
# Remediation of Buried Chemical Warfare Materiel

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Committee on Review of the Conduct of Operations for Remediation of Recovered Chemical Warfare Materiel from Burial Sites; Board on Army Science and Technology; Division on Engineering and Physical Sciences; National Research Council

# REMEDIATION OF BURIED CHEMICAL WARFARE MATERIEL

Committee on Review of the Conduct of Operations for Remediation of Recovered Chemical Warfare Materiel from Burial Sites

Board on Army Science and Technology

Division on Engineering and Physical Sciences

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*Front cover—Upper*: Worker in personnel protective equipment lifting a single-round container (U.S. Army Corps of Engineers photo). *Left:* Degraded military munitions found at Spring Valley, District of Columbia (U.S. Army Corps of Engineers photo). *Lower background:* German Traktor rocket bases filled with hydrogen mustard, Huntsville (now Redstone) Arsenal, Alabama (U.S. Army photo from 1948).

*Back cover*—Ton containers used for storage of lewisite, a blister agent and lung irritant, Huntsville (now Redstone) Arsenal, Alabama (U.S. Army photo from 1947).



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# Preface

The Committee on Review of the Conduct of Operations for Remediation of Recovered Chemical Warfare Materiel from Burial Sites was appointed by the National Research Council in response to a request by Conrad F. Whyne, Director of the Chemical Materials Agency (CMA). The study dealt primarily with the activities of the Non-Stockpile Chemical Materiel Project (NSCMP), which falls organizationally under the CMA and is headed by Laurence G. Gottschalk, Project Manager for Non-Stockpile Chemical Materiel. Mr. Whyne, Mr. Gottschalk, and their staffs heavily supported the activities of the committee.

This report is concerned with the investigation and, if required, the remediation of sites that contain buried chemical materiel. About 250 such sites, located in 40 states and territories of the United States, are thought to exist. Remediation efforts are currently under way in the Spring Valley area of Washington, D.C., and at the Camp Sibert site in Alabama. A substantially larger effort is anticipated at the Redstone Arsenal in Alabama.

The NSCMP plays a major role in remediation efforts. It has project management responsibilities for the assessment and disposal of all recovered chemical warfare materiel (RCWM) and for this purpose identifies assessment and disposal costs, disperses funds for assessment and disposal, prepares project schedules and other required documents, and obtains all approvals needed for the destruction of the RCWM. The NSCMP owns several explosive destruction systems (EDSs), used for destruction of RCWM, and arranges for use of commercial explosive destruction technologies for RCWM when needed.

One focus of the committee was investigating the technologies available to the NSCMP for investigating a burial site that is thought to contain buried chemical weapons, assessing any chemical materiel recovered, and destroying the RCWM. Deficiencies in the available technologies and research and development targeted at those deficiencies are identified.

The committee's second focus was to investigate the roles and responsibilities of the numerous organizations and offices within the Department of Defense and the Department of the Army that are involved with buried chemical materiel issues. In carrying out its assigned role, the NSCMP coordinated with these agencies and offices to set priorities, obtain funding, and carry out assessment and destruction activities. It also recommended changes to the relationships between some of these organizations and offices.

The committee held six meetings. The first was at the Chemical Demilitarization Training Facility at the Aberdeen Proving Ground in Edgewood, Maryland. The second meeting, held at the Keck Center in Washington, D.C., featured a visit to the nearby Spring Valley chemical weapon remediation site. The third, fourth, and sixth meetings were also held at the Keck Center, and the fifth was held at the Beckman Center in Irvine, California. A total of 38 presentations were received from the following entities:

- Twenty agencies and offices within the Department of Defense;
- Regulatory officials from the District of Columbia, the states of Alabama and Utah, and U.S. Environmental Protection Agency regions 4 and 8;
- The Spring Valley Community Restoration Advisory Board;
- Vendors for the commercially available explosive destruction technologies; and
- A member of the staff of the Senate Armed Services Committee.

The presentations are listed in Appendix B.

This report was prepared under the auspices of the Board on Army Science and Technology (BAST) of the National Research Council. The committee offers its thanks to Bruce A. Braun, the Director of BAST, and to Nancy T. Schulte, the Study Director, for their very effective support in the conduct of this study. It also offers its thanks to the BAST staff members who capably assisted in information-gathering activities, meeting and trip arrangements, and the production of this report; they include Ann Larrow, Research Assistant, Joe Palmer, Senior Program/Project Assistant, and Harrison T. Pannella, Senior Program Officer.

Richard J. Ayen, *Chair*
Committee on Review of the Conduct of Operations
for Remediation of Recovered Chemical Warfare Materiel
from Burial Sites

# Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Fred S. Celec, Institute for Defense Analyses,
Martin Gray, State of Utah Department of Environmental Quality,
Henry J. Hatch, NAE, U.S. Army Corps of Engineers (retired),
John R. Howell, NAE, University of Texas at Austin,
Michael F. McGrath, ANSER (Analytic Services Inc.),
Leonard M. Siegel, Center for Public Environmental Oversight, and
Michael V. Tumulty, P.E., STV Incorporated.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Elisabeth M. Drake, NAE. Appointed by the National Research Council, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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# Acronyms and Abbreviations

| | |
|---|---|
| ACAT I | Acquisition Category I |
| ACSIM | Assistant Chief of Staff, Installation Management (U.S. Army) |
| ACWA | Assembled Chemical Weapons Alternatives |
| ADEM | Alabama Department of Environmental Management |
| AEC | U.S. Army Environmental Command |
| AEL | airborne exposure limit |
| AFCEE | Air Force Center for Engineering and Environment |
| AMC | U.S. Army Materiel Command |
| ANCDF | Anniston Chemical Agent Disposal Facility (Alabama) |
| ARAR | applicable, relevant, and appropriate requirement |
| ASA(ALT) | Assistant Secretary of the Army for Acquisition, Logistics and Technology |
| ASA(IE&E) | Assistant Secretary of the Army (Installations, Energy and Environment |
| ASA(ILE) | Assistant Secretary of the Army for Installation, Logistics and Environment |
| ASA(RDA) | Assistant Secretary of the Army for Research, Development and Acquisition |
| ASD(NCB) | Assistant Secretary of Defense (Nuclear, Chemical, and Biological Defense Programs) |
| | |
| BES | budget execution submission |
| BRAC | base realignment and closure |
| | |
| CAIRA | chemical accident or incident response and assistance |
| CAIS | chemical agent identification set(s) |
| CAM | Chemical Agent Monitor |
| CAMD,D | Chemical Agent and Munitions Disposal, Defense |
| CAMU | corrective action management unit |
| CARA | Chemical Biological Radiological Nuclear (Enhanced) Analysis and Remediation Activity |
| CBARR | Chemical Biological Applications and Risk Reduction |
| CBRNE | chemical, biological, radiological, nuclear and high yield explosives |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act |
| CG | phosgene |
| CMA | Chemical Materials Agency |
| CNB | CN tear gas mixed with carbon tetrachloride and benzene |
| CNO | Chief of Naval Operations |
| CNS | CN tear gas mixed with chloropicrin and chloroform |
| CONUS | continental United States |
| CSA | Chief of Staff of the Army |
| CSDP | chemical stockpile disposal program |
| CSE | Chemical Stockpile Elimination (project) |
| CSEPP | Chemical Stockpile Emergency Preparedness Project |
| CW | chemical weapons |
| CWC | Chemical Weapons Convention |
| CWM | chemical warfare materiel |
| | |
| DA | diphenylchloroarsine (Clark I) |
| DAAMS | Depot Area Air Monitoring System |
| DAB | Defense Acquisition Board |
| DASA(ECW) | Deputy Assistant Secretary of the Army for Elimination of Chemical Weapons |

| | |
|---|---|
| DASA(ESOH) | Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health) |
| DAVINCH | detonation of ammunition in a vacuum integrated chamber |
| DC | diphenylcyanoarsine (Clark II) |
| DDESB | Department of Defense Explosives Safety Board |
| DERP | Defense Environmental Restoration Program |
| DM | adamsite |
| DMM | discarded military munitions |
| DOD | Department of Defense |
| DOT | Department of Transportation |
| DRCT | digital radiography and computed tomography |
| DUSD(I&E) | Deputy Under Secretary of Defense for Installations and Environment |
| | |
| EA | executive agent |
| ECBC | Edgewood Chemical Biological Center |
| EDS | Explosive Destruction System |
| EDS-1 | EDS Phase 1 |
| EDS-2 | EDS Phase 2 |
| EDS-3 | EDS Phase 3 |
| EDT | explosive destruction technology |
| EOD | explosive ordnance disposal |
| EPA | Environmental Protection Agency |
| EPCRA | Emergency Planning and Community Right-to-Know Act |
| ER,A | Environmental Response, Army |
| | |
| FFA | federal facility agreement |
| FORSCOM | Forces Command (U.S. Army) |
| FSS | fragment suppression system |
| FTO | flameless thermal oxidizer |
| FUDS | formerly used defense site(s) |
| | |
| GA | tabun (a nerve agent) |
| GB | sarin (a nerve agent) |
| GD | soman (a nerve agent) |
| | |
| H | sulfur mustard |
| HD | sulfur mustard (distilled) |
| HEPA | high-efficiency particulate air (filter) |
| HN | nitrogen mustard |
| HN-3 | nitrogen mustard |
| HNC | Huntsville Engineering Center |
| HS | sulfur mustard |
| HSWA | Hazardous and Solid Waste Amendments |
| HT | sulfur mustard, T-mustard combination, also British mustard |
| | |
| IHF | interim holding facility |
| IMCOM | Installation Management Command (U.S. Army) |
| INST CDR | installation commander |
| IO | integrating office |
| IPT | integrated product team |
| IRP | Installation Restoration Program |
| ITRC | Interstate Technology Regulatory Council |
| | |
| L | lewisite or liter |
| LDR | land disposal restrictions |
| LITANS | large item transportable access and neutralization system |
| | |
| MARB | Materiel Assessment Review Board |
| MC | munitions constituents |
| MDAP | major defense acquisition program(s) |
| MEA | monoethanolamine |
| MEC | munitions and explosives of concern |
| MEL | mobile expeditionary laboratory (CARA) |
| MIL-SPEC | military specification |
| MINICAMS | Miniature Chemical Agent Monitoring System(s) |
| MMAS | mobile munitions assessment system |
| MMRP | Military Munitions Response Program |
| MR | munitions rule |
| MRC | multiple round container |
| MRP | munitions response program |
| MRS | munitions response site |
| MRSPP | Munitions Response Site Prioritization Protocol |
| MSU | munitions storage unit |
| | |
| NAVFAC | Naval Facilities Engineering Command |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NDAA | National Defense Authorization Act |
| NEW | net explosive weight |
| NPL | National Priorities List |
| NRC | National Research Council |
| NSCM | non-stockpile chemical materiel |
| NSCMP | Non-Stockpile Chemical Materiel Project |
| NSCWM | non-stockpile chemical warfare materiel |
| | |
| OB/OD | open burn/open detonation |
| OCONUS | outside the continental United States |
| OIPT | overarching integrated product team |

| | |
|---|---|
| O&M | operations and maintenance |
| OMA | Operations and Maintenance, Army |
| OP-FTIR | Open-Path Fourier Transform Infrared Spectrometry air monitoring |
| OSD | Office of the Secretary of Defense |
| PIG | package in-transit gas (container) |
| PINS | portable isotopic neutron spectroscopy |
| PMCD | program manager for chemical demilitarization |
| PMNSCM | Project Manager for Non-Stockpile Chemical Materiel |
| POM | Program Objective Memorandum |
| PPBES | planning, programming, budgeting and execution |
| PPE | personal protective equipment |
| RCRA | Resource Conservation and Recovery Act |
| RCWM | recovered chemical warfare materiel |
| RDECOM | Research, Development, and Engineering Command |
| RDT&E | research, development, test, and evaluation |
| RFI | RCRA Facility Investigation |
| RI/FS | remedial investigation/feasibility study |
| ROD | record of decision |
| RRS | remediation response section (CARA) |
| RSA | Redstone Arsenal |
| SCANS | Single Chemical agent identification set Access and Neutralization System |
| SDC | static detonation chamber |
| SES | Senior Executive Service |
| SPP | site prioritization protocol |
| SPT CMD | Support Command |
| SRC | single round container |
| STEL | short-term exposure limit |
| SWMU | solid waste management unit |
| TDC | transportable detonation chamber |
| TNT | trinitrotoluene |
| TOCDF | Tooele Chemical Agent Disposal Facility (Utah) |
| TPP | Technical Project Planning |
| TRAM | throughput, reliability, availability, and maintainability |
| TSDF | treatment, storage, and disposal facility |
| TU | temporary unit |
| UMSC | universal munitions storage container |
| USACE | U.S. Army Corps of Engineers |
| USACMDA | U.S. Army Chemical Materiel Destruction Agency |
| USAEC | U.S. Army Environmental Command |
| USAESCH | U.S. Army Engineering Support Center, Huntsville |
| USATCES | U.S. Army Technical Center for Explosives Safety |
| USD(A&T) | Under Secretary of Defense for Acquisition and Technology (renamed USD(AT&L)) |
| USD(AT&L) | Under Secretary of Defense for Acquisition, Technology and Logistics [formerly USD(A&T)] |
| USD(Comptroller) | Under Secretary of Defense Comptroller |
| USD(I&E) | Under Secretary of Defense for Installations and Environment |
| UTS | universal treatment standards |
| UXO | unexploded ordnance |
| VSL | vapor screening level |
| WP | white phosphorus |
| 3X | level of agent decontamination (suitable for transport for further processing) (obsolete) |
| 5X | level of agent decontamination (suitable for release for unrestricted use) (obsolete) |

# Summary

As the result of disposal practices from the early to mid-twentieth century, approximately 250 sites in 40 states, the District of Columbia, and 3 territories are known or suspected to have buried chemical warfare materiel (CWM). Much of this CWM is likely to occur in the form of small finds that necessitate continuation of the Army's capability to transport treatment systems to such locations for destruction.[1] Of greatest concern for the future are sites in residential areas (e.g., the now urban Spring Valley section of Washington, D.C.) and large sites on legacy military installations such as Redstone Arsenal, Alabama, where over 5 miles of disposal trenches have been identified.

Neither the Chemical Weapons Convention (CWC) treaty (CWC, 1997) nor existing CWM domestic legislation requires recovery of buried CWM, but pressure to do so is becoming more intense. The cost of characterization, remedy selection, and even containment of these large buried CWM sites is likely to be significant. The upper-end estimate for completely recovering and destroying buried CWM at Redstone Arsenal in Alabama alone is estimated to be several billion dollars. Although it is impossible at this time to predict the ultimate cost of completely remediating all buried CWM, the Department of Defense (DOD) should initially plan for multi-billion-dollar costs over several years.

The Army mission regarding the remediation of recovered chemical warfare materiel (RCWM) is turning into a program much larger than the existing munition and hazardous substance cleanup programs. The organizational structure being used by the Army to achieve its original mission of handling ad hoc CWM finds consists of about a dozen organizations within the Army and several offices within the DOD. For example, different offices design and acquire the specialized CWM destruction and other equipment; other offices operate the equipment; another unit transports the equipment and personnel; and various offices within the U.S. Army Corps of Engineers (USACE) and the Offices of the Secretary of the Army and of the Secretary of Defense play significant roles in setting policy, obtaining federal funding, prioritizing sites for remediation, and participating in remedy selection decisions with regulators.

In the committee's view, the Army asked the National Research Council (NRC) to examine this evolving mission in part because this change in mission is significant and becoming even more prominent as the stockpile destruction is nearing completion. One focus of the study has been the current and future status of the Non-Stockpile Chemical Material Project (NSCMP), which now plays a central role in the remediation of recovered chemical warfare materiel and which reports to the Chemical Materials Agency (CMA). The tasks that were presented in the statement of task inherently required a review of funding based on the committee's interpretation of the statement of task, discussions with Army and Office of the Secretary of Defense (OSD) personnel, and the link between organizational efficiency and funding for DOD missions. In addition to examining the organizations and their roles and the funding, the NRC was asked to review the technology tools now used in the detection, excavation, packaging, storage, transportation, assessment, and destruction of buried CWM and the tools that may be needed in the future. The full statement of task is set forth in Chapter 1. The committee's main responsibilities were as follows:

- Survey the organizations involved with remediation of suspected CWM disposal sites to determine current practices and coordination.
- Review current supporting technologies for cleanup of CWM sites.
- Identify potential deficiencies in operational areas based on the review of current supporting technologies for cleanup of CWM sites and develop options for targeted research and development efforts to mitigate potential problem areas.
- Suggest means by which the coordination among organizations involved in conducting investigations,

[1] This rapid, short-term response is often called the "firehouse" function.

recoveries, and cleanup activities concerning nonstockpile CWM can be made more efficacious and effective.

## ORGANIZATIONS INVOLVED IN THE REMEDIATION OF CWM DISPOSAL SITES

The NSCMP is the key provider of services and equipment for CWM destruction, both planned and in response to emergencies. In planned response operations such as those in Spring Valley in Washington, D.C., and Camp Sibert in Alabama, NSCMP would normally operate under the direction of a project manager from the USACE. In emergency response operations, such as remediating the 75-mm chemical munitions discovered at Dover Air Force Base, Delaware, it would operate under its own direction.

The NSCMP is responsible for managing all projects for the assessment and disposal of RCWM. Activities include identification of assessment and disposal costs, disbursement of funds for assessment and disposal, and preparation of project schedules. The NSCMP prepares the relevant documentation and obtains the approvals needed. The documents include the site plan, the site safety submission, the destruction plan, and the environmental permits. If a recovered munition is identified as a possible chemical fill, all information germane to that munition must be forwarded to the Materiel Assessment Review Board (MARB), which conducts an assessment of the munition to determine its chemical fill and explosive configuration. The NSCMP has responsibility for satisfying the obligations of the CWC.

NSCMP provides the equipment used for assessment, storage, and destruction of recovered munitions, and it has an active, ongoing program to improve this equipment and to develop new technologies.

In addition to the NSCMP, the MARB, and the USACE, other organizations are involved in hands-on aspects of remediation of buried CWM: the 20th Support Command Chemical, Biological, Radiological, Nuclear and Explosives Analytical and Remediation Activity (CARA); the Edgewood Chemical and Biological Center (ECBC); the U.S. Army Technical Center for Explosives Safety (USATCES); and the Department of Defense Explosives Safety Board (DDESB).

## TECHNOLOGIES FOR REMEDIATION OF BURIED CWM

The committee's other main responsibilities involved (1) the review of the technologies now in use for cleanup of CWM sites and identification of any deficiencies and (2) the development of recommendations for targeted research and development to correct these deficiencies. Many technologies are employed, as exemplified by a typical project in which suspected subsurface CWM are located through the application of geophysical technologies, typically magnetometry or active electromagnetic sensors. An object is uncovered by mechanized or manual excavation and the air around the site is monitored for agent. Qualified personnel remove and evaluate the suspected CWM and package it in a container approved for on-site transport to an installation bunker or an interim holding facility (IHF).

The suspected CWM will then be removed from storage and a mobile munitions assessment system (MMAS) sent to the site to provide a nonintrusive assessment of its contents. The key MMAS tools are these:

- Digital radiography and computed tomography (DRCT),
- Portable isotopic neutron spectroscopy (PINS), and
- Raman spectrometer.

The RCWM is again placed in interim storage to await review of the assessment by the MARB. In this scenario, the IHF may be off-site. If transport is required, the RCWM is packaged in a multiple round container (MRC) that has been certified by the Department of Transportation and can then be carried over public roads by CARA.

After the contents have been assessed by the MARB, they are destroyed or treated by one of the following technologies:

- Explosive destruction system (EDS),
- Transportable detonation chamber (TDC),
- Detonation of ammunition in a vacuum integrated chamber (DAVINCH), or
- Static detonation chamber (SDC).

If the RCWM is a chemical agent identification set (CAIS), the single CAIS access and neutralization system (SCANS) is used to destroy the CAIS. Secondary waste is transported to a commercial facility for final disposal.

The committee had no recommendations to make on any research and development for the following aspects of the aforementioned technologies:

- *Geophysical detection*. Other organizations have large R&D programs under way in this area. The best policy for NSCMP is to track developments in these programs.
- *Personal protective equipment*. No needs identified.
- *Conventional excavation equipment*. No needs identified.
- *CWM packaging and transportation*. As described in Chapter 4, the NSCMP is developing a universal munitions storage container. It is fabricated from high-density polyethylene, and its use will allow the destruction of overpacked munitions in the EDS without removing them from the overpack. No additional R&D needs identified.
- *CWM storage*. No needs identified.
- *SCANS*. No needs identified.
- *DRCT*. No needs identified.

- *DAVINCH or TDC detonation technologies*. No needs identified, although improvements to or refinement of the technology might be justified, depending on the application.

## TARGETED RESEARCH AND DEVELOPMENT ON REMEDIATION TECHNOLOGIES

Targeted research and development options were recommended in a number of areas.

### Robotic Excavation Equipment

Robotic technology has continued to grow in versatility and reliability. The committee judges that further investigation in and development of this technology for use in the remediation of buried chemical materiel would be fruitful.

