U.S. Department of Energy

Office of Health, Safety and Security

Office of Corporate Safety Programs

Type A Accident Investigation Report

THE JULY 27, 2007
TANK 241-S-102 WASTE SPILL
AT
THE HANFORD TANK FARMS

Volume 1

September 2007

Disclaimer

This report is an independent product of the Type A Accident Investigation Board appointed by Glenn Podonsky, Chief Health, Safety and Security Officer, Office of Health, Safety, and Security (HS-1)

The Board was appointed to perform a Type A Investigation of this accident and to prepare an investigation report in accordance with DOE 225.1A, *Accident Investigations*.

The discussion of facts, as determined by the Board, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This report neither determines nor implies any legal liability.

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Appointing Official's Statement of Report Acceptance

On August 15, 2007, I established a Type A Accident Investigation Board to investigate the July 27, 2007, Tank 241-S-102 waste spill at the Hanford Tank Farms. The Board's responsibilities have been completed with respect to the investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order, 225.1A, *Accident Investigations.*

I accept the findings of the Board and authorize the release of this report for general distribution.

9/18/07

Date

Glenn S. Podonsky
Chief Health, Safety and Security Officer
Office of Health, Safety and Security

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ACRONYMS

AMH	AdvanceMed Hanford
CH2M HILL	CH2M HILL Hanford Group, Inc.
DOE	United States Department of Energy
DSA	Documented Safety Analysis
EALs	Emergency Action Levels
EM	Emergency Management
ENG	Engineering Design
EPHA	emergency planning hazards assessment
HE	Industrial Hygiene
JON	Judgment of Needs
MBAA	Material Balance Discrepancy Data
MS	Management System
ORP	Department of Energy's Office of River Protection
PISA	Potentially Inadequate Safety Analysis
RPP	River Protection Project
SST	single shell tank
TSR	Technical Safety Requirements
USQ	Unreviewed Safety Question
WC	Work Control
WHA	Work Site Hazards Analysis

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Prologue and Executive Summary

On July 27, 2007, the Hanford Tank Farms experienced a spill of about 85 gallons of highly radioactive mixed waste from the S-102 Tank, located in the 200 West Area of the Hanford Site. The cause of the accident was an overpressure of a hose in a dilution line. Although required, the pump system did not have a mechanism (e.g., a backflow devise) to prevent a backflow and subsequent overpressure of the hose and the dilution line was not designed to handle the pressure that could be generated by the installed pump.

The Documented Safety Analysis for Tank Farms provides technical safety requirements that, if properly implemented, would preclude an overpressure situation in the dilution line. However, the engineering reviews and testing conducted to support installation of this pumping system were flawed. The accident was initially misdiagnosed and the response to the accident was deficient in a number of other areas. The accident also revealed weaknesses in work control, industrial hygiene, radiological protection, medical response, and emergency management.

The Accident Investigation Board evaluated the potential radiation and chemical vapor exposure hazard to workers at S Tank Farm. Radiation exposures were monitored and were well below any regulatory or corporate administrative control limit, and radiological surveys confirmed no spread of contamination outside the tank farm boundary. A "worst case" analysis of the spill and subsequent dispersion modeling performed by the site contractor shows that higher concentrations of toxic materials would only be experienced by individuals who were within 30 meters of the spill location and that the time period of exposure would have been short (minutes). Two individuals came within about 3 meters of the spill in the time frame when exposure to elevated concentrations may have been possible. Based on the dispersion model developed by CH2M HILL Hanford Group (CH2M HILL), the exposures to these individuals were probably low; the Accident Investigation Board's review of the model indicates that there are uncertainties in the model but that the conclusion of low exposures is supported. The symptoms and complaints reported by several individuals in the hours and days after the event were diverse and may be attributed to other causes (e.g., herbicide spraying that occurred five hours after the spill or from workers being sheltered in place in an area with limited ventilation and temperature control for several hours during the response to the event).

Because of the low concentrations and short duration of the exposure, it is not likely that the spill event caused an overexposure or chronic health impacts. However, the S-102 event could have been more severe if individuals had been in the immediate vicinity of the spill at the time of the release, where they could have been exposed to higher radiation levels and concentrations of chemical vapors for a short time. In fact, some individuals who had been working on restarting the pump had been in the immediate vicinity of the spill location only 10 minutes before the spill occurred.

Of particular concern is the failure of tank farm management to properly consider the potential for chemical vapor exposure in the initial response to the accident or in the initial medical actions. The potential chemical vapor exposures were not adequately addressed until site management received reports of symptoms among workers following the accident. Another significant concern is the design deficiency that was a cause of the spill resulted from inadequate design reviews, engineering quality assurance, and corrective action management. These concerns indicate that safety oversight was insufficient to ensure that nuclear safety and other safety requirements are met.

To ensure safe operations and prevent similar events in the future, CH2M HILL needs to

analyze the operability of the pump, perform extent of condition reviews, and improve several aspects of safety programs, including abnormal operating procedures, work control, radiation protection programs, and engineering design reviews. CH2M HILL and other site contractors (i.e., Fluor Hanford, which manages several Hanford facilities and provides the fire department and some emergency response services for the Hanford Site, and AdvancedMed Hanford, which is the Hanford Site medical provider) also need to coordinate their efforts to enhance some aspects of emergency response and medical interfaces. Significant improvements are also needed in CH2M HILL feedback and improvement programs and Department of Energy oversight of contractor operations, emergency response, and environment, safety, and health programs. The Judgments of Need that were identified by the Accident Investigation Board and that warrant priority management attention and timely action are listed in Table ES-1.

TABLE ES-1 - Judgments of Need

ENG-1: CH2M HILL needs to improve incorporation of the design features, testing, and operating limits/specifications into operating procedures associated with the S-102 tank and the Seepex pump to ensure its ability to move S-102 waste without becoming fouled.
ENG-2: CH2M HILL needs to revise its design review processes, procedures and implementation to ensure approved designs are technically correct and satisfy the requirements of the Documented Safety Analysis.
ENG-3: CH2M HILL needs to perform an engineering analysis of whether the S-102 pump can continue to be safely operated following the deformation that occurred when excessive shaft torquing was applied during maintenance.
ENG-4: The safety basis needs to be changed by CH2M HILL/ORP to require that new primary pressure boundaries for S-102 be classified as Safety Significant. Existing S-102 installed systems, structures, and components need not be upgraded from their current classification, but should be treated nonetheless, to the maximum extent practical, as if they were Safety Significant.
EM-1: CH2M HILL needs to analyze events of higher probability but lower consequence in the tank farms emergency planning hazards assessment, covering the full range of possible initiators and severity levels as required by DOE Order 151.1C, *Comprehensive Emergency Management System,* and it predecessors. Analysis needs to provide adequate documentation of assumptions.
EM-2: CH2M HILL, Fluor Hanford, and AdvancedMed Hanford need to improve procedures used for responding to abnormal events at tank farm contractor facilities.
EM-3: CH2M HILL and Fluor Hanford need to correct weaknesses and inconsistencies in the implementation of take cover protective actions.
HE-1: CH2M HILL needs to integrate industrial hygiene into responding to abnormal events which may involve a chemical release. In addition, CH2M HILL needs to establish and implement industrial hygiene procedures, sampling and monitoring protocols, and training of industrial hygiene staff for responding to the range of abnormal events identified in Tank Farm Hazard Analysis Documents.
HE-2: The Hanford Fire Department, managed by Fluor Hanford, needs to improve its emergency medical technicians/paramedics performance in the areas of improved documentation of patient encounters and communications with AdvancedMed Hanford; more frequent review of records by physicians is one needed element in the efforts to enhance documentation of patient encounters.
HE-3: CH2M HILL, Fluor Hanford, and AdvancedMed Hanford need to improve medical monitoring, documentation, and accountability of individuals with health symptoms and/or complaints following an accident.
WC-1: CH2M HILL management needs to define and implement an effective method for identifying Tank Farm small quantity waste leaks.
WC-2: CH2M HILL management needs to clarify technical safety requirements with regard to radiological measurements as indicators of waste transfer leaks.
WC-3: CH2M HILL management needs to address radiological conduct of operations deficiencies that were evident during the S-102 response to abnormal operating conditions.
WC-4: CH2M HILL workers, supervisors and management need to improve the implementation of the Conduct of Operations Program as required in the Safety Basis and the Applicability Matrix of March 20, 2007 at S Tank Farms.
MS-1: ORP and CH2M HILL needs to review and evaluate the adequacy and implementation of corrective action plans for past events and enforcement actions to the S Tank Farms, and ensure that effective lessons learned processes are performed.
MS-2: CH2M HILL and ORP need to improve S-102 waste retrieval oversight to ensure that nuclear safety and other safety requirements are met.

1. INTRODUCTION

At approximately 10:00 am on Friday, July 27, 2007, the Department of Energy's (DOE) contractor for the River Protection Project reported to DOE that a mixed radioactive and chemical waste leak had occurred in Hanford Site 200 West S-Complex tank farm in the vicinity of the S-102 tank retrieval pump discharge. The spill was discovered by a work crew investigating the cause of high radiation readings noted earlier that morning following a waste transfer and subsequent maintenance activity. Subsequent analysis of the event indicates that the spill occurred at about 2:10 am and released as much as 85 gallons of mixed waste. The accident occurred during the final efforts to free a clogged S-102 tank waste retrieval pump by reverse pumping.

The potential for workers to be exposed to the effects of chemical vapors was not fully considered during and shortly after the accident and became apparent once workers began reporting potential health effects from chemical exposures over the next several days. As a result, on August 15, 2007, the Chief Health, Safety and Security Officer of the Department of Energy in consultation with the Assistant Secretary for Environmental Management established a Type A Accident Investigation Board to conduct an independent investigation of the accident. This report presents the results of that investigation.

1.1. Purpose, Scope, and Conduct.

The Board began its investigation immediately after it was established on August 15, 2007, completed the investigation on September 14, 2007, and submitted a report to the Chief Health, Safety and Security Officer on September 18, 2007. The Appointment Letter from the Chief Health, Safety and Security Officer is included in Appendix A. The Board Members and Accident Investigation Board composition are included in Appendix B.

The purposes of this investigation were to gather facts, analyze the facts and determine the causes of the accident, evaluate its potential consequences (i.e., worker exposures and health effects) and assist DOE in understanding lessons learned to improve safety and reduce the potential for similar accidents at the River Protection Project and at other tank farm locations across the DOE complex. Section 2 provides information about the accident.

The scope of the Board's investigation included an analysis of the circumstances of the accident to determine its direct and contributing causes and an evaluation of the consequences of the accident to workers. The Board also gathered facts about and analyzed the major program elements that are intended to prevent or mitigate accidents of this nature and the aspects of these programs that were not effective. The major program elements that were analyzed as they relate to the accident included: (1) engineering design, (2) industrial hygiene and medical programs (including an evaluation of potential health effects to workers), (3) work control, (4) emergency management and response, and (5) management systems (including relevant contractor feedback and DOE oversight processes). Sections 3 though 7 present the results of the Accident Investigation Board's analysis of these major program areas, respectively. The conclusions of the Accident Investigation Board are included in Section 8.

Volume 2 provides additional background information and detailed results of the Accident Investigation. Volume 2 includes additional information about the facility and the S-102 tank, a chronology of the accident, detailed supporting information for the five evaluated program areas, and the results of the causal factor analysis, barrier analysis, and change analysis.

The Board conducted its data collection activities for this investigation employing the following methodology:

- Inspected the accident scene.
- Developed facts through interviews, document reviews, and review of phone transcripts (e.g., recorded 911 calls).
- Performed an evaluation of the retrieval pump system including arranging for sampling of

the spilled material and contents of the S-102 tank (ongoing).

