



# **The Value of Expanding the U.S. Strategic Petroleum Reserve <sup>1</sup>**

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## 1.0 Introduction

This report evaluates the net economic benefits of enhancing the U.S. SPR size and drawdown capability. The assessment of alternative U.S. sizes and drawdown capabilities is done using a numerical simulation model known as DIS-Risk. Input conditions and sensitivity cases are based upon the recommendations of the 1999 Department of Energy/Interagency SPR size study working group. As in the 1990 SPR size study, we recognize that substantial drawdown capacity already exists, both in the U.S. and elsewhere. The starting point of this analysis is the current U.S. maximum sustainable drawdown rate of 4.1 million barrels a day (MMBD) and a 580 MMB SPR size.<sup>3</sup> The focus of this study is thus placed on the *incremental* net benefits that expanding the current drawdown capacity would provide to the U.S. economy.

The world oil market has endured at least 18 significant oil supply shocks since 1951. The most notable of these, the 4 largest world oil shocks which occurred between 1973 and 1991, are now recognized to have cost the U.S. economy hundreds of billions of dollars. These costs include a loss in GDP as well as higher payments for oil imports. Since oil is traded globally, a major oil price increase spreads quickly throughout the world, with disruptive effects on most energy-using economies. Within each economy, the shock costs are spread through many sectors, the “social aspect” of which is invariably greater than the “private costs”. For this reason, oil-using firms and private consumers acting on their own behalf do not have sufficient motivation to adequately insure themselves and the nation against the widespread costs of oil price shocks. That is, the private sector will store oil at a level which is deemed profitable but which is less than socially optimal. Because most of the economy-wide costs of disruptions are “external” to the cost-benefit considerations of private agents, public investment in a program of strategic oil storage is needed.

Strategic oil stocks, by buffering oil supply losses and mitigating sudden major oil price shocks, are a direct and effective means for dealing with the risk to economies of persistent supply and price volatility. Private agents cannot justify holding large oil stocks for the long term as a contingency against unlikely, but potentially dramatic, market upheavals or geopolitical struggles. The private storage costs are too high, the planning time horizons are too long, and the direct benefits to the private agents are too low.<sup>4</sup> Thus, it is incumbent on the public sector to hold strategic oil reserves since private agents are either unwilling or unable to do so.

This paper summarizes the estimated net benefits of expanding U.S. strategic oil stocks from the current 580 million barrel (MMB) size, and analyzes the efficient reserve size. It recognizes that substantial strategic oil reserves already exist, both in the U.S. and elsewhere. The focus is on the *incremental* net benefits of expanded stocks to the U.S. economy. The estimates are based on

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<sup>3</sup> Expected SPR size and draw rate by the end of the calendar year 1999.

<sup>4</sup> Unless the government provides incentives for added storage, private oil inventories are principally “working stocks.” They are held to ensure reliable plant operations and process flows in the face of routine logistical delays, normal demand fluctuations, and modest short-term price variations.

the economic protection that additional stocks would provide, *beyond* that protection already provided by the current U.S., Asian, and European strategic oil stocks. Thus we are considering the incremental net benefits to the U.S. of incremental changes in U.S. stockpile size.

The assessment of alternative U.S. reserve sizes is done with a numerical simulation model. In Section 2.1 we begin by summarizing the analytical approach used, a probabilistic cost-benefit analysis. In Section 2.2 and 2.3 we characterize base oil market conditions used, and possible disrupted market conditions. Section 2.4 discusses the similarities to and differences from the 1990 DOE/Interagency Study. Sections 3.1 and 3.2 summarize the cost and benefits of oil stockpiling. In establishing cost and benefit determinants for this study, we draw on other background studies, including the engineering-estimates of storage facility costs developed by PB-KBB (1998, 1999). Section 3.3 summarizes the best available understanding of the macroeconomic cost of oil price shocks to U.S. economies. Sections 4.1 and 4.2 show the results for what we characterize as the Base Case. There we find that a moderate expansion of the U.S. reserve (on the order of at least 120 million barrels) is justified on the basis of its expected net benefits to the U.S. economy alone. In Sections 4.3 and 4.4 we explore the sensitivity of this conclusion to our treatment of oil market risk, sensitivity of GDP to shocks, and other relevant uncertainties. Finally, section 5.0 summarizes the implications of this economic net benefit analysis for efficient U.S. strategic reserve size.

The analysis presented here strongly supports the conclusion that expanding the U.S. Strategic Petroleum Reserve by at least 120 Million barrels is justified on the basis of its expected net benefits to the U.S. economy. Our evaluation included the reserve's ability to reduce GDP losses and oil import costs during oil shocks, and subtracted the costs of building, filling, and operating the reserve. The conclusion that a substantial reserve expansion is justified holds true over a range of conditions, including more optimistic oil market assumptions which entail lower disruption risk over the next few decades. It also holds true for a range of variation in other key parameters such as the GDP elasticity with respect to oil price shocks, and for substantially higher storage costs than those of the least expensive alternative, underground salt caverns.

## 2.0 Approach of the Current Size Study

### 2.1 Summary of the Overall Cost-Benefit Analysis Approach

The essential issues for U.S. reserve planning may be summarized in a short list:

- ! Assessing the potential causes and likelihood of oil supply disruptions taking place.
- ! Accounting for existing strategic stocks and international cooperation on the use of the stocks.
- ! Estimating the costs to the U.S. of oil disruptions, and the incremental ability of additional strategic stocks to reduce those costs.
- ! Estimating the costs of buying and storing strategic crude oil stocks.
- ! Determining the net benefit and efficient level of U.S. strategic stocks.

The cost-benefit approach uses a simple model of the oil market and the U.S. economy to unify these factors. Because oil market disruptions are of highly uncertain frequency, magnitude, and duration, net benefits are estimated by solving the model over many possible market outcomes in a randomized or probabilistic fashion. Any additional U.S. reserves are coordinated with existing U.S. and other strategic stocks, totaling roughly 1276 million barrels. New reserves expand the combined total and the maximum draw rate.<sup>5</sup> The benefits calculation takes into account recent empirical evidence on the macroeconomic cost of oil shocks, and uses shock-cost parameters estimated specifically for the U.S. economy.

#### 2.1.1 General Probabilistic Modeling Approach

The expected benefits and efficient level of U.S. strategic oil stocks is determined using a Monte Carlo simulation of the world oil market, with and without additional U.S. stocks. Each simulation is composed of thousands of samples, each sample being a randomized projection of the world oil market through the year 2030. The thousands of iteratively sampled outcomes are then recorded and used to produce the expected (or mean) value of the reserves. For a given random outcome of the world market, if a disruption occurs, any available offsets such as world excess oil production capacity are used to alleviate it. If a net disruption remains (after available offsets) then the U.S. reserve is used, in addition to existing IEA and other strategic reserves. For every random realization of the future oil market, we compare the benefits provided by the current world strategic stocks with the benefits that would be offered by expanded stocks. Clearly, the world strategic stocks added by a U.S. expansion will provide additional benefit only in the event of an especially large disruption, a long disruption, or in the rare case of a sequence of smaller disruptions in quick succession. While such events may be deemed unlikely, *if* they do occur, an expanded reserve could easily be worth \$30 billion or more in avoided economic

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<sup>5</sup>The precise treatment of this stock coordination issue does not appear to be a critical assumption for the estimation of the benefits of incremental U.S. stock. The key issue is the likelihood of situations where incremental storage is beneficial, after it is recognized that many circumstances are adequately covered by existing market buffers and strategic stocks.

shock costs. The expected net benefit calculation weights the magnitude of these large avoided shock costs by their relative frequency of occurrence, and compares that expected benefit with the cost of the reserve.

### **2.1.2 Costs and Benefits Included**

The costs included are the net costs of the oil and the cost of additional storage facilities (if required). These costs are borne by the U.S. as owners of the reserve. The benefits are the avoided disruption costs due to the reserve. These benefits are gained by all oil using and consuming economies.

Consider first the net costs of the reserve itself. Viewed like any investment, a strategic petroleum reserve has both a cost side and a revenue side. The costs include the capital expenditures necessary to build the storage facilities (if required), the cost of oil purchases, and the operation and maintenance (O&M) costs borne when filling, drawing down, or maintaining the reserve on standby.<sup>6</sup> The revenue side includes the revenue from selling the oil. The costs and revenues are distributed over time, with most of the costs preceding the revenues. The payment streams are discounted to account for the opportunity cost or time value of funds. Ordinarily, for a private venture to occur, the discounted revenues must be expected to outweigh the discounted costs, and a profit is anticipated.<sup>7</sup> However, unlike profitable private ventures, a strategic petroleum reserve's net revenues are invariably negative due to long periods of discounting, the slow projected rate of oil price increase, and the comparatively low probability of ever selling the oil at a profit during a disruption. Thus, for a private firm to hold strategic stocks there must be more incentive.

Unlike private firms, governmental entities are concerned not only with net revenues or profit, but also with external benefits to the society as a whole. Such benefits are not internalized by private firms. One such benefit is the avoided GDP losses to the entire economy due to the existence of the reserve. A strategic reserve can be used to dampen or eliminate potential oil price increases due to a shock. Oil price increases reverberate through the economy in a costly way, as discussed at length in Bjornstad, Jones, and Leiby (1997). The costs of oil market disruptions has been studied extensively over the last two decades (e.g. Hamilton 1983, Mork 1989, Mork, Olsen and Mysen 1994). The magnitude of these losses can be roughly gauged

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<sup>6</sup>These O&M costs (during filling, drawing, and standby), are modest compared to the larger costs of capacity construction and oil purchase.

<sup>7</sup>Because private agents are smaller and more risk averse than governments or entire economies, and because the private cost of funds (interest rate) typically exceeds the government cost of funds, the discount rate used by private investors is ordinarily much higher than that used in government planning. This raises another significant obstacle limiting the private long-term storage of strategic oil stocks.

through the use of the estimated GDP elasticity with respect to oil price shocks.<sup>8</sup> Another public benefit is the terms of trade effect or avoided net import costs of oil. Net import costs can be simply defined as price times import quantity. When an oil price shock occurs, price rises and demand falls. Since oil demand is highly inelastic in the short run, the price rises more than demand falls and net import costs increase. The use of the strategic reserve in these circumstances reduces the price increase and the demand decrease. The combined effect is a reduction in net import costs.

In summary, the cost and benefits of an strategic reserve can be categorized into four components. Two concern the cash flows associated with the reserve itself and are borne by the owner-operators: the capital cost stream; and reserve net revenues. The other two components concern benefits to the economy: avoided GDP losses; and avoided net import costs. The net present value (NPV) of an strategic petroleum reserve is given by the discounted sum of these components.

Writing the expected net benefit calculation in equation form, we have:

$$\begin{aligned}\text{Expected NPV(Net Benefits)} = & \\ & \text{Expected NPV(Avoided GDP Loss)} \\ & + \text{Expected NPV(Avoided Import Costs)} \\ & - \text{Expected NPV(Reserve Net Oil and O\&M Costs)} \\ & - \text{NPV(Facility Capital Costs)}\end{aligned}$$

Here “NPV” refers to the discounted Net Present Value over the time horizon of interest (1999-2030). “Expected” refers to taking the expected or average value over many thousands of possible realizations of the world oil market through 2030. These four cost and benefit components are estimated and totaled, and recorded using the probabilistic model, DIS-Risk, described in the next section.

### **2.1.3 Nature of the DIS-Risk Model Used**

#### **2.1.3.1 Brief Model Description**

The DIS-Risk Model applies risk analysis to assess the uncertain implications of oil stockpiling. It follows and extends the basic logic of the model previously used in the 1990 DOE/Interagency SPR Size Study [DOE 1990]. DIS-Risk is a proven, easily understood, versatile model which allows for a variety of sensitivity analysis. We summarize qualitatively the model behavior here. See Leiby and Bowman, 1997, 1999 and Leiby and Jones, 1993 for complete model documentation.

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<sup>8</sup>For completeness, we also include the avoided deadweight loss of consumer surplus in the category of macroeconomic losses. This contribution, which is so small in magnitude as to be essentially negligible, is attributable to avoided reduction in oil demand when price is held lower (other than import savings). This component is small because the potential distortion in demand and the resulting deadweight surplus loss is small given short-run demand inelasticity.



In the DIS-Risk model, two strategic reserve sizes (one with an expanded U.S. reserve and one without) are compared side-by-side. They are subjected to the same random disruptions. Each reserve is specified in terms of its costs, target size, target draw, normal fill rate, and maximum refill rate. Oil supply disruptions are simulated against reference paths for world oil price, world oil demand, and U.S. oil demand and supply.

In each year, a disruption may occur. Disruptions have a random duration and size. The length is uniformly distributed over a predetermined range of months. The gross disruption size is a random outcome which, as a percentage of total world demand, follows a smooth, 2-parameter probability distribution called the Weibull distribution. The gross disruption size is directly reduced by exogenously specified offsets from two sources: slack oil production capacity and short-run demand response (switching). The net disruption size is defined as the gross disruption size after these offsets are applied, but before any reserve draws.

If the net disruption size (after offsets) is positive, the U.S. and foreign reserves attempt to fully offset it. For the results presented, U.S. and other IEA stocks are assumed to be used in a coordinated fashion.<sup>9</sup> Aggregate drawdown rates are limited by the specified maximum draw rates for that year, the drawdown rule, and by the exhaustion rates. The “exhaustion rate” is given by the available oil in a particular reserve, divided by the anticipated disruption length (in days). Provided that no disruption has occurred, the U.S. reserve is filled toward its target size at specified normal fill rate. After a drawdown, both the U.S. and foreign reserves are filled at exogenously specified refill rates until either the planned fill-path is re-attained (as is the case for the U.S. reserve) or capacity is reached. Fill for the U.S. reserve then reverts to the normal fill rate until the desired target size is attained.

Oil shortfalls are calculated as the remaining disruption after all offsets and reserve draws. After world excess oil production capacity has been utilized, non-OPEC supply is assumed to be essentially fixed during the disruption. World oil price increases sufficiently for world oil demand to contract and accommodate the remaining net oil supply shortfall. Demand is somewhat responsive to price in the short run, and becomes increasingly elastic as the disruption becomes more severe. Specifically, demand elasticities are a linear function of net disruption size.<sup>10</sup> To calculate monthly elasticities, adjustment factors are applied to annual values. These monthly adjustment factors ensure that the elasticity of demand also increases from month-to-month during a disruption. Thus demand becomes more responsive as the market remains longer and longer in a protracted disrupted condition. After a disruption ends, world oil price declines toward the base level according to a fixed monthly decline rate.

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<sup>9</sup>Interaction between the U.S. reserve and all others can be specified as either “Coordinated” or “Foreign First”.

<sup>10</sup>The details of these variable elasticities are based on the treatment in the DOE/Interagency Study (1990), p. 4-5.

U.S. oil demand is also increasingly elastic in price. U.S. import demand equals U.S. demand minus exogenously specified U.S. supply, U.S. reserve drawdown, and a fixed fraction of world short-run fuel switching. The U.S. GDP responds to oil price shocks with an annual GDP-elasticity. GDP losses occur only during disruptions, not during their after-effects.<sup>11</sup> Total disruption costs are GDP losses, plus incremental import costs. The NPV of the disruption costs, capital streams, operating costs, and reserve net revenue is calculated, and program differences (with and without an expanded U.S. reserve) are reported. Thus for each randomized scenario sampled, the model tracks the incremental avoided disruption costs, less the incremental capital and operating costs of the reserve, for an expanded reserve compared to the existing reserve size.

The DIS-Risk model compares oil market outcomes and U.S. economic welfare over the next thirty-two years (1999-2030) for two distinct reserve programs. It uses the risk analysis methodology to simulate a large number of trajectories for oil prices and reserve activity over the time horizon, and gathers performance statistics. Both expected values and probability distribution information are gathered for the following outcome variables: NPV components of one program versus the other; incremental reserve utilization; and the number and severity of net disruptions. An important feature is that in a given experiment both reserve programs are used to address the same randomly-generated sequence of oil supply shocks. This minimizes the random variation of (incremental) program results attributable to the disruption sampling process. In addition this same random sequence is applied to all prospective reserve sizes, and sensitivity cases.<sup>12</sup>

### **2.1.3.2 Assumptions in the Dis Risk Model**

There are three categories of parameters in the DIS-Risk model: expectations about the ordinary operation of the oil market; characterizations of the riskiness of the oil market; and reserve program attributes.

The expectations about the oil economy are characterized by the reference (undisrupted) price and quantity paths for oil during the thirty-two year period over which the model evaluates the strategic reserve. These assumptions also include parameters determining the economic response to an oil price rise: the "GDP elasticity," which signifies the responsiveness of aggregate production to changes in oil prices; and demand elasticities.

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<sup>11</sup>While GDP losses are known to persist for at least a few quarters after the disruption, the treatment here merely requires that the GDP elasticities used be appropriately adjusted to reflect the discounted sum of contemporaneous and lagged losses.

<sup>12</sup>The number of random samples taken, 10,000 per run, was selected on the basis of two criteria: one automated and one by manual inspection. (1) the Monte Carlo engine was allowed to sample and internally monitor convergence criteria, including the combined stability of the mean values and certain percentiles from one sample iteration to the next. The software automatically declared convergence and stopped sampling at about the 7,500<sup>th</sup> sample. (2) We executed random samples of increasing size, with different random sequences, for a few important cases of interest. We plotted the time path of percentage change in sample mean values and found that stabilization occurred to within a few percent well in advance of 10,000 sample iterations.

The riskiness of the oil market is characterized by the frequency of supply disruptions, their duration and magnitude, and the availability of offsets to disruptions from various sources. The frequency and size of gross disruptions are governed by a Weibull probability distribution.<sup>13</sup> The duration of interruptions is also random, and the model structure allows various degrees of knowledge by the reserve managers about the a shock's duration in advance of their drawdown response.<sup>14</sup> The principal market offset which may mitigate disruptions is the world's available excess oil production capacity (slack). The second major source of offsets to a gross oil supply disruption is the reserves, both foreign and domestic.

The U.S. reserve program attributes include stockpile size, various physical operational characteristics, and several categories of cost. The current and target sizes for the reserve can be varied in the model. The rates at which the reserve can be filled initially, drawn down in the event of a disruption, and refilled afterward, also are specified parametrically. Hand-in-hand with the maximum drawdown rate which the reserve may achieve in the event of a disruption are the implicit rules governing under what conditions draw will occur, and at what rate (i.e., at the maximum rate or some lower rate). The reserve program is further described by a time path of maximum reserve size for each year in the thirty-two year evaluation period, reflecting the planned time-path of capacity addition for each target size. The capital costs and operating costs are specified for each year.

