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May 18, 1989

MEMORANDUM

TO: John Pyrdol, DOE/Office of Fossil Energy
FROM: Michael Godec, ICF Resources Incorporated
SUBJ: Modifications to Replacement Costs System: Interim Deliverable Under Contract No. DE-AC01-88FE61679, Task 2

PURPOSE

The purpose of this memorandum is to document the improvements and modifications made to the Replacement Costs of Crude Oil (REPCO) Supply Analysis System. While some of this work was performed under our previous support contract to DOE/ASFE, we are presenting all modifications and improvements here for completeness. The memo primarily documents revisions made to the Lower-48 Onshore Model. Revisions and modifications made to other components and models in the REPCO system which are documented elsewhere are only highlighted in this memo.

REVISIONS TO THE LOWER-48 ONSHORE MODEL

Generally, the modifications made to the Lower-48 Onshore Model reflect changes that have occurred in domestic drilling, oil field costs, and reserves since 1982, the date of the most recent available data used for the original Replacement Costs report, published in 1985. The specific model improvements are outlined below.

1. Revision of Regional Breakdown. The Lower-48 onshore was initially divided into six geographic analysis regions. In order to better delineate oil and gas supply regions into geologic basins with distinct characteristics, the Lower-48 onshore is now divided into eleven analysis regions. These regions are shown in Table 1 and Figure 1.

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, express 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.

2. Update of Regional Finding Rates and Drilling Success Rates. The Onshore Model was also updated to incorporate onshore finding rates and drilling success rates based on latest available data on drilling and reserve additions. The original REPCO report was based on data through 1982. The updated data will reflect the most recent drilling and development activity in each analysis region, reflecting data through 1987. These data are summarized in Table 2.

3. Update of Estimates for Crude Oil Resources. The most recent estimates developed by USGS/MMS and DOE of proved, inferred, indicated, and undiscovered crude oil reserves were also incorporated into the model (USGS/MMS Open-File Report 88-373). These estimates are still considered preliminary and subject to change. However, in case these preliminary estimates are rescinded, undiscovered crude oil estimates based on USGS Circular 860, updated for discoveries since 1979, the date of the estimates, were retained. Estimates for proved, inferred, indicated, and undiscovered crude oil for each REPCO analysis region are shown in Table 3 based on both the 1980 and 1988 USGS undiscovered resource estimates. In each case, the estimates were adjusted to account for discoveries made since the date of the estimate, accounting for the estimated appreciation of these discoveries over their productive life.

4. Update of Drilling, Equipment, and Operating Costs. Costs for drilling, equipment, and production operations in crude oil fields, developed from recent cost data provided by the Energy Information Administration and the Joint Association Survey of Drilling Costs for each analysis region, were incorporated into the Onshore Model. Updated 1986 costs are shown in Table 4 for the typical well depth in each analysis region.

5. Incorporation of Features of Recent Tax Reform. Recent financial analysis parameters and income tax calculation algorithms resulting from the Tax Reform Act of 1987 were included in the models. This legislation resulted in revised corporate federal income tax rates, removal of investment tax credits, changes in allowable allocations for tangible and intangible investment costs, and changes in allowable mechanisms for determination of depreciation on capital equipment. These changes are summarized below:

- *Federal Income Taxes.* As a result of the 1986 tax reform legislation, a federal corporate income tax rate of 34%, representing the maximum corporate rate, is used.
- *Royalty Rates.* The model assumes by default a 1/8 royalty on gross revenue from all onshore projects.

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- *Windfall Profits Taxes (WPT)*. Under current law, the WPT is scheduled to phase out in 1993. With the development time frames of most projects, much of the oil production would occur after the expiration of the WPT. Therefore, no Windfall Profits Taxes are included in the financial analyses in REPCO.
- *Investment Tax Credits*. The 1986 tax reform legislation repealed the 10% investment tax credit on capital expenditures placed in service after December 31, 1985. Therefore, no investment tax credit is assumed.
- *Intangible Drilling Costs (IDCs)*. For independent producers, domestic IDCs remain fully deductible under the new tax law, while integrated companies can only expend 70% of well IDCs. The remaining 30% must be capitalized and amortized, beginning in the year costs are paid or incurred. Dry hole costs continue to be fully deductible. Most projects are assumed to be operated by majors, so the intangible costing requirements for integrated companies are applied for financial analysis purposes. However, financial analyses for independent producers can also be performed by the model.
- *Depreciation of Capital Equipment*. All tangible costs are depleted in the model.

In addition, changes in state income and severance tax rates were included where appropriate. Table 5 summarizes the latest state income and severance tax rates used for each analysis region used in the Onshore Model, along with the key oil-producing state in each region.