- Reviewed the emergency and medical response actions.
- Identified causal factors were analyzed through events and causal factors charting and analysis, barrier analysis, and change analysis. Volume 2, Appendix I provides information about these techniques and show the data developed. The results of this analysis were considered in the Accident Investigation Board's analysis of the major program elements, the conclusions, and Judgments of Needs.
- Developed Judgments of Need to address the accident's casual factors and identify corrective actions designed to prevent recurrence of this or a similar type of an accident for management consideration.

1.2. Organization and Facility Overview

The contractor activities at the River Protection Project are overseen by the Department of Energy's Office of River Protection (ORP). The project mission includes storage, retrieval, immobilization, and disposal of high-level radioactive waste presently stored in 177 underground tanks located in the 200 East and 200 West Areas of the U.S. DOE Hanford Site. The waste removal mission is performed in accordance with regulatory agreements among DOE, the State of Washington, and the U.S. Environmental Protection Agency. The contractor for the storage and retrieval portion of the River Protection Program is CH2M HILL Hanford, Inc. (CH2M HILL). Certain emergency management functions at the Hanford Site are provided by Fluor Hanford, including the Hanford Fire Department. Also, AdvancedMed Hanford provides medical services for Hanford Site personnel. Fluor Hanford and AdvancedMed Hanford are contractors to the Richland Operations Office.

As shown on Figure 1-1, the S-Complex Tank Farm (also referred to as the 241-S Tank Farm) is located in the Hanford Site 200 West Area and contains 12 single shell tanks each with a approximately 758,000 gallon capacity, as well as associated waste transfer lines; leak detection systems; and tank ancillary equipment. The single shelled tanks contain a variety of solid and liquid wastes resulting from several decades of nuclear fuel reprocessing and radionuclide recovery processes conducted at the Hanford Site. Currently, the S Tank Farm single shelled tanks are treatment, storage, and/or disposal units operating under "interim status" regulation, under the Resource Conversation and Recovery Act, (in lieu of permit requirements), pending closure of the tank farms.

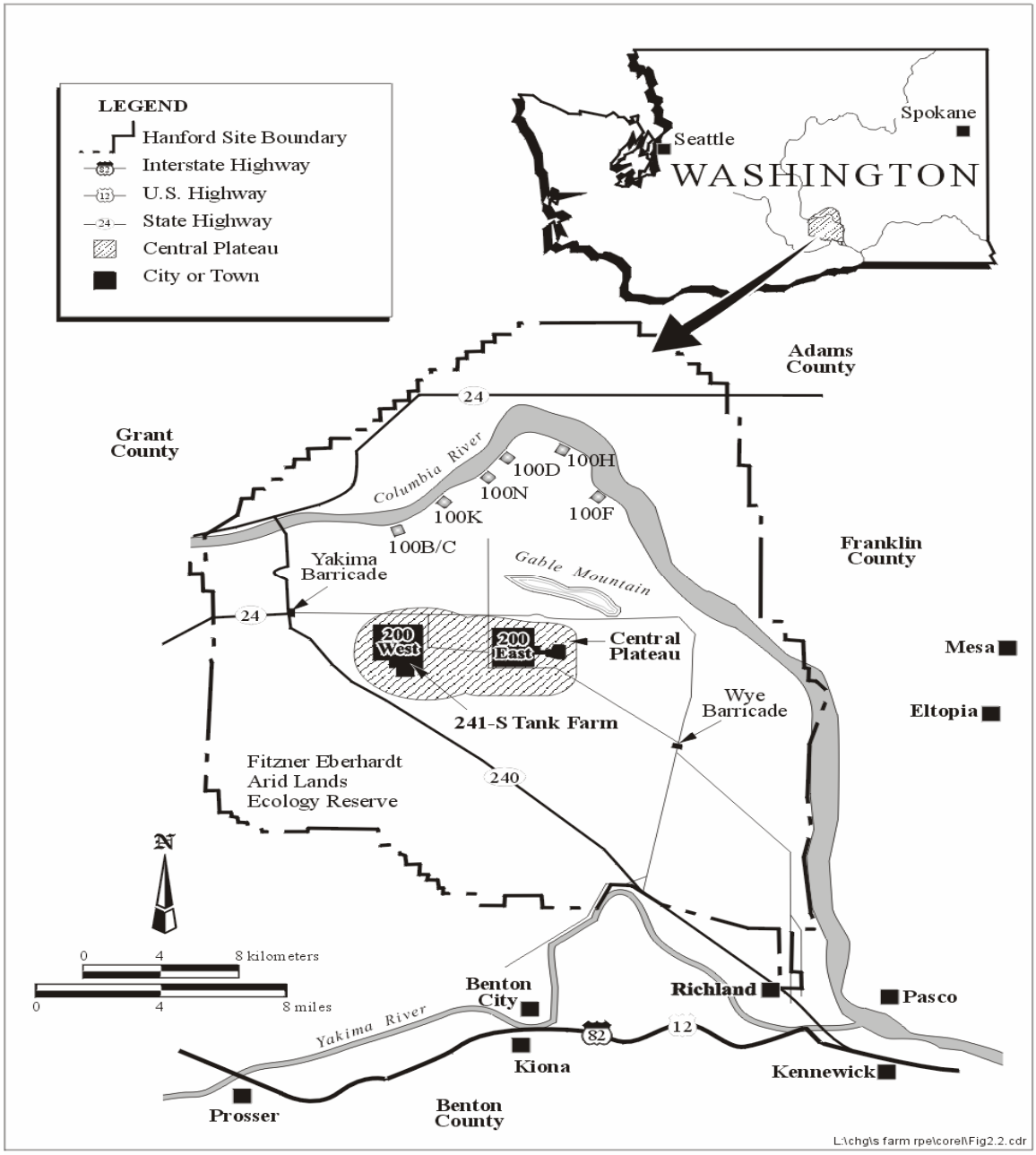


Figure 1-1 – DOE Hanford Site

Tank S-102 was constructed in 1950-51, and received high-level reduction-oxidation waste from 1953-1955. Waste transfers resumed in 1973. During the period 1973-1979, S-102 was used as the 242-S Evaporator feed tank, and received a variety of high and low level waste. S-102 was removed from service in 1980 and was partially isolated in 1982. Salt-well liquor waste was transferred from the S-102 to AW-106 during the fourth quarter of 1992 as part of the interim-stabilization process. The tank remained relatively undisturbed until interim stabilization efforts started in 2001, which involved removal of pumpable liquids from the single shelled tanks in accordance with agreements with the State of Washington.

The waste in S-102 is a phosphate-laden sludge with a dense gummy consistency, which must be mobilized and suspended in a slurry to be pumped out of the tank. The waste removal pump is mounted on top of Tank S-102 and extends into the tank through a 12" diameter riser down to near the bottom of the tank, as shown in Figure 1-2. The pump is a reversible, positive displacement, progressive cavity type pump which is driven by a reversible, variable speed, 480 VAC motor located above the tank riser extension on a platform.

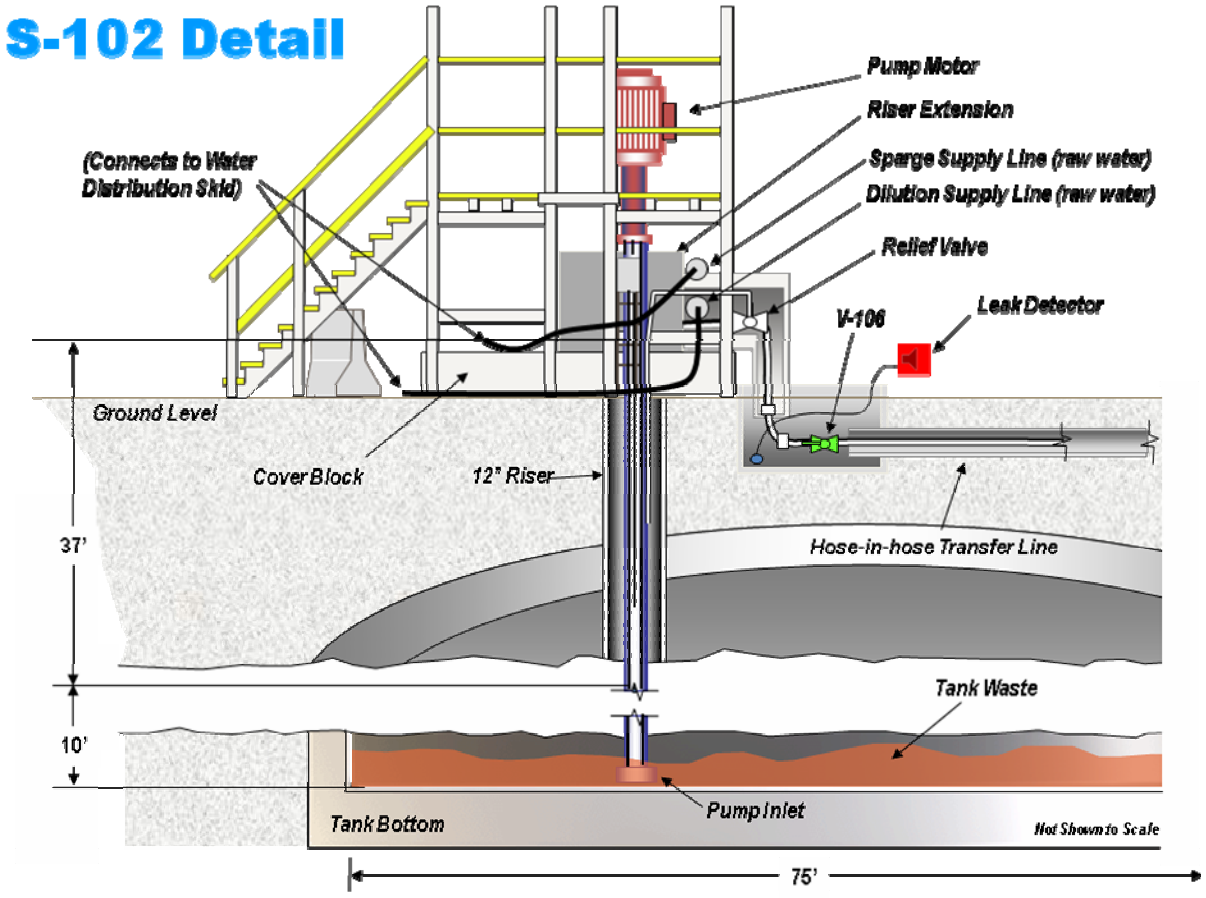


Figure 1-2. Tank and Pump Configuration

2. ACCIDENT FACTS AND ANALYSIS

2.1 Accident Facts

The spill event occurred at approximately 2:20 am, on Friday, July 27, 2007. The quantity of waste spilled is estimated to be as much as 85 gallons and covers an area of approximately 200 ft^2 at ground level, adjacent to the S-102 tank retrieval pump enclosure.

Background and Context. The retrieval and closure of Hanford's single shelled tanks are deliverables in CH2M HILL's contract. The contract milestone for S-102 is retrieval of waste by September 30, 2008. Over 90 percent of the waste has been retrieved from the tank. CH2M HILL entered into a new contract in 2006, which identified a set of milestones that OPR and CH2M HILL managers believe are realistic. Managers indicated that the milestones for the previous contract were not based on experience and most were not achieved.

Some waste in the underground storage tanks is soluble "saltcake" that is easily dissolved and pumped using standard liquid pumping technologies, such as the positive displacement progressive cavity pump used in Tank S-102. However, in many tanks, including tank S-102, there is a sludge-like waste in the bottom portion of the tank that is more difficult to retrieve. Laboratory testing of S-102 samples indicated that about 80% of the waste could be dissolved with water. Camera inspection of the waste during waste retrieval showed it resembled thick mud that appeared to harden with time.