Foreign reserves which can be used in conjunction with or prior to the U.S. reserve are characterized by capacity, current (1999) size, drawdown rate, and refill rate. The costs of maintaining foreign reserves are not tracked since they have no bearing on the optimal U.S. size. Foreign reserve capacity is assumed to remain constant across the time horizon at the current size.

## 2.2 Projected Normal (Undisrupted) Oil Market Conditions

The Energy Information Administration (EIA) projections of normal, undisrupted oil markets provide the departure point for determining stockpile net benefits. The assumed world oil price and quantities for the Base Case is from the U.S. EIA's Mid Case oil price projection (AEO99b) given in the 1999 Annual Energy Outlook (AEO99). High and low sensitivities are provided by the EIA's high world oil price (HWOP) and low world oil price (LWOP) scenarios.

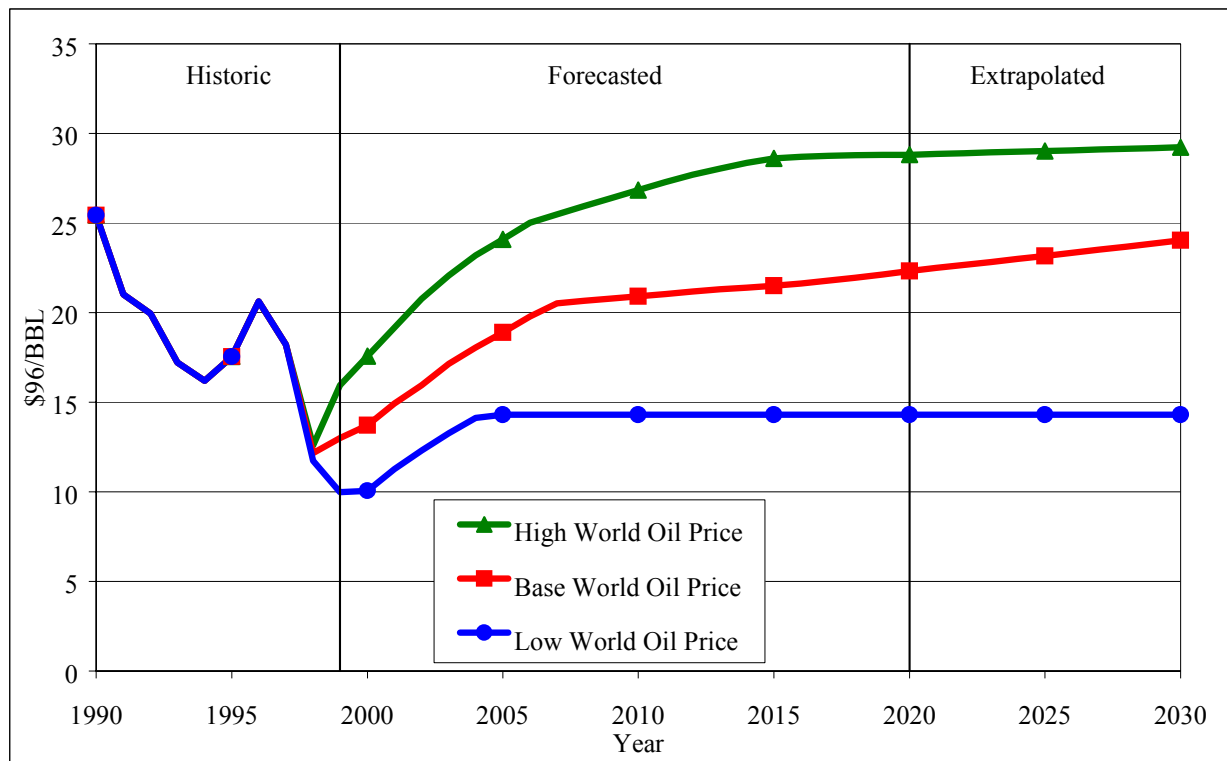
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<sup>13</sup>The Weibull distribution (also known as the extreme-value distribution) is commonly used to describe a random process where increasingly large values of a positive random variable are increasingly rare, such as the lifetime of a product, or the size of a disruption. For the Weibull distribution, the cumulative probability of observing a gross disruption of  $x$  percent or less of world demand is given by

$$F(x) = 1 - e^{-(x/\beta)^\alpha}$$

<sup>14</sup>They may have perfect knowledge about the duration, they may know the expected (average duration), or their drawdown rule may be invariant to disruption length. For this study, perfect knowledge about the duration is assumed.

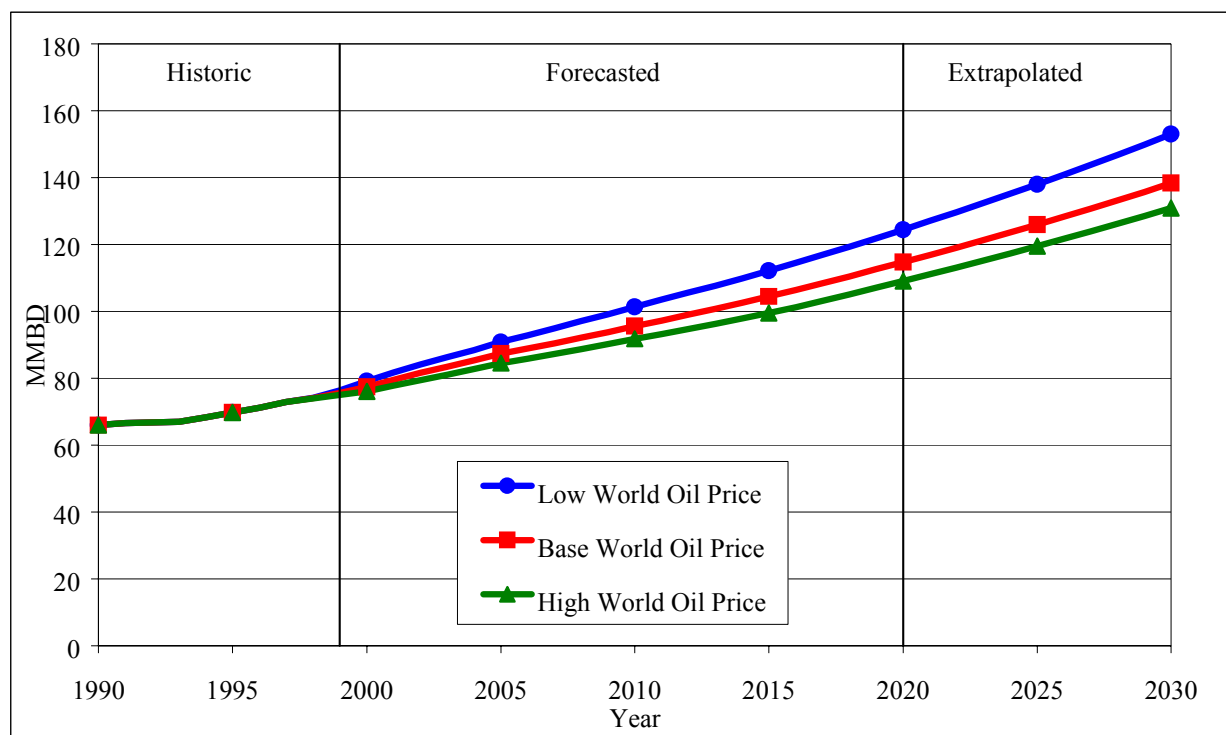
The undisrupted world oil price is used when buying oil to fill the reserve, serves as a departure point for the disrupted price, and is used to establish the value of the remaining reserve oil in 2030 (provided the market is undisrupted). As seen in Figure 2, the EIA Mid Case projection rises rapidly over the next 9 years, and then rises slowly (at about 2% per year) through 2020. This price path suggests a valuable near-term opportunity for accumulating low cost strategic stocks.



**Figure 2:** Reference (undisrupted) World Oil Price

Source: US EIA AEO99

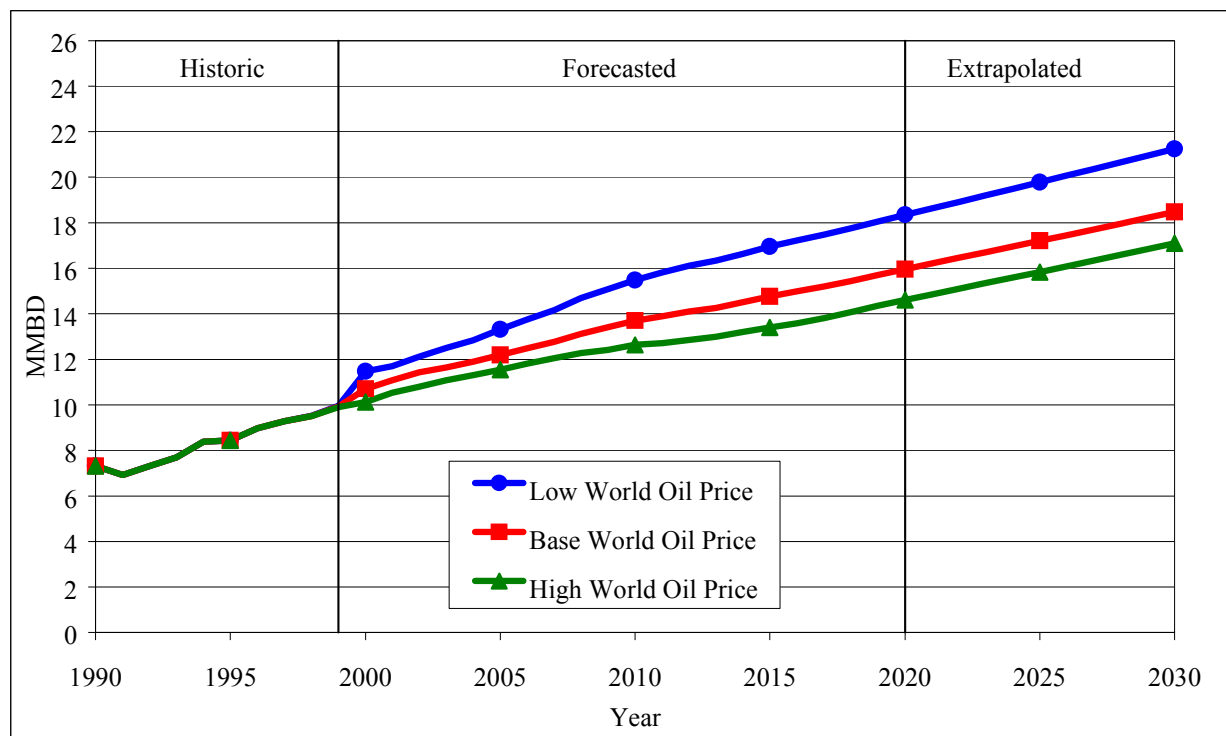
Reference levels of world oil demand (Figure 3) are used in determining the quantity of world oil shortfall given that a disruption of some percentage occurs. Elastic world oil demand (world demand less OPEC demand) adjusts to accommodate any remaining shortfall after any surge production and stock draws are applied. The elastic oil demand curve is used to calculate the world oil price at which disrupted markets rebalance.



**Figure 3:** World Oil Demand

Source: US EIA AEO99

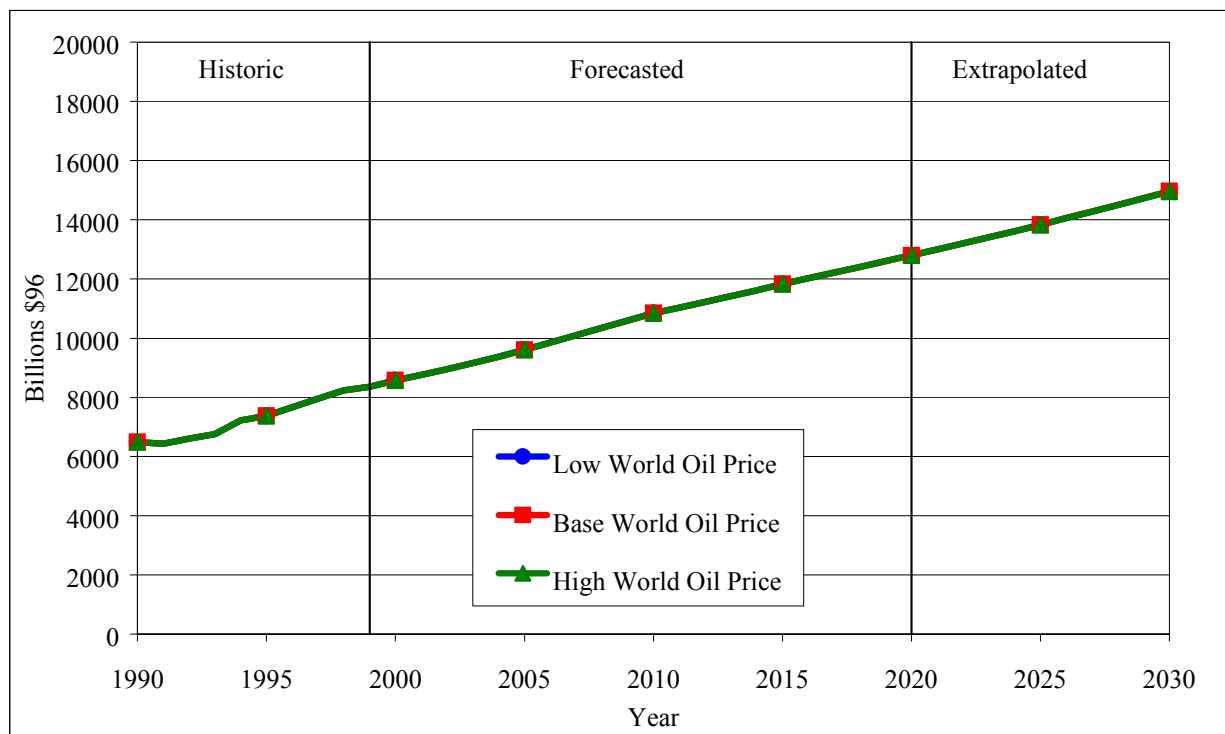
Domestic demand and domestic supply are used to determine consumer surplus and the level of net imports. Reference (undisrupted) net imports are shown in Figure 4 for the base case and high and low scenarios, and are projected by EIA to rise substantially over the forecast period.



**Figure 4:** Reference Projected (Undisrupted) U.S. Net Imports

Source: US EIA AEO99

The projected U.S. GDP path (Figure 5) indicates the magnitude of the GDP at risk to shocks each year. The magnitude of the avoided GDP losses, should a disruption occur and be mitigated by the reserve, increases in proportion to the level of GDP in the shock year. See Leiby and Bowman (1999) for further details.



**Figure 5:** Projected (Undisrupted) U.S. GDP

Source: US EIA AEO99

## 2.3 Key Determinants of Stockpile Size Analysis: Oil Market Factors

### 2.3.1 Estimated Oil Market Risk

It is very difficult, perhaps even impossible, to reliably establish the likelihood and nature of future oil market disruptions. However, there are organized ways to cope with this uncertainty. Three promising approaches to assess the risk of oil market disruptions are listed below.

- ! Look to the historical pattern and frequency of events.  
This approach relies on the limited historical record with the understanding that there are valuable lessons to be gained from history. It also is founded on the expectation that, given little information to the contrary, the past is a reasonable indicator of the future.

- ! Think about the problem carefully and apply expert judgement. This approach yields “subjective” probabilities, but goes beyond the historical data to consider what might have happened, and the important disruption events that could happen under changing conditions in the future. Expert judgement was also applied in the DOE 1990 analysis in benchmarking the probability of an extremely large event. The best published example of this expert judgement was produced by the Energy Modeling Forum (1997), which gathered a group of experts in three successive workshops to assess disruption probabilities with a subjective event-tree analysis.<sup>15</sup>
- ! Explicitly model and analyze the sources of prospective disruptions. This approach is ambitious but problematic, and has not yielded much fruit as of yet. It entails such methods as numerical modeling of OPEC power, estimates of political and economic incentives for suppliers to behave cooperatively or opportunistically, and the stability of cartel supply. Such an analysis may seek to account for expectations of growing regional imports and the implied growing OPEC share in the world oil market.

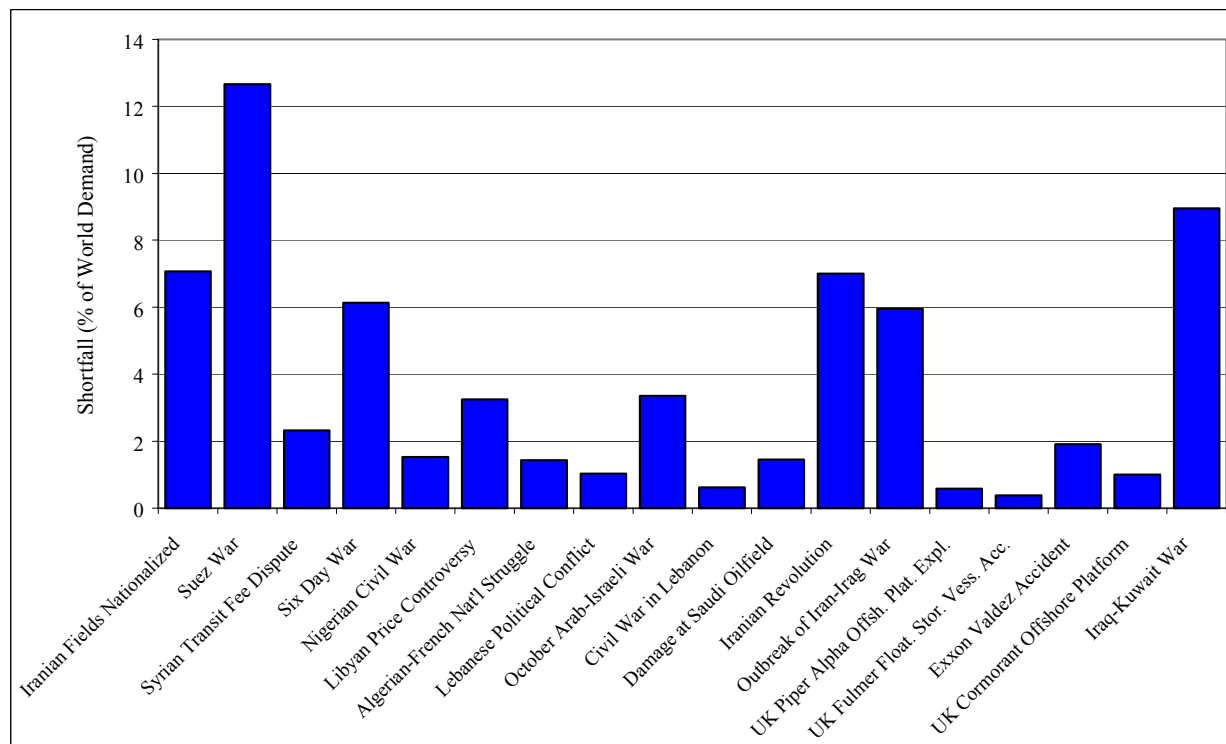
Of these three approaches, we rely on a combination of the historical and judgmental methods, as embodied in the disruption probability estimates used in the 1990 DOE/Interagency Size Study. These probabilities refer to possible global supply losses as a percentage of world demand.

