miocene, Upper	SS/SH
171	CA	77	54	30	1390	32	450	50	35	36	64	1460	155	102	1990	-1	Pliocene	UFS
172	CA	1,885	1,655	12	18316	33	2500	200	67	40	60	1150	1546	1019	1990	1890	Pleistocene	UFS
173	CA	32	19	42	150	31	2000	250	150	36	60	1400	92	60	1990	1913	Miocene, Upper	UFS
174	CA	166	110	34	1360	30	800	100	75	30	70	1703	374	247	1990	-1	Pliocene, Lower	UFS
175	CA	12	12	1	90	25	870	225	200	65	35	-1	6	3	1990	1960	Miocene	UFS
176	CA	9	9	1	90	25	870	160	150	65	35	-1	5	2	1990	1949	Miocene, Middle	UFS
177	CA	12	12	1	90	25	870	250	200	65	35	-1	6	3	1990	1959	Miocene, Middle	UFS
178	CA	397	368	7	580	21	240	2500	600	25	70	1050	44	21	1990	1951	Oligocene	SS
179	CA	291	238	18	770	29	700	350	240	30	70	-1	46	40	1990	1917	Pliocene, Lower	UFS
180	CA	254	208	18	770	25	-1	-1	250	-1	68	-1	40	35	1990	1927	Pliocene, Lower	UFS
181	CA	124	124	0	875	35	50	-1	80	35	65	-1	1	0	1986	1981	Miocene	UFS
182	CA	52	43	17	875	32	4200	75	35	32	68	1600	174	150	1990	1928	Oligocene	UFS
183	CA	24	18	25	410	33	2700	-1	30	25	75	-1	62	39	1990	1928	Oligocene	UFS
184	CA	642	629	2	2270	38	40	-1	160	40	60	1700	28	15	1990	1926	Miocene, Lower	UFS
185	CA	857	596	30	1750	33	6000	400	225	15	85	2075	563	307	1988	1926	Oligocene	UFS
186	CA	12	12	1	80	25	-1	200	131	-1	-1	-1	11	0	1990	1893	Miocene	SH
187	CA	27	25	8	140	23	100	300	185	41	59	-1	23	19	1990	1900	Pliocene	SS
188	CA	44	39	11	80	25	-1	1200	470	-1	-1	-1	16	16	1990	1953	Miocene, Upper	UFS
189	CA	217	212	2	570	36	1500	330	200	29	68	1900	196	124	1990	1943	Miocene	UFS
190	CA	42	42	1	80	25	-1	770	450	-1	-1	-1	10	6	1991	1927	Miocene	UFS
191	CA	14	11	17	100	22	80	200	180	-1	-1	775	7	7	1990	1953	Pliocene, Lower	SS
192	CA	1,946	1,946	0	4180	25	-1	950	400	-1	-1	-1	128	128	1990	1901	Miocene	UFS
193	CA	11	11	1	40	36	3700	-1	150	33	67	2009	23	13	1990	1958	Miocene	UFS
194	CA	245	229	7	870	35	2000	575	176	-1	59	1560	164	84	1990	1920	Pliocene, Upper	SS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
195	CA	Placerita	Shepard	Saugus	Coastal	12	600	85	3260	60,236	4,069,667	1990
196	CA	Playa Del Rey, Venice	Repetto, Upper	Repetto	Los Angeles	20	4000	146	18	20,114	40,802,400	1990
197	CA	Pleito, Creek Area	Santa Margarita	Santa Margarita	San Joaquin	17	4300	109	120	6,274	1,828,260	1990
198	CA	Point Pendernales, Federal-OCS	Monterey	Monterey	Coastal	16	6600	215	9	5,959,782	24,197,880	1990
199	CA	Poso Creek, Enas Area	Chanac	Chanac	San Joaquin	13	1900	103	480	3,345	912,854	1990
200	CA	Poso Creek, Enas Area	Etchegoin, Basal	Etchegoin	San Joaquin	12	1800	101	750	1,876	512,146	1990
201	CA	Poso Creek, McVan Area	Etchegoin, Basal	Etchegoin	San Joaquin	13	1150	90	2000	57,245	6,900,271	1990
202	CA	Poso Creek, Premier Area	Chanac	Chanac	San Joaquin	13	2500	112	6900	256,620	55,217,052	1990
203	CA	Poso Creek, Premier Area	Etchegoin, Basal	Etchegoin	San Joaquin	13	2400	108	7800	69,363	14,924,780	1990
204	CA	Pyramid Hills, Dagany Area	Point of Rocks	Kreyenhagen	San Joaquin	16	650	100	140	13,368	1,366,000	1990
205	CA	Pyramid Hills, Norris Area	Point of Rocks	Kreyenhagen	San Joaquin	15	800	80	330	4,910	1,031,000	1990
206	CA	Pyramid Hills, West Slope Area	Point of Rocks	Kreyenhagen	San Joaquin	17	800	100	140	30,301	2,524,000	1990
207	CA	Railroad Gap	Amnicola (Oil)	Tulare	San Joaquin	13	1100	92	1140	21,364	1,758,745	1990
208	CA	Raisin City	Miocene Tar	Zilch	San Joaquin	17	4680	140	150	42,782	10,491,040	1990
209	CA	Ramona	Del Valle	Modelo	Coastal	18	4500	156	27	34,895	8,269,716	1990
210	CA	Richfield	Breen	Puente	Los Angeles	17	3500	125	5	97,350	15,911,521	1990
211	CA	Richfield	Chapman	Puente	Los Angeles	18	2900	117	6	185,929	30,389,380	1990
212	CA	Richfield	Tar Sand	Repetto	Los Angeles	13	2000	115	230	894	146,154	1990
213	CA	Rosedale Ranch	Chanac, Upper (KCL 31-38)	Chanac	San Joaquin	20	4675	134	26	12,853	2,389,860	1990
214	CA	Rosedale Ranch	Lerdo	Etchegoin	San Joaquin	17	4200	118	30	34,988	6,505,730	1990
215	CA	Round Mountain, Coffee Canyon Area	Pyramid Hill	Freeman-Jewett	San Joaquin	19	1500	104	110	9,426	3,441,956	1990
216	CA	Round Mountain, Coffee Canyon Area	Vedder	Vedder	San Joaquin	17	1650	115	100	45,442	16,593,044	1990
217	CA	Round Mountain, Main Area	Pyramid Hill	Freeman-Jewett	San Joaquin	18	1900	132	33	34,155	11,136,783	1990
218	CA	Round Mountain, Main Area	Vedder	Vedder	San Joaquin	16	2000	132	140	134,863	43,974,407	1990
219	CA	Round Mountain, Pyramid Area	Pyramid Hill	Freeman-Jewett	San Joaquin	18	1250	92	265	2,022	373,688	1990
220	CA	Round Mountain, Pyramid Area	Vedder	Vedder	San Joaquin	16	1390	101	240	5,913	1,093,065	1990
221	CA	Round Mountain, Pyramid Area	Walker	Walker	San Joaquin	20	1535	113	54	27,401	5,065,247	1990
222	CA	Salt Lake	A Zone	Repetto	Los Angeles	16	1000	92	455	9,870	4,034,315	1990
223	CA	Salt Lake	B Zone	Puente	Los Angeles	18	2300	115	73	22,814	9,324,518	1990
224	CA	Salt Lake	C Zone	Puente	Los Angeles	16	2650	120	99	23,218	9,489,959	1990
225	CA	Salt Lake	D Zone	Puente	Los Angeles	14	2850	123	120	18,677	7,633,598	1990
226	CA	Salt Lake	E Zone	Puente	Los Angeles	18	2750	125	49	32,675	13,355,299	1990
227	CA	Salt Lake	F Zone	Puente	Los Angeles	20	3300	128	31	19,442	7,946,310	1990
228	CA	San Ardo, Main Area	Aurignac	Monterey	Coastal	13	2400	118	3100	1,332,749	194,634,329	1990
229	CA	San Ardo, Main Area	Lombardi	Monterey	Coastal	10	2000	117	3900	2,370,152	224,252,902	1990
230	CA	Sansinena, New England Area	E-1	Puente	Los Angeles	18	3800	142	28	429	63,912	1990
231	CA	Sansinena, West Area	C-3	Puente	Los Angeles	14	2100	112	210	0	246,167	1990
232	CA	Sansinena, West Area	D-3	Puente	Los Angeles	20	4500	155	15	32,433	4,029,031	1990
233	CA	Sansinena, West Area	Second Whittier	Repetto	Los Angeles	17	1300	98	230	3,150	391,286	1990
234	CA	Santa Maria Valley, Bradley Area	Monterey	Monterey	Coastal	14	5610	190	17	28,046	744,000	1990
235	CA	Santa Maria Valley, Bradley Area	Sisquoc	Sisquoc	Coastal	14	5000	180	13	579,242	22,550,953	1990
236	CA	Santa Maria Valley, Main Area	Foxen	Foxen	Coastal	17	2000	96	260	41,369	20,187,112	1990
237	CA	Santa Maria Valley, Main Area	Monterey	Monterey	Coastal	15	3360	120	110	244,041	119,087,113	1990
238	CA	Santa Maria Valley, Main Area	Point Sal	Point Sal	Coastal	15	4330	163	38	27,333	13,337,757	1990
239	CA	Santa Maria Valley, Main Area	Sisquoc	Sisquoc	Coastal	15	3330	90	840	3,203	1,563,018	1990
240	CA	Santa Maria Valley, Southeast Area	Houk	Monterey	Coastal	11	6000	162	54	0	4,824,000	1989
241	CA	Santa Maria Valley, Southeast Area	Sisquoc, Basal	Sisquoc	Coastal	11	4500	120	290	65,156	6,407,000	1990
242	CA	Santa Maria Valley, West Area	Foxen	Foxen	Coastal	14	3490	90	990	0	9,517	1990

