Mercury Storage Cost Estimates

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MERCURY STORAGE COST ESTIMATES

I. INTRODUCTION AND SUMMARY OF RESULTS

EPA has projected that in the next several decades, global supply of elemental, commodity-grade mercury will overtake a declining demand for mercury-containing products and industrial mercury applications, leading to chronic over-supply.[1] In addition, concerns over unregulated mercury emissions in the developing world have led the European Union to ban all mercury exports outside the EU by 2011.[2] In order to assess options for managing domestic mercury surpluses in this global context, EPA has convened a stakeholder panel process to provide the U.S. government with a range of management options for non-federal supplies of mercury.[3] As part of this process, the panel has explored costs associated with the permanent, private sector storage of elemental mercury as a method of safe management of excess non-federal mercury supplies. A summary of the panel's estimates of costs of permanent mercury storage was presented at a public meeting on September 20, 2007. This report elaborates on the panel's estimates, based on current and projected mercury storage practices.

This examination of the costs of private sector storage considers two storage scenarios: a storage facility that uses rented warehouses, and a storage facility that includes construction of warehouses specifically for mercury storage. For each scenario, this report first estimates unit costs of mercury storage and then uses these unit cost estimates to project total storage costs over a 40-year period.

Estimates of total storage costs presented in this report assume that over a 40-year period, either 7,500 or 10,000 metric tons of excess mercury supply will require storage. Exhibit 1 summarizes the total cost estimates for both the rent and build scenarios, for both 7,500 and 10,000 metric tons of mercury stored over 40 years.

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[1] EPA (U.S. Environmental Protection Agency). 2005. "Global Mercury Commodity Market Study." Office of Pollution Prevention and Toxics and Office of Solid Waste and Emergency Response, Washington, DC.

[2] EPA (U.S. Environmental Protection Agency). 2007a. Office of Prevention, Pesticides and Toxic Substances, "Background Paper for Stakeholder Panel to Address Options for Managing U.S. Non-Federal Supplies of Commodity-Grade Mercury." Washington, DC.

[3] EPA (U.S. Environmental Protection Agency). 2007a. Office of Prevention, Pesticides and Toxic Substances, "Background Paper for Stakeholder Panel to Address Options for Managing U.S. Non-Federal Supplies of Commodity-Grade Mercury." Washington, DC.

EXHIBIT 1. SUMMARY OF ESTIMATES OF TOTAL STORAGE COSTS FOR 40 YEARS (2006 DOLLARS)[4]

TOTAL COST ESTIMATES	RENT SCENARIO	BUILD SCENARIO
7,500-Metric Ton Scenario		
Total Project Costs (undiscounted)	$59.5 - $144.2 million	$50.0 - $137.7 million
NPV of Total Project Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Annualized Costs	$1.4 - $3.0 million	$1.3 - $3.1 million
Annualized Costs per pound	$0.084 - $0.181	$0.081 - $0.186
10,000-Metric Ton Scenario		
Total Project Costs (undiscounted)	$69.8 - $183.9 million	$57.3 - $174.9 million
NPV of Total Project Costs	$21.3 - $50.9 million	$20.0 - $51.9 million
Annualized Costs	$1.6 - $3.8 million	$1.5 - $3.9 million
Annualized Costs per pound	$0.072 - $0.173	$0.068 - $0.177

In order to provide a comparison between this report's cost estimates and the estimates given in a presentation in June by the Department of Defense National Stockpile Center about their own mercury storage costs, this report also estimates the cost of 40 years of storage at a facility operated by the federal government. This estimate yields a range of government storage costs that falls within the range of costs estimated for private sector storage.

Because total cost estimates depend on a large number of assumptions, this report also conducts four sensitivity analyses to gauge the change in cost estimates caused by altering several assumptions and scenarios. These analyses look at the effects of excess mercury supply arriving at the facility in a front-loaded pattern, rather than in a constant stream; of mercury being transported directly from each source of mercury, rather than passing through retorters and recyclers; of estimating the net present value of storage costs in perpetuity, rather than for 40 years; and of having two facilities to store mercury, rather than one. Exhibit 2 summarizes the percentage changes in total project cost and in net present value of total cost observed in each sensitivity analysis.

[4] Present Value calculations assume a seven percent discount rate.

EXHIBIT 2: SUMMARY OF RESULTS OF SENSITIVITY ANALYSES

SENSITIVITY ANALYSES (7,500-TON ONLY)	RENT SCENARIO	BUILD SCENARIO
1. Supply Pattern Analysis		
% Increase in Total Project Costs	Less than 5%	Less than 5%
% Increase in NPV of Total Project Costs	8.7% - 16.3%	6.7% - 15.3%
2. Transportation Analysis[5]		
% Change in Total Project Costs	Less than 5%	Less than 5%
% Change in NPV of Total Project Costs	Less than 5%	Less than 5%
3. Planning Period Analysis		
% Increase in Total Project Costs	Not Applicable	Not Applicable
% Increase in NPV of Total Project Costs	6.2% - 7.5%	4.7% - 6.6%
4. Facility Number Analysis		
% Increase in Total Project Costs	45.4% - 13.8%	52.8% - 14.2%
% Increase in NPV of Total Project Costs	56.3% - 14.2%	61.2% - 17.0%

For all cost estimates, the report focuses on direct costs to operators of storage facilities and does not attempt to estimate costs (i.e. prices) that would be paid by generators seeking storage for mercury. Evaluation of prices requires consideration of expected profits, management costs, business risk, and market power, and is beyond the scope of this analysis. However, cost estimates presented in this analysis likely provide reasonable lower-end estimates of market prices for storage.

Section II of this report presents the methodology used to estimate unit costs and total 40-year costs of mercury storage. Section III discusses the assumptions that support these estimates, as well as associated limitations. Section IV presents unit cost estimates and explains how each was developed. Section V discusses the assumptions that apply to the estimates of total 40-year storage costs and presents these estimates for both 7,500 and 10,000 total metric tons stored. Section VI briefly discusses the costs incurred by a government-operated storage facility, applying most of the assumptions used in the private-sector analysis. Finally, Section VII presents four sensitivity analyses and Section VIII concludes with a discussion of the results and their limitations.

II. METHODOLOGY

This examination of the costs of private sector storage considers two storage scenarios: a storage facility that uses rented warehouses, and a storage facility that includes construction of warehouses specifically for mercury storage, hereafter referred to as the

[5] In this sensitivity analysis, minimum cost estimates increased while maximum cost estimates decreased. In both cases, the percent change was less than five percent.

"rent scenario" and the "build scenario." For each scenario, this report first estimates unit costs of mercury storage and then uses these unit cost estimates to project total storage costs over a 40-year period. This section discusses the methodology and sources used to develop these estimates.

UNIT COST ESTIMATES

For each storage scenario, this report estimates unit costs for all cost categories associated with long-term storage of mercury. These cost categories include costs of acquiring storage buildings, transporting the mercury and preparing it for storage, maintaining and insuring the storage facility, and satisfying regulatory requirements, including financial assurance.

Estimating these unit costs involved consultation with several sources in the U.S. government and relevant private industries. Key sources included Linda Barr of the Office of Solid Waste and the professional experience and input from a sub-group of experts from the Mercury Stakeholder Panel, consisting of the following individuals:

- David Lennett of the Natural Resources Defense Council
- Edward Balistreri of the Colorado School of Mines Department of Economics and Business
- Bruce Lawrence of Bethlehem Apparatus Company, Inc.
- Brad Buscher of Mercury Waste Solutions, Inc.
- Dennis Lynch of the Defense Logistics Agency
- William Fortune of the U.S. Department of Energy
- Joseph Pollara of Newmont Mining Corporation.

Wherever possible, unit cost estimates are based on current practice, either at existing storage facilities operated by mercury recyclers and retorters or at the Defense National Stockpile Center (DNSC)'s mercury storage facility at the Hawthorne Army Depot in Nevada.[6] Where information on current mercury storage practices is lacking, this report refers to general industry standards and costs incurred at similar facilities (e.g. storage warehouses, hazardous waste disposal facilities).[7]

TOTAL COST ESTIMATES

After identifying unit cost estimates for each storage scenario, this report then estimates total costs for each scenario using a 40-year cash flow model. Total cost estimates use a planning period of 40 years as a proxy for "permanent storage" for two reasons. First,

[6] Information on DNSC's mercury storage practices came from personal communication with Dennis Lynch at the Defense Logistics Agency (July 11, 2007) and from DNSC's 2007 Mercury Storage "Cost Comparison Matrix" (Defense Logistics Agency 2007a. Prepared by Dennis Lynch), a document that details capital and operations & management costs associated with mercury storage at the Hawthorne Army Depot and at DNSC's other storage sites.