6. Incorporation of Revised Cost/Price Relationships. In the Replacement Cost report published in 1985, the costs that were input to the economic analysis routines were adjusted as a function of oil price. The relationships between oil field costs and oil prices were modeled based on algorithms developed and used as part of the 1984 NPC report entitled "Enhanced Oil Recovery." Recent work sponsored by DOE/FE under Contract No. DE-AC01-85FE60603 has reanalyzed cost/price relationships since the NPC report. This analysis, reported in the study entitled "Relationship of Oilfield Costs to Oil Prices and Other Market Factors," show that oil field drilling, equipment, and operating costs are related to both oil prices and market infrastructure, described by drilling rig utilization rates. Thus, algorithms were developed which relate oil field costs to prices and rig utilization rates, and these algorithms were incorporated into all the resource assessment models in the Supply Analysis System.

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7. Incorporation of Capability of Analyzing Incremental Regulatory Costs. Based on work performed under another task of this contract, estimated incremental costs of proposed regulations on the management and disposal of drilling muds and cuttings and on produced brines were incorporated in the model, to be specified by the user. These costs were included to give the models the capability of examining the economic and energy impacts of proposed regulations on U.S. undiscovered crude oil supplies. These costs were documented in a report delivered in March 1988 under Contract No. DE-AC01-85FE60603, entitled "The Impact of Increased Waste Management Regulations on the Economics of Developing U.S. Undiscovered Crude Oil Resources."

REVISION TO OTHER PARTS OF THE REPLACEMENT COSTS SYSTEM

1. Lower-48 Offshore Model. A substantially improved model for assessing undiscovered crude oil resources in the offshore Outer Continental Shelf (OCS) was also developed to replace the original offshore model in the REPCO system. This model incorporates many features which improve its capabilities over the previous model. In particular, the model considers most of the recent innovations in deepwater offshore technology, including tension leg platforms, compliant towers, floating and semi-submersible production facilities, and subsea completions, which overcome the direct correlation between water depth and costs for fixed steel platforms. The model also includes more up-to-date costs for drilling, surface and subsurface equipment, pipelines, facilities operations, and pollution control. Finally, the model includes the ability to analyze the effects of federal offshore leasing strategies and land set-asides.

In addition, improvements such as those described under Items 3, 4, 5, 6, and 7 for the Lower-48 Onshore Model were also included in the Offshore Model. These improvements are described in detail in the report entitled, "A Model for the Economic Analysis of U.S. Undiscovered Resources in the Lower-48 Offshore," prepared and delivered under this contract.

2. Arctic Economics Model. Like those described for the offshore model, the Arctic Economics Model (AEM) was revised and updated as part of the REPCO system update. The AEM now includes the ability to analyze the effects of federal leasing strategies and land set-asides. In addition, improvements such as those described under items 3, 4, 5, 6, and 7 for the Lower-48 Onshore Model were also incorporated into AEM.

TABLE 1
ASSIGNMENT OF STATE AND SUBSTATE
UNITS TO REVISED ONSHORE ANALYSIS REGIONS

| Analysis Regions | State and/or Substate Units |
|--------------------------|---|
| Pacific | California, Oregon, and Washington |
| Northern Rocky Mountains | Montana, North and South Dakota |
| Central Rocky Mountains | Colorado, Utah, Wyoming, Nevada, Idaho, and Nebraska |
| Southern Rocky Mountains | Arizona and Western New Mexico |
| West Texas | Eastern New Mexico, Texas Railroad Commission Districts 7B, 7C, 8A, and 9 |
| East Texas | Northern Louisiana, Texas Railroad Commission Districts 5 and 6 |
| Gulf Coast | Southern Louisiana, Texas Railroad Commission Districts 1, 2, 3, and 4 |
| Southeast | Alabama, Florida, and Mississippi |
| Mid-Continent | Arkansas, Kansas, Missouri, Oklahoma, and Texas Railroad Commission District 10 |
| North Central | Illinois, Iowa, Michigan, Minnesota, and Wisconsin |
| Appalachia/Atlantic | Indiana, Kentucky, New York, Ohio, Pennsylvania, Tennessee, West Virginia, Virginia, Georgia, South Carolina, North Carolina, Maine, New Hampshire, and Vermont |