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
195	CA	61	57	7	870	25	-1	105	60	-1	-1	-1	41	21	1990	1951	Pliocene	UFS
196	CA	183	142	22	342	25	-1	1050	460	-1	-1	-1	7	6	1990	1930	Pliocene, Lower	UFS
197	CA	33	31	6	200	24	200	200	125	30	70	1350	18	11	1990	1951	Miocene	SS
198	CA	4,553	4,529	1	19840	10	-1	600	510	-1	58	-1	19	13	1990	1982	Miocene, Upper	SS
199	CA	70	69	1	260	33	940	190	150	30	70	1562	24	15	1990	1929	Miocene	UFS
200	CA	39	39	1	260	36	1100	100	90	40	60	1450	14	8	1990	1938	Pliocene	UFS
201	CA	24	17	29	405	34	2600	-1	40	45	55	1300	165	77	1990	1932	Pliocene	UFS
202	CA	1,109	1,054	5	3610	33	1400	390	200	-1	60	1468	537	267	1990	1920	Miocene, Upper	UFS
203	CA	300	285	5	2000	35	1500	195	92	30	60	1477	145	72	1990	1944	Pliocene, Lower	UFS
204	CA	29	28	5	135	34	730	-1	125	26	66	1792	39	34	1990	1954	Eocene	UFS
205	CA	23	22	4	185	28	250	-1	70	30	-1	1792	19	15	1990	1955	Eocene	UFS
206	CA	45	42	6	260	31	900	-1	120	40	60	1480	50	43	1990	1940	Eocene	UFS/SH
207	CA	19	18	9	230	35	2500	65	60	48	52	1416	22	14	1990	1965	Pleistocene	UFS
208	CA	29	18	36	1675	30	1200	360	20	63	37	750	42	17	1990	1946	Miocene, Middle	UFS/SH
209	CA	96	88	9	280	18	40	810	511	35	48	303	44	31	1990	1943	Miocene, Upper	SS
210	CA	316	300	5	900	27	540	-1	250	33	67	1247	24	17	1990	1933	Miocene, Upper	UFS
211	CA	532	501	6	900	31	1000	500	390	-1	63	1524	45	31	1990	1919	Miocene, Upper	UFS
212	CA	90	89	0	1045	23	1200	165	80	49	-1	445	1	1	1990	1957	Pliocene	UFS
213	CA	48	46	5	453	29	130	-1	80	35	59	1325	10	5	1990	1953	Miocene, Upper	SS
214	CA	90	83	7	750	27	140	160	92	38	62	1420	57	32	1990	1945	Pliocene, Lower	UFS
215	CA	90	87	4	475	34	40	150	120	40	60	1600	15	10	1990	1928	Miocene	SS/STS
216	CA	23	7	71	475	35	11600	135	30	40	60	1600	72	48	1990	1928	Oligocene	UFS/STS
217	CA	142	131	8	550	37	40	-1	150	40	60	1550	37	26	1990	1927	Miocene	UFS
218	CA	151	107	29	990	35	10000	150	80	-1	70	1883	146	103	1990	1927	Oligocene	UFS/STS
219	CA	40	40	1	310	37	40	145	130	65	35	900	3	2	1990	1944	Miocene, Lower	STS/SS
220	CA	20	18	6	290	32	1200	160	40	32	68	1930	9	5	1990	1937	Oligocene	UFS/STS
221	CA	22	17	23	310	31	1000	55	50	40	60	1425	42	24	1990	1943	Eocene	UFS/STS
222	CA	48	44	8	350	25	-1	200	117	-1	-1	-1	3	2	1990	1902	Pliocene, Lower	UFS
223	CA	251	241	4	1380	25	-1	250	156	-1	-1	-1	8	5	1990	1903	Miocene, Upper	UFS
224	CA	294	284	3	1380	34	300	275	117	31	69	-1	8	5	1990	1904	Miocene, Upper	UFS
225	CA	256	248	3	1380	34	-1	200	117	-1	-1	-1	7	4	1990	1960	Miocene, Upper	UFS
226	CA	73	60	18	640	25	-1	100	98	-1	-1	-1	12	7	1990	1960	Miocene, Upper	UFS
227	CA	32	24	25	350	25	-1	100	79	-1	-1	-1	7	3	1990	1960	Miocene, Upper	UFS
228	CA	1,014	819	19	4320	36	5700	-1	120	30	70	1840	609	344	1990	1948	Miocene, Middle	UFS
229	CA	1,232	1,007	18	4320	35	1700	-1	150	-1	70	1834	692	183	1990	1948	Miocene, Middle	UFS
230	CA	12	11	1	50	33	200	-1	150	-1	-1	-1	1	1	1990	1954	Miocene, Upper	UFS
231	CA	34	33	1	270	32	290	-1	100	20	50	-1	1	0	1990	1951	Miocene, Upper	UFS
232	CA	35	31	12	270	23	370	-1	120	47	-1	-1	10	8	1990	1949	Miocene, Upper	UFS
233	CA	31	31	1	270	25	-1	-1	100	-1	-1	-1	1	1	1990	1898	Miocene, Upper	UFS
234	CA	17	16	4	50	25	-1	-1	288	-1	-1	-1	9	2	1990	1972	Miocene, Upper	SH-fract
235	CA	105	82	21	500	26	15	-1	160	35	65	1008	29	27	1990	1972	Pliocene, Lower	SS/silt/SH
236	CA	316	295	6	2380	37	260	200	105	56	44	-1	33	11	1990	1934	Pliocene, Lower	STS/SS
237	CA	1,862	1,743	6	4000	25	-1	960	400	-1	-1	-1	195	67	1990	1934	Miocene, Upper	SH-fract
238	CA	209	195	6	1120	20	60	-1	200	40	60	-1	22	8	1990	1936	Miocene, Middle	STS/SS/LS
239	CA	24	23	6	480	25	1300	400	75	65	35	-1	3	1	1990	1934	Pliocene, Lower	STS/UFS
240	CA	108	103	4	310	25	-1	1000	300	-1	-1	-1	12	-1	1989	1952	Miocene	UFS
241	CA	84	78	8	310	27	200	500	250	48	52	-1	50	13	1990	1941	Pliocene, Lower	SS/SH
242	CA	59	59	0	440	31	180	400	160	65	35	-1	1	0	1990	1953	Pliocene, Lower	UFS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
243	CA	Santa Maria Valley, West Area	Franciscan	Franciscan	Coastal	14	4660	120	140	0	86,524	1990
244	CA	Santa Maria Valley, West Area	Monterey	Monterey	Coastal	14	4410	178	33	7,119	550,282	1990
245	CA	Santa Maria Valley, West Area	Sisquoc	Sisquoc	Coastal	19	3610	120	49	22,066	1,705,677	1990
246	CA	Simi, Canada De La Brea	First Sand, Lower	Sespe	Coastal	17	975	88	450	3,001	294,109	1990
247	CA	Simi, Canada De La Brea	First Sand, Upper	Sespe	Coastal	15	650	82	1480	640	62,754	1990
248	CA	Simi, Canada De La Brea	Second Sand	Sespe	Coastal	19	1600	96	158	6,748	661,304	1990
249	CA	Simi, Canada De La Brea	Third Sand	Sespe	Coastal	20	2235	112	55	14,359	1,407,218	1990
250	CA	Summerland, Offshore	Vaqueros	Vaqueros	Coastal	16	1400	99	275	112,370	20,514,000	1990
251	CA	Tapia Oil Field	Yule	Saugus	Coastal	17	1050	93	320	11,824	1,540,644	1990
252	CA	Tapo Canyon, South	Sespe, Fourth	Sespe	Coastal	18	2200	117	67	9,013	1,238,644	1990
253	CA	Tapo Canyon, South	Sespe, Second	Sespe	Coastal	18	1800	106	110	3,664	503,514	1990
254	CA	Tapo Canyon, South	Sespe, Third	Sespe	Coastal	18	1880	108	100	16,121	2,215,461	1990
255	CA	Tapo, North	III	Modelo	Coastal	18	1500	101	150	2,162	550,439	1990
256	CA	Tejon, Central Area	Santa Margarita	Santa Margarita	San Joaquin	18	2900	102	420	21,629	2,781,591	1990
257	CA	Tejon, Central Area	Transition	Transition	San Joaquin	17	2725	84	665	8,740	1,124,005	1990
258	CA	Tejon, Eastern Area	Transition-SM	Santa Margarita	San Joaquin	18	2000	84	495	6,793	1,781,000	1990
259	CA	Tejon, Southeast Area	Reserve, Upper	Fruitvale	San Joaquin	17	1810	100	200	24,584	949,726	1990
260	CA	Tejon, Western Area	Pulv (Reserve)	Fruitvale	San Joaquin	20	4600	117	46	11,165	6,866,507	1981
261	CA	Tejon, Western Area	Transition	Santa Margarita	San Joaquin	16	2600	113	190	4,940	3,037,863	1990
262	CA	Tejon, Western Area	Valv	Round Mountain	San Joaquin	19	5400	135	28	2,706	1,718,386	1990
263	CA	Torrance, Onshore	Tar Ranger	Repetto	Los Angeles	19	2800	152	14	351,054	58,590,479	1990
264	CA	Union Avenue	Chanac	Chanac	San Joaquin	15	4100	124	80	4,591	745,732	1990
265	CA	Union Avenue	Santa Margarita	Santa Margarita	San Joaquin	15	5000	130	70	4,730	768,268	1990
266	CA	West Mountain	Sespe	Sespe	Coastal	20	4500	134	26	27,865	3,950,000	1990
267	CA	Wheeler Ridge, Northeast Area	FA-2	Fruitvale	San Joaquin	18	2900	90	420	7,251	1,314,000	1990
268	CA	White Wolf	700 Sand	Chanac	San Joaquin	16	815	73	470	4,212	439,964	1990
269	CA	White Wolf	Antelope	Monterey	San Joaquin	14	1770	83	450	5,277	551,163	1990
270	CA	White Wolf	Reef Ridge	Reef Ridge	San Joaquin	14	2350	93	440	1,492	155,873	1990
271	CA	Whittier, Central Area	First Sand	Repetto	Los Angeles	16	900	90	620	18,541	3,845,092	1990
272	CA	Whittier, Central Area	Second Sand	Repetto	Los Angeles	19	1300	115	80	18,380	3,811,537	1990
273	CA	Whittier, Central Area	Third Sand	Repetto	Los Angeles	17	1600	115	55	30,835	6,394,548	1990
274	CA	Whittier, La Habra Area	First Sand	Repetto	Los Angeles	17	900	110	160	1,347	262,387	1990
275	CA	Whittier, La Habra Area	Second Sand	Repetto	Los Angeles	20	1150	95	135	772	150,356	1990
276	CA	Whittier, La Habra Area	Third Sand	Puente	Los Angeles	20	1400	99	100	1,189	231,662	1990
277	CA	Whittier, Rideout Height	Fifth Sand	Puente	Los Angeles	20	2300	115	200	45,299	2,941,000	1990
278	CA	Wilmington, Offshore Area	Ranger	Repetto/Puente	Los Angeles	18	2500	141	29	3,046,724	213,144,212	1990
279	CA	Wilmington, Offshore Area	Tar	Repetto	Los Angeles	14	2100	122	280	1,540,288	107,756,240	1990
280	CA	Wilmington, Offshore Area	Terminal, Upper	Puente	Los Angeles	19	3000	151	19	4,619,515	323,174,360	1990
281	CA	Wilmington, Onshore Area	Ranger	Repetto/Puente	Los Angeles	19	2500	141	50	1,201,351	160,123,364	1990
282	CA	Wilmington, Onshore Area	Tar Zone	Repetto	Los Angeles	14	2200	124	283	739,026	98,501,925	1990
283	CA	Wilmington, Onshore Area	Terminal, Upper	Puente	Los Angeles	20	3000	150	35	1,866,457	248,772,710	1990
284	CA	Yorba Linda	Main (Signet Sand)	Repetto	Los Angeles	15	1950	95	1600	24,785	9,908,000	1990
285	CA	Yorba Linda	Shallow (Conglomerate)	La Habra	Los Angeles	13	425	78	7100	859,905	70,849,000	1990
286	CA	Yorba Linda	Shell (F Sands)	Repetto	Los Angeles	16	1850	112	540	25,399	5,543,049	1990
287	CO	Padroni, West	Fuson M	Dakota M	Denver/J	15	5063	143	45	21,492	1,907,824	1988
288	CO	Padroni, West	Lakota	Dakota O	Denver/J	16	5108	144	37	17,194	1,526,260	1988
289	CO	Rush Willadel	J Sand	Dakota J	Denver/J	20	3938	123	36	91,660	5,175,649	1988
290	IL	Carlinville, North	Pottsville	Pottsville	Illinois	20	437	72	870	-1	1,900	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
243	CA	76	76	0	440	24	-1	300	155	-1	-1	-1	1	0	1990	1953	Cretaceous	UFS
244	CA	40	39	1	170	25	-1	-1	200	-1	-1	-1	6	2	1990	1953	Miocene, Upper	SH-fract
245	CA	158	156	1	440	30	2000	570	280	45	55	-1	18	5	1990	1953	Pliocene, Lower	UFS/SH
246	CA	56	55	1	140	30	-1	300	285	-1	-1	-1	1	1	1991	1909	Oligocene	UFS
247	CA	39	39	0	140	30	-1	250	200	-1	-1	-1	1	1	1991	1909	Oligocene	UFS
248	CA	44	43	2	140	25	-1	325	270	-1	-1	-1	3	3	1991	1909	Oligocene	UFS
249	CA	33	31	4	140	25	-1	200	200	-1	-1	-1	7	7	1991	1910	Oligocene	UFS
250	CA	126	105	16	360	25	-1	-1	300	-1	-1	-1	37	11	1990	1929	Miocene, Lower	UFS
251	CA	21	19	7	160	25	-1	-1	100	-1	67	-1	32	9	1990	1957	Pleistocene/Pliocene	UFS
252	CA	8	7	15	80	25	400	180	123	58	42	-1	11	6	1990	1954	Oligocene	SS
253	CA	3	3	15	60	25	-1	180	70	-1	40	-1	4	3	1990	1954	Oligocene	SS
254	CA	14	12	15	80	25	-1	260	220	-1	42	-1	19	12	1990	1954	Oligocene	SS
255	CA	44	44	1	200	25	-1	310	190	-1	-1	-1	9	7	1990	-1	Miocene, Upper	SS
256	CA	154	152	2	1045	28	1000	-1	100	32	68	1600	18	6	1990	1950	Miocene	UFS
257	CA	68	67	2	575	30	35	-1	85	-1	-1	-1	7	3	1990	1950	Miocene, Upper	UFS
258	CA	46	44	4	210	26	500	-1	150	28	72	1400	18	16	1990	1943	Miocene, Upper	UFS
259	CA	46	45	2	175	35	460	190	155	37	63	1500	12	11	1990	1951	Miocene	UFS
260	CA	117	111	6	665	28	1200	220	125	35	65	1225	33	13	1981	1949	Miocene, Upper	UFS
261	CA	52	49	6	665	30	2500	65	55	39	61	1339	14	6	1990	1945	Miocene, Upper	UFS
262	CA	57	55	3	665	28	510	-1	60	34	66	1123	16	7	1990	1957	Miocene, Middle	SS
263	CA	639	581	9	6750	33	800	-1	50	24	74	1788	115	87	1990	1922	Pliocene	UFS
264	CA	14	13	5	50	28	200	-1	200	35	65	1310	1	1	1990	1941	Miocene, Middle	SS
265	CA	15	14	5	50	25	1400	400	200	25	75	1900	2	2	1990	1941	Miocene, Middle	UFS
266	CA	318	314	1	240	25	25	1500	1340	-1	51	-1	21	20	1990	1946	Oligocene	SS
267	CA	35	33	4	160	31	200	240	125	28	72	1650	6	5	1990	1955	Miocene, Middle	SS
268	CA	79	79	1	150	30	340	500	350	35	65	1470	7	3	1990	1964	Pliocene/Miocene	UFS
269	CA	100	99	1	150	25	-1	740	570	-1	-1	-1	9	4	1990	1964	Miocene, Upper	SH-fract
270	CA	28	28	1	150	31	390	200	120	35	65	1466	3	1	1990	1959	Miocene	UFS
271	CA	39	35	10	141	30	380	300	187	-1	64	-1	20	17	1990	1916	Pliocene, Lower	UFS
272	CA	32	28	12	141	29	500	200	150	33	67	1390	17	14	1990	1904	Pliocene, Lower	UFS
273	CA	55	49	12	176	28	175	250	225	36	64	1268	29	24	1990	1896	Pliocene, Lower	UFS
274	CA	29	28	1	115	26	640	200	190	25	65	-1	3	1	1990	1918	Pliocene, Lower	UFS
275	CA	16	16	1	115	25	-1	150	115	-1	64	-1	2	1	1990	1912	Pliocene, Lower	UFS
276	CA	25	25	1	115	27	-1	-1	175	-1	60	-1	2	1	1990	1912	Miocene	UFS
277	CA	37	34	8	90	28	250	400	250	25	75	1552	10	8	1990	1919	Miocene	UFS
278	CA	1,662	1,449	13	6200	32	1270	-1	150	25	72	1620	235	161	1990	1939	Pliocene/Miocene	UFS
279	CA	840	733	13	4030	35	1000	-1	120	31	64	1558	119	82	1990	1943	Pliocene, Lower	UFS
280	CA	2,521	2,197	13	4898	33	900	-1	300	30	67	1572	356	245	1990	1939	Miocene	UFS
281	CA	1,915	1,755	8	7242	32	1600	500	150	29	71	1733	240	145	1990	1932	Pliocene/Miocene	UFS
282	CA	1,178	1,079	8	5069	32	1600	325	120	22	78	2046	148	89	1990	1937	Pliocene, Lower	UFS
283	CA	2,975	2,726	8	6359	30	740	600	300	33	67	1414	373	225	1990	1936	Miocene	UFS
284	CA	37	27	27	200	29	1000	150	120	31	69	1496	37	20	1990	1930	Pliocene, Lower	UFS
285	CA	173	102	41	455	28	500	-1	250	-1	70	1418	453	347	1990	1954	Pleistocene	UFS
286	CA	29	23	19	120	37	500	300	125	33	67	1575	8	1	1990	1937	Pliocene, Lower	UFS
287	CO	6	4	34	640	19	150	-1	10	-1	-1	-1	-1	-1	-1	1951	Cretaceous	SS
288	CO	5	3	32	640	20	150	28	8	-1	-1	-1	-1	-1	-1	1952	Cretaceous	SS
289	CO	16	10	33	880	19	150	-1	20	-1	-1	-1	11	7	1988	1961	Cretaceous	SS
290	IL	1	1	0	100	18	100	-1	10	-1	-1	-1	-1	-1	-1	1941	Pennsylvanian	SS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
291	IL	Omaha	Pennsylvanian	Pennsylvanian	Illinois	19	580	73	1040	-1	10,000	1984
292	KS	Iola	Bartlesville	Bluejacket	Cherokee	20	892	69	700	21,122	954,982	1988
293	LA	Bayou Middle Fork	Sligo	Sligo	Arkla	16	5214	163	23	4,549	378,867	1991
294	LA	Bellevue	Nacatoch	Nacatoch	Arkla	19	350	80	530	-1	32,923,042	1991
295	LA	Sulphur Mines	Miocene	Miocene	Gulf C	18	2676	120	60	-1	33,996,018	1991
296	MI	Dorr	Salina	Salina	Michigan	17	2922	94	290	-1	18,078	1991
297	MI	Pennfield Pool A	Salina	Salina	Michigan	18	2681	92	260	-1	66,325	1991
298	MI	Zeeland	Salina	Salina	Michigan	20	2792	92	150	-1	99,511	1991
299	MO	Eastburn	Eastburn	Bluejacket	Cherokee	20	110	61	700	5,500	550,000	1977
300	MO	Stotesbury	Warner	Warner	Cherokee	19	193	62	4600	0	133,018	1984
301	MS	Avera	Eutaw	Eutaw	Miss. Salt	20	6879	198	7	8,217	187,481	1991
302	MS	Baxterville	Tuscaloosa Massive, Lower	Tuscaloosa	Miss. Salt	17	8750	229	8	1,232,536	178,903,529	1989
303	MS	Baxterville, SE	Tuscaloosa, Lower	Tuscaloosa	Miss. Salt	16	8507	229	8	23,279	406,888	1991
304	MS	Bryan	Paluxy	Paluxy	Miss. Salt	13	8718	231	10	240	87,802	1991
305	MS	Camp Shelby	Paluxy	Paluxy	Miss. Salt	18	13309	314	3	42,399	345,493	1991
306	MS	Carmichael	Eutaw	Eutaw	Miss. Salt	17	3773	142	33	8,182	656,292	1991
307	MS	Eucutta, East	Christmas	Eutaw	Miss. Salt	20	4938	163	13	26,568	291,436	1991
308	MS	Eucutta, East	Eutaw	Eutaw	Miss. Salt	20	4884	152	70	323,002	47,874,170	1991
309	MS	Glazier	Tuscaloosa, Upper	Tuscaloosa	Miss. Salt	14	7056	206	13	44,429	806,621	1991
310	MS	Heidelburg, West	Christmas	Eutaw	Miss. Salt	19	4974	150	19	218,552	6,610,043	1991
311	MS	Heidelburg, West	Eutaw	Eutaw	Miss. Salt	20	4772	150	97	281,062	32,893,679	1991
312	MS	Junction City	Eutaw	Eutaw	Miss. Salt	16	3710	120	89	73,755	5,539,242	1991
313	MS	Junction City	Selma Chalk	Selma Chalk	Miss. Salt	18	2950	127	45	5,442	344,302	1991
314	MS	Langsdale	Eutaw	Eutaw	Miss. Salt	19	3659	120	170	26,732	5,464,882	1991
315	MS	Langsdale, West	Selma Chalk	Selma Chalk	Miss. Salt	18	3421	136	29	0	373,259	1991
316	MS	Laurel	Christmas	Eutaw	Miss. Salt	15	7006	165	25	48,632	239,720	1991
317	MS	Laurel	Tuscaloosa, Lower	Tuscaloosa	Miss. Salt	17	8144	180	14	205,151	899,004	1991
318	MS	Mize	Washita Fredericksburg	Washita Fredericksburg	Miss. Salt	16	9000	236	7	38,575	1,356,047	1991
319	MS	Ovett	Eutaw	Eutaw	Miss. Salt	10	7350	170	52	51,704	6,796,234	1991
320	MS	Reedy Creek	Eutaw	Eutaw	Miss. Salt	13	6191	185	22	21,854	775,577	1991
321	MS	Reedy Creek	Paluxy, 9400	Paluxy	Miss. Salt	20	9426	207	6	0	867,463	1991
322	MS	Reedy Creek	Tuscaloosa, 6200	Tuscaloosa	Miss. Salt	11	6250	187	29	7,938	1,806,401	1991
323	MS	Reedy Creek	Washita Fredericksburg, 9250	Washita Fredericksburg	Miss. Salt	19	9250	215	6	21,518	1,327,676	1991
324	MS	Sand Hill, North	Tuscaloosa	Tuscaloosa	Miss. Salt	19	6836	197	8	31,984	1,466,652	1991
325	MS	Sandersville	Eutaw	Eutaw	Miss. Salt	11	5276	160	57	47,240	5,320,644	1991
326	MS	Soso	Hosston, 12799	Hosston	Miss. Salt	20	13111	310	3	22,290	3,220,910	1989
327	MS	Summerland	Washita Fredericksburg, Upp	Washita Fredericksburg	Miss. Salt	19	9356	242	5	47,143	834,333	1991
328	MS	Summerland	Washita Fredericksburg, Upp	Washita Fredericksburg	Miss. Salt	19	9450	200	8	42,403	5,736,488	1991
329	MS	Thompsons Creek	Tuscaloosa	Tuscaloosa	Miss. Salt	19	8123	207	7	19,801	1,776,213	1991
330	MS	Wausau	Tuscaloosa	Tuscaloosa	Miss. Salt	15	7430	208	11	53,367	2,596,322	1991
331	MS	Yellow Creek, East	Eutaw	Eutaw	Miss. Salt	20	4724	160	190	30,041	7,620,730	1989
332	MS	Yellow Creek, East	Eutaw Unit No. 1	Eutaw	Miss. Salt	20	4724	160	190	30,521	1,005,056	1991
333	MS	Yellow Creek, North	Eutaw	Eutaw	Miss. Salt	20	4735	160	190	14,435	3,657,528	1991
334	MS	Yellow Creek, West	Eutaw	Eutaw	Miss. Salt	19	4938	160	20	215,629	28,446,180	1991
335	MT	Big Wall	Amsden	Amsden	Ctl MT Uplift	19	2498	98	140	25,061	1,052,000	1991
336	MT	Bowes Sawtooth Unit	Sawtooth/Eagle	Sawtooth/Eagle	Williston	19	3377	132	32	110,503	9,565,000	1988
337	MT	MacKay Dome	Greybull	Greybull	Bighorn	18	3700	119	61	0	66,000	1985
338	MT	Soap Creek	Tensleep/Amsden/Madison	Tensleep	Powder River	19	1650	85	210	42,260	2,636,000	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
291	IL	3	3	0	350	19	100	-1	10	-1	-1	-1	-1	-1	-1	1940	Pennsylvanian	SS
292	KS	12	11	8	500	25	200	30	20	-1	-1	-1	-1	-1	-1	1937	Pennsylvanian	SS
293	LA	3	2	14	960	15	250	-1	4	-1	-1	-1	-1	-1	-1	1970	Cretaceous	LS
294	LA	70	37	47	900	38	500	-1	40	-1	66	-1	-1	-1	-1	1921	Cretaceous	UFS
295	LA	55	21	62	820	24	500	-1	60	-1	-1	-1	200	24	1991	1926	Miocene	UFS
296	MI	2	2	1	620	12	80	-1	7	-1	-1	-1	-1	-1	-1	1956	Silurian	Dol
297	MI	5	5	1	80	12	80	-1	113	-1	-1	-1	3	1	1991	1976	Silurian	Dol
298	MI	1	1	12	300	12	80	-1	5	-1	-1	-1	33	-1	1991	1958	Silurian	Dol
299	MO	3	2	19	340	25	650	23	20	-1	22	-1	-1	-1	-1	-1	Pennsylvanian	SS
300	MO	9	9	1	280	24	375	25	25	-1	70	-1	-1	-1	-1	1914	Pennsylvanian	SS
301	MS	2	2	10	120	20	560	-1	16	-1	-1	-1	3	1	1991	1965	Cretaceous	SS
302	MS	408	229	44	6400	24	1474	-1	57	12	-1	-1	148	129	1991	1944	Cretaceous	SS
303	MS	2	1	24	200	23	680	-1	8	18	-1	-1	-1	6	1991	1973	Cretaceous	SS
304	MS	2	2	5	200	18	375	-1	10	-1	-1	-1	5	4	1991	1966	Cretaceous	SS
305	MS	1	1	24	80	14	375	-1	28	-1	-1	-1	2	2	1991	1972	Cretaceous	SS
306	MS	8	7	9	600	30	1270	-1	9	-1	-1	-1	23	10	1991	1960	Cretaceous	SS
307	MS	2	2	13	160	30	560	-1	10	-1	-1	-1	4	4	1991	1983	Cretaceous	SS
308	MS	165	117	29	4080	30	210	59	29	36	-1	-1	81	60	1991	1943	Cretaceous	SS
309	MS	3	2	25	240	24	200	116	12	-1	-1	-1	3	3	1991	1951	Cretaceous	SS
310	MS	55	48	12	880	29	1100	-1	46	37	-1	-1	22	22	1991	1971	Cretaceous	SS
311	MS	107	74	31	2560	29	300	-1	31	33	-1	-1	57	57	1991	1944	Cretaceous	SS
312	MS	32	27	17	2040	31	1090	-1	11	35	-1	-1	53	51	1991	1958	Cretaceous	SS
313	MS	2	1	19	120	30	-1	-1	11	-1	-1	-1	8	6	1991	1962	Cretaceous	Chalk-fract
314	MS	41	36	13	1320	25	200	-1	27	40	-1	-1	45	23	1991	1944	Cretaceous	SS
315	MS	3	2	13	400	5	-1	-1	30	-1	-1	-1	14	0	1991	1960	Cretaceous	Chalk-fract
316	MS	1	1	17	80	25	75	-1	15	35	-1	-1	2	2	1991	1961	Cretaceous	SS
317	MS	15	14	6	320	20	600	-1	50	35	-1	-1	8	8	1991	1961	Cretaceous	SS
318	MS	6	5	22	240	22	200	-1	25	59	-1	-1	6	6	1991	1964	Cretaceous	SS
319	MS	24	17	29	680	30	300	-1	25	35	-1	-1	19	16	1991	1950	Cretaceous	SS
320	MS	4	3	21	280	28	560	-1	10	-1	-1	-1	7	5	1991	1961	Cretaceous	SS
321	MS	3	2	26	240	20	125	35	15	-1	-1	-1	3	0	1991	1960	Cretaceous	SS
322	MS	13	11	14	600	30	150	20	15	-1	-1	-1	8	5	1991	1961	Cretaceous	SS
323	MS	3	2	44	200	23	150	30	14	-1	-1	-1	4	4	1991	1960	Cretaceous	SS
324	MS	5	4	29	640	24	600	-1	7	-1	-1	-1	17	16	1991	1963	Cretaceous	SS
325	MS	31	26	17	900	25	1060	-1	30	-1	-1	-1	-1	17	1989	1955	Cretaceous	SS
326	MS	9	6	36	480	20	300	-1	20	-1	-1	-1	-1	6	1989	1966	Cretaceous	SS
327	MS	2	1	45	80	20	265	-1	25	-1	-1	-1	3	2	1991	1962	Cretaceous	SS
328	MS	15	9	39	600	20	265	-1	26	21	-1	-1	9	5	1991	1961	Cretaceous	SS
329	MS	7	6	24	280	22	600	-1	26	21	-1	-1	5	4	1991	1959	Cretaceous	SS
330	MS	6	3	45	260	24	1666	70	20	-1	-1	-1	6	5	1991	1964	Cretaceous	SS
331	MS	35	27	22	1440	29	250	-1	18	-1	-1	-1	28	15	1991	1948	Cretaceous	SS
332	MS	10	9	10	440	28	250	-1	18	-1	-1	-1	12	11	1991	1972	Cretaceous	SS
333	MS	12	9	30	760	25	275	-1	14	45	-1	-1	-1	12	1991	1952	Cretaceous	SS
334	MS	154	125	18	3560	29	450	-1	32	52	-1	-1	70	54	1991	1947	Cretaceous	SS
335	MT	4	2	30	280	16	70	100	17	-1	-1	-1	-1	-1	-1	1953	Pennsylvanian	Dol
336	MT	46	37	21	3760	12	132	75	22	-1	-1	-1	-1	-1	-1	1949	Cretaceous	Dol/LS/SS
337	MT	4	4	2	160	10	150	-1	56	-1	-1	-1	-1	-1	-1	1960	Cretaceous	SS
338	MT	11	8	24	650	15	285	-1	24	-1	-1	-1	-1	36	1984	1952	Penn. (Madison)/Miss.	SS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
339	MT	Soap Creek, East	Tensleep	Tensleep	Powder River	17	3400	100	95	8,712	153,000	1991
340	NB	Darnall	J Sand	Dakota J	Denver/J	20	5000	142	20	0	622,047	1991
341	OK	Butterly, NE	Oil Creek (Simpson)	Oil Creek	Anadarko	13	4000	115	800	-1	6,200,000	1983
342	OK	Davis	First Bromide	Bromide	Anadarko	12	2564	97	1000	-1	25,589,000	1977
343	OK	Deese, NW	Third Hoxbar	Hoxbar	Ardmore	14	636	65	24200	191	14,294	1991
344	OK	Eola-Robberson	Skaggs	Skaggs	Anadarko	20	1900	86	240	-1	2,435,749	1981
345	OK	Hewitt, East	Second Bayou	Second Bayou	Ardmore	14	2866	77	4000	-1	23,455	1977
346	OK	Laffoon, SE	Second Wilcox	Tulip	Chat Pl	19	4200	125	6	-1	5,873,000	1977
347	OK	Loco	Loco	Hoxbar	Anadarko	20	350	62	590	-1	688,000	1984
348	OK	Paul's Valley	Bromide	Bromide	Anadarko	16	4200	125	70	-1	28,309,000	1984
349	OK	Paul's Valley, SE	Oil Creek	Oil Creek	Anadarko	10	4300	116	7500	-1	1,503,000	1984
350	OK	Peck	Wilcox	Tulip	Chat Pl	20	4150	124	34	-1	4,364,000	1984
351	OK	Red Bank	Dutcher	Atoka	Chat Pl	19	3300	110	70	-1	315,000	1975
352	OK	Sho-Vel-Tum (Des Moines Unit)	Fourth Deese	Deese	Ardmore	14	1500	75	1600	-1	2,943,000	-1
353	OK	Sho-Vel-Tum (E Velma-M/Blk Humphreys)	Humphreys	Springer	Ardmore	20	5150	95	135	-1	2,096,863	1977
354	OK	Sho-Vel-Tum (E Velma-M/Blk Sims	Sims	Springer	Ardmore	10	5500	97	1900	-1	27,930,472	1977
355	OK	Sho-Vel-Tum (H. Hefner)	Pennsylvanian	Pennsylvanian	Ardmore	18	2000	75	900	-1	2,064,604	1965
356	OK	Sulphur, NW	Simpson/Basal	Simpson	Anadarko	16	1490	79	80	4,833	416,346	1991
357	OK	Wheeler	Pontotoc	Pontotoc	Ardmore	20	5056	102	230	-1	19,579,000	1977
358	TX	Alba	Sub- Clarksville	Sub- Clarksville	East Texas	15	4074	151	36	131,816	7,981,027	1991
359	TX	Albrecht	Yegua	Yegua	Gulf C, TX	17	4642	162	20	4,034	216,171	1991
360	TX	Alta Vista	Annacacho	Navarro	Gulf C, TX	12	1100	95	1220	558	75,364	1991
361	TX	Arnim, East	Wilcox	Wilcox	Gulf C, TX	20	2151	115	50	13,693	467,679	1991
362	TX	Big Creek	Frio	Frio	Gulf C, TX	18	4500	160	18	67,316	25,364,965	1991
363	TX	Blalock Lake, E.	Wolfcamp	Wolfcamp	Permian	17	7914	185	12	244,551	4,545,062	1991
364	TX	Boggy Creek	Wilcox	Wilcox	East Texas	17	1549	103	170	1,127	22,118	1991
365	TX	Brenham	Cockfield	Cockfield	Gulf C, TX	17	1400	101	195	6,584	973,044	1991
366	TX	Burmil	Wilcox, W-2	Wilcox	Gulf C, TX	20	2659	125	41	10,236	226,704	1991
367	TX	Camp Hill	Carrizo	Carrizo	East Texas	19	540	75	600	77,040	2,412,289	1991
368	TX	Campana, South	1870 Sand	1870 Sand	Gulf C, TX	20	1870	109	64	6,632	182,309	1991
369	TX	Campana, South	Chernosky	Chernosky	Gulf C, TX	20	2225	116	47	12,254	1,723,215	1991
370	TX	Casa Blanca	Cole	Whitsett	Gulf C, TX	20	1190	97	27	32,905	5,091,281	1991
371	TX	Cebolla	3660	3660	Gulf C, TX	20	3660	144	20	6,696	428,811	1991
372	TX	Cedro Hill	Jackson	Jackson	Gulf C, TX	19	1440	101	30	7,215	6,590,217	1991
373	TX	Chapel Hill, East	Paluxy	Paluxy	East Texas	16	5693	182	14	4,864	75,125	1991
374	TX	Chapel Hill, East	Paluxy 5600	Paluxy	East Texas	20	5619	181	9	26,578	387,693	1991
375	TX	Charamousca, South	Cole	Whitsett	Gulf C, TX	20	1500	103	88	24,166	2,805,082	1991
376	TX	Charco Redondo	Jackson	Jackson	Gulf C, TX	17	160	77	450	1,116	658,171	1991
377	TX	Cistern	Wilcox	Wilcox	Gulf C, TX	18	1187	97	195	7,147	277,669	1991
378	TX	Colemena	Jackson	Jackson	Gulf C, TX	19	1500	103	100	30,914	3,964,036	1991
379	TX	Colony	Poth	Poth	Gulf C, TX	18	1892	110	92	232	25,406	1991
380	TX	Como, NE	Sub-Clarksville	Sub-Clarksville	East Texas	13	4020	150	53	35,169	209,889	1991
381	TX	Cost	Austin Chalk	Austin Chalk	Gulf C, TX	20	7296	213	6	97,046	2,586,317	1991
382	TX	Dangle	Strawn 1600	Strawn 1600	Permain	18	1614	105	450	4,939	300,086	1991
383	TX	DCR 79	Cole	Whitsett	Gulf C, TX	20	1478	102	89	0	1,487,154	1990
384	TX	Deu Pree	Woodbine	Woodbine	East Texas	15	5738	160	28	6,666	207,739	1991
385	TX	Dinn	Jackson	Jackson	Gulf C, TX	19	1805	108	81	1,784	325,603	1991
386	TX	Dinsmoor	Carrizo	Carrizo	Gulf C, TX	19	2060	113	65	7,747	867,692	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
339	MT	1	1	18	120	15	285	15	10	-1	-1	-1	-1	3	1984	1977	Pennsylvanian	SS
340	NB	2	1	31	280	19	150	-1	8	-1	-1	-1	6	-1	1991	1956	Cretaceous	SS
341	OK	19	13	32	190	24	850	145	90	-1	-1	-1	71	43	1991	1945	Ordovician	SS
342	OK	45	19	57	1660	24	500	-1	24	-1	-1	-1	-1	-1	-1	1961	Ordovician	SS
343	OK	2	2	1	180	13	95	-1	18	-1	-1	-1	9	2	1991	1963	Pennsylvanian	SS
344	OK	14	11	18	325	21	1000	-1	43	-1	-1	-1	-1	-1	-1	1923	Pennsylvanian	SS
345	OK	6	6	0	680	13	100	-1	14	-1	-1	-1	-1	-1	-1	1963	Pennsylvanian	SS
346	OK	22	16	27	3011	26	50	-1	6	-1	-1	-1	-1	-1	-1	1964	Ordovician	SS
347	OK	45	44	2	2300	28	2500	18	13	-1	69	-1	-1	-1	-1	1940	Pennsylvanian	UFS
348	OK	140	111	20	4000	15	100	50	50	-1	-1	-1	-1	-1	-1	1942	Ordovician	LS
349	OK	21	20	7	325	24	2000	100	58	-1	-1	-1	-1	-1	-1	1955	Ordovician	UFS
350	OK	22	18	20	950	24	500	21	21	-1	-1	-1	-1	-1	-1	1926	Ordovician	SS
351	OK	3	3	9	340	22	1600	10	10	-1	-1	-1	-1	-1	-1	1953	Pennsylvanian	SS
352	OK	60	57	5	705	28	500	75	50	-1	78	-1	-1	-1	-1	1941	Pennsylvanian	SS
353	OK	21	18	10	560	21	50	90	30	-1	75	-1	-1	-1	-1	1950	Pennsylvanian	SS
354	OK	170	142	16	930	16	70	245	245	-1	-1	-1	-1	-1	-1	1950	Pennsylvanian	SS
355	OK	10	8	20	120	28	500	160	66	-1	-1	-1	-1	-1	-1	1921	Pennsylvanian	SS
356	OK	21	21	2	320	26	50	55	55	-1	-1	-1	9	6	1991	1947	Ordovician	SS
357	OK	95	75	21	1960	26	50	40	40	-1	-1	-1	-1	-1	-1	1904	Permian/Pennsylvanian	SS
358	TX	26	18	30	1502	21	50	-1	18	31	-1	-1	101	50	1991	1948	Cretaceous	SS
359	TX	9	9	2	400	25	-1	-1	20	-1	-1	-1	-1	1	1991	1952	Eocene	SS
360	TX	6	6	1	250	25	2	-1	20	-1	-1	-1	12	8	1991	1915	Miocene	LS
361	TX	6	6	7	240	33	300	-1	17	-1	-1	-1	6	4	1991	1950	Eocene	UFS
362	TX	74	48	34	4540	29	720	-1	12	-1	-1	-1	65	22	1991	1922	Oligocene	UFS
363	TX	16	11	28	800	10	40	-1	43	-1	-1	-1	20	17	1991	1971	Permian	Dol/LS
364	TX	2	2	1	200	26	67	-1	7	48	-1	-1	3	2	1991	1957	Eocene	UFS
365	TX	18	17	5	1640	24	500	-1	10	-1	-1	-1	146	111	1991	1915	Eocene	UFS
366	TX	2	1	14	132	32	829	11	8	39	-1	-1	4	3	1991	1967	Eocene	UFS
367	TX	28	26	9	650	37	1200	-1	25	-1	-1	-1	320	65	1991	1955	Eocene	UFS
368	TX	1	1	13	360	27	100	-1	3	-1	-1	-1	2	2	1991	1952	Eocene	UFS
369	TX	9	7	20	360	35	1360	-1	15	-1	-1	-1	12	9	1991	1958	Eocene	UFS
370	TX	21	16	25	820	36	520	22	15	30	-1	-1	54	24	1991	1939	Eocene	UFS
371	TX	3	3	13	200	22	100	-1	16	-1	-1	-1	4	3	1991	1977	Cretaceous	UFS
372	TX	31	25	21	1800	31	700	-1	12	44	-1	-1	43	9	1991	1938	Eocene	UFS
373	TX	3	3	2	239	23	280	-1	13	-1	-1	-1	2	2	1991	1959	Cretaceous	SS
374	TX	6	5	7	280	24	300	-1	18	47	-1	-1	5	4	1991	1967	Cretaceous	SS
375	TX	10	7	28	400	32	600	-1	17	-1	-1	-1	15	7	1991	1940	Eocene	UFS
376	TX	36	35	2	1500	34	2800	-1	15	39	-1	-1	219	24	1991	1913	Eocene	UFS
377	TX	2	2	12	200	24	500	-1	10	-1	-1	-1	12	9	1991	1943	Eocene	UFS
378	TX	31	27	13	950	28	1958	-1	25	-1	-1	-1	50	30	1991	1936	Eocene	UFS
379	TX	1	1	2	80	31	1275	-1	10	20	-1	-1	5	3	1991	1965	Eocene	UFS
380	TX	2	2	12	200	24	200	-1	8	-1	-1	-1	5	5	1991	1985	Cretaceous	SS
381	TX	29	27	9	5280	12	-1	-1	10	-1	-1	-1	56	46	1991	1977	Cretaceous	Chalk-fract
382	TX	6	6	5	284	23	36	-1	21	20	-1	-1	8	5	1991	1954	Pennsylvanian, Middle	LS
383	TX	4	2	42	190	33	972	-1	12	-1	-1	-1	19	0	1989	1948	Eocene	UFS
384	TX	13	13	2	650	20	250	-1	18	30	70	-1	7	3	1991	1951	Cretaceous	SS
385	TX	23	23	1	240	31	600	-1	67	-1	-1	-1	4	2	1991	1949	Eocene	UFS
386	TX	3	2	29	225	24	500	-1	12	-1	-1	-1	7	7	1991	1952	Eocene	UFS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
387	TX	Dove	Strawn	Strawn	Permian	18	2960	130	430	21,368	2,079,019	1991
388	TX	Dragoon Creek	Gov't Wells, Upper	McElroy	Gulf C, TX	16	1022	93	410	17,689	374,488	1991
389	TX	Dragoon Creek, SW	Gov't Wells	McElroy	Gulf C, TX	18	1120	95	210	1,629	119,547	1991
390	TX	Eagle Hill	Jackson	Jackson	Gulf C, TX	19	1500	103	100	20,682	5,790,183	1991
391	TX	Edlasater, West	Cole 950	Cole 950	Gulf C, TX	19	950	92	120	840	15,406	1991
392	TX	Ezzell	Loma Novia	McElroy	Gulf C, TX	20	1500	103	88	10,706	6,973,879	1991
393	TX	Forest Hill	Eagle Ford	Eagle Ford	East Texas	16	4452	159	25	22,721	4,455,900	1991
394	TX	Forest Hill	Harris sand	Harris	East Texas	12	4679	185	1000	182,997	3,669,970	1991
395	TX	Forest Hill	Sub-Clarksville 1st	Sub-Clarksville	East Texas	16	4642	162	23	2,015	532,502	1991
396	TX	Foss	Mirando	Caddell	Gulf C, TX	20	490	83	300	3,476	75,627	1991
397	TX	Gloriana	Poth A	Wills Point	Gulf C, TX	19	1630	105	95	25,738	1,466,573	1991
398	TX	Govt. Wells, North	1000 Sand	1000 Sand	Gulf C, TX	19	1062	94	180	2,195	87,992	1991
399	TX	Govt. Wells, North	1800-E	1800-E	Gulf C, TX	20	2026	112	56	1,815	49,559	1991
400	TX	Govt. Wells, North	Catahoula, 900 sand	Catahoula	Gulf C, TX	20	918	91	165	516	317,434	1991
401	TX	Hubbard	Woodbine	Woodbine	East Texas	20	1160	96	125	0	16,172	1990
402	TX	Huff	2950 Sand	2950 Sand	Gulf C, TX	20	2942	130	29	15,298	159,139	1991
403	TX	Imogene, SE	Carrizo	Carrizo	Gulf C, TX	20	1822	109	65	15,171	1,311,503	1991
404	TX	Jeanie	Serpentine	Serpentine	Gulf C, TX	12	2900	129	145	3,509	153,157	1991
405	TX	Joe Moss	Jackson, 500	Jackson	Gulf C, TX	20	500	84	295	1,202	559,540	1991
406	TX	Jourdanton	Reklaw	Reklaw	Gulf C, TX	19	1409	101	120	10,130	381,000	1991
407	TX	Kohler, NE	Mirando 2	Caddell	Gulf C, TX	19	2633	124	42	79,928	1,465,659	1991
408	TX	Las Animas-Lefevre	Jackson	Jackson	Gulf C, TX	19	1793	108	41	26,104	3,482,341	1991
409	TX	Liska	Hockley	McElroy	Gulf C, TX	19	975	93	190	692	72,694	1991
410	TX	Lopez, North	Lopez sand	Jackson	Gulf C, TX	20	2064	113	53	17,226	2,277,847	1991
411	TX	Los Olmos	Frio	Frio	Gulf C, TX	20	450	83	310	2,299	991,316	1991
412	TX	Lundell	Cole	Whitsett	Gulf C, TX	19	1528	103	23	56,890	10,546,258	1991
413	TX	Manziel	Sub-Clarksville, FB A	Sub-Clarksville	East Texas	18	4169	153	21	4,340	205,827	1991
414	TX	McCrary	Sub-Clarksville	Sub-Clarksville	East Texas	20	4364	157	14	5,249	1,264,625	1991
415	TX	McCrary, West	Sub-Clarksville	Sub-Clarksville	East Texas	17	4345	157	22	6,779	539,993	1991
416	TX	Mitchell Creek, North	Paluxy	Paluxy	East Texas	17	4474	159	21	11,644	1,591,267	1991
417	TX	Neely, West	1150	Jackson	Gulf C, TX	20	1132	96	125	982	115,293	1991
418	TX	Newsome	Sub-Clarksville	Sub-Clarksville	East Texas	18	3854	147	24	20,865	1,991,099	1991
419	TX	Nolan Edward	Sub-Clarksville	Sub-Clarksville	East Texas	20	4762	165	12	2,126	2,346,438	1991
420	TX	Norman Paul	Woodbine	Woodbine	East Texas	18	5237	174	15	4,645	555,880	1991
421	TX	Nova	Sub-Clarksville	Sub-Clarksville	East Texas	20	4800	165	12	3,417	162,546	1991
422	TX	Nova, South	Sub-Clarksville 8	Sub-Clarksville	East Texas	19	4760	164	14	1,644	142,326	1991
423	TX	Oakville	Jackson	Jackson	Gulf C, TX	20	1830	109	65	19,754	2,019,902	1991
424	TX	Oates	Rustler	Rustler	Permian	18	790	85	450	13,322	1,037,313	1991
425	TX	Olson	Grayburg-San Andres	Grayburg-San Andres	Permian	18	1828	100	160	189,193	14,374,369	1991
426	TX	Petrox	Chernosky	Whitsett	Gulf C, TX	20	2024	113	20	44,887	2,724,916	1991
427	TX	Pewitt Ranch	Eagle Ford	Eagle Ford	East Texas	19	4507	160	16	224,624	23,862,716	1991
428	TX	Pittsburg	Sub-Clarksville	Sub-Clarksville	East Texas	13	3844	120	2200	83,345	2,727,278	1991
429	TX	Pittsburg	Sub-Clarksville B	Sub-Clarksville	East Texas	16	3793	146	35	32,391	1,111,514	1991
430	TX	Pleasanton, South	Carrizo Sand	Carrizo	Gulf C, TX	18	1887	110	93	18,274	2,889,964	1991
431	TX	Port Neches	Frio	Frio	Gulf C, TX	19	6000	188	9	99,305	24,918,808	1991
432	TX	Pryor Ranch, West	Elaine	Elaine	Gulf C, TX	15	2506	122	100	901	36,262	1991
433	TX	Purt	Woodbine	Woodbine	East Texas	19	3088	133	31	10,161	249,154	1991
434	TX	Quitman, South	Sub-Clarksville	Sub-Clarksville	East Texas	16	4217	154	28	4,961	109,607	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
387	TX	4	2	57	265	21	12	-1	14	26	-1	-1	17	15	1991	1950	Pennsylvanian, Middle	SS
388	TX	3	2	14	180	32	532	-1	10	-1	-1	-1	19	11	1991	1965	Eocene	UFS
389	TX	2	1	8	120	28	500	-1	10	-1	-1	-1	7	3	1991	1967	Eocene	UFS
390	TX	13	7	46	770	35	600	-1	10	-1	-1	-1	9	6	1991	1933	Eocene	UFS
391	TX	3	3	1	80	30	710	-1	25	35	-1	-1	2	1	1991	1968	Eocene	UFS
392	TX	24	17	29	2500	30	300	-1	7	-1	-1	-1	35	20	1991	1937	Eocene	UFS
393	TX	16	12	28	1320	29	740	-1	9	-1	-1	-1	23	9	1991	1950	Cretaceous	SS
394	TX	48	44	8	1950	28	740	-1	18	-1	63	-1	133	83	1991	1954	Cretaceous	SS
395	TX	2	1	33	180	24	200	-1	8	-1	-1	-1	2	2	1991	1965	Cretaceous	SS
396	TX	1	1	6	90	33	1000	-1	9	33	-1	-1	14	11	1991	1959	Eocene	UFS
397	TX	8	7	18	490	35	1000	-1	10	-1	-1	-1	21	8	1991	1965	Paleocene	UFS
398	TX	8	8	1	120	26	-1	-1	55	-1	-1	-1	3	3	1991	1950	Oligocene	SS
399	TX	1	1	3	120	26	-1	-1	10	-1	-1	-1	3	3	1991	1980	Eocene	SS
400	TX	2	2	13	100	33	1068	-1	16	-1	-1	-1	5	3	1991	1948	Oligocene	UFS
401	TX	1	1	1	100	25	-1	-1	10	-1	-1	-1	4	0	1990	1959	Cretaceous	SS
402	TX	5	5	3	80	25	-1	-1	51	-1	-1	-1	2	2	1991	1951	Miocene	SS
403	TX	4	3	30	500	37	2505	-1	5	-1	-1	-1	20	17	1991	1952	Eocene	UFS
404	TX	31	31	0	45	25	-1	-1	600	-1	-1	-1	4	3	1991	1976	Cretaceous	SS
405	TX	7	7	8	510	30	500	-1	10	-1	-1	-1	76	7	1991	1952	Eocene	UFS
406	TX	2	2	16	440	24	500	-1	5	-1	-1	-1	35	34	1991	1956	Eocene	UFS
407	TX	6	4	25	400	32	600	-1	10	-1	-1	-1	19	15	1991	1980	Eocene	UFS
408	TX	10	6	37	600	31	600	-1	11	-1	-1	-1	58	15	1991	1937	Eocene	UFS
409	TX	3	3	2	280	25	-1	-1	9	-1	-1	-1	8	5	1991	1951	Eocene	SS
410	TX	7	5	33	430	35	428	-1	10	-1	-1	-1	16	10	1991	1951	Eocene	UFS
411	TX	3	2	33	200	32	900	-1	10	-1	-1	-1	59	30	1991	1925	Oligocene	UFS
412	TX	89	79	12	5000	32	2630	-1	12	-1	-1	-1	49	37	1991	1937	Eocene	UFS
413	TX	2	2	9	160	24	200	-1	13	-1	-1	-1	4	3	1991	1970	Cretaceous	SS
414	TX	7	6	19	560	26	1400	-1	10	-1	-1	-1	11	8	1991	1952	Cretaceous	SS
415	TX	2	1	29	240	24	200	-1	7	-1	-1	-1	3	3	1991	1966	Cretaceous	SS
416	TX	4	2	42	200	15	24	-1	27	40	-1	-1	6	4	1991	1948	Cretaceous, Lower	SS
417	TX	2	2	5	120	20	500	-1	20	-1	-1	-1	2	1	1991	1962	Eocene	SS
418	TX	9	7	23	620	12	847	-1	25	-1	-1	-1	16	14	1991	1953	Cretaceous	SS
419	TX	12	9	20	403	24	250	-1	26	-1	-1	-1	8	4	1991	1949	Cretaceous	SS
420	TX	5	5	11	200	25	500	40	22	-1	-1	-1	3	2	1991	1946	Cretaceous	SS
421	TX	3	3	6	160	24	200	-1	15	-1	-1	-1	3	2	1991	1971	Cretaceous	SS
422	TX	3	3	5	280	24	113	-1	10	-1	-1	-1	2	2	1991	1980	Cretaceous	SS
423	TX	8	6	26	180	24	500	-1	38	-1	-1	-1	18	13	1991	1936	Eocene	UFS
424	TX	7	6	14	360	8	40	-1	55	-1	-1	-1	8	5	1991	1947	Permian	Dol
425	TX	85	70	17	2840	16	-1	-1	40	-1	-1	-1	143	68	1991	1940	Permian	Dol
426	TX	12	10	22	590	30	400	-1	15	35	-1	-1	22	9	1991	1955	Eocene	UFS
427	TX	66	42	36	6560	24	1400	-1	9	-1	-1	-1	103	54	1991	1949	Cretaceous	UFS
428	TX	16	13	17	2120	23	460	-1	7	-1	-1	-1	52	42	1991	1958	Cretaceous	SS
429	TX	4	3	27	520	24	200	-1	7	-1	-1	-1	14	8	1991	1964	Cretaceous	SS
430	TX	10	7	30	220	36	868	-1	26	-1	-1	-1	22	16	1991	1952	Eocene	UFS
431	TX	204	180	12	4880	30	500	-1	30	-1	-1	-1	83	25	1991	1929	Oligocene	UFS
432	TX	2	2	2	60	26	30	-1	26	-1	-1	-1	6	2	1991	1977	Cretaceous	SS
433	TX	4	4	6	160	25	500	-1	22	-1	-1	-1	4	2	1991	1949	Cretaceous	SS
434	TX	1	1	9	160	24	200	-1	7	-1	-1	-1	3	3	1991	1965	Cretaceous	SS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
435	TX	Raccoon Bend	Miocene Y	Miocene	Gulf C, TX	19	1952	111	71	23,975	1,016,287	1991
436	TX	Raccoon Bend	Miocene Z	Miocene	Gulf C, TX	19	2194	116	58	35,294	1,176,981	1991
437	TX	Raccoon Bend	Paine	Paine	Gulf C, TX	19	2734	126	39	6,554	283,583	1991
438	TX	Rinehart	Austin Chalk	Austin Chalk	Gulf C, TX	20	1163	96	124	218	653,783	1991
439	TX	Saxet	Oakville/Anahuac	Oakville/Anahuac	Gulf C, TX	20	4060	151	16	62,740	63,300,686	1991
440	TX	Seven Sisters	Jackson	Jackson	Gulf C, TX	20	2112	114	51	48,366	56,057,461	1991
441	TX	Shirley-Barbara, East	Woodbine	Woodbine	East Texas	16	6232	192	12	339	107,620	1991
442	TX	Simmons City	Govt. Wells	McElroy	Gulf C, TX	20	1340	99	100	5,495	102,480	1991
443	TX	Sinton, West	Frio	Frio	Gulf C, TX	19	5450	178	11	0	7,655,177	1989
444	TX	Sinton, West Shallow	Bayder	Catahoula	Gulf C, TX	19	3368	138	27	10,663	5,779,028	1991
445	TX	Slocum	Carrizo	Carrizo	East Texas	19	490	75	1000	120,809	9,082,495	1991
446	TX	Stockdale	Carrizo	Carrizo	Gulf C, TX	18	452	83	540	196	16,284	1991
447	TX	Sugar Hill	Paluxy	Paluxy	East Texas	18	4836	166	16	3,804	266,408	1991
448	TX	Sutil	Austin	Austin	Gulf C, TX	19	6050	189	9	28,303	911,197	1991
449	TX	Tami	Sub-Clarksville	Sub-Clarksville	East Texas	13	3968	149	54	1,542	137,774	1991
450	TX	Trice	Woodbine	Woodbine	East Texas	13	5621	181	24	263	803,223	1991
451	TX	Trix-Liz	Woodbine "A"	Woodbine	East Texas	20	3390	138	23	4,472	1,009,658	1991
452	TX	Tully	Paluxy	Paluxy	East Texas	17	4456	159	21	2,132	18,986	1991
453	TX	Viola 4000	Catahoula	Catahoula	Gulf C, TX	18	4097	152	22	0	756,933	1990
454	TX	Wardlaw	Glen Rose	Glen Rose	Permian	18	300	78	845	1,371	74,371	1991
455	TX	Wheeler Mag	Jackson, 1200	Jackson	Gulf C, TX	15	1193	97	425	13,228	484,648	1991
456	TX	Winn-Dulce	Bracero	Bracero	Gulf C, TX	19	3074	132	32	21,597	428,053	1991
457	TX	Winn-Dulce	Del Monte Oil	Del Monte	Gulf C, TX	15	2921	130	74	13,998	268,498	1991
458	TX	Winn-Dulce	Elaine	Elaine	Gulf C, TX	15	2790	127	81	28,630	411,254	1991
459	TX	Yantis	Sub-Clarksville	Sub-Clarksville	East Texas	20	4210	154	15	13,114	2,677,151	1991
460	UT	Duchesne	Wasatch	Wasatch	Uinta	20	7500	186	8	4,746	83,211	1991
461	UT	Valley Kaibab, Upper	Redwall	Mississippian	Paradox	17	8777	208	9	74,140	4,873,139	1991
462	WY	Aspen Creek	Dinwoody/Phosphoria	Dinwoody/Phosphoria	Bighorn	20	3551	129	30	0	332,334	1989
463	WY	Berger Hill	Minnelusa	Minnelusa	Powder River	19	6159	162	15	43,998	888,532	1991
464	WY	Bison Basin	Frontier	Frontier	Wind River	18	603	65	4300	67,815	2,781,570	1991
465	WY	Black Mountain	Amsden	Amsden	Bighorn	20	3865	103	180	-1	276,000	1989
466	WY	C & H	Minnelusa	Minnelusa	Powder River	20	7566	187	8	20,199	5,310,764	1991
467	WY	Casper Creek, South	Tensleep	Tensleep	Wind River	13	2500	90	680	430,439	14,477,731	1991
468	WY	Clark Ranch	Tensleep	Tensleep	Wind River	15	4678	100	440	16,475	1,608,622	1991
469	WY	Cowley	Tensleep	Tensleep	Bighorn	20	4538	109	64	6,850	813,075	1991
470	WY	Dallas	Tensleep	Tensleep	Wind River	19	1260	100	125	78,097	9,401,405	1991
471	WY	DuBois	Phosphoria	Phosphoria	Wind River	20	2062	85	138	2,582	521,084	1991
472	WY	Eitel	Minnelusa	Minnelusa	Powder River	20	6005	160	14	26,639	890,272	1991
473	WY	Ferguson Ranch	Phosphoria	Phosphoria	Bighorn	14	3528	118	150	2,819	100,928	1991
474	WY	Ferguson Ranch	Tensleep	Tensleep	Bighorn	14	3838	110	235	98,673	3,532,487	1991
475	WY	Fourbear	Darwin	Darwin	Bighorn	14	3470	115	180	8,845	1,172,270	1991
476	WY	Fourbear	Dinwoody	Dinwoody	Bighorn	14	3268	112	215	3,786	501,745	1991
477	WY	Fourbear	Madison	Madison	Bighorn	15	3702	119	115	21,102	2,796,899	1991
478	WY	Fourbear	Phosphoria	Phosphoria	Bighorn	14	3370	113	195	22,111	2,930,567	1991
479	WY	Fourbear	Tensleep	Tensleep	Bighorn	14	2905	130	445	123,348	16,348,542	1991
480	WY	Garland	Amsden	Amsden	Bighorn	20	4026	138	23	0	5,348,916	1989
481	WY	Garland	Darwin	Darwin	Bighorn	20	4486	138	23	-1	3,774,045	1989
482	WY	Garland	Madison	Madison	Bighorn	20	3970	140	22	-1	46,247,067	1989