[7] Consultation with representatives of the Waste Management Division of the Wisconsin Department of Natural Resources confirmed that this report's estimated unit costs of storage are consistent with the costs of their mercury storage operation.

this scenario is consistent with the cost projection period used in DNSC's environmental impact statement (EIS) for mercury storage at the Hawthorne Army Depot. Second, the uncertainty surrounding assumptions behind the unit cost estimates complicates projecting costs further into the future.[8]

This report estimates total costs for each storage scenario assuming two different total quantities of mercury to be stored over the 40-year period, 7,500 metric tons and 10,000 metric tons. These quantities are based on two excess domestic mercury scenarios reflecting different sets of assumptions about excess U.S. mercury supply over the next four decades. The 7,500-ton scenario assumes that roughly 1,200 metric tons of U.S. excess supply will come from mercury cell chlor-alkali plants, roughly 2,050 metric tons will come from product recycling and waste recovery, and about 4,250 metric tons will come from by-products of gold mining. The 10,000-ton scenario reflects these assumptions and assumes that an additional 2,500 metric tons of excess mercury will be shipped from Newmont Mining in Peru.[9]

III. ASSUMPTIONS AND LIMITATIONS

To generate reliable estimates of unit costs for mercury storage, this report makes several assumptions regarding the characteristics of the storage facility and the regulatory environment surrounding mercury storage. Most of the assumptions listed below reflect current practice in government and private sector mercury storage. Assumptions for which current practice does not serve as an adequate guide are examined more closely in the sensitivity analyses in Section VII.

GENERAL/FACILITY ASSUMPTIONS

Based on current practice at storage facilities in the mercury sector and in similar industries, this report makes the following assumptions regarding the logistics, physical characteristics, and location of the mercury storage facility when generating estimates of mercury storage unit costs:

- **Facility Number and Location**: The analysis assumes that all excess mercury will be stored at a single facility, located in either the mountain west or the central-southeast regions of the US. This report uses Nevada and Tennessee (current locations of mercury storage) as example locations in different regions, but these locations are not intended to represent actual future storage locations.
- **Retrofits for Rental Buildings**: For the rental scenario, the rented warehouses will require most of the retrofits that were required at DNSC's mercury storage

[8] DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. Note also that the costs associated with a 40-year time horizon, when discounted and presented in current dollars as a net present value calculation, capture over 90 percent of the total costs associated with projecting costs indefinitely, as discussed in Section VII.

[9] IEc estimates. These estimates were made early in the stakeholder consultation process, prior to recent announcements of mercury cell chlor-alkali plant closures. However, given uncertainties over recovery of Hg from different sources, the overall quantities of 7,500 tons and 10,000 tons appear to be reasonable scenarios.

facility at the Hawthorne Army Depot, namely adding proper ventilation and a sealed and curbed floor with catchment, but not including fire suppression.[10]

- **Storage Arrangement**: The facility will store mercury in one-metric-ton containers on pallets, with three containers fitting on each four-foot-by-four-foot pallet. This arrangement allows 6,612 pounds of mercury to be stored for every 16 square feet, equivalent to 413.25 pounds of mercury for each square foot of storage space. However, each storage building will need to set aside 20 percent of total storage space as clearance to facilitate inspection of stored mercury, meaning that only 330.6 pounds of mercury will be stored for every square foot of total space in each storage building.[11]
- **Security**: Security will consist of a fence that will enclose the entire facility, forming a perimeter 300 feet from the storage buildings. This fence will have one security post with 24-hour surveillance by camera and on-site personnel.[12]
- **Sources of Mercury**: Although mercury is expected to come from gold mines, mercury recyclers and retorters, and closed mercury cell chlor-alkali facilities, this report assumes that all mercury will pass through mercury recyclers and retorters for packaging before being transported to the storage facility. For the purposes of developing an initial cost estimate, this report assumes that mercury will come from the three largest mercury recyclers/retorters—Bethlehem Apparatus, D.F. Goldsmith, and Mercury Waste Solutions—in fixed, equal proportions. In order to capture the total costs associated with mercury storage, this report makes the initial assumption that all costs of preparing mercury and transporting it to the storage facility will be borne by the facility operator.

REGULATORY AND INSURANCE ASSUMPTIONS

The U.S. EPA currently classifies mercury recovered from secondary sources and retorted as a commodity because it is traded in a global market. Accordingly, current mercury storage facilities are not subject to RCRA Subtitle C regulation if the mercury has met RCRA requirements by being retorted from mercury-containing waste. However, when estimating the costs of long-term mercury storage, this report makes the conservative (i.e., high-cost) assumption that mercury storage facilities will face more rigorous regulatory requirements as trade of mercury declines and/or eventually ceases. Because this analysis focuses on costs borne by the storage facility operator, costs of government oversight of regulatory compliance are not included. For unit cost estimates,

[10] Retrofit practices at Hawthorne come from personal communication with Dennis Lynch, July 11, 2007. This report assumes that private sector storage would rent buildings made from non-flammable materials (Lawrence, Bruce. Personal Communication, August 15, 2007).

[11] This arrangement reflects current storage practice at Bethlehem Apparatus (Lawrence, Bruce. Personal Communication, August 15, 2007).

[12] IEc estimate.

this report assumes the following regarding regulatory compliance and liability insurance:[13]

- **Planning Permitting**: Unlike current Federal mercury storage facilities, private sector storage will not require a development of a formal environmental impact statement (EIS). However, some level of planning document preparation and permitting will be required by federal, state, or local regulations every ten years.[14] This report therefore uses the costs of certain federal and state permitting programs, such as Nevada's Chemical Accident Prevention Program, as proxies for likely (but unspecified) planning requirements.
- **RCRA Permitting**: Mercury stored perpetually will be classified as a hazardous waste. Consequently, a mercury storage facility will be classified as a Treatment, Storage, and Disposal Facility (TSDF) under RCRA and will require a RCRA Subtitle C, Part B permit (or some state or local equivalent) every ten years.
- **Liability Insurance**: A storage facility will be required to purchase Environmental Damage Liability Insurance and Standard Liability Insurance.
- **RCRA Financial Assurance**: A storage facility will be required to satisfy RCRA financial assurance requirements using the Trust Fund vehicle, in which the "owner/operator deposits money specifically earmarked for closure and/or post closure care."[15] This report assumes the use of this financial assurance vehicle because it represents the high-end cost option, and may be more appropriate than other options incorporating company financial status or risk-transfer (e.g., letters of credit, financial test, or surety bonds), given that the facility will be designed to store mercury in perpetuity.
- **Trust Fund Closure Costs**: This report estimates trust fund costs using a formula that uses an estimate of closure costs, a pay-in period of ten years, a trust fund rate of return of four percent, and a trust fund marginal tax rate of twenty percent. Estimates of the closure costs which must be paid into the trust fund are based on three closure scenarios:
    1. The current facility operator shuts down and a new operator takes over the storage facility. This is the low-cost scenario.
    2. The existing facility closes and all stored mercury is transferred to a new facility. This is the mid-cost scenario.
    3. The existing facility closes and all stored mercury is stabilized and disposed of. This is the high-cost scenario.

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[13] These assumptions in no way reflect actual policies being considered by EPA, but are rather best guess estimates of what could potentially be required.

[14] Pollara, Joseph, Personal Communication, August 15, 2007.

[15] EPA (U.S. Environmental Protection Agency). 2007b. "TSDFs: Meeting the Financial Assurance Requirements." http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/financial/famech.htm, accessed October 1, 2007.

IV. UNIT COSTS

Estimates of unit costs for long-term mercury storage in both the rent and build scenarios are presented in Exhibits 3 and 4, with the appropriate unit indicated for each cost. Exhibit 3 presents estimates of unit costs for expenses that recur periodically every ten years, with the exception of land purchase cost, which is incurred only once at the beginning of the planning period. These periodic expenses consist of obtaining RCRA and planning permits, preparing the storage facility site and buildings, conducting regular inspection of mercury containers, and a portion of the activities associated with regulatory compliance. Exhibit 4 presents estimates of unit costs that recur every year of storage, such as the costs to prepare and transport a year's worth of mercury to the facility, operations and maintenance costs, costs of insurance, and the remainder of the costs associated with regulatory compliance. The following is a list of all unit costs and a brief description of how each was estimated:

1. Periodic Unit Costs: These costs are related to facility permitting, building preparation, regulatory requirements, and material inspection, and are incurred either once at the beginning of the 40-year storage planning period, or periodically once every ten years.

    - **Land Purchase**: The land purchase unit cost applies only to the build scenario, as this report assumes that the cost to rent storage buildings will include the cost of renting the surrounding land. For the build scenario, this cost represents the typical land costs for industrial use in rural Nevada, provided by an article in the July 2007, issue of *Nevada Business Journal*.[16] This cost is incurred once per facility at the beginning of the 40-year storage planning period.

