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Tank Riser Pit Decontamination System (Pit Viper) Return on Investment and Break-Even Analysis

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June 2003



Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Richland, WA 99352

Executive Summary

This study assessed the cost benefit of Pit Viper deployment for 80 tank farm pit entries required to be cleaned out and decontaminated between October 1, 2003 and September 30, 2012 under the technical baseline in place in FY 2002 for applicable double-shell tank (DST) and single-shell tank (SST) projects. After this assessment had been completed, the U.S. Department of Energy (DOE) Richland Operations Office (RL) and Office of River Protection (ORP) published the *Hanford Performance Management Plan* (August 2003) that accelerated the schedule for SST retrievals. Then, DOE/CH2M HILL contract modification M064 (October 2002) and *The Integrated Mission Acceleration Plan* (March 2003) further accelerated SST retrieval and closure schedules compared with the Hanford Performance Management Plan. Twenty-six to 40 tanks must be retrieved by 2006. The result is that the schedule of SST pit entries is accelerated and the number of SST pit entries is increased relative to the number and schedules shown in this report. However, overall conclusions are still valid, provided that the work scope in the pits is not changed significantly.

The radiation dose at the edge of the pits that were studied varies from 0 to 3,000 mrem/hr. The DST projects analyzed in this study with pit work suitable for the Pit Viper include W-314, Tank Farm Restoration and Safe Operation; W-211, DST Waste Retrieval Systems; and W-521, Waste Feed Delivery Systems. The Interim Stabilization Project will conduct work in pits between now and 2004, but it was qualitatively determined that the work schedule may begin too soon and be too short in duration for early Pit Viper deployment. SST retrieval projects will also include pit work that is suitable for the Pit Viper.

This study estimates the Pit Viper return on investment (ROI) and the number of pits where Pit Viper deployment would break even or save money over current manual practices. The results of the analysis indicate a positive return on the federal investment for the deployment of the Pit Viper provided it is used on a sufficient number of pits. When sunk costs are not included, 70 of the 80 pits will break even with a 95% learning curve assumption.

The results are sensitive to the assumptions made for labor hours to do work in the pits, the learning curve for the Pit Viper, the loss of efficiency due to weather, the shielding requirements and costs, the number of pit entries, the number of Pit Vipers required, and the radiation dose rates of pits (see Section 4). The total capital investment and development costs associated with the Pit Viper are about \$2.3 million, and the savings resulting from Pit Viper deployment exceed \$10.1 million, with a 95 percent learning curve if a single Pit Viper is used for 70 out of 80 pit entries. The calculated ROI is 33.5 percent. If the Pit Viper is used in fewer pits or not used on some high dose-rate pits that provide high returns, the ROI for the federal dollars spent will be less favorable. Also, a significant but smaller number of pits will exceed the break-even point.

In summary, this study shows that Pit Viper deployment saves money for CH2M HILL and results in ROI for pit work done in extreme weather, in pits with numerous tasks to be completed (long labor hours), where shielding is required, and where the dose rate at the edge of the pit is greater than 50 mrem/hr (Figure ES.1). The analysis shows that deployment of the Pit Viper will exceed break-even (the point at which savings exceeds expenses, excluding payback of the development dollars where they are sunk costs) in 70 out of 80 pit entries evaluated in the CH2M HILL work scope between FY 2003 and FY 2012 under these conditions. Figure S.1 supports this conclusion and illustrates the time table and the returns for high-, medium-, and low-dose pits. The ROI includes the sunk costs, which are mostly the development costs, and any known future development and deployment costs. At the break-even point the user is no longer losing money. The break-even analysis considers only the future costs for Pit Viper development and deployment from FY 2003 to FY 2012.



	Amount of Work with Weather Restrictions	Labor Required	Dome Load Limits and Shielding Requirements	Radiation Dosage	Schedule	
					Before 2004	After 2004
High Cost Benefit	Extreme weather	Jumper removal Install field instruments	Pit cleanup and coating Shielding required	Dome load limits applied >50 mrem/hr at pit edge	X	X
Moderate Cost Benefit	Moderate weather	Pit cleanup and coating	Shielding required	20-50 mrem/hr		X
Low Cost Benefit	Moderate weather	Jumper removal	No requirements	< 20 mrem/hr	X	
						

Figure S.1. Optimum Types of Pit Viper Projects

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1.0 Introduction

This section provides background information on the types of pits encountered in the tank farms, explains the need for remote systems for pit maintenance and upgrades, and describes the scope and objectives of this study.

1.1 Background

Pumps, monitoring equipment, and transfer systems for Hanford underground storage tanks are typically contained in below-grade concrete enclosures or “pits.” These pits are shielded with removable concrete cover blocks when work is not underway inside them. There are several different types of pits, and although each pit has its own characteristics, almost all of them are contaminated. It is difficult to make generalizations about the dose rate inside a pit without surveying the pit with the cover block removed.

According to HNF-SD-WM-SAR-067 Revision 3d (Cuneo 2002), there are 578 pits in the tank farms. Not all the types of pits are present at each tank, and not all pits are candidates for remote deployment tools like the Pit Viper as shown Table 1.1. In general, valve pits, sluice pits, heel pits, and pump pits are good candidates for remote deployment of tools required for pit work.

Table 1.1. Types of Tank Farm Pits

Type of Pit	Potential for Pit Viper Deployment		
	Likely	Moderate	Unlikely
Central Pump Pits	X		
Feed Pump Pits	X		
Sluice Pits	X		
Heel Pits	X		
Valve Pits	X		
Drain Pits		X	
Condenser Pits		X	
Saltwell Pits		X	
DCRT Pits		X	
Catch Tank Pits		X	
Annulus Pump Pits			X
Leak Detection Pits			X
Flush Pits			X
Cleanout Boxes			X

Active diversion boxes, catch tank pits, and double-contained receiver tanks might also require remote work. Flush pits, annulus pump pits, clean out boxes, and leak detection pits are not likely to be contaminated to the degree that would require the use of remote deployment tools.

The types of pits associated with the tank farms are described further in the following subsections. Dimensions are provided when available.

1.1.1 Good Candidates for Remote Deployment Tools

The following types of pits contain equipment used to transfer highly radioactive waste from the tank to other locations. The waste may leak over time at the many junction points between piping and equipment. These pits are also located directly above the HLW tanks, resulting in additional dose rate inside the pit.

Central Pump Pits. Pump pits, located at the center of the tank dome, provide for installation of retrieval equipment and draining leaked transfer fluids through floor drains back into the tank. Pump pits are constructed of reinforced concrete walls with floors located below grade and are provided with removable reinforced concrete cover blocks located approximately at grade elevation. A special protective coating is applied on the inside surfaces of many of the concrete enclosures and associated cover blocks. Mixer pumps are installed when needed through the central pump pits. Central pump pits for double-shell tanks (DSTs) typically measure approximately 2.1 m (7 ft) square by 3.0 m (10 ft) deep. The 241-AN central pump pit is 2.4 m (8 ft) x 4.2 m (14 ft) x 1.8 m (6 ft) deep. A shielding plug is provided that can be removed for observation purposes.

Feed Pump Pits. Feed pump pits are located off center on DSTs 241-AW-102, AP-102, and SY-102^(a) to provide another means of pumping the tank contents. A shielding plug is provided that can be removed for observation purposes. Feed pump pits typically measure approximately 2.1 m (7 ft) square by 2.51 m (8.25 ft) deep, with 0.3-m-(1-ft)-thick reinforced concrete walls and 0.51-m-(20-in.)-thick concrete cover blocks. These pits have floor drains for returning leaked waste to the tank.

Sluice Pits. Sluice pits are reinforced concrete pits through which high-pressure liquids are routed to the sluicer assembly. Sluice pits are typically 4.3 m square x 3.84 m deep (14 ft square x 12.6 ft deep). These pits are located over off-center primary tank risers on single-shell tanks (SSTs) and DSTs AY-101, AY-102, AZ-101, and AZ-102. These pits have floor drains for returning leaked waste to the tank. In the AY tank farm, Tanks AY-101 and AY-102 have four sluice pits. The AZ tank farm is equipped with two sluice pits per tank and a central sluice

(a) Hanford waste tanks are designated by the prefix 241- followed by the tank farm indicator and tank number. In this report, as in common usage, the prefix is dropped.

transfer diversion box, AZ-152, which can be used to return condensate to the tanks. A shielding plug is provided that can be removed for observation purposes.

Heel Pits. Located off center, heel pits can also be used for equipment installation. Heel pits have dimensions of 1.8 m (6 ft) x 2.7 m (9 ft) x 1.2 m (4 ft).

Valve Pits. Valve pits allow waste or process solution to be diverted to pipelines by means of valves, jumpers (temporary piping systems), or both. Several lines are located in a single pit. The pits contain process solution that may have leaked at the valve connections.

1.1.2 Good Candidates for Remote Deployment Tools

The following pits require work periodically and may have a high dose rate; however, the types of activities conducted in these pits are limited.

Drain Pits. Drain pits are located over an off-center primary tank riser on Tanks AN-101, AP-103, AW-102, and SY-102 to provide a means for returning fluids to the tank. Drain pits typically measure approximately 2.4 m x 2.1 m (8 ft x 7 ft) x 3.53 m (11.58 ft) deep with 0.3-m-(1-ft)-thick walls and are covered with a 0.51-m-(20-in.)-thick concrete cover block. A shielding plug is provided that can be removed for observation purposes.

Condenser Pits. Located off center, condenser pits contain condensers to condense tank vapors.

Saltwell pit. Located off-center, a saltwell pit is used for installing saltwell pumps and piping in SSTs.

Double-Contained Receiver Tank (DCRT) and Catch Tank Pits. Catch tanks are underground storage tanks that collect small amounts of waste drained from waste transfer systems and DST equipment. Catch tanks located in vaults have pump pits centered above them. A DCRT may function as an interim short-term storage facility for liquid wastes pumped from other storage sites or facilities, or as a valve pit to route wastes. A DCRT has both a pump pit and a filter pit located above the tank.

1.1.3 Unlikely Candidates for Remote Deployment Tools

The following pits do not handle contaminated solutions routinely. The pits are not likely to be contaminated to the degree that would require the use of remote deployment tools.

Annulus Pump Pits. Annulus pump pits provide a means for pumping out any liquids that may accumulate in the annular space from a primary tank leak. Annulus pump pits typically measure approximately 2.1 m (7 ft) square by 3.53 m (11.58 ft) deep [AN pits are 3 m (10 feet) deep]

with 0.3-m-(1-ft)-thick concrete walls. Annulus pump pits are covered with a 0.51-m-(20-in.)-thick concrete cover block. A shielding plug in the cover block may be removed for observation purposes. These pits have floor drains for routing leaked waste to the tank annulus. If leaks occur, deep-well vertical turbine pumps will be installed as needed in annulus pump pits. The waste may then be pumped to a suitable tank through the existing transfer piping.

Leak Detection Pits. Leak detection pits house level indicators and leak-monitoring instruments and collect liquid from the drainage grid at the top of the concrete foundation (upon which the secondary liner bottom rests). Each pit is fabricated as two parts, a leak detection pit and a radiation detection dry well. A removable shielding plug is provided.

Flush Pits. Flush pits provide piping through which water is supplied to flush pipelines after waste transfer. They do not handle process solutions and therefore are not considered process pits and may not be contaminated.

1.1.4 Pit Identification

Numbers and letters are used to identify the pits. In general, the pit number is the tank farm numbers (prefix) and letters plus the last two numbers of the specific tank. The letter at the end of the title helps identify the type of pit, where A= pump pit; B = heel or annulus pit; C = sluice pit; and D = sluice, drain, or leak detection pit. As an example, a pump pit for Tank 241-AY-102 would be called 241-AY-02A. Typical pits for C-farm (SST) are shown in Figure 1.1. The picture shows the cover blocks for Tank C-104 pits.

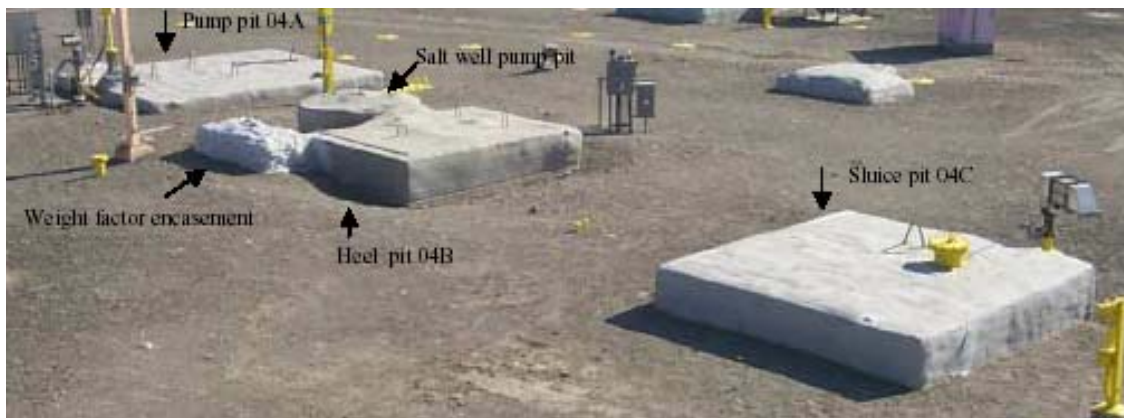


Figure 1.1. SST Pit Configurations

1.2 Need for Remote Systems

Tank farm pits must be maintained and upgraded to manage Hanford's high-level waste efficiently. Baseline methods for modifying, operating, cleaning, and decontaminating these pits are labor-intensive, costly, and result in a high radiation dose to workers. Currently, work associated with pits is the single largest contributor to River Protection Project (RPP) Operations dose levels. For example, the dose rate in the C-106 pits was 40 R/hr during Project W-320. After investing \$2 million and five months, the dose rate had not been reduced sufficiently for workers to enter the pit area. During the pit decontamination operations, 25 person-rems were accumulated (TFA 2001).

The need for remote systems to support Tank Farm pit operations was identified in the Hanford Science and Technology Needs/Opportunities Statement, RL-WT021, "Cleaning, Decontaminating, and Upgrading Hanford Pits," dated September 1998. In addition, an analysis performed for the W-314 Project indicated that use of the Pit Viper technology would be cost-effective for any pits inside which the dose rate was above 55 mR/hr. Many pits are substantially higher than this (Minteer and Mauser 2000).

In December 2001, CH2M HILL and PNNL^(a) successfully completed a hot deployment and limited demonstration of the Pit Viper capabilities in the C-104 heel pit. The deployment supported design and construction activities for Hanford Project W-523, the C-104 Waste Retrieval System (Niebuhr and Mewes 2002).

1.3 Scope and Objectives

The objective of this project was to help CH2M HILL evaluate pits for Pit Viper deployment from FY 2003 through FY 2012. ROI and break-even analyses were conducted for bounding scenarios based on labor-hour resource requirements. The project also identified potential Pit Viper technology development requirements for tank farm pit activities and determined the cost-effectiveness of those activities in successfully completing CH2M HILL's mission through 2012. This study did not address the 26 to 40 additional retrievals under the accelerated closure plan (DOE 2002) and the CH2M HILL recent Contract Change and Performance-Based Incentives.^(b)

Radiation survey data and project work scope/schedule information were collected and summarized for upcoming pit work required for the projects listed in Table 1.2.

