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MEMORANDUM

To: DOE Oil Stockpiles
From: J. Read
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This memorandum explores several alternative theories of oil inventory management and their implications for the level of private petroleum stockpiling. In what follows, we outline four theories, describe their qualitative implications for private oil stocks, and estimate the value of government payments required to induce additional stockpiling under the four policy options outlined in the DOE memo of October 1981.

We consider four alternative but related theories. In each case, managers recognize the potential for capital gains and losses on petroleum stocks. The distinctions are the influence acquisitions and sales have on market prices, the assessment of the risk of investing in oil stocks, and expectations concerning petroleum market failure during a disruption.

The first theory might be referred to as the "perfect markets" case. It assumes that the product markets are competitive and the capital markets are efficient. It also assumes that investors expect oil markets to function during a disruption. These assumptions are embodied in the CRA private petroleum stockpiling model.*

The other three theories relax these assumptions. First, we consider the results when oil stockpilers influence the price at which they can buy or sell strategic oil stocks. Second, we lift the assumption that the owners of oil inventories are diversified investors. This implies that they consider the diversifiable as well as the non-diversifiable risk of oil. Finally, we consider the case in which petroleum markets fail during a disruption.

Based on our assessment of the effects of these alternative assumptions on cash flows and implicit discount rates, we describe the qualitative implications for the level of private stocks. These are then explored more fully using a modified form of the CRA private petroleum stockpiling model. The memo looks at the four policy options that were analyzed in depth in the DOE memo to the OMB of October 1981. We estimate the required level of payments under each of these policy options based on the four theories described in the text.

* CRA (1981) contains a complete description of the private petroleum stockpiling model. See Chapters 6 and 7.

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I. THEORIES OF OIL INVENTORY MANAGEMENT

The theory of oil inventory management implicit in CRA's earlier work (see Chapter 6 of Public Policy and Private Petroleum Stockpiling) provides the point of departure for this memo. We made the following important assumptions: that the product market for oil is competitive and that the capital market through which investments in oil stockpiles are financed is efficient. We also assume that these conditions are expected to prevail even in the event of a supply interruption. These assumptions constitute our "benchmark" theory of oil inventory management. Variations on this theme provide the alternative theories of inventory behavior explored below.

CASE I: THE BENCHMARK CASE. Competitive product markets and efficient capital markets. These assumptions are described more fully next.

By competitive product markets, we mean that there are "many" buyers and sellers of oil. More specifically, the number of buyers is sufficiently large that the acquisition of strategic oil stocks by a single buyer does not influence the purchase price of oil. Likewise, drawdown and sale of oil during a disruption does not have a perceptible effect on price. Thus the managers of petroleum stockpiles behave as price takers when deciding to purchase or sell strategic stocks.

Competitive product markets also embody the feature that corporate managers undertake valuable investment opportunities. Their objective is to maximize the value of the firm. Investment value depends on the amount and timing of expected cash flows, and the returns available from investments of comparable risk.

By efficient capital markets, we mean two things. First, that information is fully and quickly reflected in the market price of securities. This means that when profitable investment opportunities arise, it will be possible to raise the necessary capital to finance those investments. The empirical literature provides substantial evidence that U.S. capital markets are efficient in this sense.*

The second idea implicit in our use of the term "efficient capital markets" is that wealth tends to be held in diversified portfolios of investments. Because the returns on different investments are imperfectly correlated, the risk of a particular investment in isolation and the risk of the same investment in the context of a portfolio are different. It is generally the case that much of the risk of an investment can be "diversified away"

* See Fama (1970) for a review of this literature.

through a portfolio. Moreover, it has been shown that holding as few as ten, randomly selected securities provides most of the effects of complete diversification.*

Virtually all of the current research on the subjects of investments and corporate finance is based on the concepts of portfolio analysis. Although there is not complete agreement on a single theory of asset pricing, all of the candidate theories specify the expected return on a risky asset in terms of non-diversifiable (systematic) risk; diversifiable (unique) risk is inconsequential. Probably the most popular model is the Sharpe-Lintner Capital Asset Pricing Model (CAPM).