    - **Building Design (retrofit and new building)**: The unit cost for building design is estimated by taking the total design cost for the retrofit construction undertaken at the Hawthorne Army Depot and dividing it by the total number of buildings that received retrofits. This report assumes that the unit cost for design will be the same for retrofit construction and new building construction. This cost is incurred every ten years if new storage buildings are required.

[16] Foley, Kathleen. 2007. "Nevada's Industrial Demand Fuels Growth." Nevada Business Journal, July. http://www.nbj.com/issue/0707/2/1634, accessed July 15, 2007.

EXHIBIT 3: PERIODIC UNIT COSTS OF MERCURY STORAGE (2006 DOLLARS)

	UNIT	UNIT COST		SOURCE
		RENT SCENARIO	BUILD SCENARIO	
Building Preparation				
Land Purchase (once)	square foot	N/A	$3 - $4	1
Building Design (retrofit & new building)	building	$48,214	$48,214	2 (Hawthorne)
Construction (retrofit & new building)	square foot	$23	$59 - $83	2 (Hawthorne), 3
Permitting				
Planning Permit	facility	$250,000	$250,000	4
RCRA B Permit	facility	$150,000	$150,000	5
Regulatory Compliance				
Financial Assurance: Trust Fund Initial Payment	pounds stored	$0.0250 - $0.4944	$0.0024 - $0.4944	6
Inspections: Equipment	facility	$16,081	$16,081	7
Material Inspection				
Year 10 Inspection, Disposal, & Replacement	pounds stored	$0.0024	$0.0024	8 (Appendix D)

Sources:

1. Foley, Kathleen. 2007. "Nevada's Industrial Demand Fuels Growth." Nevada Business Journal, July. http://www.nbj.com/issue/0707/2/1634, accessed July 15, 2007.
2. DLA (Defense Logistics Agency). 2007a. "Cost Comparison Matrix," prepared by Dennis Lynch.
3. Wille, Rod F. 2003. "The Business Case for Building Green." Development Magazine. National Association of Industrial and Office Properties, Winter Issue.
4. Pollara, Joseph, Personal Communication, September 10, 2007
5. Lawrence, Bruce. Personal Communication, August 15, 2007.
6. EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium.* Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc
7. Mercury Tracker 3000, http://www.mercury-instrumentsusa.com/MercuryTracker3000.html, accessed July 15, 2007.
8. DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. All costs are adjusted to 2006 dollars.

Notes:

- All costs are incurred once every ten years, unless otherwise indicated.
- Costs for inspections equipment represent the cost of the "Mercury Tracker 3000" mercury vapor detector, which has an estimated operating life of ten years.

EXHIBIT 4: ANNUAL UNIT COSTS OF MERCURY STORAGE (2006 DOLLARS)

	UNIT	UNIT COST: RENT SCENARIO	UNIT COST: BUILD SCENARIO	SOURCE
Mercury Preparation				
Labor & Materials (Flasks, Overpacks)	pounds added	$0.7409	$0.7409	1, Appendix D
Material Handling	pounds added	$0.1653	$0.1653	2, Hawthorne
Transportation				
Cost to Tennessee	pounds added	$0.1497	$0.1497	cost per ton per mile from 3
Cost to Nevada	pounds added	$0.4398	$0.4398	
Operations & Maintenance				
Rent	square foot	$6.00 - $9.00	N/A	4
Maintenance	square foot	$0.54 - $2.63	$0.54 - $2.63	2, All Sites
Security	facility	$164,362	$164,362	5
Insurance				
Environmental Damage Liability	facility	$150,000	$150,000	5
Standard Liability	facility	$100,000 - $200,000	$100,000 - $200,000	6
Regulatory Compliance				
Inspections: Labor	building	$158 - $685	$158 - $685	5
Staff Training	facility	$158 - $685	$158 - $685	5
Financial Assurance: Trust Fund Payments	pounds stored	$0.0250 - $0.4944	$0.0024 - $0.4944	formula from 5

Sources:

1. DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. All costs are adjusted to 2006 dollars.
2. DLA (Defense Logistics Agency). 2007a. "Cost Comparison Matrix," prepared by Dennis Lynch.
3. EPA (U.S. Environmental Protection Agency). 2006. "Assessment of the Potential Costs, Benefits, and Other Impacts of Chat Use in Transportation Projects." Office of Solid Waste: Economics, Methods, and Risk Analysis Division, Washington, DC.
4. Lawrence, Bruce. Personal Communication, August 15, 2007.
5. EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium*. Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc.
6. Pollara, Joseph, Personal Communication, September 10, 2007.

Notes:

- All costs are incurred once every year.
- Trust Fund Payments assume a ten-year pay-in period.
- Security costs assume 24-hour surveillance (three FTEs at $13.17 per hour).
- Inspection costs assume one-hour inspections conducted once monthly (low-end estimate) or weekly (high-end estimate).
- Staff training costs for regulatory compliance are assumed to be similar to labor inspection costs.

- **Construction (retrofit and new building)**:[17] For the rent scenario, the unit cost of construction represents the cost per square foot of applying the same retrofits that were required at the Hawthorne storage facility. Accordingly, this cost is estimated by taking the total cost of retrofit construction at Hawthorne and dividing it by the total square feet of storage in buildings that received retrofits. For the build scenario, this unit cost reflects typical core/shell construction costs for industrial buildings, as provided by an article in the 2003 winter issue of Development Magazine.[18] For both scenarios, this unit cost is incurred every ten years if new storage buildings are required.
- **Planning Permit**: The estimated cost of planning permitting (such as the requirements under Nevada's Chemical Accident Prevention Program) is provided by Joseph Pollara of Newmont Mining Corporation.[19] As with RCRA B permitting, this cost is incurred once for the entire storage facility every ten years.
- **RCRA B Permit**: The estimated cost of obtaining RCRA Subtitle C, Part B permits, or equivalent state and local permits, is provided by Bruce Lawrence of Bethlehem Apparatus Company, Inc.[20] This cost is incurred once for the entire mercury storage facility every ten years.
- **Financial Assurance – Trust Fund Initial Payment**: The unit cost for the initial trust fund payment is calculated using a formula provided by EPA's *Unit Cost Compendium*, which inputs total closure costs, a pay-in period, a trust fund rate of return, and a marginal tax rate, and produces a total required initial trust fund payment.[21] This initial payment is divided by the total pounds of mercury to be added every ten years to yield a per-pound unit cost for the initial trust fund payment. This report assumes ten years, four percent, and 20 percent as values for the pay-in period, the trust fund rate of return, and the marginal tax rate, respectively. Initial trust fund payments are made once every ten years for the trust fund covering closure costs of all mercury expected to be stored in the following ten-year period. Estimated closure costs are different for each of the three closure scenarios listed in Section III, as specified below:
    1. *New Operator Scenario*: Closure costs are the net present value (NPV) of perpetual storage of all mercury accumulated at the point of closure, including periodic costs related to permitting, insurance, and regulatory requirements (excluding financial assurance), as well as all annual operations and maintenance costs.

[17] For this and other per-square-foot unit costs, the unit in question is the total square feet of mercury storage buildings, not the actual square feet occupied by mercury itself. As mentioned in Section III, 20 percent of every storage building is set aside as clearance to facilitate inspection.
[18] Wille, Rod F. 2003. "The Business Case for Building Green." Development Magazine. National Association of Industrial and Office Properties, Winter Issue.
[19] Pollara, Joseph, Personal Communication, September 10, 2007.
[20] Lawrence, Bruce. Personal Communication, August 15, 2007.
[21] EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium*. Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc.

2. *New Facility Scenario*: Closure costs are the costs of transporting all mercury accumulated at the point of closure, the costs of acquiring a new storage facility, and the NPV of perpetual storage of the mercury, as described above.

3. *Stabilize and Dispose Scenario*: Closure costs are the costs of stabilizing and disposing all mercury stored at the facility at the point of closure, at an estimated cost of $10,000 per ton.[22]

To illustrate the costs of each scenario, Exhibit 5 displays example closure costs under each scenario for a facility storing 2,500 tons of mercury over a ten-year period. Because scenarios one and two incorporate the costs of perpetual storage of current mercury, minimum and maximum values are displayed, representing low- and high-end values of storage unit costs. The exhibit also displays the range of annual trust fund payments that would result from taking the minimum and maximum of these closure costs.