Since 1951 there have been 18 significant crude oil supply disruption events (Figure 6). The causes of these disruptions are varied, but can be generally classified as war (3-5 events), internal political struggles (5 events), economic disputes and embargos (3-5 events), and accidents (5 events). The effects of an oil shock, if they are felt, are usually global in nature. As the historical record on supply shocks and price movements in Figure 7 shows, oil supply disruptions did not always translate into sharp oil price increases. Some events had little price effect due to the ability and willingness of suppliers to offset the shortfall, or due to the existence (mostly prior to 1973) of long-term pricing and supply contracts. On the other hand, some disruptions of lesser quantity-size led to enormous and long-lasting price increases (e.g. the 1973 and 1979-80 events). This history supports the important conclusion that not all supply disruptions are alike. Not only do they differ in cause and duration, but they can differ in terms of price effect. As mentioned before, a key issue is the availability of excess production capacity and the willingness of undisrupted suppliers to use it.

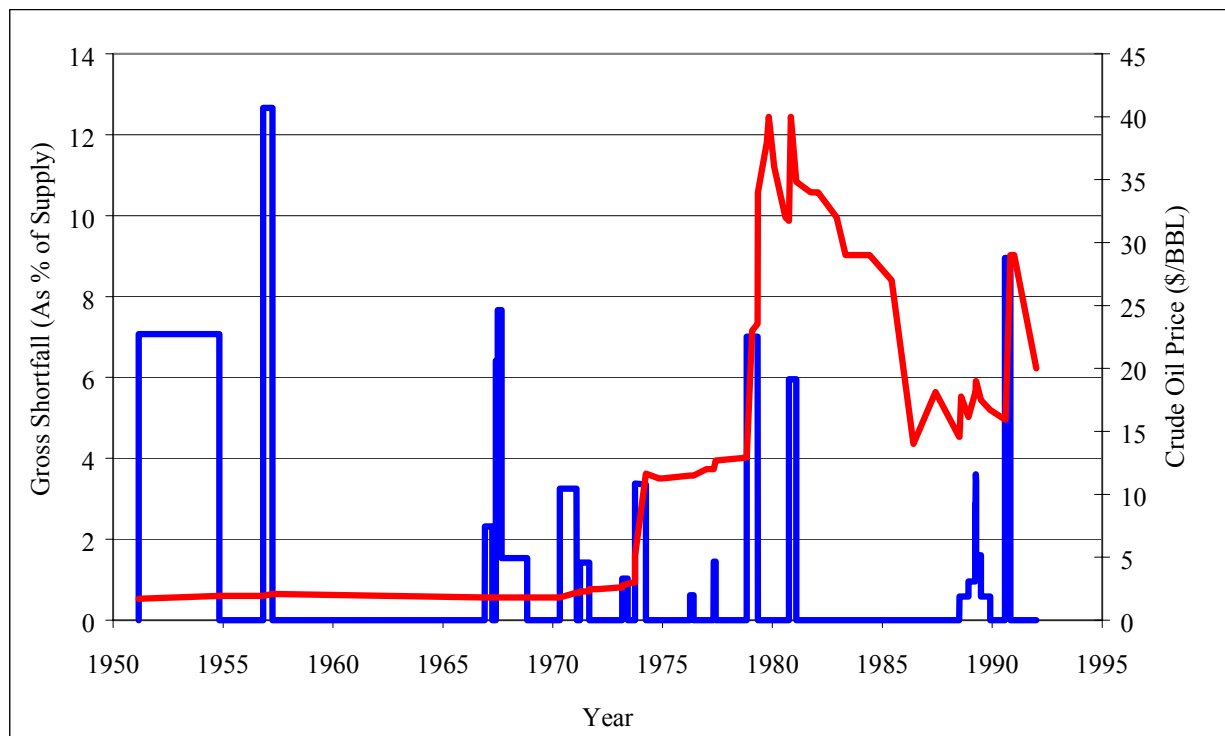
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<sup>15</sup>From 1994 to 1996 an Energy Modeling Forum (EMF) working group held three Workshops to estimate oil disruption probabilities using a process of expert judgment elicitation, akin to the Delphi method. The EMF expert panel considered specific event sequences and causes of disruptions. It focused on potential losses of supply from Saudi Arabia. It also explicitly consider the issue of disruption duration and the availability of excess production capacity as an offset.





**Figure 6:** Supply Shortfall Resulting from Crude Oil Supply Shock. 18 significant Crude Supply Shock Events since 1951.



**Figure 7:** Historical Disruptions. Not all Oil Supply Shocks Translate into Oil Price Shocks.

### 2.3.1.1 Disruption Probabilities

In this study, the Base disruption probabilities for different disruption sizes are drawn from the 1990 DOE/Interagency Study, as one of the three explicit and careful analyses currently available. The only other studies with sufficient detail and justification are based on the published work of the Energy Modeling Forum (EMF 1997) and the Central Intelligence Agency (CIA 1999, yet unpublished).<sup>16</sup> The results of these two studies, in addition to the high and low cases of the 1990 DOE Study, are included as sensitivities.

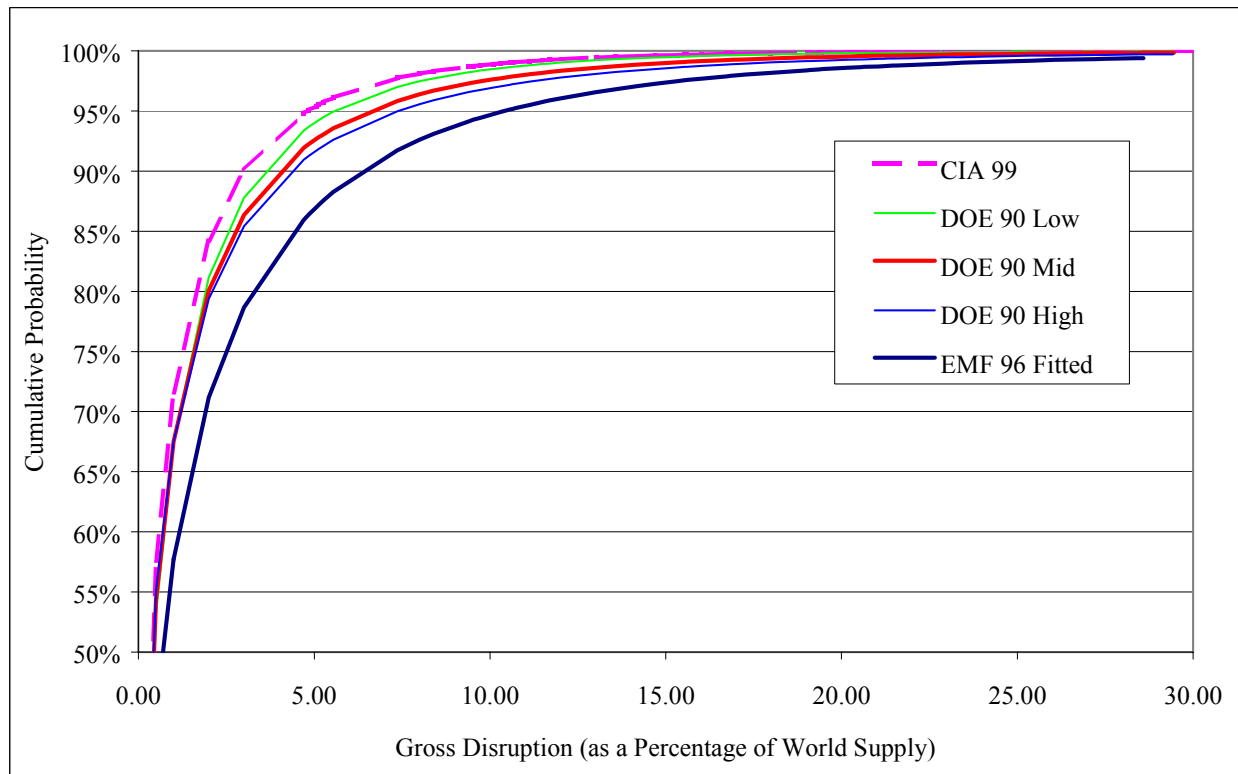
The cumulative probability distribution curves for the low, high and base case disruption probabilities of the 1990 analysis are given in Figure 8 below. They are contrasted with the cumulative subjective probabilities from the EMF expert assessment. These combined results of expert judgement from this group indicate larger disruption probabilities and greater sizes than the DOE 1990 study. However, given the lack of public review of the EMF results, and some ambiguities about their interpretation, the 1990 study results are used here instead. Conversely,

<sup>16</sup>Both the EMF and the CIA estimates are drawn from the collective opinions of a group of outside experts, with discussion guided and summarized by the sponsoring organization. While the CIA one day workshop was more recent, the EMF report relied on a more lengthy and somewhat more rigorous iterative elicitation methodology conducted in three workshops over two years.

the recent work of an outside panel sponsored by the CIA envisions a world less prone to large disruptions. Firmly in the middle of these contrasting cases is the DOE 1990 Base Case.

A crucial aspect of the disruption probability distribution is the probability it assigns to large but unlikely disruptions, since those are the cases in which available slack production capacity and existing reserves might be inadequate, and additional strategic oil stocks would be beneficial. As a guideline, it is helpful to note that the DOE 1990 Study Midcase assessed the annual likelihood of a disruption of 15% or more of world oil supply to be 1%. See the Table 1 below.

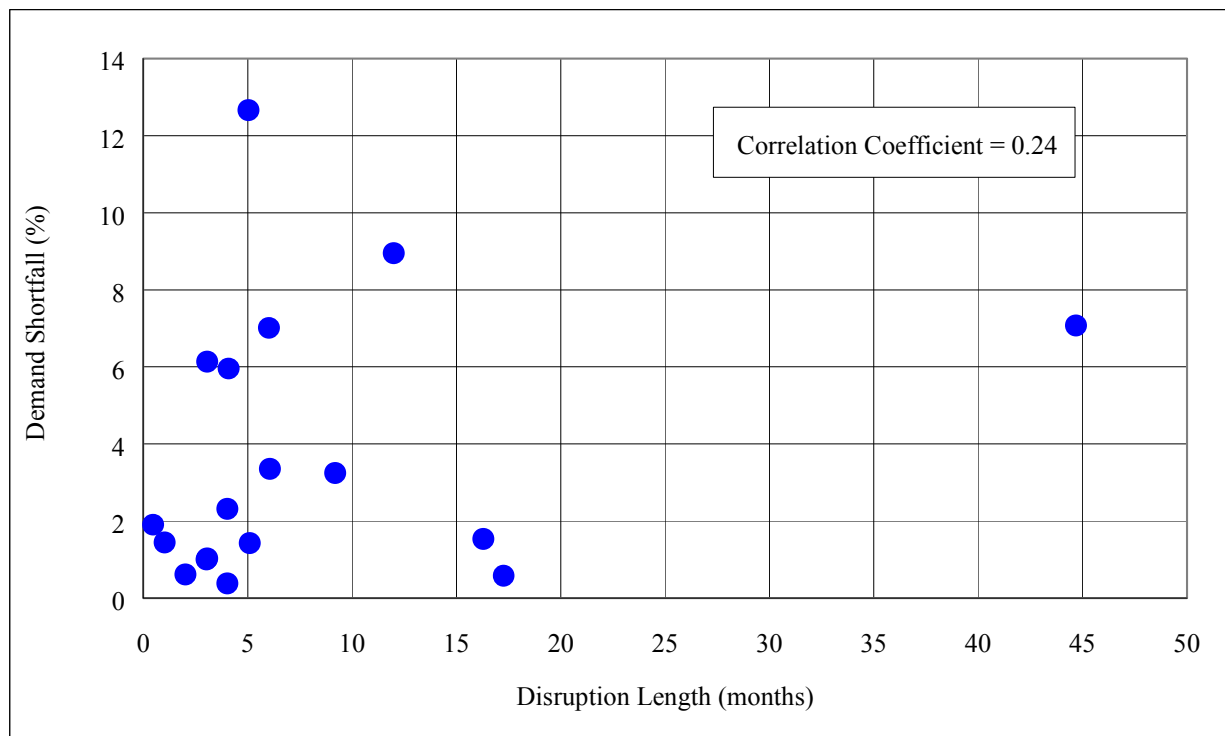
<b>Table 1: Disruption Probabilities: Annual Probability of Gross Disruption as a Percent of World Supply</b>		
<b>Case</b>	<b>Disruption of 10% or More of Supply</b>	<b>Disruption of 15% or More of Supply</b>
CIA 1999	1.1%	0.4%
DOE 1990 Lower Risk	1.5%	0.5%
DOE 1990 Midcase	2.4%	1.0%
DOE 1990 Higher Risk	3.1%	1.4%
EMF 1996	5.3%	2.5%



**Figure 8:** Comparing Disruption Probabilities. Cumulative Probability Distributions (Probability of Disruption with Size  $\leq$  Given Percentage of Supply) from DOE 1990 Study, EMF 1996 Assessment, and CIA 1999.

### 2.3.1.2 Disruption Lengths

A less studied issue is the length of the disruptions given a disruption occurs. No clear evidence points to a relationship between disruption size and disruption length (Figure 9), however the median historic disruption length appears to be about five months (Figure ?). Recognizing this uncertainty, disruption lengths are assigned a random, uniformly distributed probability. In keeping with the low historical correlation between disruption size and duration, we treat the random size and duration outcomes as independent. Sensitivity analysis using disruption lengths of 1-6; 3 and 6; 3, 6 and 9; and 3, 6, 9 and 12 months are performed with the length of 3 and 6 chosen for the Base Case.

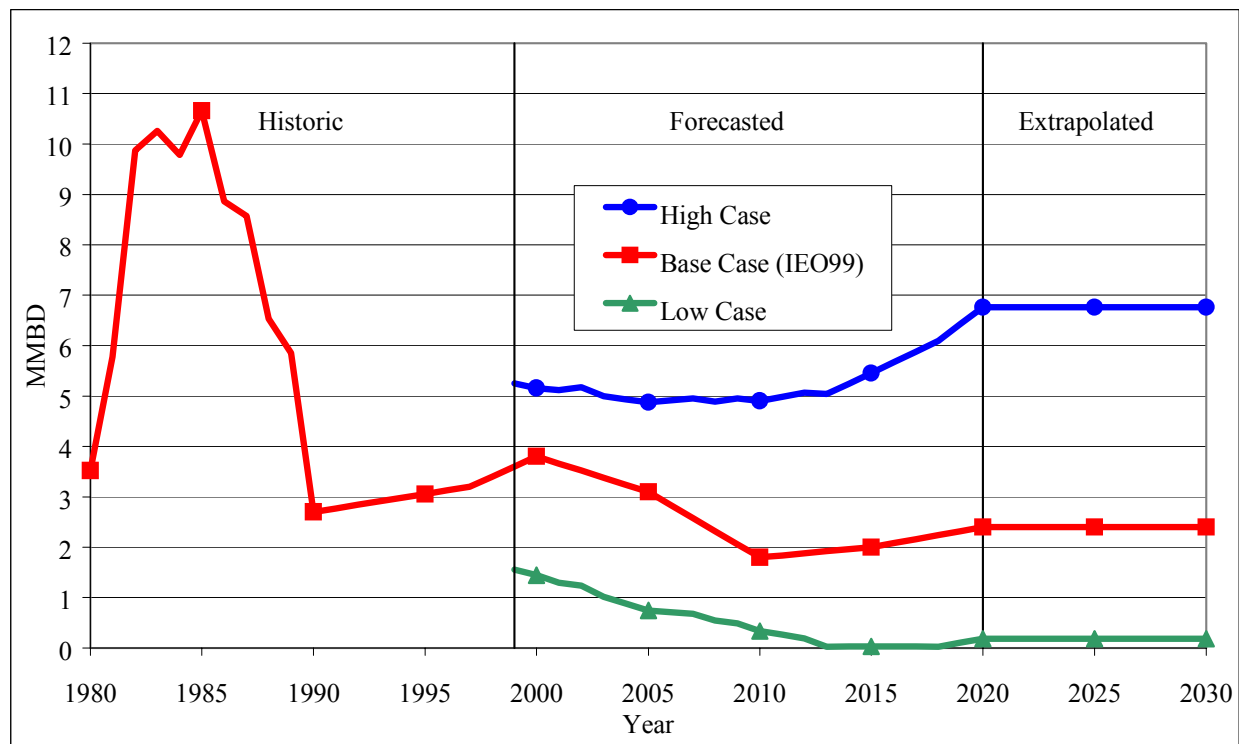


**Figure 9:** Correlation of Disruption Sizes and Lengths. Historically, Disruption Size and Duration Only Loosely Correlated.

### 2.3.2 Treatment of Offsets Available to Mitigate Disruptions

#### 2.3.2.1 Excess Oil Production Capacity Available

Disruption probabilities determine the gross disruption level but not the net disruption level. That is gross disruptions after offsets and prior to a strategic petroleum reserve drawdown. Offsets which attempt to accommodate a gross disruption include excess oil production capacity (slack capacity), demand switching, and current world strategic stocks. Slack is the excess capacity which can go online immediately (within a month) to address a gross disruption. Slack offset estimates are drawn from the Energy Information Administration (IEO, 1999) and extrapolated to 2030. The Base Case excess oil production capacity estimate begins around 4 million barrels per day (MMBD) and falls to around 2.5 MMBD by 2020. High and low slack sensitivities are estimated assuming a +/- 5% change in OPEC capacity utilization. The resulting excess capacity in the high slack case is quite high, above 5 MMBD for most of the forecast horizon, and reaching near 7 MMBD in the later years (see Figure 10). Additional sensitivities considered but not shown here are provided by Kendell (1998) and ICF (1999).



**Figure 10:** Projected Excess Production Capacity based upon IEO 1999

Given that the vast majority of excess capacity exists among OPEC members and uncertainty surrounding its availability during a disruption, these slack estimates should be considered an upper bound. All or at least a large portion of the assumed excess capacity could be unavailable in the event of a large disruption.

### 2.3.2.2 Fuel Switching

Fuel switching relates to capability of firms (primarily utilities) to switch from crude oil to other sources such as natural gas in the short run, at virtually no cost and in response to very small price changes. Fuel switching comprises small fraction of the total offsets.<sup>17</sup> The final offset which can be used to address a gross disruption is other strategic oil reserves. These include current reserves held in the U.S., Europe, and Southeast Asia.