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
435	TX	2	1	41	190	28	700	-1	10	-1	-1	-1	13	5	1991	1958	Miocene	UFS
436	TX	4	3	30	600	28	700	-1	5	-1	-1	-1	19	12	1991	1956	Miocene	UFS
437	TX	1	1	20	80	25	500	-1	15	-1	-1	-1	2	1	1991	1952	Miocene	SS
438	TX	4	3	16	730	12	-1	-1	10	-1	-1	-1	19	9	1991	1950	Cretaceous	Chalk-fract
439	TX	232	169	27	9900	28	700	-1	18	-1	-1	-1	32	14	1991	1930	Miocene	UFS
440	TX	503	447	11	5150	28	225	-1	75	-1	-1	-1	123	34	1991	1935	Eocene	UFS
441	TX	1	1	10	120	25	500	-1	8	-1	-1	-1	2	1	1991	1964	Cretaceous	SS
442	TX	8	8	1	800	28	23	-1	8	40	60	-1	6	5	1991	1972	Eocene	SS
443	TX	23	16	33	560	30	600	-1	30	-1	-1	-1	1	0	1989	1944	Oligocene	UFS
444	TX	24	18	24	1700	30	600	-1	10	-1	-1	-1	25	8	1991	1944	Oligocene	UFS
445	TX	106	97	9	2500	38	2655	-1	24	-1	-1	-1	545	185	1991	1955	Eocene	UFS
446	TX	3	3	1	200	31	730	-1	10	40	-1	-1	7	3	1991	1971	Eocene	UFS
447	TX	1	1	20	120	22	375	-1	11	-1	-1	-1	4	2	1991	1952	Cretaceous	UFS
448	TX	6	5	16	1040	12	-1	-1	10	-1	-1	-1	10	8	1991	1976	Cretaceous	Chalk-fract
449	TX	5	5	3	440	24	24	-1	10	-1	-1	-1	3	2	1991	1978	Cretaceous	SS
450	TX	11	10	8	560	27	500	-1	15	-1	-1	-1	4	1	1991	1951	Cretaceous	SS
451	TX	4	3	28	620	31	500	-1	4	-1	-1	-1	16	10	1991	1950	Cretaceous	SS
452	TX	1	1	1	80	24	300	20	15	-1	-1	-1	2	1	1991	1979	Cretaceous	SS
453	TX	3	3	23	240	30	600	-1	10	-1	-1	-1	2	0	1990	1954	Oligocene	UFS
454	TX	16	15	0	640	29	58	-1	18	-1	-1	-1	55	9	1991	1947	Cretaceous	UFS
455	TX	3	3	14	350	30	400	-1	7	-1	-1	-1	35	21	1991	1965	Eocene	UFS
456	TX	6	6	7	500	27	45	-1	10	-1	-1	-1	24	16	1991	1983	Cretaceous	SS
457	TX	2	2	13	180	24	500	-1	10	-1	-1	-1	17	8	1991	1983	Cretaceous	UFS
458	TX	12	12	3	660	26	40	-1	15	-1	-1	-1	21	16	1991	1982	Cretaceous	SS
459	TX	15	12	18	1160	27	500	-1	10	-1	-1	-1	20	10	1991	1948	Cretaceous	SS
460	UT	34	33	0	800	12	100	-1	75	-1	-1	-1	34	33	1991	1951	Eocene	SS
461	UT	27	22	18	3350	10	20	-1	17	-1	-1	-1	-1	-1	-1	1949	Mississippian	LS
462	WY	2	1	21	160	14	20	-1	15	-1	-1	-1	-1	0	1991	1974	Triassic/Permian	Dol
463	WY	2	1	41	140	22	300	-1	15	-1	-1	-1	-1	2	1991	1975	Permian	SS
464	WY	18	15	15	1480	22	100	-1	12	-1	-1	-1	-1	13	1991	1929	Cretaceous	SS
465	WY	2	1	16	120	12	70	70	25	-1	-1	-1	-1	-1	-1	1946	Pennsylvanian	LS
466	WY	12	6	45	667	18	230	-1	21	-1	-1	-1	-1	4	1991	1967	Pennsylvanian	SS
467	WY	37	22	39	330	20	500	170	120	-1	-1	-1	-1	69	1991	1923	Pennsylvanian	SS
468	WY	5	4	30	140	22	150	127	37	-1	-1	-1	-1	5	1991	1955	Pennsylvanian	SS
469	WY	2	1	39	200	14	110	-1	16	-1	-1	-1	-1	2	1991	1964	Pennsylvanian	SS
470	WY	28	18	34	220	18	300	230	150	-1	-1	-1	91	79	1991	1884	Pennsylvanian	SS/LS
471	WY	3	3	15	240	22	5	93	14	-1	-1	-1	-1	3	1991	1946	Permian	LS
472	WY	3	2	27	160	19	300	-1	23	-1	-1	-1	-1	4	1991	1976	Permian	SS
473	WY	4	4	3	280	15	7	-1	20	30	-1	-1	-1	3	1991	1971	Permian	LS
474	WY	31	28	11	280	16	300	177	150	-1	-1	-1	-1	11	1991	1963	Pennsylvanian	SS
475	WY	5	4	24	350	9	15	35	34	-1	-1	-1	-1	2	1989	1948	Pennsylvanian	LS/SS
476	WY	2	2	24	1528	10	13	-1	3	-1	-1	-1	-1	1	1989	1973	Triassic	Dol
477	WY	12	9	24	273	13	4	-1	72	-1	-1	-1	-1	3	1989	1948	Mississippian	Dol/LS
478	WY	12	10	24	1217	10	2	-1	22	-1	-1	-1	-1	4	1989	1962	Permian	Dol
479	WY	70	53	24	982	9	7	-1	169	-1	-1	-1	-1	22	1989	1928	Pennsylvanian	Dol/SS
480	WY	12	7	45	1700	10	-1	-1	15	-1	-1	-1	9	0	1989	1940	Pennsylvanian	Dol
481	WY	12	8	32	1320	12	-1	-1	16	-1	-1	-1	9	4	1989	1959	Pennsylvanian	SS-fract
482	WY	145	98	32	2054	18	16	-1	84	-1	-1	-1	126	115	1989	1930	Mississippian	LS

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
483	WY	Garner Lake	Minnelusa	Minnelusa	Powder River	20	8018	195	7	24,066	375,718	1991
484	WY	Glo North	Minnelusa	Minnelusa	Powder River	20	7900	130	30	145,077	1,244,175	1991
485	WY	Gooseberry	Phosphoria	Phosphoria	Bighorn	19	5670	127	130	14,834	497,629	1989
486	WY	Gooseberry	Tensleep	Tensleep	Bighorn	20	5800	131	58	51,921	1,741,703	1989
487	WY	Half Moon	Phosphoria	Phosphoria	Bighorn	14	3365	110	1250	67,812	2,290,180	1991
488	WY	Half Moon	Tensleep	Tensleep	Bighorn	15	3590	110	620	180,833	6,107,145	1991
489	WY	Hamilton Dome	Curtis	Curtis	Bighorn	19	1445	94	160	-1	2,542,705	1987
490	WY	Hamilton Dome	Madison	Madison	Bighorn	15	3332	125	88	-1	13,606,520	1987
491	WY	Hidden Dome	Tensleep	Tensleep	Bighorn	20	4559	100	39	196,753	6,864,258	1991
492	WY	Hunt	Phosphoria	Phosphoria	Bighorn	13	4069	110	300	7,536	187,677	1991
493	WY	Hunt	Tensleep	Tensleep	Bighorn	14	4225	115	180	18,449	459,485	1991
494	WY	King Dome	Tensleep	Tensleep	Bighorn	18	3060	142	28	11,349	163,818	1991
495	WY	Kummerfeld	Minnelusa	Minnelusa	Powder River	20	7643	130	38	76,507	5,321,460	1991
496	WY	Lamb & Lamb Anticline	Madison	Madison	Bighorn	19	3978	130	34	8,434	359,816	1991
497	WY	Little Buffalo Basin	Darwin	Darwin	Bighorn	19	5614	130	34	13,895	77,579	1991
498	WY	Little Buffalo Basin	Phosphoria	Phosphoria	Bighorn	18	4650	122	39	404,502	29,012,430	1991
499	WY	Little Buffalo Basin	Tensleep	Tensleep	Bighorn	20	4600	128	43	1,331,045	95,467,691	1991
500	WY	Little Laramie	Tensleep	Tensleep	Laramie	18	3712	119	61	7,430	1,241,984	1991
501	WY	Oil Mountain	Tensleep	Tensleep	Wind River	13	2622	95	885	4,350	175,930	1991
502	WY	Okie Draw	Tensleep	Tensleep	Bighorn	20	3199	120	41	85	100,504	1991
503	WY	Olsen	Minnelusa	Minnelusa	Powder River	20	9588	223	5	12,340	512,589	1991
504	WY	Oregon Basin, South	Madison	Madison	Bighorn	19	4170	120	77	625,557	37,771,175	1991
505	WY	Oregon Basin, South	Phosphoria	Phosphoria	Bighorn	20	3539	115	43	1,247,782	75,341,099	1991
506	WY	Oregon Basin, West	Phosphoria	Phosphoria	Bighorn	16	4311	100	296	8,657	916,269	1991
507	WY	Pitchfork	Phosphoria	Phosphoria	Bighorn	19	3440	125	150	851,760	21,416,221	1991
508	WY	Pitchfork	Tensleep	Tensleep	Bighorn	18	3620	121	155	763,129	19,187,725	1991
509	WY	Pleasant Valley	Minnelusa	Minnelusa	Powder River	20	8150	197	6	44,372	1,121,377	1991
510	WY	Poison Spider	Tensleep	Tensleep	Wind River	14	2402	96	590	6,000	174,000	1991
511	WY	Prong Creek	Minnelusa	Minnelusa	Powder River	19	6373	166	14	134,425	5,477,841	1991
512	WY	Rawhide	Phosphoria	Phosphoria	Bighorn	17	5057	115	90	0	44,208	1989
513	WY	Red Springs	Madison	Madison	Bighorn	11	900	72	28300	59	257,553	1988
514	WY	Rocky Point	Minnelusa	Minnelusa	Powder River	16	5426	170	19	146,398	10,859,741	1991
515	WY	Rose Creek	Phosphoria	Phosphoria	Bighorn	15	5069	152	35	5,460	190,317	1991
516	WY	Sage Creek	Madison	Madison	Bighorn	20	3445	120	41	0	247,341	1989
517	WY	Sheep Point	Phosphoria	Phosphoria	Bighorn	17	3644	117	82	12,251	570,176	1991
518	WY	Shoshone	Phosphoria	Phosphoria	Bighorn	18	4752	120	59	33,756	1,225,714	1991
519	WY	Shoshone	Tensleep	Tensleep	Bighorn	18	4930	123	52	75,456	2,739,830	1991
520	WY	Spence Dome	Amsden	Amsden	Bighorn	18	448	56	490	12,163	297,074	1991
521	WY	Spence Dome	Madison	Madison	Bighorn	18	545	56	490	18,244	445,610	1991
522	WY	Spring Creek, South	Darwin (Amsden)	Darwin (Amsden)	Bighorn	15	4340	130	71	4,640	220,670	1991
523	WY	Spring Creek, South	Madison	Madison	Bighorn	13	4502	108	345	30,228	1,437,541	1991
524	WY	Spring Creek, South	Phosphoria	Phosphoria	Bighorn	15	4139	127	670	45,533	2,165,361	1991
525	WY	Spring Creek, South	Tensleep	Tensleep	Bighorn	15	3929	106	600	298,171	14,179,105	1991
526	WY	Sunshine, North	Phosphoria	Phosphoria	Bighorn	16	3562	110	420	22,838	691,758	1991
527	WY	Sunshine, North	Tensleep	Tensleep	Bighorn	16	3825	110	420	63,438	1,921,550	1991
528	WY	Sunshine, South	Phosphoria	Phosphoria	Bighorn	16	2480	100	460	0	380,428	1989
529	WY	T. E. Ranch	Dinwoody	Dinwoody	Bighorn	19	3613	108	175	3,132	82,483	1991
530	WY	T. E. Ranch	Phosphoria	Phosphoria	Bighorn	19	3908	108	175	5,010	131,974	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
483	WY	2	1	23	200	22	300	-1	8	-1	-1	-1	-1	2	1991	1966	Permian	SS
484	WY	4	3	31	200	19	150	-1	23	-1	-1	-1	-1	3	1991	1985	Permian	SS
485	WY	3	3	16	235	14	12	75	20	-1	-1	-1	-1	-1	-1	1937	Permian	LS
486	WY	9	7	19	235	12	25	-1	70	-1	-1	-1	-1	-1	-1	1937	Pennsylvanian	SS
487	WY	24	22	10	920	14	18	-1	40	-1	-1	-1	-1	9	1991	1944	Permian	Dol
488	WY	63	57	10	920	15	251	-1	98	-1	-1	-1	-1	23	1991	1945	Pennsylvanian	SS
489	WY	26	24	10	2500	15	40	-1	15	-1	-1	-1	-1	-1	-1	1918	Jurassic	SS
490	WY	48	34	29	400	16	25	-1	160	-1	-1	-1	-1	-1	-1	1948	Mississippian	LS
491	WY	21	14	32	484	15	92	-1	63	-1	-1	-1	-1	14	1991	1947	Pennsylvanian	SS
492	WY	5	5	4	240	16	26	-1	29	-1	-1	-1	-1	1	1991	1966	Permian	Dol
493	WY	16	15	3	240	20	157	-1	71	-1	-1	-1	-1	3	1991	1966	Pennsylvanian	SS
494	WY	3	3	5	130	11	55	-1	46	-1	-1	-1	-1	1	1991	1981	Pennsylvanian	SS
495	WY	14	9	38	712	17	208	-1	25	-1	-1	-1	-1	5	1991	1969	Permian	SS
496	WY	1	1	28	280	5	4	-1	20	-1	-1	-1	-1	3	1991	1950	Mississippian	LS
497	WY	5	5	2	245	12	3	-1	35	-1	-1	-1	-1	-1	-1	1985	Pennsylvanian	SS
498	WY	66	37	44	2800	13	9	-1	39	-1	-1	-1	-1	-1	-1	1945	Permian	Dol
499	WY	237	141	40	1500	14	61	288	158	-1	92	-1	-1	-1	-1	1944	Pennsylvanian	SS
500	WY	5	4	23	137	23	1570	-1	37	-1	-1	-1	-1	2	1991	1948	Pennsylvanian	SS
501	WY	12	11	2	100	20	400	230	125	-1	-1	-1	-1	5	1991	1945	Pennsylvanian	SS
502	WY	1	1	9	80	15	300	-1	20	-1	-1	-1	-1	1	1991	1976	Permian/Pennsylvanian	SS
503	WY	9	8	6	200	19	300	-1	50	-1	-1	-1	-1	1	1991	1965	Permian	SS
504	WY	96	58	39	1325	13	6	-1	120	-1	-1	-1	-1	-1	-1	1943	Mississippian	LS/Dol
505	WY	136	61	55	6108	16	45	-1	30	-1	-1	-1	-1	-1	-1	1928	Permian	Dol
506	WY	4	3	24	140	18	11	37	32	-1	-1	-1	-1	2	1991	1955	Permian	Dol
507	WY	106	84	20	800	15	31	-1	189	-1	-1	-1	-1	71	1991	1930	Permian	Dol
508	WY	95	75	20	800	20	45	127	127	-1	-1	-1	-1	71	1991	1930	Pennsylvanian	SS
509	WY	6	4	20	240	20	300	36	25	-1	-1	-1	-1	1	1991	1963	Permian	SS
510	WY	3	2	7	60	26	750	-1	35	-1	-1	-1	-1	3	1991	1962	Pennsylvanian	SS
511	WY	17	11	32	640	21	623	-1	27	-1	-1	-1	-1	10	1991	1959	Pennsylvanian	SS
512	WY	2	2	2	160	16	26	-1	15	-1	-1	-1	-1	0	1991	1953	Permian	Dol
513	WY	3	2	10	80	12	20	-1	60	-1	-1	-1	-1	1	1991	1919	Mississippian	LS
514	WY	24	13	45	671	18	475	350	43	-1	-1	-1	-1	18	1991	1961	Permian	SS
515	WY	4	4	5	200	8	-1	66	50	-1	-1	-1	-1	2	1991	1957	Permian	Dol-fract
516	WY	1	1	17	160	10	20	-1	20	-1	-1	-1	-1	-1	-1	1948	Mississippian	LS
517	WY	10	9	6	300	16	20	-1	45	-1	-1	-1	-1	3	1991	1957	Permian	Dol
518	WY	3	2	38	270	15	13	60	17	-1	-1	-1	-1	5	1991	1929	Permian	Dol/LS
519	WY	5	3	50	282	11	80	-1	38	-1	-1	-1	-1	11	1991	1942	Pennsylvanian	SS/Dol
520	WY	2	1	17	460	8	69	-1	10	-1	-1	-1	-1	18	1991	1957	Pennsylvanian	SS/Dol
521	WY	4	4	10	460	14	31	160	15	-1	-1	-1	-1	27	1991	1944	Mississippian	LS/Dol
522	WY	2	2	10	160	18	200	-1	16	-1	-1	-1	1	1	1989	1947	Pennsylvanian	SS
523	WY	6	4	26	200	12	20	-1	50	-1	-1	-1	2	2	1989	1946	Mississippian	LS
524	WY	6	4	34	600	15	55	30	15	-1	-1	-1	14	13	1989	1946	Permian	Dol
525	WY	41	27	34	1040	17	150	125	50	-1	-1	-1	35	27	1989	1930	Pennsylvanian	SS
526	WY	3	2	24	100	17	5	-1	36	-1	-1	-1	-1	5	1991	1955	Permian	Dol
527	WY	6	4	32	100	13	70	120	100	-1	-1	-1	-1	12	1991	1928	Pennsylvanian	SS
528	WY	8	7	5	200	21	7	-1	39	-1	-1	-1	-1	0	1991	1926	Permian	Dol
529	WY	2	1	5	240	14	4	-1	10	-1	-1	-1	-1	1	1989	1959	Triassic	Dol
530	WY	2	2	6	240	13	20	-1	16	-1	-1	-1	-1	1	1989	1978	Permian	Dol

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	B	C	D	E	F	G	H	I	J	K	L
1						API	Depth,	Temp.,	Visc.,	Ann. Prod.	Cum. Prod.,	Cum. Prod.,
2	State	Field	Reservoir	Formation	Basin	Gravity	ft	°F	cP	barrels	barrels	year
531	WY	Tisdale, East	Tensleep	Tensleep	Powder River	20	2244	90	185	26,250	2,776,164	1991
532	WY	Tisdale, North	Tensleep	Tensleep	Powder River	19	2030	90	240	7,028	155,416	1991
533	WY	Warm Springs, East	Phosphoria	Phosphoria	Bighorn	19	850	80	130	38,400	600,431	1991
534	WY	Whisler	Minnelusa	Minnelusa	Powder River	20	8304	200	7	63,102	667,382	1991
535	WY	Willow Draw	Dinwoody	Dinwoody	Bighorn	18	4333	142	28	4,469	339,190	1991
536	WY	Willow Draw	Tensleep	Tensleep	Bighorn	17	4548	142	33	5,292	401,672	1991
537	WY	Windmill	Minnelusa	Minnelusa	Powder River	20	8119	197	7	204,211	3,329,254	1991
538	WY	Winkleman	Nugget	Nugget	Wind River	14	1154	92	1000	42,102	5,421,331	1991

Table 7–1 Reservoir Parameters for Heavy Oil Reservoirs in the U.S.