The CAPM gives the expected rate of return on an asset as a linear function of the current riskless interest rate, the expected return on the market, and the "beta" coefficient of the asset. Beta depends on the covariance of investment returns with the returns on assets generally. This implies that investment cash flows are discounted at a rate which reflects only systematic risk.

CASE II: MONOPOLISTIC PRODUCT MARKETS. In this case we drop the assumption that the market for oil is atomistic. Specifically, we consider the case in which oil stocks are concentrated in the hands of a few owners who perceive their market power. In contrast to the benchmark case, in which price is viewed as a parameter, the owner of strategic oil stocks sees the acquisition cost of oil rise with additional purchases; and the sale of oil stocks during a disruption depresses the price received by the owner.

In the benchmark case, the marginal cost of holding strategic oil stocks is equal to

$$(1) \quad MC = P + H$$

where P is the market price of oil and H is the holding cost, including the opportunity cost of capital. In this case, however, the marginal cost is

$$(2) \quad MC = P + (\Delta p / \Delta q)q + H$$

where the Δ 's denote increments to price and quantity due to strategic acquisitions. The latter can be rewritten as

$$(3) \quad MC = P(1 + 1/\epsilon) + H$$

where ϵ is the price elasticity of supply. In an atomistic market, the elasticity of supply is infinite; the buyer cannot influence price. Thus equations (2) and (3) just reduce to (1).

*See Evans and Archer (1968) for an elaboration of this point.

Similarly, in the benchmark case, the marginal revenue from sale of oil during a disruption is

$$MR = P$$

and in this case it is

$$MR = P + (\Delta p / \Delta q)q$$

$$(4) \quad MR = P(1 + 1/\eta)$$

where η is the price elasticity of demand during a disruption; of course, the demand elasticity will have a negative sign.

The monopolistic product markets theory may have application both to the acquisition of stocks and to the drawdown of stocks. Whether the theory is relevant to either situation depends on a number of factors. Among these are the rate of acquisition of stocks, the aggregate amount of strategic stocks, the number of independent strategic inventories, and the current utilization of worldwide production capacity. The issue is not whether strategic stocks in the aggregate influence oil prices, but whether individual inventory decisions affect price.

It is not clear that a concentrated product market is a useful assumption for analyzing the acquisition of strategic oil stocks. World production of crude oil is about 22 billion barrels per year; in 1981, OPEC production alone was over 8 billion bbls. Assuming that stocks are acquired over the course of a year and that the increment to stocks is on the order of 100 million barrels, it appears unlikely that there would be an important influence on the price of oil.

Consider an example. Suppose that a single inventory is responsible for the entire increment to strategic stocks during a twelve month period. In addition, suppose that this increment is equal to one billion barrels of oil. These are extreme assumptions. But the fraction of the annual world production represented by this stockpile is less than 5 percent. If this stockpile were distributed between 10 owners, still an unrealistically concentrated scenario, each stockpile would represent less than one-half of one percent of the world market.

A surge of oil acquisitions occurring within a short time span (due, say, to generous government subsidies for stockpiling) might well trigger a market price response. This possibility is particularly germane with a concentrated supply market (e.g. OPEC). But the price increase would not be due to an incremental acquisition of stocks. It is qualitatively different from the monopolistic product markets theory, which holds that individual inventory decisions influence price.

The sale of strategic oil stocks during a disruption also could contain elements of market power. The scenario we have in mind is a disruption of the magnitude and duration considered in detail in our earlier work: a 60 percent reduction of net oil imports for a period of nine months.