### 2.3.3.3 Existing Strategic Oil Stocks

Existing strategic stocks, including those currently held in the U.S., Europe, Japan, South Korea, and Chinese Taipei provide an important cushion between a net oil supply shock (after supply offsets) and an oil price shock. Used with any additional U.S. stocks, they are the final line of

<sup>17</sup>Not all of the world's demand that employs switchable fuel inputs can necessarily switch fast enough or at low enough cost to be included in this category. Furthermore, excess supply and distribution capacity for the substitute fuel must also be readily available.

defense after all other alternatives are exhausted. In identifying the level of strategic oil stocks, the following definition was used: strategic stocks are defined as government owned stocks *plus* government-mandated commercial stocks in excess of normal working stocks. Current strategic stocks total approximately 1276 MMB, as itemized in Table 2.

<b>Table 2: Total Existing Strategic Stocks</b>	
<b>Region</b>	<b>Size (MMBD)</b>
U.S.	580.0
Japan	315.0
South Korea	43.0
Chinese Taipei	12.5
Europe*	325.0
Total	1275.5
*OECD Europe government owned and organizational stocks. Source: International Energy Agency, <i>Monthly Oil Market Report</i> , Table 5, various issues.	

Foreign strategic stocks (Europe, Japan, South Korea, and Chinese Taipei), acting as a group, are drawn at the maximum rate of 3864 thousand barrels a day (MBD), consistent with their six-month exhaustion rate. Unlike the predecessor to this study, the 1990 DOE/Interagency study, foreign stocks are treated as exhaustible, starting out at current levels, and should a drawdown occur, refilled to current levels at a rate of 0.381 million barrels a day (MMBD). Current Domestic (U.S.) Stocks are drawn at the maximum of 4100 thousand barrels a day (MBD) short of the engineered rate of 4415 MBD. This reduced rate is a direct result of existing storage being less than existing capacity. Existing U.S. stocks are refilled (if necessary) at the rate of 0.318 MMBD.

Foreign strategic stocks (Europe, Japan, South Korea, and Chinese Taipei) are drawn down either in coordination with or prior to the U.S. strategic stocks. Coordination among existing reserves is consistent with current IEA guidelines and is considered the Base Case. Foreign reserves drawing down prior to the U.S. or “Foreign First” is consistent with the 1990 DOE/Interagency study and is considered a sensitivity.<sup>18</sup>

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<sup>18</sup> Sensitivity analysis suggests that the choice of “Foreign First” or “Coordinated” foreign stock behavior has little effect on the results. Given the closer resemblance to real world behavior, coordination among the reserves is the preferred method for this study.

## 2.4 Similarities to and Differences from 1990 DOE/Interagency Study

Overall, this study follows the structure, spirit, and assumptions of the 1990 DOE/Interagency size study closely. The DIS-Risk model was originally designed with the ability to replicate the 1990 study, given the same inputs and the choice of certain model settings. However, since then the model has been updated, as chronicled in Table 3 below. Many changes are minor, but the more important inputs changed are: the GDP elasticity, excess oil production capacity, and the discount rate.

Table 3 summarizes the migration of major assumptions from the 1990 DOE/Interagency size study to the current size study. Included in the table below are the assumptions of the 1993 ORNL size study. We include the 1993 study assumptions to provide a brief time line of some the changes in the assumptions. A large portion of the assumption changes in the table below are principally for maintenance of the modeling framework. Changes in the time period, dollars, and discount rate are examples of such changes. Other changes in the assumptions reflect refinements of the current understanding of SPR size analysis. Examples of this include changes to the GDP elasticity and the in-depth cost analysis performed by PB-KBB. Other changes such as variable disruption lengths and treatment of foreign stock are new additions designed to more soundly characterize the issue of SPR size analysis.

<b>Table 3: Comparison of Base Case Assumptions Across Studies</b>			
<b>Study Assumption</b>	<b>1990 DOE/Interagency Size Study (DOE90)</b>	<b>1993 ORNL Size Study</b>	<b>1999 Size Study</b>
Time Period of Analysis	1990-2020, quarterly	1993-2020, quarterly	1999-2030, monthly
Dollars	\$88	\$90	\$96
Discount Rate	10%	7%, OMB Circular A-94	7%, OMB Circular A-94
Discount Year	1990	1993	1999
Disruption Probabilities	Developed for Study	DOE90	DOE90
Excess Oil Production Capacity	Developed for Study	DOE90	IEO 1999
Treatment of Foreign Stock	IEA (1989) Oil Market Report. Foreign Stock divided by 180 days. Inexhaustible Flow.	DOE90	IEA (1999) Oil Market Report, APERC (1998) (for South Korea and Chinese Taipei). Exhaustible Stock.
Domestic/Foreign Stock Interaction	Foreign Draws First, U.S. second if necessary.	Foreign Draws First, U.S. second if necessary.	Coordinated (Foreign and U.S. draw at the same time).



<b>Table 3: Comparison of Base Case Assumptions Across Studies</b>			
<b>Study Assumption</b>	<b>1990 DOE/Interagency Size Study (DOE90)</b>	<b>1993 ORNL Size Study</b>	<b>1999 Size Study</b>
Oil Market Prices and Quantities	EIA, International Energy Outlook 1990, 2011-2020 extrapolated.	EIA, Annual Energy Outlook, 1993. 2011-2020 extrapolated.	EIA, Annual Energy Outlook, 1999, 2021-2030 extrapolated.
O&M Costs (\$/BBL-Yr of Capacity)	None	None	0.17 \$/96 for sizes greater than 700 MMB, PB-KBB (1998).
Capital Costs, Time Path of Expansion, Drawdown Enhancement.	ORNL (1988) Preliminary Results of the SPR Size Cost Benefit Study, Nov 17.	Gray/Borgstrom memo (1993)	PB-KBB (1999)
U.S. GDP Growth Rate	Fixed at 2%	Fixed at 2%	AEO 1999, varies
Fill and Draw Costs (\$/BBL)	None	None	0.9 \$/96 for fill, 0.10 \$/96 for draw, PB-KBB (1998)
GDP Elasticity	-2.5% from T2/T3 Working Group (1989) Macroeconomic Impacts of Oil Supply Disruptions, Nov 27. <sup>19</sup>	DOE90	-5.4% from Mork, Olsen, and Mysen (1994) and others in similar range.
Fill and Refill Rates	Refill Instantaneously and Free.	Refill over time at market prices.	Refill over time at market prices.
Treatment of Uncertain Disruption Sizes	Weibull distribution of supply loss %. Expected value derived from discretized ½% intervals	Weibull distribution of supply loss %. Expected values derived from Monte Carlo risk analysis with 1000 random samples.	Weibull distribution of supply loss %. Expected values derived from Latin Hypercube risk analysis with 10,000 random samples.
Treatment of Uncertain Disruption Lengths	Fixed at 6 months.	Fixed at 6 months.	3 or 6 months uniformly distributed.
Terminal Time Period Evaluation	No valuation of final SPR stock.	Valuation of final SPR stock.	Valuation of final SPR stock.

<sup>19</sup>The T2/T3 study group consisted of members of the Department of Treasury, Council of Economic Advisors, and Office of Management and Budget. Based upon a review of Darby (1982) and the EMF-7 study, the group recommended a GDP elasticity range of -2% to -4% with -2.5% as a base or reference case estimate. The base GDP elasticity estimate of -2.5% was chosen based upon the professional judgement of the T2/T3 study group. See EIA (1990) An Analysis of Increasing the Size of the Strategic Petroleum Reserve to One Billion Barrels, Service Report, SR/ICID/90-01, January for further details.

<b>Table 3: Comparison of Base Case Assumptions Across Studies</b>			
<b>Study Assumption</b>	<b>1990 DOE/Interagency Size Study (DOE90)</b>	<b>1993 ORNL Size Study</b>	<b>1999 Size Study</b>
Drawdown Rule	Fixed, draw to completely offset disruption if possible.	Same	Same
SPR Starting Size (MMB)	582	575	580

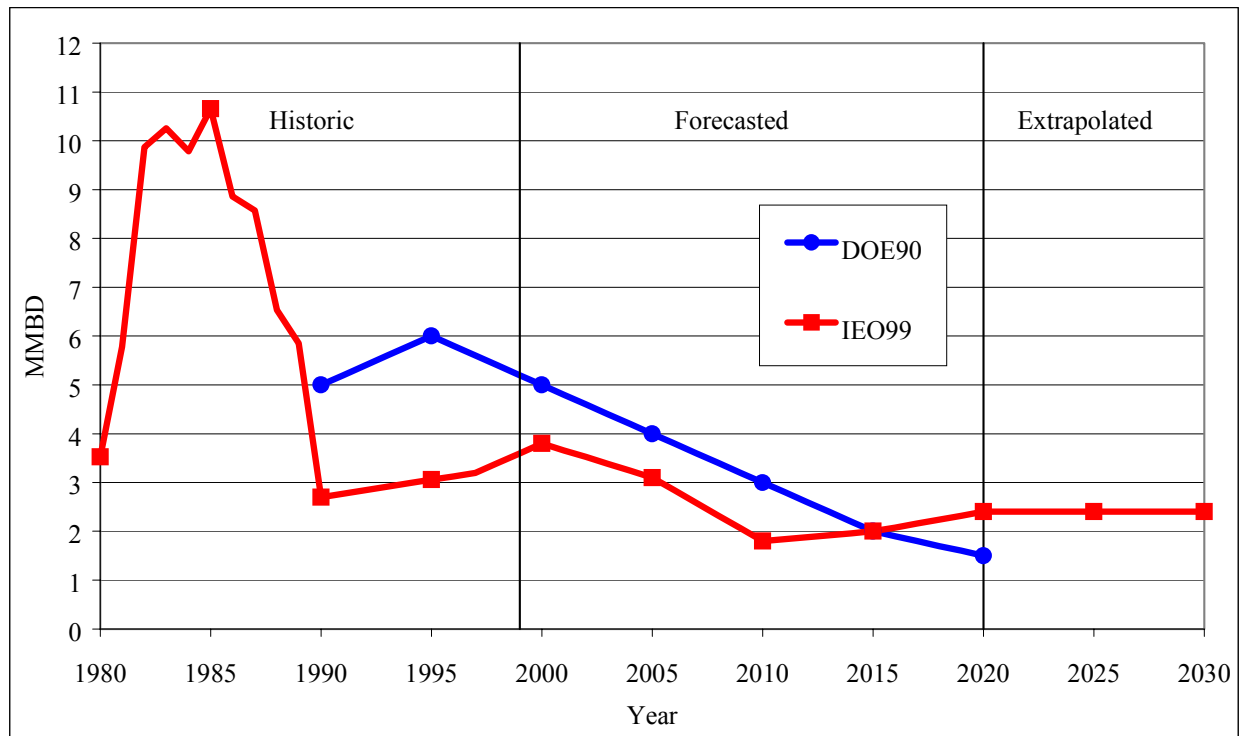
The change to the discount rate is a direct result of the OMB circular A-94 which specifies that the appropriate discount rate for the cost-benefit analysis of government projects is 7%. This circular dated after the 1990 SPR size study. Although 7% was a sensitivity case in the 1990 study, 10% was the base discount rate.

Excess production capacity in the 1990 study was the result of an ad hoc look at past excess capacities and some consideration of the future. In the 1999 study, excess production capacities are from the Energy Information Administration's International Energy Outlook 1999. Excess oil production capacities for the two studies are given in Figure 11 below.

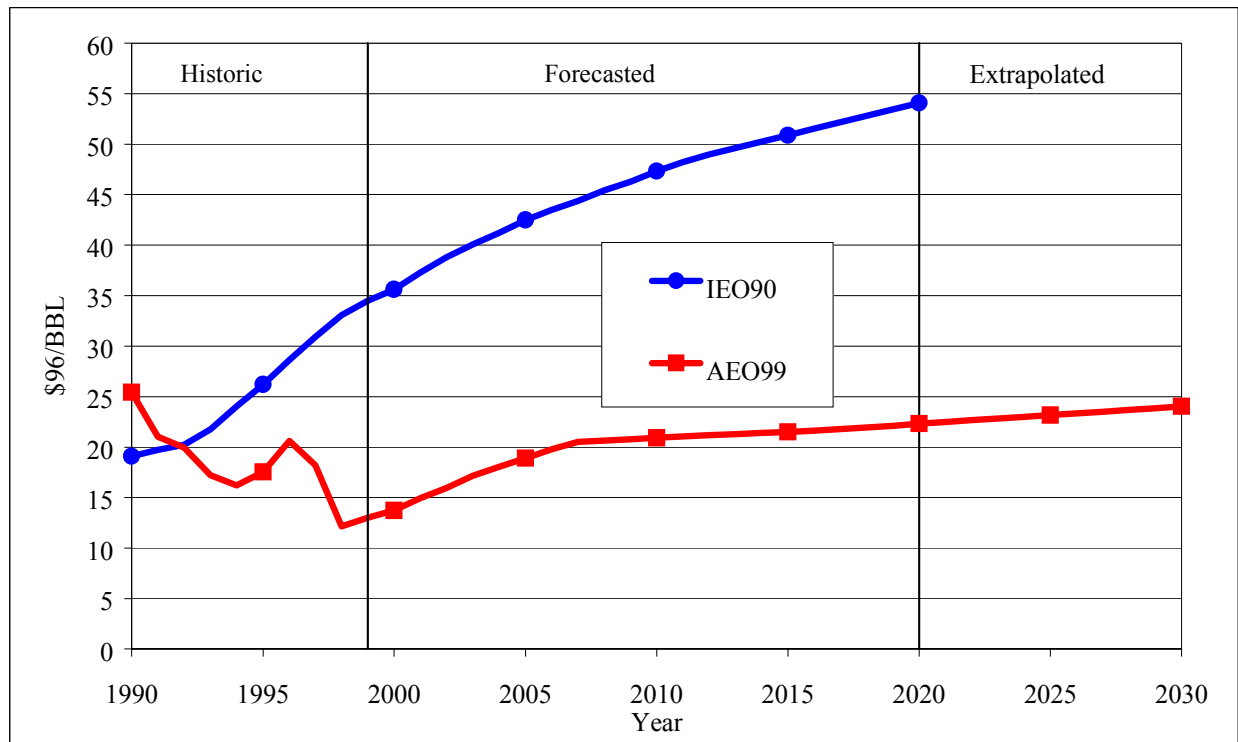
The change in the GDP elasticity estimate is a result of improved estimation tools, more time periods to analysis, improved specifications, and further careful thought on this issue. While the topic is still under study, most recent GDP elasticity studies point towards this higher estimate as our best understanding of the magnitude of the macroeconomic loss due to oil shocks.

An important change in assumptions between the two studies is the path for oil market prices and quantities. Specifically world oil price forecasts given in Figure 12 below for the 1990 study are more than double that of the current study over most of the forecast period.

Foreign stock offsets in the 1990 study were derived from current strategic stocks divided by 180 days. This produced a flow of foreign reserves which was treated as always immediately available and could never be exhausted. In the 1999 study foreign reserves are treated as a stock, which can be drawn down, refilled and, possibly in the event of large, long, or consecutive disruptions, exhausted.



**Figure 11:** Excess Oil Production Capacity for 1990 DOE Size Study and 1999 Study (IEO99)



**Figure 12:** World Oil Price for 1990 DOE Size Study (IEO90) and 1999 Study (AEO99)

### 3.0 Benefits and costs of Oil Stockpiling

#### 3.1 Key Determinants of Stockpile Size Analysis: Stockpile Cost and Performance Factors

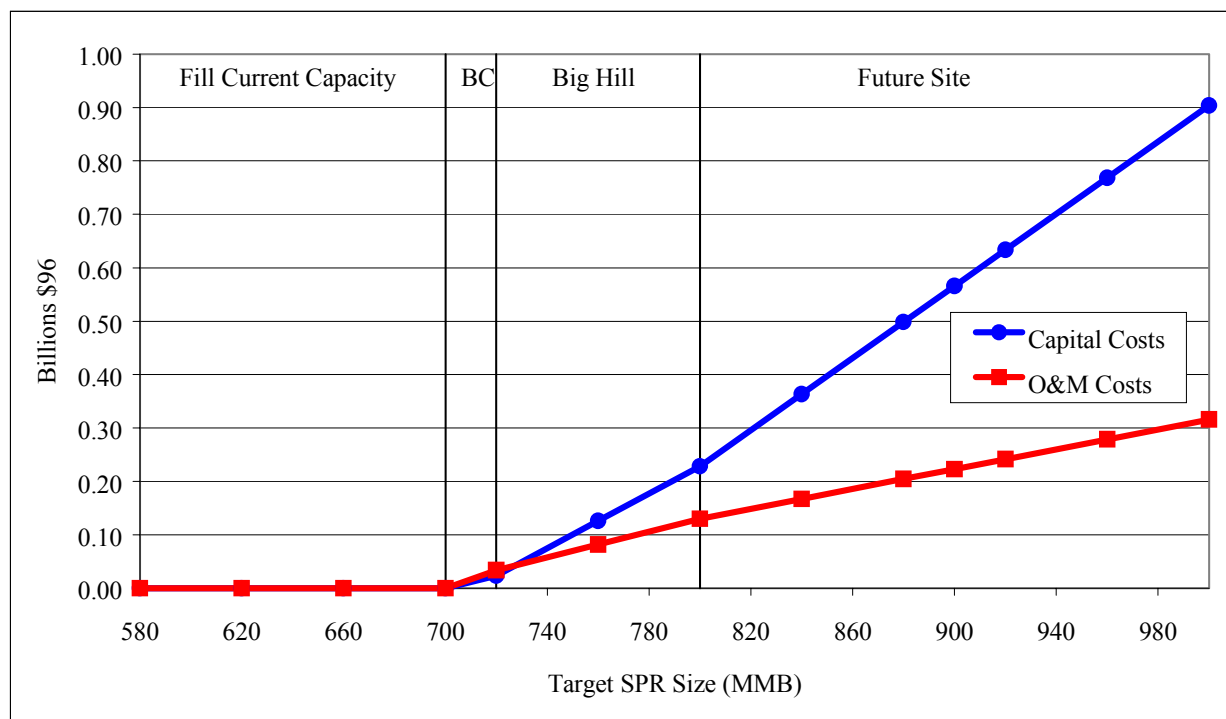
Table 4 below summarizes the cost and performance characteristics of the three potential storage sites detailed by PB-KBB in addition to the excess capacity now existing in the reserve. Note that two of these sites, Bayou Choctaw and Big Hill are additions to existing sites. The remaining facility has yet to be sited but is loosely based upon Stratton Ridge. The major cost categories are facility capital costs, operations and maintenance (O&M) costs, drawdown costs and fill costs. O&M costs are given in \$/BBL-Yr of capacity and fill and draw costs are in \$/BBL of stock).