EXHIBIT 5: TOTAL CLOSURE COSTS FOR A FACILITY STORING 2,500 TONS OF MERCURY FOR TEN YEARS (2006 DOLLARS)

CLOSURE SCENARIO	CLOSURE COSTS	
	RENT SCENARIO	BUILD SCENARIO
Closure Scenario 1	$8.7 - $11.6 million	$6.9 - $9.0 million
Closure Scenario 2	$10.8 - $13.7 million	$15.1 - $19.7 million
Closure Scenario 3	$25.0 million	$25.0 million
Range of Closure Costs	$8.7 - $25.0 million	$6.9 - $25.0 million
Annual Trust Fund Payments	*$943,100 - $2,725,000*	*$756,300 - $2,725,000*

- **Inspections - Equipment**: This item represents the cost of purchasing a Mercury Tracker 3000, a representative mercury vapor detector. [23] The Mercury Tracker 3000 is expected to have a ten-year lifespan, so this cost is incurred once per facility every ten years.

- **Year Ten Inspection, Disposal, and Replacement of Containers**: The unit cost of inspecting mercury containers every ten years is derived from the estimated container inspection costs in DNSC's Mercury Management Environmental Impact Statement for consolidated mercury storage at the Hawthorne Army Depot.[24] DNSC assumes that 0.74 percent of mercury containers will require replacement every 40 years, at a cost of $99.79 per container. Dividing the replacement percentage by four and multiplying it by the replacement cost per container yields the unit cost per pound of inspecting mercury containers once every ten years.

[22] Cost of stabilization and disposal provided by Bruce Lawrence (Personal Communication, August 15, 2007).

[23] Mercury Tracker 3000, http://www.mercury-instrumentsusa.com/MercuryTracker3000.html, accessed 7/15/07.

[24] Appendix D of DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. All costs are adjusted to 2006 dollars.

2. Annual Unit Costs: These costs are incurred every year and cover mercury preparation and transportation to the facility, operations and maintenance of the facility, liability insurance, and regulatory compliance, including financial assurance.

   - **Mercury Preparation – Labor and Materials**: The mercury preparation unit cost represents the cost, in labor and materials, of packing one pound commodity-grade mercury into one-metric-ton storage containers. This report estimates this unit cost by taking the estimated per-pound preparation cost cited in DNSC's Mercury Management EIS and applying an adjustment to account for the difference in costs between the one-ton containers used at the proposed private storage facility and the 76-pound flasks used at the public facility at Hawthorne.[25] This cost is incurred once for each new pound of mercury sent to the site and is estimated annually.

   - **Material Handling**: The material handling unit cost represents the cost to receive and reposition one pound of mercury at the storage facility. This unit cost is obtained by taking the total costs of material handling at DNSC's Hawthorne storage facility and dividing it by the total pounds of mercury stored at Hawthorne.[26] This cost is incurred once for every new pound of mercury added to the site and is estimated annually.

   - **Transportation (to Tennessee or Nevada)**: Transportation unit costs represent the cost to transport one pound of mercury from its point of origin to the site of the storage facility by truck. This report assumes that all stored mercury is packaged at the three largest mercury retorters and recyclers and then transported to a facility in either Tennessee or Nevada. The per-pound cost of transportation is estimated by taking an estimated cost of transporting one pound of mercury for one mile and multiplying it by a weighted-average distance from the three recycler/retorter facilities to sites in either Tennessee or Nevada. The report uses the cost of transporting "chat" (granular mine waste) as a proxy for the cost of transporting one pound of mercury for one mile, adjusted to account for the extra weight of mercury storage containers.[27] Transportation costs are incurred once for all new mercury brought to the storage facility and are estimated annually.

   - **Rent**: The rent unit cost applies only to the rent scenario and represents the cost of renting one square foot of industrial storage space.[28] The range of rent unit costs

[25] Appendix D of DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. All costs are adjusted to 2006 dollars. Cost of one-ton containers provided by Lawrence, 8/15/2007.

[26] DLA (Defense Logistics Agency). 2007a. "Cost Comparison Matrix," prepared by Dennis Lynch. Hawthorne data only.

[27] Chat transportation costs from EPA (U.S. Environmental Protection Agency). 2006. "Assessment of the Potential Costs, Benefits, and Other Impacts of Chat Use in Transportation Projects." Office of Solid Waste: Economics, Methods, and Risk Analysis Division, Washington, DC. Weight of mercury storage containers from Appendix C of DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA.

[28] As with construction unit costs, this unit cost applies to total square feet of mercury storage buildings, rather than the actual square feet occupied by mercury storage containers.

is provided by Bruce Lawrence of Bethlehem Apparatus Company, Inc.[29] Rent costs are incurred once per year for all square feet of storage space.

- **Maintenance**: Maintenance unit costs represent the cost per square foot of annual utilities and routine facility upkeep. To estimate maintenance unit costs, this report takes the range of maintenance costs incurred at each of DNSC's storage facilities (including pre-consolidation storage sites at Somerville, NJ, Warren, OH, and New Haven, IN) and divides them by the square feet of storage space at each site.[30] Maintenance costs are incurred on an ongoing basis and are estimated annually for all square feet of storage space.
- **Security**: Based on the security assumption specified in Section III, the security unit cost represents the cost per facility of 24-hour surveillance by a single guard at the facility's one security post. This unit cost is estimated by taking the hourly wage rate for security personnel specified in EPA's *Unit Cost Compendium* and multiplying it by three full-time equivalents.[31] This cost is incurred on an ongoing basis at the facility level and estimated annually.
- **Environmental Damage Liability Insurance**: The unit cost of environmental damage liability insurance represents the annual cost of insurance premiums to cover the risk of spilled mercury causing damage to the surrounding environment. This report uses the minimum premium required for hazardous waste combustors, as cited by EPA's *Unit Cost Compendium*, as a proxy for the cost of environmental damage liability insurance for a mercury storage facility. The *Unit Cost Compendium*'s minimum premium assumes coverage of $4 million per occurrence, $8 million total, and a $1 million deductible.[32] All insurance costs are incurred once per facility each year.
- **Standard Liability Insurance**: The unit cost of standard liability insurance represents the annual premium required to cover liability for non-environmental damages. This report uses an estimate provided by Joe Pollara of Newmont Mining Corporation.[33]
- **Inspections – Labor**: Labor unit costs for regular inspections represent the cost per building of one-hour inspections with a vapor detector performed either monthly (low-cost estimate) or weekly (high-cost estimate). This report estimates this unit cost by taking the same hourly wage used for the security unit cost and multiplying it by either 12 (monthly inspections) or 52 (weekly inspections). The per-building unit cost of regular inspections is incurred on an ongoing basis and estimated annually.

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[29] Lawrence, Bruce. Personal Communication, August 15, 2007.

[30] DLA (Defense Logistics Agency). 2007a. "Cost Comparison Matrix," prepared by Dennis Lynch.

[31] EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium*. Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc. All costs are adjusted to 2006 dollars.

[32] EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium*. Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc.

[33] Pollara, Joseph, Personal Communication, September 10, 2007.

- **Regulatory Compliance – Staff Training**: This report estimates that staff training costs for regulatory compliance will be similar to labor costs for inspections. Accordingly, the unit costs for staff training are the same as the unit costs for labor for inspections, and are incurred on an annual basis.
- **Financial Assurance – Trust Fund Payments**: As with the initial trust fund payment, the unit cost for annual trust fund payments is calculated using a formula provided by EPA's *Unit Cost Compendium*, which inputs total closure costs, a pay-in period, a trust fund rate of return, and a marginal tax rate, and produces a total required annual trust fund payment.[34] This payment is divided by the total pounds of mercury to be added every ten years to yield a per-pound unit cost for the annual trust fund payment. As specified above, this report estimates closure costs under three closure scenarios and assumes ten years, four percent, and 20 percent as values for the pay-in period, the trust fund rate of return, and the marginal tax rate, respectively.

V. TOTAL COST ESTIMATES

For each storage scenario, this report estimates total costs for two mercury quantity scenarios: 7,500 metric tons stored and 10,000 metric tons stored, yielding four estimates of total costs. The report's analysis of total costs reflects an overall facility-operating period of 40 years, but assumes that facility operators will estimate costs in four separate ten-year planning cycles (consistent with permit requirements). The analysis assumes that operators will design facilities and make capital investments to meet projected mercury storage requirements for each ten-year period.

For each total cost estimate, the following assumptions apply:

- **Planning Period**: In order to account for time needed to prepare a mercury storage facility, the 40-year planning period begins in 2011, with year zero costs occurring in 2010.
- **New Buildings**: At the beginning of each ten-year period, construction or retrofitting of buildings at a storage facility will be based on the total projected storage needs of the upcoming decade, with new buildings added to the facility as projected storage requirements dictate.
- **Building Size**: The size of buildings at the storage facility will be 10,000, 15,000, or 20,000 square feet, depending on projected storage needs. Because of clearance requirements, 8,000, 12,000, and 16,000 square feet will be available for mercury storage, respectively.[35] In the 7,500-ton scenario, approximately 12,500 square feet of building space will be required for the ten-year period beginning in 2011, followed by 25,000 square feet in 2021, 37,500 square feet in 2031, and 50,000 square feet in 2041. Similarly, in the 10,000-ton scenario, approximately

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[34] EPA (U.S. Environmental Protection Agency). 2000. *Unit Cost Compendium*. Office of Solid Waste: Economics, Methods, and Risk Analysis Division, prepared by DPRA, Inc.