**Recommendation 6-1**. The Army should demonstrate that robotic systems can be reliably utilized to access and remove buried chemical warfare materiel, and, where applicable, it should use them.

### Air Monitoring

As a detected subsurface object is excavated, the air in the area is monitored for agent. The Miniature Chemical Agent Monitoring System (MINICAMS) is used for this purpose, but it is a fragile system, not sufficiently robust to be moved from anomaly to anomaly. This results in long downtimes. A more rugged and portable system for near-real-time air monitoring is needed to reduce downtime. The multiagent meter now being developed by NSCMP might fit this need.

### Assessment of Recovered Munitions

Before RCWM can be destroyed, each item is assessed to determine the nature of the contained agent and energetics. The noninvasive analytical method used for this purpose is PINS. While PINS is an essential tool in the assessment of recovered munitions, it is not totally reliable. Munitions have been misidentified, and improvements are needed in the PINS analytical method to provide more definitive information for the identification of chemical fills in recovered munitions.

**Recommendation 6-3**. Research and development should continue on the processing of data from portable isotopic neutron spectroscopy to provide more definitive information for the identification of chemical fills in recovered munitions.

After conducting the PINS analysis for fill and explosive content, the MARB reviews all available information for each RCWM and presents its assessment. The procedure is involved and lengthy and the results are sometimes heavily qualified. Future large remediation projects, e.g., Redstone Arsenal, might entail assessing tens or hundreds of thousands of munitions or opened munitions. When dealing with such large quantities, the current PINS/DRCT/MARB approach may not be able to carry out its assessments in a sufficiently timely fashion, and the results may not be sufficiently accurate to guarantee the safety of treatment equipment operators.

**Recommendation 6-4.** The Non-Stockpile Chemical Materiel Project should recommend modifications to the current PINS/DRCT/MARB assessment approach or adopt an alternative approach that will function more quickly and with more definitive and more accurate results when tens of thousands or hundreds of thousands of munitions are to be assessed at a single site.

### Destruction of Contaminated RCWM

As noted above, the committee did not identify any areas of research for two of the four explosive destruction technologies—the DAVINCH and the TDC—available for treatment of RCWM. It did, however, identify areas of research for the EDS and the SDC.

#### *Explosive Destruction System*

The NSCMP has a substantial product improvement program under way to increase the capabilities of the EDS, including the use of steam injection to decrease cycle time and the identification of a universal reagent that will be effective for neutralization of all chemical warfare agents.

#### *Dynasafe Static Detonation Chamber*

The committee judges that the Dynasafe technology is a viable approach to processing large numbers—tens or hundreds of thousands—of burned and open chemical munition bodies that might contain residual agent or energetics.

As described in Chapter 4, many problems were encountered as the SDC 1200 was operating on chemical munitions at the Anniston Chemical Agent Disposal Facility (ANCDF), and work was begun on correcting these problems. One such problem was the sometimes incomplete combustion of carbon monoxide. Since then, Dynasafe has enlarged the thermal oxidizer for its SDC 1200s. This will allow better control of excess oxygen and hence more reliable combustion of carbon monoxide.

**Recommendation 6-5.** The Non-Stockpile Chemical Materiel Project should investigate the benefits of the larger thermal oxidizer now used in Dynasafe's standard SDC 1200. If, as expected, the larger oxidizer aids in controlling excess oxygen, leading to the more complete and consistent combustion of carbon monoxide, the project should consider replacing the current thermal oxidizer with the larger oxidizer.

Since the SDC system was started up, it has become clear that the spray dryer is not effective at preventing the formation of dioxins and furans, and the activated carbon adsorbers in the off-gas treatment system must be depended on to capture the dioxins and furans formed there. Also, the solids formed in the spray dryer sometimes accumulate on its interior walls. Eliminating the spray dryer and using a heat exchanger to cool the hot gases from the detonation chamber, as is done in the CH2M HILL TDC process, might improve the reliability of the process.

**Recommendation 6-6.** The Non-Stockpile Chemical Materiel Project should evaluate the costs and benefits of improving the reliability of the Dynasafe static detonation chamber system by replacing the spray dryer with a water-cooled heat exchanger and continuing to rely on activated carbon adsorbers to capture the dioxins and furans formed as off-gas from the thermal oxidizer is cooled. If disposal of liquid waste (i.e., spent scrubber solution) becomes a problem, the Non-Stockpile Chemical Materiel Project should consider replacing the caustic scrubbers with a dry lime injection system.

A major process improvement program for the Dynasafe SDC 1200 system was under way at the ANCDF as this report was being written. This program was well planned and was expected to increase the reliability of the process.

**Recommendation 6-7.** The Non-Stockpile Chemical Materiel Project should continue its efforts to improve throughput and reliability of the Dynasafe static detonation chamber system.

Some of the RCWM at large burial sites will not contain energetics such as bursters and fuzes but may still contain detectable quantities of agent. Many options exist for decontaminating these items to either the ≤1 vapor screening level (VSL) or to the suitable for unrestricted release level, including the following:

- Processing through high-temperature furnaces, including furnaces similar to those used in stockpile chemical weapon plants.
- Processing through a commercial transportable hazardous waste incinerator.
- Processing through a car bottom furnace.
- Treating with decontamination solution until a headspace agent concentration of ≤1 VSL is achieved.
- Using the Dynasafe SDC 1200, as noted above.

**Recommendation 6-8.** The Non-Stockpile Chemical Materiel Project should evaluate the Dynasafe static detonation chamber for its ability to destroy recovered chemical warfare materiel, including burned and previously opened munition bodies that still contain detectable traces of agent and agent-contaminated scrap metal. This evaluation should include possible modifications to the SDC feed system, changes in the residence time in the SDC chamber, and changes to its off-gas treatment system.

## CURRENT FUNDING AND ORGANIZATION FOR EXECUTION OF THE RCWM PROGRAM

As noted, the existing structure utilized by the Army, in its capacity as executive agent for destruction of non-stockpile chemical materiel, must now be reconfigured to prepare for the remediation of CWM at over 250 sites in the United States.

The current organizational structure was set on March 1, 2010, when the Under Secretary of Defense for Acquisition, Technology and Logistics [USD(AT&L)] formally designated the Secretary of the Army as executive agent for the RCWM program (see Appendix C). In 2011 the Army established a provisional RCWM integrating office to integrate, coordinate, and synchronize the DOD's RCWM response program and related activities. The USD(AT&L) memo required the Army to prepare and submit to the DOD a final implementation plan for the RCWM program. As of April 30, 2012, neither the responsible officials within the Office of the Secretary of Defense—the Deputy Under Secretary of Defense for Installations and Environment [DUSD(I&E)], the Office of the OSD comptroller, and the Assistant Secretary of Defense (Nuclear, Chemical, and Biological Defense) [ASD(NCB)]—nor the responsible officials within the Army had completed the task assigned to them by the USD(AT&L) memorandum of March 1, 2010.

**Recommendation 7-1.** The Army should formally approve, then submit, a final implementation plan for the recovery and destruction of buried chemical warfare materiel as required by the Under Secretary of Defense for Acquisition, Technology and Logistics in its memorandum of March 1, 2010.

### Funding Issues

Three major funding programs may come into play at an RCWM remediation site: Chemical Agent and Munitions Disposal, Defense (CAMD,D); Defense Environmental Restoration Program (DERP); and Operations and Maintenance (O&M). The committee was informed of the following funding practices:

- CAMD,D funding is used for the Chemical Stockpile Elimination (CSE), the NSCMP, and other projects. As is the case for other budget elements, the President's budget request for the project is authorized and appropriated annually by Congress. The President's budget request includes annual budget estimates for the following 4 years and, when available, the estimated cost to complete the project. All are subject to change. Annual funding for the program beyond 2017 has not been determined; however, the cost and time to complete the program were recently estimated to exceed the previous estimate by about $2 billion and 2 years.[2]

- DERP is a very broad program encompassing funding for early site investigation and characterization through funding for remediation, including, by definition, chemical warfare agents and chemical munitions. DERP funds are commonly used for conventional munitions cleanup at RCWM sites for site characterization and remediation up to the point of the identification of RCWM munitions. Once RCWM is discovered, DERP funding can no longer be used and funding from CAMD,D is then used for the assessment and remediation of the RCWM.
- O&M funding, in the context of RCWM, is used for the O&M of active training ranges for each of the military services, including environmental restoration of the ranges. Like funding for DERP, O&M funding is not used to assess and remediate RCWM on active training ranges. Rather, CAMD,D funding is employed.

DOD (and the Army as the RCWM executive agent) adhere carefully to congressional direction on the use of these appropriations. However, the committee notes that the current practice of not allowing the use of DERP and O&M funding for RCWM assessment and remediation might not be a statutory requirement.

**Recommendation 7-2.** The Secretary of Defense should seek a legal interpretation of the perceived prohibition on spending Defense Environmental Restoration Program (DERP) and Operations and Maintenance (O&M) funds to assess and remediate recovered chemical warfare materiel. If it is determined that only Chemical Agents and Munitions Destruction, Defense (CAMD,D) funds may be used for RCWM assessment and remediation, the Secretary should seek legislative authority to change this stricture in order to permit the commingling of DERP, O&M, and CAMD,D funding for these RCWM activities.

Authority and funding for RCWM activities, depending on how and where CWM is discovered, emanate from two OSD and two Army Secretariat offices. The two OSD offices are the ASD(NCB) for CAMD,D and the DUSD(I&E) for DERP and O&M. The two Army Secretariat offices are the Assistant Secretary of the Army for Acquisition, Logistics, and Technology [ASA(ALT)] for CAMD,D and the Assistant Secretary of the Army for Installations, Energy and Environment [ASA(IE&E)] for DERP and O&M, as shown in Figure S-1. Thus, there is no single advocate for the program. In addition, at present the NSCMP must compete annually for funding from the CAMD,D budget account, which is also the source of funding for the much larger chemical stockpile destruction program. Not only have estimates for completing the stockpile program been extended to 2021-2023, they have also increased significantly.[3] As the stockpile program nears completion, the CAMD,D account can be expected to come under increasing pressure for significant reductions, if not total elimination. The long-term funding and oversight issues inherent in a growing and enduring RCWM remediation mission need to be addressed and an enduring funding stream established that is integrated with other enduring environmental remediation programs.

**Recommendation 7-3.** The Office of the Secretary of Defense and the Army should each select a single office to champion and fund remediation of all RCWM.

Of the known large burial sites, only at Redstone Arsenal (RSA) has an effort been made to assemble a comprehensive inventory of suspected buried munitions and sites (see Chapter 5). The remediation of buried munitions (including CWM) is not clearly defined, in part because the inventory of suspected buried munitions and sites is incomplete. The lack of an accurate inventory of the buried munitions and of a reliable cost estimate for the RCWM program limits the ability of the DUSD(I&E) and the comptroller in consultation with the ASD(NCB) and the Army to establish budget requirements and draw up an appropriate funding plan for a new and separate RCWM account.

**Recommendation 7-4a.** The Secretary of Defense should, as a matter of urgency, increase funding for the remediation of chemical warfare materiel to enable the Army to complete the inventories of known and suspected buried chemical munitions no later than 2013 and develop a quantitative basis for overall funding of the program, with updates as needed to facilitate accurate budget forecasts. Pending establishment of a final RCWM management structure, this task should be assigned to the director of the CMA as chair of the provisional RCWM integrating office.

**Recommendation 7-4b.** As the RCWM executive agent, the Secretary of the Army should establish a policy that addresses all aspects of the remediation of chemical warfare materiel and that prioritizes remediation requirements, and the Secretary of Defense should identify a new long-term funding source to support the program.

[2]U.S. Army Element, Assembled Chemical Weapons Alternatives, press release "Department of Defense approves new cost and schedule estimates for chemical weapons destruction plants." Aberdeen Proving Ground, Md., April 17, 2012.

[3]U.S. Army Element, Assembled Chemical Weapons Alternatives, press release "Department of Defense approves new cost and schedule estimates for chemical weapons destruction plants." Aberdeen Proving Ground, Md., April 17, 2012.

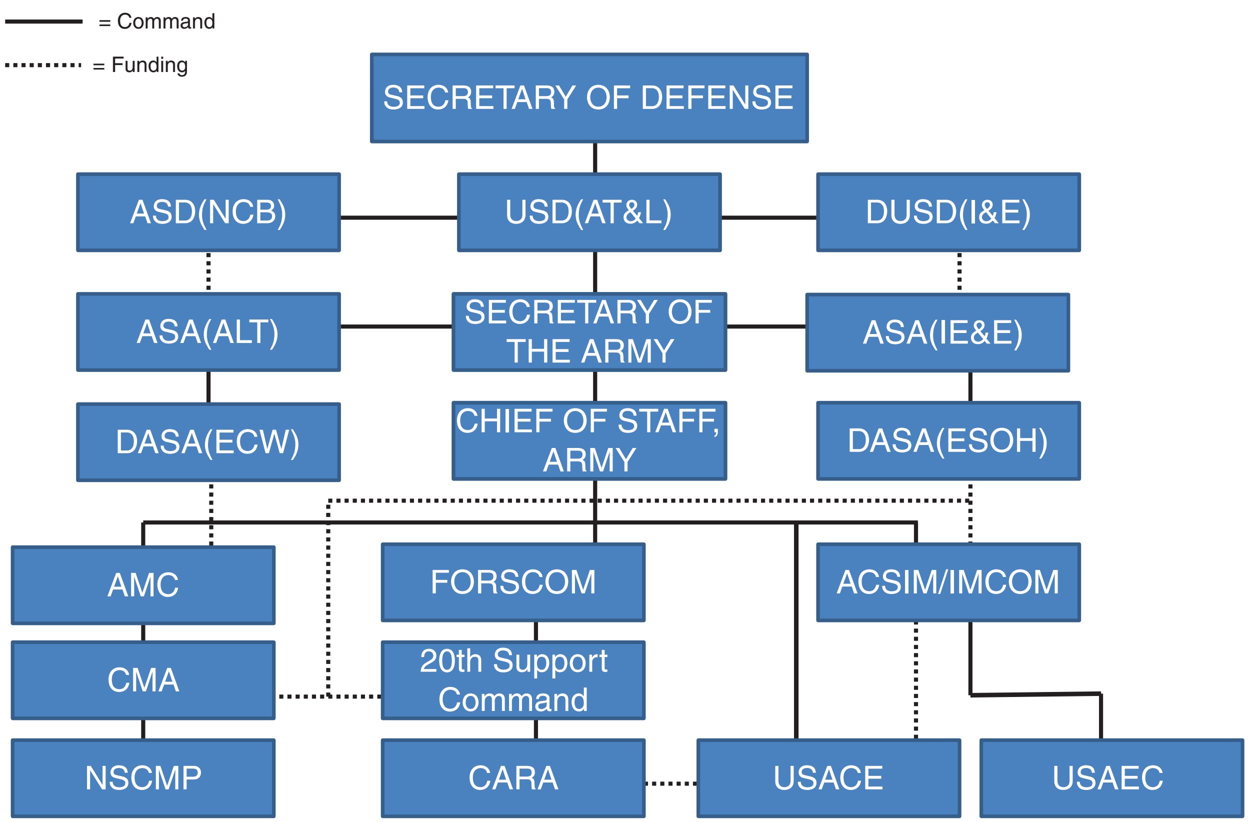


FIGURE S-1 Current organization for policy, oversight, and funding for RCWM. DASA(ECW), Deputy Assistant Secretary of the Army for Elimination of Chemical Weapons; DASA(ESOH), Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health); AMC, U.S. Army Materiel Command; FORSCOM, Forces Command (U.S. Army); ACSIM/IMCOM, Assistant Chief of Staff, Installation Management/Installation Management Command (U.S. Army); USAEC, U.S. Army Environmental Command.

**Recommendation 7-5.** The Deputy Under Secretary of Defense for Installations and Environment and the Under Secretary of Defense, Comptroller, in coordination with the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Programs and the Army, should proceed immediately to establish a separate budget account for recovered chemical warfare materiel, as directed by the memorandum of the Under Secretary of Defense for Acquisition, Technology and Logistics dated March 1, 2010, and to ensure that funding requirements for the recovered chemical warfare materiel program are included in the FY 2014-2018 Program Objectives Memorandum (POM).

### Organization for Execution

At the OSD level, two major offices, ASD(NCB) and DUSD(I&E), work on RCWM policy and funding matters (Figure S-2). Within the Department of the Army, two secretariat (i.e., policy) offices—ASA(IE&E) and ASA(ALT)—have been very involved with the RCWM program. The Army would assign responsibility to ASA(IE&E), which has enabled the Army to begin setting up a long-term organization to lead the program. At the Army staff level, the main player is the ACSIM office, and its field operating agency, IMCOM. The committee judges that the ACSIM and IMCOM are performing a creditable job of integrating the Army's cleanup requirements, including DERP and CAMD,D, and presenting them in a defendable POM and budget. Some remaining duplication of effort on the part of IMCOM's Army Environmental Command (AEC) and the USACE merits the Army's attention.

**Recommendation 7-6.** The Army should examine the RCWM roles and responsibilities to determine where money can be saved by eliminating duplication of functions, such as those of the Army Environmental Command and the U.S. Army Corps of Engineers.

### Provisional RCWM Integrating Office

The provisional RCWM integrating office (IO) coordinates emergency response and planned RCWM projects for DOD in keeping with the Army's roles as RCWM executive agent. The member organizations are shown as the integrated product team in Figure S-2. The provisional RCWM IO has conducted some meetings while it awaits formal approval by

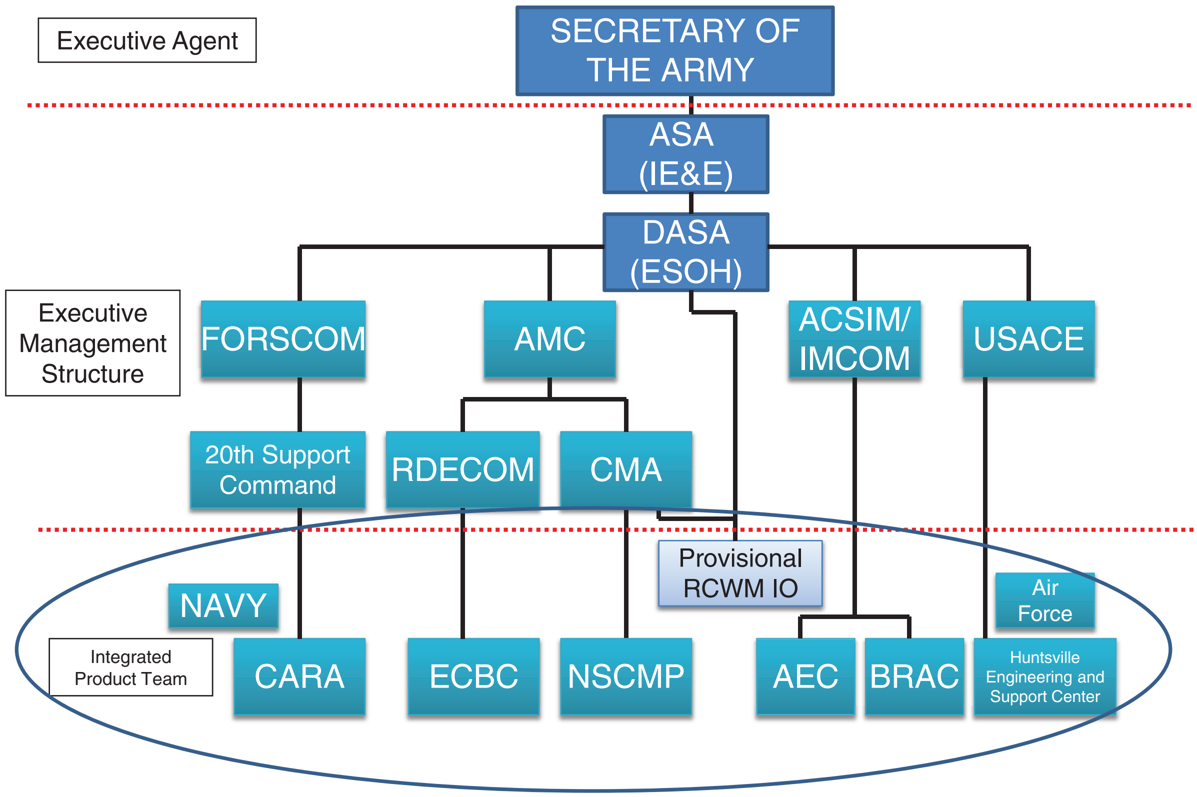


FIGURE S-2 RCWM Army execution structure. RDECOM, Research, Development, and Engineering Command; BRAC, base realignment and closure. SOURCE: Adapted from the presentation of J.C. King to the committee on September 26, 2011.

the Army and DOD. The committee considers the establishment of the provisional IO to be a step in the right direction in the overall management of the program but has some significant concerns. In brief, the provisional RCWM IO leader lacks directive authority, is placed too low in the Army organization, and is too junior in rank to be held accountable for the execution of the RCWM program.