Various techniques are used to remove the sludge-like waste in the bottom of tanks, such as the use of dilution water (water supplied to the pump inlet to aid in the retrieval process by diluting the slurry to the appropriate specific gravity conducive to waste transfer) and sparge water (water directed from the pump suction area that helps to break up the tank sludge near the pump suction).

CH2M HILL has experienced a number of technical challenges in the attempts to retrieve the remaining waste material in Tank S-102. For example, the sludge had previously stalled two pumps. After a pump failure and cessation of operations, CH2M HILL recently completed the installation of a new pump on July 17, 2007 and resumed retrieval operations on July 25, 2007. CH2M HILL had successfully pumped the waste from a different tank (S-112) using a pump design similar to that used in Tank S-102. However, although the same design flaw was present at Tank S-112, the pumping operations at the previous tank did not result in any spills primarily because the waste in Tank S-112 was more readily pumpable and reverse pump operations were not needed as often as for the sludge in Tank S-102.

The Spill Event. On the day before the accident, July 26, 2007, CH2M HILL operators experienced events in which the pump stopped or was shutdown because of various factors (e.g., high discharge pressures, high electrical current indications). The pump was restarted and run in reverse to clear the pump of clogs. After another shutdown, at about 11:30 pm on July 26, 2007, the operators again tried to operate the pump in reverse but were not successful and the operating engineer called out a work crew to try manual rotation in reverse followed by electrical "bumping." After a few more attempts, the work crew was successful in restarting the pump. The crew remained to observe pump operations while the operator remotely ran the pump in reverse for two cycles and left the area at about 2:00 am on July 27.

About ten minutes later, with no one in area of the S-102 tank, a remote operator (in the control trailer) successfully ran the transfer pump in reverse for about a minute and forty seconds. The pump suction or foot of the pump was clogged with waste and a portion of the waste was forced to flow into the dilution line, pressurizing this line. At about 2:10 am, a hose connected to the dilution line failed because of an overpressure situation. As much as 85 gallons of highly radioactive mixed waste were released to the ground near the pump platform at the top of tank S-102.

A high radiation (about 200 mrem per hour) abnormal condition was discovered shortly (about 10 minutes) after the event when a Health Physics Technician and Nuclear Chemical Operator returned to the tank farm to perform a transfer line survey and shutdown valve lineup. The initial readings were taken with the detector set to detect gamma radiation (i.e., window closed mode).

Immediate Post Event Actions. Over the next half hour, the Health Physics Technician performed additional measurements with another instrument that confirmed the elevated radiation levels but the Health Physics Technician did not get close enough to the actual spill area to detect the much higher radiation levels that would be discovered later. Supervisors were notified, the area inside the tank farm fence was evacuated, and access was controlled to prevent unintended radiation exposure to workers.

Throughout the rest of the night, there were various communications and actions by operators, Health Physics Technicians, and supervisors. These included additional radiation measurements, confirmation that the area was secure, notification of management, and calls for additional operator and radiation control support. Throughout the night, managers were informed that operators believed that the high radiation area was caused by a plug contained in the transfer line.

When the day shift arrived, radiation measurements and investigatory actions continued at the tank farm fence boundary and outside the tank farm, and personnel continued to believe that the problem was a plugged transfer line. In two cases, personnel reported that there was no evidence of a leak based on viewing the area with the tank farm cameras and binoculars.

A reentry plan was initiated around 9:45 am. Shortly thereafter, the reentry team identified much higher radiation readings around the S-102 tank (more than 5 rad per hour) and observed a dark liquid around the pump. Management was contacted and informed that a spill had occurred.

At about 7:30 am, an unrelated herbicide spreading activity was initiated in the area to the east of the Tank Farms (as close as about 100 meters to the location of the spill). The herbicide spreading continued until about 10:00 am (the site take cover alarm sounded around 10:30 am).

Subsequent Events and Investigations. In the hours and days following the spill, a number of Hanford workers identified odors, experienced symptoms or health effects, or expressed concerns about their potential exposure to the waste chemicals from the spill. As of September 1, 2007, twenty four workers from CH2M HILL, Fluor Hanford, and their subcontractors had reported to medical and indicated a possible exposure to tank vapors resulting from the July 27, 2007, spill. Some symptoms and complaints were reported within hours of the spill event, and others were reported several weeks following the spill.

As a result of the symptoms and concerns reported by workers, the Manager of the Office of River Protection requested the Chief Health, Safety and Security Officer to exercise his management prerogative under DOE Order 225.1A, *Accident Investigations*, to appoint a Type A accident investigation Board. CH2M HILL effectively fulfilled its responsibilities to preserve the accident scene and related information and to support the Accident Investigation Board. CH2M HILL also initiated an investigation and has been cooperatively sharing their event facts and supporting documents with the Accident Investigation Board.

ACCIDENT ANALYSIS

Based on the accident analysis techniques (see Appendix J) and the Accident Investigation Board's evaluation, the Board identified the direct, root and contributing causes as follows.

The **direct cause** of the July 27, 2007 accident was leakage of high level waste from the retrieval pump system in S-102, due to the failure of a utility hose in the dilution line as a result of overpressure. The **root cause** was the failure to implement the Documented Safety Analysis (DSA) requirement to provide isolation (e.g., backflow prevention) of this hose from the waste transfer route, as prescribed in the technical safety requirements (TSRs).

A synopsis of the **contributing causes** are listed below and categorized according to the major program areas (i.e., engineering design, industrial hygiene/medical, work control, emergency management, and management systems). Contributing causes, as listed below, include factors that contributed to the spill event and also to the subsequent deficiencies in response to the abnormal event. The next five sections of this report discuss these five areas in more depth, including a more detailed discussion of some of the contributing causes and associated Judgments of Need (JONs).

- **Engineering Design Contributing Causes (See JONs ENG-1 to ENG-4)**
  - The design process failed to verify proper implementation of DSA and TSR required Safety Significant design features for the Retrieval pump system and the associated dilution and sparge lines.
  - The dilution and sparge lines were not classified as safety significant (specifically the portions of the lines within the pump housing to the incorrectly located back flow preventers).
  - The retrieval pump system design specifications were not fully incorporated into operating procedures.

- **Industrial Hygiene/Medical Contributing Causes (See JONs HE-1 to HE-3)**
  - Industrial hygiene monitoring/sampling was not performed in a timely manner for most aspects of the spill in a manner that would ensure worker protection.
  - Hanford Fire Department/Emergency Medical Technician procedures did not have the necessary level of detail about patient encounter documentation and patient followup instructions for employees that may have been exposed to chemical hazards.
  - Industrial Hygiene response procedures for abnormal events, such as a spill, were not adequately developed.

- **Work Control Contributing Causes (See JONs WC-1 to WC-4)**
  - Supervisors and workers did not rigorously implement event related S-Tank Farm normal and abnormal procedures before or during the spill event. For example, efforts to unclog the retrieval pump were not covered by the retrieval operating procedure and supporting maintenance efforts were outside the scope allowed by the verbal-directed work provisions.
  - Management and supervisors did not fully ensure work activities and radiation protection measures were conducted within S-Tank Farm approved procedures.
  - Work control hazard analysis and implementing controls were not fully effective during the various reentry activities during the event.
  - Many event related portions of S-Tank Farm procedures were inadequate. For example, the retrieval procedure was inadequate in defining the requirements for conducting radiological surveys and leak detection activities and with defining correct actions upon discovery of high radiation caused by a waste leak.

- **Emergency Management Contributing Causes (See JONs EM-1 to EM-3)**
  - The abnormal operating procedure for response to a high radiation area does not conservatively require that precautions be taken for a potential release until the cause of the high radiation is determined.

- The emergency planning hazard assessment is not complete and an emergency action level was not developed that would provide for the prompt recognition and predetermined protective actions for an event of this type.
- Take cover protective actions were not effectively implemented.

- **Management System Contributing Causes (See JONs MS-1 and MS-2)**
  - Management failed to apply lessons learned from previous contamination and vapor exposure incidents.
  - ORP and CH2M HILL oversight and design reviews were inadequate to identify deficiencies in the pump system design, including non-conformance with TSRs.

3. ANALYSIS OF ENGINEERING DESIGN

The Engineering subteam consisted of four engineers with experience in evaluating engineered systems and safety bases. The subteam focused on the pump, piping, and related systems to determine the cause of the spill and on related engineered safety systems and safety bases to determine elements that failed and contributed to the accident.

Background. The Tank Farms are a category 2 nuclear facility. The tanks, pumps, and related safety systems are covered by a Documented Safety Analysis (DSA) and a set of Technical Safety Requirements (TSRs). As discussed in Section 2, CH2M HILL had experienced a number of technical challenges in pumping the hardened sludge from the S-102 Tank. Various designs had been tried and some pump failures had occurred as a result of clogging of the pump and auxiliary systems. The pump that was involved in this accident was installed in mid July 2007 and was only operated for a few days before the accident. The dilution water and sparge water nozzles located on the pump suction are shown in Figure 3-1.

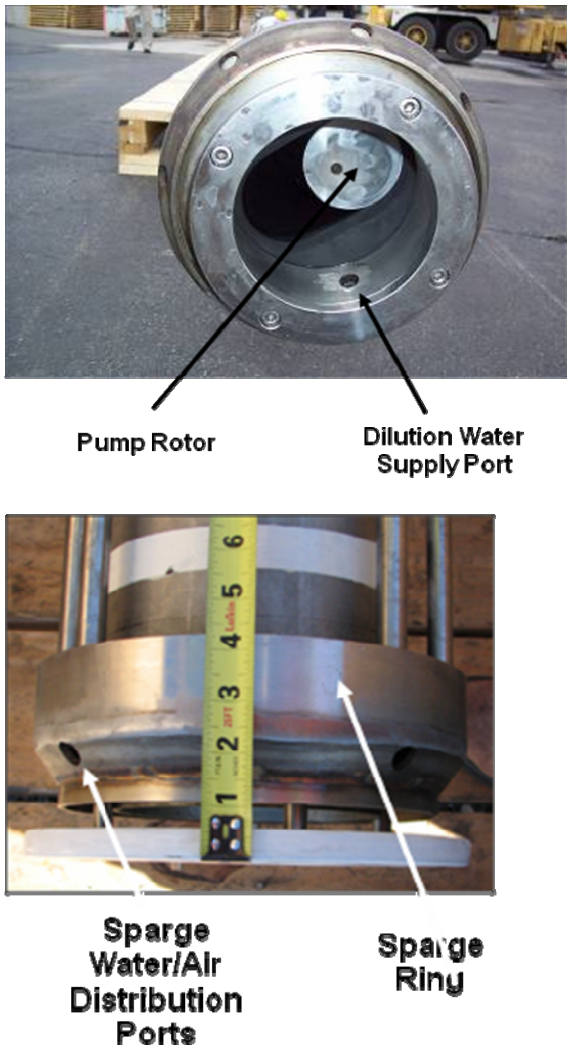


Figure 3-1. Pump Components

Engineering Design Causes. The Accident Investigation Board concluded that the direct cause of the spill was an overpressure of a hose connected to a dilution line on the retrieval pump system. The hose overpressure and spill occurred because of the absence of an isolation device, such as a backflow preventer, between the dilution water system (service water), which was a non-waste transfer system, and the waste transfer route. Such a device is required by the DSA and the TSRs. The sparging water system (also service water), also met the DSA definition of a non-waste transfer system "physically connected" to the waste transfer route, and also was not protected by such an isolation device. A few other engineering design factors contributed to the overpressure event. First, the transfer

evolution was begun in spite of the absence of sparging. The sparging feature had been added to the revised pump design to break up and diffuse the sludge before it entered the pump suction to minimize the potential that the pump would stall, which had been a problem in a previous pump design. The pump sparging capability was included in the design of the current pump but was believed to be plugged by the operators and thus not available for use at the time of this event. Second, hoses within the potentially affected pressure barriers of the non-waste transfer systems that were not backflow preventer protected should have been qualified for the pressures to which they might be subjected. **(See JON ENG-1, ENG-2, and ENG-3)**