<b>Table 4: Summary of Oil Stockpiling Information</b>				
<b>Facility</b> <b>Characteristic</b>	<b>Fill Current Capacity</b>	<b>Additions to Bayou Choctaw Capacity</b>	<b>Additions to Big Hill Capacity</b>	<b>New Facility</b>
Storage Capacity (MMB)*	120	20	80	200
Drawdown Capacity (MBD)*	315	35	350	1200
Years to Build*	0	4	8	11
Years to Fill	5	5	5	5
Capital Costs (Billions \$96)*	0.000	0.026	0.267	0.938
Capital Costs (\$96/BBL)	0.00	1.30	3.33	4.69
O&M Costs (\$96/BBL-Yr)**	0.17	0.17	0.17	0.17
Draw Costs (\$96/BBL)**	0.10	0.10	0.10	0.10
Fill Costs (\$96/BBL)**	0.09	0.09	0.09	0.09
* PB-KBB (1999) Conceptual Design for 300 MMB SPR Site Expansion, Final Draft, April 19.				
** PB-KBB (1998) Strategic Oil Storage Concepts and Costs for Asia Pacific Region, Final Draft, October 30.				

This table also provides some of the more important operating characteristics of the proposed additions. These include “Years to Build” (development time) and “Years to Fill”. The development time is a result of the technical analysis performed by PB-KBB. Years to Fill is limited less by technical factors than budgetary and political considerations. Looking across proposed additions, there are no differences in operating, filling, and drawing costs of the three technologies, though there are noticeable differences in capital costs. Note that “Filling Available Capacity” incurs no capital costs and can be undertaken immediately.

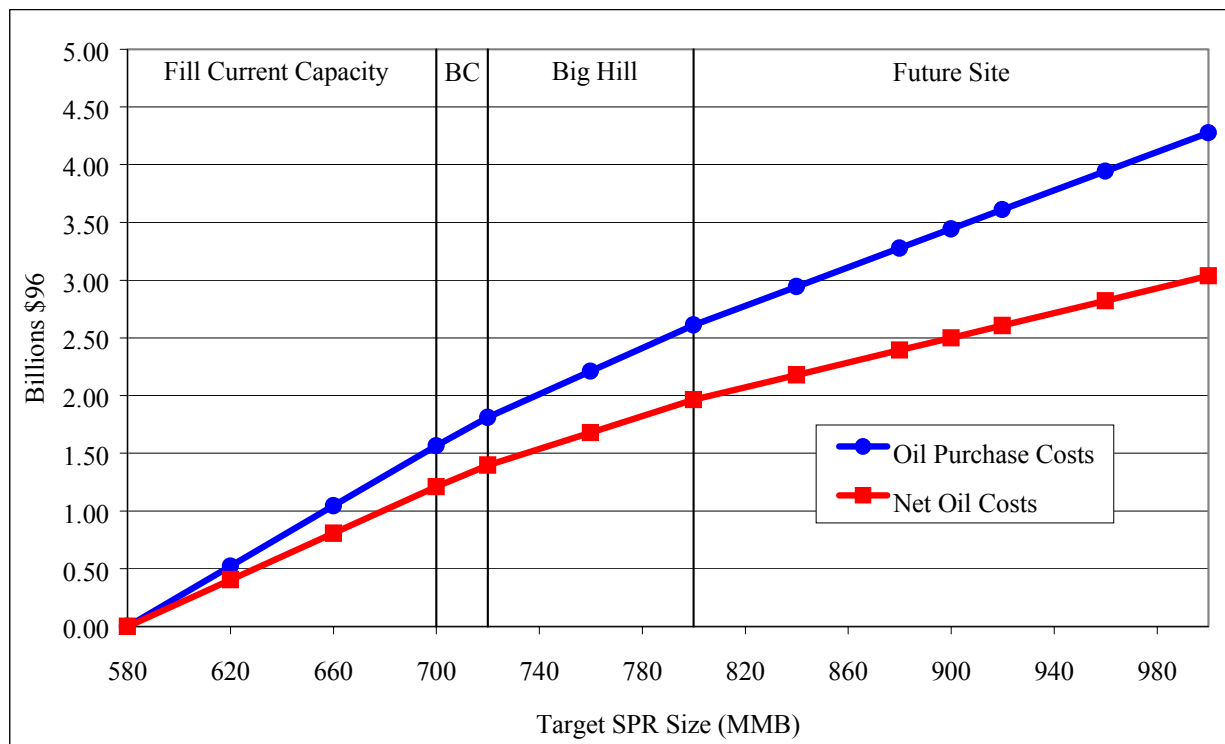
In contrast to Table 4 above, Figure 13 shows the cumulative discounted capital and operations and management (O&M) costs incurred by adding stock/capacity given the Base Case assumptions of 1999 discount year, 7% discount rate, and 2000 start year. Figure 10 shows that for a SPR size of say 800 MMB (fill available SPR capacity, and build additions to Bayou Choctaw and Big Hill), the added discounted costs are approximately 0.25 Billion \$96 of capital and 0.15 Billion \$96 of O&M. Figure 11 shows the discounted, undisrupted oil purchase costs and net oil costs to the SPR assuming 1999 discount year, 7% discount rate, and 2000 start year.<sup>20</sup> Net oil costs include oil purchase costs and oil salvage revenues at the end of the time period. Salvage revenues are necessary in any finite analysis to recognize that any oil left in the reserve at the end of the time period has value.

The rank of capital costs as well as “Years to Build” dictate that the ordering of additions to stock should be “Fill Available Capacity” first, “Additions to Bayou Choctaw Capacity” second, “Additions to Big Hill Capacity” Third, and building a “New Facility” fourth. Aside from the obvious reasons for filling available capacity first, since it is available immediately, filling available capacity could take advantage of the anticipated lower near-term oil prices shown in Figure 2.



**Figure 13:** Discounted Cumulative Capital and O&M Costs of Additions to SPR Size/Capacity

<sup>20</sup> Note these are undisrupted costs. If filling is delayed, the costs would be different.



**Figure 14:** Discounted Cumulative Oil Purchase and Net Costs

### 3.2 Key Determinants of Stockpile Size Analysis: Disruption Cost Factors

In calculating the effect of disruptions, the elasticity of world demand determines the world oil price change,  $\Delta P$ , for any given net oil supply shortfall (after supply offsets and the use of the reserve). The two principal economic costs to the U.S. due to disruptions, increased cost of oil imports and macroeconomic (GDP) adjustment costs, are then easily calculated. The net import demand elasticity determines import levels  $I$  for the given price change  $\Delta P$  during the shock, and shock import costs  $\Delta C_I$  are the product of the import level and the price change:

$$\Delta C_I = I \Delta P$$

The macroeconomic losses during the shock are summarized by a parameter  $\sigma$ , called the “GDP-elasticity” with respect to oil price shocks. The GDP elasticity specifies the percent GDP change for each percent change in the oil price.<sup>21</sup>

<sup>21</sup>This is a very close approximation. The actual calculation is done with the elasticity formulation:

$$\left(1 + \frac{\Delta GDP}{GDP}\right) = \left(1 + \frac{\Delta P}{P}\right)^\sigma$$

$$\% \Delta \text{GDP} \approx \sigma \% \Delta P$$

Work by Mork, Olsen and Mysisen (1994) sheds considerable light on the nature of the macroeconomic costs of oil price shocks. The methods used followed the general body of oil shock research and relied on available aggregate macroeconomic data. These methods and other similar results are discussed in Section 3.3. The results of the Mork et al. study produce a central (mean) GDP elasticity estimate of -5.4%. As a sensitivity analysis, we consider a variety of elasticities within the tail ends of the 95% confidence interval around the central estimate.

### **3.3 Estimated Empirical Relationship Between Oil Shocks and GDP Losses**

#### **3.3.1 Oil Price/GDP Transmission Mechanism**

The GDP elasticity is a measure of how changes in oil prices (primarily shocks) affect the economy. Embodied in this relationship between a price shock and GDP response is three principal transmission mechanisms: sectoral shocks, investment uncertainty, and demand composition. The sectoral shocks mechanism works through the markets for productive inputs. An oil price shock in either direction changes the values of many characteristics of a firm's labor force as well as its capital stock. For example, a buyer's personal contact network in supplying firms may become worth less because it is optimal for his firm to buy products supplied by different firms. Capital equipment may become obsolete overnight because of its energy use or generation characteristics. And categories of both labor and capital have their complementarities and substitutabilities among one another, which link labor and equipment not directly affected by the price changes. Firms' responses to such rearrangements of relative prices are to eliminate some jobs (called "job destruction") and create some new ones (called "job creation"), entailing considerably more gross movement between jobs than is indicated by a net measure such as the unemployment rate. These reallocations of firms' resources occur regardless of the direction of the price change. Plant-level evidence from the United States from the mid-1950s through the early 1990s reveals considerable job destruction and creation in response to positive oil price shocks, and a somewhat smaller gross movement following negative oil price shocks (Davis and Haltiwanger, 1996).

The investment uncertainty mechanism operates through delays. Unanticipated positive oil price shocks can cause firms to delay planned capital outlays and purchases of accompanying current materials while they learn the full meaning of the price shock for their business. These pauses in activity caused by uncertainty surrounding the price shock are weaker because of asymmetric effects of "good" and "bad" news on irreversible but deferrable investment decisions. This effect at least partly accounts for a smaller response of gross job destruction to negative oil price shocks than to positive ones. U.S. responses of unemployment, industrial production, and GDP to oil price shocks have shown consistencies with such uncertainty mechanisms (Li et al., 1995; Ferderer, 1996).



An oil price shock can change what individuals and firms want to purchase. One of the best examples is the substitution of smaller vehicles for larger ones during the 1970s. The American automobile industry suffered on balance while the Japanese automobile industry experienced a bonanza. Even within the United States, layoffs occurred at plants that produced large vehicles while new hires were being made at plants that produced small ones. Seldom were the two types of production facilities close enough to each other for the workers laid off at one plant to be able to take up work quickly at an expanding plant, so the consequence was a large number of movements in and out of jobs, just as characterized by the concept of separate job destruction and creation envisaged in the sectoral shocks mechanism. Interstate migration was required to complete the labor market adjustments, and some of the residual unemployment effects were still felt after nine years (Bresnahan and Ramey, 1992; Davis et al., 1997).

More nearly symmetric transmission mechanisms implicitly or explicitly underlay the earlier, symmetric specification of the oil price variable in empirical investigations of the impacts of oil price shocks. These included “sticky” wages and prices—wages and prices that do not move in response to changes in underlying productivities or demand changes, commonly because of contracts—and investment multipliers that do not account for limited reversibilities and respond symmetrically to positive and negative productivity shocks. While these mechanisms have not necessarily been proven “wrong,” they have been found to be incomplete.

### **3.3.2 Asymmetric Responses to Oil Price Shocks**

Oil price shocks can be negative, as happened during the 1986 oil price collapse, as well as positive as they were in the 1973-74 OPEC embargo, the 1979-80 crises associated with Iran and Iraq, and the 1990 Iraqi invasion of Kuwait. The combination of consequences generally—although not necessarily—add up to considerably weaker effects of negative shocks than positive shocks. Conceptually, the consequences of an oil price shock can be divided into two components, production possibilities effects in which a price increase reflects temporarily decreased physical supplies available, and adjustment effects in which real resources are devoted to reorganizing business activity to any realignment of prices facing producers and consumers. Positive price shocks shrink production possibilities while negative shocks expand them, but the adjustment costs are the same regardless of the direction of the price shock. Consequently, when a positive oil price shock hits the economy, the production possibilities effect and the transition effect work in the same direction to produce a negative effect on GDP, but with a negative price shock, the effects on employment and output tend to offset each other. This differential response of GDP to oil price shocks—negative responses to positive shocks, weak positive to neutral responses to negative shocks—is called “asymmetry.”

Estimation of the aggregate response of the economy to oil price shocks is more precise when the effects of positive and negative oil price changes are assessed separately. Current practice is to estimate separate elasticities for the response of GDP to positive and negative oil price shocks. The estimate of -0.054 is such an asymmetric oil price-GDP elasticity: it describes the reaction of the U.S. GDP only to positive oil price shocks. Using a symmetric specification of oil

price—letting a single variable contain both positive and negative oil price changes—by its construction will yield a smaller (in absolute value) estimate of the oil price-GDP elasticity.

### **3.3.3 Separating the Effects of Monetary Policy and Oil Price Shocks**

Some observers have questioned whether the recessions following the major oil price shocks of the 1970s and '80s were really attributable to the preceding oil price shocks or were primarily attributable to monetary policy that itself might have responded to the oil price shocks with monetary tightening, possibly accounting for the asymmetry in the aggregate response to oil price shocks (Bohi 1989). This has been a challenging issue to address because of the difficulty of separating monetary policy changes from independent changes in the private demand for and supply of money, and it is the subject on which there is probably the least consensus in the nexus of oil price-GDP relationships. Hooker (1996) found that during the 1980s, much of the information content of oil price shocks began to be transmitted through the money market. But, separating changes in monetary policy into those that seemed to respond systematically to oil price shocks (called “endogenous” monetary policy)—primarily to combat inflation—and those that were independent of oil prices (exogenous monetary policy), Hooker found that positive oil price shocks still had an independent, negative influence on GDP and the unemployment rate when controlling for exogenous monetary policy. Balke et al. (1998) studied interest rate reactions to oil price shocks and concluded that those shocks had strong effects on interest rates and GDP, independent of any changes in monetary policy.

### **3.3.4 Empirical Analyses of the Oil Price Shock-Macroeconomy Relationship**

The early studies of the oil price-GDP relationship used symmetric specifications of the oil price, implicitly hypothesizing that negative oil price shocks would be as good for the economy as positive ones were bad. A Darby (1982) study that produced a -0.021 elasticity value was such a study. Hamilton's (1983) study of oil price influences on U.S. business cycles from 1948-1980 also used the symmetric specification but obtained the much larger (in absolute value) elasticity value of -0.14. The oil price-GDP relationship weakened in the second half of Hamilton's time period, prompting Mork (1989) to introduce the asymmetric oil price specification into empirical analysis. Following theoretical predictions of several earlier models of oil price influences on business cycles (Gilbert and Mork, 1986; Hamilton, 1988), Mork found that the asymmetric specification of oil prices—separate variables for positive and negative oil price changes—yielded statistically significant, negative oil price-GDP elasticities for positive shocks over the entire period 1949-1988, while the negative shocks did not produce a statistically significant response. Mory (1993) obtained similar results using annual data from the United States over the period 1952-1990.

The elasticity magnitude of -0.054 recommended as the best estimate for the United States comes from a cross-country analysis of seven OECD economies over the period 1967-1992, using the asymmetric oil price specification (Mork et al., 1994). This study accounted for interactions among the countries in deriving this estimate for the United States.

The responsiveness of the U.S. economy to oil price shocks is neither particularly high nor particularly low in comparison to the responses estimated for other industrialized and developing countries. Mork et al. estimated elasticities of -0.023 for Japan and -0.038 for the United Kingdom, but -0.081 for West Germany and -0.098 for France. Canada's sensitivity was roughly the same as that of the United States, at -0.064, while Norway's response was positive, undoubtedly because of the magnitude of its oil production sector. Recent estimates for Asian economies such as South Korea, Indonesia, Thailand, and Taiwan range from -0.06 to -0.08 (Bachman and Ingram, 1999). No systematic analysis has attempted yet to explain the differences in these countries' elasticities, but scholars have accepted the notion that they reflect differences in their economic and institutional structures.

## 4.0 Numerical Analysis of the Net Present Value of SPR Expansion Benefits

### 4.1 Base Case Results for the Benefits of Incremental Storage Capacity

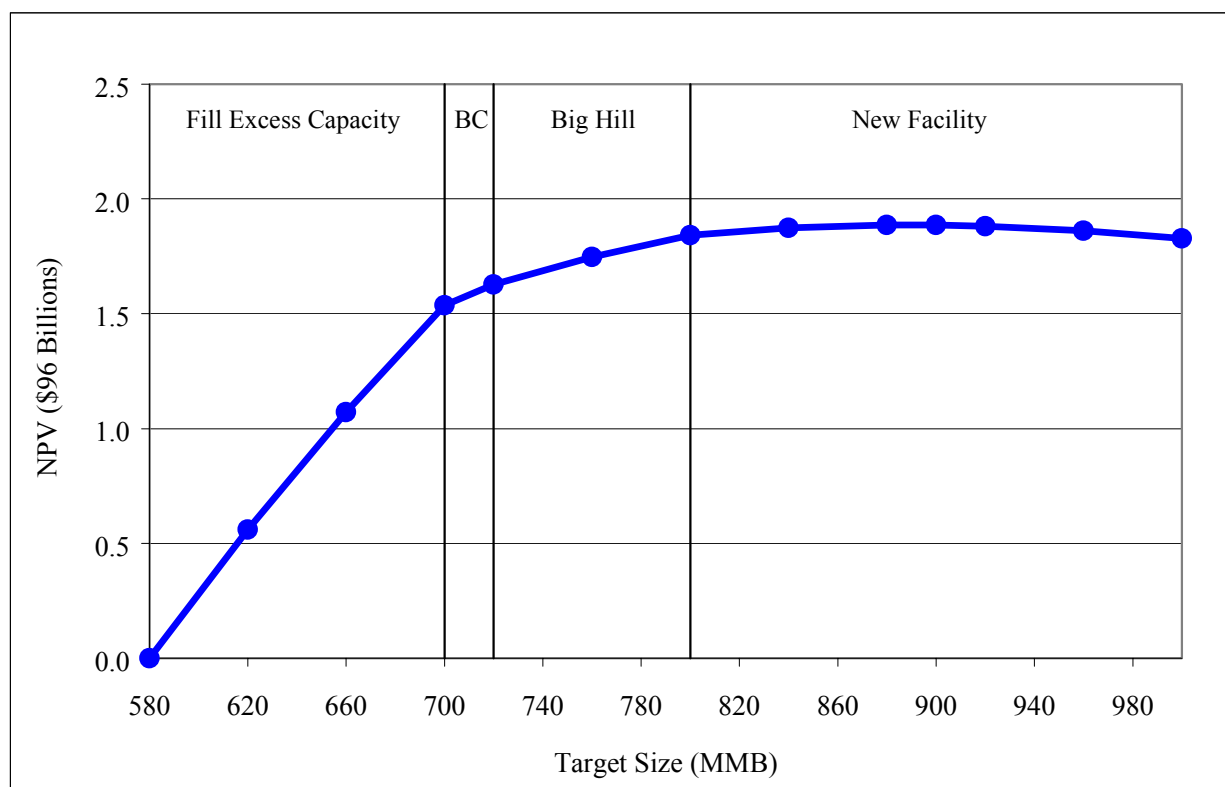
#### 4.1.1 Recap of Base Case Assumptions

The “Base Case” for the SPR size study is comprised of the assumptions given in Table 5 below. These base assumptions are the product of discussions with the SPR size study working group.