(a) Procurement and deployment of the Pit Viper system was a cooperative effort between the Tanks Focus Area (TFA), the Robotics Crosscut Program (RBX), CH2M HILL, Numatec Hanford Corporation (NHC), Pacific Northwest National Laboratory (PNNL), and Oak Ridge National Laboratory (ORNL). PNNL is performing system integration and testing of Pit Viper technologies. NHC has the lead to explore enhanced pit operations for the RPP.

(b) Amendment to CH2M HILL Hanford Group Contract De-AC27-99RL14047 No. M064; available at <http://www.hanford.gov/orpext/uploadfiles/14047-mod064.pdf>.

Table 1.2. Scope of Pit Data Collection

Project	Task	Completion Date
Mission	C-106 retrieval	12/31/2003
Acceleration Tank Closure	C-106 closure	02/28/2004
Initiative	S-112 closure	06/30/2006
	S-102 closure	12/31/2006
	C-104 closure	06/30/2007
SST Retrieval Baseline ^(a)	S-112 retrieval	04/12/2005
	S-102 retrieval	06/20/2006
	C-104 retrieval	08/25/2008
	S-106 retrieval	06/18/2009
	S-105 retrieval	09/22/2009
	C-107 retrieval	01/20/2010
Interim Stabilization	Isolate 41 tank pits	09/30/2004
Project W-314	Refurbish AN, AY, AZ, AP, SY and AW pits	06/30/2005
Project W-521	Complete waste feed delivery system upgrades for eight tanks: AY-101, AY-102, SY-101, SY-102, SY-103, AW-101, AW-103, AW-104, and complete SY and AW upgrades	05/08/2017 ^(b)
Project W-523	Construct C-104 retrieval system	12/31/2006
Project W-211	Upgrade and install jumper/transfer pump in 10 tanks: AZ-101, AZ-102, AN-101, AN-102, AN-104, AN-103, AN-105, AN-107, AP-102, AP-104	11/03/2015 ^(b)
Tank Farm Operations	SST and DST transfer pump and electrical system maintenance and repairs	No out-year schedule available
(a) Garfield and Kirkbride 2000.		
(b) This study only addressed the portion of the work through 2012.		

2.0 Pit Radiation Doses and Work Schedules

This section provides information collected on pit radiation dose rates, work scope, and schedules. In Section 2.1, pits are categorized by project, radiation dose rate, and start date of pit entry. In Section 2.2, work scope and schedules are summarized.

2.1 Summary of Radiation Dose Rates

Figures 2.1 and 2.2 illustrate the radiation dose rate for each pit identified as part of the CH2M HILL work scope through 2012. The pits and assumed start dates for pit work shown in these figures are listed in Table 2.1.

Available radiation dose rate data was collected using the Records Management Information System (RMIS) for the pits. Radiation Survey Reports are found by selecting “Radiation Report” as the record type and entering the Pit ID under search criteria. While a Radiation Survey Report is often available, the data quality is highly variable. Radiological survey data cover only one assignment, and include the date and general location of the survey. More information on radiological surveys is found in HNF-IP-0842 (CH2M HILL 2001).

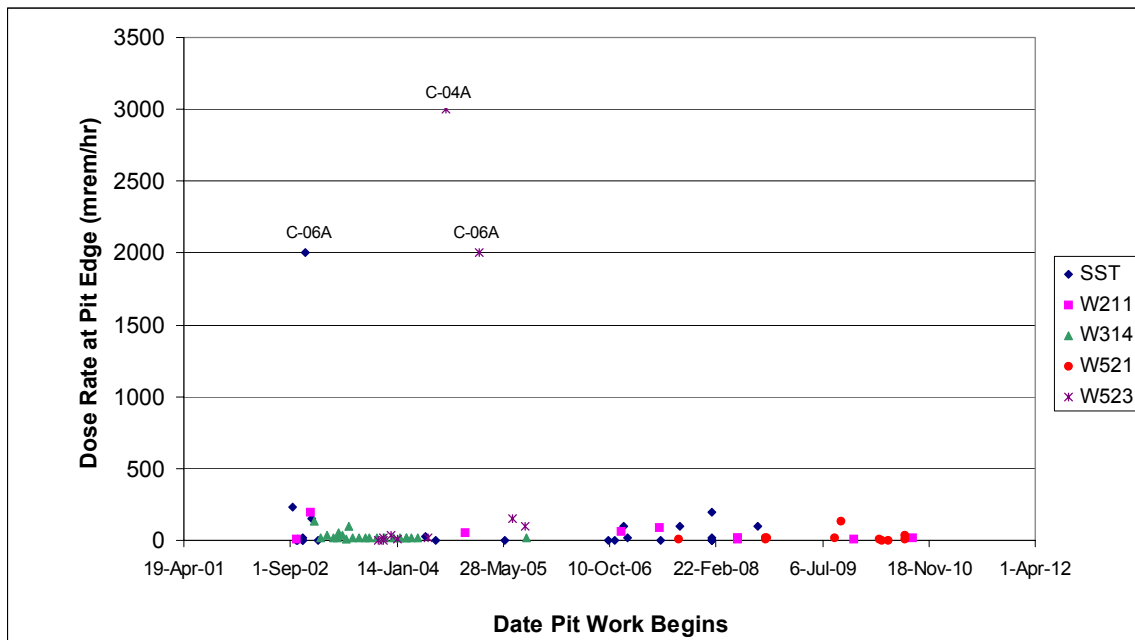


Figure 2.1. Radiation Dose Rate Data with Hot Pits Included

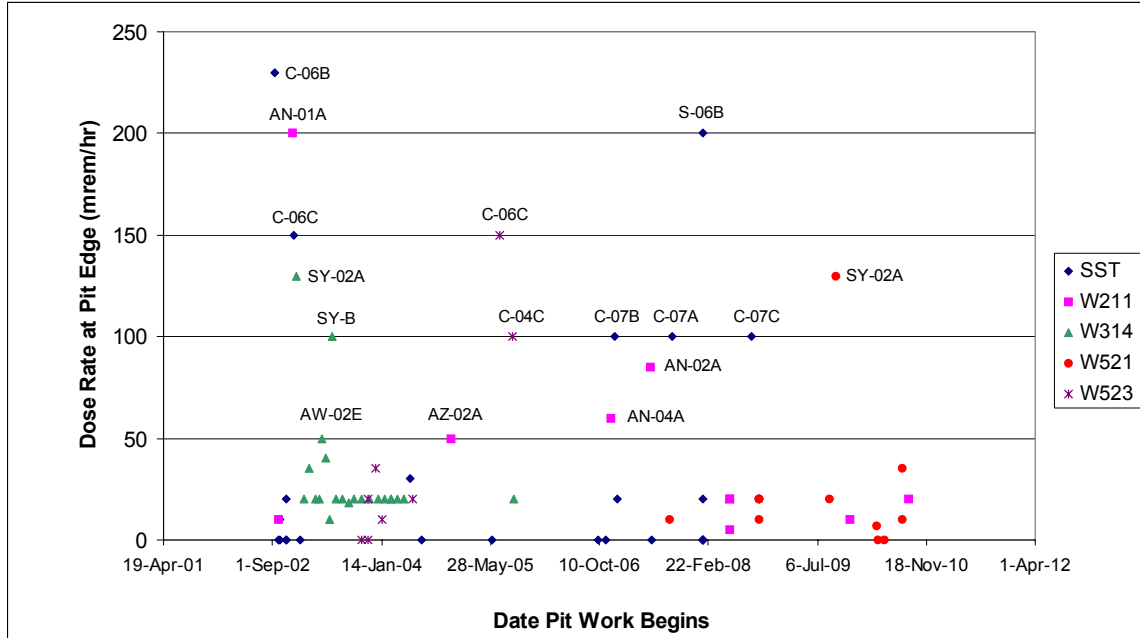


Figure 2.2. Radiation Dose Rate Data with Hot Pits Excluded

Table 2.1. Estimated Radiation Dose Rates at Pit Edge for Selected Projects Analyzed in Study

Pit ID	Project	Assumed Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)
C-06B	SST	11-Sep-02	230
AY-02G	SST	1-Oct-02	0
AZ-01A	211	1-Oct-02	10
AY-02E	SST	7-Oct-02	0
AY-02A	SST	7-Oct-02	10
S-112B	SST	1-Nov-02	20
SY-A	SST	1-Nov-02	0
S-112A	SST	1-Nov-02	0
C-06A	SST	8-Nov-02	2000
AN-01A	211	2-Dec-02	200
C-06C	SST	8-Dec-02	150
SY-02A	314	20-Dec-02	130
C-06D	SST	8-Jan-03	0
SY-02D	314	23-Jan-03	20
AW-02A	314	18-Feb-03	35
AW-02D	314	20-Mar-03	20
SY-03A	314	7-Apr-03	20

Table 2.1 (contd)

Pit ID	Project	Assumed Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)
AW-02E	314	18-Apr-03	50
SY-A	314	6-May-03	40
AW-03A	314	19-May-03	10
SY-B	314	4-Jun-03	100
AW-04A	314	18-Jun-03	20
AW-05A	314	18-Jul-03	20
AW-06A	314	18-Aug-03	18
AP-02A	314	9-Sep-03	20
AP-03A	314	14-Oct-03	20
C-04D	523	16-Oct-03	0
AY-01G	523	13-Nov-03	0
AY-101	523	13-Nov-03	20
AP-03D	314	18-Nov-03	20
C-04B	523	17-Dec-03	35
AP-04A	314	29-Dec-03	20
AY-01A	523	16-Jan-04	10
AP-05A	314	28-Jan-04	20
AP-06A	314	27-Feb-04	20
AW-01A	314	27-Feb-04	20
AP-07A	314	26-Mar-04	20
AP-08A	314	23-Apr-04	20
S-02B	SST	26-May-04	30
AY-01E	523	7-Jun-04	20
S-02A	SST	16-Jul-04	0
C-04A	523	1-Sep-04	3000
AZ-02A	211	1-Dec-04	50
C-06A	523	7-Feb-05	2000
SY-A	SST	7-Jun-05	0
C-06C	523	12-Jul-05	150
C-04C	523	7-Sep-05	100
AP-01A	314	14-Sep-05	20
C-07D	SST	6-Oct-06	0
AY-01G	SST	6-Nov-06	0
AN-04A	211	1-Dec-06	60
C-07B	SST	17-Dec-06	100

Table 2.1 (contd)

Pit ID	Project	Assumed Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)
AY-01A	SST	1-Jan-07	20
AN-02A	211	1-Jun-07	85
AY-01E	SST	7-Jun-07	0
AY-02A	521	30-Aug-07	10
C-07A	SST	7-Sep-07	100
S-05A	SST	31-Jan-08	0
S-05B	SST	31-Jan-08	20
SY-A	SST	31-Jan-08	0
SY-A	SST	31-Jan-08	0
S-06A	SST	31-Jan-08	0
S-06B	SST	31-Jan-08	200
AP-02D	211	2-Jun-08	5
AP-02A	211	2-Jun-08	20
AP-04A	211	2-Jun-08	20
C-07C	SST	6-Sep-08	100
AY-01A	521	12-Oct-08	10
AY-01B	521	13-Oct-08	20
AY-01C	521	14-Oct-08	20
AY-01D	521	15-Oct-08	20
SY-03A	521	1-Sep-09	20
SY-02A	521	1-Oct-09	130
AN-07A	211	1-Dec-09	10
SY-01A	521	2-Apr-10	7
AW-B	521	9-Apr-10	0
AW-A	521	9-May-10	0
AW-03A	521	30-Jul-10	10
AW-02A	521	30-Jul-10	35
AN-05A	211	1-Sep-10	20
Key: SST = SST Retrieval Project; 314 = W-314 Project; 521 = W-521 Project; 211 = W-211 Project.			

The highest applicable deep dose rates from the survey were used to develop the estimates in Table 2.1. “Deep dose” is the term used for the dose to tissue from gamma radiation. It is also reported as the “Window Closed” (WC) reading.

The data from the survey reports are attached as Appendix A, along with the estimated dose rate at the pit edge. The working data sheets in Appendix A show the actual value reported, along with the location and date of the survey report. In some cases, there were no survey reports available for the pit of concern. These pits are identified with a note stating no data were available in the RMIS database. When no data were available, a dose rate of 100 mrem/hr at the pit edge was assumed for C-farm pits and 20 mrem/hr in all other pits. In two cases, verbal reports were used: John Wright (July 2002) reported that C-06A has a deep dose rate of 2 rem/hr. On September 12, 2002, Dan Niebuhr reported that C-04A had a dose rate of 32 rem/hr at the pit bottom.

Radiation data were collected from random points and then normalized to the pit edge using the following assumptions:^(a) 1) the dose rate at the pit edge is one-tenth that at the pit bottom, and 2) the dose rate in the general area is one-fourth that at the pit edge. The radiation dose rate at the pit rail is assumed to be the same as that at the pit edge. The change in dose rate from the pit bottom to the pit edge is dependent on the depth of the pit. For example, AW pits are 4 ft deep and the others are 8 ft deep. Therefore, AW pits would read higher at the edge than the other pits would. However, the pit depth was not factored into this study. The higher the radiation dose at the pit edge, the higher the person-rem accumulated for the pit project.

There may also be differences in work practices in pits that result in labor hour differentials due to very low or very high radiation dose rates in the pits. The labor hours needed to do some jobs could be more than double if the jobs are in a high dose-rate pit. This is because numerous workers are needed to work at the pit and to manipulate the pike poles. Work practices include time to shuttle people in and out before they absorb 500 mrem. According to CH2M HILL personnel, a high-dose-rate pit would be more than 80 mrem/hr at pit edge. Conversely, a low dose rate pit may have significantly lower labor hours, because workers could work without poles and enter the pit. The only cases where workers might be allowed to enter pits without shielding are new pits or possibly pits with radiation dose rates lower than 20 mrem/hr at the bottom, depending on the situation.^(b)

The radiation dose rates at the edges of pits that will be temporarily isolated after Interim Stabilization Project completion are shown in Table 2.2. Because the timeframe for this project is near-term, the Interim Stabilization Project was not analyzed in this study. Hence, only the "A" pits were reviewed for radiation survey dose rate values. The dose rates are presented here for information purposes. This table shows that several of these pits will have high dose rates, and there may be some pits that would benefit from deployment of the Pit Viper, depending on the time and work scope required to isolate them.

(a) Phone conversation with Susan Pearce, CH2M HILL Senior Radiation Planner, September 5, 2002, and personal communication with Dan Niebuhr, CH2M HILL Facilities Operations Engineer, on July 17, 2002.

(b) Personal communication with Jim Lee, CH2M HILL on September 13, 2002.