Consider this hypothetical disruption in light of equation (4). The marginal revenue from oil sale during the disruption is

$$MR = P(1 + 1/n)$$

We have assumed elsewhere that the price elasticity of demand for oil during a disruption is 0.25. This would be the appropriate value for the marginal revenue equation of a firm if it were a monopoly source of crude oil. When there is more than one U.S. producer of oil and/or more than one strategic inventory, the market elasticity of demand must be scaled down to give the elasticity faced by a firm. That is, the individual inventory manager will see a more elastic market than a monopolist. Specifically, the firm's marginal revenue is equal to

$$(5) \quad MR = P(1 + (1/n)(s_i/Q))$$

where s_i is the size of the stockpile held by owner i and Q is equal to the size of the U.S. market during a disruption.

Consider another example. U.S. consumption of crude oil is approximately 6.7 billion bbls per year, U.S. production is 3.8 billion bbls per year, so net imports are 2.9 billion bbls. The corresponding figures for a nine month period are 5.0, 2.9, and 2.2 billion bbls, respectively. The disruption leaves 0.9 billion bbls of imported oil during the nine month period. The supply shortfall is 1.3 billion bbls.

The benchmark case provides the upper bound to marginal revenue: the price elasticity of demand is zero and marginal revenue is equal to price. A lower bound is given by the following exercise.

Suppose that strategic stocks are held by a single owner. Suppose also that the size of this stockpile is equal to the shortfall in supply during a disruption, 1.3 billion bbls. Then the fraction of the oil market represented by this stock is about 25 percent. If this scale factor is plugged into equation (5), marginal revenue is equal to zero:

$$MR = P(1 + (1/-0.25)(0.25)) = 0$$

If we consider more reasonable conditions in the market for oil, the marginal revenue approaches price. Suppose that the same size strategic stockpile is distributed evenly among 10 owners. Then the marginal revenue is

$$MR = P(1 + (1/-0.25)(0.025)) = 0.9P$$

With 20 sellers, the marginal revenue from oil sales is equal to 95 percent of price. Therefore, some market power during an import disruption is not implausible. The possibility would be reinforced if the primary holders of strategic stocks were also the major U.S. producers of petroleum.

CASE III: MANAGERIAL RISK AVERSION. There are two possible reasons for analyzing oil stockpiling behavior from the perspective of undiversified owners. One would be prior knowledge that the owners of companies most likely to invest in strategic stockpiles are in fact undiversified. This might be a valid point if, for example, most oil companies were closely held. But we are not aware of any evidence to suggest that this is true. In fact, we know that at least 40 integrated oil companies are traded on the New York and American Stock Exchanges. These include the largest integrated oil producers in the United States.

The second reason for considering petroleum stockpiles from the perspective of an undiversified shareholder is due to the separation of ownership and management in large corporations. While the owners of a corporation may be well diversified, the managers may not. One can think of the managers assets as consisting of human capital as well as financial capital. A manager's human capital will tend to be concentrated in the corporation. Furthermore, a manager's financial capital may also be concentrated in the corporation, since part of his compensation typically comes through equity shares in the corporation.

The purpose of rewarding managers with an equity position in the corporation is to provide a direct incentive to improve corporate performance. But at the same time that it provides a direct interest in the profitability of the firm, an equity position also provides the manager with an incentive to reduce the riskiness of the firm. This creates a divergence of interests between managers and (diversified) owners. It is this theory that we pursue here.

Consider a hypothetical manager with all of his assets, human and financial, invested in an integrated oil company. The manager can compare his risk-return possibilities within the company to an efficiently diversified portfolio. The Standard & Poor's index of 500 common stocks can serve as a proxy for the efficient portfolio. The mean rate of return on the S & P has been about 9 percent in real terms. Over the 1975-81 period, the standard deviation of returns on the S & P was about 15 percent.