The CMA's NSCMP and the USACE's Huntsville Engineering and Support Center are key players for the execution of both emergency responses and planned RCWM projects. NSCMP has depth in project planning and technology utilization, while USACE has hands-on technical skills in RCWM project management, construction management, and contract management. The committee is also concerned that CMA may not have a sustaining role in the Army once the stockpile program winds down in the next several years, leaving NSCMP without an enduring higher authority to report to. These factors bring significant risk and uncertainty to the RCWM program, raising the possibility that emergency responses or large planned remediation projects will not have adequate or sustainable management and funding support.

**Recommendation 7-7.** The Army should reexamine the roles and responsibilities of Edgewood Chemical Biological Center and the Chemical Biological Radiological Nuclear (Enhanced) Analysis and Remediation Activity with the objective of eliminating any overlapping functions, particularly on emergency response activities.

**Recommendation 7-8.** The Army should review the long-term requirements for executing the RCWM program with the objective of making organizational changes that will eliminate duplication of effort and ensure sustainable organizational integrity.

## ORGANIZATIONAL ALTERNATIVES

Based on the findings and recommendations above, the committee evaluated two significant organizational changes to the baseline organization (Figure S-2) to improve the efficiency, effectiveness, and accountability of the RCWM program and its leadership.

In light of the committee's conclusion that the IO and its leadership lack directive authority and are placed too low in the Army organization, the first change addresses the provisional IO and the accountability and effectiveness of its leadership. As discussed in Chapter 7, the grade of the RCWM IO leader, GS-15, is too low to allow recruitment of an individual who can effectively lead the program. The com-

1. SINGLE ACCOUNT FOR SITE REMEDIATION (Would comingle DERP, RCWM, & O&M)
2. INTEGRATED PROGRAM PLAN AND BUDGET (RCWM)
   a. Required RCWM emergency response infrastructure
   b. Research and Development, technology, procurement
   c. Planned remediation support
   d. Response to emergency response contingencies
3. INTEGRATED DOD PRIORITY LIST FOR POTENTIAL RCWM REMEDIATION
4. COORDINATED FIVE YEAR PROGRAM PLAN AND BUDGET ESTIMATE FOR REMEDIATION OF IDENTIFIED PRIORITY RCWM SITES

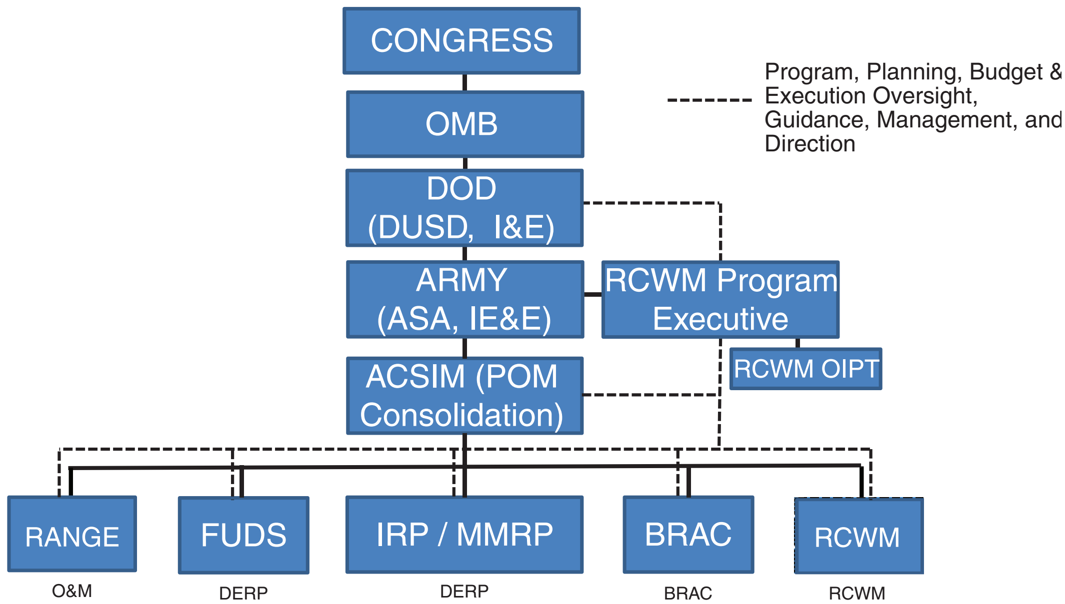


FIGURE S-3 RCWM program future funding.

mittee further concluded that the position should be upgraded to a civilian SES or a military general officer.

**Recommendation 7-9.** The Secretary of the Army should establish a new position at the level of the Senior Executive Service (civilian) or a general officer (military) to lead the RCWM program. The person who fills this position would report directly to the Assistant Secretary of the Army (Installations, Energy and Environment). The Secretary should delegate full responsibility and accountability for RCWM program performance to this person, including for programming, planning, budgeting, and execution and for day-to-day oversight, guidance, management, and direction of the program.

As previously recommended, the RCWM program requires a leader at the civilian SES or military general officer level who is assigned overall responsibility and accountability for program performance. This person would have directive authority over other program participants within the Army and, through agreements with the other Services, within appropriate RCWM activities of the Air Force and Navy and would establish, chair, and direct a new overarching integrated product team (OIPT) for RCWM.

The committee sought a reporting level within the Army at which this program executive would be most effective and concluded that the best reporting relationship would be for the program executive to report directly to the ASA(IE&E), giving him or her the organizational reach and authority needed to lead the program effectively. The new RCWM OIPT, composed of higher-level representatives of the organizations in the current provisional RCWM IO and appropriate members from OSD, would replace the provisional RCWM IO. OIPT members should be fairly senior in grade, knowledge, and experience, and their parent organizations should give them authority to make decisions (see Figure S-3).

The second organizational change evaluated by the committee involved the organizations executing the RCWM program. The committee evaluated several alternatives for the long-term reporting relationship for the NSCMP and selected one that would provide continuity of program execution, cost-effective synergy, and an enduring reporting organizational relationship for NSCMP.

**Recommendation 7-10.** The Army should realign the nonstockpile chemical materiel program from the Army Materiel Command/Chemical Materials Agency to the U.S. Army

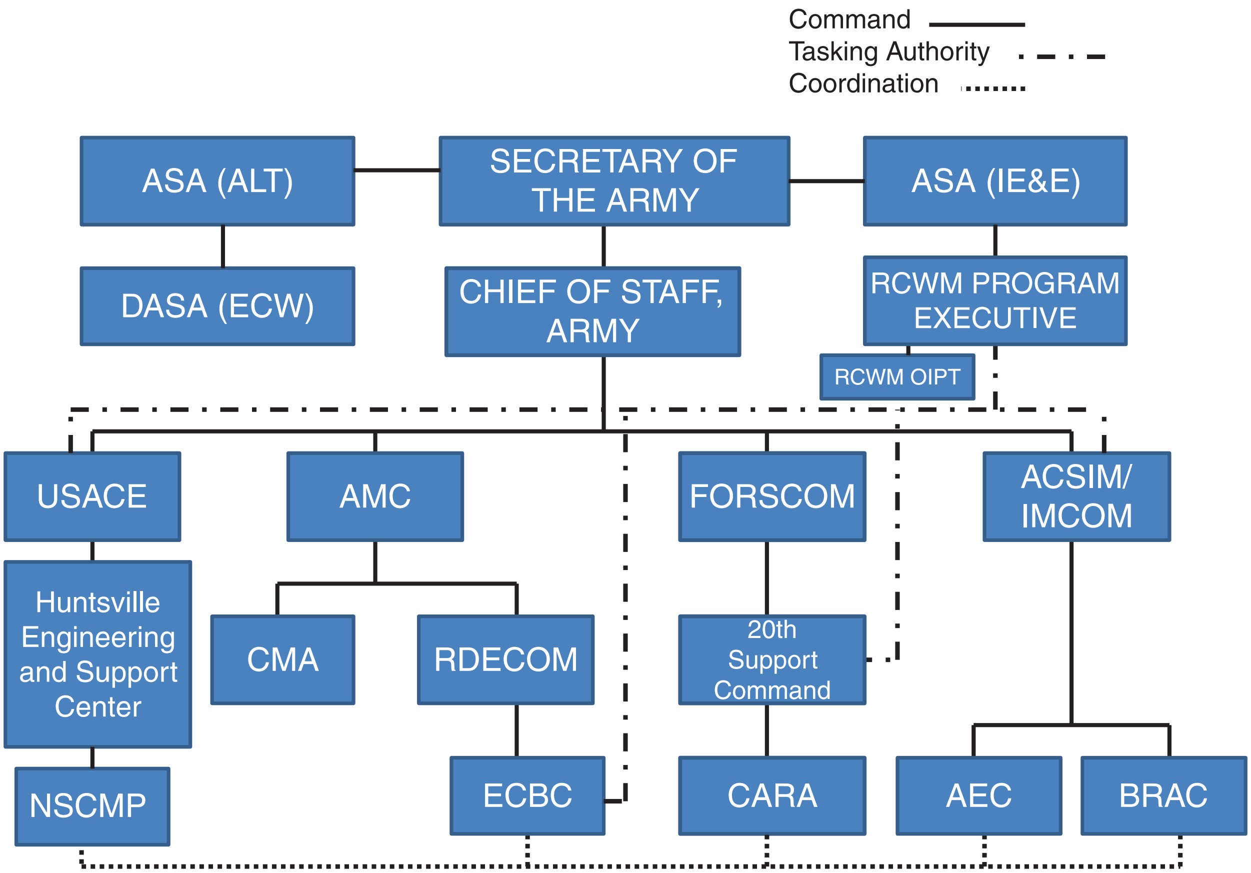


FIGURE S-4 Army RCWM organization and authority recommended by committee. NOTE: Tasking authority is the authority of the RCWM Program Executive with respect to day-to-day oversight, guidance, management, and direction of Army elements on all RCWM matters, including program and budget planning and allocation, and program and budget execution and performance by the RCWM commands, agencies, and organizations.

Corps of Engineers Huntsville Engineering and Support Center.

**Recommendation 7-11.** To provide for an effective transition, the new program executive should enter into a memorandum of understanding with the Commander of the U.S. Army Corps of Engineers and the Army Materiel Command/Chemical Materials Agency outlining the reporting ladder and transition plan for the realignment of the non-stockpile chemical materiel program.

The committee believes that the assignment of an SES civilian or general officer RCWM program executive with full authority and responsibility for planning, programming, budgeting, and execution for the RCWM program, who has direct access to and visibility at the highest levels of the Department of the Army and the OSD secretariat is absolutely critical to the future success of the program. It will be vital to the effectiveness of the program executive and the program that the executive possess the authority and ability to exercise oversight, management, and provide fiscal and operational guidance and direction to the operating elements of the RCWM and control the funds for RCWM, both during development and defense of the program plan and budget, and during the execution of the annual program.

The committee's recommendations for RCWM program and budget planning are illustrated in Figure S-3.

Once the new RCWM program executive position and the recommended OIPT are set up, the Army can begin transitioning the alignment of NSCMP from AMC/CMA to the USACE Huntsville Center.

**Recommendation 7-12.** As a necessary first step the Deputy Under Secretary of Defense for Installations and Environment, the Under Secretary of Defense Comptroller, the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Programs, and the Secretary of the Army should proceed immediately to implement the guidelines contained in the March 1, 2010, memorandum from the Under Secretary of Defense for Acquisition, Technology and Logistics.

The committee's recommended structure for Army RCWM organization and authority is shown in Figure S-4, which incorporates the recommended program executive organization with the civilian SES or military general officer-level RCWM program executive reporting to the ASA(IE&E); the RCWM OIPT under the direction of the RCWM program executive; the tasking authority of the RCWM program executive; and the realignment of NSCMP under the USACE. The figure also delineates the lines of command, tasking authority, and coordination among the various elements of the program.

## REGULATORY ISSUES

The history of the stockpile and non-stockpile programs demonstrates that regulatory concerns and a failure to involve the public can significantly delay implementation and increase costs. Much of the regulatory experience gained in the implementation of the stockpile and non-stockpile programs can be utilized in the remediation of buried CWM to increase the effectiveness and efficiency of the regulatory process. As discussed in Chapter 3, remediations must be done under appropriate federal and state environmental regulations and in compliance with the CWC. These regulations, principally the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA), along with existing Army Military Munitions Response Remedial Investigation/Feasibility Study (MMRP RI/FS) Guidance, govern the recovery of buried CWM. This guidance recommends following the Army's Technical Project Planning process prior to the commencement of field activities.

The committee identified several regulatory issues, including (1) a need for regulatory flexibility, expedited approaches, and risk reduction activities where minimal but sufficient data are available to enable selection of a cleanup technology, (2) consideration of unique circumstances presented by the recovery of buried chemical warfare materiel at active operational ranges, (3) management of remediation wastes using corrective action management units (CAMUs), (4) the need to store hazardous wastes for longer than 90 days under a RCRA corrective action, and (5) identifying regulatory approval mechanisms for the use of explosive destruction technologies to destroy RCWM.

The committee also noted the importance of public participation in Army policy decisions regarding RCWM remediation. Public involvement is embedded in both RCRA and CERCLA, in the Emergency Planning and Community Right-to-Know Act (EPCRA), and in DOD and Army regulations and policies. For the remediation project at Spring Valley in Washington, D.C., for example, partnering and planning were shown to be key to minimizing unnecessary delay and costs. Findings and recommendations related to regulatory issues and public involvement can be found in Chapter 3.

## CASE STUDY: REDSTONE ARSENAL

During the course of this study, the committee was made aware of the existence of what is arguably the largest and most complex RCWM site in the United States (in terms of the quantity and variety of materiel, regulatory issues, and existing use)—namely, Redstone Arsenal (RSA) in Huntsville, Alabama. RSA provides an excellent example of a site where, to paraphrase the committee's Statement of Task, supporting technologies and operational procedures may not be sufficient, targeted research and development may be needed, and coordination among existing organizations involved in RCWM remediation may need to be improved. The committee used RSA as a case study to illustrate the technological and operational challenges and community relations issues that the Army will face in remediating large CWM sites. Findings and recommendations concerning the application of regulatory issues to the special case of RSA may be found in Chapter 5.

# 1

# Introduction

A notable achievement by the U.S. Army as of early 2012 is that 90 percent of the legacy chemical weapons and other chemical warfare materiel (CWM) from the Second World War and cold war eras and then stockpiled by the United States have been safely destroyed.[1] Whatever cumulative risk had been posed by the existence of this CWM to communities surrounding the six military sites where it was guarded and safely maintained since the mid-twentieth century is now zero. Within a decade, the remaining 10 percent of the stockpiled CWM at two other military sites will likewise no longer exist. This monumental mission, spanning several decades, has been and continues to be accomplished safely in compliance with stringent federal and state environmental and health and safety requirements.

While the initial mission is phasing out after having overcome various scientific, regulatory, and political obstacles, an important and perhaps equally challenging mission remains that will become increasingly important over the next two decades. The international Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons, known informally as the Chemical Weapons Convention (CWC) treaty (CWC, 1997), to which the United States is a signatory, and U.S. legislation pertaining to such materiel required destruction only of CWM that was in storage (i.e., stockpiled), former production facilities that have since also been demolished, and CWM that was incidentally found and recovered from burial sites in various locations throughout the United States (so-called "small finds") (EPA, 1980). However, since the First World War, the existence and locations of hundreds of thousands of other individual CWM items that remain buried have been identified and inventoried. Much of this materiel had been buried either after open burning or, sometimes, after being fired in munition ranges and was not considered part of the declared "stockpile" for CWC compliance purposes. These buried CWMs pose a huge challenge to the nation and the Department of Defense (DOD) as the need for usable land encroaches on these burial sites.

Approximately 250 sites in 40 states, the District of Columbia, and 3 territories are known to have or are suspected of having buried CWM, including some sites where large quantities are located (DOD, 2007). Nonetheless, much of the buried CWM is likely to continue to consist of small finds that necessitate continuation of the Army's ability to transport treatment systems to such locations for their destruction (this rapid, short-term response is often called the "firehouse" function). Of greatest concern are sites in residential areas—the now urban Spring Valley section of Washington, D.C., and large sites on legacy military installations such as Redstone Arsenal, Alabama, where over 5 miles of disposal trenches have been identified. In general, large quantities of buried CWM are collocated with active or retired munition firing ranges or commingled with other hazardous substances and wastes that are routinely being cleaned up by the DOD's Military Munitions Response Program (MMRP) and other remediation programs.

Neither the CWC treaty nor existing CWM domestic legislation requires recovery of buried CWM. Thus, the decision to contain the CWM in place or to recover it, at which point it becomes recovered chemical warfare materiel (RCWM) and is subject to the international requirement that it be destroyed, is an environmental remediation decision driven by federal and state environmental law. Such decisions are inherently site-specific and require consideration of the unique circumstances of the individual site, such as risk, the maturity and appropriateness of the technology that could be used, the presence of other toxic chemicals, existing and future land use (e.g., active installation or range), and the costs. The cost of characterization, remedy selection, and remediation of these large buried CWM sites is likely to be

[1]See graph at http://www.cma.army.mil/aboutcma.aspx#. Accessed April 10, 2012.

several billion dollars.[2] Although it is impossible to predict at this time the ultimate cost of completely remediating all CWM buried during the last century, the DOD should initially plan for a multi-billion-dollar program lasting many years. This estimate should be revised as more information about the quantities and condition of the CWM to be recovered becomes available.

The Army's remediation of RCWM is becoming a very large program, greatly exceeding the existing smaller munition and hazardous substance cleanup programs. The organizational structure of the Army achieves its original mission of handling ad hoc CWM finds. Numerous organizations within the Army, as well as several offices within DOD, are involved in remediating existing RCWM sites. At present, different offices design and acquire the specialized CWM destruction and other equipment, and other offices operate the equipment; another unit transports the equipment and personnel. Moreover, various offices within the U.S. Army Corps of Engineers (USACE) and the Offices of the Secretary of the Army and of the Secretary of Defense (OSD) play significant roles in setting policy, obtaining federal funding, prioritizing sites for remediation, participating in the selection of remedies, and directing the overall cleanup.

Because of the imminent dramatic change in mission scope and the recognized complexity of the decision making and organizational issues involved, the Army asked the National Research Council (NRC) to examine this emerging mission with a view to improving its efficiency. In addition to examining the organizations and roles and the funding, the NRC was asked to review the technology tools used in the detection, excavation, packaging, storage, transportation, assessment, and destruction of buried CWM now available and those that may be needed in the future.

The committee was provided the latest information available and was given unfettered access to the full range of personnel involved in the process (including briefings and other communication with regulators). The committee benefited from the insight and candor provided by Army and DOD staff, contractors, and other stakeholders.

## THE NATURE OF THE RECOVERED CWM PROBLEM

The mission of the U.S. Army's Non-Stockpile Chemical Materiel Project (NSCMP) is "to provide management and direction to the United States Department of Defense for the disposal of non-stockpile chemical materiel in a safe, environmentally sound, cost-effective manner, while ensuring compliance with the Chemical Weapons Convention."[3] To this end, the NSCMP has pursued four mission areas:

1. Destruction of binary chemical warfare materiel;
2. Destruction of former chemical weapons production facilities;
3. Destruction of miscellaneous chemical warfare materiel covered by the CWC—for example, chemical samples, empty ton containers, and metal parts; and
4. Destruction of recovered chemical warfare materiel [chemical agent identification sets (CAIS)[4] and chemical weapons].

Mission areas 1, 2, and 3 have been completed. Efforts in mission area 4 have been under way since the establishment of NSCMP and are expected to continue for the foreseeable future.

Over the past two decades the Army has prepared several reports addressing DOD's potential liabilities for locating, excavating, and destroying decontaminated buried CWM and for managing any associated contaminated soil or groundwater. Cost estimates for these activities have varied widely because multiple agencies have been creating cost estimates using different assumptions about the number of sites needing remediation, the amount of CWM to be excavated and destroyed or decontaminated at each site, and the amount of contaminated soil or groundwater to be managed at each site. The total estimated 30-year life-cycle cost of the RCWM program ranges from a low of $2.5 billion to a high of $17 billion (DOD, 2007).

As shown in Figure 1-1, past mission area 4 activities were carried out in five areas:

- Emergency response to assess or destroy RCWM;
- Planned responses and support to planning and permitting activities;
- Research and development activities primarily related to the Army's explosive destruction system (EDS), explosive destruction technologies (EDTs), and portable isotopic neutron spectroscopy (PINS);
- Assessment support for the U.S. Army's Chemical Materials Agency (CMA) and the Assembled Chemical Weapons Alternatives (ACWA) Army element; and
- Assessment support at overseas locations.

There are planned response activities in Alaska, South Dakota, Utah, Alabama, Florida, and Arkansas. Some of the sites listed, along with sites not shown here (see following section), are expected to contain substantial quantities of buried CWM, the remediation of which might be advanced through the findings and recommendations of this report.

More detailed information on the specifics of activities in all four mission areas is presented in Figure 1-2.

[2]Deborah A. Morefield, Environmental Management, Office of the Deputy Under Secretary for Installations and Environment Department of Defense, "Remediation Operations from an OSD Installations and Environment Perspective," presentation to the committee on November 2, 2011.

[3]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Status and Update," presentation to the committee on September 27, 2011.

[4]Chemical agent identification sets (CAIS) were produced in large quantities for training purposes from 1928 through 1969. A CAIS holds several glass vessels, each containing a blister or choking agent.