Table 2.2. Estimated Radiation Dose Rates for Interim Stabilization Project Pit Work

Tank Number	Start Date	Estimated Dose Rate at "A" Pit Edge (mrem/hr)	Date of Radiation Survey
244-A	10/01/02	100	02/20/99
244-BX	10/01/01	80	05/16/94
A-101	10/01/02	20	05/24/00
A-102	10/01/03	No data	
AX-101	10/01/02	70	06/09/00
BY-102	10/01/03	No data	
BY-103	01/09/04	80	07/31/97
BY-105	10/01/02	70	6/18/98
BY-106	10/01/02	No data	
BY-109	01/09/04	200	08/01/94
C-103	09/23/02	No data	
C-105	10/01/02	No data	
C-106	01/09/03	2000	Verbal
S-101	06/04/02	250	10/02/02
S-102	10/01/01	80	10/04/98
S-103	11/26/02	60	09/04/98
S-106	01/09/04	200	09/29/98
S-107	10/01/02	25	09/14/00
S-108	10/01/03	No data	
S-110	01/09/04	200	05/17/94
S-109	04/08/02	50	10/03/00
S-111	12/18/01	110	10/29/98
S-112	08/14/02	200	10/29/98
SX-101	11/04/02	10	11/16/00
SX-102	12/15/01	70	06/30/95
SX-103	04/11/02	No data	
SX-104	02/25/02	500	02/31/99
SX-105	10/01/01	No data	
SX-106	02/25/02	90	09/15/98
S-107	10/01/02	No data	
T-101	02/25-02	No data	
T-104	02/25/02	No data	
T-110	02/25/02	No data	
T-111	02/25/02	No data	
U-102	04/15/02	50	05/26/99
U-103	04/15/02	No data	
U-105	04/15/02	No data	

Table 2.2 (contd)

Tank Number	Start Date	Estimated Dose Rate at "A" Pit Edge (mrem/hr)	Date of Radiation Survey
U-106	01/09/03	No data	
U-107	07/18/02	No data	
U-108	10/01/02	No data	
U-109	4/15/03	3	06/26/01
U-110	10/01/02	No data	
U-111	10/01/02	5	11/03/00

2.2 Summary of Project Scope and Schedules

Figure 2.3 summarizes schedule information as of August 2002 for projects that will require tank farm crews to work in or near the pits. Project work scopes are described in more detail below. The pit work has been categorized as 1) facility operations and maintenance, 2) pit upgrades, 3) waste retrieval and transfer system construction, and 4) interim stabilization and pit closure. An assessment is provided below for each category to determine whether the pit is a good candidate for potential Pit Viper deployment.

2.2.1 Facility Operations and Maintenance/Emergency Repairs

Correspondence with CH2M HILL staff indicates maintenance and repair work that support facility operations are potential opportunities for Pit Viper deployment, especially if Pit Viper use becomes routine. The cost/benefit of normal maintenance and repair work using the Pit Viper was not analyzed, because such work is not scheduled and the scope is not yet known. However, the paragraphs below qualitatively discuss the benefits of using the Pit Viper for a non-routine repair, when a pump or other equipment breaks during waste transfer.

If this happens, the waste transfer operations would be stopped. Any jumpers that were in the way of the repair would be removed and placed on the floor of the pit or in a storage box. The pit would be radiologically surveyed to determine the dose rate, and shielding would be installed. If the problem was something like motor burnout, the pump would be lifted out with a crane and the repairs would be made outside the pit to avoid worker exposure. If the repair was relatively simple, a worker would repair it from the edge of a pit using a pole or enter the pit to make the repair.

Radiation survey work and removal of small jumpers are tasks that could be accomplished using the Pit Viper. Installation of shielding would not be necessary if the Pit Viper were used instead of tank farm workers needing to make repairs. Emergency repairs are very high dose-rate activities that often require less than an hour in a pit but add significantly to worker dose, even

with shielding. With the Pit Viper, shielding requirements and high worker doses would be eliminated.

While maintenance and repair applications of the Pit Viper were not analyzed, such activities will eventually be done often enough to become predictable. Current estimates are that about twice per year, workers will enter a pit to make repairs and receive exposures to a high dose rate for a short time period. The frequency may be much greater under an accelerated schedule. In particular, as the time required for Pit Viper setup and operations declines due to the learning curve, it will be cost-effective and timely to use the Pit Viper for these quick-turnaround, high-dose-rate tasks.

This study evaluates facility maintenance and operation activities prior to reclassification of SST retrievals as normal tank farm operating activities. SST retrievals are evaluated in Section 2.2.3 as major projects. Subsequent to completion of this study, the CH2M HILL Hanford Group, Inc. contract was modified to accelerate waste retrieval activities. To achieve this schedule acceleration, SST waste retrieval projects were reclassified as facility maintenance and operations in January 2003.

2.2.2 Pit Upgrades

Project W-314, Tank Farm Restoration and Safe Operation, is the major project focused on the pit upgrades necessary for continued safe operation of existing DSTs, DCRTs, and selected SSTs. Design requirements for the project are defined in WHC-SD-W314-CDR-001, Rev. 1 (Briggs 1996). Figure 2.3 summarizes the Phase II Project W-314 scope and provides the schedule for completing the work.

Pit upgrades in the W-314 scope include pit refurbishment tasks. After the cover block is removed, the crew applies fixative and then removes the old jumpers and slurry distributors.^(a) After removing the jumpers (Figure 2.4) from the pit, the crew removes equipment and debris, sweeps, and washes down the pit with long-reach pole tools and mirrors manually operated by personnel at the edge of the pit. A camera is used to evaluate the pit contents and surface. Preparing the pit walls and floors is necessary before repairing cracks. Loose paint and other unwanted materials are removed by scraping, grinding, high-pressure steam or water spraying, blasting (particle, shot, or cryogenic), or a needle gun. Concrete repair methods (grout, polymers, etc.) are deployed as needed to safely upgrade the pit to support installing equipment for waste transfer and treatment. The concrete walls are then sprayed with protective coating to

(a) Jumpers are sections of piping that provide a route for transferring tank waste among storage locations. A distributor is a long pipe that attaches to the tank and distributes waste inside the tank. It is usually pulled and disposed of when waste will no longer be transferred into a tank.

	FY 2002 1, 2, 3, 4	FY 2003 1, 2, 3, 4	FY 2004 1, 2, 3, 4	FY 2005 1, 2, 3, 4	FY 2006 1, 2, 3, 4	FY 2007 1, 2, 3, 4	FY 2008 1, 2, 3, 4	FY 2009 1, 2, 3, 4	FY 2010 1, 2, 3, 4	FY 2011 1, 2, 3, 4	FY 2012 1, 2, 3, 4	FY 2013 1, 2, 3, 4	FY 2014 1, 2, 3, 4	FY 2015 1, 2, 3, 4
SST Interim Stabilization (Table 1)														
W-314 Transfer System Upgrades (Table 2) S/T														
W-211 AP Farm/Pipe S/T														
Design W-521 AW Farm Constr. S/T														
Design W-521 SY Farm Construction S/T														
Design W-525 Construction S/T														
DSTs														
AP-102	W-211 Construction S/T C Staged Backup Feed													
AP-104	W-211 Construction S/T C Staged Backup Feed													
AN-101	Design W-211 Construction S/T													
AP-101	Construction S/T C													
AN-102	Design W-211 Construction S/T C													
AN-104	W-211 Construction S/T MP C													
AN-107	Design W-211 Construction S/T C													
AN-105	W-211 Construction S/T MP C													
SY-101	Design W-521 Construction S/T C													
AN-103	Design W-211 Construction S/T													
AW-101	Design W-521 Construction S/T													
AW-104	Design W-521 Construction S/T													
AZ-101	W-211 Construction S/T C													
AZ-102	W-211 Construction S/T C													
AY-102	W-521 Construction S/T C													
AY-101	Design W-521 Construction S/T C													
SY-102	Design W-521 Construction S/T C													
AW-103	Design W-521 Constr. S/T													
SY-103	Design W-521 Construction S													

Table 1. Interim Stabilization Pit Isolations

SST's	Start Dates	End Dates	SST's	Start Dates	End Dates	SST's	Start Dates	End Dates	SST's	Start Dates	End Dates
244-A	10/01/02	02/01/03	C-105	10/01/02	01/08/03	S-112	08/14/02	03/30/04	T-111	02/25/02	03/15/02
244-BX	10/01/01	12/17/02	C-106	01/09/03	04/14/03	SX-101	11/04/02	12/03/02	U-102	04/15/02	04/28/03
A-101	10/01/02	02/18/05	S-101	06/04/02	02/17/04	SX-102	12/15/01	12/04/03	U-103	04/15/02	04/28/03
A-102	10/01/03	01/08/04	S-102	10/01/01	04/27/04	SX-103	04/11/02	02/28/03	U-105	04/15/02	04/28/03
AX-101	10/01/02	02/19/04	S-103	11/26/02	03/30/04	SX-104	02/25/02	01/22/04	U-106	01/09/03	04/28/03
BY-102	10/01/03	01/08/04	S-106	01/09/04	03/30/04	SX-105	10/01/01	03/28/03	U-107	07/18/02	08/30/03
BY-103	01/09/04	04/13/04	S-107	10/01/02	04/27/04	SX-106	02/25/02	02/12/02	U-108	10/01/02	11/20/03
BY-105	10/01/02	03/30/04	S-108	10/01/03	01/08/04	S-107	10/01/02	06/19/03	U-109	04/15/03	04/28/03
BY-106	10/01/02	04/27/04	S-110	01/09/04	04/13/04	T-101	02/25/02	03/22/02	U-110	10/01/02	01/08/03
BY-109	01/09/04	04/13/04	S-109	04/08/02	04/27/04	T-104	02/25/02	04/05/02	U-111	10/01/02	12/31/03
C-103	09/23/02	09/08/03	S-111	12/18/01	03/30/04	T-110	02/25/02	04/05/02			

Legend

- ▲ Key Dates
- MP Mixer Pump Installation
- S Startup
- S/T Startup/Turnover
- C Certification Activities
- R/C Retrieval/Closure Activities

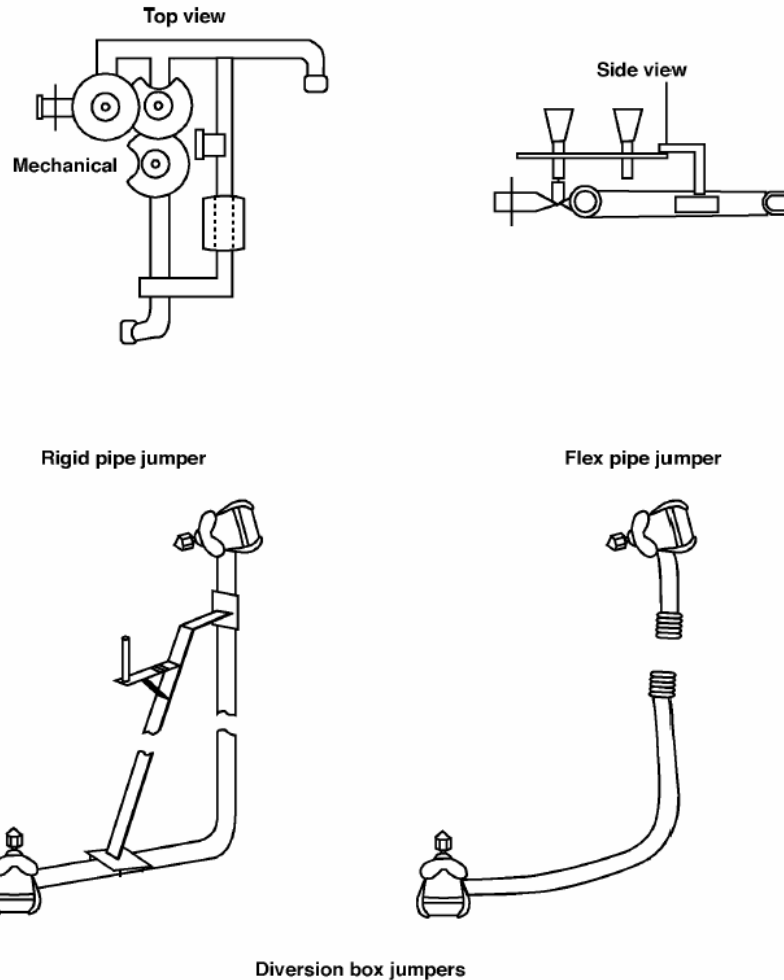
Table 2. W314 Transfer System Upgrades

Upgrades	Start Dates	End Dates
AW-A valve pit	04/01/01	12/01/01
AW-B valve pit	06/30/01	10/01/02
241-A-A valve pit bypass	03/01/04	02/01/05
AN tank farm central pump pit upgrades	06/01/01	07/01/03
AP tank farm central pump pit upgrades	10/01/02	06/01/04
244-A DCRT cross-site tie-in/bypass	02/01/03	01/01/04
AW tank farm central pump pit upgrades	10/01/03	02/01/05
SY tank farm central pump pit upgrades	11/01/03	09/01/04
244-S bypass	06/01/04	06/01/05
AY tank farm upgrades	10/03/02	09/03/03

	FY 2002 1, 2, 3, 4	FY 2003 1, 2, 3, 4	FY 2004 1, 2, 3, 4	FY 2005 1, 2, 3, 4	FY 2006 1, 2, 3, 4	FY 2007 1, 2, 3, 4	FY 2008 1, 2, 3, 4	FY 2009 1, 2, 3, 4	FY 2010 1, 2, 3, 4	FY 2011 1, 2, 3, 4	FY 2012 1, 2, 3, 4	FY 2013 1, 2, 3, 4	FY 2014 1, 2, 3, 4	FY 2015 1, 2, 3, 4
SSTs*														
C-104	Design W-521 Construction R/C													
C-106	Design Constr. R/C													
S-112	Dsgr Constr. S/T R/C													
S-102	Design Construction S R/C													
S-106	Construction S R/C													
S-105	Construction S R/C													
C-107	Design W-521 Construction R/C													

*3 other high risk tanks by 2012

Figure 2.3. FY2002 Baseline Project Schedules with Pit Work (Kirkbride et al. 2001)



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Figure 2.4. Jumper Schematics

renew secondary containment. Polyurea is an example of a protective coating that is applied to pit walls. After the pit is refurbished, a crew for waste feed delivery systems will install new jumpers, transfer pumps, and drain plugs in the refurbished pits.

The Pit Viper is useful for removing the old jumpers (depending on the size) and chopping them up for disposal. The Pit Viper could be used to sweep up debris or remove old paint and prepare pit walls for new coatings. Some jobs may be safe if performed by the Pit Viper, but not if conducted by manual methods. For example, a grinder can no longer be used on pit walls because workers remove grinder shields when the grinder does not fit under the jumper. A reportable incident to workers near pits recently occurred as a result of removing the grinder shield. If the Pit Viper is used to deploy the grinder, no workers will be near the pit edge. The Pit Viper could also deploy a water jet to remove old paint.

2.2.3 Waste Retrieval and Transfer System Construction

Twenty-eight DSTs are being used during the cleanup mission to support Waste Treatment Plant (WTP) operations. Equipment with the required capability will be installed in the DSTs to support feed delivery transfers, including a mixer pump and a decant pump (if entrainment of solids is expected to be a problem). A fixed intake pump is used if there is no concern about solids entrainment (i.e., the waste contains less than 2 wt% solids).

The major projects to support construction of DST storage and transfer systems include Project W-211, DST Retrieval Systems, and Project W-521, Waste Feed Delivery Systems. Projects W-211 and W-521 install mixer pumps and transfer pumps to facilitate retrieval of waste from DSTs. These projects provide new waste transfer pumps, mixer pumps, pipelines, jumpers, and electrical and instrumentation upgrades to the DST system. As discussed above, these projects will be conducted in the same pits that have been upgraded by Project W-314.

Figure 2.3 and Tables 2.3 and 2.4 summarize the W-211 and W-521 project scope and provide the schedule for completing the work (source Table A.10 of the HNF-SD-WM-SP-012, Rev. 3) (Kirkbride et al. 2001). The scope of W-521 is further described in the Conceptual Design Reports (CH2M HILL 2000; White 2001).