DSA and TSRs. The Accident Investigation Board's review of the DSA and TSRs indicate that they were adequate to prevent the accident, but the TSR related to isolation of non-waste transfer systems from the waste transfer route (e.g., backflow prevention) was not properly interpreted and thus were not correctly applied and implemented. The descriptions and analyses of the scenarios presented in the DSA were adequate to describe and envelope the event. The TSR controls developed in this DSA section directly reflected these requirements. Such controls would have been adequate to have prevented the event, had they been properly applied. CH2M HILL personnel initially did not consider the TSR to have been violated, but later declared a violation of the limiting condition for operation and notified DOE accordingly. **(See JON ENG-4)**

Programmatic Factors. A few programmatic factors contributed to the accident. First, CH2M HILL did not properly follow procedures and respond when a concern about overpressurization was formally raised in the review by a CH2M HILL subcontractor (a member of the review team) and comment process for the original transfer pump design. During that review, an individual submitted a comment about overpressure of the water hose in a reverse pumping operation, which was the failure mechanism for this event. The response provided to that comment was technically inadequate and did not resolve the concern. No record was found of a subsequent disposition or acceptance of the response, but the lack of any design feature to address this concern, such as backflow preventers, as required by the DSA and TSRs, shows that it was never adequately resolved. There were procedural requirements in place that should have caused the comment to be properly resolved, but CH2M HILL did not adequately accomplish the objective. This was the primary programmatic breakdown that led to the accident. **(See JONs ENG-2 and MS-2)**

Second, ineffective technical review of products provided by CH2M HILL subcontractors was a factor. CH2M HILL has generic requirements for reviewing subcontractors and some specific instructions for reviewing subcontractor calculations and test procedures. However, the expectations were not sufficiently defined and documented to ensure adequate reviews. For the pump design, a subcontractor developed a Design Requirements Compliance Matrix to document the applicable project requirements, the design assumptions/DSA assumptions, project technical assumptions that would impact design, the necessary actions to avoid, mitigate or eliminate, the technical assumptions, and how the technical assumptions were verified. CH2M HILL did not adequately review this design document and the document did not identify a few critical design deficiencies including the potential for backflow and overpressurization of the Raw Water System during a reverse flow evolution. **(See JONs ENG-2 and MS-2)**

Third, the unreviewed safety question process was not applied with sufficient rigor to detect this inadequacy with respect to the safety bases. Each time the new transfer pumps were installed in Tank S-102, the equipment change underwent the unreviewed safety question process, as required by 10 CFR 830, which is intended to identify any aspect of the change that could be outside the current approved safety basis. Each of these unreviewed safety question evaluations that did not identify the absence of isolation devices on the attached Service Water connections, as required by the DSA and TSRs, was a missed opportunity to identify the deficient condition. **(See JONs ENG-2 and MS-2)**

4.0 ANALYSIS OF INDUSTRIAL HYGIENE AND MEDICAL PROGRAMS

The DOE Type A Accident Investigation Board sub-team consisted of two medical personnel, a toxicologist, and an industrial hygienist, and addressed the potential worker chemical exposures resulting from this accident. The sub-team interviewed workers who had identified medical symptoms and/or odors potentially associated with the spill, reviewed procedures and accident events, evaluated the consequences of the spill, and investigated the reasons for the reported symptoms and health effects. Considering the nature of the accident and the location of workers, the primary focus of the chemical exposure and health effects sub-team was to determine the degree to which vapors released during the accident could cause worker exposures and subsequent health effects. To systematically examine the potential impacts on workers, the sub-team evaluated four areas: (1) industrial hygiene practices associated with monitoring of chemical vapors from Tank S-102 and industrial hygiene response to the spill event; (2) the chemical and toxicological exposure hazards and pathways associated with the spill; (3) medical symptoms and potential acute and chronic health effects of the workers in the vicinity of the spill; and (4) the adequacy of the medical response to this accident.

Background. Vapor exposures and their potential health effects on workers have been a longstanding area of attention at the Hanford Tank Farms. As a result of worker complaints, internal and external assessments and studies, and DOE and contractor initiatives, the potential for vapor exposures and the appropriate controls has been extensively evaluated in the past few years. As part of the site's efforts, Hanford Waste Tank Industrial Hygiene Program has made improvements and developed information about the composition of the vapors in the tanks, the nature and magnitude of releases, the potential health effects on workers, and the application of controls to manage the vapor exposure risks to workers. For much of the past few years, workers in the tank farms had been required to use respirators and chemical protective clothing. As a result of extensive industrial hygiene monitoring and sampling of tank vapors in the S-Tank Farms since the commencement of waste retrieval for Tank S-102 in December 2004, and with 95% of the results being below detection limits for the instruments, and all of the results being below 50% of the Occupational Exposure Limits, the requirement for the use of chemical protective clothing and respirators had been eliminated by industrial hygiene with the exception of specific work tasks involving the breach of a waste tank confinement or entry into vapor control zones. Most of the CH2M HILL efforts have focused on controlling vapor exposures for releases during normal operations through the tank breathing vents. However, the information developed in the past few years is also useful for evaluating the potential chemical exposures that result from the July 27 accident.

Industrial Hygiene Practices. The chemical constituents of hazardous chemicals within the waste tanks (such as S-102) are well analyzed and considerable monitoring and sampling data has been performed for S-102 during the current retrieval and transfer campaign. Notwithstanding the improvements in industrial hygiene programs, the Accident Investigation team identified a few areas of concern in the CH2M HILL industrial hygiene program and the industrial hygiene aspects of the response to the accident. First, communication and implementation of established requirements was not sufficiently effective. Although the vapor monitoring plan and requirements are well documented, some of the chemical hazard controls for workers in effect at the time of the spill were inadequate. For example, the existing procedures and provisions for coordination and integration of industrial hygiene in response to abnormal conditions were insufficient to ensure that chemical vapor hazards were considered in the initial response and investigations. In addition, the CH2M HILL procedures and response actions did not include adequate provisions for timely and relevant industrial hygiene monitoring to evaluate exposures in response to abnormal conditions. Although the spill was estimated to occur at approximately 2:10 am on July 27, 2007, the first industrial hygiene monitoring conducted specifically as a

result of the spill was performed at 3:30 pm (more than 13 hours after the spill). Further, this monitoring was performed in support of the emergency response team's effort to establish respiratory protection requirements at the Tank Farm boundaries and was not focused on evaluating chemical exposures to workers or providing a basis for evaluating health effects. **(See JONs HE-1 and HE-3)**

Chemical Hazards and Exposure Pathways. There was no industrial hygiene sampling or monitoring of the chemical vapor release for more than 13 hours following the spill event. However, since the release was of short duration, and the chemical vapors dissipated quickly, it would have been difficult to effectively monitor in the best of circumstances. Therefore, CH2M HILL determined that the best way to estimate worker exposures was through source term and dispersion modeling, which was performed three days after the spill by the CH2M HILL Industrial Hygiene Group. The calculation was performed, based on two "marker" chemicals. Ammonia was selected based on the abundance of ammonia within the tank and its strong odor threshold, and NDMA (N-nitroso-dimethylamine) was selected based on relative abundance with the tank headspace and low exposure threshold since NDMA is a suspect carcinogen. The CH2M HILL model predicts dispersion of both chemicals within a very short period of time (minutes) from the release. For example, concentrations of ammonia are predicted to disperse to less than the 8-hour time-weighted hour threshold limiting value (25 ppm) at two minutes after the spill for a worker 20 feet from the spill location. The results of the CH2M HILL modeling show that only individuals that were close (e.g., within the S Area Tank Farm fence line) to the spill at the time of the spill (within minutes) would have been subjected to concentrations of chemical at the occupational exposure limit, even in the worst case scenario with conservative assumptions. Only two individuals were within the area where higher exposures were credible. Based on interviews, these individuals came as close as about three meters to the spill location about 10 minutes after the spill occurred.

Figure 4-1 (two-pages) shows the area in which the Occupational Exposure Limits for ammonia and NDMA could be reached, based on the CH2M HILL model.

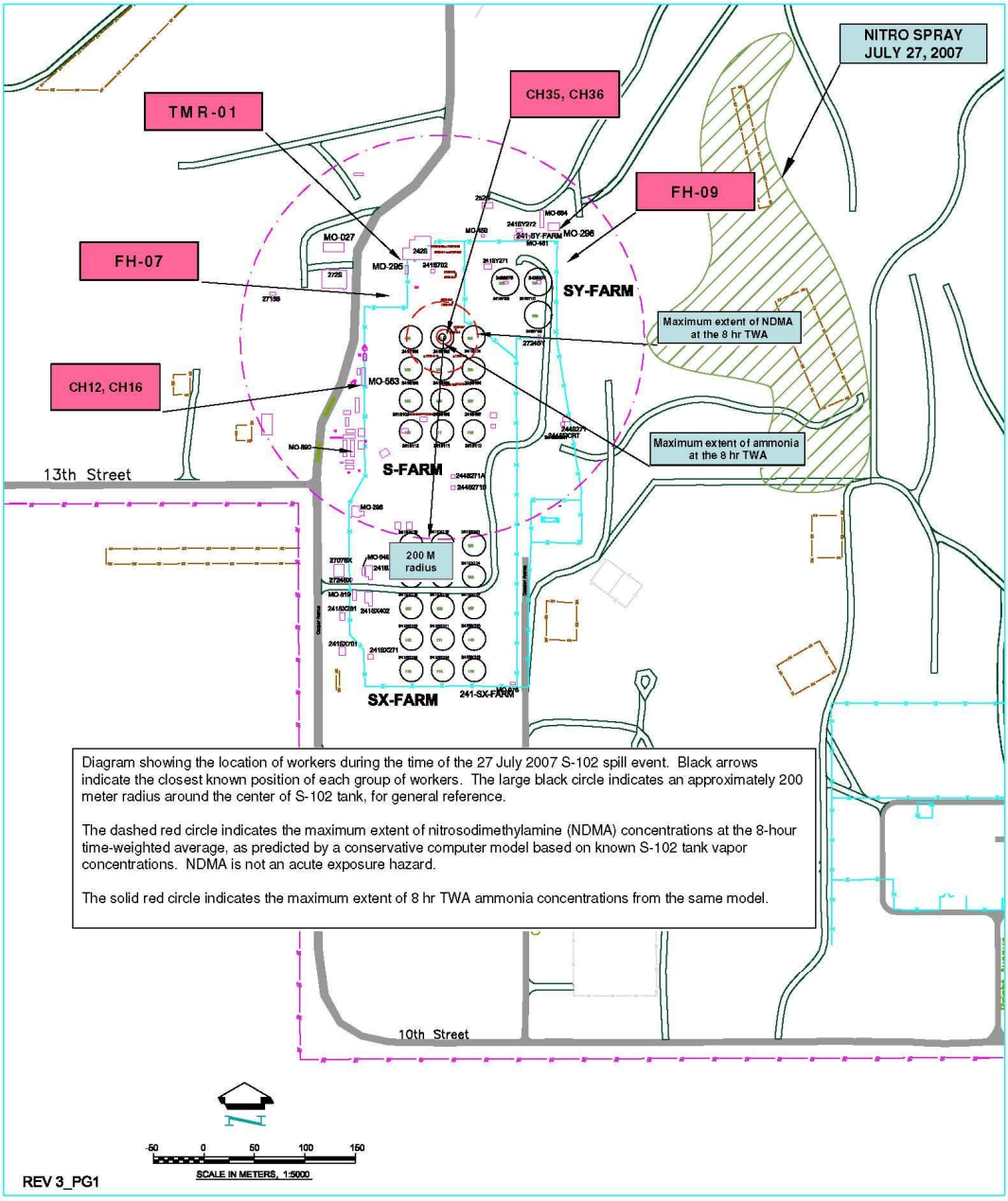
The Accident Investigation Board's review of the CH2M HILL Industrial Hygiene group model of the chemicals, source term, and dispersion indicates that the overall conclusion (that concentrations of chemicals that individuals may have encountered were low) are credible. While there are a number of assumptions inherent in the analysis, the assumptions are conservative and/or the uncertainties are reasonably well understood. For example, the assumption that the two marker chemicals are adequate to bound the credible chemical exposures is based on considerable industrial hygiene experience with the chemicals in the tanks and their toxicological effects. It is noted that the dispersion model assumes an instantaneous (which is conservative from the standpoint of the maximum concentration that could be present in the period following the spill). However, the actual spill occurred over a period of a few minutes and there could be "pooling" that resulted in dispersal over a longer period of time; if such factors were modeled, the result would be a lower maximum downwind concentration but the period of elevated concentrations could be longer. Because of these uncertainties and assumptions, it is not possible to precisely estimate the concentrations of chemicals to which the two individual were exposed. Nevertheless, the overall conclusion (i.e., individuals were exposed to low concentrations and the period of exposure was short) of the CH2M HILL model and analysis are credible and supported by the analysis.