	A	N	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		OOIP,	OIP,	Recovery	Area,	Porosity,	Perm.,	Gross	Net	Swi,	Soi,	Saturation	Wells	Wells	Wells	Disc.,		
2	State	MM barrels	MM barrels	%	acres	%	mD	Pay, ft	Pay, ft	%	%	bbl/acre*ft	Total	Prod.	Prod., year	year	Geo Series	Lith.
531	WY	6	3	50	500	20	900	30	12	-1	-1	-1	-1	11	1991	1959	Pennsylvanian	SS
532	WY	1	1	11	320	16	300	-1	6	-1	-1	-1	-1	-1	-1	1960	Pennsylvanian	SS
533	WY	3	2	20	240	22	30	-1	12	-1	-1	-1	-1	-1	-1	1917	Permian	Dol
534	WY	3	2	24	240	14	22	-1	18	-1	-1	-1	-1	3	1991	1967	Pennsylvanian	SS
535	WY	6	5	6	800	8	-1	76	19	-1	-1	-1	-1	12	1989	1972	Triassic	Dol/SS
536	WY	7	6	6	800	10	-1	42	18	-1	-1	-1	-1	1	1989	1972	Pennsylvanian	SS/Dol
537	WY	10	6	34	480	19	300	-1	23	-1	-1	-1	-1	-1	-1	1967	Pennsylvanian	SS
538	WY	11	5	50	160	23	481	80	63	-1	-1	-1	-1	18	1989	1958	Jurassic	SS

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
AL	Foshee	Tuscaloosa, Lower, Massive	19	6140	key data missing
AL	Gilbertown, South	Eutaw	17	3423	abandoned
AL	Hubbard's Landing	Dantzler	17	6617	key data missing
AL	Hubbard's Landing	Paluxy	19	8675	key data missing
AL	Langsdale	Eutaw	18	3742	abandoned
AL	Langsdale, East	Eutaw	19	3794	abandoned
AL	Tensaw Lake	Paluxy	20	8385	key data missing
AR	Artesian, East	Blossom	14	2854	abandoned, temp. 1990
AR	Berry	Graves	14	2627	small
AR	Bragg Camden	Nacatoch	16	2025	key data missing
AR	Buckner	Tokio	20	2503	abandoned 1970
AR	Calion	Meakin	20	2314	key data missing
AR	Careyville Landing	Blossom	19	2740	abandoned, temp. 1990
AR	Careyville Landing	Travis Peak	20	2901	abandoned, temp. 1966
AR	Clear Creek	Tokio	15	2432	abandoned 1957
AR	Crain City	Baker	16	2642	small
AR	Cross Country SL.	Graves	16	2596	abandoned, temp. 1989
AR	Cypress Creek	Graves	16	2755	abandoned, temp. 1983
AR	Dry Creek	Graves	20	2749	abandoned, temp. 1990
AR	Falcon	Hill	17	2384	abandoned, temp. 1989
AR	Falcon	Tuscaloosa	17	2300	abandoned 1971
AR	Fouke, North	Tokio	16	3120	key data missing
AR	Garland City	Buckrange	18	2410	abandoned 1969
AR	Garland City	Paluxy	15	3805	abandoned, temp. 1962
AR	Garland City	Tuscaloosa	19	2980	abandoned 1964
AR	Hampton	Nacatoch	16	2286	abandoned 1958
AR	Irons	Paluxy	14	2350	abandoned, temp. 1984
AR	Lake June	Nacatoch	17	1545	abandoned 1967
AR	Lake June	Tokio	19	2550	abandoned, temp. 1990
AR	Langley	Nacatoch	13	1375	abandoned, temp. 1987
AR	Lawson, North	Graves	18	2694	small
AR	Lenz	Tuscaloosa	20	2750	key data missing
AR	Lewisville, Old Town	Tokio	19	2589	abandoned, temp. 1980
AR	Lick Creek	Blossom	14	2675	abandoned, temp. 1975
AR	Lick Creek	Cotton Valley	12	3386	abandoned, temp. 1975
AR	Lick Creek	Graves	17	2574	abandoned 1976
AR	Lick Creek	Nacatoch	17	2270	abandoned 1975
AR	Little Bodcaw	Tokio	20	2122	small
AR	Locust Bayou	Meakin	15	1990	small
AR	McKinney Bayou	Tuscaloosa	20	3050	abandoned, temp. 1989
AR	McNatt	James	20	2666	abandoned, temp. 1981
AR	Meriwether Lake	Mooringsport	18	3418	abandoned 1990
AR	Meriwether Lake	Tuscaloosa	20	2700	small
AR	Meriwether Lake, South	Paluxy	14	2816	abandoned, temp. 1989
AR	Midway	Tuscaloosa	12	2390	abandoned, temp. 1980
AR	Midway, West	Paluxy	18	2908	small
AR	Moro Bay	Cotton Valley	13	3460	small
AR	Mt. Pleasant	Tokio	15	2456	abandoned 1970
AR	New London	Smackover	12	6049	abandoned 1984

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
AR	New London, North	Reynolds Lime	12	6050	abandoned 1988
AR	Nichols	Hill	18	2800	abandoned 1969
AR	Nichols	James Lime	15	3194	abandoned 1990
AR	Nichols, Hill	Rodessa	18	2800	key data missing
AR	Olin Forest, North	Cotton Valley	18	4807	abandoned, temp. 1970
AR	Pace City	Graves	18	2350	abandoned 1986
AR	Pacy City, East	Travis Peak	18	2817	abandoned 1973
AR	Patmos	Tuscaloosa	18	2220	abandoned 1971
AR	Paup Spur	Travis Peak	16	4260	abandoned 1990
AR	Pigeon Hill	Travis Peak	18	2923	abandoned, temp. 1985
AR	Prudhoe Bay	Tokio	17	2688	small
AR	Ramsey Creek	Tokio	19	2978	abandoned, temp. 1986
AR	River Bend	Blossom	16	2731	abandoned 1963
AR	Seminary Church	Tokio	18	2540	small
AR	Shiloh	Tokio	14	2700	key data missing
AR	Shiloh	Tuscaloosa	19	2975	small
AR	Short	Blossom	20	2858	abandoned, temp. 1986
AR	Smackover	Uncontrolled	19	1920	key data missing
AR	Spirit Lake	Buckrange	19	2650	key data missing
AR	Spirit Lake, North	Tokio	17	2540	small
AR	Spirit Lake, North	Tuscaloosa	18	3015	abandoned, temp. 1987
AR	Stamps, East	Tokio	19	2490	small
AR	Stamps, West	Paluxy	17	3310	abandoned, temp. 1989
AR	Stamps, West	Tokio	18	2568	abandoned, temp. 1986
AR	Stephens	Nacatoch	17	1350	abandoned, temp. 1990
AR	Stephens	Rodessa	16	2939	abandoned, temp. 1969
AR	Stow Lake	Graves	16	2764	abandoned, temp. 1987
AR	Troy, East	Nacatoch	15	1309	abandoned, temp. 1989
AR	Troy, North	Nacatoch	16	1723	abandoned, temp. 1980
AR	Troy, North	Rodessa	20	2853	small
AR	Urbana	Meakin	20	2500	abandoned 1960
AR	Wesgon	Nacatoch	15	1637	small
AR	Wesson	Nacatoch	15	1500	abandoned, temp. 1990
AR	Wesson, North	Nacatoch	15	1358	abandoned, temp. 1986
AR	Willisville, Southwest	Tokio	15	2070	abandoned, temp. 1989
AR	Willisville, West	Tokio	19	2135	small
AR	Wilmington	Graves	18	3438	abandoned 1971
CA	Alegria	Rincon	18	2120	abandoned
CA	Anaheim	Oil Sand, Pico	11	4350	abandoned
CA	Antelope Hills, Hopkins Area	Point of Rocks	17	2250	small
CA	Antelope Hills, North	Button Bed	16	2340	small
CA	Antelope Hills, North	IIA	15	2360	small
CA	Antelope Hills, North	Packwood	11	950	small
CA	Antelope Hills, Williams Area	Bitton Bed	17	2100	small
CA	Antelope Hills, Williams Area	Button Bed	17	2100	small
CA	Antelope Hills, Williams Area	Upper	12	1122	small
CA	Arroyo Grande, Tiber Area	Martin	17	2000	key data missing
CA	Asphalto	Etchegoin	19	3050	key data missing
CA	Belgian, Northwest Area	Phacoides	16	1400	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
CA	Blackwell Corner	Devilwater	12	700	small
CA	Blackwell Corner	Grit	14	1400	small
CA	Brea-Olinda	First, Second, Third Pliocene	17	2100	key data missing
CA	Capitan, Offshore Area	Vaqueros	16	1250	abandoned
CA	Carneros	Button Bed	13	2100	small
CA	Cat Canyon, East Area	Brooks	10	3600	key data missing
CA	Charlie Canyon	Unnamed	14	600	abandoned
CA	Conejo	Unnamed	18	150	abandoned
CA	Cymric, Salt Creek Main Area	Etchegoin	13	650	key data missing
CA	Deer Creek	Vedder	13	2340	abandoned
CA	Deer Creek, North	Santa Margarite	12	790	small
CA	Del Valle, Kinler	Del Valle	20	7100	abandoned
CA	Edison, Northeast	Chanac	13	900	small
CA	Fruitvale, Calloway Area	40-7	20	4050	small
CA	Fruitvale, Calloway Area	42-0	20	4150	small
CA	Fruitvale, Greenacres Area	Chanac	19	4400	abandoned
CA	Fruitvale, Greenacres Area	Lerdo	20	4300	abandoned
CA	Gaffey	Pliocene	10	1500	abandoned
CA	Gonyer Anticline	Gonyer	12	1700	abandoned
CA	Hanford	Zilch	20	5250	abandoned
CA	Hopper Canyon North Area	Unnamed	14	600	abandoned
CA	Hopper Canyon, Main Area	I	16	1000	key data missing
CA	Huasna-Tar Springs Area	Monterey	17	2550	abandoned
CA	Hyperion	Nodular	17	6835	small
CA	Hyperion	Schist	17	7125	small
CA	Hyperion	Schist Cong	17	7045	small
CA	Jesus Maria East Area	Monterey	12	1950	small
CA	King City 3-1-32 Area	Thorup	13	1860	small
CA	King City Kent-Bashman Area	Thorup	16	2450	small
CA	Kraemer	Kraemer	19	2400	abandoned
CA	Kraemer	Upper	18	1900	abandoned
CA	Kraemer, West	Puente	19	3100	abandoned
CA	Las Posas	Unnamed	20	4770	small
CA	Long Beach, Old Area	Upper Wilbur	19	2000	key data missing
CA	Lopez Canyon	Pt. Sal	15	2375	abandoned
CA	Los Angeles City	Third	14	1500	small
CA	Los Lobos	Etchegoin	17	7500	small
CA	Mahala, Abacherli Area	Abarcherli	19	2500	key data missing
CA	Mahala, Prado Dam Area	Michelin	20	3500	abandoned
CA	Mahala, Prado Dam Area	Michelin	20	3500	key data missing
CA	McCool Ranch	E	12	2250	small
CA	McCool Ranch	Lombardi	12	2150	small
CA	McKittrick, Northeast Area	Olig	15	1900	small
CA	McKittrick, Northeast Area	San Joaquin	12	1050	small
CA	Montalvo, West, Offshore Area	Sespe	17	10300	key data missing
CA	Moorpark, West	Unnamed	13	6410	small
CA	Mount Poso, Baker-Grove Area	Vedder	15	1750	small
CA	Mount Poso, Granite Canyon Ar	Vedder	15	1390	small
CA	Mount Poso, West Area	Vedder	16	2575	small

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
CA	Newhall, Elsmere Area	Pico	15	780	abandoned
CA	Newhall, Townsite Area	Braille	20	2735	small
CA	Newport, Beach Area	Puente	12	1225	abandoned
CA	Newport, Mesa Area	Puente	12	500	abandoned
CA	Ojai, Sisar Creek Area	Miocene	14	3680	key data missing
CA	Ojai, Sisar Creek Area	Pliocene	14	1070	key data missing
CA	Ojai, Sisar Creek Area	Saugus	14	750	key data missing
CA	Point Arguellos, Federal-OCS	Monterey	20	7900	key data missing
CA	Poso Creek, McVan Area	Pyramid Hill	17	3150	small
CA	Poso Creek, McVan Area	Santa Margarita	13	1800	small
CA	Prado-Corona, Goedhart Area	Hunter, Lower	16	2425	small
CA	Prado-Corona, Goedhart Area	Hunter, Upper	13	2350	small
CA	Prado-Corona, Sardco Area	Hunter, Lower	15	2425	small
CA	Prado-Corona, Sardco Area	Hunter, Upper	15	2350	small
CA	Pyramid Hills, Norris Area	Miocene (Temblor)	12	850	small
CA	Quinado Canyon	Gambob-Kelly	18	2030	abandoned
CA	Ramona	Bering	19	6500	small
CA	Ramona	Lower	17	7900	small
CA	Ramona, North	Black	17	3100	small
CA	Ramona, North	Deaton	19	3500	small
CA	Rosedale Ranch	Etchegoin Sand	15	3500	key data missing
CA	Round Mountain, Alma Area	Vedder	13	2600	small
CA	Round Mountain, Sharktooth A	Vedder	13	2400	small
CA	Rowland	Unnamed	20	2382	abandoned
CA	San Ardo, North Area	Lombardi	12	2100	abandoned
CA	Sansinena, 12-G Area	C-3	14	3100	small
CA	Sansinena, 12-G Area	Pliocene (1st Whittier)	17	1800	small
CA	Sansinena, New England Area	1st Whittier	17	1760	small
CA	Sansinena, New England Area	C-3	14	2600	small
CA	Sansinena, New England Area	D-3	20	3600	small
CA	Santa Maria Valley	Foxen	13	2250	abandoned
CA	Santa Maria Valley, Southeast A	Foxen	10	2600	key data missing
CA	Sespe, Sections 23&26	Coldwater	12	825	key data missing
CA	Simi, Alamos Canyon	First Sand	19	1400	key data missing
CA	Sisquoc Ranch	Monterey	13	1900	abandoned
CA	Sockeye Offshore, Federal-OCS	Monterey	16	4880	key data missing
CA	Sockeye Offshore, Federal-OCS	Topanga, Upper	18	5200	key data missing
CA	Somis	B-1	16	3950	abandoned
CA	Talbert	E Sands	19	5700	abandoned
CA	Talbert	Lamb	19	5400	abandoned
CA	Tapo Ridge	1325 Sand	17	1750	small
CA	Tejon, Southeast Area	2-1 Sand	16	2670	key data missing
CA	Temblor Ranch	Piaocides(Wygal)	16	400	small
CA	Temblor, East	Wygal(Phacoides)	20	2060	abandoned
CA	Terra Bella	Santa Margarita	16	860	abandoned
CA	Walnut	1st Walnut	16	1200	small
CA	Welcome Valley	Tumey	12	100	abandoned
CA	Wheeler Ridge, Northeast Area	Hargood	17	5100	abandoned
CA	Whittier Heights, North	Lower	16	1600	abandoned

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
CA	Whittier Heights, North	Upper	19	1100	abandoned
CA	Whittier, Central Area	4th Sand	18	2100	key data missing
CA	Whittier, Rideout Heights Area	A-3	15	800	small
CO	Armstrong	O sand	17	5797	key data missing
CO	Cope	J sand	20	3591	key data missing
CO	De Nova	J sand	20	3672	key data missing
CO	Justice	J sand	20	4009	key data missing
CO	Mount Hope, East	O sand	16	5259	key data missing
CO	Stallion	J sand	20	3918	key data missing
CO	Walker	Lakota	18	5000	key data missing
KS	Brock	Arb	20	3680	key data missing
KS	Chris	L-KC	19	3042	key data missing
KS	Cochran	L-KC	18	3328	key data missing
KS	Crocker	Arb	19	3913	key data missing
KS	Davis Ranch	Hun	19	2950	key data missing
KS	Degraff, N	P Con	15	2473	key data missing
KS	Dunes SW	L- KC	20	3728	key data missing
KS	Nashville	Ind Cv	15	2510	key data missing
KS	Paxico	Hun	19	2411	key data missing
KS	Solomon	Arb	19	3629	key data missing
KS	Solomon	Top	19	2990	key data missing
KS	Solomon, SE	Arb	18	3682	key data missing
KS	Williams	Arb	19	3733	key data missing
KS	Williams	Shaw	19	3386	key data missing
LA	Bellevue	Ozan	18	1055	key data missing
LA	Big Bayou	Wilcox	20	4865	key data missing
LA	Caddo Pine Island	Nacatoch	20	800	key data missing
LA	Colgrade	Wilcox	20	1278	abandoned
LA	Crossroads	Wilcox	20	1425	abandoned
LA	Manifest	Sparta	20	1742	abandoned
LA	Minden	Rodessa	13	6462	key data missing
LA	Nebo Hemphill	Cockfield	19	1420	key data missing
LA	Nebo Hemphill	Sparta	20	1711	key data missing
LA	Rogers	Cockfield/Sparta	20	1867	key data missing
LA	Starks	-1	20	742	key data missing
LA	White Castle	Iberville	16	1200	key data missing
LA	White Sulphur Springs	Cockfield	20	789	abandoned
MO	Bellamy	Lower Zone	10	60	key data missing
MS	Avera	Paluxy	18	-1	key data missing
MS	Bolton	Washita Fredericksburg, 8124	15	8124	abandoned
MS	Carmichael	Selma Chalk	19	-1	key data missing
MS	Chaparral	Eutaw	20	4313	key data missing
MS	Clara West	Washita Fredericksburg	20	9445	key data missing
MS	Cypress Creek	Eutaw	19	-1	key data missing
MS	Cypress Creek, North	Eutaw	19	-1	key data missing
MS	Davis	Smackover	17	16337	key data missing
MS	Ellisville Junction	Washita Fredericksburg	17	-1	key data missing
MS	Eucutta, East	Tuscaloosa	19	-1	key data missing
MS	Eucutta, East	Tuscaloosa, Upper	17	6221	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
MS	Flat Branch	Tuscaloosa, Upper	20	-1	key data missing
MS	Gitano	Christmas	12	-1	key data missing
MS	Gitano	Eutaw	16	6878	key data missing
MS	Gitano	Tuscaloosa	19	-1	key data missing
MS	Laurel	Eutaw, Lower	17	-1	key data missing
MS	Laurel	Stanley	13	-1	key data missing
MS	Laurel	Tuscaloosa, Upper	12	-1	key data missing
MS	Martinville	9930 Washita/Fredericksburg	20	9930	key data missing
MS	Martinville	Paluxy	13	9787	key data missing
MS	Ovett	Washita Fredericksburg	11	9639	key data missing
MS	Pistol Ridge	11560 Paluxy	13	11530	key data missing
MS	Quitman	Eutaw	15	3715	key data missing
MS	Quitman, East	Smackover C	20	11400	key data missing
MS	Quitman, NW	Eutaw	17	-1	key data missing
MS	Ralston	Lower Tuscaloosa	16	-1	key data missing
MS	Reedy Creek	6100	13	6100	key data missing
MS	Reedy Creek	7100	13	7100	key data missing
MS	Reedy Creek	7150	19	7187	key data missing
MS	Reedy Creek	7200	19	7200	key data missing
MS	Reedy Creek	7300	19	7282	key data missing
MS	Reedy Creek	Paluxy	20	9426	key data missing
MS	Reedy Creek	Tuscaloosa	20	-1	key data missing
MS	Reedy Creek	Tuscaloosa, Upper	13	6264	key data missing
MS	Sandersville	Christmas	14	-1	key data missing
MS	Sandersville	Stanley	13	-1	key data missing
MS	Soso	10914 Mooringsport	16	11203	key data missing
MS	Soso	7554 Tuscaloosa	17	7862	key data missing
MS	Soso	8785 Fredericksburg	20	9112	key data missing
MS	Soso	9417 Paluxy Oil	15	9699	key data missing
MS	Soso	Paluxy, 9411 Oil	10	9643	abandoned
MS	Soso, South	Tuscaloosa, Lower	17	7940	key data missing
MS	Summerland East	Tuscaloosa, Upper	12	8010	key data missing
MS	Thompsons Creek	Lower Tuscaloosa Massive	20	-1	key data missing
MS	Thompsons Creek	Washita Fredericksburg	19	10178	key data missing
MS	Thompsons Creek, South	9300 Washita Fredericksburg	20	9352	key data missing
MS	Tribulation	Eutaw	18	-1	key data missing
MS	Valley Park	Mooringsport	19	6264	key data missing
MS	Valley Park	Rodessa	13	6136	key data missing
MS	Wausau	Tuscaloosa Massive, Lower	16	-1	key data missing
MS	Wausau, North	Lower Tuscaloosa	17	7480	key data missing
MS	Wausau, North	Tuscaloosa	14	-1	key data missing
MS	Wausau, North	Tuscaloosa, Upper, Massive	15	-1	key data missing
MS	Yellow Creek, West	Paluxy/U. L. Cretaceous	19	7391	small
MT	Pole Creek	Amsden	18	3584	key data missing
MT	Roscoe Dome	Lakota	13	2828	key data missing
MT	Rudyard	Sawtooth	18	3374	key data missing
MT	Utopia	Sawtooth	18	2450	key data missing
MT	Woman's Pocket	Amsden	19	2412	key data missing
NB	Macklin Canyon	Lansing	12	4115	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
NB	Spring Creek	Pennsylvanian Basal	20	4230	key data missing
NM	Barber	Yates	20	1400	key data missing
NM	Button Mesa, S.	San Andres	18	4177	key data missing
NM	Chisum	San Andres	20	2028	key data missing
NM	Crossroads, W.	San Andres	18	480	key data missing
NM	Jenkins	San Andres	19	4846	key data missing
NM	Leslie Spring	San Andres	19	1484	key data missing
NM	Magruder	Yates	16	570	key data missing
NM	Maroon Cliffs	Bone Spring	20	6786	key data missing
NM	Maroon Cliffs	Tansill	20	2179	key data missing
NM	Mescalero	San Andres	18	4063	key data missing
NM	Parallel	Tansill	20	2358	key data missing
NM	PCA	Yates	20	1500	key data missing
NM	Ranger Lake	San Andres	17	4833	key data missing
NM	Tower	San Andres	19	4148	key data missing
OK	Alden	Pontotac A	20	560	key data missing
OK	Alden	Pontotac B	20	628	key data missing
OK	Alden	Pontotac D	20	738	key data missing
OK	Alma, NE	Pickens	18	5110	key data missing
OK	Byars, East	Viola	15	4170	key data missing
OK	Carrier	Osage	16	6686	key data missing
OK	Chigley, West	Hoxbar	17	2134	key data missing
OK	Conway, NW	Booch	18	1440	key data missing
OK	Iona	Penns. D sand	16	1308	key data missing
OK	Johnsonville	Viola	16	4044	key data missing
OK	Knox, SE	Permian	18	1326	key data missing
OK	Sandy Creek	Oil Creek	18	1920	key data missing
OK	Stratford, South	Unconformity	17	1987	key data missing
OK	Whitebead, SW	First Bromide	20	4772	key data missing
OK	Wynnewood, North	Oil Creek	11	4375	key data missing
TX	Andy Brown	Buda	20	5305	key data missing
TX	Arriola, South	Yegua 1-C	20	9904	key data missing
TX	Barbour	Strawn	20	6450	key data missing
TX	Big Hill	Heterostegina	19	7500	key data missing
TX	Bo-Nan-De	Sub-Clarksville	15	4070	small
TX	Bob Hindes, 2100 Seg. B	Carrizo	19	2096	key data missing
TX	Boling	Lago	20	4800	key data missing
TX	Bolton	Strawn	20	3424	key data missing
TX	Camaron Ranch	Queen City	19	2235	key data missing
TX	Casey Jasper	Woodbine	19	5268	key data missing
TX	Cistern, North	Wilcox	18	1130	key data missing
TX	Cistern, North	Wilcox-J-	16	2258	key data missing
TX	Clear Creek	Cisco	19	1636	key data missing
TX	Collinsville, East	Strawm 2750	19	2758	key data missing
TX	Como	Sub-Clarksville	18	4028	key data missing
TX	Condo	Grayburg	17	2352	key data missing
TX	DCR 79, South	Chernosky	19	1812	key data missing
TX	Dewville	Poth	18	2295	key data missing
TX	Dinsmoor	Queen City	15	1891	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
TX	Dorchester, North	Ordivion Limestone	20	7103	key data missing
TX	Doreen	Strawn 1200	20	1223	key data missing
TX	Dove	Pennsylvanian Basal	13	3708	key data missing
TX	Dozier	Oil Creek	13	6351	key data missing
TX	E. B. G.	Paluxy	18	4438	small
TX	Elm Grove	Wilcox, Upper	20	1886	key data missing
TX	Emily, A	Wilcox 1990	19	1994	key data missing
TX	Era, West	Ellenburger	20	1088	key data missing
TX	Everett	San Angelo	17	987	key data missing
TX	Fluvanna	Leonard	15	5160	key data missing
TX	Fritcher Sand	Sand	18	2870	key data missing
TX	Galba	Carrizo	19	1578	key data missing
TX	Goldfinch	Austin Chalk	20	6095	key data missing
TX	Govt. Wells	900 sand	19	920	small
TX	Govt. Wells, North	1150	20	1167	small
TX	Govt. Wells, North	1550	20	1547	small
TX	Grassroots	Sand	19	42	key data missing
TX	Hagist Ranch	Purple Sand	20	1826	key data missing
TX	Hawkins	Woodbine (version 2)	12	4531	key data missing
TX	Hence	Grayburg	20	4473	key data missing
TX	Holly Creek	Woodbine	20	5331	key data missing
TX	Hosannah	Woodbine	20	2644	key data missing
TX	Houdman, West	Hockley 2100	17	2091	key data missing
TX	Itty Bitty	Paluxy	18	7108	key data missing
TX	J. L. B.	Atkinson	20	3263	key data missing
TX	Jack Frost	Crockett	20	1300	small
TX	Jean Taylor	Woodbine	20	2744	key data missing
TX	Jourdanton	Nixon Sand	19	906	small
TX	K., B. & Z.	Woodbine B	15	4897	key data missing
TX	Katie Sue	Paluxy	16	6355	key data missing
TX	Kingsbury	170	20	178	key data missing
TX	Kingsbury, East	Austin Chalk	19	2028	key data missing
TX	Kingsville	2500	19	2533	key data missing
TX	Kingsville	Oakville	20	2286	key data missing
TX	Kittie, West	Hockley, Upper	20	1853	key data missing
TX	La Vernia	190 Sand	19	189	small
TX	La Vernia	Austin Chalk	17	1723	small
TX	Labbe	Cole	20	1938	key data missing
TX	Labbe	Loma Novia	20	2908	key data missing
TX	Little Alamo	Alamo	18	2258	key data missing
TX	Log-Pat	Wichita-Albany	20	5094	key data missing
TX	Mackoy	Strawn 3100	18	3154	key data missing
TX	Mackoy, East	Strawn 4200	16	4184	key data missing
TX	Mackoy, East	Strawn 4200 #2	20	5350	key data missing
TX	Manziel, West	Sub-Clarksville	16	4178	key data missing
TX	Maple Hughes	1550 Burton	16	1560	small
TX	Massie, West	Paluxy	18	360	key data missing
TX	Merigale-Paul	Woodbine	16	5450	key data missing
TX	Milbur	Poth	17	2377	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
TX	Minnie Bock, North	5500	19	5500	key data missing
TX	Mitchell Creek, North	Paluxy	18	9340	key data missing
TX	Muldoon, South	Reklaw	20	2230	key data missing
TX	Muldoon, Southwest	Reklaw	20	2230	key data missing
TX	Neely, East	700	20	670	key data missing
TX	Neely, East	1130	20	1142	key data missing
TX	Neely, East	1150	19	1156	key data missing
TX	Nolington	Blossom	20	2366	key data missing
TX	Orlee	Jackson	20	1697	small
TX	Pine Mills, West	Woodbine "B"	19	5508	key data missing
TX	Presa De Oro	Yegua-C-	20	1112	small
TX	Presa De Oro	Yegua-G-	17	1214	small
TX	Pressly-Capi	Poth B	17	2213	key data missing
TX	Quitman, Southeast	Sub-Clarksville	16	4201	key data missing
TX	Quitman, Southeast	Woodbine	15	4581	key data missing
TX	Quitman, Southeast	Woodbine, Upper	11	4512	key data missing
TX	Raccoon Bend	Gutowsky, EFB	20	3278	key data missing
TX	Raccoon Bend	Miocene X	18	1439	key data missing
TX	Raccoon Bend	Oakville 970	14	984	key data missing
TX	Rancho Solo	Extension	19	1836	small
TX	Renate	Elaine	19	3233	key data missing
TX	Richardson	Cole	20	1784	small
TX	Saint Jo, Southwest	Conglomerate	20	6711	key data missing
TX	Sand Hills, South	Holt	20	3723	key data missing
TX	Serbin	Wilcox	19	3090	small
TX	Sezar	Wilcox 3600	18	3600	key data missing
TX	Southmayd	Barnes	14	4838	key data missing
TX	Southmayd	Strawn 4700	20	4760	key data missing
TX	Talco, West	Paluxy	17	4296	abandoned temp. 1989
TX	Texam	Cole	20	1885	key data missing
TX	Thompson, Southwest	13A-1	18	4161	key data missing
TX	Tobe, North	Lower Leonard	20	4718	key data missing
TX	Toborg	Trinity	19	350	key data missing
TX	Triple A	6450 Frio	19	6430	key data missing
TX	Turney	Glen Rose	20	600	key data missing
TX	Tyler TA	Paluxy	19	7608	key data missing
TX	Van, West	Woodbine	13	3080	key data missing
TX	W. C. Finch	Simsboro 1900	17	1930	key data missing
TX	Walt	Paluxy	17	284	small
TX	Welder Ranch	2140	20	2137	key data missing
TX	Wherry & Green	Carrizo	19	1690	small
TX	Wherry & Green	Reklaw	20	1710	small
TX	Wherry & Green	Reklaw	20	1710	small
TX	White Creek, East	2100	20	2010	key data missing
TX	White Creek, East	1800 Hockley	19	1811	key data missing
TX	Windmill Creek	Escondido	17	716	key data missing
TX	Winnsboro, Southeast	Sub-Clarksville	12	4146	key data missing
TX	Winston	Austin Chalk	20	7376	small
TX	Zimet	Yegua-G-	18	1221	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
TX	Zimet	Yegua-H-	20	1227	key data missing
WY	Alkalai Anticline	Darwin	18	5824	key data missing
WY	Ash	Minnelusa	20	-1	key data missing
WY	Baumfalk	Minnelusa	19	-1	key data missing
WY	Brosa Draw	Minnelusa	16	-1	key data missing
WY	Bud	Tensleep	18	7899	key data missing
WY	Casper Creek, North	Tensleep	20	3200	key data missing
WY	Crystal Creek	Tensleep	19	845	key data missing
WY	Double Shield	Minnelusa	20	8330	key data missing
WY	Dutton Basin	Phosphoria	20	762	key data missing
WY	Fourbear	Amsden	13	3180	key data missing
WY	Garland	Jefferson	16	4328	key data missing
WY	Gibbs, North	Minnelusa	20	-1	key data missing
WY	Gray (abandoned)	Minnelusa	20	7915	key data missing
WY	Hamilton Dome	Chugwater	17	1200	key data missing
WY	Horse Ranch	Tensleep	19	5160	key data missing
WY	Hugie Draw	-1	20	-1	key data missing
WY	King Dome	Phosphoria	18	2864	key data missing
WY	Kohler	Phosphoria	20	4435	key data missing
WY	Kummerfeld West	Minnelusa	20	7680	key data missing
WY	Lamb & Lamb Anticline	Phosphoria	18	3429	key data missing
WY	Lite Butte	Madison	14	4165	key data missing
WY	Little	Minnelusa	19	7804	key data missing
WY	Lovell Draw	Phosphoria	18	2004	key data missing
WY	Mapes	Minnelusa	20	-1	key data missing
WY	Marnie	Minnelusa	20	-1	key data missing
WY	Moorcroft	Minnelusa	20	-1	key data missing
WY	Mule Herder	Minnelusa	20	-1	key data missing
WY	Murphy Dome	Curtis	19	3176	key data missing
WY	Neta	Minnelusa	20	-1	key data missing
WY	Pebble Beach	Minnelusa	20	-1	key data missing
WY	Pine Mountain	Phosphoria	19	1600	key data missing
WY	Pitchfork	Madison	15	4250	key data missing
WY	Ponderosa Ridge	Minnelusa	13	-1	key data missing
WY	Prong Creek, West	Minnelusa	20	-1	key data missing
WY	Rawhide	Tensleep	17	5298	key data missing
WY	Red Springs	Tensleep	16	574	key data missing
WY	Rozet	Minnelusa	17	8156	key data missing
WY	Rumph	Minnelusa	20	-1	key data missing
WY	Shoshone North	Phosphoria	17	5176	key data missing
WY	Shoshone North	Tensleep	17	5406	key data missing
WY	Simpson Ranch	Minnelusa	20	7880	small
WY	Spindletop	Sundance	19	1100	key data missing
WY	Spindletop North	Ervay	19	3378	key data missing
WY	Thompson Creek	Muddy	20	-1	key data missing
WY	Travis	Phosphoria	18	836	key data missing
WY	Well Creek (R-T)	Minnelusa	20	7805	key data missing
WY	Well Creek (Unnamed)	Minnelusa	18	7995	key data missing
WY	Well Creek (Well Creek)	Minnelusa	20	7908	key data missing