<b>Table 5: U.S. Strategic Petroleum Reserve Size Analysis Base Case Assumptions</b>	
Disruption Probability	DOE/Interagency 1990 Base Case (Weibull distribution over disruption sizes, with a 1% annual probability of a disruption equal to 15% or more of world demand).
Disruption Lengths	Uniformly distributed over 3 and 6 months (mean of 4.5 months).
Slack Production Capacity	EIA International Energy Outlook 1999 base path, corresponding to 3.6 MMBD in 1999, declining to 1.8 MMBD by 2010, and then recovering to 2.4 by 2020. Assumed OPEC production capacity utilization rises from current 90% to 96% by 2010 and beyond.
GDP Elasticity	Mid value, -0.054. Roughly, a sudden oil price doubling causes a 5.4% reduction in GDP.
Disruption Lengths	Random, uniformly distributed over 3 or 6 months in duration (average duration is 4.5 months).
Start Build Year (Start Fill Year for Sizes less than 700MMB)	2000. For “Fill Available SPR Capacity” option, fill begins in 2000. For capital projects, construction begins in 2000 with fill as soon as the facility is complete.
Undisrupted Oil Price Path	EIA Annual Energy Outlook 1999 Base Case (AEO99b)
Foreign Draw Coordination	U.S. and foreign reserves coordinate drawdowns.
Import Demand Elasticities	Following the DOE/Interagency 1990 analysis, U.S. and World net import demand elasticities for 1999 are approximately -0.125 in the short run (first month of a disruption). Elasticities rise over the duration of the disruption, increasing by 50% after 12 months. First-month elasticities also increase over time, rising to -0.15 by 2020.
Discount Rate	7%, per OMB Circular A94-B
Fill and Refill Rates	Initial fill and refill rates are sufficient to fill reserve in 5 years.

### 4.1.2 Reserve Size Maximizing Expected Net Economic Benefit

Under the base assumptions, expansion to 700 MMB provides an expected net benefit of \$1.5 billion. Expansion to 700 MMB is worth, on average, about \$12 per additional BBL stored. The Base Case results are presented in 15 below.



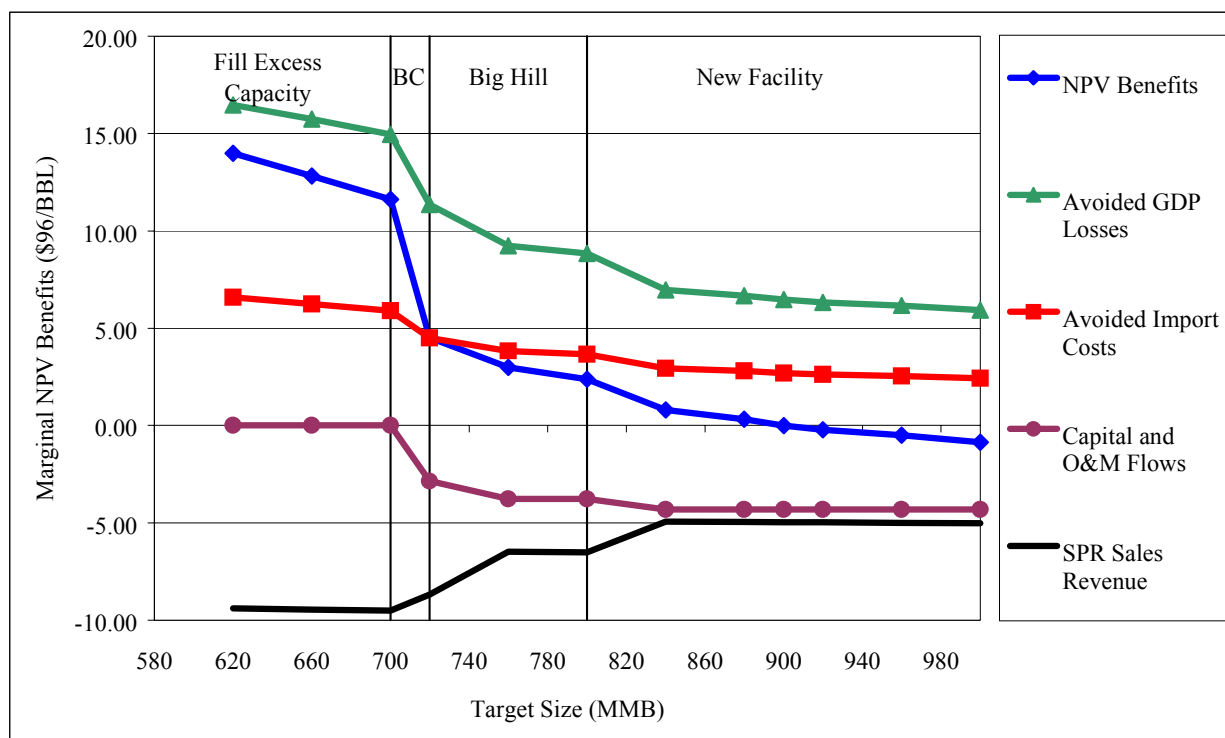
**Figure 15:** Net Economic Benefits of Expansion, Base Case

## 4.2 The Components of the Net Benefits of Stockpile Expansion

It is instructive to separate the total Net Benefits of alternative reserve sizes out into the various cost and benefit components. As discussed above, the principal components are

- |                     |  |
|---------------------|--|
| GDP Savings         | ◆ Avoided GDP losses due to disruptions  |
| Import Cost Savings | ◆ Avoided import costs due to disruptions  |
| Reserve Net Revenue | ◆ Reserve oil sales revenue minus oil purchase costs and transaction (fill/draw) costs |
| Capital Stream      | ◆ A negative financial flow corresponding to facility capital costs and O&M costs.     |

Figure 16 shows how each of these components increases as a function of increasing reserve size. The benefit terms for GDP Savings and Import Cost Savings are positive contributions, and are shown that way. The Capital Stream, representing capital and O&M costs, is shown as a negative term. The reserve Net Revenue, or net oil costs for the reserve, is negative, indicating that on average the reserve oil is sold for less than its purchase cost (in real terms).



**Figure 16:** Marginal NPV Benefits of Expansion

The marginal benefits of expansion decline sharply after the 700 MMB size is achieved. At this level, additional capital expenditures are required. The capital and O&M costs of incremental storage capacity are \$2.90 BBL for the first 20 MMB beyond 700, and \$3.75 for the next 80 MMB (up to 800 MMB capacity). Beyond that size it is estimated that NPV capital costs rise to \$4.30 per BBL. The expected discounted carrying costs of oil plateaus at about \$5/BBL for the larger sizes.<sup>22</sup> This does not, however, explain the drop in marginal avoided disruption costs (GDP and net import losses) beyond 700 MMB. The reduction in marginal benefits can be attributed, in part, to the delay in additional coverage capital projects necessitate. Take the addition to Bayou Choctaw for example (720 MMB from 700 MMB). To build additional capacity to Bayou Choctaw would take approximately four years. This is four additional years of exposure to disruptions and in discounted terms the dollar value of exposure is even higher. Additionally, Bayou Choctaw capacity expansion results in additional drawdown capacity of only

<sup>22</sup>By carrying costs we mean purchase price less the expected resale value at the end of the time horizon.

35 MMBD. Small in comparison to the other additions. This leads, in part, to the dramatic fall in marginal benefits at the 700 MMB to 720 MMB increment. Also, in general, as the reserve expands, the likelihood that each marginal barrel will be needed declines. Therefore, for larger expansion sizes, the estimated dollars of benefit (in avoided damage costs) per marginal barrel declines.

By far the largest benefit of the reserve is the Avoided GDP losses. The avoided GDP losses are about four times as large as the avoided import costs. This is an important insight: while U.S. policy makers are rightly concerned about the growing levels of U.S. oil imports, the vulnerability of the U.S. economy to transitional losses during sudden price movements due to allocative dislocations appears to be an even larger concern. The curves in Figure 16 Also show the slow marginal decline of avoided import costs and avoided GDP losses as the reserve size expands. This is because as the reserve increases in size, we would anticipate fewer and fewer situations in which the added size is needed. The first 120 million barrels of expansion (700 MMB Size) provides an expected marginal GDP savings of about \$1.9 billion, or \$15/barrel. By 220 million barrels (800 MMB Size) that marginal savings has declined to about \$9/barrel, and it declines more rapidly thereafter.

SPR net revenue which averages about 1.5 Billion \$96 more than capital and O&M costs is by far the largest cost. The net cost of reserve oil is not its purchase price, but rather its purchase price plus transaction costs *minus* the expected, discounted sales price (either in a subsequent disruption or in the reserve “salvage” calculation for the end year 2030).

The ability to decompose expected reserve net benefits in this way offers a powerful opportunity for sensitivity analyses. Knowing the magnitude of expected GDP losses allows us to examine the sensitivity of reserve net benefits to GDP levels, and to the GDP Elasticity with respect to oil shocks. Knowing the magnitude of expected import cost savings allows sensitivity analysis with respect to oil import levels.

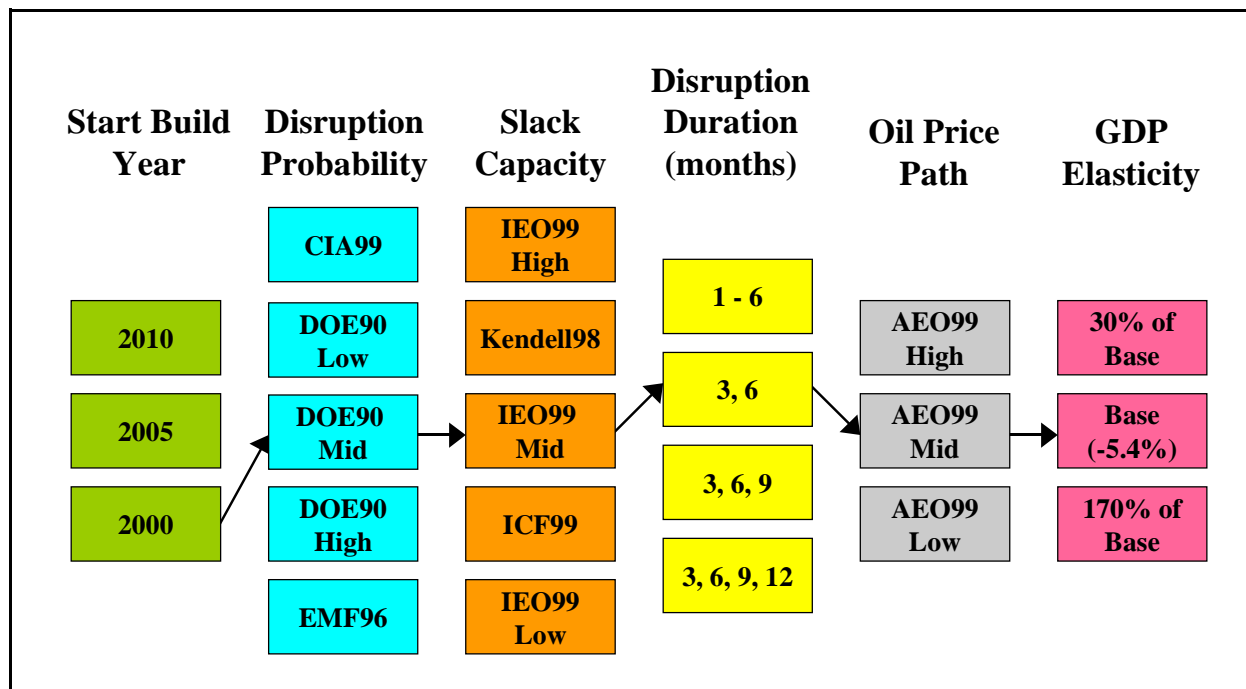
### **4.3 Sensitivity Cases Considered**

Past studies of the U.S. strategic petroleum reserve have provided valuable insight into which factors most strongly influence the benefits of strategic oil stockpiling. The list in the Table 6 below reports the parameters that have been shown to be most influential, in approximate order of importance.

<b>Table 6: Key Parameters for Strategic Reserve Size</b>		
<b>Factor</b>		<b>Strength of Influence on Benefits</b>
!	Disruption Size Probability	(+++)
!	Disruption Offsets	(+++)
!	GDP Elasticity	(+++)
!	Disruption Length Probabilities	(++)
!	Discount Rate	(--)
!	Reserve Fill Rate	(++)
!	Import Levels	(++)
!	Import Demand Elasticities	(++)
!	GDP Growth Rate	(+)
!	Maximum Reserve Draw Rate	(+)
!	Oil Price Path	(-)
!	Coordination with Foreign Stocks	(-)
!	Reserve Refill Rate/Policy	(-)
!	Short-run Fuel Switching	(-)
Note: Those parameters that are followed by “plus” signs (+) lead to higher benefits when they are increased in magnitude, and lower benefits when they are decreased. The converse holds true for parameters followed by a “minus” sign (-). The number of pluses or minuses is a rough indicator of the strength of the effect.		

Recognizing these principal uncertain inputs which influence the reserve size evaluation, we structured a small set of important sensitivity-analysis cases. They include the top five parameters on the above table. Their inputs are shown schematically in Figure 17. Key factors, including disruption probability and slack production capacity, were given special attention. Other sensitivities include disruption lengths, different start years for the reserve expansion (2000, 2005, and 2010), discount rates, coordination with foreign stocks (Foreign First versus Coordinated), and three reference oil price path scenarios, (the EIA’s 1999 Low, Base, and High World Oil Price projections). The sensitivity of both expansion benefits and the optimal expansion size to the assumed elasticity of GDP with respect to oil price shocks was considered, for a wide range of GDP elasticities.





**Figure 17:** Schematic diagram of the sensitivity cases considered. Key: A case consists of one selection from each column. The arrows connect the selected elements in the “Base” case. Not all combinations of the conditions were examined.

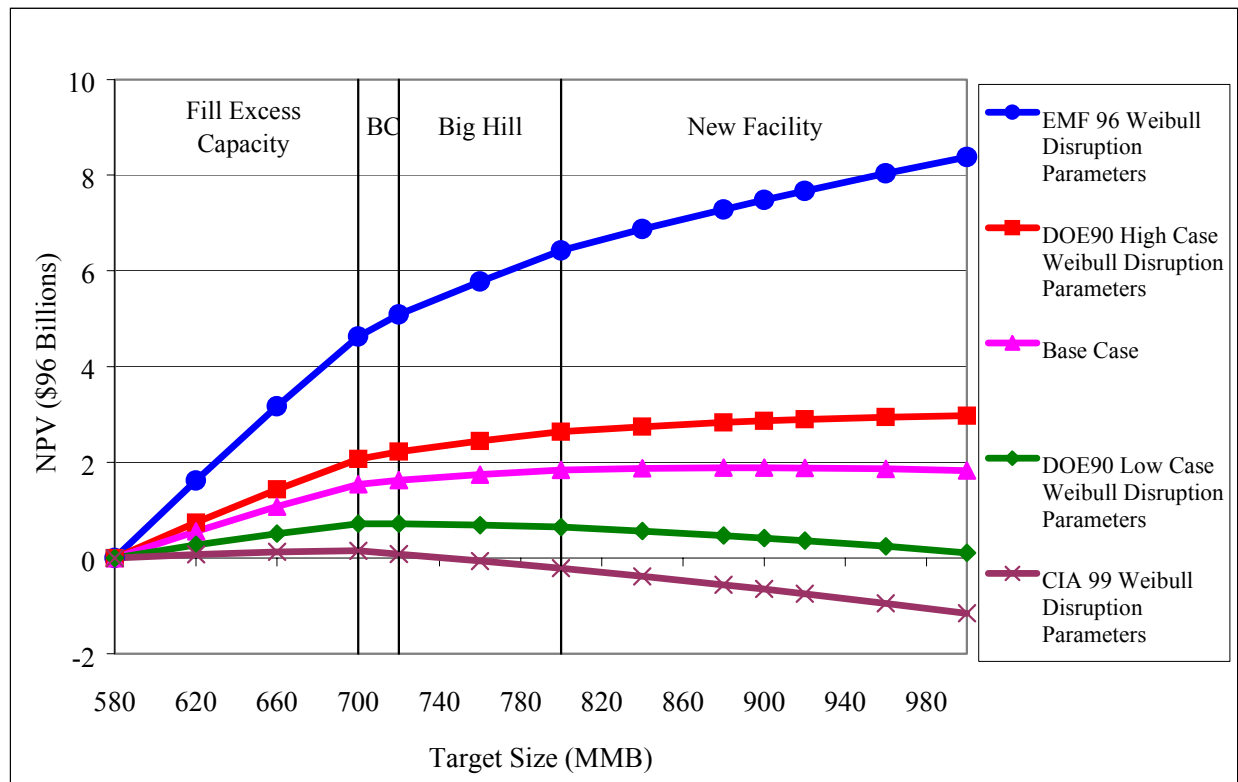
#### 4.4 Confidence Intervals and Sensitivity Analysis Results

In this section we consider the variation of benefits under cases of lower and higher shock risk. This includes cases of lower and higher disruption probability and slack capacity, as well as the variation in benefits if the expected duration of disruptions is longer (or a bit shorter) than the Base Case average of 4.5 months. We also report the effect on benefits and efficient reserve sizes for higher and lower GDP elasticity, and higher and lower reference oil prices.