Medical Symptoms and Health Effects. The two individuals (a Nuclear Chemical Operator and a Health Physics Technician) who entered the tank farm shortly (about 10 minutes) after the leak event and came within 8-10 feet of the leak may have been exposed to tank vapors, especially considering the pooling/ground saturation that probably occurred according to the event scenario. The levels were probably low, based on the dispersion model. One of the individuals reported noticing a strong odor and

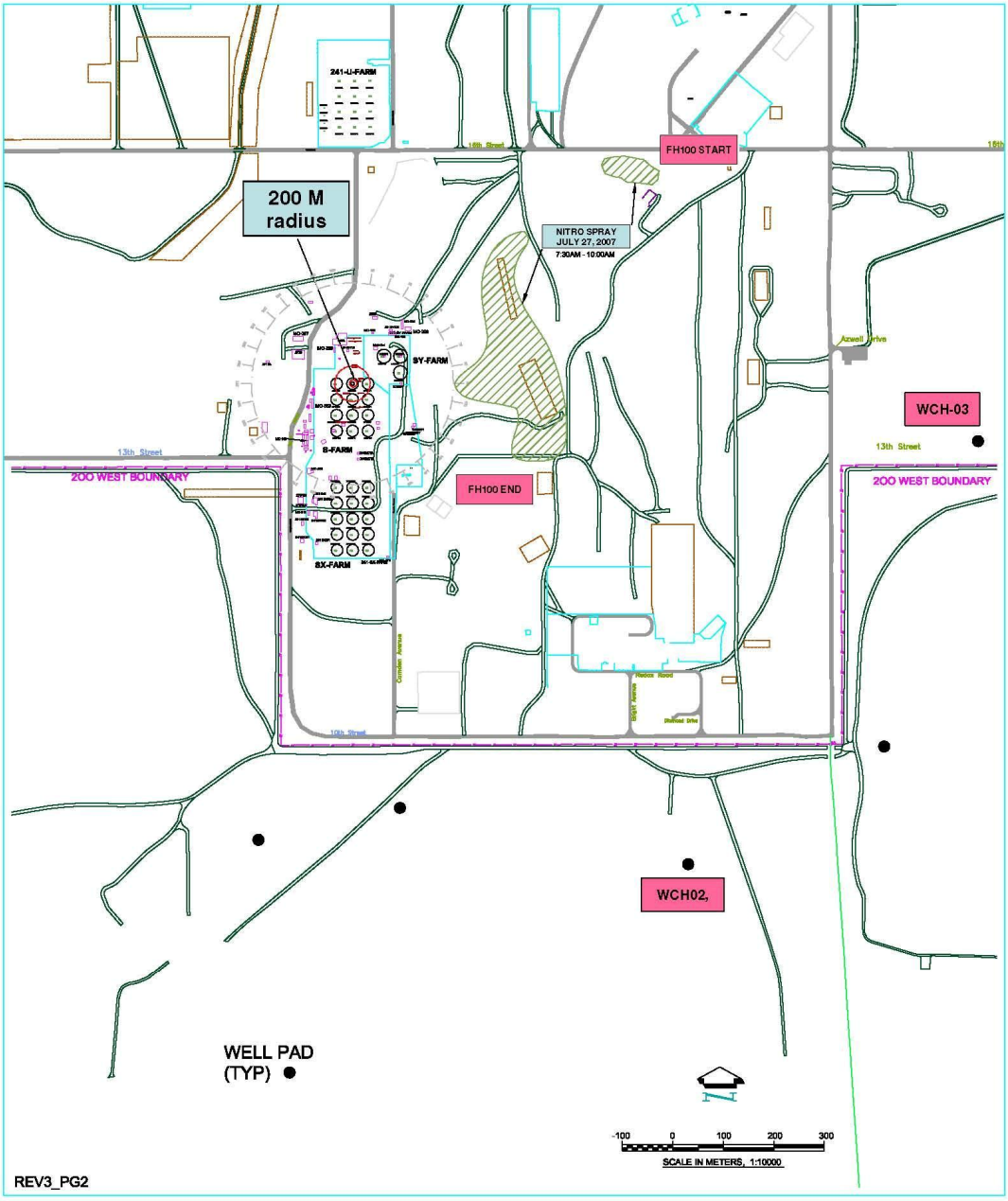
later reported some symptoms. Based on interviews, the lack of odor perception by the Health Physics technician only a few feet away may have occurred because of his focus on his radiation measurement task.

Other individuals who have reported symptoms were on the west side of the tank farm, outside the tank farm fence. The closest distance to the spill region from the fence was estimated at 40 meters. The volume of distribution and dispersion would indicate that exposure to an individual outside the S Tank Farm boundary fence would be very low as a result of this spill from the tank.

Most of the symptoms were reported several hours or more after the spill occurred, at which time concentrations would be very low. The delayed presentation of symptoms is not usual for an irritant exposure. A response unique to the individual is a possibility. A low level of exposure with minor respiratory track irritation, resultant coughing and persistence due to the exacerbation of respiratory tree irritation caused by the coughing itself, is also a possibility.



S-102 Tank Spill Exposure
July 27, 2007
Figure 4-1, Page 1 of 2



S-102 Tank Spill Exposure
July 27, 2007
Figure 4-1, Page 2 of 2

Some of the individuals who reported symptoms could have been exposed to aerosols from an herbicide spray that was occurring the morning of July 27. Figure 4-1 also shows the area where the herbicide was applied.

The sequestering and sheltering of workers following the spill in Building MO027 in a warm environment without ventilation may have exacerbated the possible exposure and some symptoms (e.g., headaches) could be the result of stress associated with a concern about possible adverse health effects from the spill. One worker had abnormal liver function tests after the spill event but was approximately ¼ mile from S-l02 and not at that location until several hours after the spill, such that it is unlikely that the spill caused health impacts to the liver (and the herbicide components do not pose a liver toxicity risk on contact exposure). Nevertheless, this individual should be monitored and all possibilities of liver toxicity need to be explored.

While significant health impacts resulting from this accident are not evident, the exposures and associated health impacts could have been more significant if circumstances were different (e.g., people in the immediate vicinity). There were individuals in the immediate vicinity of the spill only 10 minutes before the spill occurred; if the hose failure and spill had occurred when they were present, these individuals could have been contaminated (sprayed with waste) and exposed to high levels of radiation and hazardous chemicals. In addition, although a spill could not be ruled out as a cause of the high radiation levels, the initial high radiation area was not treated as also indicative of a potential toxicant release and thus CH2M HILL missed opportunities to apply the occupational medicine paradigm of prevention being more desirable than treatment. For example, delaying non-vital work activities (e.g., herbicide application) that were scheduled to be carried on during the day shift in areas outside the Tank Farm fence but near the Tank Farm could have reduced or eliminated concerns about exposures to a significant number of people. **(See JONs HE-1 and HE-3)**

Medical Emergency Response. Medical response to the mixed waste spill was generally provided in accordance with established procedures. However, the established procedures were not sufficient to fully address some aspects of a possible chemical exposure. Specific concerns were identified with the communications between the Hanford Fire Department and Advanced Medical Hanford (to ensure that possible chemical exposures are evaluated by Advanced Medical Hanford), training for emergency medical technicians with respect to chemical exposures that are not trauma related, and improved medical monitoring and accountability of individuals with health symptoms. **(See JON HE-2)**

5.0 ANALYSIS OF WORK CONTROL

The Accident Investigation Board assigned 4 personnel with expertise in work control and/or radiation protection to evaluate the CH2M HILL work control process as applied to the spill event. The evaluation considered three aspects of work: operations, maintenance, and radiation protection activities. These aspects were reviewed against the core functions of integrated safety management. The Accident Investigation Board focused on work activities that were conducted prior to and during this event, including troubleshooting of the variable frequency drive, operations and maintenance activities to free the clogged pump (manual pump rotation combined with electrical pump bumping), waste retrieval pumping operations, and radiological controls associated with retrieval operations and during the event response.

Some aspects of operations and maintenance activities were performed in accordance with procedures and in accordance with the core functions of ISM. For example, the Operations procedure adequately defined the scope of work for normal operations. However, there were numerous deficiencies in the procedures and conformance with procedures including the following examples: **(See JONs WC-1 and WC-4)**

- The governing Operations procedure did not cover important off normal activities (e.g., reverse pumping, recovering from a clogged pump), and there were some errors and ambiguities in the procedure (e.g., omitting a valve reopening step).
- The standing Minor Maintenance Instruction used to trouble shoot the stalled pump and then to clear the clogged pump contained requirements that were not consistent with the facility level procedure for Work Control.
- Procedures were not always followed, in one case requiring a pump shutdown due to an improper valve line up, and some activities (taking phase to ground readings) were performed outside task directions.
- Some logs were not properly maintained or completed in accordance with instructions.
- Some operations instructions were not incorporated into the operating procedure as required by site requirements. Some controls were established through informal (email) communications and were not always communicated to the workers.
- A required job walkdown and completion of a Worksite Hazard Analysis had not been performed/updated since 2006.
- Training requirements were not adequately defined and one Nuclear Chemical Operator involved in the event had not attended a required training session that addressed recent changes in retrieval pump design and operations.
- There was no operating or maintenance procedure that defines the scope, hazards, controls and coordination required for rotating the waste retrieval pump manually and intermittently "bumping" the pump electrically. The work was performed in accordance with a standing minor work instructions, a lockout/tagout process, and verbal direction, and a general lack of rigor was identified with the safety controls (e.g., failure to meet prerequisites for use of a defined lockout/tagout process, and the electrical plug was not always within line of sight of all involved personnel and authorized worker locks and danger tags had not always been applied to the plug).
- Recent software changes associated with Waste Transfer Pump Low Flow and Low Pressure resulted in no audible alarm when the transfer pump shutdown. This deficiency is similar to one listed in a Notice of Violation and associated civil penalty from the DOE Office of Price-Anderson Enforcement to CH2M HILL, which indicates a weakness in the CH2M HILL lessons learned/corrective action management system.
- Operations procedural controls and procedural compliance for rotating the pump manually and intermittently "bumping" the pump electrically did not adequately specify controls for the activities involving electrical and rotating machinery hazards, which required close coordination among workers. Some specified controls were not always met (e.g., failure to meet prerequisites for use of a defined lockout/tagout process, the electrical plug was not always within line of sight of all involved personnel, authorized worker locks and danger tags had not always been applied to the plug, and administrative lock requirements were not always followed).