Table 2.3. Project W-211 Scope and Schedule

Project Scope	Project	Start Date	Completion Date
Connection of 200-E WTS to AP tank farm and pipelines to WTP	W-211	06/01/02	09/16/04
AN-101 Waste Retrieval System	W-211	10/01/02	10/25/04
AZ-101 Waste Retrieval System	W-211	04/01/02	04/21/05
AZ-102 Waste Retrieval System	W-211	10/01/04	06/26/07
AP-102 Waste Retrieval System	W-211	04/01/08	09/21/10
AP-104 Waste Retrieval System	W-211	04/01/08	09/21/10
AN-102 Waste Retrieval System	W-211	04/02/07	08/19/10
AN-103 Waste Mixing and Retrieval System	W-211	10/01/12	03/24/15
AN-104 Waste Retrieval System	W-211	10/02/06	07/28/10
AN-105 Waste Retrieval System	W-211	07/01/10	12/19/12
AN-107 Waste Retrieval System	W-211	10/01/09	07/25/12

Figure 2.3 and Table 2.5 show that at least seven SSTs were to be retrieved through 2012 in FY2002 baseline. The first tank retrieved is Tank C-106 in the 200-East Area. Tank C-106 had 3,000 gallons of sludge left in it, along with 30,000 gallons of liquids. The next tanks retrieved include S-102, S-112, and C-104. Project W-523 installs and operates a retrieval system in C-104. Under the accelerated schedule, pumping of C-106 began in March 2003 and pumping of Tank S-102 and S-112 will be initiated later in 2003. There is a possibility that four C-200 tanks and a number of other tanks will also be retrieved prior to late 2006, but CH2M HILL

management was still discussing the scope and schedule at the time this study was being conducted.^(a) The radiation levels and schedules for C-200 and other pits were not evaluated in this study (Fredenberg et al. 2002).

Constructing and operating both the DST waste transfer and storage systems and the SST retrieval systems requires a series of pit openings and installing equipment in the central pump or sluice pits. Old jumpers, pumps, and saltwell screens will be removed, an activity that will result in significant doses to workers if the Pit Viper is not used. The pump/screen removal activity might result in an exposure of 2 to 4 person-rems.^(b) Crews will then install new jumpers and new transfer pumps. Pits will be entered as needed during active transfer to repair and maintain equipment. At the end of retrieval activities, the pits will be decontaminated and isolated from the environment.

Table 2.4. Project W-521 Scope and Schedule

Project Scope	Project	Start Dates	Completion Date
AW Caustic Dilution Piping Upgrades	W-521	12/03/08	06/20/12
AW-101 Waste Mixing and Retrieval System	W-521	12/03/12	05/08/17
AW-103 Waste Mixing and Retrieval System	W-521	07/30/10	03/28/12
AW-104 Waste Retrieval System	W-521	03/12/13	04/09/15
AY-101 Waste Retrieval System	W-521	10/01/08	03/14/11
AY-102 Ventilation/Waste Retrieval System	W-521	08/30/07	08/30/10
SY-101 Waste Retrieval System	W-521	04/01/10	08/31/12
SY-102 Waste Mixing and Retrieval System	W-521	10/01/09	10/26/11
SY-103 Waste Retrieval System	W-521	09/01/09	01/31/12

Table 2.5. SSTs Retrieved from FY 2003 to FY 2012

Tank Number	Type of Retrieval	Year of Retrieval
C-106	Crawler System	2003
S-112	Saltcake Dissolution	2006
S-102	Fluidics System	2006
C-104	Crawler System	2007
S-106	Saltcake Dissolution	2009
S-105	Saltcake Dissolution	2009
C-107	Crawler System	2010

Most of the SSTs will use overground transfer lines (OGTs) because most of the underground transfer lines have failed. OGTs have a life of only a couple of years and will need to be

(a) Personal communication with Ed Fredenburg, CH2M HILL, on September 23, 2002.

(b) Email communication from James Biggs, CH2M HILL SST Stabilization Engineering, September 11, 2002.

replaced if retrieval lasts longer than that. Most of the work to install OGT equipment is done at the edge of the pit. Some of the pits have new cover plates that have a hole in them that accepts the “hose-in-hose” transfer line. On older pits, the crew will unseal the pits and pull the cover block. A new transfer pump and flexible jumpers are installed, and an adaptor connects the jumpers to the hose-in-hose or new transfer line. Sometimes a worker must go into the pit for short periods to finish the installation.

If new double-wall transfer lines are built, pit work will require core drilling in pit walls, welding to wall nozzles, and other tasks. In this case, there are also pre-work tasks like debris removal and application of fixative that are required prior to work entry. These are all tasks suitable for the Pit Viper.

2.2.4 Interim Stabilization and Pit Closure

As mentioned in Section 2.1, this effort did not evaluate the Interim Stabilization Project pit work for deployment of the Pit Viper. Interim stabilization is scheduled for completion by September 2004. The project works under a very tight schedule that generally does not allow sufficient time to try out new equipment.

Closure of pits was also not evaluated in this study. The new accelerated schedule calls for as many as 40 SSTs to be closed by 2006 and for 60 to 140 SSTs to be closed by 2018 (DOE 2002).^(a) However, SST closure has not been analyzed because the State of Washington and DOE have not agreed yet on what "closing" a tank means. It will entail removing all the wastes from the tank and somehow permanently sealing it. The *Accelerated Tank Closure Demonstration Basis of Design Report* (Fredenberg et al. 2002) shows that at pit closure, CH2M HILL will remove jumpers and equipment and fill the C-106 pits with grout. The suitability of the Pit Viper for grout work is unknown at this time.

Discussions on tank closure are scheduled to run from late 2002 to early 2004. The Pit Viper will likely be a useful tool for closure operations, but a detailed assessment has not been completed.

Saltwell pumping for the Interim Stabilization Project will be completed by the end of September 2003 (Hanlon 2002). At the end of saltwell pumping about 41 SSTs will be isolated, as shown in Figure 2.3. The valve and sluice pits will also be isolated from the environment. The cover will remain sealed until SST retrieval activities begin. There is at least one pit per tank, and some tanks have more pits that must be isolated. In addition, each tank farm has two valve pits.

(a) Amendment to CH2M HILL Hanford Group Contract De-AC27-99RL14047 No. M064; available at <http://www.hanford.gov/orpext/uploadfiles/14047-mod064.pdf>.

During pit isolation, tank farm crews will remove the cover plates from the pits, remove the jumpers and other unwanted transfer equipment, replace the cover plates, and foam the top of the pit cover to form a weather seal. Most of the pits use flex jumpers so they do not have to be cut up during removal. The flexible jumpers are coiled up like a garden hose, lifted up with crane, and dropped into a burial box without cutting. With the conventional approach, all of the needed tools are on long handles, so the crew works next to the pit. It takes one to two shifts to complete the work. Many of these jobs could likely be done with the Pit Viper so that a crane is not required (except to remove the cover block).

3.0 Job Analysis

This section lists the types of jobs that the Pit Viper can do “as is,” those that it might be able to do in the future with some additional technology development work, and those that it cannot do. It also describes the assumptions for the pit-specific job analyses that were done to support this study.

3.1 General List of Pit Viper Jobs

Based on the review of project scope and schedules, the cost benefit of using the Pit Viper to do work in the pits was analyzed for two of the four categories of activities: pit upgrades and retrieval system construction. As described in Bailey et al. (1999), the baseline for conducting these activities includes remote viewing by mirrors, hand signals, and radios; use of ropes and poles to guide tools being deployed by the crane; and personnel working behind shield blankets.

For any of these tasks, the alternative to using the Pit Viper is to build a new pit. This would allow workers to conduct initial work inside the pit without receiving significant doses. This alternative was not analyzed further for several reasons. For the larger pits located above the tanks, the new pit would consist of a stainless steel liner placed inside the existing pit. This reportedly costs several million dollars, which would not be cost-effective. One study shows the cost of a stainless steel liner as \$4,800,000 (\$1995) (WHC 1995).

Based on recommendations from CH2M HILL and PNNL developers and users, this study team made the following assumptions for 1) the jobs that the Pit Viper can do, 2) the jobs it may do in the future with further technology development, and 3) the jobs that the Pit Viper is not expected to do.

3.1.1 Jobs the Pit Viper Can Do

Debris removal

Size reduction of material such as pipe, plate, angle

Pit preparation – cutting, grinding, scooping, scraping, crack repair

Pit cleanup

Jumper removal (small pieces once the jumper is cut up)

Jumper installation (only if the jumper is small)

Application of fixatives, but not polyurea

Installation of leak detector relay (LDK)

Installation of field instrumentation (gross manipulation only)

Radiation surveys and pit characterization (i.e., retrieval of smears or samples)

Installation of shielding (for small applications)

Removal of shielding (for small applications)
Removal and installation of new pumps (all types) under 200 pounds
Radiation/environmental surveys/mapping
Painting
Spray decontamination.

3.1.2 Jobs the Pit Viper Can Do with Additional Development

Spray polyurea
Vacuum pit for pit debris cleanup.

3.1.3 Jobs the Pit Viper Could Potentially Do if Requirements Were Determined (e.g., work definition, equipment weight, installation process)

Removal and installation of new pumps (all types) over 200 pounds
Installation of variable speed drive (VSD)/ vacuum-fluorescent display (VFD) controller
Installation of retrieval equipment
Installation of camera riser
Installation of prefab pit
Removal and installation of distributor
Removal of flex receiver.

3.1.4 Jobs the Pit Viper Will Not Do

Building of a greenhouse
Removal of cover block
Replacement of cover block
Removal and installation of new pumps (large pumps)
Installation of shielding (for large applications)
Removal of shielding (for large applications).

This study assumed for the initial estimate of ROI and the break-even analysis that the Pit Viper could apply fixatives, including polyurea, which requires some additional investment. However, if the fixative task was listed in the activity schedule prior to cover block removal, it was not something that applied to Pit Viper operation. Cover block fixative application is done in preparation for removing the block.

3.2 Pit-Specific Analysis

A pit-specific job analysis was developed for the cost model using the information presented in Appendix A. This list was determined by analyzing the project-specific schedules for jobs that the Pit Viper could do. Schedules were obtained from projects or from available Conceptual Design Reports. Project staff identified the jobs to be performed in the pits. Two detailed schedules for retrieval projects were obtained for S-102 (Sturges 2002) and Project W-523 (Carpenter 2001). Start dates and scope for other pit work were estimated from the S-102 schedule for S-Farm retrievals and from Project W-523 for C-Farm retrievals based on the following assumptions:

1. All pit work for the S-farm retrievals is similar to S-102 except that S-102 requires that a jet pump be installed in the S-02B distribution pit. S-102 is a power fluidics retrieval, and the other S-farm retrievals are low-volume density gradient (LVDG) retrievals. All S-farm retrievals require the removal and installation of rigid jumpers in the pump pit (Pit A) and OGT and LDK in the distribution pit (Pit B). The transfers from each S-farm retrieval involve installing new flex jumpers in pit SY-A.
2. All pit work for C-farm retrievals are similar to the C-104 project.
3. For W-523 (C-104 retrievals), retrieval equipment will be installed in existing pits C-04A, C-04B, and C-04C. Two temporary transfer pits, currently identified as C-06D and AY-01G, are above-grade structures to collect any potential leakage from the waste transfer lines or associated equipment for leak detection and provide drainage of the collected waste to an appropriate waste tank. Booster pumps will be installed in C-06A and C-06C. Supernatant transfer pumps will be installed in AY-01E. A slurry distributor will be installed in AY-01A.
4. For C-106 retrieval, retrieval equipment will be installed in existing pits C-06A, C-06B, and C-06C. Two temporary transfer pits, currently identified as C-06D and AY-02G, will be new, above-grade structures to collect any potential leakage from the waste transfer lines or associated equipment for leak detection and provide drainage of the collected waste to an appropriate waste tank. Booster pumps will not be required. Supernatant transfer pumps will be installed in AY-02E. A slurry distributor will be installed in AY-02A.
5. For C-107 retrieval, retrieval equipment will be installed in existing pits C-07A, C-07B, and C-07C. Two temporary transfer pits, currently identified as C-07D and AY-01G, will be new, above-grade structures to collect any potential leakage from the waste transfer lines or associated equipment for leak detection and provide drainage of the collected waste to an appropriate waste tank. Supernatant transfer pumps will be installed in AY-01E. A slurry distributor will be installed in AY-01A.

When dates for pit work were not available, the pit work appears was assumed to be two years ahead of the start date for retrieval from a tank. For C-106, the initial retrieval pit work was

completed by Project W-320. However, additional pit work would reportedly be required to install the retrieval equipment in FY 2003.^(a) This pit work was completed in the first quarter of FY 2003 to meet the accelerated schedule (DOE 2002).

(a) Personal communication with Terry Hissong, September 17, 2002.

4.0 Return on Investment

4.1 Introduction

The ROI analysis is designed to identify net savings resulting from deployment of the Pit Viper in Projects W-211, W-314, W-521, and W-523 and in SST Retrieval Project pit jobs. The ROI analysis includes pit work in a 10-year (FY 2003–FY 2012) study timeframe. All data and results are presented in constant 2002 dollars. This section of the report provides an overview of the Pit Viper ROI model, identifies and documents the assumptions used in the ROI analysis, and presents study findings.

4.2 Return-on-Investment Model

The ROI model developed for this study enables the user to evaluate the impact of various assumptions (e.g., radiation dose rate, project schedule, weather conditions and learning curves) on the rate of return for deploying the Pit Viper.^(a) The basis of the analysis, as embedded in the model, is the following equation:

$$\text{Annual ROI \%} = [((\text{Sum Savings} - (\text{CI} + \text{DTC}))/\text{Y}) / (\text{CI} + \text{DTC})]$$

where

CI = Capital investment in Pit Viper

DTC = Pit Viper development and training costs

Y = Number of years in ROI analysis

Sum Savings = (sum(value of labor differences) + sum(person-rem value difference) + sum(shielding savings) + sum(personal protective equipment savings) – sum(Pit Viper operations and maintenance costs))

Based on this general framework, the model computes rates of return and performs break-even analysis for the deployment of the Pit Viper, both in the aggregate and on a pit-by-pit basis. The ROI includes all prior costs associated with Pit Viper development. At the break-even point the deployment is no longer losing money. That does not include prior development costs. Furthermore, the model is designed to provide flexibility to the user in performing sensitivity analysis for scenarios based on varying assumptions.

The outcome of the ROI analysis is driven by a number of assumptions regarding key variables (e.g., learning curves, radiation doses, weather, labor hours and dome load limits) that are discussed in the next section. The ROI model can be used to perform sensitivity analysis for

(a) The impact of airborne contamination is not evaluated in the model, but using the Pit Viper will avoid accidents involving unwanted exposure to airborne, which carries the potential for additional return on investment.

each of these key variables to assess their impact on the rate of return. For example, conducting pit work in extreme weather yields a 12.5 percent efficiency loss under the conventional approach because heat results in night work schedules, and extreme cold and snow inhibit operations under the conventional manual approach. For each pit included in the ROI analysis, there is a trigger that enables the user to select it as an extreme weather pit (depending on the season in which the work is planned) or exclude weather as a condition of analysis.

Pits were identified for analysis based on the type of work planned for each pit; that is, if there is a job within the pit work schedule that could be performed by the Pit Viper, the pit was included in the analysis. There are five project types with pit work in their scope covered in this analysis (W-523, W-521, W-211, W-314, and SST retrievals). As such, some pits are analyzed within the model more than once. For example, a single pit may be entered to install retrieval equipment and then entered a second time later in the project timeline to refurbish and use as a booster pump pit.