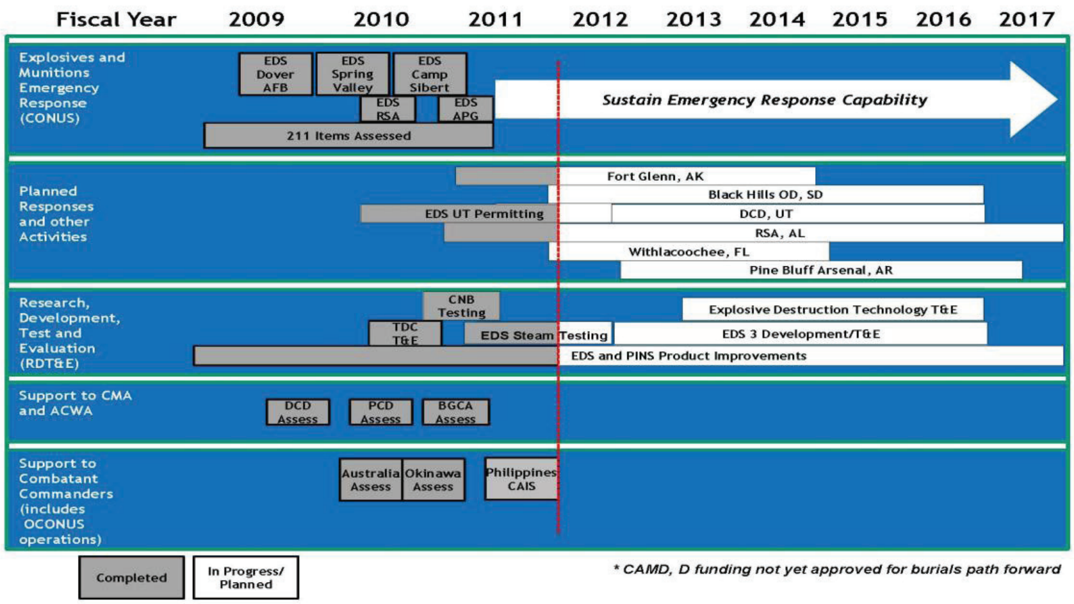


FIGURE 1-1 NSCMP mission area 4 past and projected schedule. RSA, Redstone (Alabama) Arsenal; APG, Aberdeen Proving Ground; OD, ordnance depot; T&E, testing and evaluation; CNB, CN tear gas mixed with carbon tetrachloride and benzene; TDC, transportable detonation chamber; PCD, Pueblo (Colorado) Chemical Depot. SOURCE: Personal communication from Laurence G. Gottschalk, Project Manager for Non-Stockpile Chemical Materiel, to Nancy Schulte, NRC study director, March 7, 2012.

Figure 1-2 shows a wide range of information, including the following:

- States with known or possible buried CWM;
- Locations of past or planned NSCMP activities under all four mission areas, including assessment; destruction of agent, facilities, and munitions; and research and development; and
- The number and types of CWM destroyed in past operations or for which destruction is planned.

## Non-Stockpile Chemical Warfare Material in the United States

CWM is defined by the DOD as follows:

> Items generally configured as a munition containing a chemical compound that is intended to kill, seriously injure or incapacitate a person through its physiological effects. CWM includes V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other-than-munition configurations; and certain industrial chemicals (e.g., hydrogen cyanide (AC), cyanogen chloride (CK), or carbonyl dichloride (called phosgene or CG)) configured as a military munition. (DOD, 2007)

The Army's 2007 RCWM Program Implementation Plan lists 249 known or suspected CWM sites in 35 states, the District of Columbia, Guam, and the U.S. Virgin Islands (DOD, 2007). They include active environmental restoration sites, formerly used defense sites (FUDS), base realignment and closure (BRAC) sites, and active military ranges (DOD, 2007, Tables B-1, B-2, and B-3).[5] A 2011 estimate by the NSCMP raises to 40 the number of states with known or possible buried CWM.[6]

The sites in the Army inventory where remediation work is planned during the FY 2012-2018 budget cycle are listed in Table 1-1. These include active, BRAC, and FUDS sites at which site investigations and/or cleanup work are expected to take place based on the Army's current understanding of site-specific conditions.[7]

Known and suspected CWM sites include former manufacturing facilities, former demilitarization operations, former storage areas, disposal trenches and pits, chemical warfare demonstration areas, test sites, and training facilities. An early overview of the possible attributes of buried CWM is found in the Survey and Analysis Report, second edition, produced by the Program Manager for Chemical Demilitarization (U.S. Army, 1996). The executive summary of that report says, "although documentation surveys, interviews,

[5]There are also 699 locations for which there exists only anecdotal evidence for the presence of CWM.

[6]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Status and Update," presentation to the committee on September 27, 2011.

[7]Personal communication from Bryan M. Frey, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, Department of the Army, to Nancy Schulte, NRC study director, February 3, 2012.

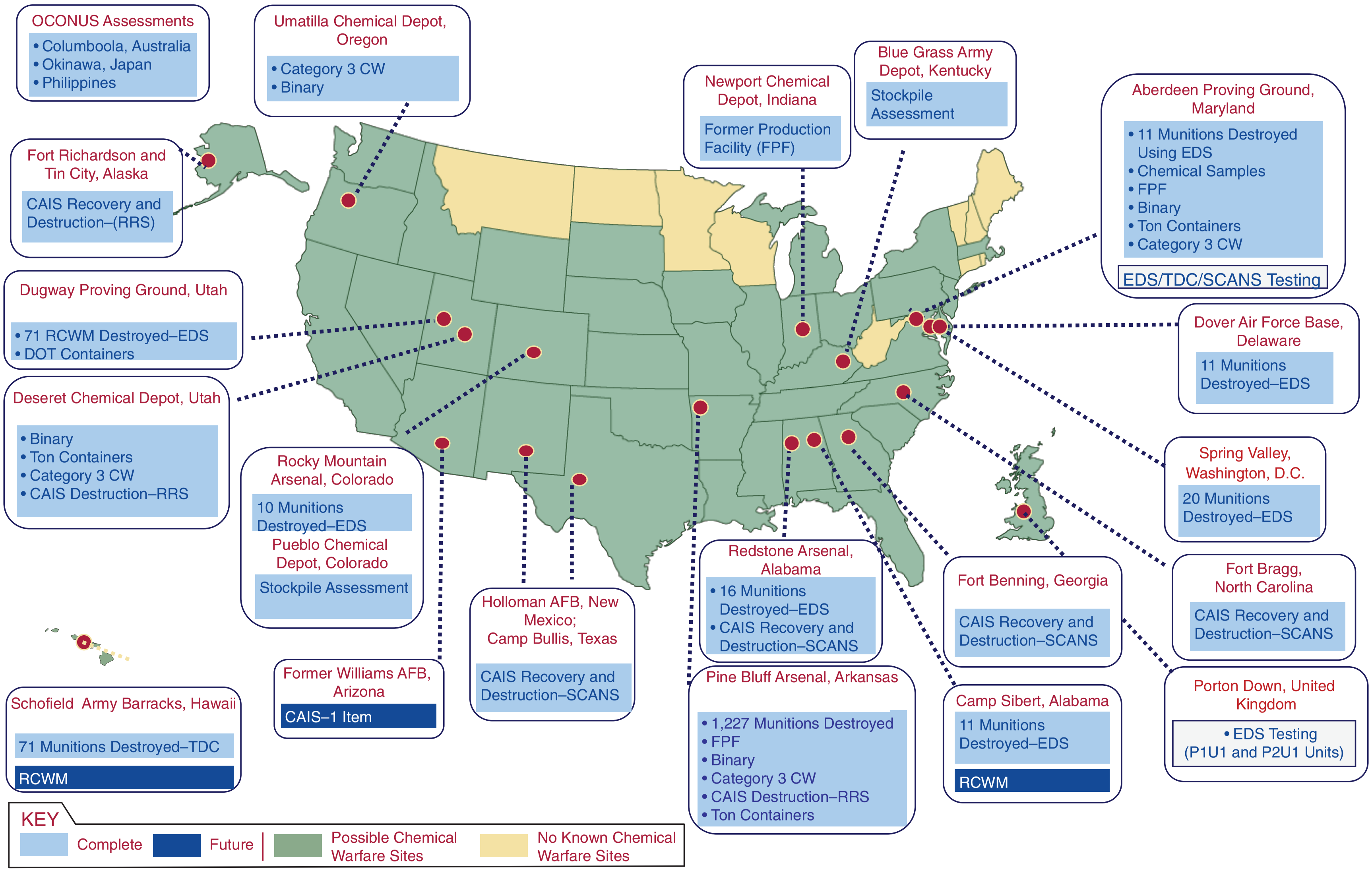


FIGURE 1-2 Past and future mission areas 1-4 activities; locations and munitions destroyed. RRS, rapid response system, DOT, Department of Transportation; SCANS, single (chemical agent identification set) accessing and neutralization system; FPF, former production facility. SOURCE: Laurence G. Gottschalk, Project Manager for Non-Stockpile Chemical Materiel, presentation to the committee on September 27, 2011.

TABLE 1-1 Inventory of Army RCWM Sites

| Name of Installation | Type of Installation |
|---|---|
| Redstone Arsenal, Ala. | Active |
| Pine Bluff Arsenal, Ark. | Active |
| Aberdeen Proving Ground, Md. | Active |
| Dugway Proving Ground, Utah | Active |
| Schofield Barracks, Hawaii | Active |
| Deseret Chemical Depot, Utah | Active |
| Pueblo Chemical Depot, Colo. | BRAC |
| Spring Valley, Washington, D.C. | FUDS |
| Camp Sibert, Ala. | FUDS |
| Former Schilling AFB, Kans. | FUDS |
| Fort Glenn, Alaska | FUDS |
| Withlacoochee, Fla. | FUDS |
| Black Hills, S.Dak. | FUDS |

SOURCE: Bryan M. Frey, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, Department of the Army, briefing to the committee on January 18, 2012.

and site visits have been conducted, much information concerning buried CWM remains unknown."

The little that is known about the nature of the buried CWM at each site is summarized in that report as follows:

> The CWM that may be found at these potential buried CWM sites includes CAIS, mortar rounds, aerial bombs, rockets, projectiles, and storage containers of agent in cylinders, 55-gallon drums, and ton containers (TCs). Buried chemical agents include, but are not limited to, blister agents [mustard (H) and lewisite (L)], nerve agents (GA, GB, and VX), blood agents [hydrogen cyanide (AC) and cyanogen chloride (CK)], and choking agent [phosgene (CG)].

More up-to-date information about the quantities of CWM at each site, the agents that may be contained in the CWM, and the condition of the CWM items is being developed by the Army site by site using historical records and documents, visual observation of exposed materials found at sites, and interviews with retired Army personnel who have knowledge of chemical materiel at specific sites.

## Study Context

The Army's efforts to demilitarize chemical weapons are transitioning from programs designed to destroy smaller finds subject to the emergency response function, former production facilities, and individual CWM that are periodically discovered in areas where exposure may occur, to a program of CWM remediation that continues to implement an emergency response function but also recovers and destroys or provides containment of CWM that is present in pits and trenches at identified sites. This effort will occur amidst a complex web of environmental regulations and guidance, which are also examined in this report.

Also discussed in this report are the capabilities the NSCMP and the Edgewood Chemical Biological Center/Chemical Biological Applications and Risk Reduction (ECBC/CBARR) program have been developing and implementing for conducting emergency responses and for supporting remediation efforts of substantial size. Examples of the latter type of effort include those at Spring Valley in Washington, D.C., and Camp Sibert in Alabama. Thus, a critical mass of technology and experience now exists that can be applied to remediation of larger sites that contain buried chemical weapons.

State and federal regulators have taken note of the regulatory situation and the availability of technology and expertise, and they are advocating moving forward with remediation efforts. A state regulator involved with the Redstone Arsenal in Alabama pointed out the following:

- A combination of expertise, technology, personnel exists;
- Growth of the Redstone area will require property reuse;
- Groundwater is known to impact areas in and around disposal sites;
- It may take several years to develop, design, and implement remedies that adequately reduce the risks to human health and the environment associated with the identified exposure pathways[8]; and
- If you never start, you will never finish.[9]

Other factors have been identified as well:

- Many military sites have a combination of buried chemical weapons, buried conventional weapons, industrial pollutants, and contaminated soil and groundwater. To clean up such a site, the project managers will need to ensure that their cleanup capabilities encompass the complete range of potential hazards, including CWM, conventional ordnance, and environmentally contaminated media (soil, water, and air). According to the CWC, once an item has been determined to fall into one of the categories of chemicals covered by the treaty, steps must be taken to declare and destroy it.[10]

[8]An exposure pathway is the route of contaminants from the source of contamination to potential contact with a medium (air, soil, surface water, or groundwater) that represents a potential threat to human health or the environment).

[9]Stephen A. Cobb, Chief, Government Hazardous Waste Branch, Land Division, Alabama Department of Environmental Management, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

[10]Personal communication from Lynn Hoggins, Director, CBW Treaty Management, Office of the Deputy Assistant Secretary of Defense, Nuclear Chemical, Biological, to Nancy Schulte, NRC study director, January 6, 2012.

- Once a military facility is no longer active, the forces that push it into non-military control can become intense. Local governments will want the property to become subject to property tax. Developers will want parts of the property to become available for residential or commercial development. Prior to use for these purposes, buried chemical weapons, along with conventional weapons and contaminated soil, must be removed, and contaminated groundwater must be appropriately managed.
- Mechanisms have been established for providing the funding for remediation efforts. See Chapter 6 for a discussion of this topic.

To facilitate the increased emphasis on remediation of buried chemical weapons in an efficient and cost-effective manner, the roles and responsibilities of many of the relevant organizations within the Army and DOD may need to change. This report addresses that issue.

### Statement of Task

The National Research Council (NRC) will establish a committee to

- Survey the organizations involved with remediation of suspected CWM disposal sites to determine current practices and coordination. At a minimum, the NRC will seek briefings from the following offices/organizations: Deputy Assistant Secretary of the Army, Environment, Safety and Occupational Health; Deputy Assistant Secretary of the Army for the Elimination of Chemical Weapons; Chemical Materials Agency; Corps of Engineers Huntsville, Engineering and Support Center; Chemical Biological Radiological Nuclear (enhanced) Analysis and Remediation Activity; Edgewood Chemical and Biological Center; and other directly involved entities identified as playing a role in CWM burial site remediations.
- Review current supporting technologies for clean-up of CWM sites. This review would encompass excavation equipment and techniques, containment facilities, filtering techniques, personal protective equipment, monitoring, assessment, packaging, storage, transportation (on-site and intrastate), destruction technologies, and waste storage and disposal.
- Identify potential deficiencies in operational areas based on the review of current supporting technologies for clean-up of CWM sites and develop options for targeted research and development efforts to mitigate potential problem areas.
- Suggest means by which the coordination among organizations involved in conducting investigations, recoveries, and clean-up activities concerning non-stockpile CWM can be made more efficacious and effective.

### Addressing the Statement of Task

Chapter 1 has provided an overview of the issues surrounding current programs and plans for the demilitarization of non-stockpile chemical materiel and the remediation of sites where such materiel is located. A description of the contents of the remaining chapters of this report follows. Each chapter examines a different aspect of the overall effort and how it impinges on the transitioning of the current program activities to larger-scale remediation efforts to recover CWM.

Chapter 2 delves into the very complicated web of organizations in which NSCMP functions. The history of the chemical demilitarization program, including the establishment of NSCMP, is described briefly. The numerous DOD and Department of the Army offices and organizations with which the NSCMP is involved are listed and described. The current reporting relationships and the flow of funding to NSCMP are described. Finally, the management practices employed by NSCMP to carry out its RCWM remediation mission are discussed.

Chapter 3 summarizes the regulatory framework for NSCMP's RCWM program. The need to remediate known or suspected chemical weapon burial sites—especially the larger sites—has become more urgent in recent years. The factors responsible for this situation are examined in this chapter. The CWC, the treaty governing all activities involving chemical weapons, is described. The impact of the two main relevant U.S. regulatory programs, RCRA (EPA, 1976) and CERCLA (EPA, 1980), is briefly described. Finally, the roles and responsibilities of NSCMP with respect to public involvement are discussed. Regulatory background is provided in Appendix D.

Chapter 4 summarizes the technologies that are currently owned by or are available to NSCMP and closely related organizations for the range of activities involved in locating a buried chemical munition, bringing it to the surface, assessing the munition, and destroying the munition. Recent remediation activities that have employed these technologies, recent advances in technology, and ongoing research and development activities by NSCMP and others are listed and discussed.

Chapter 5 presents a discussion of several aspects of the possible future remediation of the buried chemical warfare materiel at Redstone Arsenal in Huntsville, Alabama, which is very likely the largest and most complex of the burial sites in the United States. A history of the existence and disposal of non-stockpile chemical materiel at this very large and complex site has been compiled by the Army and is described. Munitions and other items expected to be found are listed. The abilities of technologies currently available to NSCMP to assess the expected recovered items and to destroy or decontaminate them are discussed. Regulatory considerations and a possible organizational partnering concept for the effort at the Redstone Arsenal are described.

Chapter 6 provides recommendations for targeted research and development in the areas of (1) munition assessment, (2) destruction of intact munitions, and (3) decontamination of empty contaminated items.

Chapter 7 presents a review the current NSCMP organizational relationships and flow of funding as presented in Chapter 2, and the impact of the future diminished role of the CMA is discussed. Recommendations for changes in both NSCMP organizational relationships and the flow of funding for remediation of CWM sites are then presented and discussed.

# 2

# Current Policy, Funding, Organization, and Management Practices

## INTRODUCTION

This chapter describes current federal policies, funding programs, and relevant government offices, particularly within the Department of Defense (DOD), that deal with recovered chemical warfare materiel (RCWM) and provides a short review of the management practices that have evolved under the RCWM program. The policy discussion addresses the legislative history of the program along with relevant DOD policy and procedural direction to the DOD components involved. The special nature of the program for RCWM has led to a multilayered DOD bureaucracy to plan, program, budget, and execute the program. With the exception of the Army offices that are specifically focused on safe storage and demilitarization of the remaining chemical weapons stockpile and dealing with non-stockpile remediation activities, the overall organizational construct for the RCWM program within DOD follows the existing mission and functions of the relevant DOD offices. This overlay of requirements for dealing with RCWM on top of the existing DOD organization has led to a set of complex management practices, which are summarized in this chapter.

Whereas this chapter focuses on describing the current policies, funding organizations, and processes for the RCWM program, Chapter 7 will examine the results, future needs, and shortcomings of the current programmatic design. That analysis concludes with comprehensive, forward-looking committee guidance on these aspects of the program for RCWM.

## POLICY DEVELOPMENT

### Historical and Organizational Overview (First World War-2007)

From the beginnings of the U.S. chemical warfare program during the First World War, the destruction and disposal of obsolete or unserviceable chemical warfare agents and munitions was accomplished by open pit burning, land burial, or ocean dumping, and large quantities of U.S. and foreign chemical agents and munitions were destroyed by these methods. In the late 1960s the use of these methods was discontinued owing to health, safety, and environmental concerns, and chemical neutralization and incineration became the preferred alternatives. During the 1970s the United States destroyed several thousand tons of nerve and mustard agents and munitions and expanded its research and development program for the destruction of chemical agents and munitions.

The United States is a signatory of the Chemical Weapons Convention (CWC), an international treaty under the auspices of the United Nations. The requisite number of signatory nations for the CWC to enter into force was reached on April 29, 1997. The national policy of the United States, even before April 29, 1997, and certainly after that date, has been and remains to eliminate the entire U.S. stockpile of chemical weapons as well as, upon recovery, all categories of non-stockpile chemical weapons and materiel.

Before the treaty, the United States had begun a preliminary process of eliminating its declared stockpile of chemical weapons, referred to as the chemical stockpile disposal program (CSDP). The United States had also begun to eliminate classes of nondeclared materiel related to chemical agents and chemical weapons; these became characterized as non-stockpile chemical material (NSCM).

Because of the huge quantity of unitary assembled chemical weapons and the containerized storage of large quantities of chemical agents at the eight storage sites in the continental United States and Johnston Island in the Pacific Ocean southwest of Hawaii, the program manager for chemical demilitarization focused on the demilitarization of the stored weapons stockpile.