##### 4.4.1 Effect of Changing Market Risk: Disruption Probabilities and Slack Capacity

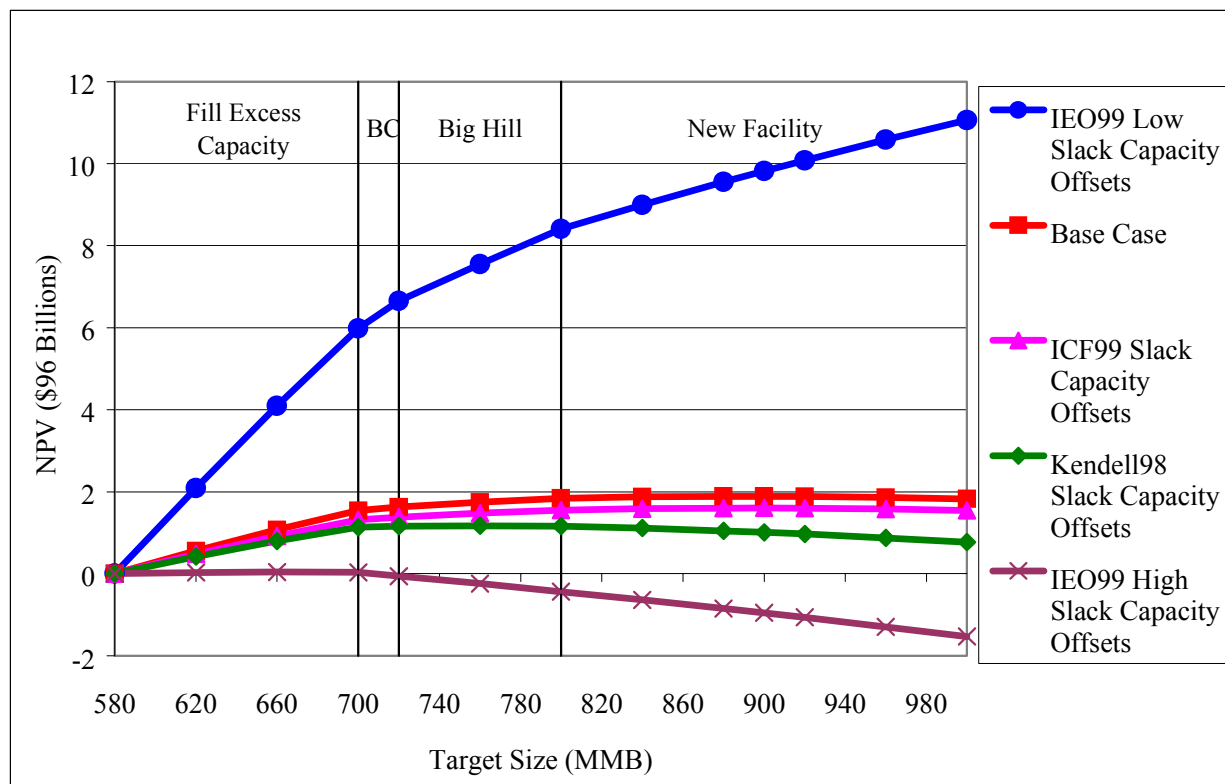
Six different disruption probabilities are evaluated, the base assumption (DOE90 Mid), and five sensitivities: EMF96, DOE90 High, DOE90 Low, and CIA99. As Figure 18 shows, expansion to at least a 700 MMB reserve is worthwhile *regardless* of the which probability is used.

Expansion benefits under the most optimistic (lowest) disruption probability are admittedly minimal, but even on an expected value basis they are still positive. Note the “Base Case” given in Figure 18 and all other result graphs hereafter is the same result given in Figure 15. Only the scale has changed.



**Figure 18:** Net Economic Benefit of Expansion, Sensitivity to Disruption Probability

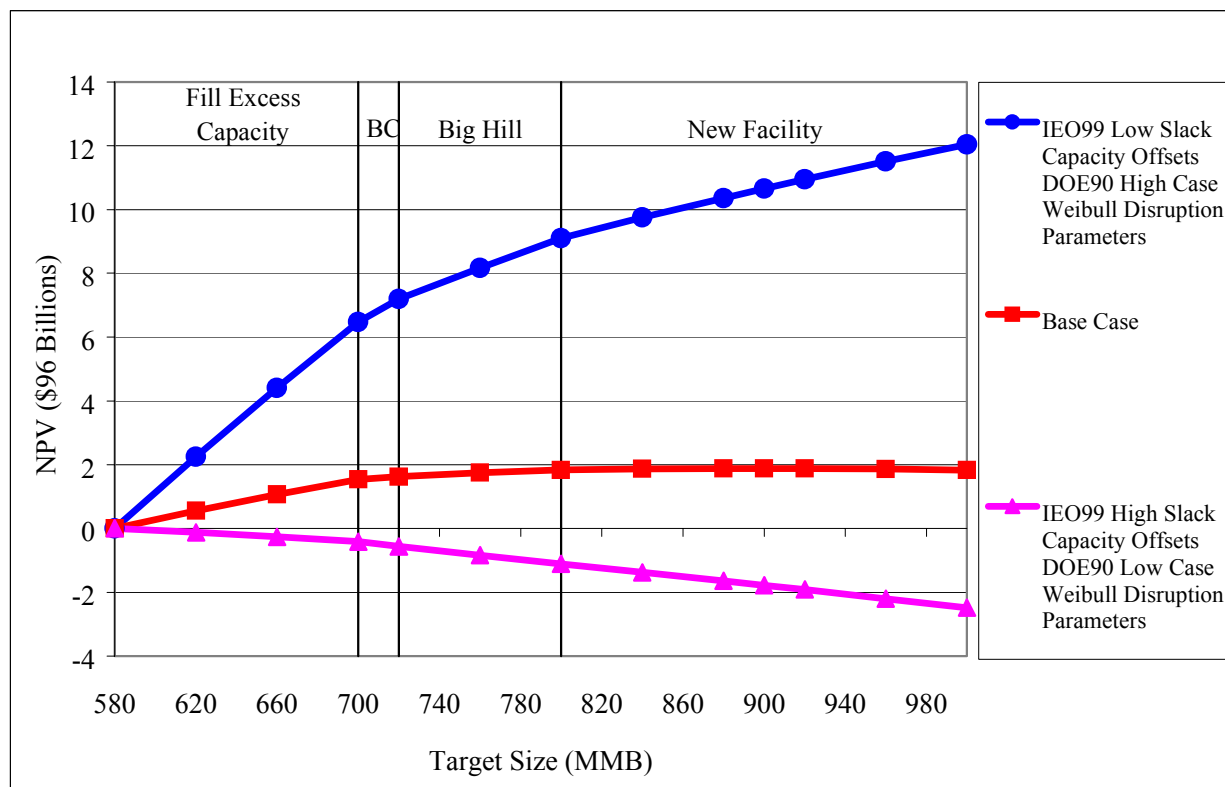
Slack or excess oil production capacity offsets are an important, key assumption to the results of the DIS-RISK size study model. Decreasing OPEC production capacity by 5% leads to a marked increase in benefits (Figure 19), given that the capacity utilization levels are near 95% in the IEO99 Base. Conversely, a 5% increase in the assumed OPEC production capacity can drive benefits down, although they are still positive for a 700 MMB SPR size. Also in Figure 19, we see that the assumed base case slack capacities (from IEO99) produce results which are close to both the previously assumed Kendell (1998) and the most recent ICF (1999) work.



**Figure 19:** Net Economic Benefit of Expansion, Sensitivities to Slack Capacity Offsets

#### 4.4.2 Effect of Changing Market Risk: Combined Disruption Probability and Offset Sensitivities

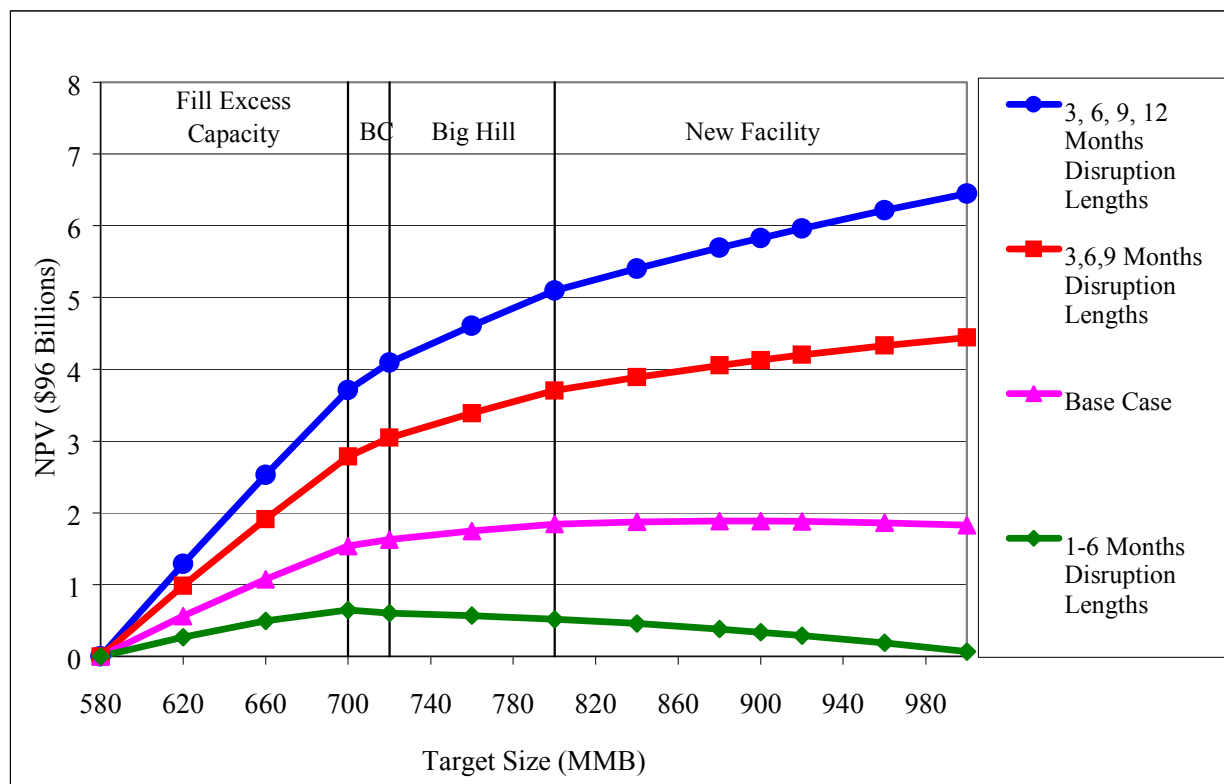
Combining the extremes of both the disruption probabilities and the slack capacity offset sensitivity cases produces what can be termed as highly optimistic and pessimistic oil market outlook. Here we see that within the wide range of this extreme set of assumptions either a 1000 MMB reserve or a 580 MMB reserve could be optimal. However, it is also apparent that the potential losses from overbuilding (should the oil market turn out to be quite stable) are modest, compared to the potential expected gains from SPR expansion, if the market turns out to be risky and volatile. This is another manifestation of the fact that the risks associated with oil shocks are asymmetric. The potential benefits and losses associated with oil stockpiling are also asymmetrically distributed. For example, in the highly optimistic, low-risk case in Figure 20, expanding to 700 MMB could lead to a loss of about \$0.4 billion, while in the highly-pessimistic, high-risk case it would lead to an *expected* gain of over \$6 billion.



**Figure 20:** Sensitivity of Benefits and Efficient Size to Levels of Oil Market Risk: Combined Sensitivity to Disruption Probabilities and Offsets.

#### 4.4.3 Effect of Changing Market Risk: Longer Disruption Lengths

Assumptions about disruption lengths are also an important driver in the model results. The base case length is 3 and 6 months (4 ½ months average). Considering longer lengths corresponds to an increase in oil market risk. It may be reasonable to consider disruptions longer than the Base Case, since the historical median disruption length is 5 months. The arithmetic average or mean historical disruption length is even longer, since the observed length-distribution is skewed to the right, with some very long duration events.<sup>23</sup> The sensitivity cases over disruption length shown in Figure 21 below indicate that both the net benefits and the efficient stock size grow markedly as disruption durations increase. If disruptions averaging longer than 4.5 months are expected, then reserve sizes substantially beyond the current 700 MMB capacity are efficient. If disruption lengths are somewhat shorter (on average) than in the Base Case (i.e. 1 to 6 months in length, 3 ½ months average) then the efficient expansion to 700 MMB is efficient.

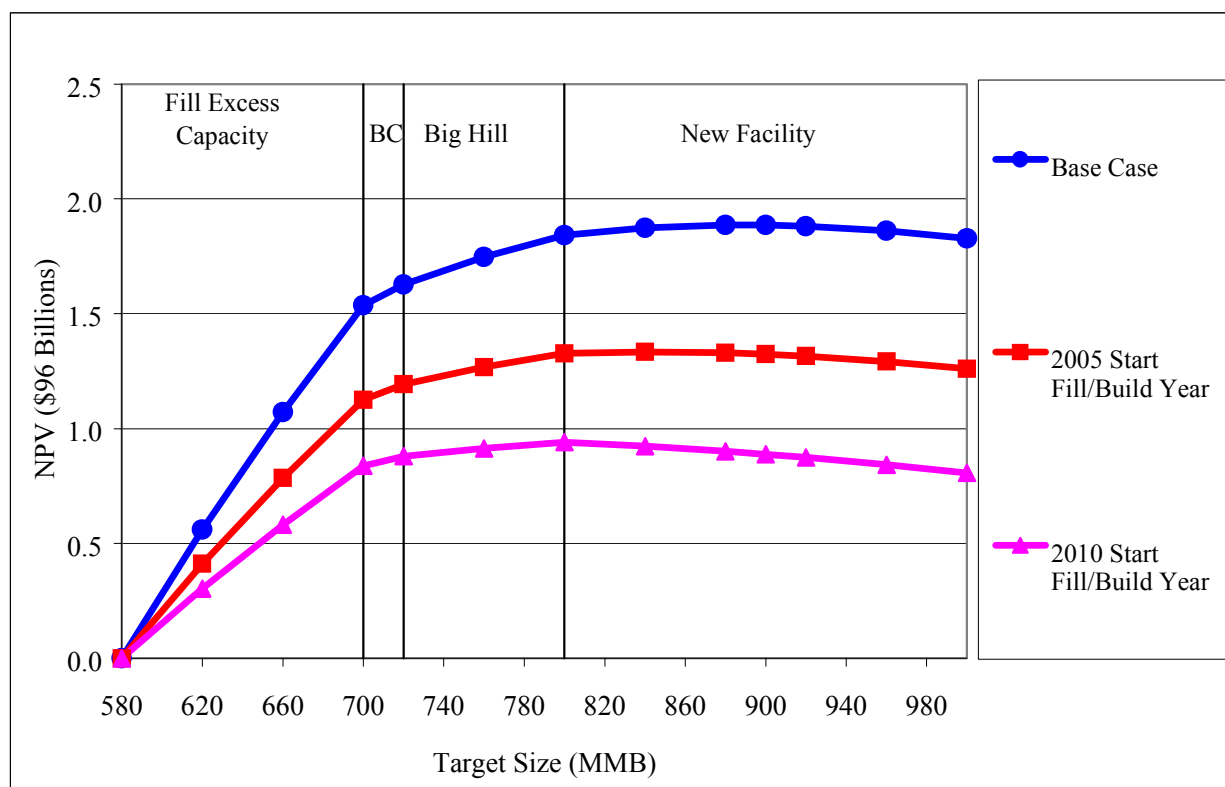


**Figure 21:** Net Economic Benefits of Expansion, Sensitivity to Disruption Lengths.

<sup>23</sup>There is however, the question of whether the reserve ever can be, or should be, designed to protect against very long events (12 months or longer). In those cases the “shock” begins to look more like a change in market regime, and there is value to allowing the price to (slowly) rise and induce the needed investment changes. Even in the case of very long disruptions, however, the strategic oil reserve can help to buffer the reduced supply and slow the price increase in the early months.

#### 4.4.4 Effects of Program Delay

Figure 22 shows the effects of program delay on the net benefits of reserve expansion. As shown in Figure 22, benefits fall as the filling of available SPR capacity and building of new capacity is delayed, by ten or even five years.



**Figure 22:** Effect of Changing the Program Start Year for Filling Available SPR Capacity and Building New Capacity.

The Base Case analysis assumes that new reserve development begins in the year 2000. This does not mean that the U.S. would be expected to commit to large expenditures up front, rather costs would be distributed over the construction and fill time of the project. Filling available SPR capacity would begin immediately. Adding to Bayou Choctaw would take four years, Big Hill eight, and any additional capacity at a new site eleven years. Filling of expanded capacity is assumed to begin immediately after the construction is complete and extends for five years.

These results indicate that delaying the expansion program by 5 or 10 years could reduce expected NPV benefits by one-third to one-half, respectively. There are several effects which are offsetting, but on balance call for expansion sooner rather than later. First, oil market conditions are changing, and delay forgoes the opportunity to fill quickly at lower anticipated prices (see Figure 2). This makes delay more costly. However, by delaying the start, oil purchasing and

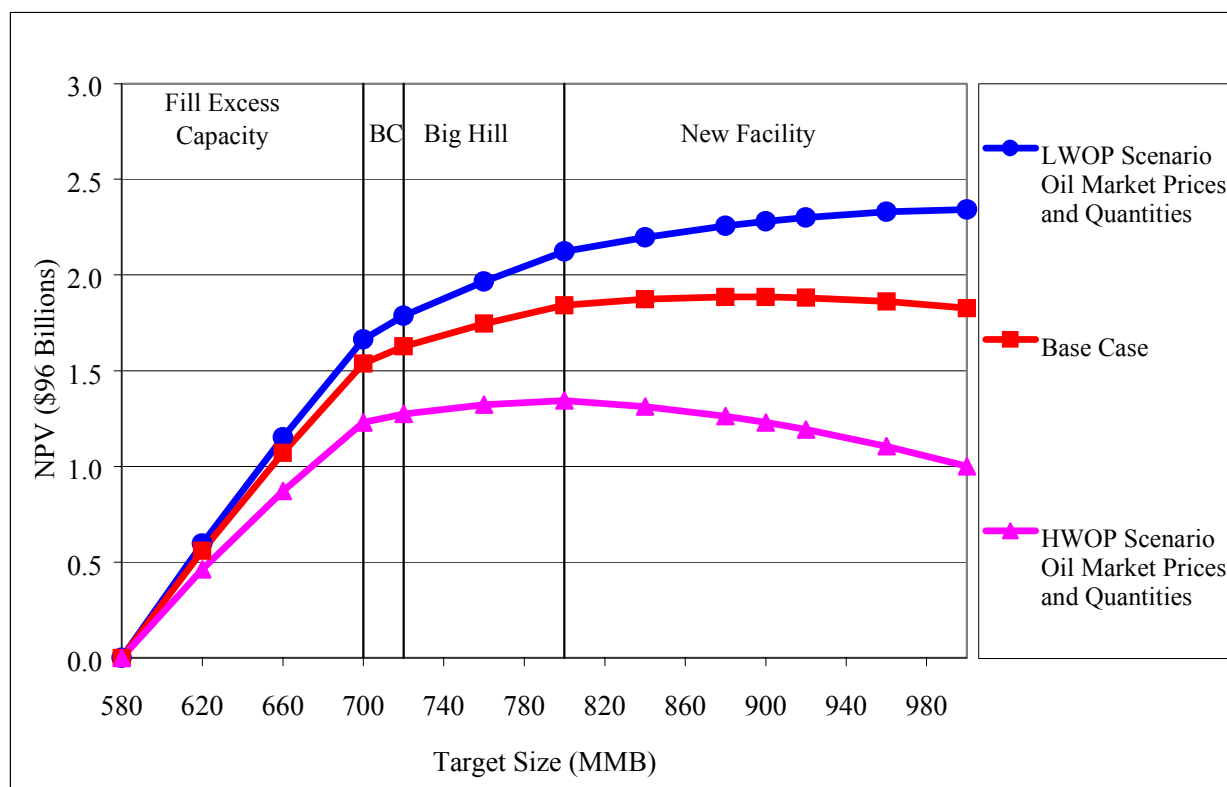
capital costs, and benefits all come later rather than sooner. While the capital costs are not expected to change in nominal dollars, delay will make them appear lower in discounted terms. Benefits, specifically avoided GDP losses and net import losses, are reduced when expansion is delayed. This reduction is a result of two factors, discounting and prolonged exposure. Delaying the start year by five or ten years has the effect of prolonging the exposure to economic shock loss due to reduced reserve protection. Since discounting puts more weight near term avoided costs as compared to later, this effect is particularly important. Even though oil market conditions are forecasted to be more pessimistic in the future (available SPR capacity, OPEC oil market share, etc.), analysis suggests that, due to discounting, the value of supply shock coverage in 2030 is half that of 2000.