TABLE 2
INPUT DATA FOR ONSHORE REPLACEMENT COSTS MODEL BY GEOGRAPHIC REGION

| Onshore Region | Reserve and Drilling Data: New Field and New Pool | | | | | | | Exploratory Drilling Performance Data | | | |
|----------------------------|---|-----------------------|---|------------------------------------|------------------------------------|---------------------------|-------------------------------------|---------------------------------------|----------------------------------|---------------------------|--|
| | Year | New Reserves (MMBbls) | No. Succ. Wells (ft x 10 ³) | Succ. Feet (ft x 10 ³) | Total Feet (ft x 10 ³) | Recovery Per Well (MBbls) | Successful Recovery Per Foot (Bbls) | Exploration Success Rate (ratio) | Development Success Rate (ratio) | Average Well Depth (feet) | |
| 1. <u>West Coast</u> | 1985 | 6 | 4 | 30 | 830 | 1500.0 | 202.1 | | | | |
| | 1986 | - | 4 | 42 | 318 | - | - | | | | |
| | 1987 | 2 | 2 | 18 | 217 | 1000.0 | 112.6 | | | | |
| 3 year Totals/Avg. | 8 | 10 | 90 | 1,365 | 800.0 | 89.2 | 0.0600 | 0.946 | 8,036 | | |
| 2. <u>Northern Rockies</u> | 1985 | 11 | 48 | 397 | 2,728 | 161.3 | 17.7 | | | | |
| | 1986 | 5 | 20 | 406 | 1,457 | 156.3 | 16.7 | | | | |
| | 1987 | 8 | 12 | 377 | 863 | 363.6 | 32.6 | | | | |
| 3 year Totals/Avg. | 24 | 80 | 1,180 | 5,048 | 196.7 | 20.6 | 0.2039 | 0.680 | 7,864 | | |
| 3. <u>Central Rockies</u> | 1985 | 23 | 165 | 141 | 7,090 | 134.5 | 17.9 | | | | |
| | 1986 | 11 | 51 | 363 | 3,510 | 161.8 | 23.4 | | | | |
| | 1987 | 14 | 54 | 419 | 3,123 | 225.8 | 29.6 | | | | |
| 3 year Totals/Avg. | 48 | 270 | 923 | 13,723 | 159.5 | 21.5 | 0.1535 | 0.753 | 7,004 | | |
| 4. <u>Southern Rockies</u> | 1985 | - | 18 | 91 | 314 | - | - | | | | |
| | 1986 | - | 4 | 12 | 50 | - | - | | | | |
| | 1987 | - | 2 | 13 | 41 | - | - | | | | |
| 3 year Totals/Avg. | - | 24 | 116 | 405 | 61.5* | - | 0.3700 | 0.943 | 4,408 | | |

* Seven-year average over the 1981-1987 time period.

TABLE 2
INPUT DATA FOR ONSHORE REPLACEMENT COSTS MODEL BY GEOGRAPHIC REGION
(Cont.)

| Onshore Region | Reserve and Drilling Data: New Field and New Pool | | | | | | Exploratory Drilling Performance Data | | | |
|---------------------------|---|-----------------------|--|------------------------------------|------------------------------------|---------------------------|---------------------------------------|----------------------------------|----------------------------------|---------------------------|
| | Year | New Reserves (MMBbls) | No. Success. Wells (ft x 10 ²) | Succ. Feet (ft x 10 ³) | Total Feet (ft x 10 ³) | Recovery Per Well (MBbls) | Successful Recovery Per Foot (Bbls) | Exploration Success Rate (ratio) | Development Success Rate (ratio) | Average Well Depth (feet) |
| 5. Mid-Continent | 1985 | 36 | 263 | 1,193 | 5,687 | 127.2 | 27.3 | | | |
| | 1986 | 13 | 158 | 1,274 | 1,683 | 64.0 | 15.3 | | | |
| | 1987 | 9 | 110 | 948 | 2,794 | 61.2 | 13.2 | | | |
| 3 year Totals/Avg. | | 58 | 531 | 3,415 | 10,164 | 91.6 | 18.6 | 0.2562 | 0.687 | 3,833 |
| 6. Gulf Coast | 1985 | 37 | 162 | 1,266 | 3,020 | 222.9 | 28.3 | | | |
| | 1986 | 12 | 104 | 748 | 1,793 | 115.4 | 16.0 | | | |
| | 1987 | 14 | 66 | 449 | 1,154 | 202.9 | 29.2 | | | |
| 3 year Totals/Avg. | | 63 | 337 | 2,463 | 5,967 | 185.8 | 24.9 | 0.3950 | 0.739 | 7,583 |
| 7. West Texas | 1985 | 23 | 86 | 609 | 682 | 53.5 | 8.7 | | | |
| | 1986 | 14 | 60 | 453 | 1,667 | 64.5 | 9.6 | | | |
| | 1987 | 18 | 34 | 273 | 1,198 | 111.1 | 17.0 | | | |
| 3 year Totals/Avg. | | 55 | 180 | 1,335 | 3,547 | 68.0 | 10.7 | 0.2243 | 0.780 | 5,620 |
| 8. East Texas | 1985 | 6 | 17 | 160 | 1,064 | 352.9 | 37.4 | | | |
| | 1986 | 1 | 34 | 236 | 813 | 27.8 | 4.1 | | | |
| | 1987 | 1 | 22 | 164 | 69 | 45.5 | 6.1 | | | |
| 3 year Totals/Avg. | | 8 | 73 | 560 | 1,946 | 106.7 | 14.0 | 0.1788 | 0.752 | 6,637 |
| | | | | | | 204.2* | 27.4* | | | |