[35] Personal communication with Bruce Lawrence 8/15/07, 9/13/07.

16,700 square feet will be required in 2011, followed by 33,300 square feet in 2021, 50,000 square feet in 2031, and 66,700 in 2041.

- **Land Purchase**: In the build scenario, the amount of land to be purchased will reflect the need for a security fence and 300-foot buffer surrounding the storage facility buildings. Total land required to store all mercury projected to be stored over 40 years will be purchased in year zero of the analysis.
- **Trust Fund Costs**: Trust fund costs for each ten-year period will be based on the closure costs for the total projected mercury added during that particular period. Trust fund costs for periods two, three, and four will not include closure costs for mercury previously stored in the facility, as those closure costs will have been accounted for in previous trust fund payments. The minimum-cost estimates use closure costs as determined by Closure Scenario 1, while the maximum-cost estimates use closure costs as determined by Closure Scenario 3.
- **Facility Location**: One storage facility will be established, located in either Tennessee or Nevada. The minimum-cost estimates assume that the storage facility is located in Tennessee, and the maximum-cost estimates assume that the storage facility is located in Nevada.
- **Mercury Transportation**: A constant amount of mercury will be transported to the storage facility every year of the 40-year planning period. This equates to 187.5 metric tons per year in the 7,500-ton scenario and 250 metric tons per year in the 10,000-ton scenario.

For each scenario, this report estimates total project costs, total project costs per pound, net present value of total costs, annualized total costs, and annualized total costs per pound, all in 2006 dollars. The net present value of total costs incorporates a real discount rate of seven percent, which accounts for the opportunity cost of capital and reflects the idea that costs borne in the future have less value than costs borne in the present. [36] The annualized total cost represents the amount that would have to be paid every year to cover total storage costs, assuming the same discount rate used to calculate net present value of total costs, which accounts for the cost of self-financing. The results of the total cost estimates are presented in Exhibits 6 and 7.

[36] A real discount rate of seven percent is recommended by OMB Circular A-94, which specifies that this discount rate reflects the opportunity cost of capital and does not require that annual costs be adjusted for inflation.

EXHIBIT 6: TOTAL COST ESTIMATES FOR 7,500 METRIC TONS OF STORAGE FOR 40 YEARS (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Total Project Costs (undiscounted)	$59.5 - $144.2 million	$50.0 - $137.7 million
Net Present Value of Total Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Annualized Costs	$1.4 - $3.0 million	$1.3 - $3.1 million
Annualized Costs per pound	$0.084 - $0.181	$0.081 - $0.186

EXHIBIT 7: TOTAL COST ESTIMATES FOR 10,000 METRIC TONS OF STORAGE FOR 40 YEARS (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Total Project Costs (undiscounted)	$69.8 - $183.9 million	$57.3 - $174.9 million
Net Present Value of Total Costs	$21.3 - $50.9 million	$20.0 - $51.9 million
Annualized Costs	$1.6 - $3.8 million	$1.5 - $3.9 million
Annualized Costs per pound	$0.072 - $0.173	$0.068 - $0.177

The large range between minimum and maximum cost estimates in each scenario is due primarily to large differences between trust fund costs for each closure scenario, with Closure Scenario 3 (stabilize and dispose) costing more than twice as much per year as Closure Scenario 1 (new facility operator). In general, total storage costs for the build scenario are slightly lower than for the rent scenario, due to the high cost of annual rent. However, because more of the costs in the build scenario are incurred in the first few years of the planning period, the difference between the net present values of total costs for each scenario is much smaller.

For both the rent and build scenarios, this report estimates that 40 years of storage of 7,500 metric tons of mercury will cost between 8 and 19 cents per pound per year. Multiplying this annualized cost per pound by 40 years yields total per-pound storage costs between $3.20 and $7.50. Assuming that storage costs are constant throughout the 40-year period, these values represent the range of cost-recovery storage fees that might be charged by a private facility for each pound stored.

Similarly, this report estimates that storage of 10,000 metric tons of mercury for 40 years will cost between 7 and 18 cents per pound per year. Multiplying this annualized cost per pound by 40 years yields total per-pound storage costs between $2.70 and $7.10.

Although total storage costs are greater in the 10,000-ton scenario than in the 7,500-ton scenario, per-pound costs are smaller in the 10,000-ton scenario because the fixed costs of mercury storage are divided among a greater quantity of mercury.

VI. GOVERNMENT STORAGE

This report focuses chiefly on the costs of private sector storage, but for comparison purposes, an estimate of total costs of storage for a government storage facility is also presented. In a presentation delivered on June 14, 2007, the Defense National Stockpile Center cited an annual cost of $0.0516 per pound for storage of mercury at the Hawthorne Army Depot in Hawthorne, Nevada.[37] However, this figure cannot be directly compared to estimates in this report of annualized costs per pound of private sector mercury storage because DNSC's estimates relied on different assumptions and only incorporated operations and maintenance costs.

In order to present a more appropriate comparison between costs of government storage and costs of private sector storage, this report estimates total costs for a government storage facility, using the same process described above. Most of the assumptions used in the private sector scenarios apply to the government scenario as well, with the following exceptions:

- The government storage facility will use rented buildings that will require the same retrofits that were required at DNSC's mercury storage facility at the Hawthorne Army Depot, *including* fire suppression.
- Mercury will be stored in 76-pound flasks enclosed within overpacks. This storage arrangement allows 70 pounds of mercury to be stored for each square foot of storage space.[38]
- A government storage facility will be required to prepare an Environmental Impact Statement (EIS) in year zero of the 40-year planning period and will therefore not need to pay for a planning permit every ten years.[39]
- The government will self insure its own storage and will therefore not need to purchase liability insurance or satisfy RCRA financial assurance requirements.

Exhibit 8 presents estimates of total storage costs, net present value of total costs, annualized costs, and annualized costs per pound for a government-operated facility, using the above assumptions. Estimated costs of government storage are higher than the minimum estimates of private sector costs (because government storage practices require more space per pound of mercury stored) but lower than the maximum estimates of private sector costs (because government storage does not require payment into a trust fund for RCRA financial assurance). These results indicate that private sector storage can be more or less expensive than government storage, depending on the nature of regulatory

[37] DLA (Defense Logistics Agency). 2007b. "Meeting DNSC's Mercury Challenge." Presentation given June 14. Defense National Stockpile Center, Fort Belvoir, VA.
[38] Hawthorne practice, from DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA.
[39] Lynch, Dennis. Personal Communication, July 11, 2007.

compliance requirements. Further detail on government facility storage cost estimates is provided in Appendix A.

EXHIBIT 8: TOTAL 40-YEAR STORAGE COST ESTIMATES FOR A GOVERNMENT FACILITY OPERATOR (2006 DOLLARS)

	7,500 METRIC TONS	10,000 METRIC TONS
Total Project Costs (undiscounted)	$78.9 - $99.8 million	$98.3 - $126.0 million
Net Present Value of Total Costs	$25.6 - $30.0 million	$30.6 - $36.4 million
Annualized Costs	$1.9 - $2.2 million	$2.3 - $2.7 million
Annualized Costs per pound	$0.116 - $0.136	$0.104 - $0.124

This report estimates that storing 7,500 metric tons of mercury for 40 years at a government-operated storage facility would cost between 10 and 14 cents per pound per year. Multiplying this cost by 40 years, as was done with the private sector cost estimates in Section V, yields a range of possible cost recovery fees of $4.60 to $5.40 per pound. Again, this range of possible fees falls within the range of fees estimated for the total 40-year costs of storing 7,500 metric tons of mercury at a private storage facility.

VII. SENSITIVITY ANALYSES

The analysis above represents a conservative approach in the sense that it avoids making assumptions that are not supported by current practice. Nevertheless, to test the validity of certain assumptions, this report conducts three sensitivity analyses to determine the effect that the following considerations would have on total cost estimates:

a. Whether mercury is delivered to the facility in a constant stream or in a pattern reflecting projected mercury supplies from mines, recyclers/retorters, and mercury cell chlor-alkali facilities

b. Whether transportation costs assume that all mercury comes to the storage facility via recyclers/retorters or that mercury comes directly from each source (mines, recyclers/retorters, mercury cell chlor-alkali facilities).

c. Whether net present value of total costs is modeled on a planning period of 40 years of storage or on perpetual storage (assuming a seven percent real discount rate).

d. Whether mercury is stored in one large storage facility or in two smaller facilities.