Radiation Protection Controls include methods to be used for waste leak identification and for performing radiological work as part of abnormal events. A number of deficiencies in processes and performance were identified. The waste retrieval pumping procedure, the abnormal operating procedures, and radiation work permits did not adequately define the scope of radiological work conducted during the event. There were also weaknesses in radiological hazard analysis contributing to deficiencies in response actions. For example, the retrieval pumping procedure lacked a documented technical basis associated with the radiological criteria of 75 mrem and 100 mrem used as trigger/action level. Conduct of operations deficiencies resulted in unclear and potentially inadequate controls during S-102 event response. For example, the entry into the S-Farm

High Radiation Area to conduct a survey to further investigate high radiation conditions was planned and authorized using an informal entry plan rather than the established formal procedure. This approach resulted in incomplete hazard analysis, lack of required work reviews, and potentially deficient controls. For example, the radiation work permit referenced by the entry plan failed to define the specific personal protective equipment requirements for the entry. **(See JONs WC-2 and WC-3)**

As discussed previously, inadequate recognition that a waste leak was the source of the high radiation readings delayed appropriate response actions for several hours. There were several controls in place intended to ensure proper recognition of waste transfer leaks, including radiological surveys. However, incomplete procedural guidance associated with radiological surveys, radiological criteria and necessary response actions, and weak implementation of survey protocols rendered the surveys ineffective in ensuring prompt detection of the spill. Further, the use of Abnormal Operating Procedures as stand alone procedures without regard to other required tank farm procedures and protocols resulted in potentially unsafe working conditions, a delay in recognizing the leak, missed opportunities to engage appropriate safety disciplines in the response, and inadequate or unclear personal protective equipment specification during response actions. For example, existing protocols require the use of silver shield gloves when the potential for encountering tank waste exists. This control was not specified or used for S-102 entries to perform application of fixative and removable contamination measurements where contact with waste material was possible. **(See JONs WC-1. WC-2, and WC-3)**

A review of the operations and radiation survey actions identified several missed opportunities to identify a spill condition: **(See JONs WC-1 through WC-4)**

- The Health Physics Technician did not follow the operating instructions for performing both open and closed window dose rate measurements, and open window reading might have detected the spill earlier. An open window measurement is sensitive to beta radiation, and beta radiation could be indicative of a spill (because beta radiation is attenuated by piping or other such materials, the presence of high levels of beta radiation indicates that waste is not contained in the piping). Review of tank farm radiological survey reports indicates this is a common practice and accepted by management.
- Visual observation of the waste spill was not accomplished in a timely manner because of inadequate lighting conditions (a previously identified deficiency) at the S Tank Farm and the inability to survey the entire waste spill area with a remotely controlled camera.
- Although members of the operating crew noticed the background radiation doubled for a short period of time, as well as simultaneous updating of the portal monitor (a PCM-1B) due to a change in background radiation level, they did not consider that those indications could be related to a waste spill.
- The report by an experienced Nuclear Chemical Operator that the area was “very stinky” did not prompt the supervisor or operating crew to consider that condition could be related to a waste spill.
- The supervisor and operating crew inappropriately used Material Balance Discrepancy Data to conclude a waste spill had not occurred. Material Balance Discrepancy Data is intended to detect large volume waste leaks (several hundred gallons) rather than the relatively small volume involved in this waste spill.

The supervisor, operating crew, and responders incorrectly believed that an aboveground and unmonitored (not detected by the Transfer Leak Detection System) waste leak was not credible and therefore did not aggressively investigate the possibility of a leak when investigating the high radiation level condition.

6.0 ANALYSIS OF EMERGENCY MANAGEMENT

The emergency management subteam consisted of two professional emergency management evaluators and focused on the application of the Fluor Hanford and CH2M HILL emergency management program element to the spill accident.

Several aspects of the response to the spill event were generally effective. These include incident command, event categorization, notification and communication, and radiological consequence assessment.

The Hanford Site has detailed emergency response and event response plans and procedures that are applicable to the event. Although many aspects were adequate, CH2M HILL did not correctly diagnose the nature of the event as a spill until about 8 hours after the event. During this time, opportunities to take additional actions to protect against radiological and chemical exposure hazards were missed. While some investigatory actions were taken and some information was received by managers (e.g., reports of no visual indication of a spill from individuals viewing with binoculars or cameras), tank farm personnel had some indications of a spill (e.g., short period of higher background radiation and strong odors) and did not have a definite basis to eliminate the possibility of a spill event. Although procedures and checklists used by the Emergency Response Organization are generally comprehensive and provided for an integrated response, the abnormal operating procedure for responding to a high radiation area does not conservatively require that precautions be taken for a release until the cause of the high radiation is determined. **(See JON EM-2)**

The Tank Farm emergency planning hazards assessment consequence analyses and emergency action levels have been developed utilizing the event scenarios contained in the respective Documented Safety Analysis (DSA). However, emergency planning did not adequately address events at the lower end of the consequence spectrum, as required by DOE Order 151.1C, *Comprehensive Emergency Management System,* and it predecessors. The emergency planning hazard analysis included consequence analyses only for bounding events identified in the DSA. As a result, an emergency action level was not developed that would provide for the prompt recognition and predetermined protective actions for events of lesser consequence, such as the one that occurred on July 27. In addition, some assumptions are not adequately documented and emergency action levels do not identify whether the protective action distances are based on radiological or chemical hazards. An extensive understanding of the DSA and emergency planning hazard analysis would be required to know which material presents the greatest hazard to workers and responders for each of the identified release scenarios. **(See JON EM-1)**

The incident command team, supported by an event coordination team, demonstrated an effective capability for initial and ongoing response to the event. However, some weaknesses (e.g., sheltering workers in hot, unventilated buildings for an extended time, lack of access controls for some areas, not directing individuals taking shelter in vehicles to a building, allowing responders to enter and exit areas before hazards were characterized) were noted in the implementation of take cover protective actions (sheltering) that would add unnecessary risk to workers and responders for events with more severe consequences. **(See JON EM-3)**

7.0 ANALYSIS OF MANAGEMENT SYSTEMS

The Accident Investigation Board examined selected aspects of management systems as part of the accident investigation. Specifically, the Board examined the application of lessons learned from previous events and selected aspects of CH2M HILL and DOE management systems that resulted in missed opportunities to avoid this accident.

Lessons Learned. This accident investigation has identified two repeat problems that indicate CH2M HILL's application of lessons learned and corrective action plans are not sufficiently

effective to prevent recurrence of undesired events. For one repeat problem, CH2M HILL was issued a Preliminary Notice of Violation and Proposed Civil Penalty, dated March 10, 2005, for $316,250 which identified several deficiencies that are very similar to issues currently being evaluated by the DOE Accident Investigation Board. The Preliminary Notice was later adopted as the final notice with no changes. Table 7-1 provides a comparison of the issues identified in the 2005 Notice of Violation and those identified on this Accident Investigation.

For a second repeat problem, CH2M HILL notified DOE of a Potentially Inadequate Safety Analysis (PISA) on September 27, 2005 to address an accumulation of waste material in the airline of the tank C-200 vacuum retrieval system. This PISA represented a scenario that was not bounded by the Documented Safety Analysis (DSA). The Board concluded that CH2M HILL did not review and evaluate the C-200 tank vacuum retrieval system PISA (2005) as a lessons learned or as an extent of condition for application to the waste retrieval system at S Tank Farms. **(See JON MS-1)**

CH2M HILL Management Systems. During the course of the Accident Investigation, the Board identified a number of aspects of CH2M HILL management systems for past or current management performance that were not effective or were missed opportunities to identify and correct the factors that led to this accident. These include: **(See JON MS-2)**
Management has not provided sufficient direction on the expectations for strict procedural compliance and full implementation of safety requirements at all times, including abnormal situations. As noted in section 4, a number of activities were performed with non-conservative application of safety requirements or that did not fully comply with established controls, and some of these activities were allowed by facility management and supervisors at the S Tank Farm.

Table 7-1.Comparison of Issues Identified in 2005 Notice of Violation and by the Spill Accident Investigation

2005 Notice of Violation	Issues currently being evaluated by the DOE Accident Investigation Board
Requirement that one of three backflow preventions systems be provided when non-waste transfer systems are physically connected to an active waste transfer pump.	Same condition identified now and resulted in a TSR violation.
Failure to position a valve to the correct position while performing an operations procedure.	Transfer Pump Discharge Valve left in closed position when the pump was started.
Failure to not formally report equipment reliability issues.	Variable frequency drive equipment known to be unreliable, directly resulted in inability to electrically operate the pump, specifically in the reverse direction to clear waste material from the pump.
Modifications to software associated with the low flow interlock was not adequately tested nor verified, as required. As a result automatic shutdown of the transfer pump on low flow conditions did not occur.	Recent software changes associated with low flow resulted in the transfer pump tripping on a fault with no audible or visual alarm function.
One of the operators involved in the accident had not completed the system walkdown portion of the training.	One of the operators had not completed the delta change training for S-102 operations, and the Millwright had not received training specific to the newly installed pump.

- Management did not provide sufficient direction and emphasis on CH2M HILL quality assurance and review and evaluation of designs and equipment provided by subcontractors and vendors during the time of the DSA preparation and engineering reviews of pump systems. Past CH2M HILL reviews did not identify the lack of a backflow preventor (or alternative isolation method) and did not identify some other design deficiencies, which have led to a number of PISAs. As discussed in section 3, the review of the subcontractor design specifications was not sufficiently rigorous or effective and the design reviews did not identify the significant flaw in the pump system design (i.e., lack of isolation/backflow prevention) or recognize the importance of evaluating off normal pumping situations (e.g., reverse pumping operations that pressurize the supply side). Schedule pressures and resource allocation under the previous contract may be a contributing factor to the failures in the design reviews.
- Management provided insufficient direction and independent/quality assurance reviews of procedures for dealing with abnormal situation from the work control, industrial hygiene, medical response, and emergency management perspectives. As discussed in sections 3, 4, 5, and 6, some elements of abnormal response procedures were not sufficiently effective.
- CH2M HILL management was not sufficiently proactive in promoting testing pump designs in the expected environment (e.g., with a simulant slurry/sludge). Better pump testing could have resulted in fewer problems with pumping operations and less need for the reverse pumping activities that were ongoing at the time of the accident.