On balance, delaying the reserve program has a moderate effect on reserve benefits. As the net-benefit curves in Figure 22 show, reserve programs delayed to 2005 or 2010 yield somewhat lower discounted benefits, and indicate slightly smaller optimal sizes. In all cases, expansion to 700 MMB is still beneficial.

#### 4.4.5 Effects of Reference Oil Market Price and Quantity Paths

The results of the sensitivity analysis with respect to the projected undisrupted oil market prices and quantities may be surprising to some, given that one might expect a higher oil price in the future to provide higher sales revenue to the SPR and to place more importance on oil in the U.S. economy. However, optimal size is largest with the AEO99 low oil price projection (LWOP) and smallest with AEO99 high oil price projection (HWOP). The reasoning for this is two fold.

- 1) It appears that the changes in the oil price and quantity projection have only a minimal effect on avoided disruption costs. There appear to be offsetting effects on import costs and GDP losses.
- 2) Net SPR revenues are far less with HWOP than with LWOP. This is generally because the SPR in most cases is buying oil, holding, and selling for an NPV loss. The higher the purchase price, the higher the financial carrying cost. Also, generally, by the time that additional capacity is built and the reserve is filled, the price is projected to level off, thus there is little undiscounted gain from storing oil.

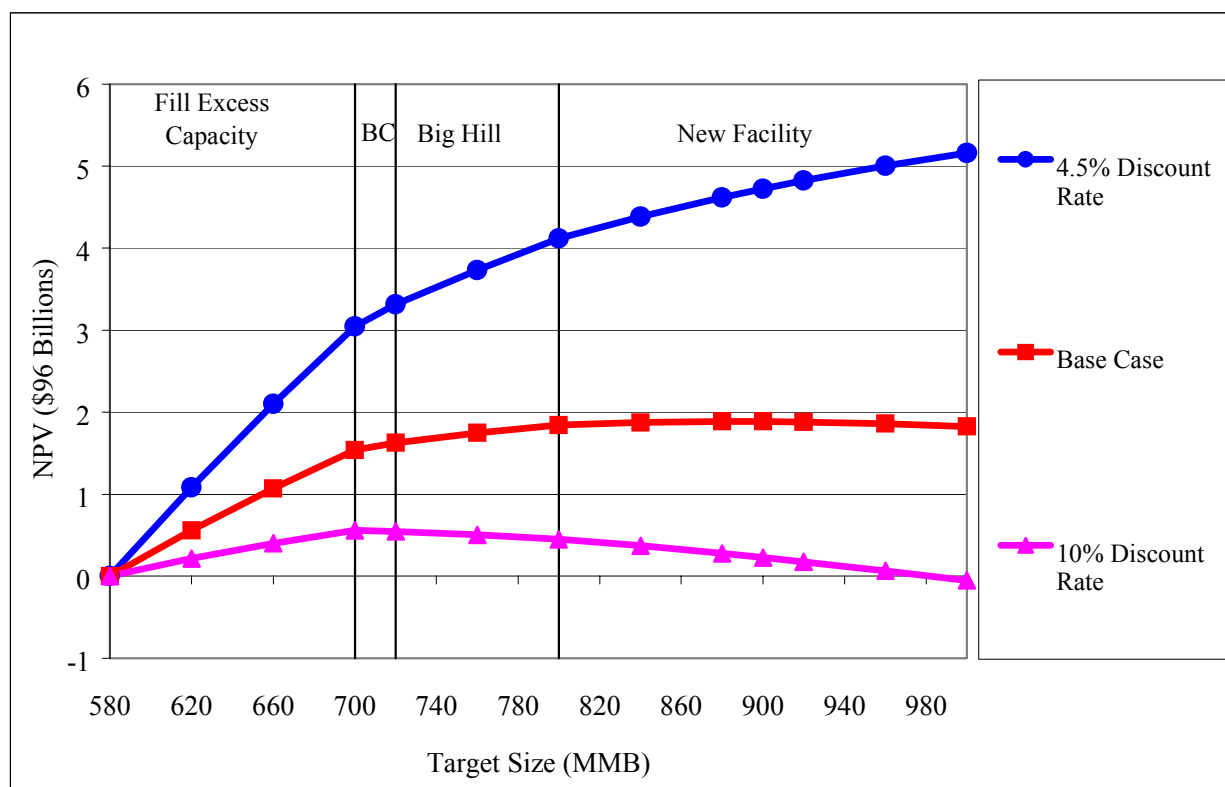


**Figure 23:** Net Economic Benefit of Expansion, Sensitivity to Oil Market Prices and Quantities



#### 4.4.6 Effects of Discount Rate

The results of changing the discount rate are straightforward. Since most of the costs are up front and the benefits later, a higher discount rate reduces the relative value of those benefits compared to the costs. The converse effect is observed for a lower discount rate.

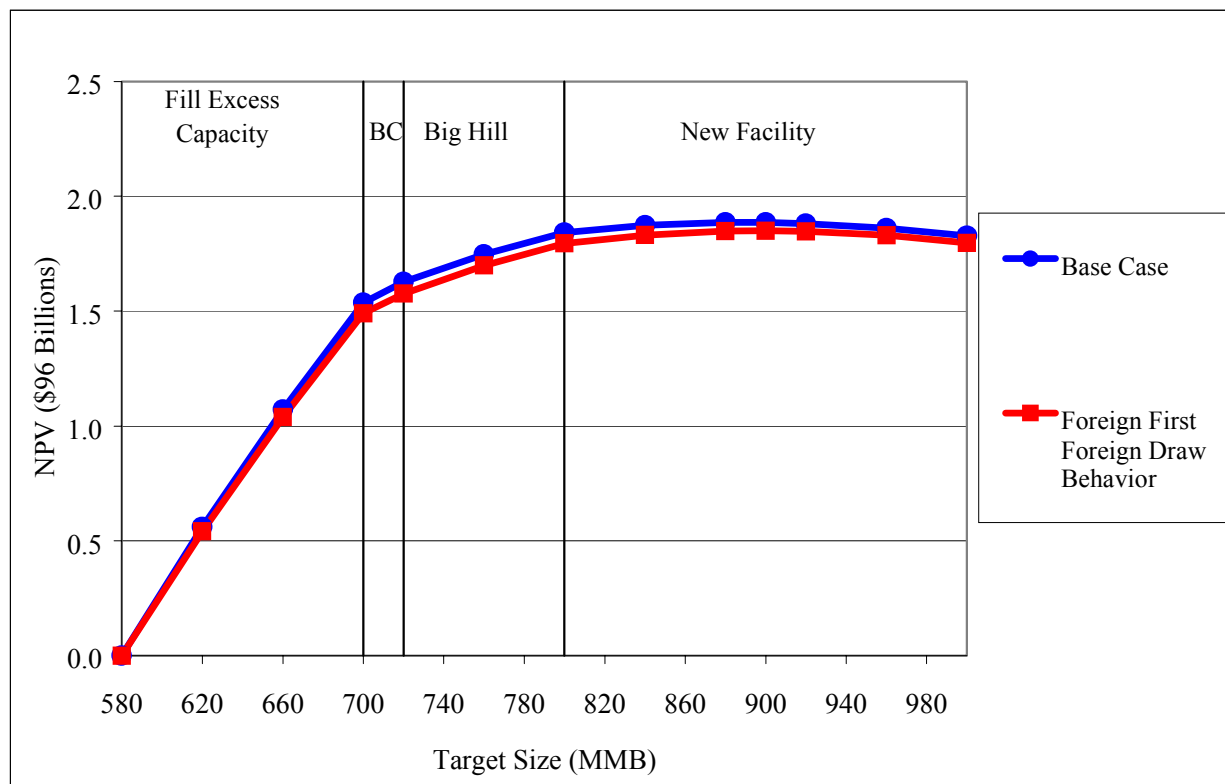


**Figure 24:** Net Economic Benefit of Expansion, Sensitivity to Discount Rate

#### 4.4.7 Effects of Foreign Draw Sequencing Assumption Sensitivity

This sensitivity case confirms our expectation that the precise sequencing of domestic and foreign strategic reserves in the modeling analysis does not strongly influence estimated expansion benefits. The sequencing assumption does not relate to the detailed timing of stockpile releases, for example over so many weeks during a shock. Rather, by "sequencing assumption" we refer to the rule regarding how much of the disruption is expected to be met by either foreign or domestic stockpiles before the other is utilized. In the 1990 DOE/Interagency Study, the previously applied rule (Foreign First) implied that in certain cases foreign government/strategic stockpiles might be used to fully offset smaller disruptions (if they are sufficient to do so) with NO use at all of the U.S. reserve. This "Foreign First" rule seems possibly unrealistic, and certainly politically embarrassing. For this reason, we adopted a "coordinated" response of U.S. and foreign reserves as the sequencing assumption for most of the analyses presented here.

We felt confident in doing so also because it was our best understanding that this assumption would have only a small effect on the estimated value of SPR expansion. Since oil from the expanded part of the U.S. reserve would only be needed in cases where both foreign and current domestic SPR oil had been exhausted, the sequencing issue is largely moot. The graph below confirms this expectation.

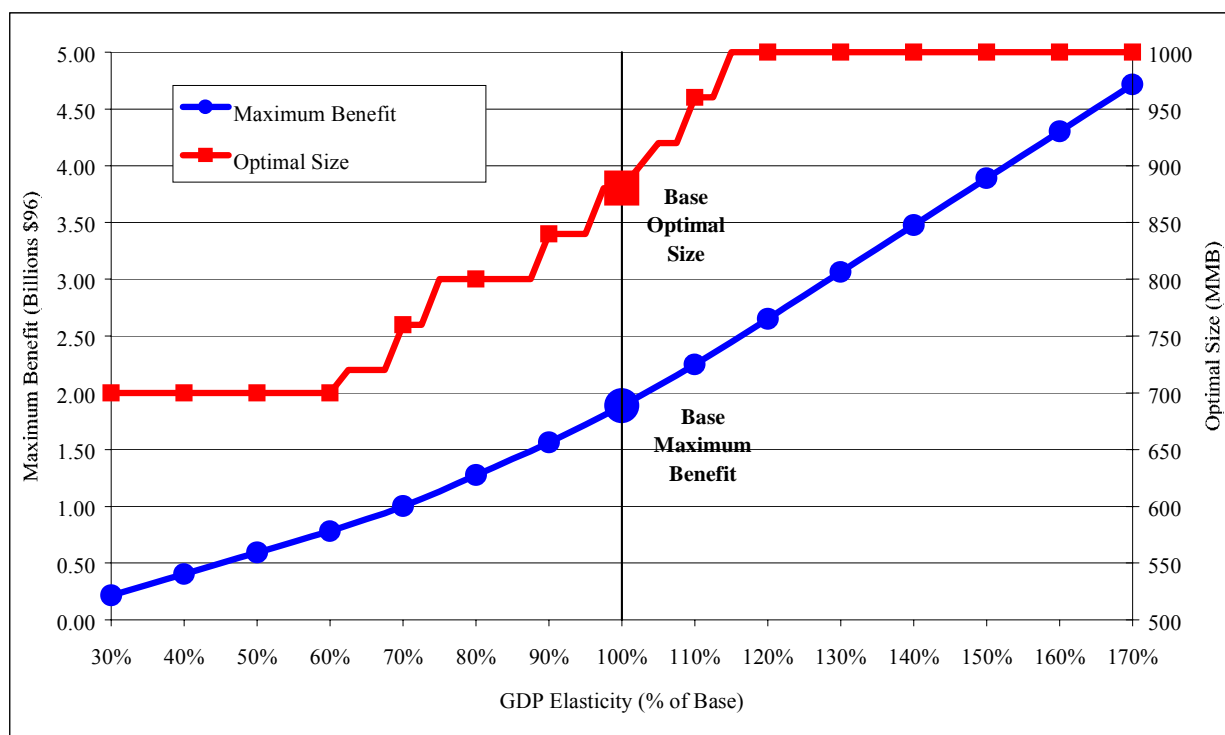


**Figure 25:** Net Economic Benefit of Expansion, Sensitivity to Foreign Draw Behavior

#### 4.4.8 Robustness Over Range of GDP-loss Elasticity

The GDP elasticity parameter is very important to the analysis. Figure 26 below shows how the efficient reserve size, and the net benefits gained at that size, vary as the GDP elasticity is varied up or down by 70% from the base case, or within more than two standard errors of the central estimate ( $-0.054$ ). This variation corresponds to a wide range of GDP elasticities, ranging from  $-0.016$  on the low end to  $-0.092$  on the high end. By using a wide range of GDP elasticity of GDP estimates we are not suggesting that the central estimate is unusually unstable. Rather Figure 26 confirms that the essential results regarding efficient size are robust for a wide variation in GDP elasticity. For the Base Case the optimal size ranges from 700 to 1000 million barrels. The resulting expected NPV benefits range from \$0.2 billion to \$4.7 billion.

Over all values of GDP elasticity considered, expansion to at least 700 MMB provides some positive expected net benefit. Admittedly, for the lowest end of the range of GDP elasticity, the net expansion benefits are modest. For the highest end considered, the optimal expansion size could even be greater than 1000 MMB, which was the largest size examined. Each of these extreme ends of the sensitivity range should be viewed as much less likely than the values near the central estimate for the GDP elasticity, over which the efficient size of the reserve is at or somewhat above 700 MMB.



**Figure 26:** Sensitivity of Maximum Benefits and Optimal Size to GDP Elasticity

## 5.0 Overall Conclusions Regarding Efficient Reserve Size

The analysis presented here strongly supports the conclusion that expanding the U.S. Strategic Petroleum Reserve by at least 120 Million barrels is justified on the basis of its expected net benefits to the U.S. economy. Our evaluation included the reserve's ability to reduce GDP losses and oil import costs during oil shocks, and subtracted the costs of building, filling, and operating the reserve. The conclusion that a substantial reserve expansion is justified holds true over a range of conditions, including more optimistic oil market assumptions which entail lower disruption risk over the next few decades. It also holds true for a range of variation in other key parameters such as the GDP elasticity with respect to oil price shocks, and for substantially higher storage costs than those of the least expensive alternative, underground salt caverns.

Collectively, the sensitivity analyses indicate that an expansion of the U.S. reserve at least to 700 MMB is worthwhile in all but the most optimistic assumptions about the world oil market. Those optimistic assumptions assume higher offsets and lower probabilities. In the high offsets case there is a substantial quantity of excess oil production capacity available in the world oil market (5 to 6 million barrels, see Figure 10) that persists across the forecast time horizon, and is readily available in the event of a disruption. The optimistic assumptions also assume that the lower disruption probability distribution is used, meaning that the likelihood of a very large disruption is half as great as in the Base Case (i.e., a 0.5% annual probability of 15% loss of world supply compared to a 1% probability in the Base Case). Finally this most optimistic case assumes that oil market disruptions are no longer than 6 months in duration, and average at most 4 ½ months in duration.

On the other hand, without all of these optimistic assumptions *combined*, there is generally a significant benefit to be gained by expanding the SPR. If only two of these optimistic assumptions (regarding offsets, disruption probability, and disruption length) hold true, then an expansion of at least 120 million barrels is worthwhile, and it could be very valuable. When it comes to analyzing the oil market, and its effect on world economies, there are unavoidably many uncertainties. Nonetheless, while our state of knowledge is imperfect, we still have a foundation on which to proceed, and proceed we must, making the best use of historical experience and expert judgement. Our estimates of the magnitude of macroeconomic loss that the U.S. economy could suffer during a future oil shock are based on a well-established empirical literature for the U.S. and other OECD economies. The input conditions for oil market risk (including disruption probabilities, disruption lengths, and available slack production capacity during a disruption) are among the most difficult of all factors to establish. For this analysis, we relied on "Midcase" disruption probabilities constructed for the 1990 U.S. SPR size study, by U.S. DOE/Interagency team. As described above, these probabilities are also roughly in the middle of two more recent disruption likelihood assessments, each of which relied on the subjective opinions of a group of experts.

For the Base Case presented here, the efficient incremental reserve size is about 700 to 850 million barrels, yielding an expected net benefit of about \$1.5-\$1.8 billion (U.S. \$).

In some cases, even a larger reserve is efficient. Specifically, the value of strategic oil stockpiling and the efficient reserve size grow markedly if we anticipate that future disruptions may be, on average, a few months longer than the somewhat optimistic “base” assumption of 4 ½ months average duration applied here. The history of 18 oil market shocks since 1951 indicates a median length of close to 6 months.

These modeling experiments indicate that a substantial addition to U.S. reserves is worthwhile under a wide range of conditions, including a number of conditions ordinarily unfavorable to strategic storage. The results provide convincing support for at least filling the existing unused SPR capacity, i.e., filling the reserve to its current capacity of 700 MMB. This is because the currently unused facilities represent a substantial and valuable investment, and because the next few years may present an opportunity to acquire oil at a comparatively low price.

The results may even underestimate the efficient expansion size, since they presume that all of the existing global “strategic stocks” (both government-owned and government-controlled commercial stocks) will be promptly used and well coordinated in the event of a disruption. They also only account for the specific economic consequences which we can easily include in the cost-benefit analysis, omitting other, less tangible or quantifiable, potential benefits.

The results on efficient size are certainly robust for variations in GDP elasticity up or down by 30%, or within one standard error of the estimate. Perhaps surprisingly, if all other assumptions are held fixed, expansion to 700 MMB still yields benefits for variations in GDP elasticity of plus or minus 70%, or over two standard errors of the estimate.

Finally, we can note that many other oil importing and consuming countries will benefit from the price-moderation effect of the U.S. reserve, without in any way reducing the ability of the U.S. to benefit from its own stockpile investment. Rather than being a cause for concern, these “spillover benefits” provide added motivation for expanding the reserve, since they assist many countries with which we have mutually beneficial trade and diplomatic relationships. They also provide a foundation upon which the countries involved can agree to undertake other, mutually beneficial actions, such as symmetrically expanding their own oil stockpiles, or some other form of energy security, environmental, or diplomatic cooperation.

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