Table 7–2 List of Additional Heavy Oil Reservoirs in the U.S. Not Analyzed in this Feasibility Study

State	Field	Reservoir	API Gravity	Depth	Status
				ft	
WY	Zimmerman Butte	Tensleep	16	4606	key data missing

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range)

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
AL	Latham	Dantzler	Dantzler	16	7086	187	120:80-120	20	275	-1	14	32	-1	-1
AR	Wesson	Nacatoch	Nacatoch	15	1500	101	280:20-280	30	1700	-1	6	35	-1	1441
CA	Aliso Canyon	Aliso	Pico	15	4150	130	270:143-570	25	770	148	89	36	64	1206
CA	Ant Hill	Olcese	Olcese	14	2300	90	875:315-875	31	530:200-1400	150	40	39	61	1680
CA	Arroyo Grande, Tiber Area	Dollie	Pismo	14	750	95:90-100	530	28	870:750-1000	400	100	66	34	-1
CA	Barham Ranch, Old Area	Monterey	Monterey	14	2800	100	40	25	-1	400	300:200-400	-1	40	-1
CA	Barham Ranch, Old Area	Sisquoc, Basal	Sisquoc	15	1400	85	40	25	400:300-500	-1	300:300-500	60	40:35-45	-1
CA	Belridge, North	Tulare, Etchegoin	Tulare/Etchegoin	13	600:600-800	100	2265	37	2500	-1	100	32	68	1850:1500-2200
CA	Belridge, South	Tulare	Tulare	13:12-15	400:400-1400	91:85-130	10753:50-13000	35:27-42	3000:100-10000	400:0-600	85:0-275	20:10-90	77:37-85	2050:1650-2050
CA	Casmalia	Monterey	Monterey	16	2038	140:100-180	2350	25	-1	1000	500:300-1000	-1	43	400
CA	Cat Canyon, Central	Sisquoc	Sisquoc	11	2800	103	620	35	1000:400-2000	100	45	35	65	1600
CA	Cat Canyon, East	Sisquoc	Sisquoc	14:7-18	3000:1700-3600	125:100-150	1970:1680-2000	33:21-35	1500:200-5000	800:650-3025	250:100-300	35:15-35	65:55-85	1600:1500-1773
CA	Cat Canyon, Gato Ridge	Monterey	Monterey	12	3800	135:110-160	690	25	-1	-1	248	-1	-1	-1
CA	Cat Canyon, Gato Ridge	Sisquoc	Sisquoc	13	2210	110	690	28	2000:1000-4000	-1	200	35	65	-1
CA	Cat Canyon, West Area	Los Flores	Monterey	17:11-26	6000:5425-6436	188:175-200	2880:2000-2980	25	-1	1500:1500-1575	550:114-550	-1	63	1164
CA	Cat Canyon, West Area	Sisquoc	Sisquoc	15	2800	105	300	29	270:150-500	-1	160	31	69	1700
CA	Coalinga, Westside Area	Etchegoin-Temblor	Etchegoin/Temblor	15:7-27	2000:450-3500	110:75-130	9608:6400-10608	30:20-46	2000:80-10000	600:50-600	200:30-200	48:35-57	45:35-89	1114:951-1561
CA	Cymric, Salt Creek Main Area	Carneros Unit	Temblor	20	1950:1500-2400	132	310	33	240:10-5940	165	150	28	70	1604:1267-1941

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Cymric, Sheep Springs Area	Etchegoin "54-21"	Etchegoin	16	2450	97	170	35	480:100-2300	105	75	-1	68	1707
CA	Cymric, Welport Area	Tulare (Amnicola)	Tulare	13:10-21	1000:400-1550	100:81-130	9050:1670-9050	34:31-38	700:200-4000	450:50-900	83:60-260	31:26-48	6950-88	1527:1250-1804
CA	Edison, Groves Area	Kern River - Chanac	Kern River/Chanac	15	1150	78	645	26	960	70	43:15-70	45	55	1110
CA	Edison, Groves Area	Olcese	Olcese	13	3450	106	179	28	1400:1000-2000	-1	100	40	60	1000
CA	Edison, Main Area	Kern River - Chanac	Kern River/Chanac	18:12-24	2475:750-5000	103:78-128	1850:1130-2500	30:24-36	1700:500-2000	360:150-700	100:100-450	47:10-47	50:50-87	1065:1000-1337
CA	Edison, Main Area	Schist	Basement	19:14.4-25	2850:1200-7700	108:83-133	1119:1119-1950	25	-1	2207	60:30-1118	-1	65	-1
CA	Edison, Main Area	Wicker	Fruitvale	16	2000:1500-2500	96:83-103	60	26	2000	60	52	-1	62	1150
CA	Edison, Race Track Hill Area	Nozu	Round Mountain	16	3260	110	860	30	1800	440	60:60-200	35	65	1350
CA	Edison, West Area	Chanac	Chanac	20	3200	101	1545	25	3000:200-10000	460	200	40	60	1050
CA	Edison, West Area	Santa Margarita	Santa Margarita	15	4000	111	1545	27	550:50-6000	50	40	42	58	1150
CA	Fruitvale, Main Area	Fairhaven	Etchegoin	17	3000	118	1460	30	1000:700-1500	80	50	30	70	1500
CA	Fruitvale, Main Area	Kernco	Chanac	19	3600:3400-3800	130	3800	28	820:410-1650	380	130	43	57	1100
CA	Guadalupe	Monterey	Monterey	12	3000	127	200	25	-1	265	120:120-200	40	60	-1
CA	Guadalupe	Sisquoc	Sisquoc	11	2700	155	2090	36	1250:1000-1550	120	65	37	63	-1
CA	Huasna-Lavoie-Hadley Area	Santa Margarita	Santa Margarita	10	1155:750-1560	95	40	25	-1	1300	520:500-1300	-1	-1	-1
CA	Huntington Beach, Offshore Area	Jones, Lower	Puente	16	2850	142	1950	28	600:400-900	-1	120	43	57	-1
CA	Huntington Beach, Onshore Area	Bolsa, Upper (Garfield)	Repetto	18	1800	126	800	31	1500:330-3220	130	100	25	75	-1
CA	Huntington Beach, Onshore Area	Jones, Upper	Puente	17:11-23	4300:2500-4300	150:127-150	3252:2923-3925	30:23-35	550:150-2000	500:190-500	142:142-325	-1:21-40	75:60-79	1751

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Huntington Beach, Onshore Area	Main	Puente	19	4300	170	790	30	1000:630-1000	-1	277	30	70	-1
CA	Jasmin	Cantleberry Sand	Vedder	14	2750	112	120	40	1300:1110-2400	80:30-80	62	30	70	1700
CA	Jasmin	Pyramid Hill	Jewett	14	1705	98	590	37	1125:470-2690	130	92	53	47	1200
CA	Jesus Maria, Main Area	Monterey	Monterey	10	2750:2600-2900	110	100	25	-1	500	305	-1	-1	-1
CA	Kern Bluff	Santa Margarita	Santa Margarita	14	950	84	715	27:27-29	3500:2000-3500	110	55	32	68	1400
CA	Kern Bluff	Transition	Transition	14	1045:740-1350	84	715	27	3500	80	55	32	68	1400
CA	Kern Front	Etchegoin-Chanac	Etchegoin/Chanac	14:11.6-18	2290:1300-2600	102:80-130	5495:3665-5340	32:29-37	1400:15-12000	490:100-800	150:40-400	35:32-43	65:50-86	1500:1300-1700
CA	Kern River	Kern River	Kern River	13:9-16.5	850:150-1500	80:78-100	10270:9075-11350	37:25-38	3000:100-7600	500:100-825	150:0-296	30:15-50	70:30-90	1950:1167-2500
CA	Kreyenhagen	Temblor	Monterey & Temblor	16	450	90	95	24	60:2.7-1220	300	130	43	57	1336
CA	Las Posas	Sespe Eocene	Sespe-Liajas	15	4600	156	20	25	-1	2000	340	-1	-1	-1
CA	Lompoc, Main Area	Monterey	Monterey	20	2500:2250-2750	170	2290	25	-1	500	183	-1	-1	-1
CA	Lost Hills	Tulare	Tulare	15:12-16	275:100-500	78:75-100	2560:1310-6340	40:30-43	1700:650-2100	450:25-450	75:19-275	40:31-40	60:10-86	1850:1300-2400
CA	Lost Hills, Northwest	Antelope	Monterey	20	3800:2200-3800	91	20	25	-1	800	380:200-800	-1	-1	-1
CA	McKittrick, Main Area	Olig	Reef Ridge	14:12-16	800	100	1400	30	3000	-1	500	20	80	1600
CA	McKittrick, Main Area	Reef Ridge, Basal	Reef Ridge	17:14-21	1500	115	60	30	1580:1000-2500	-1	400	40	60	1300
CA	McKittrick, Main Area	Tulare-San Joaquin	Tulare-San Joaquin	16:7-21	750:200-1200	98:90-110	1100:1100-1750	34:30-38	1200:10-5000	500:0-1000	153:0-500	-1:30-45	75:54-82	2000
CA	McKittrick, Northeast Area	Tulare (Amnicola)	Tulare	18:7-25	650:300-1631	97:89-100	2100:1440-1990	33:20-40	2500:1000-6000	200:50-500	50:50-460	30:22-45	70:54-82	1600
CA	Midway-Sunset	Calitroleum	Etchegoin	20	3000:1500-4500	115:100-130	9534	28	230	450	67	-1	58	1180
CA	Midway-Sunset	Gusher	Etchegoin	20	2500:2000-3000	108:100-115	1360	38	1000	75	63	-1	68	2090:1700-2480
CA	Midway-Sunset	Kinsey	Etchegoin	20	2800:2000-3600	128:120-135	458	32	450	175	90	36	64	1458
CA	Midway-Sunset	Leutholtz (Metson)	Monterey	16	2200:1200-3200	108:100-117	150	32	1900	400	220	25	75	1660

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Midway-Sunset	Marvic	Monterey	13	1000	105	200	28:20-35	700:200-2500	270	200	-1	-1:55-77	1645:1350-1940
CA	Midway-Sunset	Moco	Monterey	15	2400:2100-2700	125	150	36	1575	450	260:70-450	25	75	1980
CA	Midway-Sunset	Monarch (Spellacy)	Monterey	15:11-17	1300:600-2000	95:80-110	4964	31:22-37	1450:300-5000	4000-600	123:0-500	30:20-40	70:60-80	1550:750-1900
CA	Midway-Sunset	Mya Tar	San Joaquin	14	1100	108:95-120	300	35	950:300-3000	-1	150	50	50	1160
CA	Midway-Sunset	Obispo	Monterey	20	3600	132:130-135	150	25	-1	1500	270	-1	-1	-1
CA	Midway-Sunset	Pacific	Monterey	16	3700	136	175	15	-1	300:50-300	125:100-150	-1	-1	-1
CA	Midway-Sunset	Potter	Reef Ridge	13:11-17	1350:200-2500	98:85-280	3000	33:24-38	1800:500-6500	500:85-1250	280:0-500	28:15-50	72:50-89	1725:1350-2100
CA	Midway-Sunset	Republic	Monterey	18	3100:1300-4900	142:115-170	205:80-205	31	150	240	150	30	-1	1500
CA	Midway-Sunset	Top Oil	San Joaquin	19	1500:500-2500	108:92-125	1390	32	450	50	35	36	64	1460
CA	Midway-Sunset	Tulare	Tulare	11:11-14	800:200-1900	101:92-114	18316:5000-18316	33:21-35	2500:300-9450	200:41-550	67:41-250	40:20-40	60:50-80	1150:900-2150
CA	Midway-Sunset	Webster	Monterey	14	1650:1500-1800	112:100-113	150	31	2000	250	150:50-250	36	60	1400:1100-1700
CA	Midway-Sunset	Wilhelm	Etchegoin	20	2800:2000-3600	128:120-135	1360	30	800	100	75	30	70	1703
CA	Monroe Swell, Old Area	44	Monterey	19	2000	110	90	25	870:500-1500	225	200	65	35	-1
CA	Monroe Swell, Old Area	Beedy	Monterey	17	3200	104	90	25	870:500-1500	160	150	65	35	-1
CA	Monroe Swell, Old Area	Doud	Monterey	19	2900	109	90	25	870:500-1500	250	200	65	35	-1
CA	Montalvo West, Onshore Area	Colonia	Sespe	16:15-19.5	11000	230	580	21	240	2500	600	25	70	1050
CA	Mount Poso, Dominion Area	Vedder	Vedder	15	1560	98	875	32	4200:1500-12000	75	35	32	68	1600
CA	Mount Poso, Dorsey Area	Vedder	Vedder	15	1500	99	410	33	2700:1500-5000	-1	30	25	75	-1
CA	Mount Poso, Main Area	Pyramid Hill	Freeman-Jewett	15	1600	100	2270	38	40:20-60	-1	160	40	60	1700

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Mount Poso, Main Area	Vedder	Vedder	15	1750	110	1750	33	6000:1500-24000	400	225:50-400	15	85	2075:1950-2200
CA	Newhall, Towsley Canyon Area	Unnamed	Modelo	20	1482	98	80	25	-1	200	131:30-200	-1	-1	-1
CA	Orcutt, Main Area	Monterey	Monterey	16	1700	140:120-160	4180:2170-4180	25	-1	950	400	-1	-1	-1
CA	Paris Valley, Main Area	Ansberry, Basal	Monterey	11:10-12	1090	87	40	36	3700:3015-4454	-1	150	33:20-45	67:55-80	2009
CA	Playa Del Rey, Venice	Repetto, Upper	Repetto	20	4000:3200-4300	146	342	25	-1	1050	460	-1	-1	-1
CA	Pleito, Creek Area	Santa Margarita	Santa Margarita	17	4300	109	200	24	200:50-800	200	125	30	70	1350
CA	Point Pendernales, Federal-OCS	Monterey	Monterey	16:14-18	6600	215	19840	10	-1	600	510	-1	58	-1
CA	Poso Creek, Enas Area	Chanac	Chanac	13	1900	103	260	33	940:125-7100	190	150	30	70	1562
CA	Poso Creek, Enas Area	Etchegoin, Basal	Etchegoin	12	1800	101	260	36:27-45	1100:150-7700	100	90	40	60:45-75	1450:725-1629
CA	Poso Creek, McVan Area	Etchegoin, Basal	Etchegoin	13	1150	90	405	34:32-40	2600:1130-6000	-1	40	45	55:45-65	1300:600-1475
CA	Poso Creek, Premier Area	Chanac	Chanac	13:13-15	2500:2000-3000	112:100-122	3610:3260-3610	33:25-41	1400:125-7600	390:240-390	200:127-250	-1:30-45	60:55-70	1468:1325-1610
CA	Poso Creek, Premier Area	Etchegoin, Basal	Etchegoin	13:10-14	2400:2000-2600	108:80-122	2000:2000-3285	35:27-43	1500:150-7700	195:120-195	92:63-125	30:30-45	60:50-65	1477:1325-1629
CA	Pyramid Hills, Dagany Area	Point of Rocks	Kreyenhagen	16	650	100	135	34	730:230-2315	-1	125	26	66	1792
CA	Pyramid Hills, Norris Area	Point of Rocks	Kreyenhagen	15:12-19	800	80	185	28	250:110-550	-1	70	30	-1	1792
CA	Pyramid Hills, West Slope Area	Point of Rocks	Kreyenhagen	17	800	100	260	31	900:710-4950	-1	120	40	60	1480
CA	Ramona	Del Valle	Modelo	18	4500	156	280:104-280	18	40	810	511	35	48	303
CA	Richfield	Breen	Puente	17:16-19	3500	125	900	27	540	-1	250	33	67	1247
CA	Rosedale Ranch	Chanac, Upper (KCL 31-38)	Chanac	20	4675	134	453	29	130:16-1100	-1	80	35	59	1325
CA	Rosedale Ranch	Lerdo	Etchegoin	17	4200	118	750	27	140:1-2000	160	92	38	62	1420

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Round Mountain, Coffee Canyon Area	Pyramid Hill	Freeman-Jewett	19	1500	104	475	34	40:6-214	150	120	40	60	1600
CA	Round Mountain, Main Area	Pyramid Hill	Freeman-Jewett	18	1900	132	550	37	40:6-214	-1	150	40	60	1550
CA	Round Mountain, Main Area	Vedder	Vedder	16	2000	132	990	35	10000:17 25-35000	150	80	-1	70	1883:1730-2036
CA	Round Mountain, Pyramid Area	Pyramid Hill	Freeman-Jewett	18	1250	92	310	37	40:6-214	145	130	65	35	900
CA	Round Mountain, Pyramid Area	Vedder	Vedder	16	1390	101:100-102	290	32	1200	160	40	32	68	1930
CA	Salt Lake	B Zone	Puente	18	2300	115	1380:350 -1380	25	-1	250	156	-1	-1	-1
CA	Salt Lake	C Zone	Puente	16	2650	120	1380:350 -1380	34	300	275	117	31	69	-1
CA	Salt Lake	D Zone	Puente	14	2850	123	1380:350 -1380	34	-1	200	117	-1	-1	-1
CA	Salt Lake	E Zone	Puente	18	2750:2500-3000	125	640	25	-1	100	98	-1	-1	-1
CA	San Ardo, Main Area	Aurignac	Monterey	13:10-14	2400:2100-3025	118:102-135	4320:350 0-4370	36:31-39	5700:800 -8000	-1:30-250	120:30-250	30:27-44	70:38-88	1840:1834-1846
CA	San Ardo, Main Area	Lombardi	Monterey	10:10-14	2000:1800-2362	117:100-135	4320:414 0-4370	35:23-50	1700:600 -6000	-1:50-200	150:30-190	-1:27-41	70:52-73	1834
CA	Sansinena, West Area	C-3	Puente	14	2100	112	270	32	290:280-300	-1	100	20	50	-1
CA	Sansinena, West Area	D-3	Puente	20	4500	155	270	23	370:300-450	-1	120	47	-1	-1
CA	Santa Maria Valley, Bradley Area	Monterey	Monterey	14	5610	190	50:50-500	25	-1	-1	288	-1	-1	-1
CA	Santa Maria Valley, Bradley Area	Sisquoc	Sisquoc	14	5000	180	500	26	15:0.1-300	-1	160	35	65	1008
CA	Santa Maria Valley, Main Area	Foxen	Foxen	17	2000	96	2380	37	260:45-1545	200	105	56	44	-1
CA	Santa Maria Valley, Main Area	Point Sal	Point Sal	15	4330	163	1120	20	60:54-68	-1	200	40	60	-1

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Santa Maria Valley, Main Area	Sisquoc	Sisquoc	15	3330	90	480	25	1300:800-2000	400	75	65	35	-1
CA	Santa Maria Valley, Southeast Area	Houk	Monterey	11	6000	162:145-180	310	25	-1	1000	300	-1	-1	-1
CA	Santa Maria Valley, Southeast Area	Sisquoc, Basal	Sisquoc	11	4500	120	310	27	200:40-1000	500	250	48	52	-1
CA	Santa Maria Valley, West Area	Foxen	Foxen	14	3490	90	440	31	180:61-520	400	160	65	35	-1
CA	Santa Maria Valley, West Area	Monterey	Monterey	14	4410	178:170-185	170	25	-1	-1	200	-1	-1	-1
CA	Santa Maria Valley, West Area	Sisquoc	Sisquoc	19	3610	120	440	30	2000:1000-4000	570	280	45	55	-1
CA	Tejon, Central Area	Santa Margarita	Santa Margarita	18	2900	102	1045	28	1000:600-1500	-1	100	32	68	1600
CA	Tejon, Central Area	Transition	Transition	17	2725	84	575	30	35:0-1200	-1	85	-1	-1	-1
CA	Tejon, Eastern Area	Transition-SM	Santa Margarita	18	2000	84	210	26	500:200-1200	-1	150	28	72	1400
CA	Tejon, Southeast Area	Reserve, Upper	Fruitvale	17	1810	100	175	35	460:63-3350	190	155	37	63	1500
CA	Tejon, Western Area	Transition	Santa Margarita	16	2600	113:112-114	665	30	2500:2000-3000	65	55	39	61	1339
CA	Tejon, Western Area	Valv	Round Mountain	19	5400	135	665	28	510:500-520	-1	60	34	66	1123
CA	Torrance, Onshore	Tar Ranger	Repetto	19	2800	152	6750	33	800:427-1500	-1	50	24	74	1788
CA	Union Avenue	Chanac	Chanac	15	4100	124	50	28	200:50-838	-1	200	35	65	1310
CA	Union Avenue	Santa Margarita	Santa Margarita	15	5000	130	50	25:20-30	1400	400	200	25	75	1900
CA	Whittier, Rideout Height	Fifth Sand	Puente	20	2300	115	90	28	250	400:100-400	250	25	75	1552
CA	Wilmington, Offshore Area	Ranger	Repetto/Puente	18:12-25	2500	141	6200	32	1270	-1	150	25	72	1620

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
CA	Wilmington, Offshore Area	Tar	Repetto	14:12-15	2100	122	4030	35	1000	-1	120	31	64	1558
CA	Wilmington, Offshore Area	Terminal, Upper	Puente	19:14-25	3000	151	4898	33	900	-1	300	30	67	1572
CA	Wilmington, Onshore Area	Ranger	Repetto/Puente	19:11-33	2500:2350-4521	141:120-150	7242:6200-7242	32:24-40	1600:10-9000	500:400-980	150:100-525	29:18-34	71:64-82	1733:1559-1973
CA	Wilmington, Onshore Area	Tar Zone	Repetto	14:11-21	2200:2000-3413	124:100-130	5069:5069-7150	32:24-41	1600:100-10000	325:100-360	120:50-141	2218-50	78:48-82	2046:1969-2114
CA	Wilmington, Onshore Area	Terminal, Upper	Puente	20:12-28	3000:2850-4766	150:125-159	6359:6200-7150	30:23-42	740:250-4000	600:100-650	300:50-400	33:24-50	67:46-76	1414:1305-2172
CA	Yorba Linda	Main (Signet Sand)	Repetto	15	1950:1800-2100	95	200	29	1000:500-1800	150	120	31	69	1496:1475-1516
CA	Yorba Linda	Shallow (Conglomerate)	La Habra	13	425:200-650	78:70-85	455	28	500:50-2000	-1	250	-1	70	1418:1360-1475
CA	Yorba Linda	Shell (F Sands)	Repetto	16	1850:1700-2000	112:110-115	120	37	500	300	125	33	67	1575:1516-1633
LA	Bellevue	Nacatoch	Nacatoch	19	350	80	900	38	500:650-950	-1	40	-1	66	-1
MS	Baxterville	Tuscaloosa Massive, Lower	Tuscaloosa	17	8750:8598-8963	229	6400	24	1474:0-3000	-1	57	12	-1	-1
MS	Baxterville, SE	Tuscaloosa, Lower	Tuscaloosa	16:15-19	8507	229	200	23	680	-1	8:8-37	18	-1	-1
MS	Heidelburg, West	Eutaw	Eutaw	20:14-31	4772	150	2560	29:25-29	300:74-300	-1	31	33	-1	-1
MS	Soso	Hosston, 12799	Hosston	20:16-30	13111	310	480	20	300	-1	20:8-20	-1	-1	-1
MS	Summerland	Washita Fredericksburg, Upper	Washita Fredericksburg	19:18-34	9356	242	80	20	265	-1	25	-1	-1	-1
MS	Summerland	Washita Fredericksburg, Upper	Washita Fredericksburg	19:19-23	9450	200	600	20	265	-1	26	21	-1	-1
MS	Yellow Creek, East	Eutaw	Eutaw	20:17-22	4724	160	1440	29	250	-1	18	-1	-1	-1
MS	Yellow Creek, West	Eutaw	Eutaw	19	4938	160:150-160	3560	29:24-29	450:112-450	-1	32	52	-1	-1
OK	Loco	Loco	Hoxbar	20:16-24	350:50-1200	62	2300:2300-4000	28:20-30	2500:100-4000	18	13:13-18	-1	69	-1