For all sensitivity analyses, the effect on the 10,000-ton scenario is similar to the effect on the 7,500-ton scenario, so the report presents only the results of the sensitivity analyses for the 7,500-ton scenario in detail.[40]

MERCURY SUPPLY PATTERN SENSITIVITY ANALYSIS

In calculating total costs of 40 years of storage, this report assumes that a constant quantity of mercury will arrive at the storage facility each year, due to uncertainty about the future of U.S. mercury supplies. As a sensitivity analysis to this assumption, this report estimates total costs based on projections of the quantity and timing of mercury supplied from the three principal U.S. sources – recovery of byproduct mercury from gold mines in Nevada, waste recovery and product recycling from mercury recyclers/retorters, and recovery of mercury inventories from decommissioning mercury cell chlor-alkali facilities.

For the 7,500-ton scenario, these projections suggest that, between gold mines, recyclers/retorters, and the closure or retrofit of three mercury cell chlor-alkali plants, roughly 2,600 metric tons of excess mercury will require storage between 2011 and 2020. Between 2021 and 2030, the projections predict that mercury from recyclers/retorters and gold mines will remain constant, while the last mercury cell chlor-alkali facility will close or undergo retrofit. As a result, roughly 2,000 metric tons of excess mercury will require storage during this period. Between 2031 and 2040, gold mines and recyclers/retorters are projected to produce about 1,700 metric tons of excess mercury for storage. Finally, between 2041 and 2050, excess supply U.S. gold mines is expected to decrease, while supply from recyclers/retorters is expected to remain constant, so approximately 1,100 metric tons of excess mercury will require storage. Exhibit 9 displays the projected excess supply of mercury from each supply. The alternate supply pattern assumption used in this sensitivity analyses uses the projected quantities of mercury for each ten-year period, indicated as "Average Ten-Year Total" in the exhibit, rather than dividing the total quantity of mercury supplied equally between each period.

[40] Additionally, per-pound costs of 40 years of storage are higher for the 7,500-ton scenario, so sensitivity analyses on the 7,500-ton scenario provide conservative estimates of the effect of changing assumptions on the upper-bound estimate of costs per pound.

EXHIBIT 9: PROJECTED EXCESS MERCURY SUPPLY FROM EACH SOURCE

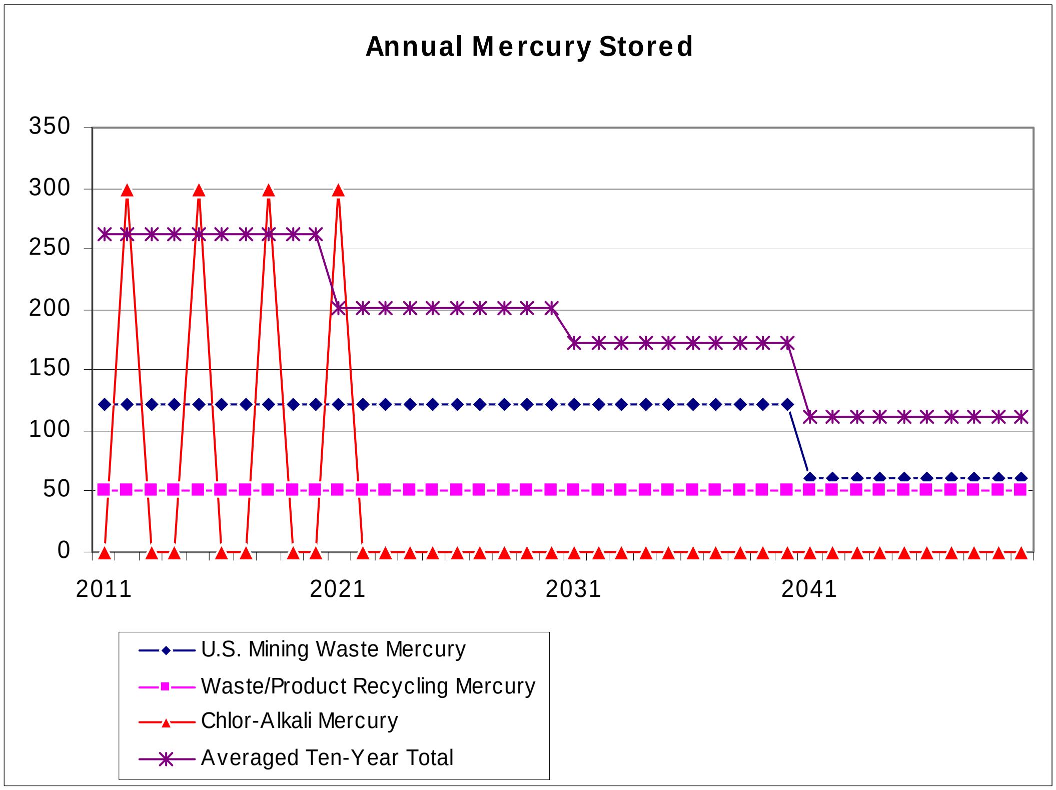

Exhibit 10 presents total costs and net present value of total costs using the base case assumptions and the alternate supply pattern assumption for the 7,500-ton scenario. Changing the mercury supply pattern assumption has a small effect (0.2 – 1.7 percent) on undiscounted total costs, because the overall quantity of mercury does not change. However, changing this assumption has a larger effect (6.7 – 16.3 percent) on the present value of total costs because the alternate mercury supply pattern assumption effectively "front-loads" projected costs, meaning that higher storage costs are incurred in earlier years, when the effect of discounting is less.

EXHIBIT 10: STORAGE COSTS FOR 7,500 TONS OF MERCURY, BASE CASE SCENARIO AND ALTERNATE SUPPLY PATTERN SCENARIO (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Base Case		
Total Project Costs (undiscounted)	$59.5 - $144.2 million	$50.0 - $137.7 million
NPV of Total Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Alternate Supply Pattern		
Total Project Costs (undiscounted)	$60.5 - $146.0 million	$50.1 - $138.0 million
NPV of Total Costs	$20.2 - $46.4 million	$19.0 - $47.3 million
Percent Change in NPV	8.7% - 16.3%	6.7% - 15.3%

Exhibit 11 illustrates how the share of total storage costs that are incurred during first ten years of storage changes when applying the alternate supply pattern assumption (7,500-ton scenario only). Even in the base-case estimate of mercury storage costs, one would expect the share of storage costs incurred during the first decade of storage to be greater than 25 percent in most scenarios. For the "build" scenario, land purchase occurs only in year zero, adding to the total costs of the first decade of storage. In addition, closure costs for the first ten years of storage, assuming Closure Scenarios 1 and 2, are greater than closure costs for subsequent decades, because the present value of perpetual storage for the mercury stored during the first ten years includes costs of permitting and insuring the post-closure storage facility, while closure costs for subsequent decades of storage do not.[41] On the other hand, the smaller size of the storage facility during the first decade acts to keep operations and maintenance costs lower than in future years. Moreover, closure costs for Closure Scenario 3 remain constant for each ten-year period of storage; they are determined simply by multiplying quantity of mercury stored by $10,000 per metric ton.

[41] Assuming that all mercury will be stored at the same facility post-closure, permitting and insurance costs will only need to be paid once for the entire facility. This analysis assumes that permitting and insurance costs will be included in the closure costs used to calculate trust fund payments during the first decade of storage. Accordingly, closure costs for trust fund payments in subsequent decades will not need to include these costs.

EXHIBIT 11: COSTS OF FIRST TEN YEARS OF STORAGE OF 7,500 METRIC TONS OF MERCURY, BASE CASE SCENARIO AND ALTERNATE SUPPLY PATTERN SCENARIO (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Base Case: Pounds Stored	4,133,667	4,133,667
Undiscounted Costs of First Ten Years	$19.2 - $33.7 million	$19.6 - $36.1 million
Share of Total 40-Year Cost	32.3% - 23.4%	39.1% - 26.2%
Net Present Value of Ten-Year Cost	$11.6 - $20.3 million	$12.3 - $22.6 million
Annualized Cost	$1.6 - $2.9 million	$1.8 - $3.2 million
Annualized Cost per Pound	$0.399 - $0.701	$0.425 - $0.778
Alternate: Pounds Stored	5,801,307	5,801,307
Undiscounted Cost of First Ten Years	$21.9 - $44.9 million	$21.7 - $47.1 million
Share of Total 40-Year Cost	36.3% - 30.8%	43.3% - 34.1%
Net Present Value of Ten-Year Cost	$15.1 - $31.1 million	$15.6 - $33.6 million
Annualized Cost	$2.1 - $4.4 million	$2.2 - $4.8 million
Annualized Cost per Pound	$0.371 - $0.762	$0.383 - $0.825

As the exhibit demonstrates, in both the rent and build scenarios, applying the alternate supply pattern assumption increases the share of total costs that are incurred during the first ten years of the planning period. However, the annualized cost per pound of storing mercury during this ten-year period is not significantly greater under the alternate supply pattern assumption. Although total costs for the first ten years of storage increases as mercury supply is front-loaded, the quantity of mercury also increases, bringing down the cost per pound.