The effort for non-stockpile chemical materials focused to a significant extent on that category of non-stockpile items and materiel that were definable and could be counted in much the same sense that the stockpiled weapons could

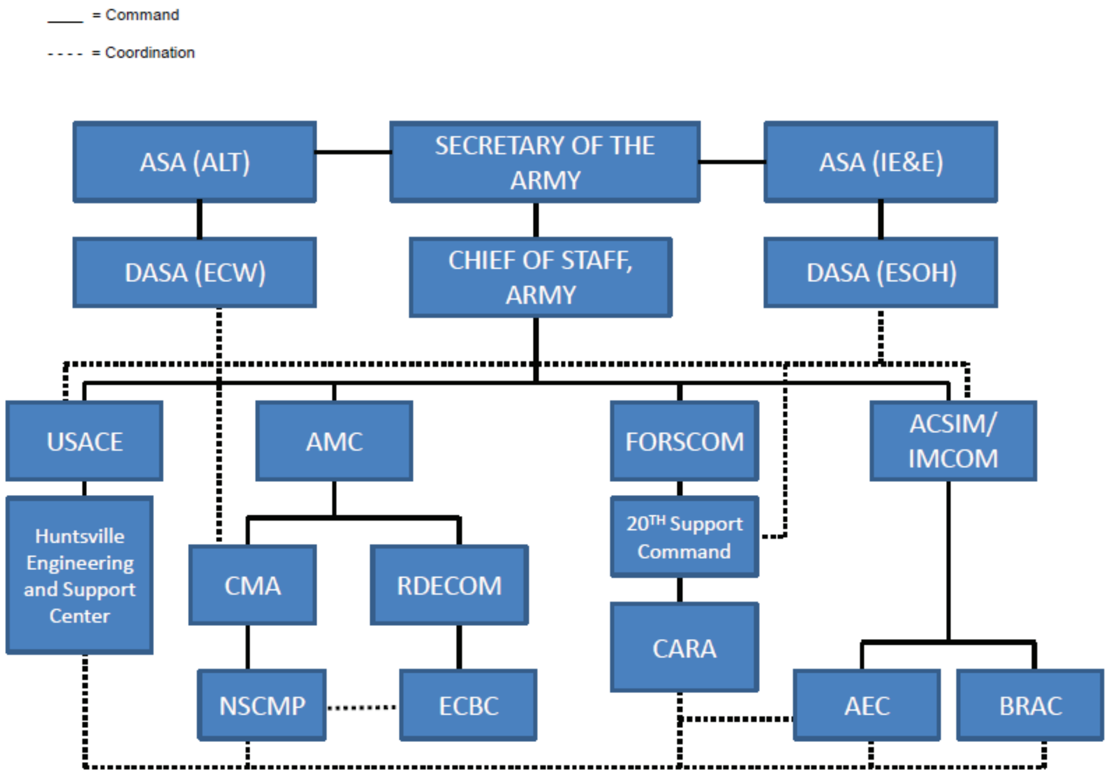


FIGURE 2-1 Current organization for policy, oversight, and funding for RCWM. ASD(NCB), Assistant Secretary of Defense (Nuclear, Chemical, and Biological Defense); USD(AT&L), Under Secretary of Defense for Acquisition, Technology and Logistics; DUSD(I&E), Deputy Under Secretary of Defense for Installations and Environment; ASA(ALT), Assistant Secretary of the Army for Acquisition, Logistics and Technology; ASA(IE&E), Assistant Secretary of the Army (Installations, Energy and Environment); DASA(ECW), Deputy Assistant Secretary of the Army for Elimination of Chemical Weapons; DASA(ESOH), Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health); AMC, U.S. Army Materiel Command; FORSCOM, Forces Command (U.S. Army); ACSIM/IMCOM, Assistant Chief of Staff, Installation Management/Installation Management Command (U.S. Army); CMA, Chemical Materials Agency; NSCMP, Non-Stockpile Chemical Materiel Project; CARA, Chemical Biological Radiological Nuclear (enhanced) Analysis and Remediation Activity; USACE, United States Army Corps of Engineers; AEC, U.S. Army Environmental Command. SOURCE: Prepared by the committee based on presentations received and research of official public information sources.

be defined and counted. There are five defined categories of non-stockpile chemical warfare materiel (NSCWM) (U.S. Army, 2004c):

(1) Binary chemical weapons;
(2) Former production facilities for chemical weapons and related items;
(3) Miscellaneous chemical weapons materiel, such as unfilled munitions and support equipment, for direct use with chemical weapons;
(4) Recovered chemical warfare materiel (RCWM)—buried chemical agent identification sets (CAIS), chemical weapons, and chemical warfare materiel—that were never stored in the stockpile and are found during activities such as range clearing; and
(5) Buried chemical weapons that were disposed of until the late 1960s, when open pit burning, land burial, and ocean dumping were ended.

The first three non-stockpile categories were clearly addressed by the Army's overall programs for chemical demilitarization. As of July 2011, the first three categories had been taken care of.[1] The remaining two categories are the subject of this study.

Figure 2-1 is a high-level chart depicting the organizations involved with policy, funding, and oversight. It is intended to frame the discussion and help the reader follow the titles, acronyms, and chain of command of the various offices involved in the program for RCWM. Further details are provided in the sections that follow. A second summary chart is provided later in this chapter to highlight the organizations that are currently most involved in the execution (i.e., implementation) of the program for RCWM.

[1]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 27, 2011.

## Chronology and Context of Directives and Instructions

Numerous instructions and directives have been issued in the course of addressing the problem of elimination of non-stockpile chemical items. This has caused the diffuse assignment of missions and mission accountability throughout the Army. It is instructive to review the chronology of these numerous instructions as they relate to the elimination of non-stockpile chemical materiel.

In 1984, Congress established the Defense Environmental Restoration Program (DERP).[2] It and the Superfund Reauthorization Act of 1986[3] required the Secretary of Defense to implement the DERP. The Secretary of Defense designated DUSD(I&E) as the DOD planning, policy, and oversight agency. DERP was silent on chemical munitions. DERP activities, in general, were somewhat uneven until base realignment and closure (BRAC) activities began in the late 1980s and cleanup of formerly used defense sites (FUDS) became a crucial component. As DERP efforts intensified, the Army designated DASA(ESOH) as the lead staff agency.

In November 1985, with passage of Public Law 99-145, Congress required that the U.S. stockpile of lethal chemical agents and unitary chemical munitions be destroyed. DOD designated the Army as executive agent (EA).

The Army published its Regulation AR 200-1 (U.S. Army, 2007a) on April 23, 1990. This prescribed the roles and responsibilities for DERP in great detail. However, it did not include procedures for non-stockpile or stockpile chemical weapons and materiel. It referred to AR 50-6, "Chemical Surety" (U.S. Army, 2008a); AR 385-10, "The Army Safety Program" (U.S. Army, 2007c); and DA Pamphlet 50-6 "Chemical Accident or Incident Response and Assistance (CAIRA) Operations" (U.S. Army, 2003a), the regulations that specify the requirements, policies, and procedures for chemical warfare agents.

On October 9, 1990, the House Defense Appropriations Committee in its House Report 101-822 expressed its belief that the fragmentation of responsibility within the Executive Branch for the destruction of chemical weapons and by-products "may cause duplication of effort, inefficiency, undue costs, and compromises to safety and the environment." The committee directed the Secretary of Defense to organize an overall program "so that operational responsibility for all Defense Department chemical warfare destruction activities rests within a single office which shall be fully accountable for total program execution."[4] On March 13, 1991, the Deputy Secretary of Defense issued a directive that designated the Secretary of the Army as the EA for chemical demilitarization activities for DOD, including "demilitarization of non-stockpile chemical warfare munitions, agents, and by-products."

In 1992, The National Defense Authorization Act (NDAA), 1993 (P.L.102-484),[5] required the Secretary of the Army to submit a report to Congress on the Army's plans for destroying all chemical warfare material of the United States not covered by Section 1412 of the NDAA 1986 (50 U.S.C. 1521) but that would be required to be destroyed if the United States became a party to the CWC.

In November 1992 the United Nations General Assembly approved the CWC, which would prohibit the production and use of chemical weapons and establish conditions for the destruction of all stockpiled chemical agents and weapons, former chemical weapons production facilities, and miscellaneous chemical warfare materiel. The CWC (to which the United States became a signatory) entered into force in April 1997.

In compliance with P.L. 102-484, the Army created the Non-Stockpile Chemical Materiel Project (NSCMP) to develop systems to safely assess, treat, and destroy chemical warfare materiel that was not part of the declared stockpile. It also established the Chemical Material Destruction Agency to consolidate responsibility for destruction of chemical materials into a single office and delegated the EA responsibility to the ASA(ILE), which exercised this responsibility for elimination of stockpile and non-stockpile chemical weapons and chemical weapons materiel until 1995.

In December 1994, USD(A&T)[6] redesignated the entire chemical demilitarization program as an Acquisition Category I (ACAT I) program that would report to the Army Acquisition Executive, who was also the Assistant Secretary of the Army for Research, Development and Acquisition [ASA(RDA)]. ACAT I programs, by law and DOD directive, required progress milestone reviews by the Defense Acquisition Board (DAB), chaired by the USD(A&T).

An experienced Chemical Corps general officer was selected as program manager for chemical demilitarization (PMCD). This gave the chemical demilitarization efforts the same status as the program executive offices for other major Army programs. The PMCD was directly responsible for management of the stockpile program; in addition, within the chemical demilitarization program office, a product[7] manager for non-stockpile was established, reporting to the PMCD. Technology and systems engineering expertise was provided to the PMCD by the Chemical Materials Agency (CMA) within the Army Materiel Command (AMC).

On February 21, 1997, AR 200-1 was updated in its entirety, ostensibly because the intensity of BRAC activi-

[2]Title 10 U.S. Code 2701 and 2810. DERP was established by Section 211 of the Superfund Amendments and Reauthorization Act (SARA) of 1986.

[3]Available at http://epw.senate.gov/sara.pdf. Accessed April 10, 2012.

[4]House Report 101-822, Report of the Committee on Appropriations to accompany H.R. 5803, Department of Defense Appropriations Bill, 1991, Title VI, p. 239, U.S. House of Representatives, October 9, 1990.

[5]H.R.5006. National Defense Authorization Act for Fiscal Year 1993, Public Law 102-484, Section 161, paragraph (d), Destruction of Non-stockpile Chemical Material, U.S. House of Representatives, October 23, 1992.

[6]USD(A&T) was subsequently renamed the Under Secretary of Defense for Acquisition, Technology and Logistics [USD(AT&L)].

[7]The name of this position was subsequently changed to "project" manager.

ties increased pressure for environmental cleanup of FUDS. The updated version again focused in great detail on DERP. Only a general statement about the disposal of RCWM was included; it referred to Army Regulations AR 50-6 and AR 385-61 and to DA Pamphlet 50-6 on policy or procedures for the NSCMP.

The CWC came into force after the 67th nation ratified it on April 29, 1997. The treaty requires reporting and destruction of both unitary stockpiled chemical weapons as well as non-stockpile chemical items. From 1997 through 2007, the chemical demilitarization program continued as an ACAT I program reporting to the Army Acquisition Executive, who had been redesignated the Assistant Secretary of the Army for Acquisition, Logistics and Technology, ASA(ALT). DOD oversight and milestone reviews were still conducted by DAB.

In September 2003, the DOD Inspector General (DOD-IG) submitted a report recommending that the environmental offices of the DOD components identify, schedule, and fund the disposal of buried CWM from active installations and from base realignment and closure installations (DOD, 2003, 2010).

In May 2005, USD(AT&L) approved the transfer of responsibilities for oversight and policy guidance for the recovery and destruction of buried CWM from the ASD(NCB) to the DUSD (I&E) (see Figure 2-1). In that same action memorandum, USD(AT&L) directed the Secretary of the Army, in coordination with DUSD(I&E), to develop an implementation plan for the recovery and destruction of buried CWM at active installations and FUDS subject to DERP. In a memorandum to the Secretary, USD(AT&L) said the plan would be "one of several factors to be considered in support of a decision by the Secretary of Defense on whether to designate the Secretary of the Army as EA for recovery and destruction of buried chemical warfare material in the U.S." At a minimum, the plan was to address the following:

(1) Requirements for consolidation of associated resources into a single Army office;
(2) Program scope;
(3. Characterization, destruction, and cleanup of residual contamination;
(4) Plans for declaring uncovered chemical weapons and/or chemical weapons-related material in accordance with the CWC;
(5) Available resources;
(6) Funding requirements over the Future Years Defense Program; and
(7) Life cycle cost requirements. (DOD, 2005)

On September 20, 2007, the Secretary of the Army responded to the USD(AT&L) tasking in "Recovered Chemical Warfare Material (RCWM) Program Implementation Plan (Recovery and Destruction of Buried Chemical Warfare Material)" (DOD, 2007). The details of the Army's RCWM Implementation Plan, 2007, and its implications for the RCWM program will be discussed in Chapter 7.

AR 50-6 was revised in its entirety as of July 28, 2008. The major responsibilities delineated in this regulation can be summarized as follows:

- Among other things, ASA(IE&E) is the principal Army secretariat for all Department of the Army matters relating to recovered chemical materiel.
- ASA(ALT) is responsible for chemical agent demilitarization.
- All Army commands and Army service component commands were required to maintain a chemical surety program and designate a chemical surety officer.
- AMC is required to maintain a force to respond to chemical accidents or incidents at a chemical facility or during the transport of chemical agents.
- The Army Forces Command will provide technical escort for the Chemical Surety Program by means of the 20th Support Command.
- For chemical accidents or incident response and assistance (CAIRA) on Army installations, the Army regulations require that the garrison commander work with the garrison chemical surety director to establish a reporting and response plan.
- AR 50-6 is not clear on procedures and responsibilities for the overall management of activities required upon discovery of a suspected chemical material.

## FUNDING

Congress authorizes programs and appropriates funding for the express purpose of implementing those programs. In most cases, a program's funding must be expended solely for activities within that program (i.e., it may not be commingled with funding allocated to any other program for other purposes). In the case of the RCWM program, remediation activities directly related to chemical munitions and materiel are funded separately under Chemical Agents and Munitions Destruction, Defense (CAMD,D) (see Figure 2-2). This is but one of three major funding programs that frequently come into play during some aspects or phases of an overall remediation effort. Congressional restrictions on the use of each of these funding programs require the Executive Branch (primarily DOD) to carefully coordinate and account for the use of these funds. At many sites, RCWM is buried along with conventional munitions, and this can make proper accounting for the activities and funding in each case costly and complex. An additional foreseeable complication for operations involving RCWM is that because the CAMD,D funding program was established primarily to destroy stockpiled chemical weapons, once the stockpiled weapons have been completely destroyed and the stockpile destruction sites

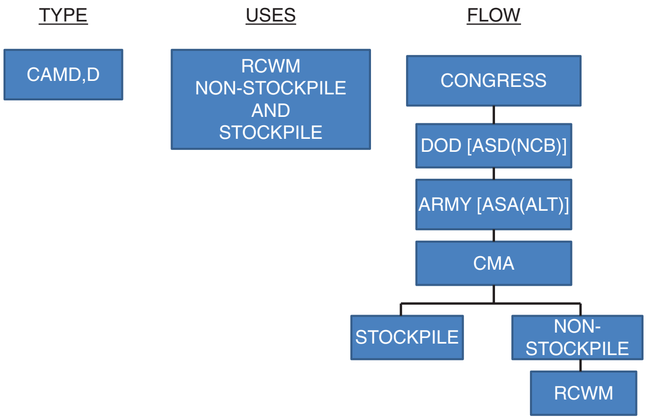


FIGURE 2-2 Current funding, CAMD,D.

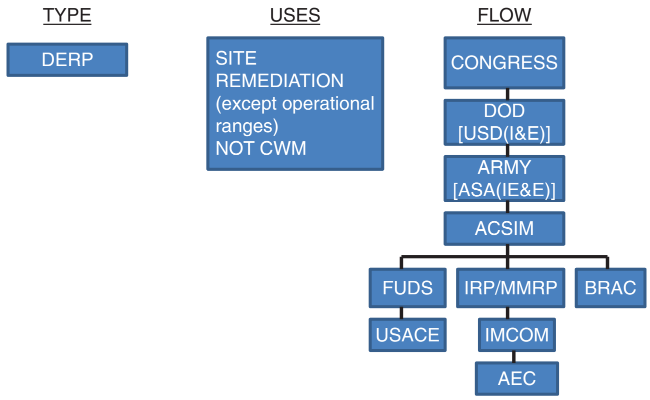


FIGURE 2-3 Current funding, DERP. USD(I&E), Under Secretary of Defense for Installations and Environment; IRP, Installation Restoration Program.

remediated (anticipated circa 2023), CAMD,D funding is expected to expire, leaving future funding for the RCWM problematic.

The three funding programs that may come into play at RCWM sites are described next.

### Chemical Agent and Munitions Destruction, Defense (CAMD,D)

As noted in the section on policy above, Congress required the destruction of chemical weapons in 1985 under P.L. 99-145. DOD requests funding under the CAMD,D account as part of its annual budget. The CAMD,D appropriation includes requirements for the Chemical Stockpile Elimination (CSE) project, the Chemical Stockpile Emergency Preparedness Project (CSEPP), the Assembled Chemical Weapons Alternatives (ACWA) program, as well as the NSCMP, which funds RCWM destruction. The FY 2013 CAMD,D budget request is $1.3 billion (compared to $1.5 billion in both FY 2011 and FY 2012), of which approximately $132 million is requested for operations and maintenance, research, development, test, and evaluation (RDT&E), and procurement for NSCMP.[8] The actual assessment and destruction of RCWM is done through CAMD,D funding. CAMD,D funding for the CSE and CSEPP will continue to decline because destruction of the stockpile is 90 percent complete. Funding for destruction of the remaining 10 percent from the ACWA program will continue until destruction is complete and the plants have been deconstructed. The NSCMP is currently funded through 2017 and funding is expected to continue for the duration of the ACWA project.[9] Funding for the program beyond 2017 has not been determined. See Chapter 7 for a discussion on future funding options.

### Defense Environmental Restoration Program (DERP)

As mentioned in the policy section above, DERP was established by Congress in 1984 to clean up wastes on active and formerly used DOD installations (except for active training ranges). DERP is a very broad program encompassing funding for early site investigation and characterization and continuing through remediation[10] (see Figure 2-3).

There are three major line items within DERP:

- *Installation Restoration Program (IRP).* This funds cleanup of wastes at active DOD installations. The Military Munitions Response Program (MMRP), established in 2002, applies to cleaning up unexploded ordnance (UXO), discarded military munitions (DMM), and munitions constituents that may be present on military facilities.[11]
- *FUDS.* Funding for FUDS is used to clean up wastes on properties that were formerly owned, leased by, or otherwise possessed by DOD and are now the property of other parties. According to a fact sheet prepared by the USACE, there are more than 9,900 potential FUDS properties and cleanup is planned or ongoing at more than 3,000 of the properties that have been evaluated. A single FUDS may consist of multiple cleanup sites. While new FUDS cleanup

[8] From Chemical Agents and Munitions Destruction, Defense FY 2013 President's Budget Estimate. Available at: http://asafm.army.mil/Documents/OfficeDocuments/Budget/BudgetMaterials/FY13//camdd.pdf. Accessed April 16, 2012.

[9] Ibid.

[10] RCWM remediation applies to the assessment, treatment, and waste disposal of RCWM munitions and resulting contamination.

[11] Military munitions include all ammunition products and components produced for or used by the armed forces for national defense and security. The term refers to chemical and riot control agents, smokes, and incendiaries, including bulk explosives and chemical warfare agents, chemical munitions, and rockets. Discarded military munitions are military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal.

projects are initiated every year, as of 2007, more than 4,600 sites at FUDS properties were undergoing cleanup.[12]

- *BRAC*. The transfer of DOD property being closed under the various BRAC sites authorized by Congress is funded separately from other DOD activities. Many closing DOD properties require cleanup prior to transfer to another owner. BRAC funds applied to those cleanup requirements are not used for the remediation of RCWM on operational ranges, which use CAMD,D funding instead.

Note the statement in paragraph 5.3, Program Management Manual for Military Munitions Response Program (U.S. Army, 2009c):

> Funds appropriated to the ER,A (Environmental Response [read: Restoration], Army) account can be used to conduct identification, investigation, removal actions, remedial actions, or a combination of removal and remedial actions to address UXO, DMM, and or MRRP when the location qualifies as a defense site or the munition at a non-defense site came from a defense site or migrated to the non-defense site from a defense site.

Note, however, that DERP funds are commonly used for cleanup of DOD waste and conventional munitions at RCWM sites but only for site characterization and remediation up to the point at which they are identified as RCWM munitions. Once an RCWM is discovered, the common practice is that CAMD,D funding is used for the processing and remediation of the RCWM.

### Operations and Maintenance (O&M)

O&M is a significant ($250-$300 billion per year) DOD program that funds a very wide spectrum of DOD requirements, including recruitment, training, day-to-day upkeep of installations, fuels, industrial operations, war fighting requirements, etc. (see Figure 2-4). O&M funding is allocated to each of the Services for their requirements. For example, the Army allocation can normally be identified as OMA, the Navy allocation as OMN, and so on. In the context of RCWM, O&M funding is used for the operations and maintenance of active training ranges for the military, including environmental restoration of the active ranges. As with DERP, O&M funding is not used to remediate RCWM on operational ranges. Rather, CAMD,D funding is employed.

DOD (and the Army as the RCWM EA) must carefully adhere to congressional direction on the use of the various appropriations above. In practice, since work must stop whenever RCWM is discovered until the appropriately funded personnel can become involved, the resultant disruption on work sites drives up costs for assessment and remediation of RCWM as well as for remediation of conventional munitions on the same site. Since CAMD,D, DERP, and O&M funds are programmed by different organizations and funding for RCWM requirements is typically lower than for the other requirements, the funding program managers must adjust their respective budgets for these unanticipated impacts. Chapter 7 contains detailed analysis, findings, and recommendations for the RCWM funding structure.