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
OK	Sho-Vel-Tum (Des Moines Unit)	Fourth Deese	Deese	14	1500	75:75-85	705	28	500	75	50	-1	78	-1
TX	Alba	Sub-Clarksville	Sub-Clarksville	15	4074	151	1502	21	50:1-2520	-1	18	31	-1	-1
TX	Alta Vista	Annacacho	Navarro	12	1100	95	250	25	2:2-10	-1	20	-1	-1	-1
TX	Boggy Creek	Wilcox	Wilcox	17	1549	103	200:20-200	26	67:10-450	-1	7	48	-1	-1
TX	Burmil	Wilcox, W-2	Wilcox	20:19-21	2659	125	132	32	829	11	8	39	-1	-1
TX	Camp Hill	Carrizo	Carrizo	19	540	75	650	37	1200:1200-2500	-1	25	-1	-1	-1
TX	Campana, South	1870 Sand	1870 Sand	20:19-21	1870	109	360	27	100	-1	3	-1	-1	-1
TX	Campana, South	Chernosky	Chernosky	20	2225	116	360	35	1360:100-1360	-1	15	-1	-1	-1
TX	Casa Blanca	Cole	Whitsett	20:19-21	1190:1030-1210	97	820	36	520:300-900	22	15:7-16	30	-1	-1
TX	Cedro Hill	Jackson	Jackson	19	1440	101	1800	31:27-35	700:600-800	-1	12	44	-1	-1
TX	Chapel Hill, East	Paluxy 5600	Paluxy	20	5619	181	280	24	300	-1	18:11-18	47	-1	-1
TX	Charamousca, South	Cole	Whitsett	20	1500	103	400	32	600	-1	17	-1	-1	-1
TX	Charco Redondo	Jackson	Jackson	17	160:160-339	77	1500	34	2800	-1	15	39	-1	-1
TX	Colemena	Jackson	Jackson	19	1500	103	950:950-1800	28:28-32	1958:485-3430	-1	25:25-45	-1	-1	-1
TX	Colony	Poth	Poth	18	1892	110	80	31	1275	-1	10	20	-1	-1
TX	Como, NE	Sub-Clarksville	Sub-Clarksville	13:12-13	4020:4020-4038	150	200	24	200	-1	8	-1	-1	-1
TX	Cost	Austin Chalk	Austin Chalk	20	7296	213	5280	12	-1	-1	10:10-188	-1	-1	-1
TX	Dangle	Strawn 1600	Strawn 1600	18	1614	105	284	23	36:1-1330	-1	21	20	-1	-1
TX	Dinsmoor	Carrizo	Carrizo	19	2060	113	225:90-225	24	500	-1	12	-1	-1	-1
TX	Dove	Strawn	Strawn	18	2960	130	265	21	12:1-150	-1	14	26	-1	-1
TX	Dragoon Creek, SW	Gov't Wells	McElroy	18	1120	95	120:120-750	28	500	-1	10	-1	-1	-1
TX	Eagle Hill	Jackson	Jackson	19	1500	103	770:700-770	35	600	-1	10	-1	-1	-1
TX	Edlasater, West	Cole 950	Cole 950	19	950	92	80	30	710:500-1000	-1	25	35	-1	-1

Table 7–3 Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
TX	Forest Hill	Eagle Ford	Eagle Ford	16	4452	159	1320:1320-2856	29	740	-1	9:9-20	-1	-1	-1
TX	Forest Hill	Harris sand	Harris	12:10-15	4679	185	1950:1674-1950	28	740:0-3500	-1	18	-1	63	-1
TX	Foss	Mirando	Caddell	20	490	83	90:60-90	33	1000	-1	9:9-20	33	-1	-1
TX	Gloriana	Poth A	Wills Point	19	1630	105	490	35	1000	-1	10	-1	-1	-1
TX	Govt. Wells, North	Catahoula, 900 sand	Catahoula	20	918	91	100:100-360	33	1068	-1	16	-1	-1	-1
TX	Jeanie	Serpentine	Serpentine	12	2900:2900-3500	129	45	25	-1	-1	600	-1	-1	-1
TX	Joe Moss	Jackson, 500	Jackson	20	500	84	510:510-1000	30	500	-1	10	-1	-1	-1
TX	Jourdanton	Reklaw	Reklaw	19	1409	101	440:70-440	24	500	-1	5	-1	-1	-1
TX	Los Olmos	Frio	Frio	20	450:450-700	83	200	32	900:150-3600	-1	10	-1	-1	-1
TX	Lundell	Cole	Whitsett	19:19-22	1528	103	5000	32	2630	-1	12	-1	-1	-1
TX	McCrary	Sub-Clarksville	Sub-Clarksville	20	4364	157	560:70-560	26	1400	-1	10	-1	-1	-1
TX	Newsome	Sub-Clarksville	Sub-Clarksville	18	3854	147	620	12	847	-1	25:10-21	-1	-1	-1
TX	Oakville	Jackson	Jackson	20	1830	109	180:180-600	24	500	-1	38	-1	-1	-1
TX	Petrox	Chernosky	Whitsett	20	2024	113	590:318-590	30:30-32	400:25-2000	-1	15	35	-1	-1
TX	Pewitt Ranch	Eagle Ford	Eagle Ford	19	4507	160	6560:1180-6560	24	1400	-1	9:9-29	-1	-1	-1
TX	Pittsburg	Sub-Clarksville	Sub-Clarksville	13	3844	120	2120:500-2120	23	460	-1	7	-1	-1	-1
TX	Pleasanton, South	Carrizo Sand	Carrizo	18	1887	110	220:120-220	36	868	-1	26	-1	-1	-1
TX	Simmons City	Govt. Wells	McElroy	20	1340	99	800	28	23:10-53	-1	8	40	60	-1
TX	Sinton, West Shallow	Bayder	Catahoula	19	3368	138	1700:770-1700	30	600	-1	10:10-96	-1	-1	-1
TX	Slocum	Carrizo	Carrizo	19	490	75	2500	38	2655:2655-3500	-1	24	-1	-1	-1
TX	Sutil	Austin	Austin	19	6050	189	1040	12	-1	-1	10:10-75	-1	-1	-1
TX	Viola 4000	Catahoula	Catahoula	18	4097	152	240	30	600	-1	10:10-55	-1	-1	-1
TX	Yantis	Sub-Clarksville	Sub-Clarksville	20	4210	154	1160:1160-4000	27	500	-1	10:6-10	-1	-1	-1
WY	C & H	Minnelusa	Minnelusa	20:20-24	7566	187	667	18	230	-1	21	-1	-1	-1
WY	Clark Ranch	Tensleep	Tensleep	15:15-16	4678	100	140	22	150	127	37	-1	-1	-1
WY	Cowley	Tensleep	Tensleep	20:20-23	4538	109	200	14	110	-1	16	-1	-1	-1

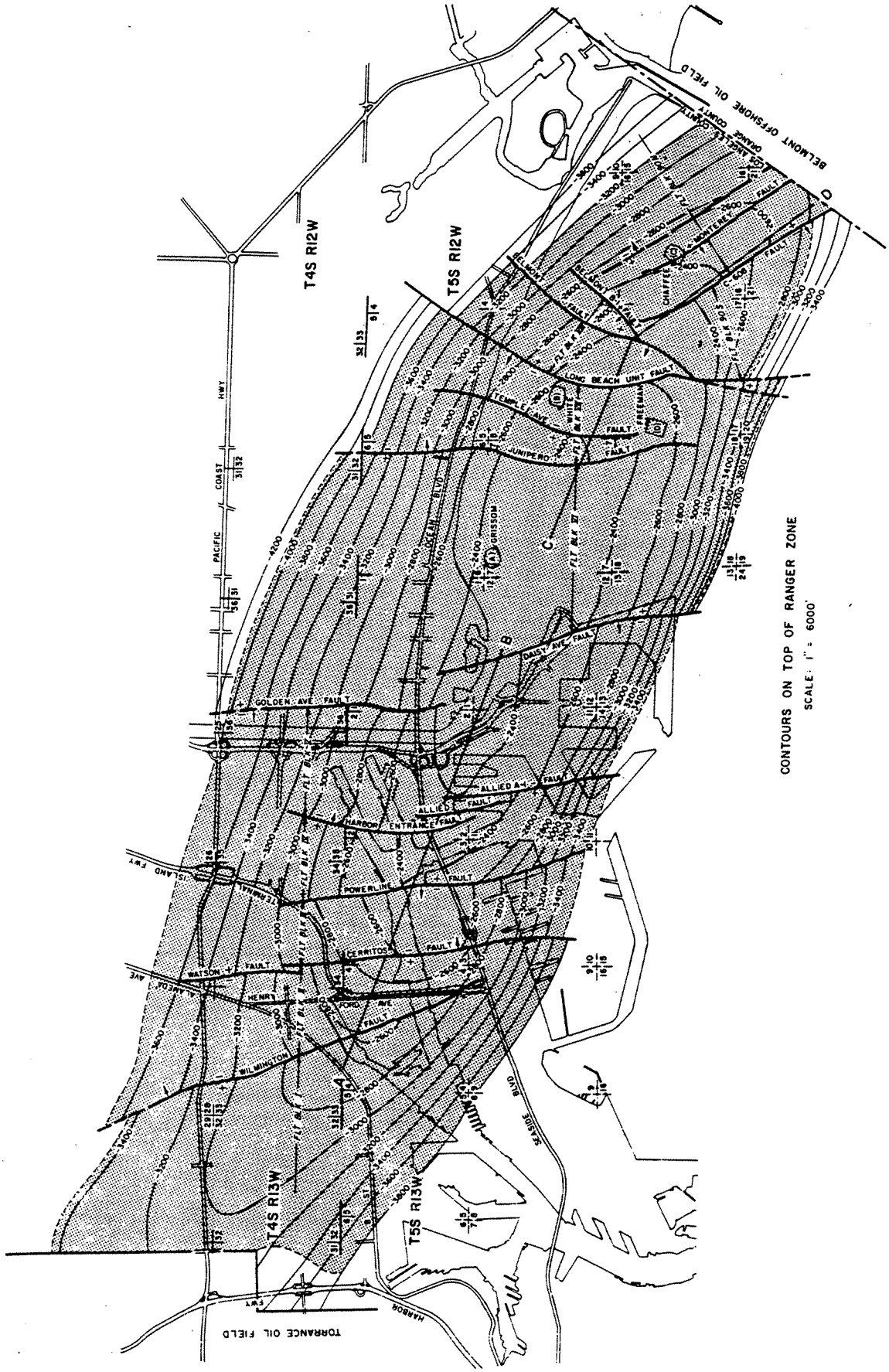
Table 7–3 *Reservoir Parameter Ranges for Selected Heavy Reservoirs and Selected Reservoir Parameters (value:value range) Cont.*

State	Field	Reservoir	Formation	Gravity, °API	Depth, ft	Temp., °F	Area, acre	Porosity, %	Perm. md	Gross Pay, ft	Net Pay, ft	S_{wi}, %	S_{oi}, %	Saturation bbl/acre*ft
WY	Eitel	Minnelusa	Minnelusa	20:19-20	6005	160	160	19	300	-1	23	-1	-1	-1
WY	Fourbear	Darwin	Darwin	14	3470:3470-3480	115	350	9	15	35	34	-1	-1	-1
WY	Fourbear	Dinwoody	Dinwoody	14	3268:3268-3296	112	1528	10	13	-1	3	-1	-1	-1
WY	Fourbear	Madison	Madison	15	3702:3470-3702	119	273	13	4	-1	72	-1	-1	-1
WY	Fourbear	Phosphoria	Phosphoria	14	3370:3370-3502	113	1217	10	2	-1	22	-1	-1	-1
WY	Fourbear	Tensleep	Tensleep	14	2905:2905-3350	130	982	9	7	-1	169	-1	-1	-1
WY	Glo North	Minnelusa	Minnelusa	20	7900	130	200	19:16-19	150	-1	23	-1	-1	-1

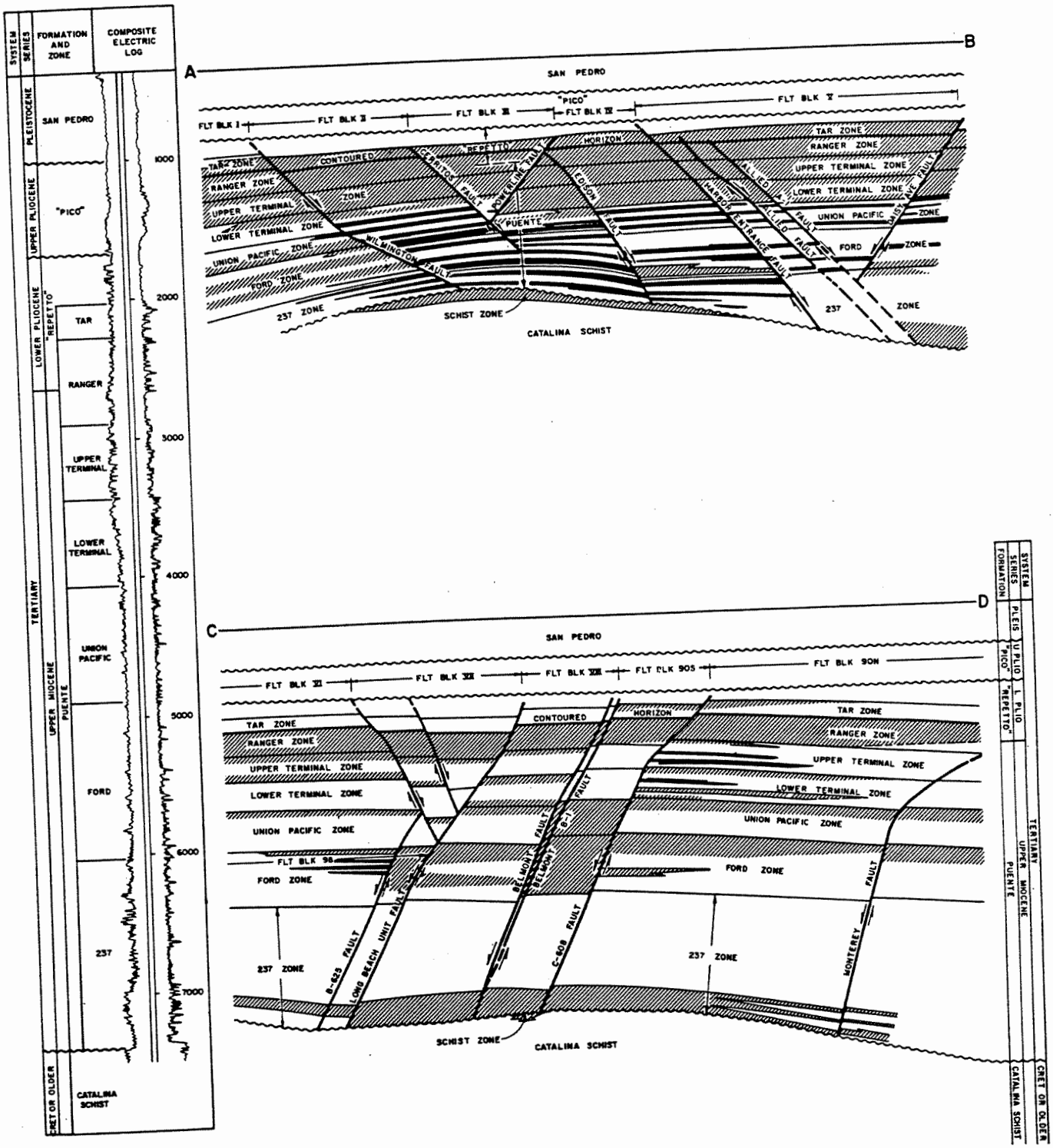
APPENDIX B
STRATIGRAPHIC MAPS OF MAJOR CALIFORNIA HEAVY OIL FIELDS

All maps reproduced with permission from the California Division of Oil and Gas, TR11 (1985) and TR12 (1991)