* Seven-year average over the 1981-1987 time period.

TABLE 2
INPUT DATA FOR ONSHORE REPLACEMENT COSTS MODEL BY GEOGRAPHIC REGION
(Cont.)

| Onshore Region | Reserve and Drilling Data: New Field and New Pool | | | | | Exploratory Drilling Performance Data | | | | |
|--------------------------|---|-----------------------|---|------------------------------------|------------------------------------|---------------------------------------|-------------------------------------|----------------------------------|----------------------------------|---------------------------|
| | Year | New Reserves (MMBbls) | No. Succ. Wells (ft x 10 ³) | Succ. Feet (ft x 10 ³) | Total Feet (ft x 10 ³) | Recovery Per Well (MBbls) | Successful Recovery Per Foot (Bbls) | Exploration Success Rate (ratio) | Development Success Rate (ratio) | Average Well Depth (feet) |
| 9. <u>Appalachia</u> | 1985 | 1 | 111 | 181 | 595 | 6.1 | 3.6 | | | |
| | 1986 | - | 35 | 60 | 225 | - | - | | | |
| | 1987 | - | 32 | 69 | 297 | - | - | | | |
| | 3 year Totals/Avg. | 1 | 178 | 310 | 1,117 | 3.7 | 2.0 | 0.3829 | 0.877 | 1,556 |
| 10. <u>North Central</u> | 1985 | 5 | 45 | 166 | 2,671 | 63.3 | 17.6 | | | |
| | 1986 | 2 | 32 | 125 | 1,059 | 39.2 | 11.2 | | | |
| | 1987 | 3 | 21 | 79 | 195 | 115.4 | 29.8 | | | |
| | 3 year Totals/Avg. | 10 | 98 | 370 | 3,925 | 64.1 | 17.7 | 0.1751 | 0.680 | 2,970 |
| 11. <u>Southeast</u> | 1985 | 14 | 39 | 386 | 2,064 | 359.0 | 36.3 | | | |
| | 1986 | 4 | 30 | 324 | 131 | 133.3 | 12.4 | | | |
| | 1987 | 11 | 15 | 159 | 736 | 687.5 | 62.4 | | | |
| | 3 year Totals/Avg. | 29 | 84 | 869 | 4,110 | 341.2 | 32.7 | 0.2141 | 0.573 | 10,005 |

* Seven-year average over the 1981-1987 time period.

Source: API/AGA/EIA Data Series
Drilling and Field Size AAPG Data Series
Prepared By: ICF-Lewin Energy, 1989

TABLE 3
COMPARISON OF UNDISCOVERED CRUDE OIL RESERVES ESTIMATES
FROM 1980 AND 1988 USGS STUDIES - ADJUSTED TO 1987
(Million Barrels)

| Region | Circular 860 | MMS 88-373 | Discoveries (1980-1987) | Discoveries (1987) | Discoveries Appreciation* (1980-1987) | Discoveries Appreciation* (1987) | Circ. 860 Adjusted Undiscovered | MMS 88-373 Adjusted Undiscovered |
|---------------------|---------------|---------------|-------------------------|--------------------|---------------------------------------|----------------------------------|---------------------------------|----------------------------------|
| West Coast | 4,300 | 3,490 | 48 | 2 | 369 | 15 | 3,936 | 3,475 |
| N. Rockies | 2,800 | 040 | 145 | 8 | 1,099 | 61 | 1,701 | 879 |
| C. Rockies | 19,900 | 4,830 | 141 | 14 | 1,069 | 106 | 18,831 | 4,724 |
| S. Rockies | 1,000 | 250 | 4 | 0 | 30 | 0 | 970 | 250 |
| Mid-Continent | 4,700 | 1,890 | 168 | 9 | 1,273 | 68 | 3,427 | 1,822 |
| West Texas | 4,900 | 2,560 | 173 | 16 | 1,311 | 121 | 3,589 | 2,439 |
| East Texas | 1,200 | 420 | 51 | 1 | 387 | 8 | 813 | 412 |
| Gulf Coast | 3,600 | 3,050 | 358 | 14 | 2,714 | 106 | 886 | 2,944 |
| Appalachia/Atlantic | 800 | 290 | 23 | 7 | 174 | 53 | 626 | 237 |
| Southeast | 2,800 | 990 | 60 | 11 | 455 | 83 | 2,345 | 907 |
| North Central | 1,700 | 1,510 | 42 | 3 | 318 | 23 | 1,382 | 1,487 |
| TOTAL | 47,700 | 20,220 | 1,213 | 85 | 9,914 | 644 | 38,506 | 19,626 |