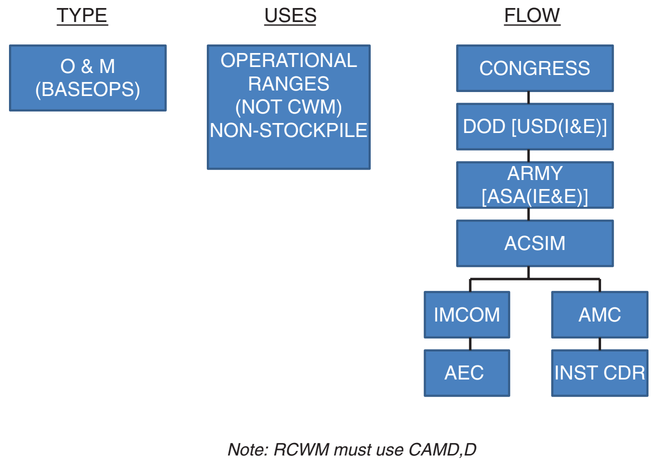


FIGURE 2-4 Current funding, O&M. INST CDR, installation commander.

## ORGANIZATION

This section outlines the government organizations that play a significant role in planning, programming, budgeting, and executing the RCWM program. The main players are offices at various levels of the Department of Defense (DOD). The information presented in this section is drawn, for the most part, from presentations to the committee made by representatives of the respective offices. The role played by government contractors in the RCWM program is very significant, particularly in the planning, design, and construction of government equipment and remediation of munitions disposal sites. As these contractors are contracted to perform specific scopes of work under the supervision of the government, this chapter does not distinguish between the tasks performed by government offices and employees or those done by the contractors they hire to assist them.

Figure 2-5 provides a high-level summary of the offices most involved with implementing the RCWM program. Several of these offices are also involved in the policy, funding, and oversight of the program, which was described earlier.

[12]U.S. Army Corps of Engineers fact sheet. “Formerly Used Defense Sites Program.” Available at https://environment.usace.army.mil/downloaddbfile.cfm?file_id=C98708FB-188B-313F-1B2BBF5FFBB85FA1. Last accessed June 4, 2012.

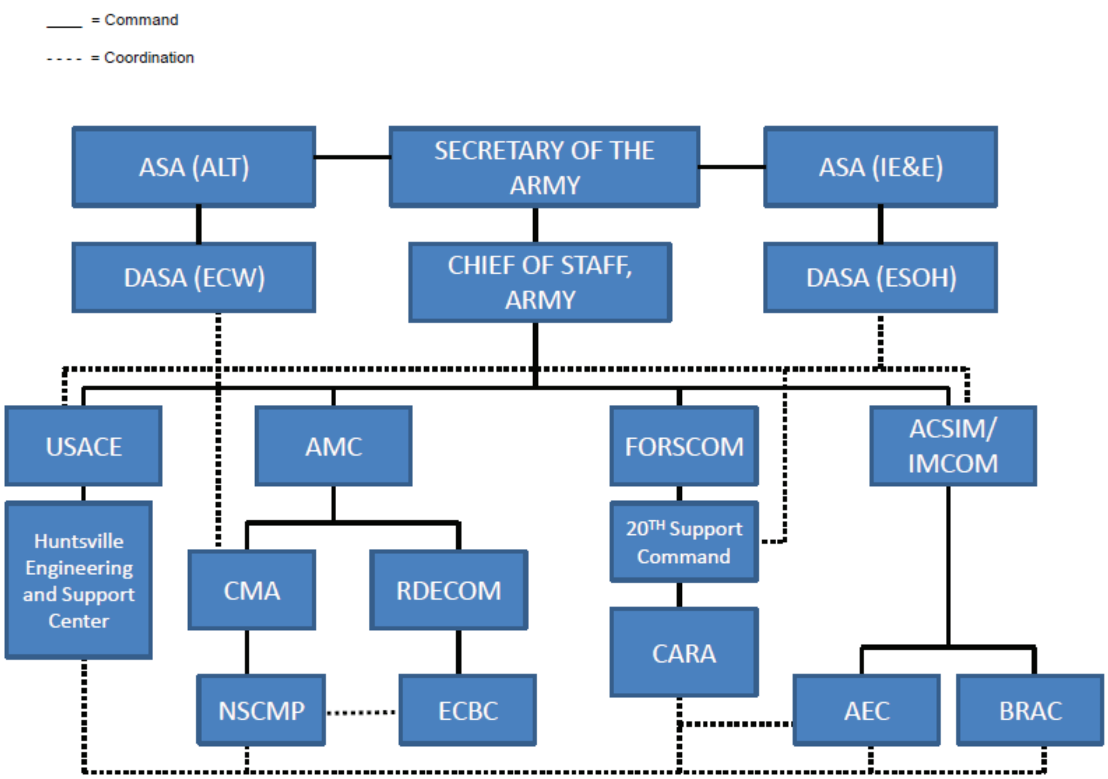


FIGURE 2-5 Current organization for execution for RCWM. ECBC, Edgewood Chemical Biological Center; RDECOM, Research, Development, and Engineering Command.

## Department of Defense

The DOD organization relevant to RCWM is illustrated in Figure 2-5. DOD is a large and complex organization with a rigid structure that leads to specialization of the many offices. This size and specialization requires DOD offices to possess a sophisticated set of management practices and coordination skills in order to execute the RCWM program and the many other programs covered later in this chapter.

### *Office of the Secretary of Defense*

The Office of the Secretary of Defense (OSD) is the highest staff organizational level in DOD. OSD is led by the Secretary of Defense and has many supporting lower level offices. The top positions are led by political appointees or civilian members of the Senior Executive Service (SES).

*Under Secretary of Defense (Acquisition, Technology and Logistics).* The office of the USD(AT&L), shown in Figure 2-6, is responsible for the policies for many operational staff functions within DOD. The Under Secretary reports directly to the Secretary of Defense and the Deputy Secretary of Defense. USD(AT&L) responsibilities include these:[13]

- Supervising DOD acquisition,
- Establishing acquisition policies for DOD,
- Establishing policies for logistics, maintenance, and sustainment support for DOD, and
- Establishing DOD policies for maintenance of the defense industrial base.

The four organizations that are highlighted in Figure 2-6 are the primary organizations under the OSD that bear upon the RCWM program and function through the following:

*Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs.* As the principal advisor to the Secretary and Deputy Secretary of Defense and the USD(AT&L) on nuclear energy, nuclear weapons, and chemical and biological defense, the ASD(NCB) provides program, policy, and budget guidance for the U.S. program for destruction of the U.S. chemical weapons stockpile and of non-stockpile chemical materiel and makes recommendations on the safety, surety, security, and safe destruction of the chemical weapons stockpile and non-stockpile chemical weapons and materiel. This includes the program for destruction of non-stockpile chemical materiel that is managed and executed under the supervision of the Secretary of the Army (DOD, 2011). Oversight, coordination and integration for this mission are executed on a day-to-day basis by

[13]Available at http://www.acq.osd.mil/. Accessed February 13, 2011.

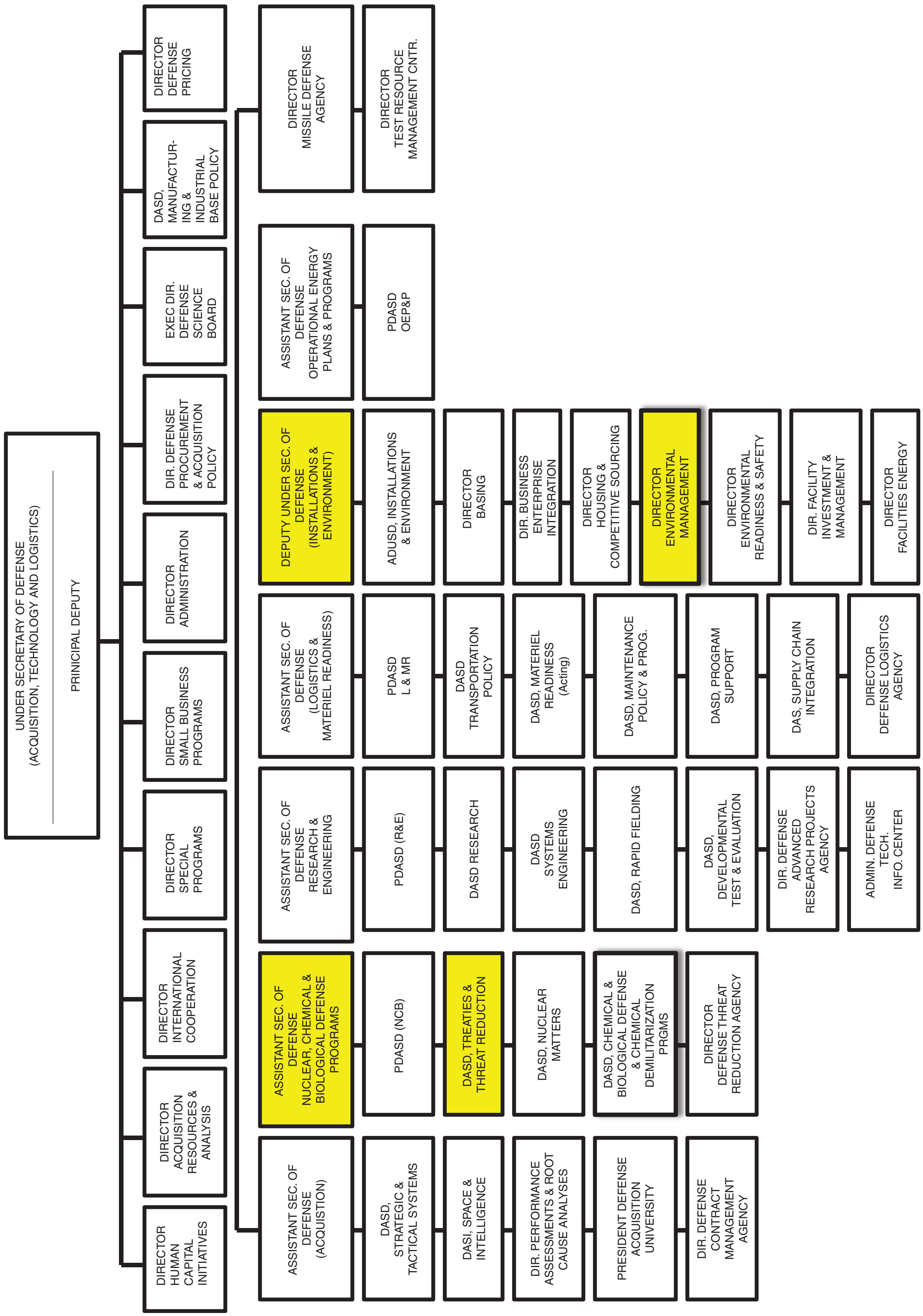


FIGURE 2-6 Organizational chart for USD(AT&L). SOURCE: Adapted by the committee from material provided by Deborah A. Morefield, Manager, Defense Environmental Restoration Program, Environmental Management, Office of the Deputy Under Secretary for Installations and Environment, Department of Defense, November 1, 2011.

the Deputy Assistant Secretary of Defense for Treaties and Threat Reduction (see first highlight under ASD[NCB] in Figure 2-6).

*Deputy Under Secretary of Defense (Installations and Environment).* The mission of the Office of the DUSD(I&E) is to provide management and oversight of military installations worldwide and manage environmental, safety, and occupational health programs for the DOD. DUSD(I&E) has staff responsibility for the Defense Environmental Restoration Program and funding. The Director of Environmental Management, highlighted under DUSD (I&E) in Figure 2-6, has the immediate responsibility within DUSD(I&E) for the RCWM program.

Not shown in Figure 2-6 but also under the DUSD(I&E), the DOD Explosives Safety Board (DDESB) administers the explosives safety program for DOD and ensures that chemical agent operations are performed safely. DDESB is responsible for resolving issues that arise between explosives safety and environmental standards. It also oversees the implementation of safety standards at all munitions response sites with the goal of ensuring safe handling, storage, and disposal of munitions and explosives of concern (MEC). The Services involved in cleanups at munitions response sites are required to submit to DDESB for its review and approval Explosive Safety Site Submissions and, where CWM are known or anticipated, Chemical Safety Submissions for all cleanup operations. Within the component Services, applications must first be approved by the respective Service safety organization. DDESB regulations are articulated in DOD 6055.9M (DOD Ammunition and Explosives Safety Standards).

## Office of the Secretary of the Army

The Office of the Secretary of the Army is the civilian-led policy organization responsible for leading the U.S. Army. It has a very broad mission encompassing all peacetime and wartime responsibilities for the U.S. Army. As part of this mission the office has significant environmental responsibilities stretching through all levels of the U.S. Army. Note that assistant secretaries of the Army have similar civilian and military organizational structures. The Office of the Secretary of the Army has been assigned as DOD EA for the stockpile and non-stockpile (RCWM) chemical weapons remediation programs and has redelegated these to other parts of the Office of the Secretary of the Army organization.

A high-level depiction of the Army organizations that play a role in the Army's total environmental responsibilities (a small piece of which is RCWM) is provided in Figure 2-7.

The tiers depicted in Figure 2-7 for the Army environmental organizational structure are distinguished by the roles of policy, delivery, or execution. The policy roles are shared by offices in the Pentagon as principal Secretariat or Army staff offices.

### *Assistant Secretary of the Army (Acquisition, Logistics and Technology)*

ASA(ALT) is the political appointee reporting to the Office of the Secretary of the Army. He or she is the Army Acquisition Executive, Senior Procurement Executive, Science Advisor to the Secretary, and the senior research and development official for the U.S. Army.[14] ASA(ALT) is also responsible for all policy matters related to U.S. Army logistics. For the chemical demilitarization program, the Secretary assigned both stockpile and non-stockpile leadership to ASA(ALT). The chemical weapons responsibilities within ASA(ALT) are discharged by the Deputy Assistant Secretary of the Army for Elimination of Chemical Weapons (DASA(ECW)). The Secretary has since decided to delegate non-stockpile (such as RCWM) responsibilities to ASA(IE&E), a counterpart to this office.

### *Assistant Secretary of the Army (Installations, Energy and Environment)*

ASA(IE&E) provides strategic direction for Army installations and facilities in all matters related to infrastructure, energy, and the environment, to support global missions in a cost-effective, safe and sustainable manner.[15] The policy and oversight of the RCWM program has been assigned to the office of DASA(ESOH). This office has served as an integrator of the Army with the other military service offices involved in the execution of the RCWM program.

### *Chief of Staff of the Army*

The Chief of Staff of the Army (CSA) is the most senior uniformed officer serving in the Department of the Army, the principal military advisor to the Secretary of the Army, and a member of the Joint Chiefs of Staff. A four-star general responsible for the recruitment, training, readiness, and sustainment capabilities of the U.S. Army, the CSA leads a large, diverse, multilayered staff organization that is responsible for the planning, programming, budgeting, and execution (PPBES) of missions assigned to the U.S. Army by the Congress.

*Assistant Chief of Staff (Installation Management).* ACSIM is an Army staff organization led by a three-star general and is responsible for the planning, programming, budgeting, and executing Army resources required to build, operate, and maintain the Army's installations and facilities. A significant part of this charge is to serve as the leader of the Army's environmental stewardship role. ACSIM plays an important role in the RCWM program since the requirements and budgets of this program are rolled up to the ACSIM and defended by

[14] Available at http://www.army.mil/asaiee. Accessed February 15, 2012.
[15] Ibid.

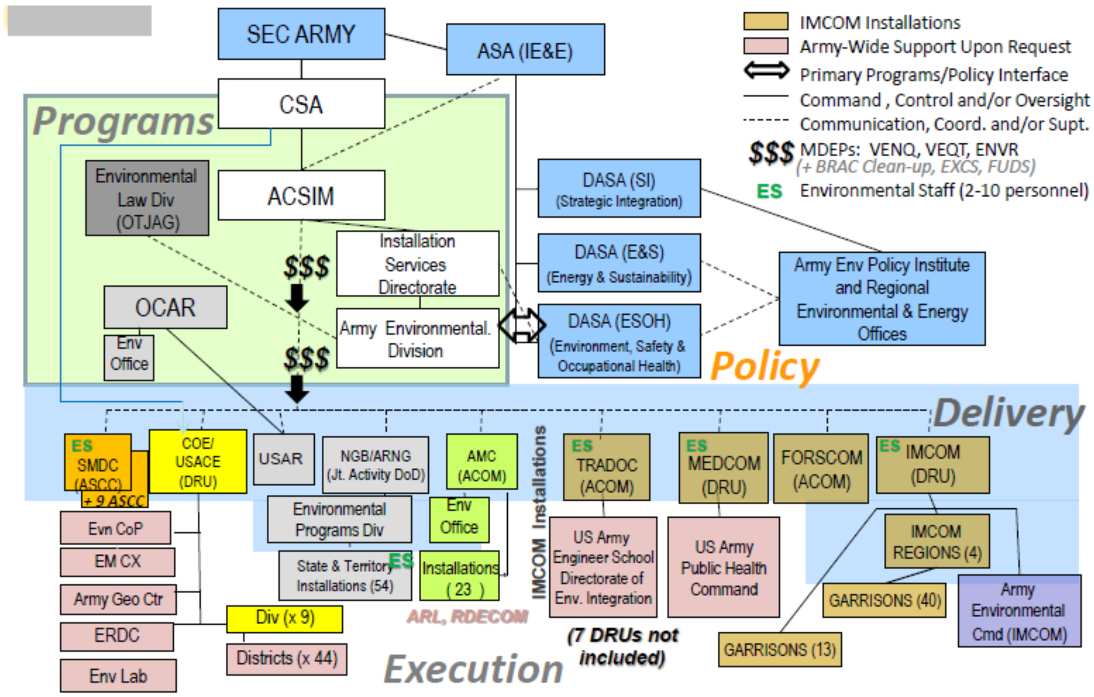


FIGURE 2-7 Army environmental organizational structure. SMDC(ASCC), Space and Missile Defense Command (Army Service Component Command); DRU, Direct Reporting Unit; USAR, U.S. Army Reserve; NGB/ARNG, National Guard Bureau/Army National Guard; ACOM, U.S. Army Command; MEDCOM, U.S. Army Medical Command; Evn CoP, Environmental Community of Practice; EM CX, Environmental and Munitions Center of Expertise; Army Geo Ctr, Army Geospatial Center; ERDC, Engineering Research and Development Center; Env Lab, Environmental Laboratory. SOURCE: Bryan Frey, Headquarters, Department of the Army, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, presentation to the committee on January 18, 2012.

this office. The organization, roles, and responsibilities of the ACSIM are depicted in Figure 2-8.

RCWM funding is managed by the cleanup branch of the Army Environmental Division of the Installation Services Directorate. The functions of the Army Environmental Division for the RCWM program are these:[16]

- Provide environmental policy guidance, execution (allocation of funds) authority, and overall program management for resourcing under DERP.
- Coordinate and integrate the efforts of the Army program execution managers.
- Participate as a member of the RCWM Integrated Product Team.
- Defend RCWM program funding requirements to the OSD.

### *Installation Management Command*

The U.S. Army Installation Management Command (IMCOM) is a field operating agency of ACSIM.[17] The three-star general who leads ACSIM is also the IMCOM Commander. IMCOM "supports the United States Army's warfighting mission by providing standardized, effective & efficient services, facilities and infrastructure to Soldiers, Civilians and Families for an Army and Nation engaged in persistent conflict." IMCOM is headquartered in San Antonio, Texas, on Fort Sam Houston. Its headquarters relocated in October 2010 from Arlington, Virginia, as part of the Base Realignment and Closure Act of 2005.[18]

IMCOM directly manages the Army's 180-plus installations throughout the world. AMC still manages its 21 installations, depots, arsenals, ammunition plants, RD&E centers and laboratories and other such installations, although a pilot study is under way to measure the effectiveness of transferring them to IMCOM. The IMCOM functions on each

[16]Bryan M. Frey, Headquarters, Department of the Army, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, presentation to the committee, January 18, 2012.

[17]Available at http://www.imcom.army.mil/hq/kd/cache/files/69B948B6-423D-452D-4636808C49A57094.pdf. Accessed February 14, 2012.

[18]Available at http://www.imcom.army.mil/hq/about/commander/. Accessed February 22, 2012.