For the base case scenario, the first ten years of mercury storage cost between 40 and 78 cents per pound per year. Multiplying the annualized cost per pound by ten yields a range of per-pound storage costs of $4.00 - $7.80, which is higher than the range of per-pound storage costs based on the total, 40-year cost of storing 7,500 tons of mercury. Because a greater share of storage costs are borne during the first ten years (in most scenarios), a per-pound cost-recovery fee would necessarily be higher for this period alone than for the 40-year period taken as a whole. Because storage facility operators are assumed to estimate costs in ten-year planning cycles, a facility operator would likely charge the higher cost-recovery per-pound storage fee for the first ten years of storage. In subsequent years, the facility operator could lower fees to reflect decreased storage costs, but it is more likely that per-pound storage fees would remain at the higher value.

MERCURY TRANSPORTATION COST SENSITIVITY ANALYSIS

This report's base-case estimates of total storage cost assume that all mercury will be transported to the long-term storage site from the three largest mercury recyclers/retorters, with an equal amount coming from each of the three facilities. In the 7,500-ton scenario, these costs total roughly $2.5 million for transportation to Tennessee and $7.3 million for transportation to Nevada, representing approximately five percent of total undiscounted costs for both the rent and build scenarios.[42] In order to test the effects of changing this assumption, this sensitivity analysis assumes that mercury will be transported to the storage facility directly from each of the three principal mercury sources (mines, recyclers/retorters, mercury cell chlor-alkali plants). As discussed in Section II, the projection used to generate the 7,500-ton estimate of total U.S. excess mercury between 2011 and 2050 assumes that about 1,200 metric tons will come from mercury cell chlor-alkali plants, about 2,050 metric tons will come from product recycling and waste recovery, and about 4,250 metric tons will come from by-products of gold mining. The alternate transportation cost assumption uses these distributed quantities to estimate transportation costs from each source, multiplying each quantity by the cost of transportation from each source to either Nevada or Tennessee.[43]

The overall impact of changing transportation assumptions on undiscounted costs is that transportation costs to a facility in Nevada decrease and transportation costs to a facility in Tennessee decrease, to the point where transportation costs to Nevada are slightly less than transportation costs to Tennessee. Accordingly, estimates of total costs in this sensitivity analysis assume transport to Nevada in the minimum-cost estimate and transportation to Tennessee in the maximum-cost estimate, the reverse of the assumption used in the base-case analysis. As one would expect, using the alternate transportation cost assumption increases the minimum estimate of transportation costs and decreases the maximum estimate of transportation costs, relative to the base-case estimate, as shown in Exhibit 12. Likewise, the share of total costs that is related to transportation increases in the minimum estimates and decreases in the maximum estimates for both rent and build scenarios. The effect on total project costs, and on net present value of total costs, of applying only the alternate transportation cost assumption is less than four percent, indicating that the effects of changing the transportation cost assumption are likely to be relatively small.

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[42] The minimum cost estimate for each scenario assumes a facility location in Tennessee, while the maximum cost estimate assumes a facility location in Nevada. Accordingly, total transportation costs to Tennessee represent about five percent of the minimum estimate of total costs, while total transportation costs to Nevada represent about five percent of the maximum estimate of total costs. If these assumptions were changed, transportation to Nevada would represent 12-15 percent of the minimum estimate of total costs, while transportation to Tennessee would represent less than two percent of the maximum estimate of total costs.

[43] For each source category, the report estimates a weighted average cost of transportation by averaging the distance to each storage facility location (Nevada and Tennessee) from all sources within that category. For example, the cost of transportation from mercury cell chlor-alkali facilities to storage in Nevada is estimated by averaging the distances from the four mercury cell chlor-alkali facilities expected to cease operation during the 40-year planning period and multiplying that average distance by the unit cost of transporting one pound of mercury over one mile used in the base-case analysis.

EXHIBIT 12: TOTAL STORAGE COSTS FOR 7,500 METRIC TONS OF MERCURY, BASE CASE SCENARIO AND ALTERNATE TRANSPORTATION SCENARIO (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Base Case		
Total Project Cost	$59.5 - $144.2 million	$50.0 - $137.7 million
Total Transportation Cost	$2.5 - $7.3 million	$2.5 - $7.3 million
Percent of Total Cost	4.2% - 5.0%	5.0% - 5.3%
Alternate Transportation		
Total Project Cost	$60.6 – $142.1 million	$51.1 - $135.6 million
Total Transportation Cost	$3.6 - $5.1 million	$3.6 - $5.1 million
Percent of Total Cost	5.9% - 3.6%	7.0% - 3.8%

LENGTH OF PLANNING PERIOD

Calculations of net present value of costs used in this report consider estimated costs for 40 years of storage, primarily because the uncertainty about projecting costs beyond that period makes it difficult to estimate total costs with any degree of confidence. Nevertheless, this report conducts a sensitivity analysis on the 40-year planning period used in the base-case analysis by calculating the net present value of the costs of perpetual storage. To estimate costs of perpetual storage, this analysis projects estimated costs for years 31-40 for all future years. Because of discounting, the present value of future costs approaches zero as the planning period grows larger, so it is possible to calculate a fixed net present value of the total costs of perpetual storage. Assuming a seven percent discount rate, the NPV of total costs of perpetual storage is approximately 4.8 - 7.5 percent greater than the 40-year NPV of total costs in the base-case scenario (7,500-ton scenario only), as shown in Exhibit 13. This sensitivity analysis demonstrates that the estimate of the NPV of total costs using a 40-year planning period is within 10 percent of the expected NPV of costs of perpetual storage.

EXHIBIT 13: NET PRESENT VALUE OF STORAGE COSTS FOR 7,500 METRIC TONS OF MERCURY, BASE-CASE SCENARIO AND PERPETUAL STORAGE SCENARIO (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Base Case (40-year planning period)		
NPV of Total Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Perpetual Storage		
NPV of Total Costs	$19.8 - $42.9 million	$18.7 - $43.8 million
Percent Change	6.2% - 7.5%	4.8% - 6.6%

NUMBER OF FACILITIES

The estimates of total costs presented above assume that all mercury is sent to a single facility, located in either Tennessee or Nevada. This use of a single storage facility is based on the assumption that the savings from decreased transportation costs would be outweighed by the cost increases by doubling per-facility costs, such as permitting and liability insurance. To examine whether this assumption is justified, this sensitivity analysis estimates total storage costs for a scenario in which mercury is stored in two facilities – one in Tennessee and one in Nevada. In this scenario, all mercury will be sent to the nearest storage facility, with mercury from gold mines going to the facility in Nevada, and mercury originating from closing mercury cell chlor-alkali plants and from mercury recyclers/retorters going to the facility in Tennessee, according to the same distribution as described in the transportation cost sensitivity analysis above. A comparison between the net present value of total costs in the one-facility base-case scenario and the NPV of total costs in the two-facility scenario is presented in Exhibit 14. This comparison indicates that the cost savings from lower transportation costs are in fact greatly outweighed by the increased costs from permitting and insuring two separate facilities, resulting in a 56-62 percent increase in minimum estimates and a 14-17 percent increase in maximum estimates of NPV of total costs when two storage facilities are used.[44]

[44] The annualized cost per pound changes by an equal percentage, because this cost is derived directly from the NPV of total costs.

EXHIBIT 14: NET PRESENT VALUE OF STORAGE COSTS OF 7,500 METRIC TONS OF MERCURY, BASE-CASE SCENARIO AND TWO-FACILITY SCENARIO (2006 DOLLARS)

	RENT SCENARIO	BUILD SCENARIO
Base Case (one facility)		
NPV of Total Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Two Facilities		
NPV of Total Costs	$29.0 - $45.6 million	$28.9 - $48.0 million
Percent Change	56.3% - 14.2%	61.7% - 17.0%

VIII. DISCUSSION AND LIMITATIONS

In summary, this report estimates that the net present value of total costs of 40 years of storing mercury at a private sector storage facility will be between $17 and $41 million assuming 7,500 metric tons of mercury stored, and between $20 and $52 million assuming 10,000 metric tons of mercury. In general, total storage costs for the rent scenario are higher than total costs for the build scenario, but due to the timing of costs incurred in each scenario, the difference in net present value of costs is negligible. For both mercury quantity scenarios, estimated annualized storage costs are between 7 and 19 cents per pound. Multiplying the annualized per-pound cost by 40 years yields possible per-pound cost recovery fees between $2.70 and $7.50. Analysis of the first ten years of storage suggests that higher up-front costs might cause a storage facility operator to charge a cost recovery fee between $4.00 and $7.80.