The Accident Investigation Board also interviewed senior CH2M HILL managers to determine their perspectives on the accident and plans for enhancing current management systems. Managers indicated that the current contract (started October 2006) included realistic schedules and achievable milestones. Senior management also indicated their intention to require testing of all new retrieval technologies using a simulant in the ORP Cold Test Facility. Senior management indicated, based on lessons learned from this accident, that engineering and feedback and improvement capabilities were not as effective as they expected, and outlined a number of initiatives to enhance CH2M HILL capabilities in these areas. In addition, senior managers indicated that staff recognition of the potential for spread of radioactive contamination during retrieval activities needed to be improved and that continuous monitoring of selected hazardous chemicals during retrievals appeared appropriate. They indicated that these areas would be emphasized and that systems for continuous chemical monitoring were being developed. **(See JON MS-2)**

Although CH2M HILL initiatives are appropriate, a systematic evaluation of the operability of the pump and the weaknesses identified on this investigation is needed to develop comprehensive corrective actions. An extent of condition review is needed to ensure that the potential weaknesses are also considered for tanks, systems, facilities, and organizations that were not involved in this accident. **(See JONs ENG-1 and MS-2)**

DOE Oversight. During the course of the Accident Investigation, the Board interviewed selected DOE managers and gathered information about DOE perspectives and oversight activities. Interviews revealed that DOE managers believed that the current schedules and milestones are realistic. The Accident Investigation Board also determined that the ORP Facility Representative Program and other oversight activities have focused on improving CH2M HILL performance in radiological protection, industrial safety and hygiene, and integrated safety management systems. Progress has been made in many aspects of industrial hygiene and workplace monitoring and ORP oversight has led to some improvements in work control. However, the results of this Accident Investigation indicate that increased DOE management attention and oversight of all safety and health programs at the S Tank Farm are warranted. **(See JON MS-2)**

A particular concern is the past deficiencies in DOE and ORP oversight of engineering. DOE review and testing of the design of retrieval systems for S-102 was inadequate for the modified character of the waste in the tank. The change in pump design and the inadequate testing program were not reviewed or identified by ORP or DOE. Contributing factors may include a lack of engineering expertise, inadequate staff, and schedule pressures. For example, the engineering of the pump installations was performed during the period from late 2002 through early 2003. At that time, ORP was reviewing and approving the first DSA and did not apply personnel to review the S-112 and S-102 retrieval pump designs. Although the backflow prevention criteria in the DSA approved by ORP were adequate, ORP did not identify the deficiency in the design (e.g., lack of required isolation/backflow prevention) or the fact that some portions of the systems physically connected to the tanks should have been classified as Safety Significant. In the five years since the design was completed, ORP oversight of CH2M HILL engineering and nuclear safety has been very limited. In the last two years, division supervision has been diverted to other temporary assignments for extended periods. **(See JON MS-2)**

Overall, improvements in CH2M HILL management systems and feedback and improvement processes and DOE oversight are needed to address the causes of this accident and to prevent recurrences of similar accidents and events.

8.0 CONCLUSIONS AND JUDGMENTS OF NEED

The Accident Investigation Board concluded that this accident could have been prevented if a backflow prevention device had been installed, as required by the DSA and TSRs for Tank Farms. The Accident Investigation Board also concluded that although several workers reported symptoms, it is unlikely that the accident resulted in significant radiation or chemical exposures to workers. However, the event could have been significantly worse if individuals had been in the immediate vicinity of the spill at the time of the release.

Table 8-1 provides the Accident Investigation Board's detailed conclusions and the associated Judgments of Need. The detailed conclusions in that Table consider significant facts, causal factors, and pertinent analytical results. Judgments of need are managerial controls and safety measures believed necessary to prevent or mitigate the probability or severity of a recurrence. They flow from the causal factors and are directed at guiding managers in developing follow-up actions.

Table 8-1 Conclusions and Judgments of Need

Conclusions	Judgments of Need
Engineering	
• The criteria for sparging for S-102 operation were not specified in the operating requirements. The Seepex pump sparging capability was included in the design but was believed to be plugged by the operators and thus not available during this event. • Although the current design did contain a flushing line between the discharge of the pump inside the riser column and just above the normal impeller discharge, that could be used to provide flushing water directly into the pump in reverse flow operation, it was capped inside the riser extension enclosure and not used. • The required usage of the High Pressure Mixer was not provided as a design modification input, and was not translated into operating requirements.	**ENG-1:** CH2M HILL needs to improve incorporation of the design features, testing, and operating limits/specifications into operating procedures associated with the S-102 tank and the Seepex pump to ensure its ability to move S-102 waste without becoming fouled.

Conclusions	Judgments of Need
• The limit on how long the Seepex pump could remain idle with waste in the pump before hardening occurred was not determined as a design modification input. • The Seepex pump installed in S-102 Tank was only tested using water that did not adequately simulate the condition of the waste in the tank.	
• The leak most likely occurred through the dilution line hose that was not protected by an isolation device, as required by the DSA. • CH2M HILL did not ensure that the generation and approval of design inputs and hazard analysis were maintained current with the evolution of design for the in-house and the subcontracted design products for the Seepex pump projects. • CH2M HILL did not ensure that credible operating conditions, both normal and off-normal, for all components of the Seepex pump engineered systems are correctly and fully identified, and that the design is fully capable of withstanding and performing as required under these conditions. • Formal design reviews by CH2M HILL were not performed at intermediate steps and at the completion for the subcontracted design products for the Seepex pumps for S-102. • CH2M HILL did not use the design inputs and hazards analysis as a basis for review and approval of the Seepex pump project including the development of guides on how to perform these reviews. (e.g., discipline applicability review checklists; discipline specific checklists; etc.) • Design processes insufficiently delineated roles and responsibilities for the in-house and subcontracted design products and did not sufficiently develop implementing procedures.	**ENG-2:** CH2M HILL needs to revise its design review processes, procedures and implementation to ensure approved designs are technically correct and satisfy the requirements of the Documented Safety Analysis.
• The second S-102 pump (retrieval pump # 3) shaft was subjected to a torque greater than its yield stress during the accident. This overtorquing caused some subcomponents in the pump coupling to permanently deform. An inadequate analysis of the effects of this overtorquing on the coupling was conducted.	**ENG-3:** CH2M HILL needs to perform an engineering analysis of whether the S-102 pump can continue to be safely operated following the deformation that occurred when excessive shaft torquing was applied during maintenance.
• The DSA does not require classification of the primary pressure boundary of waste transfer routes and connecting systems that are part of that boundary as safety systems. • The first safety significant boundaries required for the waste transfer route are generally the mitigative confinement boundaries outside the primary boundaries, such as the outer hose of the hose-in-hose waste transfer lines and the pump riser extension enclosure for the transfer pump and associated supporting system hoses located in the riser extension enclosure.	**ENG-4**: The safety basis needs to be changed by CH2M HILL/ORP to require that new primary pressure boundaries for S-102 be classified as Safety Significant. Existing installed systems, structures, and components need not be upgraded from their current classification, but should be treated nonetheless, to the maximum extent practical, as if they were Safety Significant.

Conclusions	Judgments of Need
• The DSA does not consider the primary pressure boundary for the waste transfer routes and connected systems as safety significant preventative or defense in depth systems, with the exception of the isolation devices that separate non-waste transfer systems from the waste transfer routes. • 10 CFR 830 defines safety significant structures, systems, and components" as those "…whose preventative or mitigative function is a major contributor to defense in depth " • The relevant DOE standards and guides (DOE-STD-3009-94, DOE G 420.1-1, and DOE G 421.1-2 for example) reemphasize the applicability and importance of these requirements, and amplify and interpret the safety classification requirements, emphasizing that preventative controls are preferred over mitigative controls.	
Emergency Management	
• The Tank Farm emergency planning hazards assessment and emergency action levels are based only on events analyzed in the Documented Safety Analysis (DSA). • High-probability, low-consequence events are not analyzed in the emergency planning hazard analysis and as a result appropriate emergency action levels have not been developed. • Assumptions used in EPHA consequence assessments are not adequately documented. • Emergency action levels tables do not indicate whether the results were determined from the radiological isotopes or the chemical constituents.	**EM-1:** CH2M HILL needs to analyze events of higher probability but lower consequence in the tank farms emergency planning hazards assessment, covering the full range of possible initiators and severity levels as required by DOE Order 151.1C, *Comprehensive Emergency Management System,* and it predecessors. Analysis needs to provide adequate documentation of assumptions.
• The abnormal operating procedure (AOP-006) used for responding to high radiation areas does not require that the cause of the high radiation area be conservatively assumed to be a release until determined otherwise. • Although the abnormal operating procedure for responding to a high radiation area required a call to 911, it does not specify what actions were expected as a result of that call and quick reaction checklists are not developed for 911 calls on abnormal events. • The crash phone announcements contained in the quick reaction checklists were specifically written for emergencies, and some of the language was not applicable to the spill, which was an abnormal event.	**EM-2:** CH2M HILL, Fluor Hanford, and AdvancedMed Hanford need to improve procedures used for responding to abnormal events at tank farm contractor facilities.
• Workers were sheltered in a trailer for an extended time without ventilation on a day when outside temperatures exceeded 90 degrees Fahrenheit. During this time responders entered and exited without personal protective equipment and before hazards were characterized. • Persons working outdoors in areas beyond facility boundaries took cover in their vehicles when the	**EM-3:** CH2M HILL and Fluor Hanford need to correct weaknesses and inconsistencies in the implementation of take cover protective actions.

Conclusions	Judgments of Need
siren sounded. They were not directed by Hanford Patrol officers, the incident command post or event coordination team to take cover in a building. • Access controls were not established for all areas under the take cover order.	
Industrial Hygiene and Medical Programs	
• The potential chemical hazards associated with abnormal conditions were not sufficiently identified by operations personnel or communicated to industrial hygiene to ensure an effective and timely industrial hygiene response. • The existing industrial hygiene procedures and/or protocols are not sufficient for responding to the potential of chemical exposures resulting from spills or other unanticipated events other than a vapor odor. • Industrial hygiene sampling and monitoring plans have not been sufficiently addressed for abnormal or unanticipated events. • Industrial hygiene has not been sufficiently integrated into the development and maintenance of Worksite Hazard Analyses. The Worksite Hazard Analyses in effect at the time of the spill did not indicate the appropriate hazard controls for the operation of the S-102 tank retrieval pump.	**HE-1:** CH2M HILL needs to integrate industrial hygiene into responding to abnormal events which may involve a chemical release. In addition, CH2M HILL needs to establish and implement industrial hygiene procedures, sampling and monitoring protocols, and training of industrial hygiene staff for responding to the range of abnormal events identified in Tank Farm Hazard Analysis Documents.
• Emergency medical technician first responders did not adequately record their findings at the time of the event especially in regard to organ systems (skin, respiratory, eyes/nose, gastrointestinal complaints). • Patient encounter forms did not include place and time of the evaluation and document fully history, physical findings, analysis of the situation and plan for disposition. • The physician responsible for the emergency medical technician has conducted limited review of emergency medical technician performance over the last year. • Emergency medical technician /paramedics lack experience with the evaluation processes for possible chemical exposures, likely toxicants to be encountered, and resources for immediate additional expertise, etc. • There were no formalized procedures and protocols for direct communication between AdvancedMed Hanford and the Hanford Fire Department for potential chemical exposure events including directly sharing information such as the description of the event, number of people anticipated requiring an evaluation, and possible toxicants involved (if known).	**HE-2:** The Hanford Fire Department, managed by Fluor Hanford, needs to improve its emergency medical technicians/paramedics performance in the areas of improved documentation of patient encounters and communications with AdvancedMed Hanford; more frequent review of records by physicians is one needed element in the efforts to enhance documentation of patient encounters.
• Post exposure medical monitoring and follow up needs to be improved. Company policy did not ensure that all involved personnel are required to	**HE-3:** CH2M HILL, Flour Hanford, and AdvancedMed Hanford need to improve medical monitoring, documentation, and accountability of individuals with health

Conclusions	Judgments of Need
report to AdvancedMed Hanford for evaluation. Employees may have a right to refuse an examination and/or blood work, but need to be seen ASAP to obtain pertinent history/symptoms and hopefully physical findings and biological monitoring. • After the initial event, CH2M HILL and Fluor Hanford did not closely coordinate with AdvancedMed Hanford the return of workers to review test results in a timely manner. • CH2M HILL and Flour Hanford did not adequately coordinated workers return clinic visits to AdvancedMed Hanford at a reasonable interval to capture any delayed reported symptoms and obtain further tests as appropriate. Individuals who report abnormalities or have abnormal lab values (and not explained by other causes) should be followed to resolution.	symptoms and/or complaints following an accident.
Work Control	
• The S-102 radiation survey performed shortly after the waste spill failed to identify that a waste spill had occurred because beta dose rates were not measured and the operations procedure did not contain sufficiently clear and detailed instructions for acting on abnormal radiological conditions. • The report by an experienced Nuclear Chemical Operator that the area was "very stinky" did not prompt the Operations Engineer or operating crew to consider that condition could be related to a waste spill. • Although members of the operating crew noticed a temporary doubling in background radiation that returned to approximately 200 cpm in a short period of time, as well as simultaneous updating of the PCM-1B due to a change in background radiation level, they did not consider those indications could be related to a waste spill. • The operating crew inappropriately used Material Balance Discrepancy Data and Transfer Leak Detection System to conclude a waste spill had not occurred. Material Balance Discrepancy Data is intended to detect large volume waste leaks (several hundred gallons) rather than the relatively small volume involved in this waste spill. • The operating crew incorrectly believed that an aboveground and unmonitored (Transfer Leak Detection System) waste leak was not a credible event and therefore did not aggressively pursue that possibility when investigating the high radiation level condition. • Visual observation of the waste spill was not accomplished in a timely manner because of inadequate lighting (a previously identified deficiency) conditions at the S Tank Farm and the inability to survey the waste spill area with a remotely con-	**WC-1:** CH2M HILL management needs to define and implement an effective method for identifying Tank Farm small quantity waste leaks.