The Standard & Poor's index of integrated domestic petroleum companies can serve as a proxy for the manager's portfolio. The standard deviation of returns on that index was about 22 percent from 1975-81. Now consider an incremental investment in oil stocks. The marginal contribution of this investment to the variance (standard deviation) of the manager's portfolio is proportional to the covariance (root covariance) between returns on the portfolio and returns on oil stocks. If the returns are very highly

correlated, the covariance is just equal to the product of the standard deviation of returns on the portfolio and the standard deviation of returns on oil stocks. The latter was equal to 22 percent from 1975-81. Thus the new investment neither increases nor decreases the standard deviation of portfolio returns.

One way to evaluate the implicit discount rate is as follows. The manager can make additional investments in oil assets (i.e. inventories) with a standard deviation of returns equal to 22 percent. An alternative is to invest in the market (the S & P 500) with a standard deviation of returns of returns equal to 15 percent. If the latter investment is selected, the expected rate of return is 9 percent. The rate of return on oil assets consistent with this opportunity is 13 percent. This is more than twice as large as the required rate of return estimated by CRA (1982).

We think this provides an extreme estimate of the "managerial risk premium" that would be applied to stockpile investments. Because the returns to a risky investment are (by definition) uncertain, the value of a risky investment is a matter of judgement. No doubt managers are able to exercise some discretion in project selection, but it is highly unlikely that it could be as large as this exercise implies. After all, if the managerial risk aversion argument is taken to the extreme, we should observe more diversification activity at the corporate level than we do. Corporate managers are ultimately accountable to the stockholders. Blatent disregard for the interests of stockholders is untenable.

CASE IV: INTERNAL REQUIREMENTS MODEL. We now consider a case in which stocks of crude oil and refined products are held by firms for internal requirements only. The assumption is that oil markets are not expected to function in the event of an oil supply interruption. In order to guarantee availability of stocks, refiners and end users must stockpile petroleum for their own account.

By market failure we mean that investors expect government intervention to restrict oil prices to pre-disruption levels. Any trading of oil during a disruption takes place at these prices, but the amount of oil available is rationed by some non-price mechanism. There are three cases to consider:

1. Refined product markets function while crude oil markets fail.
2. Crude oil markets function while product markets fail.
3. Both crude and product markets fail.

These cases are considered in turn.

Failure of the crude oil market would preclude the realization of capital gains on crude oil inventories. However, refiners could still capture the value of crude oil in the prices of refined products. If these circumstances are anticipated, the universe of potential stockpilers is restricted to refiners. A subtle, though nonetheless important, implication of a restricted universe is that inventories would be concentrated in a few, politically vulnerable hands. In any case, an open market in crude oil, which would encourage widespread ownership, would not be forthcoming.

Failure of the refined product markets would preclude the realization of capital gains on product inventories. Even if the crude oil market continued to function, the opportunity for capital gains on crude would be limited by the inability to trade refined products at market prices. This case is qualitatively like the case in which both crude and products markets fail.

If neither crude nor product markets function, it will not be possible to realize capital gains on either crude or refined oil inventories during a disruption. This does not, however, preclude stockpiling for disruptions entirely. Inventories might still be acquired for internal requirements. The margin between pre-disruption prices and variable production costs provides some incentive for refiners to hold strategic inventories. Costs related to shutdown/startup of refineries, if any, provide a further incentive.

Refined product stockpiling by end users is another possibility. This could involve many sectors (e.g. industrial boilers, electric utilities, freight transportation), each with unique cost and benefit considerations. Cost characteristics include the use of inefficient storage media and the decay of refined products (gasoline, for example, evaporates). Value characteristics depend on factors such as whether or not regulators allow storage costs to be passed through to ratepayers.

If strategic inventories are confined to end users, it is unlikely that many will be able to exploit the inexpensive, floating storage capacity available through ocean tankers in the current market (approximately \$2.50 per barrel per year). CRA (1981) found that the capital costs for a 50,000 gallon underground storage tank were about \$40 per bbl. If such facilities were used for five years with no residual value, the annual storage cost is about \$8 per bbl. Thus even without considering the costs of product decay, it is not difficult to imagine storage costs three times that of the most efficient storage media, which are assumed in the benchmark case.