EXHIBIT 15. SUMMARY OF ESTIMATES OF TOTAL STORAGE COSTS FOR 40 YEARS (2006 DOLLARS)[45]

TOTAL COST ESTIMATES	RENT SCENARIO	BUILD SCENARIO
7,500-Metric Ton Scenario		
Total Project Costs (undiscounted)	$59.5 - $144.2 million	$50.0 - $137.7 million
NPV of Total Project Costs	$18.5 - $39.9 million	$17.8 - $41.0 million
Annualized Costs	$1.4 - $3.0 million	$1.3 - $3.1 million
Annualized Costs per pound	$0.084 - $0.181	$0.081 - $0.186
10,000-Metric Ton Scenario		
Total Project Costs (undiscounted)	$69.8 - $183.9 million	$57.3 - $174.9 million
NPV of Total Project Costs	$21.3 - $50.9 million	$20.0 - $51.9 million
Annualized Costs	$1.6 - $3.8 million	$1.5 - $3.9 million
Annualized Costs per pound	$0.072 - $0.173	$0.068 - $0.177

The report's sensitivity analyses demonstrate that altering assumptions about transportation, mercury supply pattern, or facility planning period has only modest impacts on the base case scenario estimates. Of these, changing the assumption about mercury supply has little effect on total storage costs but increases the net present value of total costs by as much as 16 percent over the NPV of total costs in the base-case estimate; changing the assumption about transportation of mercury increases minimum-cost estimates and decreases maximum-cost estimates, but the effect on both is minimal; and changing the facility planning period increases total costs by less than 10 percent. Only changing the number of facilities had a large impact on total storage costs, indicating that the increased costs of permitting and insuring two facilities greatly outweigh the potential cost savings in mercury transportation.

[45] Present Value calculations assume a seven percent discount rate.

EXHIBIT 16: SUMMARY OF RESULTS OF SENSITIVITY ANALYSES

SENSITIVITY ANALYSES (7,500-TON ONLY)	RENT SCENARIO	BUILD SCENARIO
1. Supply Pattern Analysis		
% Increase in Total Project Costs	Less than 5%	Less than 5%
% Increase in NPV of Total Project Costs	8.7% - 16.3%	6.7% - 15.3%
2. Transportation Analysis[46]		
% Change in Total Project Costs	Less than 5%	Less than 5%
% Change in NPV of Total Project Costs	Less than 5%	Less than 5%
3. Planning Period Analysis		
% Increase in Total Project Costs	Not Applicable	Not Applicable
% Increase in NPV of Total Project Costs	6.2% - 7.5%	4.7% - 6.6%
4. Facility Number Analysis		
% Increase in Total Project Costs	45.4% - 13.8%	52.8% - 14.2%
% Increase in NPV of Total Project Costs	56.3% - 14.2%	61.2% - 17.0%

It is important to emphasize that this report's unit cost and total cost estimates represent initial estimates, and are constrained by the following limitations.

- Where possible, this report bases its unit cost estimates on design and construction costs for representative storage facilities, but actual design and construction costs may vary widely depending on the site of the storage facility or facilities.
- The location of the storage facility might have impacts on costs aside from construction and design costs. Transportation costs would vary the location of the storage facility, although not by a substantial amount. More importantly, regulatory and insurance requirements might vary from state to state, with associated effects on costs.
- This report estimates security costs assuming that the only security concern for mercury storage is the risk of environmental damage. Due to the toxic nature of elemental mercury and its use in certain weapons technologies, it is possible that mercury storage might be seen as a national security concern, in which case security costs would be much higher.

[46] In this sensitivity analysis, minimum cost estimates increased while maximum cost estimates decreased. In both cases, the percent change was less than five percent.

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APPENDIX A:

ESTIMATED COSTS OF MERCURY STORAGE IN A GOVERNMENT FACILITY

To estimate total storage costs at a government facility, this report first estimated unit costs for mercury storage at such a facility. As noted in Chapter VI, costs faced by a government facility differ from those faced by a private facility, based on a number of assumptions:

- **Permitting**: A government storage facility will be required to prepare an Environmental Impact Statement (EIS) once in year zero of the 40-year planning period and will therefore not need to pay for a planning permit every ten years.[47] RCRA B permits will still be required every ten years.
- **Building Preparation**: The government storage facility will rent buildings that will require the same retrofits that were required at DNSC's mercury storage facility at the Hawthorne Army Depot, *including* fire suppression. Land rental costs will be included in building rental costs, so the facility will not need to purchase land.
- **Regulatory Compliance**: The government storage facility will be required to perform a Process Hazard Analysis every five years.[48] Because the government self-insures, financial assurance will not be required, so the facility will not have to make any trust fund payments.
- **Mercury Preparation**: Mercury will be stored in 76-pound flasks enclosed within overpacks.[49] These materials cost slightly more than the one-metric-ton containers used by the private facility modeled above, raising mercury preparation unit costs.
- **Operations and Maintenance**: Rent and maintenance unit costs reflect the actual costs incurred at the existing Hawthorne Army Depot storage facility.
- **Insurance**: Because the government self-insures, environmental damage liability and standard liability insurance will not be required.

Exhibit A-1 displays the unit cost estimates used in calculating total cost of storing mercury for 40 years in a government storage facility. When calculating total costs, an additional consideration becomes relevant. Because the government storage facility stores mercury in flasks and overpacks, only 70 pounds of mercury can be stored for each square foot of storage space. Accordingly, the government facility needs about six times as much storage space as a private facility in order to store the same quantity of mercury. The increased storage space requirement increases all costs related to building preparation as well as to operations and maintenance, contributing to higher minimum costs of storage, as noted in Chapter VI.

[47] DLA (Defense Logistics Agency). 2007a. "Cost Comparison Matrix," prepared by Dennis Lynch.

[48] Lynch, Dennis. Personal Communication, July 11, 2007.

[49] Hawthorne practice, from DLA (Defense Logistics Agency). 2003. *Mercury Management Environmental Impact Statement*. Defense National Stockpile Center, Fort Belvoir, VA. All costs are adjusted to 2006 dollars.

EXHIBIT A-1: UNIT COST ESTIMATES FOR MERCURY STORAGE AT A GOVERNMENT FACILITY (2006 DOLLARS)

	UNIT	UNIT COST	SOURCE
Periodic Costs			
Permitting			
Environmental Impact Statement (once)	facility	$8,696,674	1
RCRA B Permit	facility	$150,000	2
Planning Permit	*facility*	*N/A*	
Building Preparation			
Building Design (retrofit)	building	$48,214	3 (Hawthorne)
Construction (retrofit)	square foot	$23	3 (Hawthorne)
Land Purchase	*square foot*	*N/A*	
Fire Suppression	building	$295,914	3 (Hawthorne)
Regulatory Compliance			
Process Hazard Analysis (every five years)	facility	$308,894	3 (Hawthorne)
Inspections: Equipment	facility	$16,081	4
Financial Assurance: Trust Fund Initial Payment	*pounds stored*	*N/A*	
Material Inspection			
Year 10 Inspection, Disposal, & Replacement	pounds stored	$0.0024	5 (Appendix D)
Annual Costs			
Mercury Preparation			
Labor & Materials (Flasks, Overpacks)	pounds added	$0.9433	5 (Appendix D)
Material Handling	pounds added	$0.1653	3 (Hawthorne)
Transportation			
Cost to Tennessee	pounds added	$0.1497	cost per ton per mile from 6
Cost to Nevada	pounds added	$0.4398	
Operations & Maintenance			
Rent	square foot	$3.07	3 (Hawthorne)
Maintenance	square foot	$0.54	3 (Hawthorne)
Security	facility	$164,362	7
Insurance			
Environmental Damage Liability	*facility*	*N/A*	
Standard Liability	*facility*	*N/A*	
Regulatory Compliance			
Inspections: Labor	building	$158 - $685	7
Staff Training	facility	$158 - $685	7
Financial Assurance: Trust Fund Payments	*pounds stored*	*N/A*	

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2. Lawrence, Bruce. Personal Communication, August 15, 2007.
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6. EPA (U.S. Environmental Protection Agency). 2006. "Assessment of the Potential Costs, Benefits, and Other Impacts of Chat Use in Transportation Projects." Office of Solid Waste: Economics, Methods, and Risk Analysis Division, Washington, DC.
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Notes:

- All periodic costs are incurred once every ten years, unless otherwise indicated.
- Costs for inspections equipment represent the cost of the "Mercury Tracker 3000" mercury vapor detector, which has an estimated operating life of ten years.