Conclusions	Judgments of Need
trolled video camera.	
• The operations procedure lacked a documented technical basis including data quality objectives associated with radiological criteria of 75 mrem and 100 mrem used as trigger levels for response actions. • There is no formal mechanism to ensure Subject Matter Experts responsible for procedure reviews understand whether radiological surveys are to be used to implement TSR requirements for leak detection and if not, how any differences in objectives are to be addressed. • Comparison of operations procedures for waste transfers where radiological monitoring was the primary TSR leak detection control showed no difference in the rigor, technical basis, quality or clarity of how radiological surveys are to be used as an indicator of waste leaks. This indicates an extent of condition concern with regard to radiological measurements and leak detection beyond S-102. • Once the pump was able to perform an acceptable electrical reverse operation, the pump was shutdown per the Shut Down Waste Transfer instructions. However, the shutdown instructions call for the Health Physics Technician to perform and record a final radiological survey but do not link to the action steps for high radiation.	**WC-2:** CH2M HILL management needs to clarify TSR requirements with regards to radiological measurements as indicators of waste transfer leaks.
• Abnormal operating procedures were considered and used incorrectly as stand alone procedures without regard to other required tank farm procedures and protocols (i.e., radiation work permit, investigative surveys, etc.). • Managers and supervisory personnel believed informal actions to be appropriate and within the authorization basis of abnormal operating procedures however the actions taken did not ensure adequate application of the core functions of integrated safety management including accurate work scope definition, hazard analysis and specification of controls. • Conduct of operations expectations were not clearly delineated in abnormal operating procedures including linkage and/or reference to existing procedures and processes that must be followed and/or acceptable conditions for deviation.	**WC-3:** CH2M HILL management needs to address radiological conduct of operations deficiencies that were evident during the S-102 response to abnormal operating conditions.
• During initial start of retrieval operations with the newly installed SEEPEX Pump, the S-102 Waste Retrieval pumping procedure was not properly performed and the SEEPEX pump (a positive displacement pump) was started with Discharge Valve V-106 shut and therefore in the wrong position per the procedure. • TO-420-905 Checklist 2, *Pre-Transfer Valve*	**WC-4:** CH2M HILL workers, supervisors and management need to improve the implementation of the Conduct of Operations Program as required in the Safety Basis and the Applicability Matrix, March 20, 2007

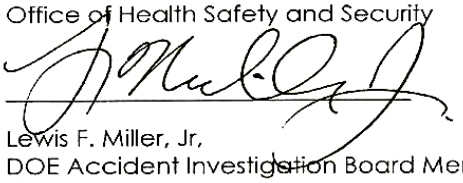
Conclusions	Judgments of Need
Alignment, Section B, specifies that valve POR60-RW-V-308 (Sparger Isolation Valve) expected position is closed. Section 5.4, Operate the Dilution/Sparger Line, does not address subsequently opening this valve to initiate sparge operations. • The S-102 Waste Retrieval Pumping procedure requires that workers performing this procedure, walk down the job and document hazards and controls in the Worksite Hazard Analysis. The Worksite Hazard Analysis had not been performed/updated since 2006. • Procedures and implementation for Waste Transfer Pump Bumping and Administrative Lock Control were inadequate to meet TSR requirements during troubleshooting of the variable frequency drive followed by Seepex pump bumping. • Not all information discussed in DOE O 5480.19 regarding logs and records is included in the compilation of logs, checklists, and data sheets associated with S-Farm Operations. • Continuing training requirements of DOE O 5480.20A relating to annual training and examination covering abnormal facility procedures and emergencies, and training drills are not included in Tank Farm operator and supervisor training. • Instructions in Process Memos and Field Work Supervisor oral instructions for retrieval pump operations and maintenance were not established in Operating Procedures. • The requirements of the Standing Minor Work Instructions are not consistent with the Tank Farm Contractor Work Control procedure and were not implemented in a manner consistent with either document. Specifically, the Minor Work Instructions require the generation of a trouble shooting plan if it is determined that trouble shooting is required. The Tank Farm Contractor Work Control procedure only requires the generation of a trouble shooting plan if it is determined one is needed. Further, The Minor Work Instruction requires the FWS to ensure a Worksite Hazards Analysis has been completed unless the hazards for the task are general or a previous Worksite Hazard Analyses can be reused. The Tank Farm Contractor Work Control procedure allows minor work requiring routine repetitive tasks to be accomplished using verbal direction without a Worksite Hazard Analyses.	
Management Systems	
• The "lesson learned" gained by CH2M Hill following Preliminary Notice of Violation and Proposed Civil Penalty in March 2005 was ineffective in identifying deficiencies in this event concerning	**MS-1:** ORP and CH2M HILL needs to review and evaluate the adequacy and implementation of corrective action plans for past events and enforcement actions to the S Tank Farms, and ensure that effective lessons

backflow preventers, software control and qualifications. • The declaration of a PISA on September 27,2005, combined with the conclusions on this accident investigation regarding the adequacy of the DSA supporting waste retrieval from tank S-102, indicates that CH2M HILL has not developed and implement corrective action plans that prevent similar events from happening again.	learned processes are performed.
• The original Seepex pump installation in simulant for Tank S-102, and the effective range of the high pressure mixers in simulant were not adequately tested. • A lack of questioning attitude concerning the Seepex pump design performance under reverse flow, the acceptance of inadequate primary physical barriers for confinement of highly radioactive waste, and over reliance on successful performance of the Seepex pump in Tank S-112 when the operating environment changed in Tank S-102 were indicators of insufficient attention to detail and insufficient rigor in management and engineering approaches to safety management and over emphasis on an unrealistic retrieval schedule. • ORP oversight of engineering related to S-112 and S-102 retrieval was inadequate in the period 2003 to the present due to lack of staff, expertise, supervision, and management commitment..	**MS-2:** CH2M HILL and ORP need to improve S-102 waste retrieval oversight to ensure that nuclear safety and other safety requirements are met.

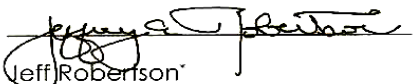
9.0 BOARD MEMBER SIGNATURES

BOARD SIGNATURES

William E. Miller*
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Office of Health Safety and Security



Lewis F. Miller, Jr.
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of River Protection



Jeff Robertson*
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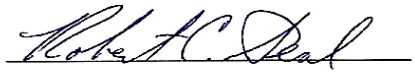

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* Trained Accident Investigator

APPENDIX A

Appointing Official's Memorandum of Establishment

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Department of Energy
Washington, DC 20585

August 15, 2007

MEMORANDUM FOR SHIRLEY OLINGER
ACTING MANAGER
OFFICE OF RIVER PROTECTION

FROM: GLENN PODONSKY
CHIEF HEALTH, SAFETY AND SECURITY OFFICER
OFFICE OF HEALTH, SAFETY AND SECURITY

SUBJECT: Type A Accident Investigation Office of River Protection Tank Farm Waste Spill

I hereby establish a Type A accident investigation of the July 27, 2007, Tank 241-S-102 Waste Spill at the Hanford Tank Farms. I have determined that this incident warrants a Type A accident investigation consistent with Department of Energy Order 225.1A, *Accident Investigations*. I appoint Mr. William Miller, Deputy Director, Office of Environment, Safety and Health Evaluations to serve as the Board Chairperson. The Board will be composed of the following: Robert Seal, Idaho Operations Office; Lew Miller, Office of River Protection; Thomas Williams and Jeffery Robertson, of the Office of Health, Safety and Security (HSS). In addition, Mr. Dennis Vernon, HSS, will serve as the overall team coordinator for process, schedule and logistics.

The investigation shall evaluate the effectiveness of Integrated Safety Management principles and functions, and will analyze causal factors, identify root causes and determine Judgments of Need to prevent recurrence. The scope will review:

- Potential health effects to workers located in the vicinity of the waste spill
- Emergency management plans and response to the event
- Engineering design, modifications and approval of the current S-102 pumping equipment
- Work control process associated with S-102 tank retrieval pumping during the event

The Board Chairperson will provide me with progress reports during this investigation. Discussions of the investigation and copies of the draft work products and report will be strictly controlled. The draft report will be provided to my office by September 14, 2007.

cc: Dennis Spurgeon, US
Benjamin Getto, S
Adam Ingols, US
James A. Rispoli, EM-1
Ines Triay, EM-3
William Miller, HS 64
Michael A. Kilpatrick, HS-1
Charles B. Lewis, HS-30

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APPENDIX B

Accident Investigation Board

Management and Support Team

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Management

Glenn S. Podonsky, Chief, Health, Safety and Security Officer
Michael A. Kilpatrick, Deputy Director for Operations, Office of Health, Safety and Security
Charles B. Lewis III, HSS Acting Director, Office of Corporate Safety Analysis
Bradley Peterson, Director, HSS, Office of Independent Oversight

Board

William Miller, Chairperson, HSS
Lewis Miller, Member, ORP
Jeff Robertson, Member, HSS
Robert Seal, Member, Idaho Operations Office
Thomas Williams, Member, HSS

Support Staff

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Paul Creighton, MD, Advisor
Thomas Davis, Advisor
Deborah A. Johnson, Advisor
Jon Johnson, Advisor
Sarah Licht, Administrative Assistant
Jim Lockridge, PE, CIH, CSP, Advisor
Tim Martin, Advisor
Terri McEvoy, Desktop Publisher
Marvin Mielke, RN, Advisor
Erik Olds, Media Advisor, Office of River Protection, Department of Energy
Joe Panchison, Advisor
Don Prevatte, Advisor
Robert Quirk, Observer, Hanford Site Representative, Defense Nuclear Facilities Safety Board
John H. Riley, Advisor
Lee Roginski, Administrative Assistant
Michael Shlyamberg, Advisor
Robert Snyder, Advisor
Scott D. Stubblebine, Legal Counsel, Office of River Protection
Dennis Vernon, Advisor
Mario Vigliani, Advisor

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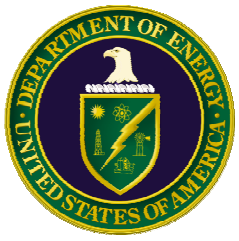

U.S. Department of Energy

Office of Health, Safety and Security
Office of Corporate Safety Programs