The model also conducts a break-even analysis for 80 pit entries. The break-even analysis compares the differences between the cost of the conventional manual approach and the cost of deploying the Pit Viper within each pit. The model performs the break-even analysis without inclusion of the previously incurred Pit Viper capital and development costs (sunk costs).

4.3 Assumptions

The results of the analysis are sensitive to assumptions used in the ROI and break-even analyses, including those associated with the impact of harsh weather conditions, radiation exposure, and learning curves. For example, if the Pit Viper is deployed in only a few pits or not used for high dose-rate pits early in the schedule, the ROI is much less. If no learning curve is assumed, fewer pits break even or show savings when the Pit Viper is used. This section of the report provides an overview of the assumptions used in developing the ROI and break-even analyses and documents the basis for each assumption. These assumptions are collectively based on reviewed literature, data collected for this study, and input received from those performing pit work and other experts. A sensitivity analysis is performed for critical variables.

4.3.1 Weather Delays

Extreme weather at Hanford results in efficiency losses in terms of time required to perform operations. Weather phenomena resulting in efficiency losses include summer heat with temperatures exceeding 85°F, winter temperatures below 32°F, sustained wind gusts of 20–25 miles per hour, and snowy conditions. These weather phenomena result in increased costs due to the increased time required to travel to pits, the time needed to knock snow off tents, compressed night schedules during summer months, and the illumination of pits during nighttime operations.

Extreme weather can also result in compressed schedules and more overtime hours, paid at 1½ to 2 times regular salaries.

The efficiency loss resulting from extreme weather is assumed to be equal to one hour per day in the summer months of July and August and the winter months of January and February, or 12.5 percent. The estimated efficiency loss is based on past experience, as documented by managers of pit operations. These estimates are supported with Hanford climatological data, as shown in Figure 4.1. From 1945 to 1999, the vast majority of all days with temperatures exceeding 90°F occurred in the months of July and August. During the same timeframe, temperatures dipped below 32°F an average of 25 days per year, with 19 of those days falling in the months of December and January²⁰.

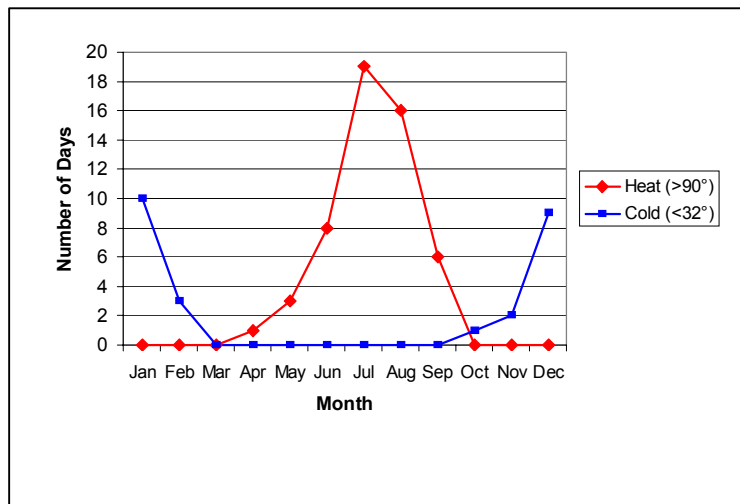


Figure 4.1. Extreme Temperatures at Hanford (average, 1945–1999)

4.3.2 Learning Curves

The theory of learning recognizes that repetition of an operation leads to a reduction in the time and effort required to perform the operation. This theory would be relevant in the operation of the Pit Viper. As operators use the Pit Viper to perform work within the pits, the hours required to perform each operation would be expected to decline.

The Wright learning curve^(a) is built on the hypothesis that the number of hours required to perform an operation would decrease by a fixed percentage each time the number of operations is doubled. For example, a 90-percent learning curve is built on the assumption that the second operation would take 10 percent less time than the first, the fourth operation would take 10 percent less time than the second, and the eighth operation would take 10 percent less time

(a) The original model was developed by TP Wright in 1936 and is referred to as the Cumulative Average Model, or Wright's Model.

than the fourth. Each time the number of operations doubles, the time required to perform the operation declines by 10 percent. An 85-percent learning curve assumes that each doubling of operations leads to a 15-percent reduction in the time required to perform the operation, while a 95-percent learning curve corresponds to a 5-percent reduction in hours for each doubling of operations.

Figure 4.2 illustrates the 85-, 90-, and 95-percent learning curves. Compared with the 95-percent learning curve, the 85-percent learning curve would yield significantly more time savings as a result of enhanced operator expertise. In the absence of test data to establish a learning curve for the Pit Viper, the 95-percent learning curve was selected as the preferred measure because it is conservative, and data obtained from a number of industries involved in repetitive mechanical operations (electronics manufacturing, machining, and welding operations) support it as an appropriate measure for cost analysis. Further, the 95-percent learning curve was also selected because knowledgeable CH2M HILL personnel identified it as most representative of the Pit Viper. The Pit Viper ROI model is designed to support scenario analyses using the 85-, 90-, or 95-percent learning curves.

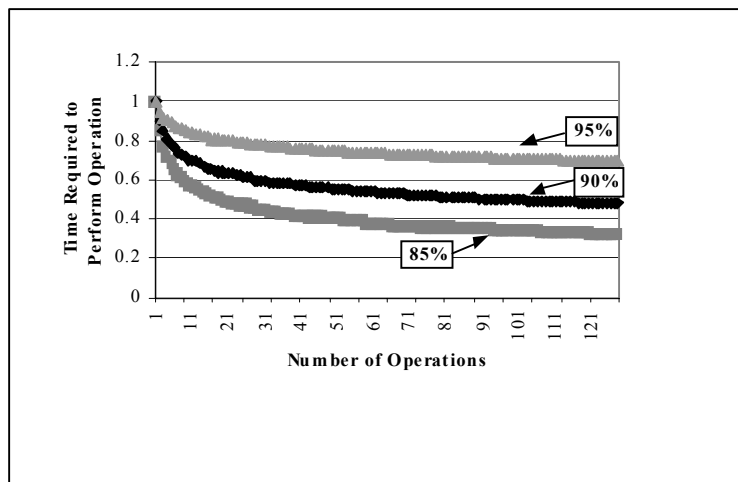


Figure 4.2. The 85-, 90-, and 95-Percent Learning Curves

4.3.3 Monetary Value of a Person-Rem

A significant qualitative benefit accrued as a result of Pit Viper deployment is reduced human exposure to radiation. To adequately capture the effect of reduced occupational exposure to radiation, PNNL assigned a monetary value for a unit of collective dose (dollars per person-rem). PNNL reviewed current Nuclear Regulatory Commission (NRC) standards, As Low as Reasonably Achievable (ALARA) Hanford-reported values, and existing literature to determine the most appropriate monetary value for reductions in radiation exposures in dollars per person-rem.

In 1995, the Nuclear Regulatory Commission published *An Assessment of NRC's Dollar per Person-Rem Conversion Factor Policy*, which established the recommended value of a person-rem at \$2,000 (NRC 1995). In a 1997 publication, NUREG/BR-184 *Regulatory Analysis Technical Evaluation Handbook*, the NRC re-affirmed \$2,000 as an appropriate monetary value of a person-rem (NRC 1997). The NRC estimate is designed to capture the health impact of radiation exposure only and does not cover the non-health effects (e.g., training costs and lost productivity) of human exposure to radiation.

In an approach designed to capture both the health and non-health effects of occupational exposure to radiation, Millsap (date unknown) constructed an equation designed to capture the costs associated with lost productivity, the risk to human life, health care costs, the impact on dependents, and training costs. In *An Approach to Determining the Monetary Value of Collective Dose for Occupational Exposures*, Millsap documented the equation and presented estimates of the monetary value of a person-rem at around \$30,000. However, the paper does not use actual data to monetize occupational exposure to radiation. Rather, it uses illustrative data to demonstrate how the equation could be used to assign a value per person-rem. Based on our understanding of the available data, this method could be used to determine the costs associated with radiation exposure.

The selected alternative was the value provided by CH2M HILL to ALARA for planning purposes. Each Hanford organization has established its own value per person-rem. The CH2M HILL-established value of \$12,000 per person-rem was selected for use in this study. It is important to note, however, that work performed in high dose-rate pits could result in additional costs associated with individual workers meeting maximum annual dose limits, thus reducing the availability and productivity of the existing work force.

4.3.4 Reductions in Radiation Exposure

Radiation dose data are processed in terms of mrem per hour at pit edge. High-dosage pits are scheduled throughout the life of the project and vary from negligible amounts of radiation exposure at the pit edge to as high as 3,000 mrem per hour at pit edge. Radiation dose data for each pit were estimated from radiation survey reports. In the absence of a measured dose rate at pit edge, the dose rate at pit edge is assumed to be one-tenth of that measured at pit bottom. Total radiation exposure is measured in terms of hours of work performed at pit edge. Initial estimates of person-rem exposure are factored down based on an assumption of protection provided by shielding and estimates of radiation exposure estimated for various jobs, as provided by CH2M HILL staff. The risks from exposure to airborne contamination were not evaluated.

The same dose to workers is attributed to a specific job, despite the labor hour estimate used in the model, because no published information was found to differentiate dose to workers or labor hours for low, medium, or high dose-rate pits. This is a reasonable assumption because work practices can be adjusted to keep worker exposure as low as possible. The person-rem for a

specific job is based on the estimates provided in the appendix of the Pit Viper Deployment report (see Table 4.1) for a pit with 400 mrad/hr at the pit edge (Niebuhr and Mewes 2002). The person-rem for a specific job assumed for a 400 mrad pit at the edge is factored up or down based on the dose at the pit edge for the pit being evaluated, assuming a linear relation between dose at the pit edge and dose to workers.

Table 4.1. Dose to Workers Inside Tent (assumes 400 mrem/hr at pit edge)

Jobs	Total Person-Rem for Current Practice	Total Person-Rem for Pit Viper without Learning Curve
Remove and Package Jumpers	1	0.53
Cleanout and Decontaminate Pit	0.94	0.50
Apply Polyurea	0.29	0.13
Install LDK	0.014	0.007
Install Field Instrumentation	Negligible	Negligible

4.3.5 Tasks Performed by Pit Viper

Based on the PNNL report *Remote Pit Operation Enhancement System: Concept Selection Method and Evaluation Criteria* (Bailey et al. 1999), the outcome of field tests and input from its designers, the Pit Viper is assumed to be capable of performing the following tasks:

- Remove and package jumpers
- Clean out and decontaminate pits
- Install LDK equipment
- Pit coating.

Labor Hours and Labor Rates

In the base-case scenario, labor hours for each of the tasks are based on the hours reported in the Project W-523 Conceptual Design Report (Carpenter 2001) and shown in Table 4.2.

Table 4.2. Labor Hour Estimates for Tasks

Task	High Labor- Project W-523 Basis	Low Labor- Plant Forces	Low Labor- Construction Forces
Remove Jumpers	684	160	208
Clean Out/Decon Pit	7840	432	576
Install Jumpers	672	160	208
Install LDK	720	160	208
Pit Coating	2960	224	320

PNNL has also developed a low labor-cost ROI estimate based on input from CH2M HILL staff and information in Table 4.2 for plant forces.^(a) The ROI analysis is based on the assumption that the hours required to operate the Pit Viper and human labor are equal and that labor savings accrue through the deployment of the Pit Viper over time due to enhanced operator skill, based on the 95-percent learning curve differential. Tests of the Pit Viper indicate that the technology may not currently complete operations in as timely a manner as conventional labor, but the Pit Viper works 60 percent longer in a shift than a standard crew. The time savings due to the elimination of crew preparation and cleanup (dressing, undressing and decontamination) time are assumed to offset the additional time to complete the operations.

Based on input from CH2M HILL staff, an average labor rate of \$75/hour was used to monetize labor hour savings. Note that the ROI analysis makes no assumptions regarding reductions in work force potentially realized as a result of deploying the Pit Viper; however, additional savings outside of the scope of this analysis may accrue due to accelerated project schedules, enhanced workforce flexibility and a reduction in the number of pit workers meeting annual radiation dose exposure limits. If the Pit Viper frees up labor for other productive capabilities, work schedules could be compressed, and there would be additional flexibility during the job.

(a) Low labor estimates based on telephone communication with Jim Lee of CH2M HILL, September 13, 2002. In some places, the labor hours provided by Lee differed by a factor of 10 from the W-523 estimate, especially if plant forces were used. The difference was discussed with Dennis Gunderson, CH2M HILL cost estimator, on September 19, 2002. His opinion was that the differences are likely due to scope differences as well as other factors that are considered when doing a Conceptual Design Report cost estimate.

4.3.6 Dome Load Limits and Shielding Installation

Human presence in the pits necessitates the installation of protective shielding. The shielding protects laborers while they perform operations within each pit. The application of the Pit Viper to perform the same work removes the shielding requirement, resulting in cost savings to the project.

Shielding is not necessary for work performed in pits with radiation doses of less than 12 mrem per hour at pit edge. For pits where shielding is required, labor hours to install shielding are based on the conventional approach, resulting in \$9,000 in additional project costs. Labor hours required to install shielding are assumed to double for tanks with concentrated dome load limits at or below 200,000 lb-force. Dome loading limits are a Tank Farms Technical Safety Requirement (TSR) (WHC 1997). HNF-IP-1266, Section 5.16.B, Rev. 0B is the implementing program for this TSR that defines the dome loading limits by tank farm. This document also provides references to the dome limit calculations. The tank groups with concentrated load limits that would incur additional shielding costs include the SSTs and SY Farm DSTs. The shielding cost is considered to be double, or \$18,000, for these tanks. Note, however, that these savings would not be realized if shielding were required to protect human laborers during any part of work scheduled for a pit in which the Pit Viper is planned for deployment.

4.4 Personal Protective Equipment

The deployment of the Pit Viper would reduce the need for personal protective equipment (PPE), resulting in project savings in laundry service. Based on information provided by CH2M HILL staff, this study assumes that each job performed by the Pit Viper reduces the need for PPE on that job by roughly 62.5 percent. Laundry costs per PPE are assumed to be \$3.50 per day.^(a)

Backhoe Operation and Replacement Costs

One of the components of the Pit Viper is a backhoe. Therefore, backhoe operations and maintenance costs have been factored into the ROI analysis. Hourly backhoe operations and maintenance costs were determined using a Caterpillar cost guide, useful life data prepared by the University of Minnesota, and information provided by the maintenance department at Fluor Hanford.^(b) Based on input from these sources, we used the following assumptions to determine hourly replacement cost (\$4.60/hr) and operations and maintenance (\$12.67/hr):

(a) Personal communication with Al Jarimillo, CH2M HILL on September 17, 2002.

(b) Phone conversation with Dave Baie, Fluor Hanford, on September 18, 2002. Fluor Hanford operates several backhoes. The replacement costs came from the University of Minnesota website. These estimates are extremely conservative for the Pit Viper.

- Preventative maintenance schedule requires a visit to the shop every 100 hours for oil change, lube, and other minor maintenance activities.
- One annual detailed inspection.
- Fuel consumption of 3 gallons per hour.
- Inclusion of additional tire and corrective maintenance costs equal to 10 percent of the sum of preventative maintenance and annual inspection costs.
- The backhoe will have a useful life of 12 years and, under normal operations, incur 960 hours of use per year.