II. IMPLICATIONS FOR PRIVATE PETROLEUM STOCKPILING

The implication of each of the alternative theories of oil stockpiling behavior considered here is qualitatively the same: the level of private petroleum stocks will be less than the benchmark case.

With respect to the monopolistic oil markets theory, we considered the possibility that market power might influence the marginal cost of acquiring strategic petroleum stocks and the marginal revenue derived from drawdown during a disruption. It appears unlikely, but not entirely implausible, that market power has a significant influence on these decisions. If it did, the marginal cost of acquisitions would be higher than in the benchmark case and the marginal revenue from sale would be lower. Both factors tend to reduce the value of stockpiles relative to the benchmark case. They imply lower equilibrium inventories.

We reviewed the concepts of portfolio theory to show how the cost of capital is determined. Because investors can diversify some of the risk of an investment, only the non-diversifiable risk is relevant to the capital budgeting decision. Two situations in which this theory might not be applicable were described and one of them found worth pursuing: corporate managers may display aversion to diversifiable risk because their personal wealth is undiversified. This theory implies a higher cost of capital for oil stockpiles than does the benchmark case. It, too, implies a lower value to incremental oil stocks, hence a lower level of private oil stockpiles.

In the internal requirements model, inventory managers anticipate that oil markets will not function in the event of a disruption. It is assumed that refiners and end users can stockpile oil, but only for internal use. If product markets are expected to function, then the implications for private stockpiles are not necessarily severe. Even if crude markets fail, at least some of the value of oil can still be captured through product markets. If refined product markets are expected to fail, or if product markets and crude markets both are expected to fail, then the value of stocks is severely constrained. The implications are sharply lower levels of stocks.

III. POLICY OPTIONS UNDER ALTERNATIVE THEORIES

We now consider the quantitative implications of alternative theories for private oil stockpiling. The policy options considered are those described in the October 1981 memorandum prepared by DOE for the OMB. A modified version of the CRA private petroleum stockpiling model is used to estimate the required government payments under each policy option.

GOVERNMENT POLICY OPTIONS. The DOE memo described four policy options for augmenting the Strategic Petroleum Reserve.

1. Purchase oil and lease storage facilities. Oil would be purchased by the federal government and stored in segregated facilities (steel tanks, tankers) leased from the private sector. Upon termination of the lease, oil would either be sold or (assuming the government has expanded its capacity by that time) transferred to the government SPR.

2. Lease oil and lease storage facilities. Under this scheme the federal government would lease both the oil and the storage facilities from the private sector. The lease would provide control of the oil and an option to purchase. In the event of a supply disruption, the government could trade or allocate oil. If the option was not exercised by the end of the lease, control of the oil would revert to the owner.

3. Competitive subsidy. The federal government would solicit bids from the private sector to hold a specified amount of oil for a specified period. The contractor would retain possession of the oil, but would be prohibited from using it unless an "oil emergency" was declared. In the latter event, the owner would be free to trade oil. At the conclusion of the contract, control of the oil would revert to the contractor.

4. Fixed subsidy. The federal government would establish a per-barrel subsidy for oil stocks held above "normal" levels. Participating firms would submit a statement reporting the normal stock level and the amount in excess of this level that qualified for the subsidy.

The government payments under Policy Option 1 are for the purchase of crude oil and the lease of storage capacity. Crude oil prices are readily observable in the petroleum market. Current oil tanker rates, which provide an estimate of short-term storage costs, are also observable. The government bears the risk of oil. Therefore, we need not estimate a payment to the private sector for holding oil in this Option.

Under Policy Option 2, the government makes lease payments for storage capacity and for holding oil. Included in the payment is a premium for the value of the call option implicit in Option 2. We estimate the size of the payment necessary to induce 100 million barrels of strategic private stocks.