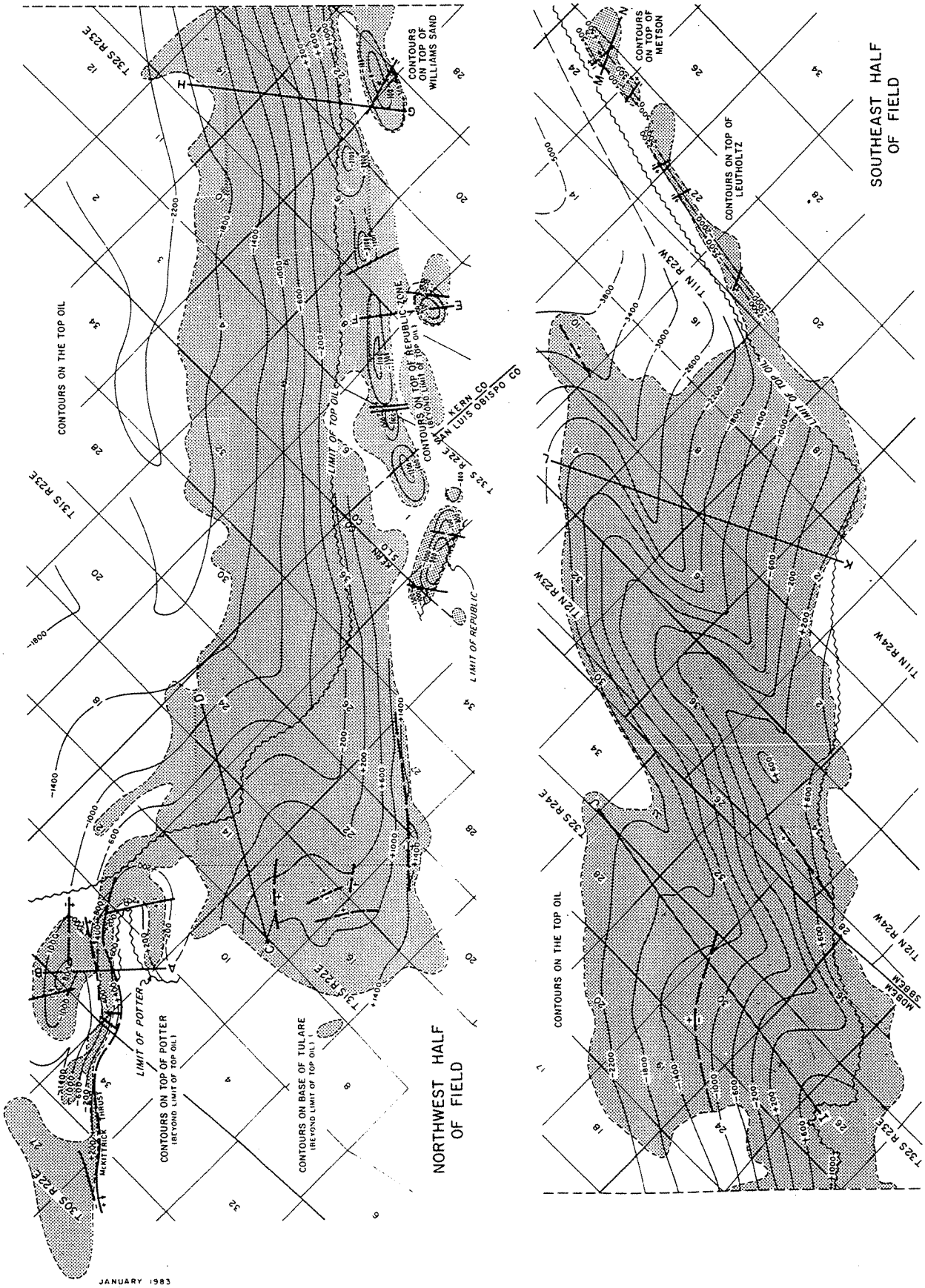
WILMINGTON OIL FIELD



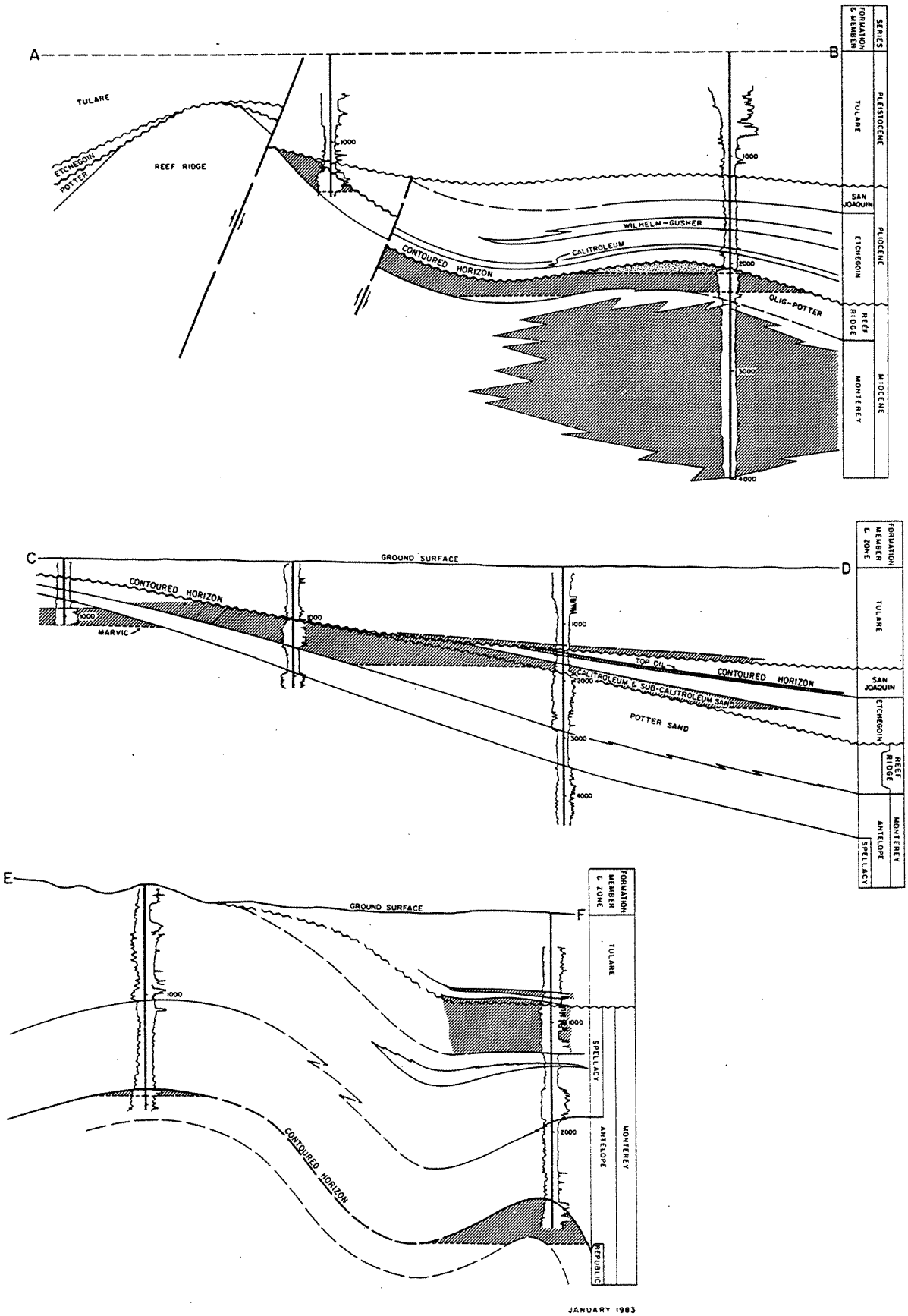
WILMINGTON OIL FIELD



MIDWAY-SUNSET OIL FIELD

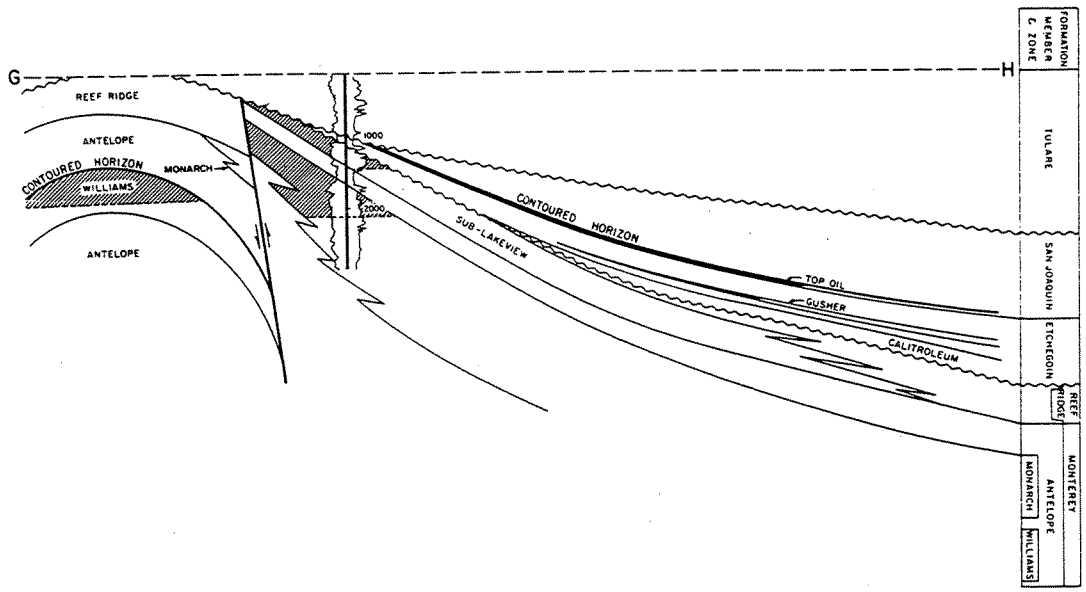


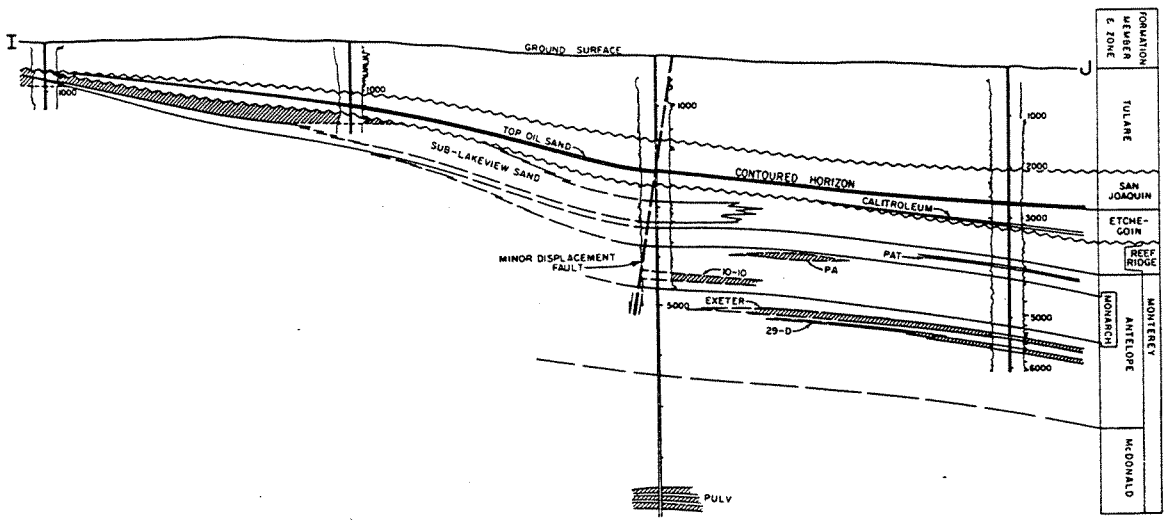
MIDWAY-SUNSET OIL FIELD



JANUARY 1983

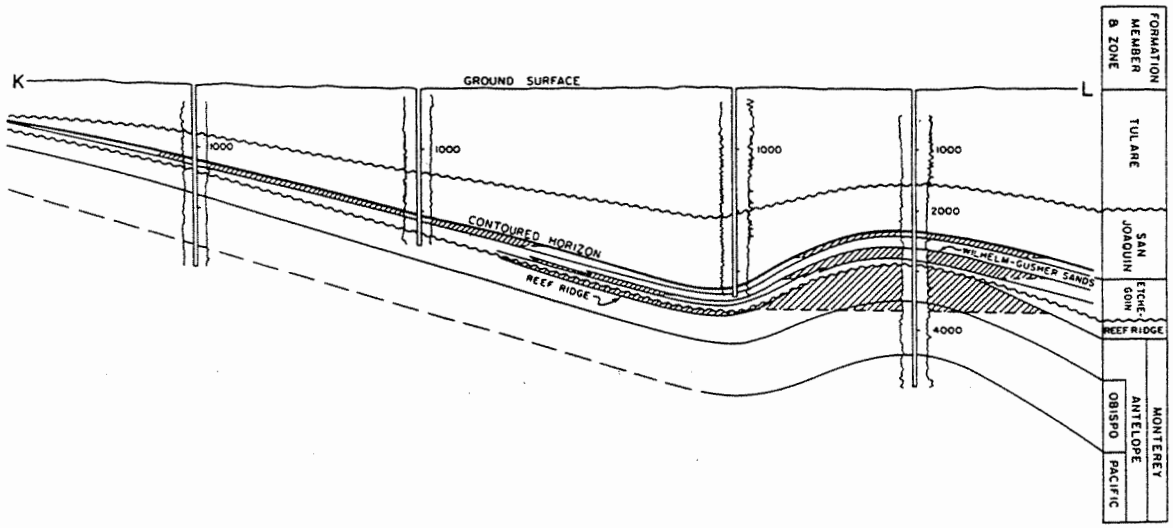
MIDWAY-SUNSET OIL FIELD

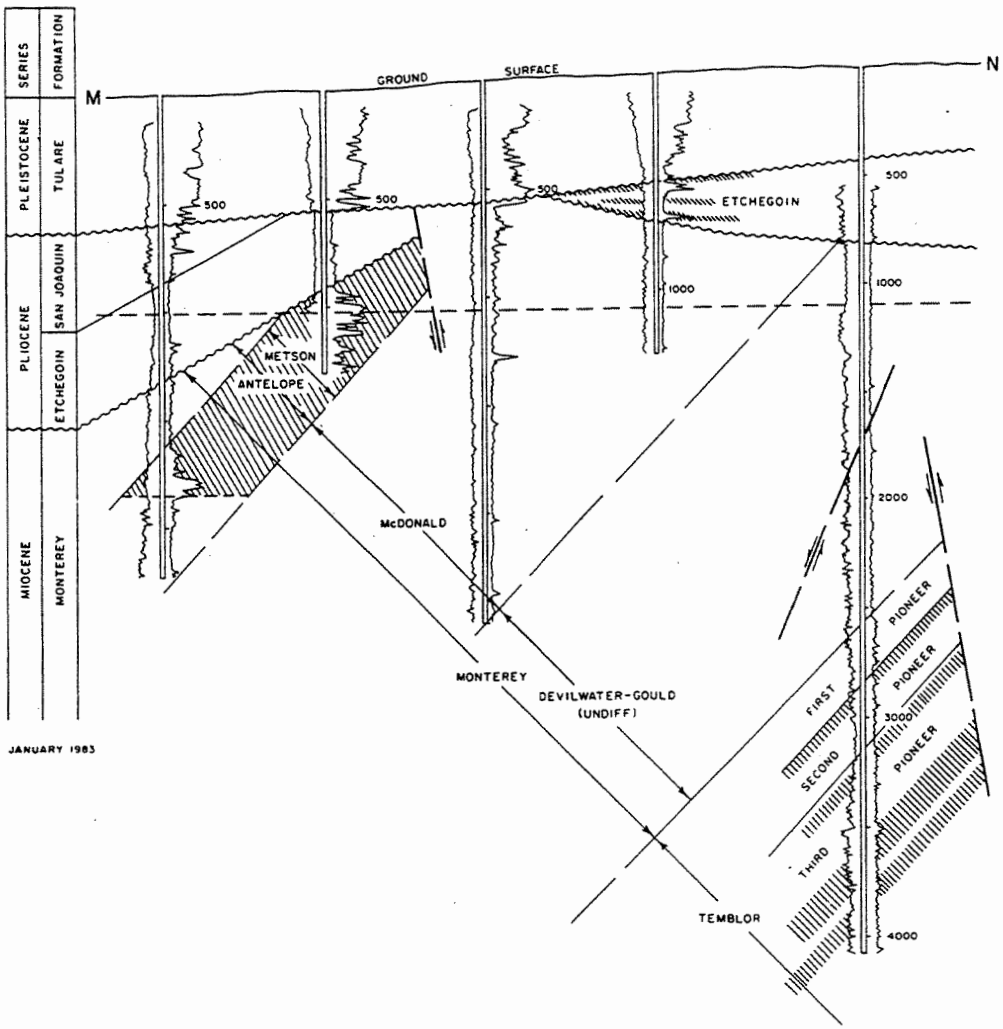




JANUARY 1983

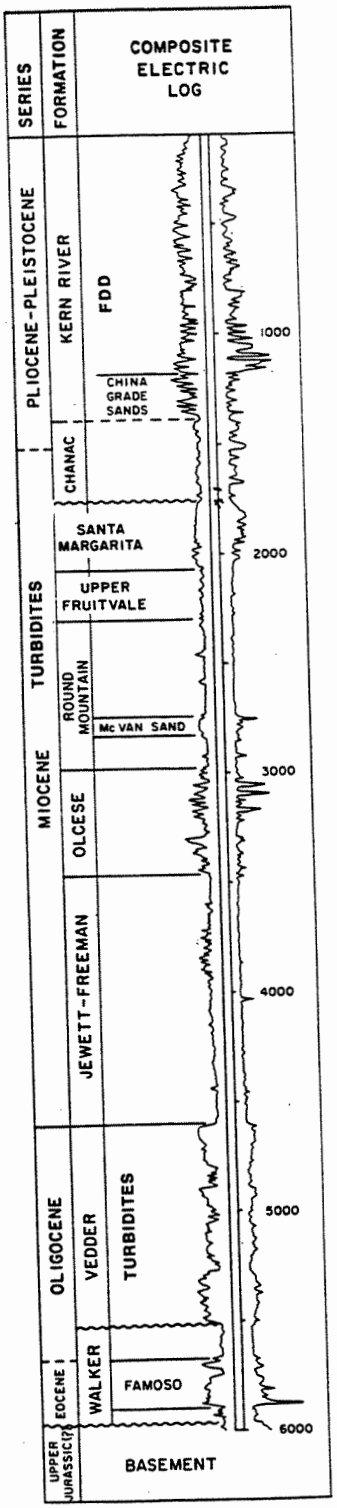
MIDWAY-SUNSET OIL FIELD



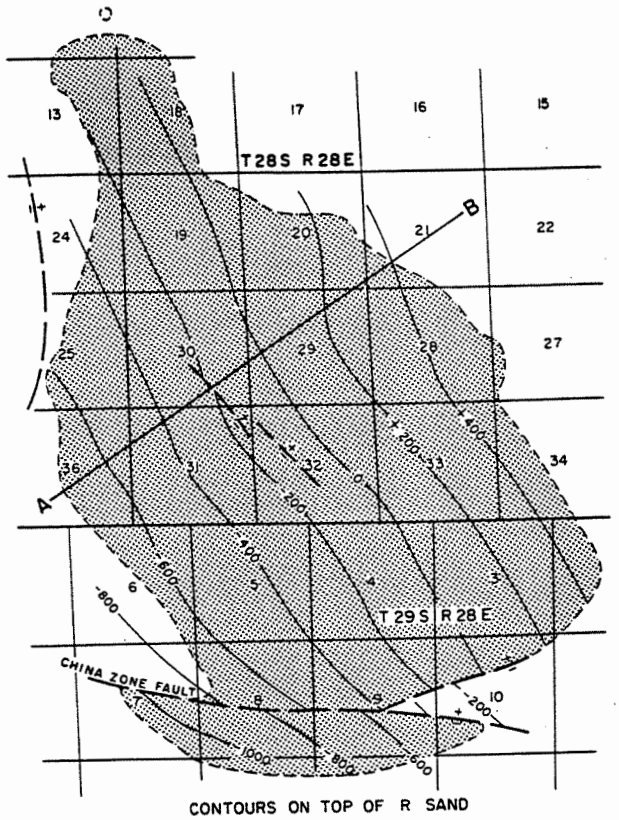


JANUARY 1983

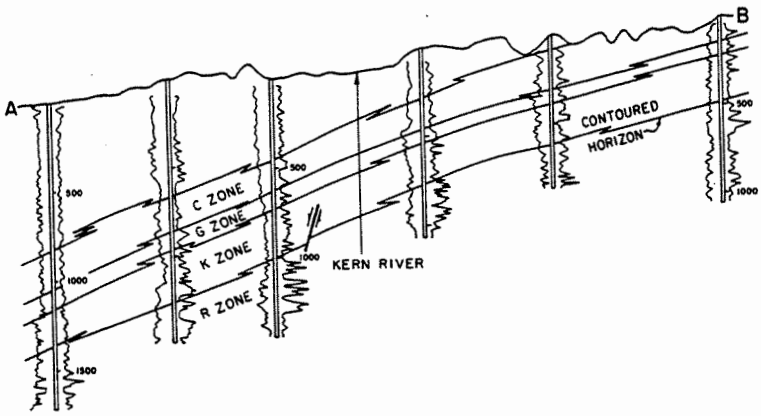
KERN RIVER OIL FIELD



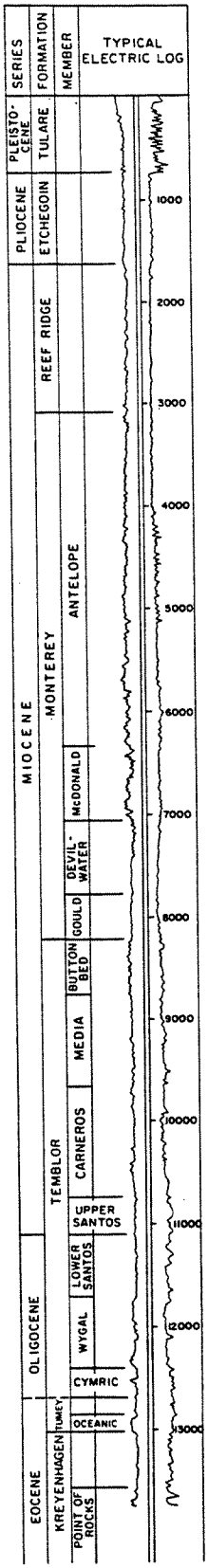
JULY 1981

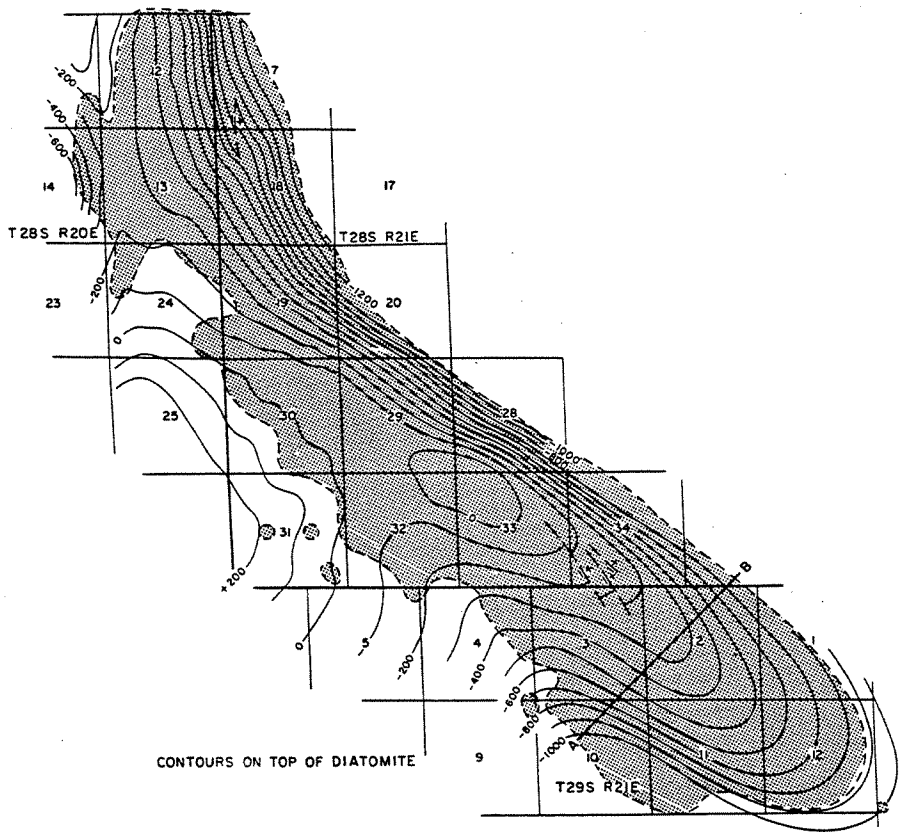


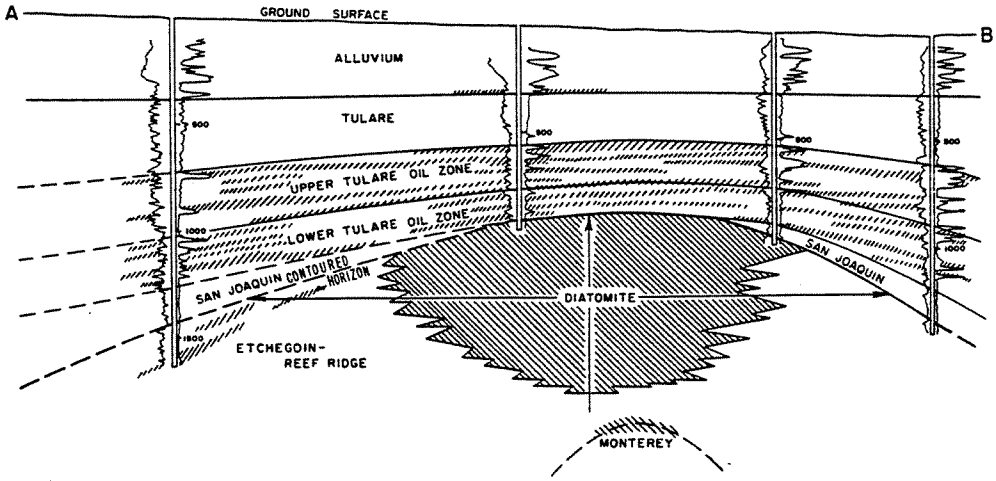
CONTOURS ON TOP OF R SAND



SOUTH BELRIDGE

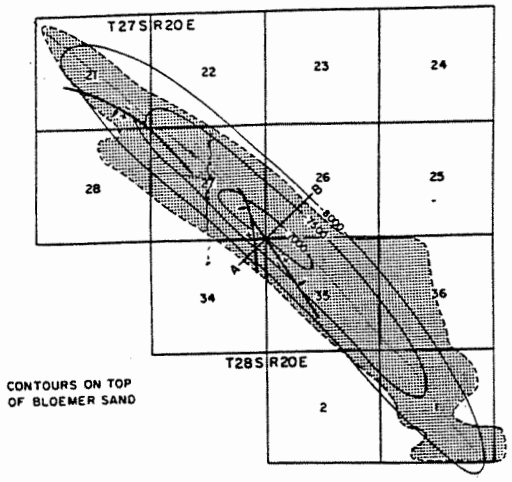




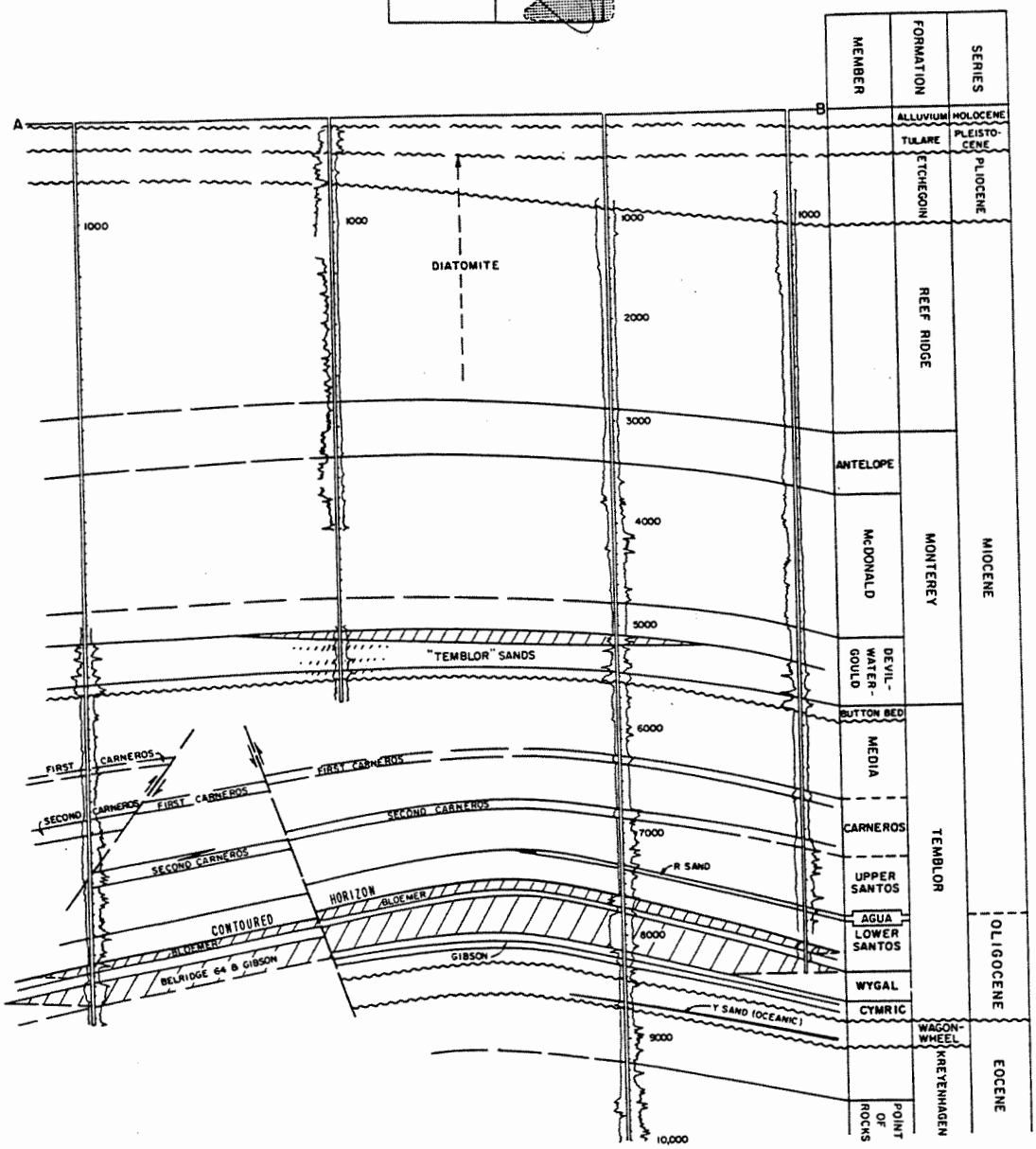


JUNE 1981

NORTH BELRIDGE

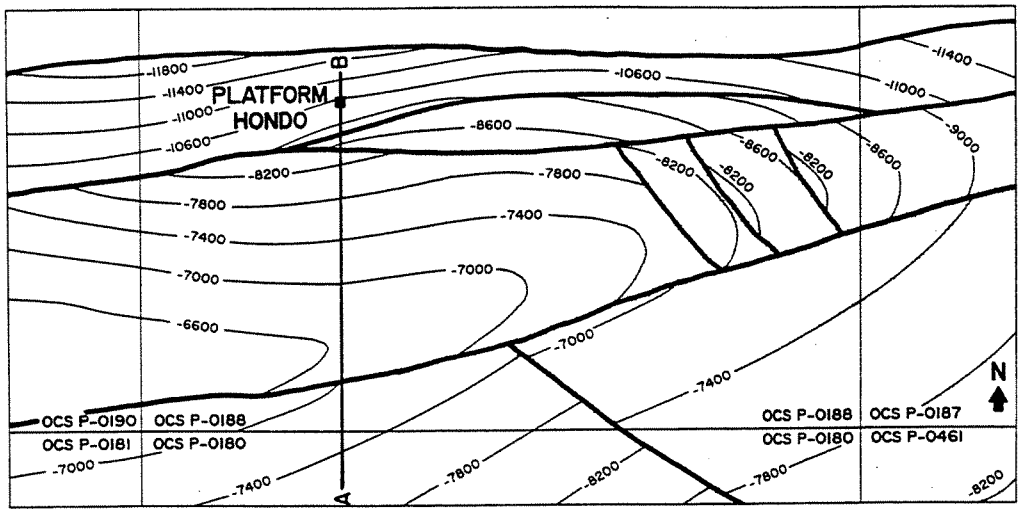


CONTOURS ON TOP OF BLOEMER SAND

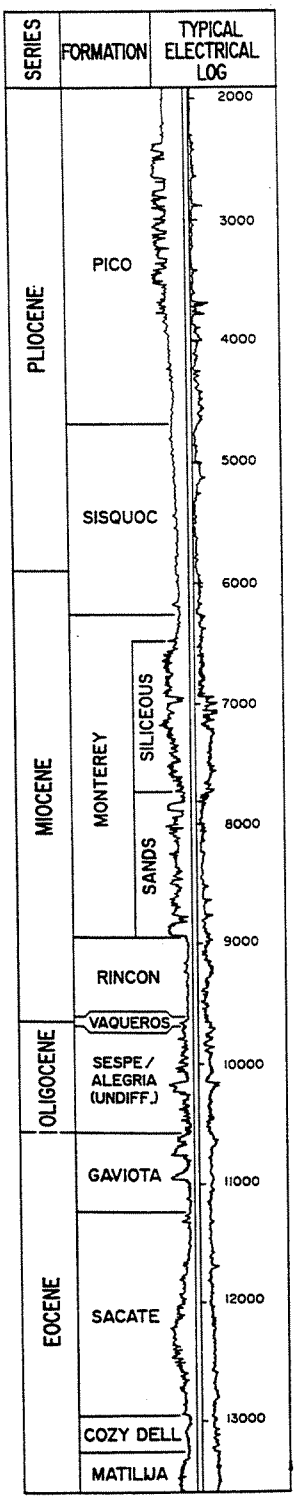


JANUARY 1985

HONDO OFFSHORE OIL FIELD
FEDERAL OCS

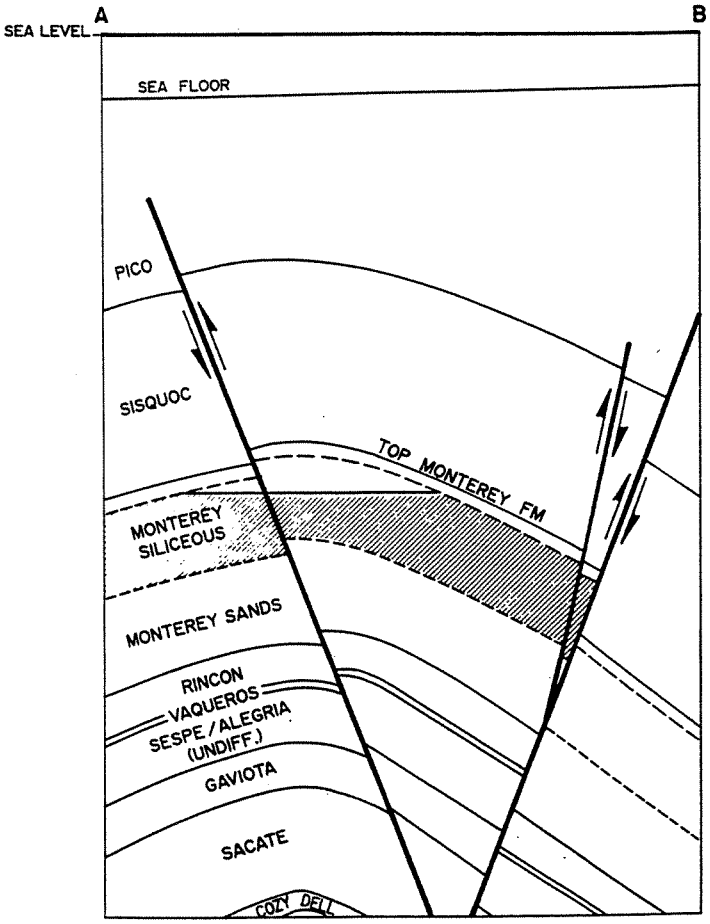


CONTOURS ON TOP MONTEREY SILICEOUS STRUCTURE

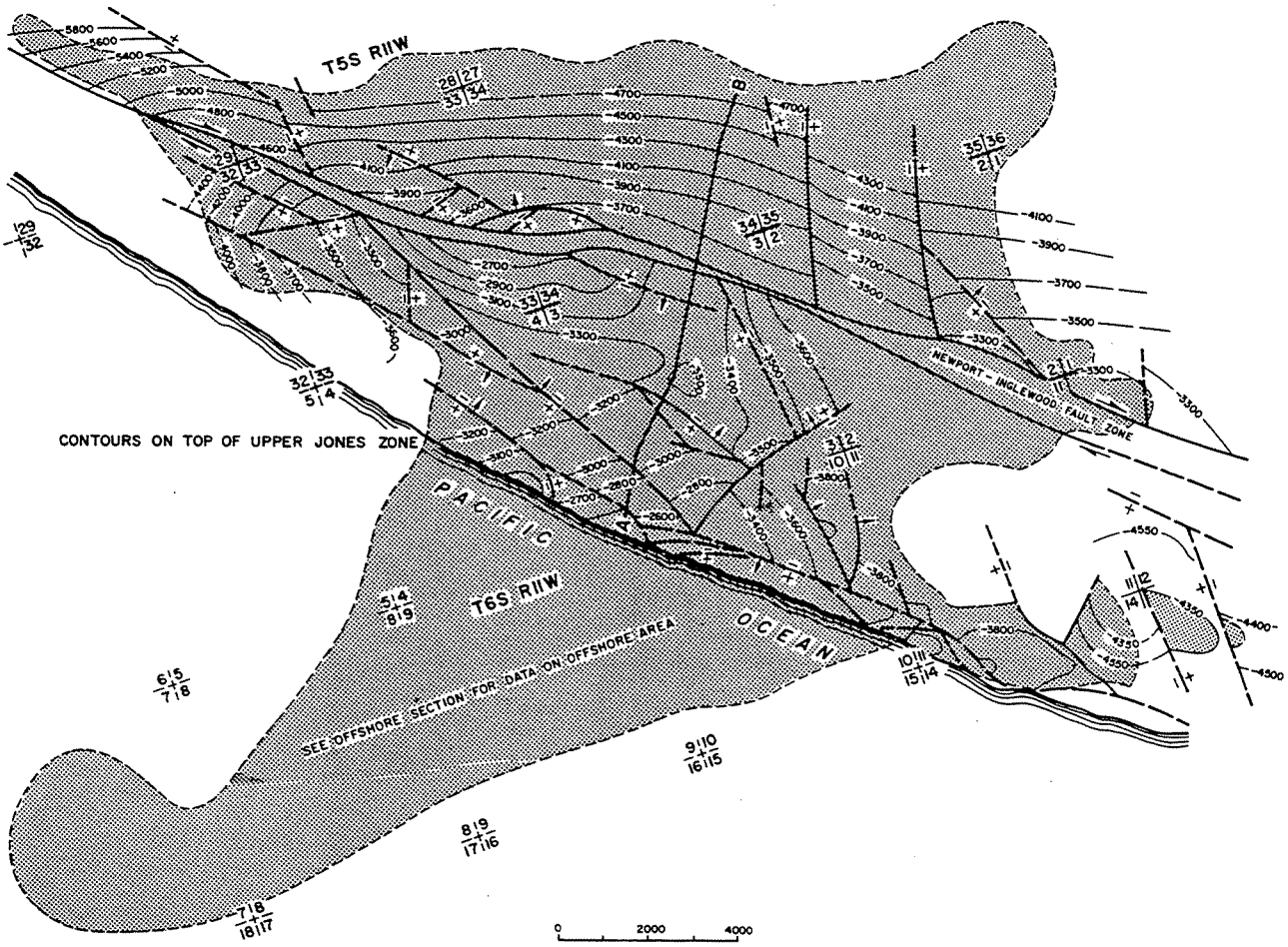


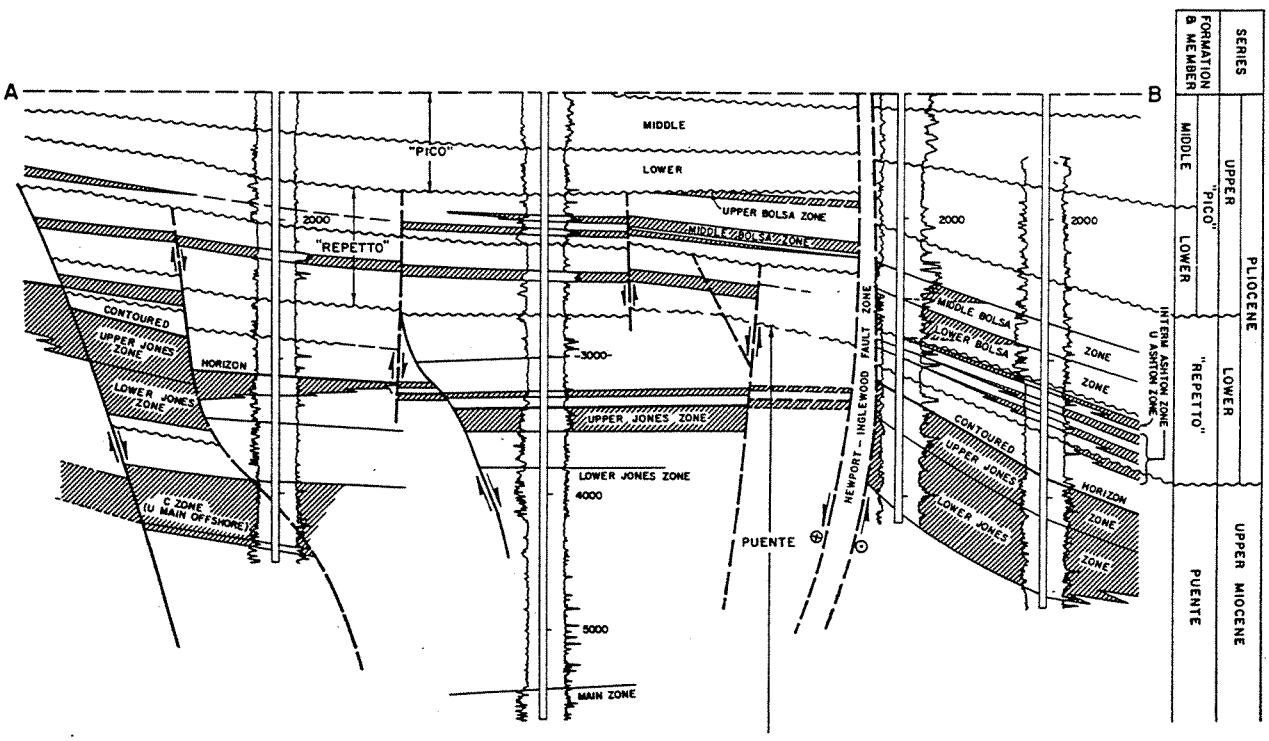
COURTESY OF EXXON CO., USA

HONDO "A" CROSS SECTION

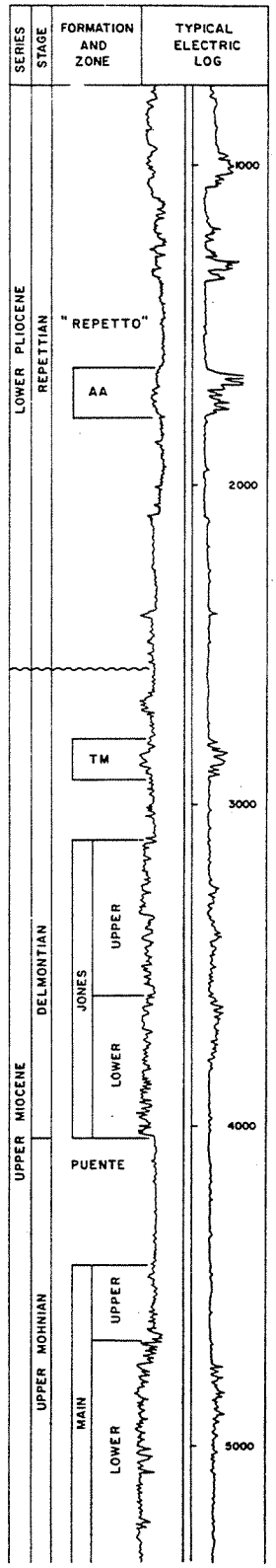


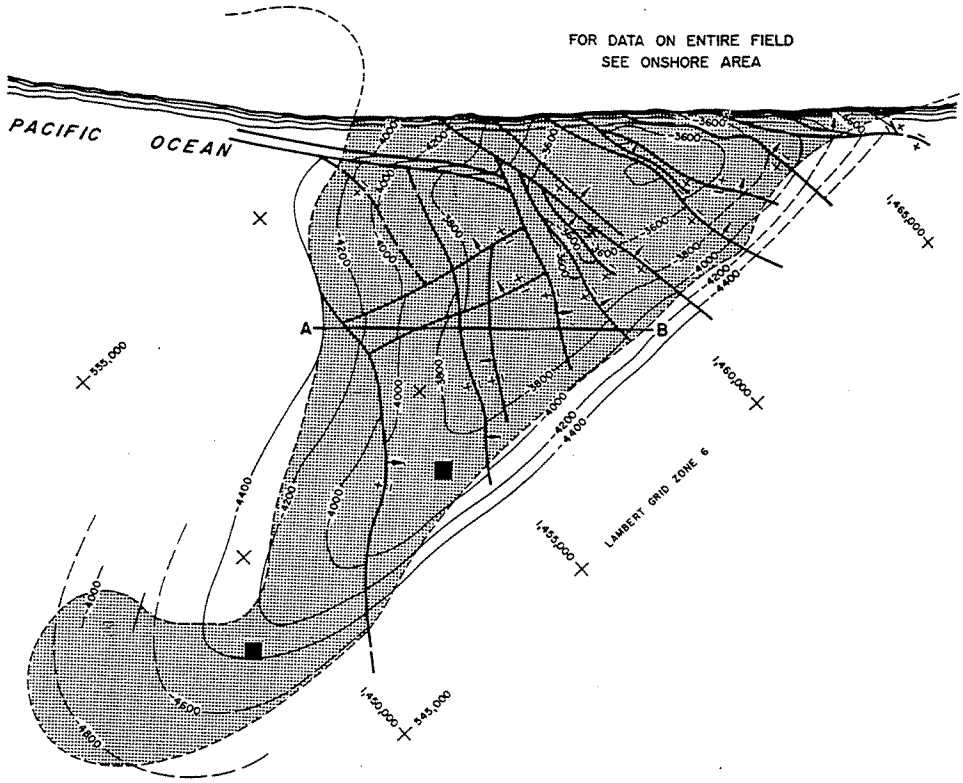
HUNTINGTON BEACH OIL FIELD





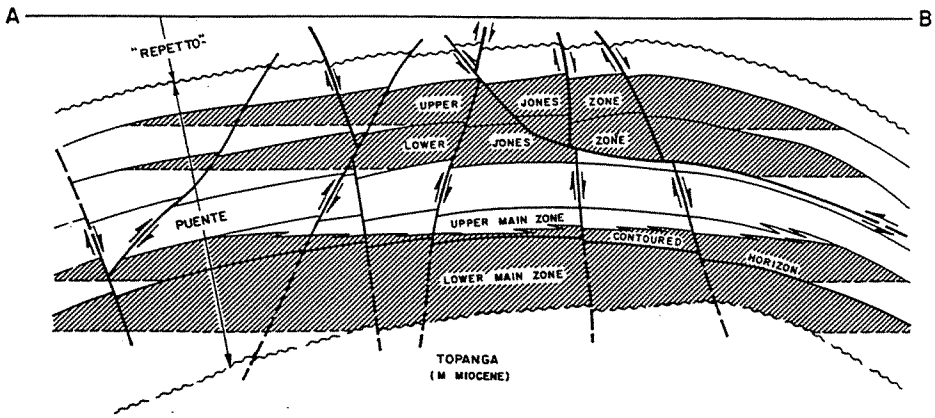
HUNTINGTON BEACH OIL FIELD
Offshore Area