4.5 Pit Viper Availability

PNNL has made no assumption regarding the availability of the Pit Viper to complete work. PNNL assumes that there is only one Pit Viper used in this project. To the extent that multiple pits must be worked on by the Pit Viper simultaneously to ensure projects are completed on-schedule, additional development and training costs would be incurred to add more Pit Vipers and staff to operate the equipment (Grams 2001).

4.6 Results

The results of this study indicate a positive ROI for the deployment of the Pit Viper, provided that the Pit Viper is used for high dose-rate pits early in the schedule, works in multiple pits per year, and supports numerous pit entries and jobs. Seventy of 80 pit entries will exceed the break-even point if the Pit Viper is used when a 95-percent learning curve is assumed. As demonstrated in the tables that follow, the outcome of the ROI analysis is sensitive to the treatment of key variables such as labor hours, learning curves, weather, shielding requirements, and radiation doses. This section identifies the rates of return for the Pit Viper in its current form and for potential development alternatives and analyzes the outcome of sensitivity analyses designed to quantify the impact of each of the variables driving the outcome of the ROI analysis.

Figure ES.1 stratifies pits based on their characteristics into high, medium, and low cost-benefit categories. High-return pits are the best candidates for deployment of the Pit Viper. As shown, the findings of this study suggest that Pit Viper deployment will exceed the break-even point and provide higher returns on investment for pit work completed in extreme weather, in pits with numerous tasks to be completed (long labor hours), where shielding is required, and where the dose rate at the edge of the pit is greater than 50 mrem/hr.

Table 4.3 shows the breakdown of costs and ROI for the Pit Viper assuming no further development of capabilities. In constant CY 2000 dollars, the total capital investment and development costs associated with deploying the Pit Viper total roughly \$2.3 million. Project savings

Table 4.3. Breakdown of Costs and Return on Investment for Pit Viper for Current Capabilities with 95% Learning Curve

Initial Capital Investment		\$1,946,128
Total Project Startup Funds		\$390,000
Total Development		\$2,336,128
Savings		
Labor		
Learning	\$7,392,987	
Weather	\$1,821,525	
Subtotal		\$9,214,512
REM		\$292,932
PPE		\$3,441
Shielding		\$468,000
Dome Loading		\$198,000
Total		\$10,176,885
Added Costs		
O&M		453,660
Savings		\$10,123,224
Annualized Net Savings (10 years)		\$778,710
Annualized Return on Investment		33%

resulting from the deployment of the Pit Viper exceed \$10.1 million. Of that amount, \$7.4 million are attributable to time savings as a result of enhanced operator expertise, as quantified through the application of learning curves. The ability of the Pit Viper to work in inclement weather accounts for an additional \$1.8 million in savings. Dome load limits and the reduction in shielding requirements account for \$198,000 and \$468,000 in cost savings, respectively. The monetary value of person-rem savings due to the Pit Viper deployment is estimated to be \$293,000. Finally, deployment would generate savings due to a reduction in the number of PPE issued to perform pit work (\$3,400) but would cost the project an additional \$53,600 due to backhoe operation and maintenance costs. Net savings to the project are estimated to total \$7.8 million. Thus, the total ROI equates to approximately 335 percent, or 33.5 percent on an annualized basis.

Table 4.4 shows the ROI as a function of learning and estimated labor for both the high and low labor-hour scenarios for the 95-percent learning curve. As noted in the preceding section, PNNL has received high labor hour estimates in the W-523 Conceptual Design Reports and low labor

Table 4.4. Return on Investment as a Function of Learning and Estimated Labor

	Learning Factor (%)			
	100	95	90	85
High Estimated Labor	2	33	59	81
Low Estimated Labor	-7	-4	-2	-1

hour estimates for specific operations from CH2M HILL staff. The selection of the appropriate learning curve is a strong determinant in the outcome of the analysis. As shown, the assumption of “no learning” reduces the annualized ROI to 2 percent under the high-labor-hour scenario and a –7 percent return assuming low labor-hour estimates. In contrast, an 85-percent learning curve generates an estimated 81 percent annual rate of return for the high labor-hour scenario and a –1 percent rate of return for the low-labor-hour scenario. The high labor-hour scenario generates higher rates of return because the time savings associated with learning curves and extreme weather are applied on a percentage basis to the labor hours for each operation. As the total number of hours required to perform an operation increase, the time savings grow and thus generate more labor cost savings.

ROI as a function of weather and estimated labor is shown in Table 4.5. Under the conventional approach, work performed in July, August, December and January is assessed a 12.5 percent labor efficiency loss due to the impact of extreme weather on the ability of humans to perform operations. In the high-labor-hour scenario, extreme weather accounts for 7 percent of the annual rate of return estimated for deployment of the Pit Viper. The impact of weather in the low-labor-cost scenario is less pronounced, equal only to 1 percent of the annual rate of return. Though extreme weather yields 12.5 percent efficiency losses, the impact of weather is lower because much of the work performed within the pits is completed in months that generally experience more moderate weather conditions.

Table 4.5. Return on Investment as a Function of Weather and Estimated Labor

	Weather	No Weather
High Estimated Labor	33%	26%
Low Estimated Labor	-4%	-5%

Table 4.6 identifies the number of pits with positive returns under various scenarios where one or a combination of variables is included in the analysis. For example, after removing all other variables (labor, collective dose savings, shielding, and dome load limits) from consideration, extreme weather would result in 26 pits with positive savings. That is, deployment of the Pit Viper yields savings in 26 of 80 pits accrued as a result of extreme weather. Through the addition of learning curves at the 95 percent level of learning, an additional 42 pits become

Table 4.6. Characteristics of Pit that Make Pit Viper Profitable

	Number of Pits with Positive Savings Category			
	Weather	Labor	Labor plus REM	Labor, REM, Shielding, Dome Loading
No Learning				
High Estimated Labor	26	27	38	57
Low Estimated Labor	26	26	29	57
95% Learning Factor				
High Estimated Labor	26	68	70	70
Low Estimated Labor	26	68	69	70

profitable. Collective dose savings account for an additional two pits. Thus, when all the key factors are included in the analysis, 70 of the 80 pits yield savings to the project when the Pit Viper is used. Appendix B documents the pit-by-pit outcome of the break-even analysis. Appendix B break-even results do not include the sunk costs. The break-even value represents the marginal operational benefits of deploying the Pit Viper. If you add up all the values in the table, it sums to the monetary benefit of deploying the Pit Viper (\$10.2 million) without consideration of the sunk investment costs. When sunk costs are included, the net ROI is reduced to \$7.8 million.

Table 4.7 highlights the ROI analysis for the proposed future development of the Pit Viper to enable it to apply coatings such as polyurea, work remotely, and reduce cabling to move toward wireless operations. In virtually all of the scenarios analyzed, each of the proposed development activities yields positive returns to the project. In the base-case scenario, assuming high labor cost and a 95-percent learning curve, the development of polyurea application capabilities yields a 141 percent annual rate of return, remote operations results in an 18 percent annualized ROI,

Table 4.7. Return on Investment for Future Development

	Learning Factor (%)			
	100	95	90	85
High Estimated Labor				
Polyurea	11	141	240	323
Remote operations	15	18	18	18
Cabling	23	27	27	27
Low Estimated Labor				
Polyurea	-8	1	9	15
Remote Operations	15	18	18	18
Cabling	23	27	27	27

and removal of cables generates a 27 percent annual ROI. These results suggest that additional development of the Pit Viper would be cost-effective, especially if development results in more labor-intensive jobs amenable to the Pit Viper.

Tables 4.8 through 4.10 provide more in-depth analyses of the costs and returns for each of the proposed development activities. Based on input from a Pit Viper developer, we have assumed the following benefits resulting from proposed development activities.^(a)

- Removal of cabling requirements will reduce Pit Viper setup (1.5 days labor for seven people) and teardown costs (1.5 days for five people and 1 day for four people).
- Remote operations are assumed to eliminate the need for a crane operator, three riggers and a backhoe crew during setup and teardown.
- Polyurea application is treated in the same manner as all other Pit Viper capabilities, with savings accruing as a result of labor cost and radiation dose reductions.

Section 5.0, Tool Development Needs, contains a more detailed description of proposed Pit Viper development activities.

Table 4.8. Breakdown of Costs and Returns for Pit Viper for Polyurea (95% learning curve)

Initial Capital Investment	\$150,000
Savings	
Labor	\$2,226,660
REM	\$33,342
PPE	\$3,441
Total	\$2,263,443
Added Costs	
O&M	\$4,901
Savings	\$2,258,542
Annualized Net Savings (10 years)	\$210,854
Annualized Return on Investment	141%

(a) Personal communication with Sharon Bailey, September 26, 2002.

Table 4.9. Analysis of Returns for Pit Viper Remote Operations (95% learning curve)

Initial Capital Investment	\$450,000
Savings	
Labor	\$1,273,800
REM	-
PPE	-
Total	\$1,273,800
Added Costs	
O&M	-
Savings	\$1,273,800
Annualized Net Savings (10 years)	\$82,380
Annualized Return on Investment	18%

Table 4.10. Breakdown of Costs and Returns for Pit Viper for Cabling (95% learning curve)

Initial Capital Investment	\$250,000
Savings	
Labor	\$924,000
REM	-
PPE	-
Total	\$924,000
Added Costs	
O&M	
Savings	\$924,000
Annualized Net Savings (10 years)	\$67,400
Annualized Return on Investment	27%

5.0 Tool Development Needs

This section summarizes the December 2001 Pit Viper demonstration and the path forward for recommended system improvements.

5.1 Pit Viper Demonstration

Over a three-day period in December 2001, the Pit Viper remote system achieved a milestone in Tank Farm operation and maintenance by demonstrating its ability to perform real and meaningful work in a radioactively contaminated underground pit with no personnel in the containment tent to assist. This demonstration was the first step toward full field deployment of a system that can greatly reduce overall worker radiation exposure and accomplish the pit work tasks with a marked increase in worker safety. The Pit Viper successfully demonstrated the ability to perform tasks common to pit clean out and refurbishment work scope, including:

- Decontamination water spraying in the pit
- Size reduction of equipment and materials in the pit
- Removing discrete objects from the pit
- Collecting small and loose debris from the pit floor and walls
- Preparing and cleaning wall surfaces for painting.

The overall demonstration was very successful, both in concept and in actual field operation. During the C-104 heel pit deployment, the Pit Viper system demonstrated sufficient dexterity to conduct the tasks in Table 5.1 using techniques similar to those employed by field crews.

Table 5.1. Summary of Pit Viper Demonstration Results^(a)

No.	Activity	Viper System Results	Tool Results
1	Size reduce objects within the pit	Successful	Not Successful
2	Remove discrete objects from the pit	Successful	Not Applicable
3	Collect and remove debris from pit floor	Successful	Successful
4	Prepare and clean pit wall and floor	Successful	Limited Success
5	Deliver pressurized sprays	Successful	Successful
6	Remove discrete objects from pit and redistribute them inside the disposal container	Successful	Successful
(a) Niebuhr and Mewes 2002.			

Overall, the system should successfully perform the following tasks without additional development:

- Debris removal
- Washing
- Spraying
- Remote manipulation
- Paint preparation (grinding, sand blasting, etc)
- Radiation surveys
- Size reduction.

Robotic arm software control and reliability issues were noted during the hot demonstration in the C-104 heel pit. During operation, the computer software for the Cybernetix locked up frequently. When the computer needed to be rebooted, the arm moved abruptly as the system was restored, and the gripper often released the object it was holding. Subsequently, this issue was resolved by software improvements and installing blocking valves to prevent the loss of the gripped object during power failures.

The field performance of the pan and tilt cameras and controllers procured for direct support of the Pit Viper system needed improvement. The operating team is seeking replacements and alternatives from commercial sources known to have higher-quality and more versatile imaging equipment.

5.2 Pit Viper Opportunities

The opportunity exists to increase the scope of tasks that can be completed using the Pit Viper. These tasks fall into the following areas:

- Tool Development - Further tooling development would be beneficial for:
 - Tools that could deliver polyurea spray.
 - Tools that could grind and scrub down large areas of the sides of the pit and repair concrete.
 - Tools to assist in jumper installation, pump installation and repair, and equipment repair.
 - Improved tools for removing the old-style jumpers and chopping them up, and for installing rigid jumpers.
 - “Shop-vac” tools that could vacuum debris from the pit

- Ease of Deployment Improvements - Another improvement that was suggested for the longer term is climate-controlled containment for the Pit Viper. For example, in July and August, work on pit jobs does not occur during the day due to extreme heat. However, it should be noted that the control room trailer is already climate controlled, and efforts to provide climate control for the tents are already planned for current practices. These improvements benefit Pit Viper deployments and do not require any additional investment. In addition, when the Pit Viper is operating, the crews should not need to be in the containment tent, except for setup and tear down.

5.3 Tasks for Recommended System Improvements

5.3.1 Task A - Improve Remote Operation (\$450K, 10.5 months)

- Independence from Tank Farm Resources (eliminates the external HPU and run power/hydraulics off backhoe, eliminates the need for a crane and crew for setup and takedown) -- \$200K, 4 months
- Remote the backhoe (run boom/stick from control trailer, eliminates the need for a worker to be in the backhoe during pit operations) -- \$50K parts, \$60K labor, 4 months
- Self-sufficient power – Power generator on backhoe -- \$40K parts, \$40K labor, 2 months
This eliminates the need for cranes to position viper equipment in the farm, and eliminates the need to tie into any Tank Farm resources, such as power.
- Local tooling – rack on backhoe -- \$10K, 2 weeks

5.3.2 Task B - Reduce Cabling, Improve Vision (\$250K, 3 months)

- Transition to FO and/or wireless communications, and digital cameras

5.3.3 Task C - Improve System Efficiency - Automated tool acquisition (\$20K, 1 month)

- Tool interface/acquisition. Determine the optimal tool interface (currently this is a “t-handle”) and implement automated tool acquisition.
- Auto assist on certain pit tasks – depends on task

5.3.4 Task D - Contamination Control – tent design, boot design (cost estimate TBD)

- Booting – perhaps change to replaceable gripper parts that do not require booting.

Completion of this task would decrease setup and takedown time significantly (up to 75 percent more efficient in the farm) and translate to significant increases in system capability, and make the system easier to setup, train, use and maintain.

5.3.5 Task E - Performing New Tasks

Doing “new” tasks really means “tool” development and testing/training for the Pit Viper. The current system has the generic capabilities, but without defined requirements for the work, we cannot estimate its cost at this time. An approximate estimate is as follows for individual remote tool development based on defined pit tasks.

- \$50-100K, 2–5 months per new task (obviously a very difficult task and could be a lot more expensive)

No additional investment is necessary to deploy tools to vacuum the pit.

5.3.6 Task F - Polyurea Spraying (\$150K and 4 months to improve pit viper ability to apply polyurea)

6.0 Conclusions

This assessment provides a preliminary decision-making framework based on modeling and deploying the Pit Viper for 80 planned pit entries in CH2M HILL's work scope. The results present a favorable outcome for routine Pit Viper deployment if the assumptions used for modeling Pit Viper deployment are valid. The model is based on wide scale use of a single Pit Viper in 80 tank farm pits for the projects listed in conclusion 1 below.