In Policy Option 3, bids from the private sector reflect the opportunity cost of storage capacity and of holding oil. Bids also reflect a small premium for the restriction on sale of oil during the term of the contract.* We estimate the one-time payment required to induce 100 million barrels of stocks under these conditions.

In Policy Option 4, the government subsidy must compensate the private sector for storage capacity and for holding oil. We estimate the annual payments required to induce the private sector to hold 100 million barrels of oil.

VALUATION OF PRIVATE OIL STOCKS. Since these policy options were designed with a relatively short-term time horizon in mind--that is, to augment the U.S. Strategic Petroleum Reserve--we used a modified version of the CRA private petroleum stockpiling model to value stocks. Instead of assuming the construction of new, efficient, long-term storage facilities, we assume that storage capacity is purchased on a short-term basis.

Our modified stockpiling model includes the following expected cash flows. The incremental cost of storage capacity, including operating costs, is equal to H dollars per barrel per year. An additional amount of F dollars per barrel is incurred to either fill or empty this capacity. Oil is purchased at a price of P_0 dollars per barrel and is expected to be sold in T years at a price of P_T , if a disruption does not occur before then. An amount equal to X dollars per barrel is expected to be earned in the event of an oil import disruption. All of these are pre-tax values.

The expected disruption cash flow depends on the magnitude and duration of the disruption, stock size, and oil market supply and demand parameters. We assume that there is a 5 percent probability of disruption (π) each year. If a disruption occurs, there will be a 60 percent reduction in imports for a period of nine months. During a disruption, the price elasticity of demand for oil is 0.25; the income elasticity of demand is 1.0; and the price elasticity of supply is 0.1.

We estimate two types of government payments to the private sector for holding oil stocks. The first is a one-time fee, denoted G , for holding a barrel of oil for a period of T years (Policy Options 2 and 3). The second is an annual fee, denoted G' , for holding a barrel of oil for each of the next T years (Policy Option 4).

The expected values of these flows, including the government payments to the private sector, are computed based on the specified disruption probability. We assume that if a disruption occurs within the next T years, then the stocks are sold but not refilled. The pattern of expected pre-tax cash flows is illustrated in Figure 1.

* We use a liquidity premium of 1 percent. See CRA (1982).

Figure 1

Valuation of Private Oil Stocks

Expected Pre-Tax Cash Flows*

<u>YEAR 0</u>	<u>YEAR 1</u>	<u>YEAR 2</u>	...	<u>YEAR T</u>
- P_0				+ $P_T(1-\pi)^T$
- F				- $F(1-\pi)^T$
- H	- $H(1-\pi)$	- $H(1-\pi)^2$	...	
	+ X_π	+ $X_\pi(1-\pi)$	...	+ $X_\pi(1-\pi)^{T-1}$
+ G				
+ G'	+ $G'(1-\pi)$	+ $G'(1-\pi)$	...	

* See text for explanation of symbols.

ESTIMATED GOVERNMENT PAYMENTS. Using the valuation methodology outlined above, including the specified disruption scenario and oil market parameters, we estimated the required government payments for each policy option under the four alternative cases described in this memorandum. These are gross-of-tax payments. If payments were declared tax-free, the required amounts would be approximately one half as large.

We made the following operating assumptions: the cost of storage capacity (H) is \$2.50 per bbl per year; the cost to empty or refill (F) is \$0.10 per bbl; gains on oil are taxed at the 46 percent corporate income tax rate; the project time horizon (T) is five years; the current price of crude (P_0) is \$30 per bbl; and investors anticipate no real growth in the price of oil ($P_T = P_0$).