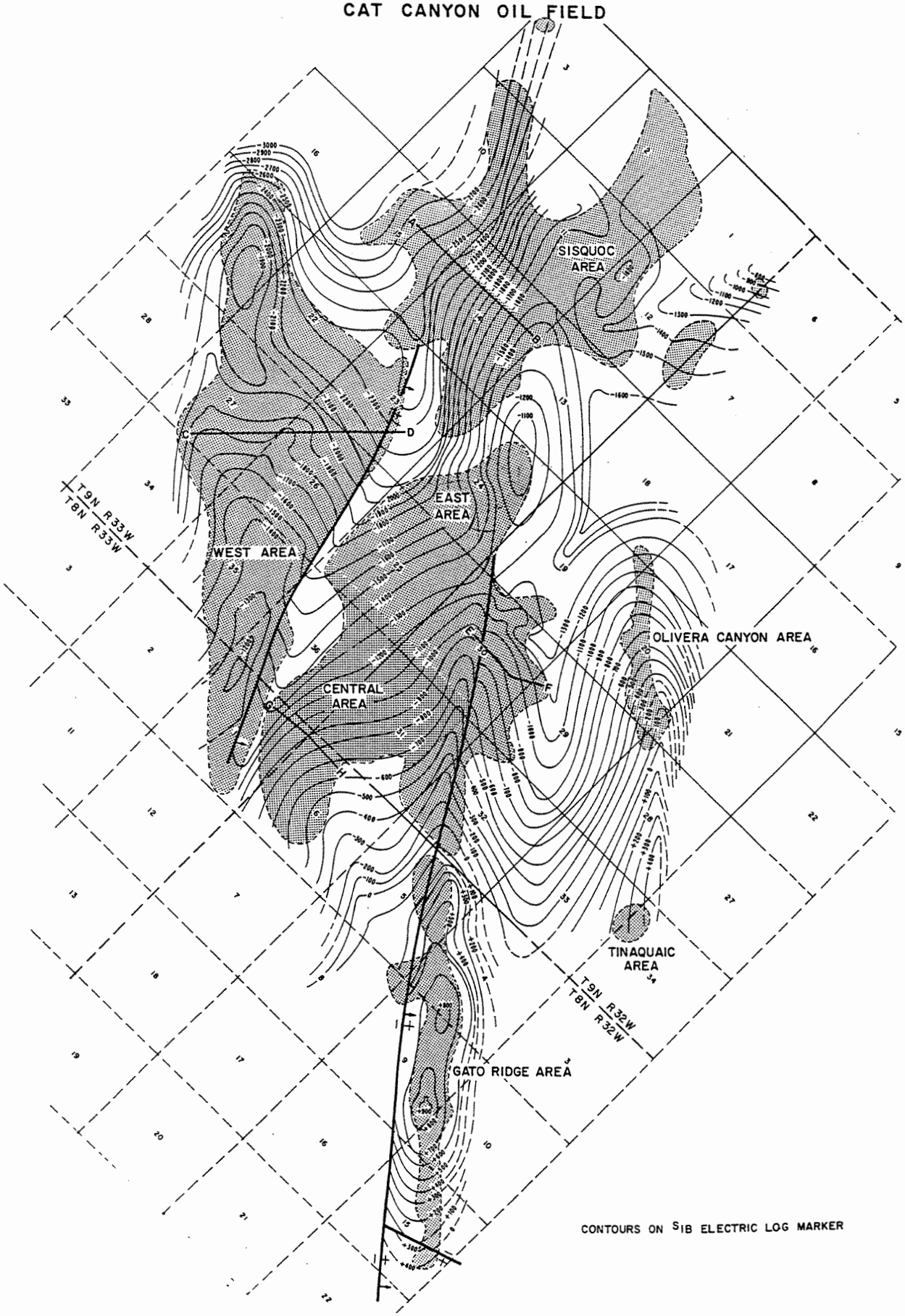


CONTOURS ON TOP OF LOWER MAIN ZONE

SCALE
0 2000 4000



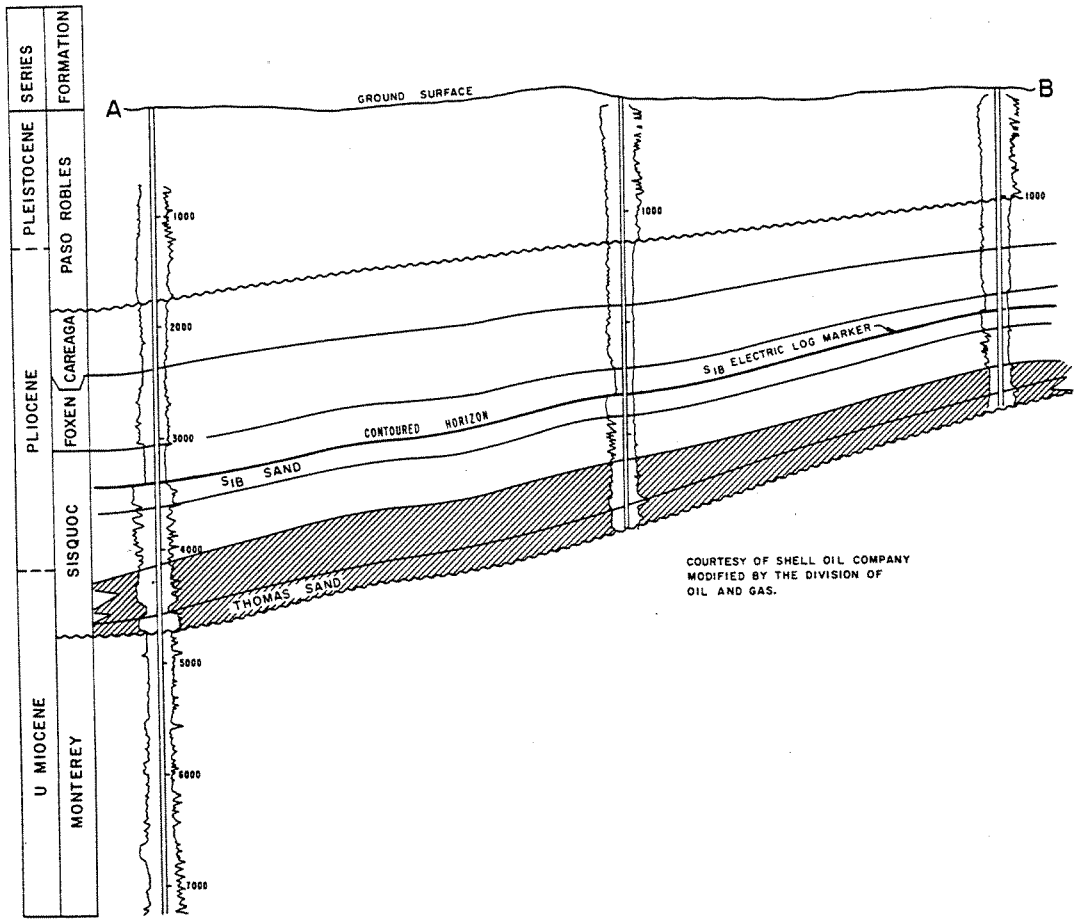
CAT CANYON OIL FIELD



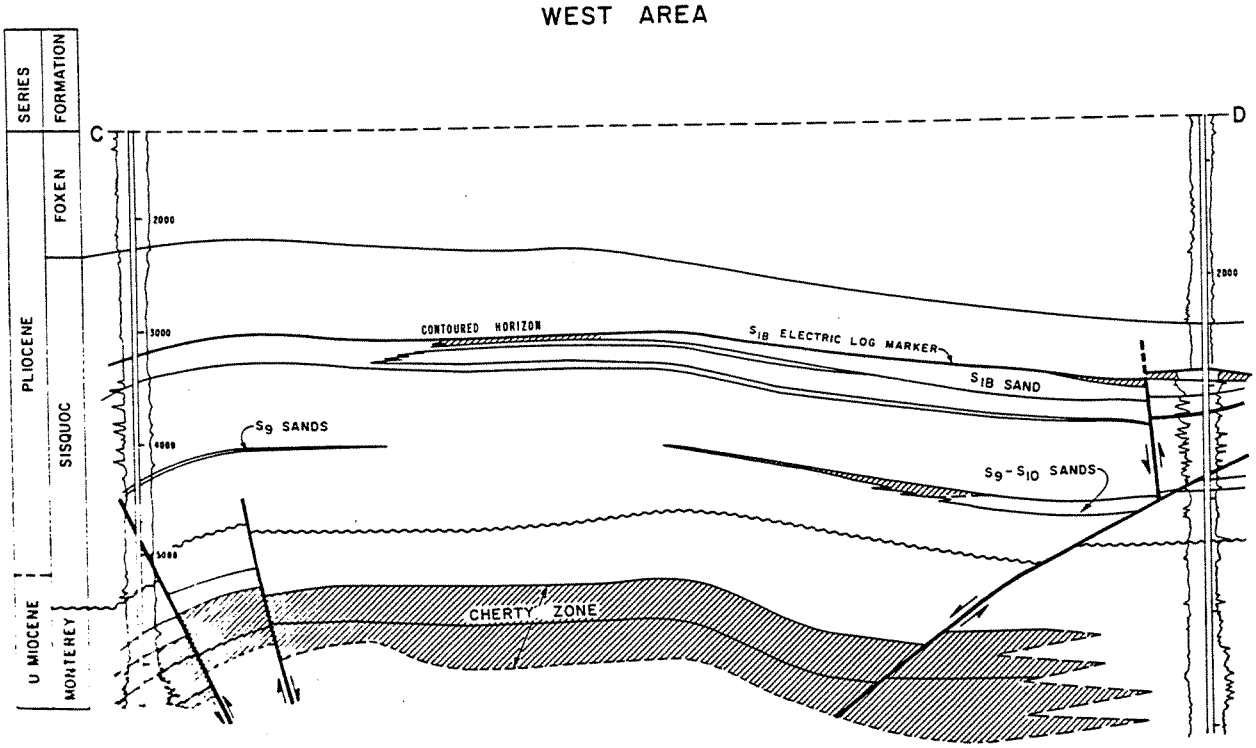
CAT CANYON OIL FIELD

Sisquoc Area and West Area

SISQUOC AREA

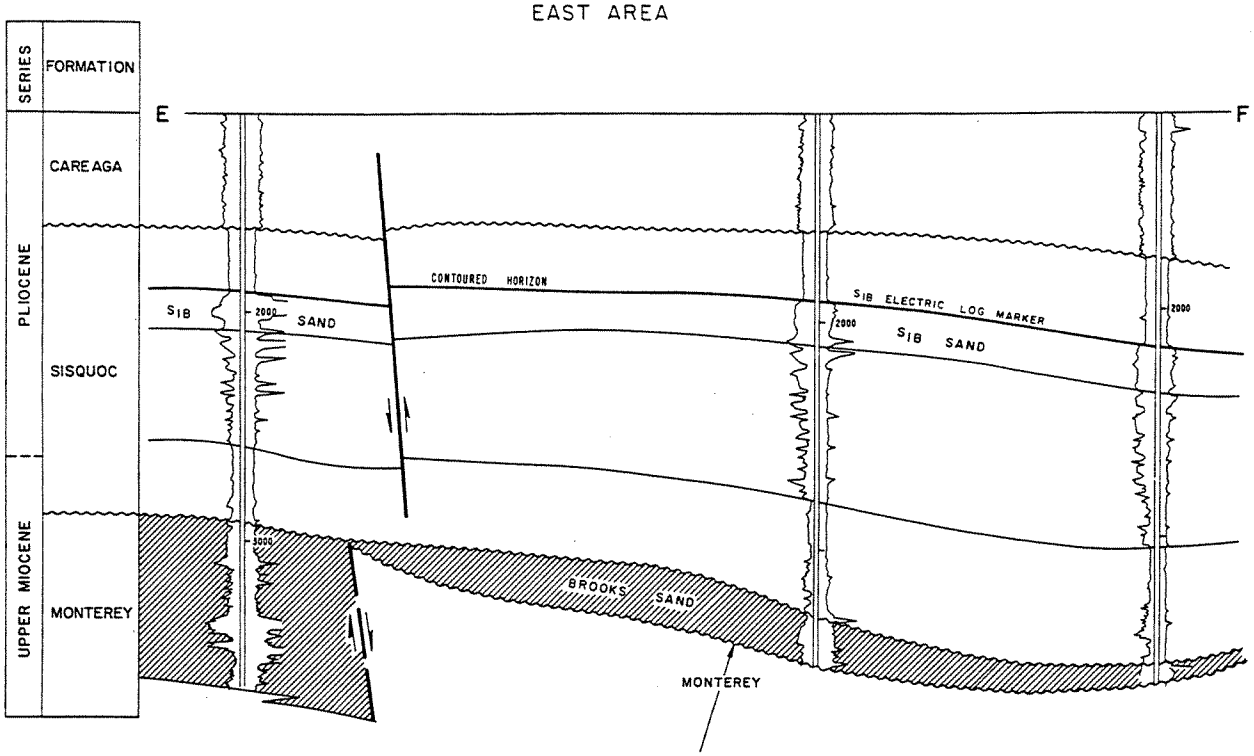


WEST AREA

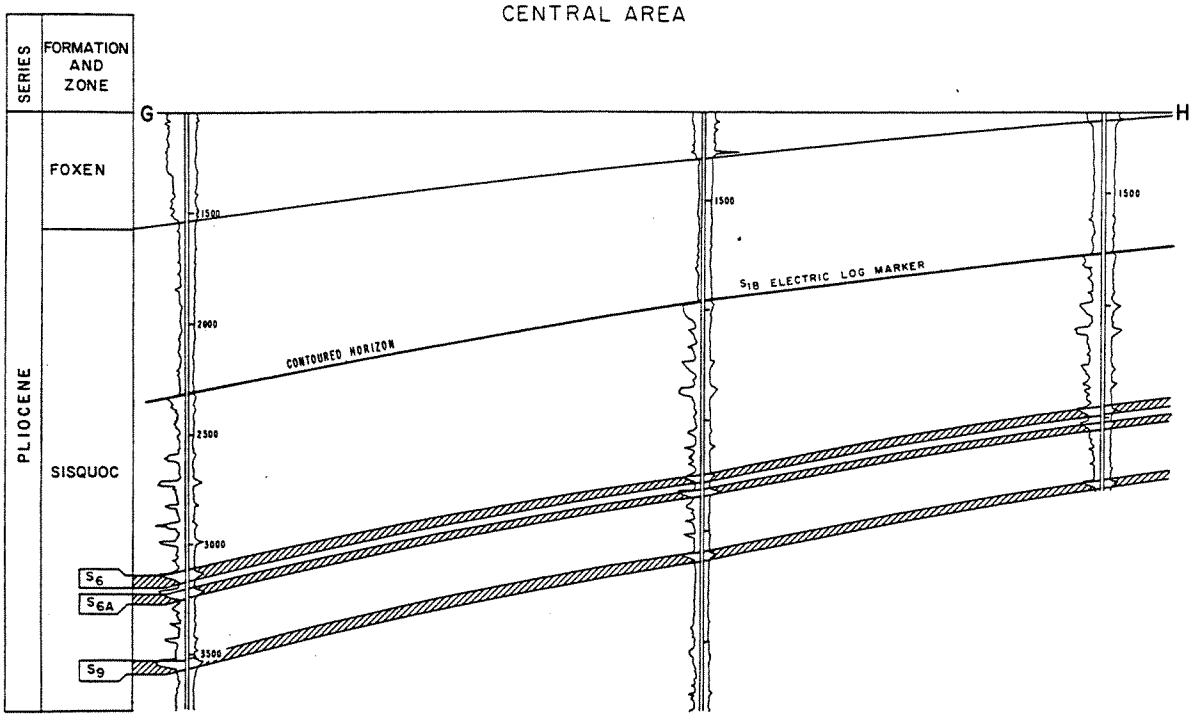


CAT CANYON OIL FIELD
East Area and Central Area

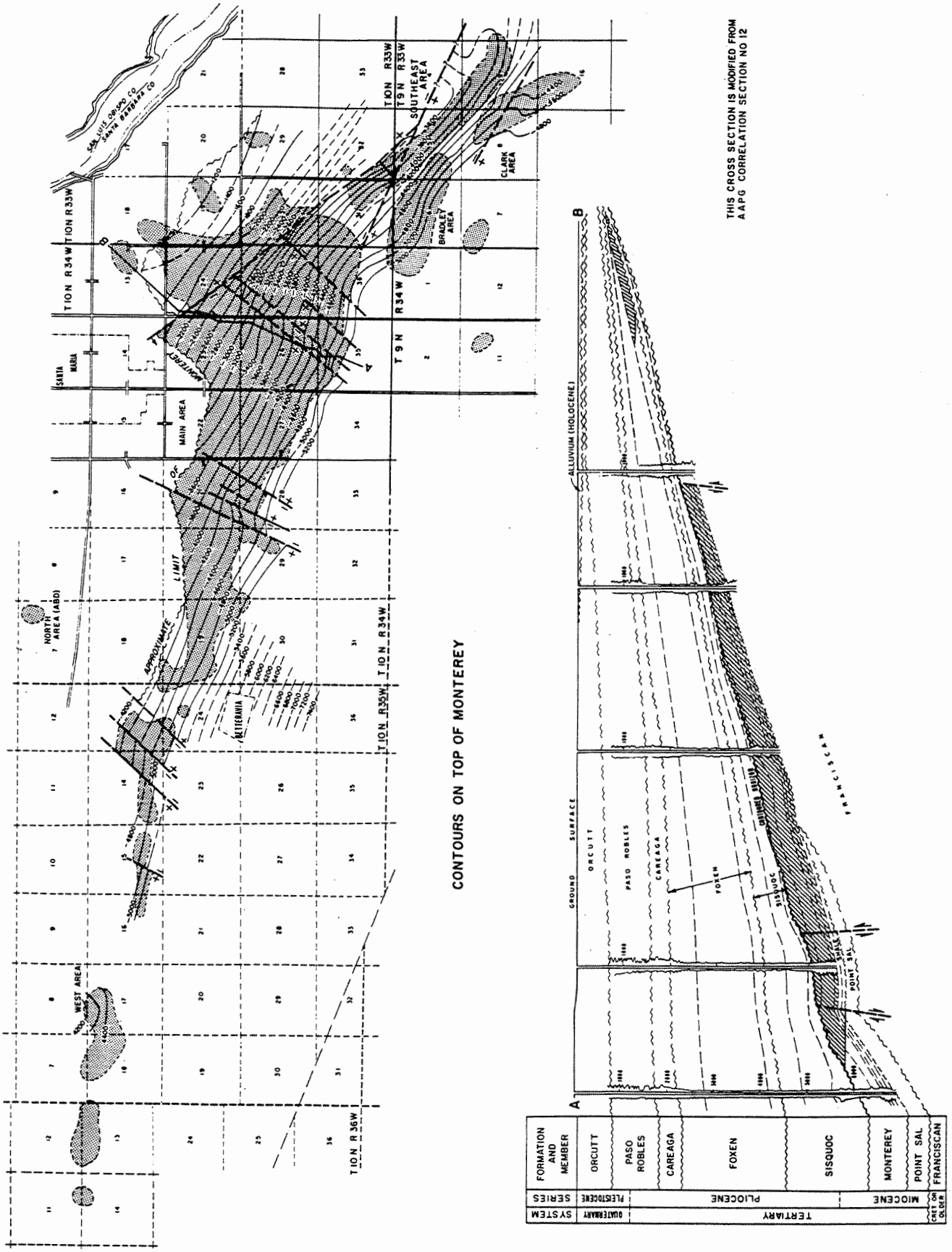
EAST AREA



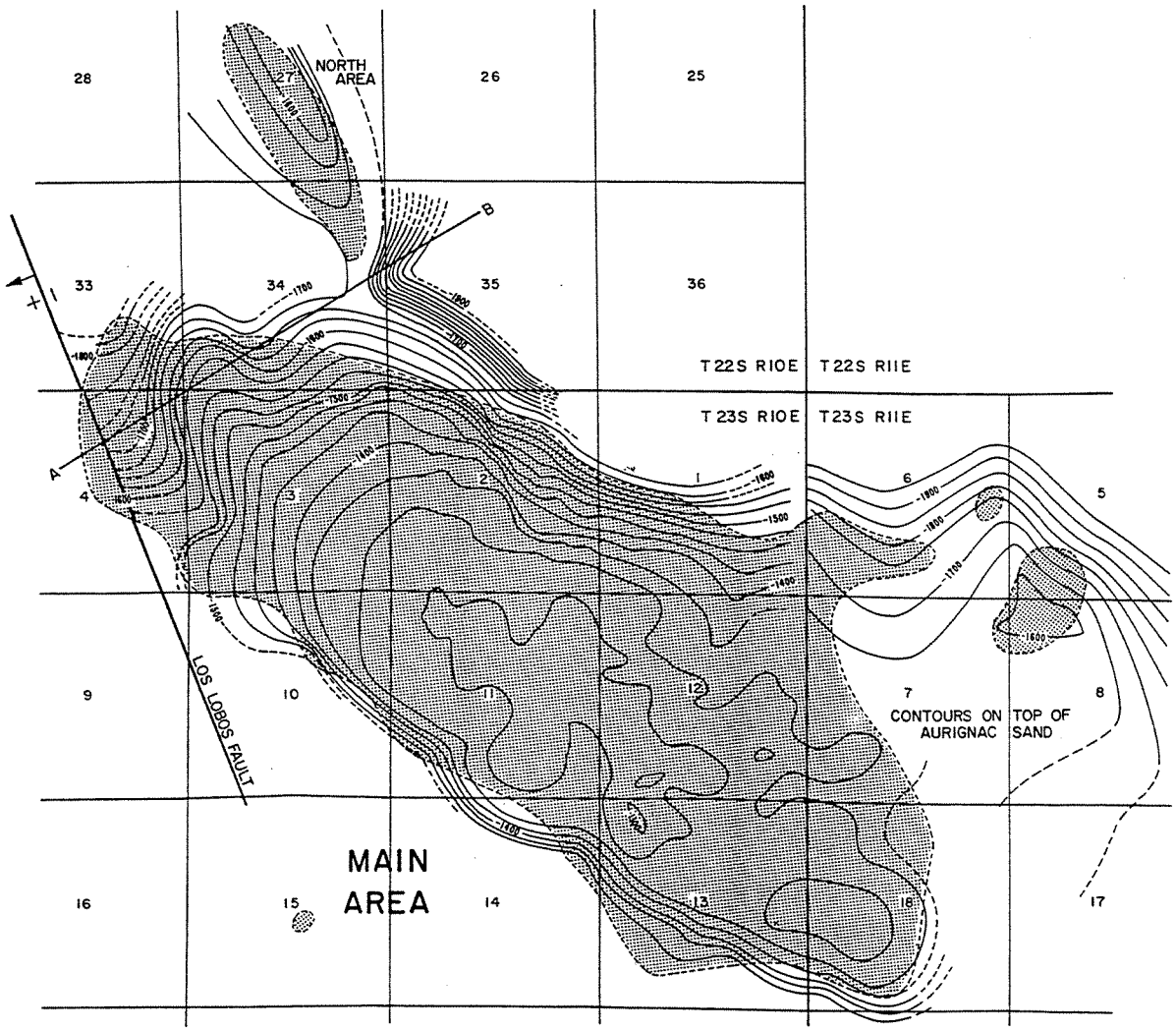
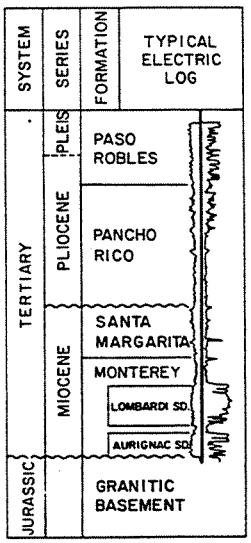
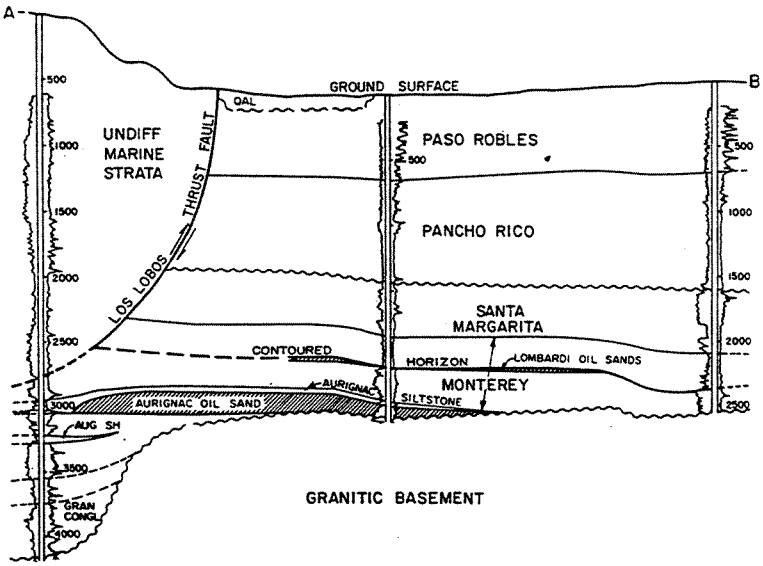
CENTRAL AREA



SANTA MARIA VALLEY OIL FIELD



SAN ARDO OIL FIELD



CONTOURS ON TOP OF LOMBARDI OIL SAND OR EQUIVALENT