This assessment supports the following conclusions:

1. The Pit Viper would be useful throughout the CH2M HILL contract period and beyond. Opportunities for use include Projects W-314, W-211, W-521, W-523, and other SST Retrieval Projects. Because the initial investment in the Pit Viper is already completed, the additional investment includes training and procedures. There are very few, if any, additional setup and tear-down costs over current practices, which means that the Pit Viper breaks even in a significant number of pits, provided there are no unforeseen negatives to its operation.
2. According to the model, 70 of the 80 pits exceed the break-even point, and the most significant factors for exceeding break-even in a pit are whether the shielding can be eliminated, whether the pit will be worked during months with extreme weather, and where the pit is in the schedule as later pits realize increased benefit from the learning curve. The amount of labor hours that can be replaced with the Pit Viper instead of current practices determines the amount of positive cost benefit. Some of the factors leading to a positive break-even are uncertain. For example, jobs other than those analyzed by the model may require the use of shielding, and this need is not determined by the model.
3. The learning curve should substantially increase the cost benefit of Pit Viper deployment. With high labor hours and no learning curve, there is a small annual return on investment if a single Pit Viper is deployed on a wide scale throughout the CH2M HILL contract period, including high dose-rate pits early in the schedule. The annual return on investment increases to 81 percent when an 85-percent learning curve is assumed for the Pit Viper. In addition, the ROI increases as we increase the number of very high-dose-rate pits within CH2M HILL's scope.
4. The initial investment for the Pit Viper will be recouped provided the Pit Viper is used consistently throughout the CH2M HILL contract period. The Pit Viper ROI becomes more positive in the pits as operator speed increases as a result of the learning curve. In the early stages, it breaks even on high-dose-rate pits. As operator speed increases, it

reaches a point where the Pit Viper breaks even on lower-dose pits, provided there are sufficient tasks to perform in the pit.

5. There are a number of high dose-rate pit jobs that are suitable for the Pit Viper in the next few years that play a key role in helping CH2M HILL recoup the additional Pit Viper investment.

Further evaluation is needed to make conclusive pit-by-pit recommendations using the model. Decisions for individual pit deployments must consider the full scope of the projects, the detailed schedule, and full evaluation of the conditions in the pits. Modeling results would be improved by considering the accelerated schedules, better information on the condition of the pits, and a comprehensive comparison of the jobs in the pits. While actual radiation survey information is used in most cases, the dose to workers is attributed to a specific job rather than the labor hour estimate used in the model.^(a) Labor hour estimates do not differentiate between high or low dose-rate pits. While all assumptions used in the model have been discussed with tank farm staff, there was not always a consensus.^(b) As the information becomes more refined and accurate on a pit-by-pit basis, the utility of this model increases and allows more specific recommendations.

The current thinking of Pit Viper developers is that the Pit Viper labor hour estimates used in this analysis are conservative. Pit Viper operational experience will validate operational and learning curve assumptions. For example, the study assumes that the labor hours to conduct a task with current practices are equal to the hours required to do the task with the Pit Viper (Grams 2001).

(a) No published information could be found to differentiate labor hours for low, medium, or high dose-rate pits.

(b) The labor hours to conduct the jobs in the pits were based on the W-523 cost estimate, an estimate provided by Jim Lee, and communications with other CH2M HILL staff. There was wide variation in the labor hour estimates to conduct specific jobs from different sources. In some places, the labor hours differed by a factor of 10.

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Appendix A

Supporting Data Tables

Appendix A

Supporting Data Tables^a

Table A.1. Project W-314 Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AW-A	200	WO: 300 mR/hr @ >30 cm WC: 300 @ >30 cm -- Dose Rate @ Hole A 1' down WO: 2300 mR/hr @ Contact WC: 2000 @ Contact (6/23/98 at pit bottom)	Completed
AW-B	20	WO: 150 mR/hr @ >30 cm WC: 20 mR/hr (7/28/00 Splash Guard)	Completed
241AA Valve Pit	40	Shallow Dose-670 mrem/hr @ Field Deep Dose-40 mrem/hr--30 cm over pit (4/27/98)	Complete pipeline tie-ins and turnover to operations
244-A DCRT	250	Shallow dose, 250 mrem/hr; deep dose, 250 mrem/hr (10/2/00 key block at splash guard)	Excavate tie-ins and construct bypass
AY-01A	10	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO:100 mrem/hr @ 3" WC:100 mrem/hr @ 3" (4/22/98 1ft to 6ft down inside pit)	No pit work on schedule, assume completed
AY-02A	10	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO:100 mrem/hr @ 3" WC:100 mrem/hr @ 3" (4/22/98 1ft to 8ft down inside pit)	No pit work on schedule, assume completed
AZ-01A	10	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO: <100 mrem/hr @ 3" WC: <100 mrem/hr @ 3" (4/22/98 1ft to 9ft down inside pit)	Completed
AZ-02A	50	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO:<100 - 6500 mrem/hr @ 3" WC: <100 - 500 mrem/hr @ 3" (4/22/98 1ft to 9ft down inside pit)	Completed
AN-01A	200	WC: 200 mrem@ F (3/4/02 highest dose rate after key block removal)	No pit work on schedule--assume completed

(a) Blank cells use assumed values for dose at pit edge.

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AN-02A	85	Deep Dose--850 mrem/hr @ lower part of pit (1/03/02)	Mobilize equipment/ erect greenhouse, pull cover blocks, remove jumpers & reinstall cover blocks, evaluate pit 02A for coating applications, prep pit & apply special protective coating, install drain seal, perform functional test of drain seal, reconfigure pit/install cover blocks
AN-03A	30	WO: 48 mR/hr @ >30 cm WC: 30 mR/hr @ >30 cm-- Highest Dose in pit WO: <.5 mR/hr @ Contact WC <.5 mR/hr @ Contact--2 Waste bags	Remove cover block, install LDE sleeve, install TBX boxes/ cordsets, install LDE probe assembly, inspect pit 03A for polyurea applications, clean pit floor with solvent, evaluate pit 03A for special protective coating, apply pit coatings, install drain seal, perform functional test of drain seal, reconfigure pit/install cover blocks
AN-04A	60	WO: 600 mR/hr @ >30 cm WC: 600 mR/hr @ >30 cm--5 ft. down valve port (6/11/98)	Not on schedule
AN-05A	No data	No data	Core drill cover block (1 hole); coatings for cover blocks; install LDE sleeve CF8/20/02, TBX boxes and cordsets, and LDE probe assembly; pull cover blocks 05A – PF; remove pit decon & jumper – PF, evaluate pit 05A for coating applications, apply pit coatings, install drain seal, perform functional test of drain seal, reconfigure pit/install cover blocks
AN-06A	80	Deep Dose: 80 mrem/hr (2/12/02 at south side of pit edge)	Core drill cover block (1 hole), coatings for cover blocks, install LDE sleeve, TBX boxes/cordsets, LDE probe assembly, apply pit coatings, install drain seal, perform functional test of drain seal, install jumpers 06A, install cover blocks 06A and leak check jumpers

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AN-07A	10	WC: 100 mR/hr@ (12/29/00 inside valve handle opening)	Core drill cover block (1 hole), evaluate coatings for cover blocks, install LDE sleeve, TBX boxes/ cordsets, LDE probe assembly, inspect planning/setup, mobilize equipment/ erect greenhouse 07A, pull cover blocks 07A, remove jumpers & reinstall cover blocks 07A, evaluate pit 07A for coating applications, apply pit coatings 07A, install drain seal 07A, perform functional test of drain seal 07A, install jumpers 07A, cover blocks 07A, leak test, jumpers 07A
AP-01A		WO: .5 mR/hr @ 2.54 cm WC: <.5 mR/hr @ 2.54 cm (6/27/01)	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), inspect pit coatings, install LDE sleeve, coatings for cover blocks, drain seal, reconfigure pit/install cover blocks, install LDE probe assembly
AP-02A	20	WC: 20 mR/hr @ Field-- Extender dose rate (04/12/01)	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit decon & remove jumpers, core drill cover block (1 hole), pit coatings, install LDE sleeve, coatings for cover blocks, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AP-03A		No data	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AP-03D		No data	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AP-04A		WO: <.5 mR/hr @ 2.54 cm WC: <.5 mR/hr @ 2.54 cm-- General area (11/29/99)	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AP-05A		No data	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AP-06A		WO: <.5 mR/hr @ Contact WC: <.5 @ Contact--Work area post job (11/30/99)	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AP-07A		WO: <.5 mR/hr @ 1" WC: <.5 mR/hr @ 1"--Center shield plug hook (1/25/99)	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coatings, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AP-08A		WC: <.5 mR/hr @ F"-- Baseline (11/07/01)	Planning/setup/inspection, erect greenhouse/pull cover blocks, pit decon & jumper removal, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, drain seal installation, reconfigure pit/install cover blocks, install LDE probe assembly
AW-01A		No Data	Mobilize & set up for pit work, planning/mobilization/inspection, shop fab LDE sleeves, erect greenhouse/pull cover blocks, pit decon & jumper removal – PF, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly
AW-02A	35	Shallow dose--35 mrem/hr @ F Deep dose--35 mrem/hr @ F (9/18/01)-open pit edge deep dose 100 mrem/hr (4/16/01 3 ft inside)	Planning/setup/inspection, erect greenhouse/pull cover blocks, pit decon & jumper removal, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly
AW-02D		No data	Planning/setup/inspection, erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AW-02E	50	Open 50 mR/h @ F--top of south rail (3/21/97) ?pen: 3000 mrem/hr @ F(3/17/97at bottom of pit after flush)	Erect greenhouse/pull cover blocks, decon pit & remove jumper, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AW-03A	10	Shallow dose-14 mrem/hr @ F-north side of pit at splash guard/deep dose--10 mrem/hr @ F (3/24/01)-north side of pit at splash guard/deep dose 70 mrem/hr in pit at 4 ft (3/15/01)	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly
AW-04A		WO: <.5 mR/hr @ 2.54 cm WC: <.5 mR/hr @ 2.54 cm-general area (11/29/99)	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly
AW-05A		No data	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
AW-06A	18	Shallow Dose: 204 mR/hr @ Field Deep Dose: 18 mR/hr @ Field--drained pit-pit opening (2/13/00)	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seals, reconfigure pit/install cover blocks, install LDE probe assembly
SY-02A	130	Shallow Dose: 170 mrem/hr @ C, Deep Dose: 130 mrem/hr @ C (12/7/99 1st C-Block Removed)	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks install LDE probe assembly
SY-02D		No data	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly

Table A.1 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
SY-03A		No data	Erect greenhouse/pull cover blocks, decon pit % remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seals, reconfigure pit/install cover blocks and LDE probe assembly
SY-A	40	Shallow Dose: 85 mR/hr @ field Deep Dose: 40 mR/hr @ field--north side of pit (03/29/01)	Erect greenhouse/pull cover blocks, decon pit & remove jumpers, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal, reconfigure pit/install cover blocks, install LDE probe assembly, valve position indicator conduit and wire
SY-B	100	? Pen: 1000 mrem/hr@C (11/26/961@ inside pit)	Erect greenhouse/pull cover blocks, pit decon & jumper removal, core drill cover block (1 hole), install LDE sleeve, coatings for cover blocks, pit coating, install drain seal reconfigure pit/install cover blocks install LDE probe assembly, valve position indicator conduit/wire

Table A.2. W-211 Project Radiation Dose and Scope

Pit Number	Estimated Dose at Pit Edge	Dose Data from Radiation Survey	Jobs in pit [cost estimate from E. Nordquist (Fluor Federal Services) 8/28/03]
AZ-01A	10	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO: <100 mrem/hr @ 3 in. WC: <100 mrem/hr @ 3 in. (4/22/98 1 to 9 ft down inside pit)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, and cover block
AZ-02A	50	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO:<100–6500 mrem/hr @ 3 in. WC: <100–500 mrem/hr @ 3 in. (4/22/98 1 to 9 ft down inside pit)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, and cover block
AN-01A	200	WC: 200 mrem@ F (3/4/02 highest dose rate after key block removal)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, and cover block
AN-02A	85	Deep Dose--850 mrem/hr @ lower part of pit (1/03/02)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, and cover block
AN-03A	30	WO: 48 mR/hr @ >30 cm WC: 30 mR/hr @ >30 cm-highest dose in pit; WO: <.5 mR/hr @ contact WC <.5 mR/hr @ contact-2 waste bags	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block
AN-04A	60	WO: 600 mR/hr @ >30 cm WC: 600 mR/hr @ >30 cm-5 ft down valve port (6/11/98)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block
AN-05A		No data	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block
AN-07A	10	WC: 100 mR/hr@ (12/29/00 inside valve handle opening)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block
AP-02A	20	WC: 20 mR/hr @ field-extender dose rate (04/12/01)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," mixer pump, cover block
P-02D	5	WC: 5 mR/hr @ field-extender dose rate (04/12/01)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block
AP-04A		WO: <.5 mR/hr @ 2.54 cm WC: <.5 mR/hr @ 2.54 cm-general area (11/29/99)	Build greenhouse, remove cover block and existing equipment, install jumpers, "MOV," transfer pump, cover block

Table A.3. Project W-522 Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AW-A	200	WO: 300 mR/hr @ >30 cm WC: 300 @ >30 cm - dose rate @ hole A 1 ft down WO: 2300 mR/hr @ contact WC: 2000 @ contact (6/23/98 at pit bottom)	Remove cover block, core drill pit, install new jumpers and cover block
AW-B	110	WO: 10,300 mR/hr @ contact WC: 1100 @ contact (6/23/98 at 5 ft pit bottom)	Remove cover block, core drill pit, install new jumpers and cover block
AW-01A	20	No data	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
AW-02A	35	Shallow dose, 35 mrem/hr @ F; Deep dose, 35 mrem/hr @ F (9/18/01)-open pit edge deep dose 100 mrem/hr (4/16/01 3 ft inside)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover blocks
AW-03A	10	Shallow dose, 14 mrem/hr @ F, north side of pit at splash guard; Deep dose, 10 mrem/hr @ F (3/24/01), north side of pit at splash guard; Deep dose 70 mrem/hr in pit at 4 ft (3/15/01)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
AW-04A	20	WO: <.5 mR/hr @ 2.54 cm WC: <.5 mR/hr @ 2.54 cm. General area (11/29/99) Use default for pit edge.	Remove cover block, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover blocks
AY-01A	10	WO:100 mrem/hr @ 3" WC:100 mrem/hr @ 3" (4/22/98 1 to 6 ft down inside pit)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers and in-tank instruments, mount mixer pump, and install cover block
AY-01B	20	No data in RMIS, use default.	Remove cover block, replace coating on pump pit walls, install new jumpers, mount mixer pump, and install cover block
AY-01C	20	No data in RMIS use default.	Remove cover block, replace coating on pump pit walls, install new jumpers, mount mixer pump, and install cover block
AY-01D	20	No data in RMIS. Use default.	Remove cover block, replace coating on pump pit walls, install new jumpers, mount mixer pump, install cover block

Table A.3 (contd)

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
AY-02A	10	WO: <.5 mrem/hr @ 1 in. WC: <.5 mrem/hr @ 1 in. (4/22/98 open hole in cover block) WO: 100 mrem/hr @ 3 in. WC:100 mrem/hr @ 3 in. (4/22/98 1 to 8 ft down in pit)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
SY-01A	7	WO: 7 mrem/hr @ C WC: 7 mrem/hr @ C (3/29/01 dose with pit open)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
SY-02A	130	Shallow dose: 150 mrem/hr @ C, deep dose: 130 mrem/hr @ C (12/7/99 1st C-block removed)	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
SY-03A	20	No data-use default	Remove cover block, core drill, replace coating on pump pit walls, install new jumpers, in-tank instruments, and cover block
AP-A	New	New	Install new cast-in-place pit, new jumpers and valve manifold, and new cover block
AP	300	Shallow dose: 3000 mrem/hr @ F, deep dose: 3000 mrem/hr @ F (5/6/98 5 ft down pit)	Remove cover block, install new jumpers, valve manifold, and cover block
SY-A	40	Shallow Dose: 85 mR/hr @ Field Deep Dose: 40 mR/hr @ Field--North side of pit (03/29/01)	Remove cover block, remove existing equipment, replace protective coating, install new jumpers and new cover block
SY-B	100	? Pen: 1000 mrem/hr@C (11/26/961@ inside pit)	Remove cover block and existing equipment, replace protective coating, install new jumpers and new cover block