The rate at which cash flows are discounted depends on the particular case and policy option being explored. However, for each combination of case and policy option, we calculated the required payment using two alternative assumptions regarding capital market conditions. Although the riskless interest rate in real terms has averaged one percent or less in the past, current market conditions imply a much higher real cost of capital. Current yields on government debt, both short and long term, are in the vicinity of 13 percent. Yet recent inflation rates have been very low. We guess that the current, real interest rate is at least 4 percent higher than it has been historically. Therefore, we make our calculations based both on historical capital market conditions and on our assessment of current market conditions.

In Policy Option 2, the government purchases an implicit call option on oil. The private sector must be compensated for the value of that option in the lease payments. As discussed in CRA (1982), the option value depends on several factors, including the exercise price and maturity of the option. If we assume that the option has an exercise price of \$45 and a maturity of one year, the value of the option is \$0.68. If, however, the maturity is five years, consistent with the length of the oil lease, the value of the option is over \$10! This would add enormously to the cost of Option 2. Instead of a simple five-year call option, the lease might include a provision for periodically adjusting the option exercise price, a feature that could substantially reduce the implicit option value.

Case I: Benchmark Case. In the benchmark case, inventory managers act as price takers, stocks are valued at the market cost of capital, and oil markets are expected to function in the event of an oil supply interruption. We assume that the cost of capital for oil stockpiling is slightly less than the cost of capital for average business investments.* The discount rate under historical market conditions would be about 5 percent. Under current market conditions, it is probably closer to 9 percent.

* See CRA (1982) for an analysis of the cost of capital for oil stockpiling. We rely on that analysis for the estimates reported here.

Case II: Monopolistic Product Markets. In this case, oil inventory managers perceive that acquisition of strategic stocks will influence the cost of oil. Likewise, their decision to sell oil during a disruption will depress prices. To illustrate the potential impact of these effects, we increase the marginal cost of oil by 5 percent and reduce the marginal revenue from oil sales by 5 percent when calculating the disruption cash flow. The cost of capital is the same as in case I.

Case III: Managerial Risk Aversion. Our analysis in Part I of this memo suggested that managers might apply a much higher discount rate to incremental investments in oil stocks. However, we concluded that there is a limit to the extent of such risk aversion. In this case, the discount rate includes a "managerial risk premium" of 2 percent over and above the cost of capital.

Case IV: Internal Requirements Model. This case is more complex than the others considered in this memo. A detailed approach might involve a sector by sector analysis of tertiary inventories, including such sectors as freight transportation, industrial boilers, and electric utilities. Holding costs and value are unique to each sector. One could assess the available storage media, the perishability of refined products, and the sectoral demand factors. That would be a study in itself. To assess the implications of the theory, we assume that the internal benefits to stockpiling at the tertiary level are offset by the high cost of storing oil. We further assume that internal benefits at the primary level--incremental profits--are negligible. These assumptions provide a lower bound to the value of stockpiling. The estimated payments compensate for the full holding cost, including the cost of capital. They are an upper-bound estimate of the payments required to induce additional private stocks of oil.

RESULTS. Of the four cases considered in this memorandum, the estimated cost to the government of building additional private stocks of oil is least under Case I. This result is consistent with our qualitative analysis. When markets work well, as Case I postulates, the private value of oil stocks is greatest, and the government needs to provide a minimum of compensation to induce additional stockpiling. We estimate the cost of a lease to the private sector to hold a barrel of oil for five years to be about \$21 in current market conditions. This cost must be adjusted upwards for any option to purchase those stocks negotiated by the government.

The case in which market power enters the the decision to stockpile petroleum (Case II) results in higher costs. However, even if we make rather strong assumptions about these factors--the marginal cost of acquiring oil is 5 percent higher than price and the marginal revenue from sale of oil during a disruption is 5 percent lower than price--the additional compensation to the private sector is rather modest. The five-year lease under current market conditions costs about \$25 per barrel, plus the option value. Most of the additional lease cost is due to the higher marginal acquisition cost of oil,

Table 1

Estimated Government Payments*

CASE I: BENCHMARK CASE

Historical Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$14.11/bbl + option value
3	\$15.93/bbl
4	\$3.41/bbl/year

Current Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$20.83/bbl + option value
3	\$22.30/bbl
4	\$5.38/bbl/year

* Based on a project life of five years. See the text for a complete description of the assumptions underlying these estimates.