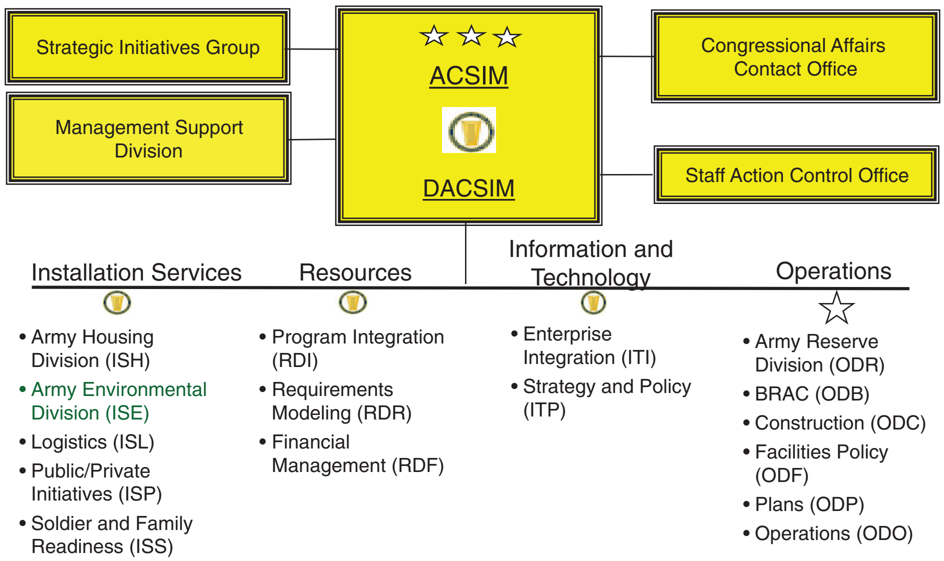


FIGURE 2-8 Office of the Assistant Chief of Staff for Installation Management. DACSIM, Deputy Assistant Chief of Staff for Installation Management. SOURCE: Bryan Frey, Headquarters, Department of the Army, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, presentation to the committee on January 18, 2012.

installation are performed by a garrison staff. A map of the Army's installations is provided in Figure 2-9.

Environmental management is a key function of the garrison staffs at each Army installation. With respect to the RCWM program for both IMCOM and AMC installations, the installation commander (i.e., the highest ranking military mission leader) and the garrison commander would be charged with the management of planned or unplanned RCWM remediation at active installations and BRAC sites.

### *Army Environmental Command*

The Army Environmental Command (USAEC) is the component within the IMCOM staff responsible for developing environmental requirements (including those for RCWM) and executing the budgeted projects as directed by ACSIM. The USAEC organization and RCWM roles are provided in Figure 2-10.

In the non-stockpile RCWM program, Army Environmental Center (AEC) develops requirements and plans and executes the DERP (IR and MR) and the Compliance Cleanup (CC) Program. Program activities may be funded by the Environmental Restoration, Army (ER,A) or OMA accounts. AEC is responsible for everything from initial investigations through the implementation of remedial actions for sites containing hazardous waste, traditional munitions, and constituents in media. It is also responsible for the handling and disposal of items not considered CWM, such as riot control agents; chemical herbicides; smoke- and flame-producing items; soil, water, debris, or other media contaminated with chemical agent; and MEC.[19]

### *U.S. Army Forces Command*

FORSCOM is one of three Army major commands (MACOMs). Its mission statement is as follows:

> FORSCOM prepares conventional forces to provide a sustained flow of trained and ready land power to Combatant Commanders in defense of the Nation at home and abroad."[20]

FORSCOM is headquartered at Ft. Bragg, North Carolina. Its RCWM responsibilities are exercised by an element of its subcommand, 20th Support Command.

### *20th Support Command (Chemical, Biological, Radiological, Nuclear and High-Yield Explosives)*

The 20th Support Command (CBRNE) was activated on October 16, 2004, by FORSCOM to provide specialized CBRNE response in support of military operations and civil authorities. Subordinate elements include the 48th Chemical Brigade, the 52d Ordnance Group [Explosive Ordnance Disposal (EOD)], the 71st Ordnance Group (EOD), and the CBRNE Analytical and Remediation Activity (CARA), all under a single operational headquarters at the Edgewood Area of Aberdeen Proving Ground, Maryland. CBRNE operations detect, identify, assess, render safe, dismantle, transfer, and dispose of unexploded ordnance, improvised explosive devices and other CBRNE hazards. These opera-

[19]Jim Daniel, Chief, Cleanup and Munitions Response Division, Army Environmental Command, and Tim Rodeffer, Cleanup and Munitions Response Division, "Operations of Recovered Chemical Warfare Material from Burial Sites," presentation to the committee on December 12, 2011.

[20]Available at http://www.forscom.army.mil/. Accessed February 15, 2012.


FIGURE 2-9 Map of U.S. Army Installation Management Command garrisons. Installations in green are managed by IMCOM headquarters. SOURCE: http://www.imcom.army.mil/hq/about/garrisons/. Accessed February 14, 2012.

tions also include decontaminating personnel and property exposed to CBRN materials during response.

### *Chemical, Biological, Radiological, Nuclear and High Yield Explosives (CBRNE)/Analytical and Remediation Activity (CARA)*

CARA is an all-civilian unit of the 20th Support Command established in 2007 (Jensen, 2008). CARA's mission is to deploy and conduct operations in support of combatant commanders or other government agencies in order to counter CBRNE and threats of weapons of mass destruction in support of national efforts to combat weapons of mass destruction. It includes operations within the continental United States and outside of it.[21] CARA asserts that it is the only organization within the DOD authorized to escort chemical surety material off a military installation (U.S. Army, 2008a).

According to CARA's briefings to the committee, CARA has four sections: two remediation response sections, an

[21]LTC Charles A. Asowata, Acting Director, and Dalys Talley, Chief of Operations, CARA, "CBRNE Analytical and Remediation Activity Missions," presentation to the committee on September 28, 2011.

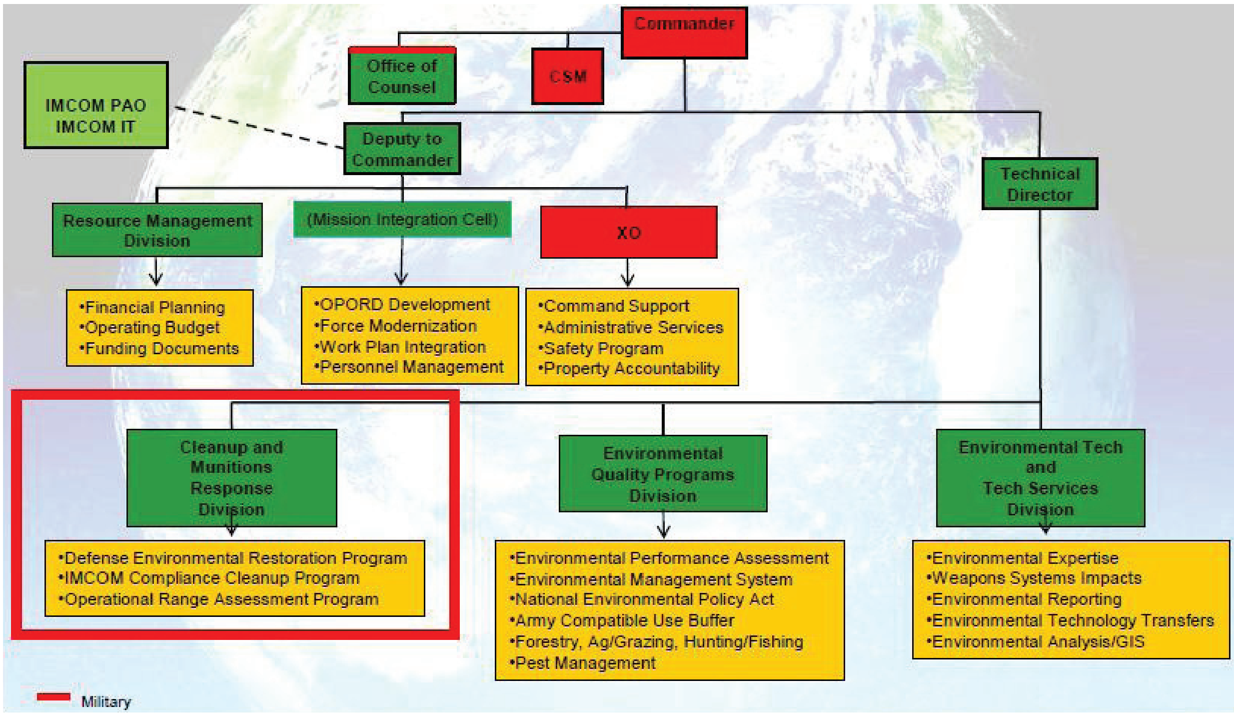


FIGURE 2-10 U.S. Army Environmental Command. PAO, Public Affairs Officer; CSM, Command Sergeant Major; XO, Executive Officer; GIS, Geographic Information Systems. SOURCE: Jim Daniel, Chief, Cleanup and Munitions Response Division, Army Environmental Command, and Tim Rodeffer, Cleanup and Munitions Response Division, "Operations of Recovered Chemical Warfare Material from Burial Sites," presentation to the committee on December 12, 2011.

aviation section, and the mobile expeditionary laboratory (MEL).[22]

The remediation response sections (RRSs) (RRS East at Aberdeen Proving Grounds, Maryland, and RRS West at Pine Bluff Arsenal, Arkansas) conduct site characterization, assessment, demilitarization, and elimination of RCWM; site remediation projects; emergency response to RCWM incidents; and technical escorts of chemical surety and nonsurety material. They also support Army stockpile and non-stockpile operations.

The aviation section transports chemical surety escort teams, RCWM emergency response teams, and the 20th Support Command's response teams.

The mission of the MEL is to conduct field confirmatory chemical, biological, and explosive analyses as well as near-real-time chemical air monitoring. The lab also operates the tactical mobile expeditionary labs that bring the necessary analytical capability to any location as soon as the need becomes known.

CARA performs remediation operations at FUD sites, military installations, and BRAC sites in support of installation commanders, other agencies, and USACE. CARA operates in the continental United States as well as abroad.

In a typical operation in which military munitions are found, CARA would conduct the emergency response if the munitions are determined to be chemical. If a munition is determined to have a liquid fill, CARA conducts a non-intrusive assessment using portable isotopic neutron spectroscopy (PINS) on board a mobile munitions assessment system (MMAS). CARA operates the MMAS on behalf of the NSCMP.

### U.S. Army Materiel Command

The AMC is a second Army major command with responsibilities for the RCWM program. Its roles and responsibilities are as follows:[23]

> The U.S. Army Materiel Command (AMC) is the primary provider of materiel to the United States Army. The Command's mission includes the research & development of weapons systems as well as maintenance and parts distribution. AMC operates research and development engineering centers; Army Research Laboratories; depots; arsenals; ammunition plants; and other facilities, and maintains the Army's prepositioned stocks, both on land and afloat. The command is also the Department of Defense EA for the

[22] Ibid.

[23] Available at http://www.amc.army.mil/amc/Fact%20sheets/HQAMC2011.pdf. Last accessed February 15, 2012.

> chemical weapons stockpile and for conventional ammunition. AMC is responsible within the United States Department of Defense for the business of selling Army equipment and services to allies of the United States and negotiates and implements agreements for co-production of U.S. weapons systems by foreign nations. AMC is currently headquartered at Redstone Arsenal in Huntsville, Alabama, and is located in approximately 149 locations worldwide, including more than 49 American States and 50 countries. AMC maintains employment of upwards of 70,000 military and civilian employees.

### *Materiel Assessment Review Board*

The Army's Materiel Assessment Review Board (MARB) evaluates digital radiography and computed tomography (DRCT) and PINS data, photographs, and historical data and recommends methods for disposing of the RCWM. The MARB is made up of representatives from a dozen Army organizations, including AMC's RDECOM, Edgewood Chemical Biological Center, CMA, PMNSCM, the 20th Support Command; and CARA.[24] The MARB usually convenes within two or three days of receiving assessment data. After all the assessment data are reviewed, members vote to recommend one of four ways to dispose of the suspect item: If an item is found to contain chemical agent, the board may select either nonexplosive or explosive system demilitarization. If an item is found to be conventional, its disposition is determined locally. If it is found to be unsafe, the MARB recommends immediate destruction.[25]

### *U.S. Army Chemical Materials Agency*

The CMA is a subordinate agency of the Army Materiel Command focused on the destruction of the chemical munitions stockpile and non-stockpile agents and materiel. The mission of CMA is as follows:

> The U.S. Army's Chemical Materials Agency (CMA) is the world leader in programs to store, treat, and dispose of chemical weapons safely and effectively. The agency developed and used technologies to safely store and eliminate chemical weapons at seven stockpile sites while protecting the public, its workers and the environment. CMA also has the storage mission at the Nation's final two stockpile sites. CMA was created to incorporate the former Program Manager for Chemical Demilitarization and portions of the U.S. Army Soldier and Biological Chemical Command into one agency.[26]

[24]MARB fact sheet, U.S. Army Chemical Materials Agency. Available at http://www.pmcd.army.mil/fndocumentviewer.aspx?docid=003677814. Last accessed February 6, 2012.

[25]Ibid.

[26]Available at http://www.cma.army.mil/home.aspx. Last accessed February 15, 2012.

### *Non-Stockpile Chemical Materiel Project*

Background information on the NSCMP was presented in Chapter 1. Organizationally, the NSCMP falls under CMA. Its mission is to provide centralized management and direction to the U.S. Department of Defense for the disposal of non-stockpile chemical materiel in a safe, environmentally sound, cost-effective manner while ensuring compliance with the CWC.[27] At this time and for the foreseeable future, the chemical agent identification sets (CAIS) and chemical weapons that are accidentally or deliberately recovered from bodies of water or burial sites constitute the primary non-stockpile chemical materiel requiring disposal. The organization chart and roles and responsibilities for NSCMP are shown in Figure 2-11.[28]

*Project Management.* The NSCMP is responsible for project management for the assessment and disposal of all RCWM. Activities include estimation of assessment and disposal costs, disbursement of funding for assessment and disposal, and preparation of project schedules. The NSCMP prepares the relevant documentation and obtains the approvals needed to commence and carry out operations. The documents involved include the site plan, the site safety submission, the destruction plan, and the environmental permits. If either explosives or chemical agents, or both, are involved the site safety submission must be approved by the Department of Defense Explosive Safety Board (DDESB). If a recovered munition is to be destroyed, all information germane to that munition must be forwarded to the MARB, which conducts an assessment of that munition to determine its chemical fill and explosive configuration. The MARB's assessment determines the conditions under which destruction of the munition is carried out. The NSCMP also has responsibility for satisfying the obligations of the CWC.[29] (See the "Treaty Requirements" section in Chapter 3.) The NSCMP also works with USACE in public involvement and public relations efforts in communities near remediation projects, providing literature and speakers as needed.

*Ownership and/or Management of Assessment and Disposal Systems*. The assessment and disposal equipment employed by the NSCMP is listed and described in Chapter 4. For the most part, this equipment—notably, the Explosive Destruction Systems (EDSs)—is owned and maintained by NSCMP. An exception is the TC-60 Transportable Detonation Chamber (TDC), which is owned by CH2M HILL and is

[27]U.S. Army Chemical Materials Agency, Fact Sheet, Non-Stockpile Chemical Materiel Project Overview. Available at http://www.cma.army.mil/fndocumentviewer.aspx?DocID=003671053. Last accessed March 21, 2012.

[28]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 27, 2011.

[29]Dan G. Noble, U.S. Army Corps of Engineers, comments to committee during Spring Valley site visit on November 1, 2011.

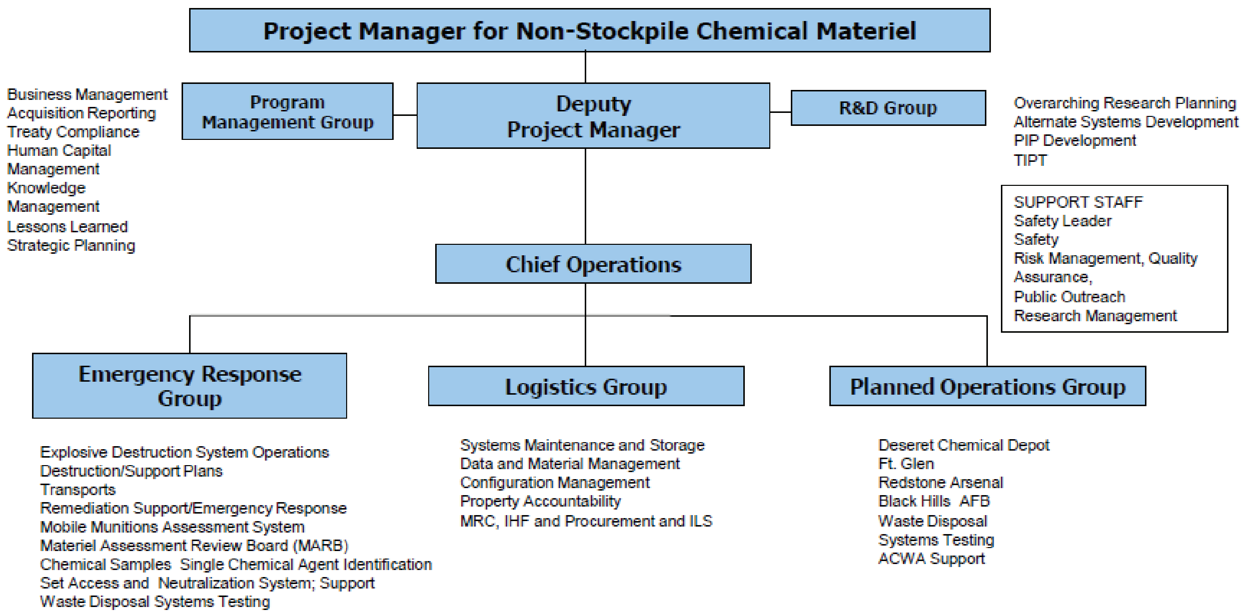


FIGURE 2-11 NSCMP organizational chart. EDS, explosive destruction system, SCANS, Single Chemical agent identification set Access and Neutralization System; MRC, multiple round container. PPI, planned product improvement; ILS, integrated logistical support; TIPT, test integrated product team. SOURCE: Personal communication from Laurence G. Gottschalk, Project Manager, Non-Stockpile Chemical Materiel, to Nancy Schulte, NRC study director, March 7, 2012.

leased from that company under a basic ordering agreement. Field operation of the EDSs and the TDC is carried out by ECBC. These systems and other equipment are described in Chapter 4.

NSCMP provides the interim holding facilities (IHFs) described in Chapter 4 and used for safeguarding recovered munitions at remediation sites.

NSCMP has an active, ongoing R&D program to improve the various systems that it uses to assess and destroy chemical warfare materiel. These systems and the improvements to them that are under way are described in Chapters 4 and 7.

*NSCMP Relationships with Other Organizations.* One focus of this report is very large CWM remediation efforts, in which NSCMP works with USACE. Other military organizations that are directly involved include the U.S. Army Technical Center for Explosives Safety (USATCES), the DDESB, CARA, USACE, and ECBC. The general relationships between these organizations when executing a project managed by USACE are shown in Figure 2-12.

### *U.S. Army Research, Development, and Engineering Command*

RDECOM is a direct reporting command under the Commander, AMC. According to RDECOM's Web site,[30]

> The U.S. Army Research, Development and Engineering Command is the Army's technology leader and largest technology developer. RDECOM ensures the dominance of Army capabilities by creating, integrating and delivering technology-enabled solutions to our Soldiers. To meet this commitment to the Army, RDECOM develops technologies in its eight major laboratories and research, development and engineering centers. It also integrates technologies developed in partnership with an extensive network of academic, industry, and international partners. RDECOM provides the Army with an organic research and development capability. More than 17,000 Soldiers, civilian employees and direct contractors form this world-class team. As part of that team, there are 11,000 engineers and scientists, many of whom are the Army's leading experts in their fields.

### *Edgewood Chemical Biological Center*

ECBC is designated under the CWC as a laboratory that is able to accurately and predictably identify prohibited chemical compounds. ECBC also maintains the only declared facility under the CWC where chemical compounds regulated by the CWC treaty can be produced for protective purposes. It is also the single repository for the Army's research and development stock of toxic chemical agents.

The center houses analytical equipment, including self-contained mobile modular laboratories that allow for near-real-time monitoring of an airborne chemical agent.

In support of USACE in the remediation of FUD sites, ECBC has provided chemical and biological analysis of

[30]Available at http://www.army.mil/rdecom.

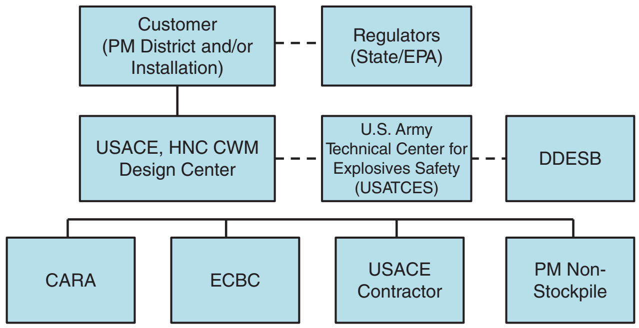


FIGURE 2-12 Typical chemical warfare materiel project. PM, Project Manager; HNC CWM, Huntsville Engineering and Support Center, Chemical Weapons Materiel. SOURCE: Christopher L. Evans, Special Assistant for Military Munitions Support Services Headquarters, U.S. Army Corps of Engineers, "USACE Military Munitions Support Services for Chemical Warfare Materiel," presentation to the committee on December 13, 2011.

environmental samples and chemical agent filtration systems. It has also built vapor containment structures and certified them.

ECBC operates and maintains (but does not own) several systems for the disposal of recovered chemical warfare material, including the EDS, the TDC, the detonation of ammunition in a vacuum-integrated chamber (DAVINCH), and the static detonation chamber (SDC). These systems are discussed in Chapter 4.