Table A.4. C-106 Retrieval Project Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
C-06A	2000	WO: 240 mrem/hr WC:80 mrem/hr (10-4-98 shield plug removed) 2 R/hr at pit edge (7/2002 John Wright) gamma pen: 2500 mrem/hr @2.54 cm (7/26/94 at pit edge)	Remove/package cover block, build greenhouse, build shield wall, remove cover block, remove & package jumpers, clean out pit, remove equipment in pit, pit coating, install new in-pit jumpers and support, install LDK, remove & dispose of existing pump, install flex receiver, MRS equipment, camera/camera riser
C-06B	230	Shallow dose: 6740 mrem/hr @ F Deep Dose: 230 mrem/hr @F (8/7/98 top of pit over shield wall) ?pen: 1300 mrem/hr @ F (10/16/95 at pit ledge)	Remove/package cover block, build greenhouse, build shield wall, remove existing jumpers, clean out/prep pit, remove equipment in pit, pit coating, install new in-pit support, jumpers, LDK, remove existing heel jet, install flex receiver, MRS equipment, camera/camera riser
C-06C	150	Shallow dose: 2700 mrem/hr @ F Deep dose: 150 mrem/hr @F (2/1/99 north side over shield wall)	Build greenhouse, install camera and level detector, build greenhouse, excavate on riser, attach riser extension, install level detector
C-06D	New	New	Install concrete pad, prefab pit, MRS pump equipment, rigid jumper, LDK, and steel pit cover plate
AY-02A	10	WO: <.5 mrem/hr @ 1" WC: <.5 mrem/hr @ 1" (4/22/98 open hole in cover block) WO:100 mrem/hr @ 3" WC:100 mrem/hr @ 3" (4/22/98 1 to 8 ft down inside pit)	Build greenhouse and shield wall, remove cover block, existing slurry distributor, and flex receiver, clean out pit, install slurry distributor, new jumpers, and steel pit cover plate
AY-02E	5	WO: <.5 mrem/hr @ 1 in. WC: <.5 mrem/hr @ 1 in. (2/25/99 opened pit), 32 mrem/hr @ C (10-2-95 pit floor)	Build greenhouse, build shield wall, remove cover block, clean out pit, pit coating, install transfer pump, jumper, LDK, and steel pit cover plate
AY-02G	New	New	Install concrete pad, new transfer pit, LDK, jumper, and cover

Table A.5. C-104 Retrieval Project Radiation Dose and Scope Data

Pit Number	Dose at Pit Edge	Dose Data from Survey	Jobs in Pit
C-04A	2000	30 R/hr at pit bottom (Dan Niebuhr 7/17/02)	Remove/package cover block, build greenhouse and shield wall, remove cover block, remove & package jumpers, clean out pit, remove equipment in pit, pit coating, install new in-pit jumpers and support, install LDK, remove & dispose existing pump, install flex receiver, MRS equipment, and camera/camera riser
C-04B	35	35 mrem/hr (12/15/01 at rail)	Remove/package cover block, build greenhouse and shield wall, remove existing jumpers, clean out/prep pit, remove equipment in pit, pit coating, install new in-pit support, jumpers, LDK, flex receiver, remove existing heel jet, MRS equipment, and camera/camera riser
C-04C			Build greenhouse, install camera and level detector, excavation on riser, attach riser extension, install level detector
C-04D		New	Install concrete pad, prefab pit, MRS pump equipment, rigid jumper, LDK, and steel pit cover plate
C-06A	2000	WO: 240 mrem/hr WC:80 mrem/hr (10-4-98 shield plug removed) 2 R/hr at pit edge (7/2002 John Wright)	Build greenhouse and shield wall, remove & store cover blocks, remove existing booster pump, clean out pit, remove equipment in pit, pit coating, install new jumpers, LDK, and steel cover plate
C-06C	150	Shallow dose: 2700 mrem/hr @ field; deep dose: 150 mrem/hr @ field (2/1/99 north side over shield wall)	Build greenhouse and shield wall, remove & store cover blocks, remove existing booster pump, clean out pit, pit coating, install new jumpers, LDK, and steel cover plate
AY-01A	10	WO: <.5 mrem/hr @ 1 in. WC: <.5 mrem/hr @ 1 in. (4/22/98 open hole in cover block) WO: 100 mrem/hr @ 3 in. WC: 100 mrem/hr @ 3 in. (4/22/98 1 to 6 ft down in pit)	Build greenhouse and shield wall, remove cover block and existing slurry distributor, remove flex receiver, clean out pit, install slurry distributor, new jumpers, and steel pit cover plate
AY-01E	No data	No data	Build greenhouse and shield wall, remove cover block, clean out pit, pit coating, install transfer pump, jumper, LDK, and steel pit cover plate
AY-01G	New	New	Install concrete pad, new transfer pit, LDK, jumper, and cover plate

Table A.6. S-102 Retrieval Project Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Dose Data from Survey	Jobs in Pit
S-02A	140	Deep dose: 250 mrem/hr (10/30/98 3 ft into pit), 90 mrem/hr (10/30/98 work area), 140 mR/hr (5/9/00 over pit)	Remove cover plate, install new cover plate, remove cover plate, install new rigid jumpers, install cover plate
S-02B	30	Deep dose: 90 mrem/hr (5/14/97 on top of cover block), WC: 300 mrem/hr (3/10/99 open pit), deep dose: 300 mrem/hr @ 2 in. (5/16/97 floor of pit)	Remove cover plate, remove/dispose jumper & pump, remove/dispose pump legs & dip tubes on riser 13, remove/dispose saltwell screen on riser 13, remove/dispose adapter plate, install new cover plate, remove cover plate, install charge vessel, cover plate, jet pump skid& connect, valve manifold, valve actuators on cover plate, install LDK, OGTs from 02B
SY-A	40	Shallow dose: 85 mR/hr @ field Deep dose: 40 mR/hr @ field--north side of pit (03/29/01)	Remove cover plates, install OGT, install new flex jumpers, install cover plate
North Condenser Pit		No data	Replace cover
South Condenser Pit		No data	Replace cover

Table A.7. S-106 Retrieval Project Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Dose Data from Survey	Jobs in Pit
S-06A	90	Deep dose: 90 mR/hr @ F-open pit (11/12/98)	Remove cover plate, install new rigid jumpers and cover plate
S-06B	200	Deep Dose: 200 mR/hr @ F-Open Pit (11/12/98)	Remove cover plate, remove/dispose jumper & pump, remove/dispose pump legs & dip tubes, remove/dispose saltwell screen, remove/dispose adapter plate, install OGT, LDK, and new cover plate
SY-A	40	Shallow dose: 85 mR/hr @ field deep dose: 40 mR/hr @ field-north side of pit (03/29/01)	Remove cover plates, install OGT, new flex jumpers, and cover plate
North Condenser Pit		No data	Replace cover
South Condenser Pit		No data	Replace cover

Table A.8. S-112 Retrieval Project Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Radiation Dose	Jobs in Pit
S-112A	90	Deep dose: 450 mrem/hr (2/26/00 3" from pit cover)	Remove cover plate , install new rigid jumpers and cover plate
S-112		No data	Remove cover plate, remove/dispose jumper & pump, remove/dispose pump legs & dip tubes, saltwell screen, adapter plate, install OGT, LDK, new cover plate
SY-A	40	Shallow dose: 85 mR/hr @ field deep dose: 40 mR/hr @ field-north side of pit (03/29/01)	Remove cover plates, install OGT, new flex jumpers, and cover plate
North Condenser Pit		No data	Replace cover
South Condenser Pit		No data	Replace cover

Table A.9. S-105 Retrieval Project Radiation Dose and Scope

Pit Number	Dose at Pit Edge	Dose Data from Survey	Jobs in Pit
S-05A		No data	Remove cover plate, install new rigid jumpers and cover plate
S-05B		No data	Remove cover plate, remove/dispose jumper & pump, pump legs & dip tubes, saltwell screen, adapter plate, install OGT, LDK, and new cover plate
SY-A	40	Shallow dose: 85 mR/hr @ field deep dose: 40 mR/hr @ field-north side of pit (03/29/01)	Remove cover plates, install OGT, new flex jumpers, and cover plate
North Condenser Pit		No data	Replace cover
South Condenser Pit		No data	Replace cover

Table A.10. C-107 Retrieval Project Radiation Dose and Schedule

Pit Number	Dose at Pit Edge	Dose Data from Survey	Jobs in Pit
C-07A		No data	Remove/package cover block, build greenhouse, build shield wall, remove cover block, remove & package jumpers, clean out pit, remove equipment in pit, pit coating, install new in-pit jumpers and support, install LDK, remove & dispose existing pump, install flex receiver, MRS equipment, and camera/camera riser
C-07B		No data	Remove/package cover block, build greenhouse, build shield wall, remove existing jumpers, clean out/prep pit, remove equipment in pit, pit coating, install new in-pit support, jumpers, LDK, remove existing heel jet, install flex receiver, MRS equipment, and camera/camera riser
C-07C		No data	Build greenhouse, install camera, install level detector, build greenhouse, excavation on riser, attach riser extension, install level detector
C-07D	New	New	Install concrete pad, prefab pit, MRS pump equipment, rigid jumper, LDK, steel pit cover plate
AY-01A		No data	Build greenhouse, build shield wall, remove cover block, remove existing slurry distributor, remove flex receiver, clean out pit, install slurry distributor, new jumpers, and steel pit cover plate
AY-01E		No data	Build greenhouse, build shield wall, remove cover block, clean out pit, pit coating, install transfer pump, jumper, install LDK, and steel pit cover plate
AY-01G		New	Install concrete pad, new transfer pit, LDK, jumper, and cover

Appendix B

Estimated Dose Rates at Pit Edge and Returns for Selected Projects

Appendix B

Estimated Dose Rates at Pit Edge and Returns for Selected Projects

Table B.1. Estimated Dose Rates at Pit Edge and Returns for Selected Projects (\$)

#	Pit ID	Project	Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)	Returns (\$)
1	C-06B	SST	11-Sep-02	230	21,141
2	AY-02G	SST	1-Oct-02	-	2,588
3	AZ-01A	211	1-Oct-02	10	28,865
4	AY-02E	SST	7-Oct-02	-	50,574
5	AY-02A	SST	7-Oct-02	10	58,272
6	S-112B	SST	1-Nov-02	20	23,374
7	SY-A	SST	1-Nov-02	--	--
8	S-112A	SST	1-Nov-02	--	--
9	C-06A	SST	8-Nov-02	2,000	158,146
10	AN-01A	211	2-Dec-02	200	155,404
11	C-06C	SST	8-Dec-02	150	31,772
12	SY-02A	314	20-Dec-02	130	195,730
13	C-06D	SST	8-Jan-03	--	14,198
14	SY-02D	314	23-Jan-03	20	199,892
15	AW-02A	314	18-Feb-03	35	198,369
16	AW-02D	314	20-Mar-03	20	117,569
17	SY-03A	314	7-Apr-03	20	127,626
18	AW-02E	314	18-Apr-03	50	126,123
19	SY-A	314	6-May-03	40	126,818
20	AW-03A	314	19-May-03	10	123,016
21	SY-B	314	4-Jun-03	100	135,994
22	AW-04A	314	18-Jun-03	20	139,422
23	AW-05A	314	18-Jul-03	20	226,084
24	AW-06A	314	18-Aug-03	18	227,066
25	AP-02A	314	9-Sep-03	20	146,362
26	AP-03A	314	14-Oct-03	20	146,878
27	C-04D	523	16-Oct-03	--	968
28	AY-01G	523	13-Nov-03	--	11,228
29	AY-101	523	13-Nov-03	20	9,004
30	AP-03D	314	18-Nov-03	20	147,419
31	C-04B	523	17-Dec-03	35	243,651
32	AP-04A	314	29-Dec-03	20	240,480

Table B.1 (contd)

#	Pit ID	Project	Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)	Returns
33	AY-01A	523	16-Jan-04	10	196,469
34	AP-05A	314	28-Jan-04	20	241,021
35	AP-06A	314	27-Feb-04	20	241,021
36	AW-01A	314	27-Feb-04	20	246,904
37	AP-07A	314	26-Mar-04	20	160,758
38	AP-08A	314	23-Apr-04	20	160,758
39	S-02B	SST	26-May-04	30	41,468
40	AY-01E	523	7-Jun-04	20	159,460
41	S-02A	SST	16-Jul-04	--	--
42	C-04A	523	1-Sep-04	3,000	286,430
43	AZ-02A	211	1-Dec-04	50	217,933
44	C-06A	523	7-Feb-05	2,000	287,933
45	SY-A	SST	7-Jun-05	--	--
46	C-06C	523	12-Jul-05	150	268,435
47	C-04C	523	7-Sep-05	100	36,528
48	AP-01A	314	14-Sep-05	20	168,239
49	C-07D	SST	6-Oct-06	--	12,848
50	AY-01G	SST	6-Nov-06	--	12,848
51	AN-04A	211	1-Dec-06	60	218,099
52	C-07B	SST	17-Dec-06	100	267,028
53	AY-01A	SST	1-Jan-07	20	232,320
54	AN-02A	211	1-Jun-07	85	150,906
55	AY-01E	SST	7-Jun-07	--	153,294
56	AY-02A	521	30-Aug-07	10	214,113
57	C-07A	SST	7-Sep-07	100	186,260
58	S-05A	SST	31-Jan-08	--	--
59	S-05B	SST	31-Jan-08	20	55,465
60	SY-A	SST	31-Jan-08	--	--
61	SY-A	SST	31-Jan-08	--	--
62	S-06A	SST	31-Jan-08	--	--
63	S-06B	SST	31-Jan-08	200	60,612
64	AP-02D	211	2-Jun-08	5	140,530
65	AP-02A	211	2-Jun-08	20	149,820
66	AP-04A	211	2-Jun-08	20	155,703
67	C-07C	SST	6-Sep-08	100	31,882
68	AY-01A	521	12-Oct-08	10	146,495
69	AY-01B	521	13-Oct-08	20	155,703
70	AY-01C	521	14-Oct-08	20	155,703
71	AY-01D	521	15-Oct-08	20	155,703

Table B.1 (contd)

#	Pit ID	Project	Start Date	Estimated Dose Rate at Pit Edge (mrem/hr)	Returns
72	SY-03A	521	1-Sep-09	20	164,703
73	SY-02A	521	1-Oct-09	130	166,557
74	AN-07A	211	1-Dec-09	10	219,995
75	SY-01A	521	2-Apr-10	7	146,444
76	AW-B	521	9-Apr-10	--	--
77	AW-A	521	9-May-10	--	--
78	AW-03A	521	30-Jul-10	10	225,876
79	AW-02A	521	30-Jul-10	-35	235,341
80	AN-05A	211	1-Sep-10	20	161,586

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