Source: Calculations by Charles River Associates, April 1982.

Table 2

Estimated Government Payments*

CASE II: MONOPOLISTIC PRODUCT MARKETS

Historical Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$18.07/bbl + option value
3	\$19.85/bbl
4	\$4.37/bbl/year

Current Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$24.67/bbl + option value
3	\$26.13/bbl
4	\$6.37/bbl/year

* Based on a project life of five years. See the text for a complete description of the assumptions underlying these estimates.

Source: Calculations by Charles River Associates, April 1982.

Table 3

Estimated Government Payments*

CASE III: MANAGERIAL RISK AVERSION

Historical Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$17.65/bbl + Option Value
3	\$19.28/bbl
4	\$4.41/bbl/year

Current Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$23.70/bbl + Option Value
3	\$25.04/bbl
4	\$6.32/bbl/year

* Based on a project life of five years. See the text for a complete description of the assumptions underlying these estimates.

Source: Calculations by Charles River Associates, April 1982.

Table 4

Estimated Government Payments*

CASE IV: INTERNAL REQUIREMENTS MODEL

Historical Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$32.37/bbl
3	\$33.76/bbl
4	\$7.83/bbl/year

Current Capital Market Conditions

<u>Policy Option</u>	<u>Required Payment</u>
2	\$37.44/bbl
3	\$38.54/bbl
4	\$9.68/bbl/year

* Based on a project life of five years. See the text for a complete description of the assumptions underlying these estimates.

Source: Calculations by Charles River Associates, April 1982.

since that is an immediate, certain cash flow. The disruption cash flow has only a 23 percent chance of occurring during the term of the lease (based on a 5 percent probability of disruption), so the reduced expected revenue is not as important a factor.

Managerial risk aversion (Case III) also increases the size of required government payments. Based on a 2 percent managerial risk premium for investing in oil, the additional cost of the five-year lease over and above the benchmark case is \$3 per barrel, for a total estimated payment of \$24 per barrel. The two percent risk premium was selected through heuristic reasoning, so we can not argue strongly that this particular value is correct. Ultimately, however, there has to be a limit to the shareholder value that management can elect to ignore to meet its own objectives.

Under the theory that oil markets are expected to fail completely during an oil supply interruption (Case IV), the required payments for the four policy options are estimated to increase drastically. For the five-year oil lease, the required payment is \$37 per barrel, \$16 per barrel more than in the benchmark case. To derive these estimates we assumed that it would not be possible to realize capital gains on crude or refined products. We also assumed, in effect, that the benefits to stockpiling for internal purposes are nil. The estimated payments compensate the private sector for the entire burden of holding costs. These are extreme assumptions, so Case IV estimates are upper bonds to the amount that the government would have to pay to build additional private stocks.

The reader should bear in mind that these results depend on the entire set of assumptions made regarding disruption expectations and the structure of the petroleum market. These assumptions determine the expected reward for stockpiling petroleum. In particular, the required government payments would be smaller (larger) given:

1. A higher (lower) probability of disruption;
2. A longer (shorter) expected disruption duration;
3. An increase (decrease) in the expected terminal price of oil;
4. A smaller (larger) price elasticity of demand for oil.

All of these can have a large influence on the required payments. In contrast, holding costs, including the cost of capital, are possible to estimate with greater confidence. Perhaps the most important source of uncertainty in assessing the required payments is the expectations of investors regarding the behavior of the government in the event of a disruption. As the estimates in Case IV demonstrate, expectations of market failure make it very expensive to induce the private sector to hold additional stocks.

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