* Using a Hubbert/Root reserves growth appreciation factor of 7.58.

TABLE 4
ONSHORE DRILLING, EQUIPMENT, AND OPERATING COSTS
(1987 \$)

| Onshore Region (Depth, ft) | COST/WELL | | | | ANNUAL COST/YEAR | |
|-------------------------------|-----------------------|----------|------------------------------|----------------------|------------------------|--------------------------------------|
| | Drilling & Completion | Dry Hole | Production & Lease Equipment | Waterflood Equipment | Primary Operating Cost | Incremental Secondary Operating Cost |
| Pacific (8,036) | 623,082 | 495,248 | 114,945 | 175,461 | 29,901 | 55,072 |
| N. Rockies (7,864) | 315,227 | 311,048 | 105,982 | 134,043 | 16,708 | 38,551 |
| C. Rockies (7,004) | 241,290 | 201,513 | 97,165 | 117,458 | 15,821 | 34,884 |
| S. Rockies (4,408) | 174,891 | 135,962 | 76,540 | 67,738 | 13,474 | 18,111 |
| Mid-Continent (3,833) | 101,553 | 87,426 | 58,517 | 57,599 | 10,812 | 19,252 |
| West Texas (5,620) | 196,553 | 146,920 | 73,984 | 86,445 | 14,720 | 22,351 |

Sources of Data:

1. Equipment & Operating Costs: DOE/EIA-0185(86)
2. Drilling & Dry Hole Costs: 1987 Joint Association Survey on Drilling Costs

Prepared By: ICF-Lewin Energy (1989)

TABLE 4
ONSHORE DRILLING, EQUIPMENT, AND OPERATING COSTS
(1987 \$)
(Continued)

| Onshore Region (Depth, ft) | COST/WELL | | | | ANNUAL COST/YEAR | |
|----------------------------------|--------------------------|----------|------------------------------------|-------------------------|------------------------------|--|
| | Drilling & Completion | Dry Hole | Production & Lease Equipment | Waterflood Equipment | Primary Operating Cost | Incremental Secondary Operating Cost |
| East Texas (6,107) | 248,915 | 190,301 | 101,243 | 105,124 | 15,117 | 25,907 |
| Gulf Coast (6,569) | 224,522 | 178,899 | 75,520 | 127,642 | 20,384 | 42,579 |
| North Central (3,295) | 88,659 | 62,430 | 50,714 | 47,464 | 9,826 | 17,265 |
| Appalachia (1,623) | 37,297 | 23,555 | 37,929 | 41,944 | 8,211 | 14,004 |
| Southeast (8,969) | 512,570 | 512,438 | 123,589 | 174,052 | 36,114 | 41,870 |

Sources of Data:

1. Equipment & Operating Costs: DOE/EIA-0185(86)
2. Drilling & Dry Hole Costs: 1987 Joint Association Survey on Drilling Costs

Prepared By: ICF-Lewin Energy (1989)

TABLE 5
STATE INCOME AND SEVERANCE TAX RATES
Used in the REPCO Onshore Model

| Analysis Region | State Income Tax Rate (%) | State Severance Tax Rate (%) | Key Oil Producing State |
|------------------|------------------------------|---------------------------------|----------------------------|
| West Coast | 9.6 | 0.0 | California |
| Northern Rockies | 6.75 | 5.5 | Montana |
| Central Rockies | 5.0 | 5.0 | Wyoming |
| Southern Rockies | 6.0 | 7.78 | New Mexico |
| Mid-Continent | 4.0 | 7.0 | Oklahoma |
| West Texas | 0.0 | 5.0 | Texas |
| East Texas | 0.0 | 5.0 | Texas |
| Gulf Coast | 8.0 | 12.5 | Louisiana |
| North Central | 6.5 | 0.0 | Illinois |
| Appalachia | 0.0 | 0.0 | Kentucky |
| Southeast | 5.0 | 8.0 | Alabama |

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