### *U.S. Army Corps of Engineers (USACE)*

USACE plays an important role in demilitarizing chemical warfare materiel on behalf of the U.S. Army and other DOD organizations. USACE does this utilizing the skills available at its Washington, D.C., headquarters, nine division offices, 41 district offices, and over 900 field offices. There are approximately 600 military personnel and 37,000 civilian employees distributed worldwide throughout USACE offices. USACE has two main missions: military programs and contingency operations and civil works and emergency operations. The latter mission is authorized and funded separately from Army and DOD authorizations and budgets. Alternatively, the military programs and contingency operations mission is authorized and funded entirely by DOD. With the exception of headquarters and division offices, the bulk of USACE requirements are project-funded for both mission areas. In addition to in-house assets, USACE utilizes a vast array of private sector talent through over 10,000 contracts.[31]

The chemical demilitarization program is managed centrally for USACE by its Huntsville Engineering Center (HNC). While it does not have any field offices, HNC partners with USACE district offices to execute its programs. Private sector assets for HNC programs, including chemical demilitarization, are tasked through contracts managed by HNC and by USACE district offices. Funding for any given requirement is appropriated by Congress.

USACE has a long history of executing stockpile and non-stockpile chemical demilitarization as requested by the Army and DOD authorities. In general, USACE performs the following functions for chemical demilitarization customers:

- Centralized program management and financial management,
- Decentralized project, contract, and quality management,
- On-site technical expertise and contractor quality and safety assurance,
- Requirements assessment and site characterization,
- Public outreach and strategic communications,
- Regulatory coordination and compliance,
- Real property appraisal, acquisition, and disposal, and
- Targeted applied research and development.

The USACE organizations involved with the military environmental management programs include the HQUSACE Special Assistant for Military Munitions Support Services; five military munitions design centers; the HNC Mandatory Center of Expertise for Chemical Weapons, and nine remedial action districts. The relationship between these USACE organizations is provided in Figure 2-13.

As briefed to the committee, the USACE role in the nonstockpile buried chemical material program includes the above generalized functions tailored to the needs and direction of the responsible Army program executive:[32]

- Execute CWM responses and other planned activities, with the exception of explosives or munitions emergency responses where the probability of encountering CWM or chemical agent identification sets (CAIS) is medium to high or where CWM or CAIS have been encountered.
- Provide the provisional RCWM integrating office (described in Chapter 7) with a single point of contact that has decision and tasking authority to coordinate the scheduling and execution of CWM responses or other planned activities.
- Coordinate scheduling of CWM responses or other planned activities (e.g., range clearance activities) that may involve CWM or CAIS with the RCWM IO and, when required, with ASA(IE&E).

[31] Available at http://www.amc.army.mil/amc/Fact%20sheets/HQAMC2011.pdf, and http://www.usace.army.mil/Missions/MilitaryPrograms.aspx. Accessed March 22, 2012.

[32] J.C. King, Assistant for Munitions and Chemical Matters, Office of the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health, "The Army RCWM Program A Policy Perspective," presentation to the committee on September 27, 2011.

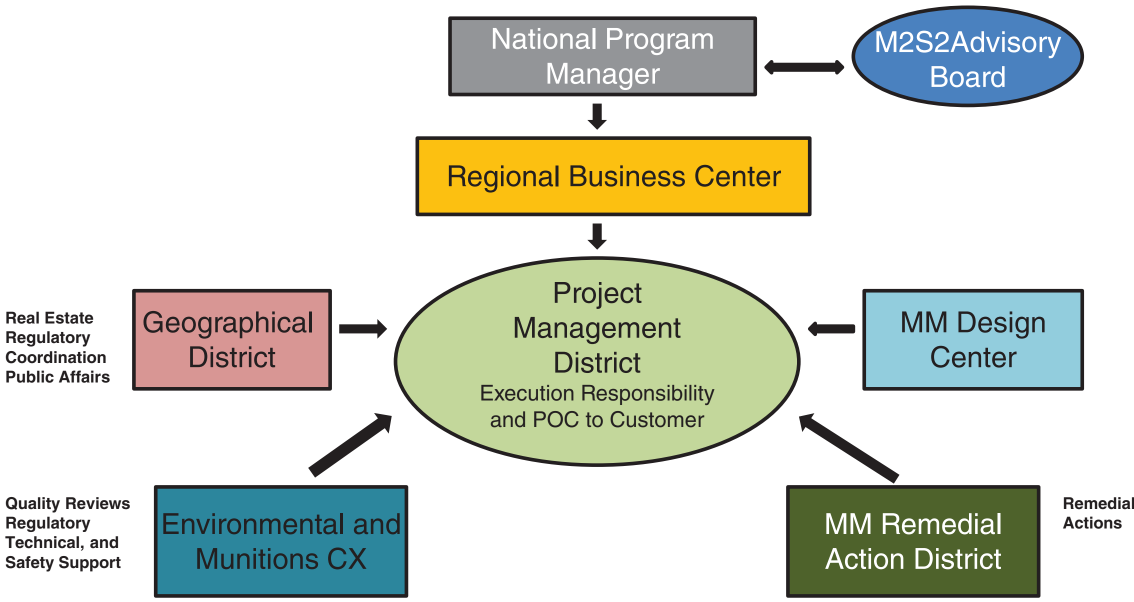


FIGURE 2-13 USACE Military Munitions Support Services. M2S2, Military Munitions Support Services; MM, military munitions; CX, center of expertise, POC, point of contact. SOURCE: Christopher L. Evans, Special Assistant for Military Munitions Support Services Headquarters, USACE, "USACE Military Munitions Support Services for Chemical Warfare Materiel," presentation to the committee on December 13, 2011.

- Provide technical advice to DOD components on the need for and design of CWM responses, operational range clearance and other activities where the probability of encountering CWM or CAIS is medium to high, and when requested, when the probability of such encounters is low.
- Support DOD components in
  - —Providing public affairs support for information exchange and public involvement related to CWM responses, to include the implementation of required UXO safety education programs.
  - —Responding to regulatory inquires and concerns.
  - —Preparing and coordinating DDESB required safety submissions for conventional munitions according to DOD and the appropriate Service's policy.
  - —Coordinating plans and operational details with the stakeholders.
- Plan CWM responses.
- In coordination with the Army program execution managers, develop cost-to-complete estimates for the DERP portion of RCWM program site costs.
- Prepare and submit required reports related to CWM responses or other actions under its management.
- Coordinate and integrate all on-site CWM response activities, including security of RCWM and other munitions or materials of interest.
- Coordinate and conduct required preoperation surveys and table top exercises per DOD and Army policy.
- Manage on-site CWM site activities, in coordination with the DOD Services environmental program managers, Army program execution managers, and site project managers.
- Perform contract activities for CWM responses, except those related to (1) assessment and destruction and (2) response involving CAIS.
- Perform real estate functions—for example, obtaining rights of entry, reviewing deed restrictions—required to support a CWM response.
- Provide for safety oversight on all CWM responses and responses involving CAIS.
- Schedule assessment of munitions or other materials of interest and, when appropriate, CAIS.
- Participate on the Munitions Assessment Review Board (MARB).

USACE relationships with other DOD organizations, regulators, and contractors are depicted in Figure 2-13. The roles and responsibilities of state and federal regulatory authorities are described in Chapter 3. The roles and responsibilities of the DDESB are described in Chapter 4.

### Office of the Secretary of the Navy

There are very few RCWM sites for the Navy compared to those for the Army. By its latest count, the Navy has identified only two suspected and three potential RCWM sites. Nonetheless, it is responsible for environmental issues on its installations, including any buried chemical weapons

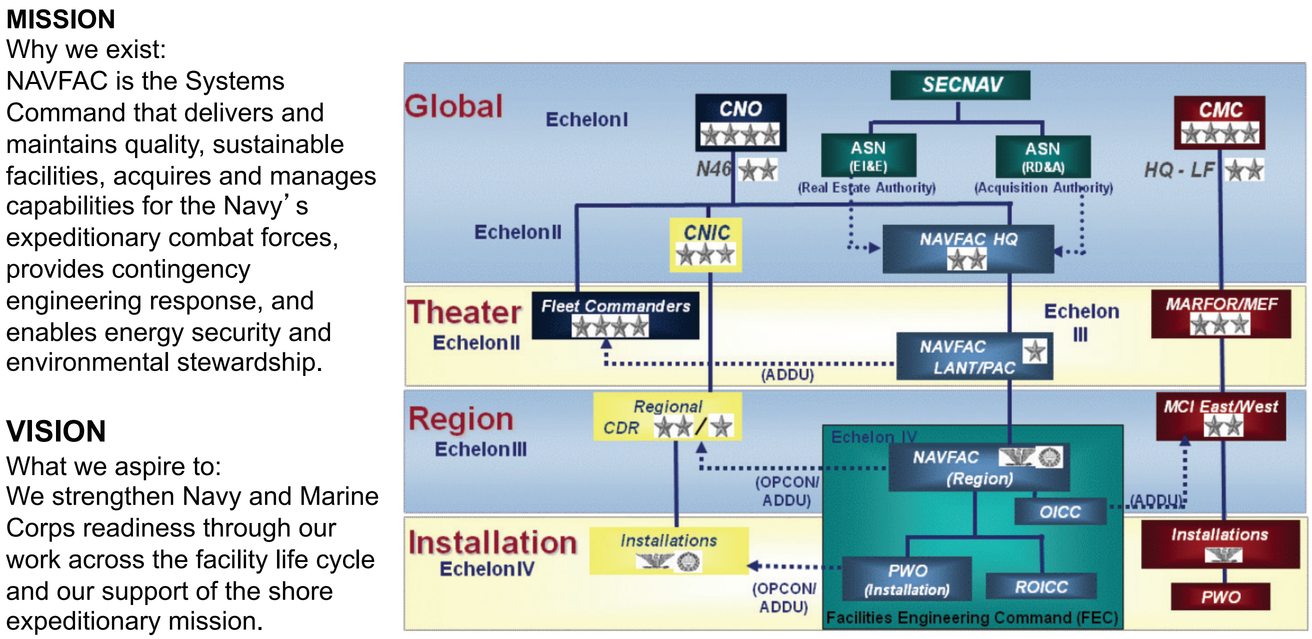


FIGURE 2-14 NAVFAC overview. CNO, Chief of Naval Operations; ASN, Assistant Secretary of the Navy; CNIC, Commander Navy Installation Command; NAVFAC, Naval Facilities Engineering Command; LANT/PAC, Atlantic, Pacific; OPCON/ADDU, Operational Control/Additional Duty; OICC, Officer in Charge of Construction; PWO, Public Works Officer; ROICC, Resident/Regional Officer in Charge of Construction; CMC, Command Master Chief; MARFOR/MEF, Marine Corps Forces/Marine Expeditionary Force; MCI, Marine Corps Institute. SOURCE: Robert Sadorra, Manager Munitions Response Program Naval Facilities Engineering Command, "The Navy's Roles and Responsibilities Related to Remediation of RCWM," presentation to the committee on January 18, 2012.

munitions recovered on its properties. Once RCWM is suspected on Navy property, the Navy acts through the Department of the Army, which is the EA for the chemical demilitarization program, for the remediation of any RCWM munitions.

Like the Office of the Secretary of the Army, the Office of the Secretary of the Navy provides civilian political and policy leadership for the Department of the Navy. The Navy RCWM program is overseen by the Assistant Secretary of the Navy (Installations and Environment). Funding and policy requirements for the Navy are determined and defended by this office. Planning, programming, budgeting, and execution of Navy requirements are performed through the Navy staff organization led by the Chief of Naval Operations, as outlined below.

### *Office of the Chief of Naval Operations*

The Chief of Naval Operations (CNO) is the senior naval officer in the Department of the Navy. A four-star admiral, the CNO is responsible to the Secretary of the Navy for the command, utilization of resources, and operating efficiency of the forces of the Navy and of the Navy shore activities assigned by the Secretary. The CNO is the Navy counterpart to the Chief of Staff of the Army. The RCWM requirements are defined and executed on behalf of the CNO through the Navy Facilities Engineering Command, which is headquartered in Washington, D.C.

### *Naval Facilities Engineering Command*

The Naval Facilities Engineering Command (NAVFAC) has military construction responsibilities similar to those of USACE and responsibilities for the installation of public works similar to those of the Army's Installation Management Command. NAVFAC is organized according to Figure 2-14.

NAVFAC performs roles much like those of the Army Environmental Command but for Navy DERP requirements at active Navy installations. It identifies suspected and planned Navy RCWM in close coordination with the Army's provisional RCWM integrating office. This also requires integrating the planned RCWM activities into the relevant DERP projects (as performed by ACSIM for the Army). NAVFAC assigns a Project Manager to coordinate with USACE on RCWM remediation (funded by CAMD, D) and carry out the Navy's real estate, installation security, and explosive safety responsibilities.[33]

[33]Robert Sadorra, Manager Munitions Response Program Naval Facilities Engineering Command, "The Navy's Roles and Responsibilities Related to Remediation of RCWM," presentation to the committee on January 18, 2012.

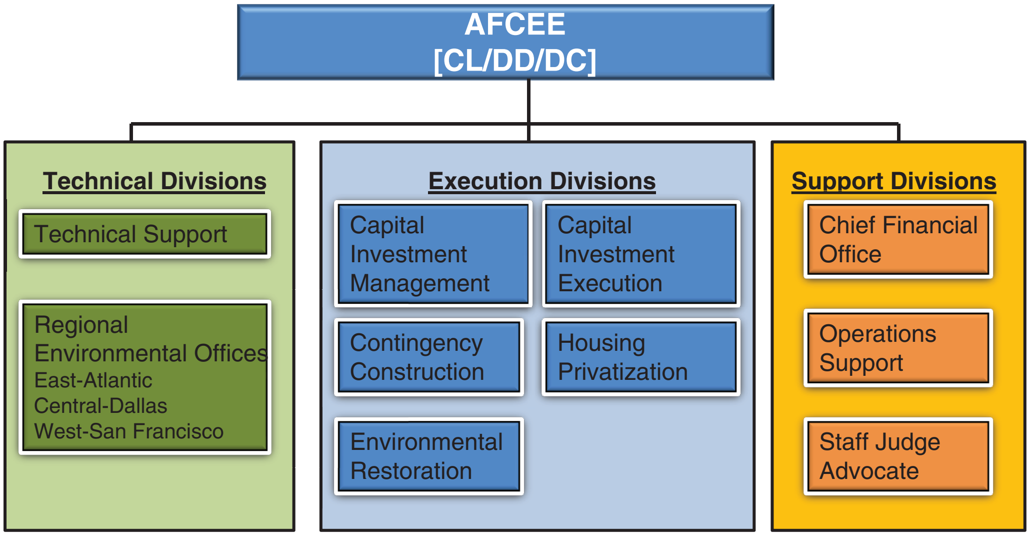


FIGURE 2-15 Air Force Center for Engineering and Environment. SOURCE: Adapted from http://www.afcee.af.mil/about/organizationalchart/index.asp.

## Office of the Secretary of the Air Force

As is true for the U.S. Army and the U.S. Navy, the civilian leadership of the U.S. Air Force is vested in the Secretary of the Air Force. The Office of the Secretary of the Air Force oversees the mission and programs assigned to the Air Force through a structure similar to those of the other Services. The Air Force is held responsible for the environmental quality of its installations, including any planned and/or discovered chemical weapons munitions, but like the Navy, the number of RCWM sites is very small compared to the Army. The remediation of RCWM on Air Force installations is executed by the U.S. Army, through the PMNSCM.

### *Air Force Civil Engineer*

The Air Force Civil Engineer is a two-star general billet within the Air Force staff. The Air Force staff is led by the Chief of Staff of the Air Force, a four-star general. The Air Force Civil Engineer reports to the Deputy, Chief of Staff, Logistics, Installations and Mission Support. The Air Force Civil Engineer is responsible for installation support at the Air Force's 166 installations. The office is also responsible for organizing, training, and equipping the Air Force engineering force, for planning, developing, building, and maintaining Air Force bases worldwide, and for their utilities and environmental quality. Additionally, the Air Force Civil Engineer oversees the Air Force Civil Engineer Support Agency at Tyndall Air Force Base, Florida, and the Air Force Center for Engineering and the Environment at Brooks City Base, Texas.[34]

### *Air Force Center for Engineering and Environment*

The Air Force Center for Engineering and Environment (AFCEE) is a field operating agency under the Air Force Civil Engineer organization. AFCEE is led by an Air Force civilian from the SES. The mission of AFCEE is to "provide integrated engineering and environmental products, services, and advocacy that optimize Air Force and Joint capabilities through sustainable installations."[35] AFCEE's organization chart is provided in Figure 2-15.

The RCWM program is managed within the Environmental Restoration (ER) Division. ER "provides centralized management of the Air Force Environmental Restoration Program and serves as the Air Force Restoration Program Management Office to facilitate the cleanup of contaminated sites at all active installations except Air National Guard and base realignment and closure facilities."[36] This office performs functions like those of the U.S. Army Environmental Command (USAEC) and NAVFAC, for DERP requirements; and it coordinates with the Army, as EA for all RCWM program activities on active Air Force installations.

## PROCESSES

As described above, the RCWM program is governed by a long history of legislation, regulation, and policy at the federal, state, and local levels. The impact of this policy legacy (and the accompanying multitude of funding sources) on the

[34] Available at http://www.afcesa.af.mil/shared/media/document/AFD-110103-058.pdf, and http://www.af.mil/information/bios/bio.asp?bioID=9882. Accessed April 16, 2012.

[35] Available at http://www.afcee.af.mil/about/organization/index.asp. Accessed March 14, 2012.

[36] Available at http://www.afcee.af.mil/publications/factsheets/factsheet.asp?id=18928. Accessed March 14, 2012.

existing multilayered government organizational structure requires that a complex set of management practices be put into use. This last section summarizes the processes by which these organizations apply their policy mandates within the context of an uncertain threat posed by recovered chemical weapons. These management practices are provided in Appendix E.

There are two categories of RCWM sites to which the government must respond: (1) planned RCWM recoveries at buried locations and (2) emergencies. For planned RCWM recoveries, the sites have been identified through a detailed literature research effort, largely by DOD and its contractors. The nature of the buried chemical munitions is only generally understood. In many instances they are buried alongside conventional munitions. The necessity of remediating these sites calls for a systematic planning, programming, budgeting, and execution (PPBES) approach following DOD established PPBES management practices. Management practices for these planned sites are depicted in Figure E-1, Management Practices for U.S. Army Planned RCWM Recovery at Burial Locations, in Appendix E.

The planned RCWM management practices are performed in seven phases: response; planning; packaging; assessment; storage (if required); treatment; and waste disposal and site closure. The first phase, response (notification) differs depending upon whether the site is an active Army CONUS installation, an active Army installation in Alaska or Hawaii, a FUDS site, or a BRAC site, since different government offices are responsible for the real property and the funding. Funding for each phase of the process changes according to the appropriation rules: DERP funds response, planning, packaging, and storage, while CAMD,D funds assessment, treatment, waste disposal and site closure. Army regulations govern which entity performs each phase, with installation commanders, CARA, USACE, NSCMP, CMA, ECBC, ACSIM, AEC and others being brought in to perform the tasks that fall within their relevant responsibilities. Figure E-1 details the planning, packaging, assessment, storage, treatment, and disposal tasks and identifies the players for three levels of anticipated RCWM munitions. Each phase has different levels of emphasis as the number of munitions at a given site increases. The processes apply only to U.S. Army organizations. Navy and Air Force sites would have similar processes at the installation level and shared processes in the execution of the remediation tasks with the Army.

Requirements for the second category of RCWM management practices—response to an emergency—are characterized, in general, by a discovery of suspected RCWM on active installations or on BRAC installations, FUDS, or on private property. The discovery of suspected RCWM requires immediate attention by civil authorities and Army personnel until such time as the risk to the public (including military personnel) has been assessed. In addition to law enforcement units, CARA and PMNSCM are alerted and involved in the preliminary phases of an emergency RCWM response. The PMNSCM tasks for these sites are commonly described as its "firehouse" function. (See Figure E-2, Management Practices for U.S. Army RCWM Emergency Response at Burial Locations.) The management practices are the same as those for the phases in the planned response scenario with the exception of the planning phase. Emergency responses involve a larger number of organizations in the response phase than do planned (and more deliberate) recovery operations. Until such time as discovered munitions have been identified, packaged, and assessed, emergency response activities are accelerated to ensure that public safety is maintained. Depending on the type and condition of munition(s) found, the storage, treatment, and waste disposal and site closure phases may be carried out at an accelerated pace or a more deliberate one.

These complex RCWM management practices involve many organizations, several funding sources, and several large and small sets of equipment and other technology. This complexity is partly the result of extensive policy direction in the form of congressional statutes, federal regulations, and internal (primarily DOD) directives. In addition, applying business rules for the various funding sources and coordinating with numerous government agencies adds many activities (and overhead cost) to the management practices. Because these management practices are performed in a public safety context that does not tolerate failure, the costs and time delays experienced during each phase may be significant.

## SUMMARY

This chapter provided an overview of the government policies, organization, and processes related to the RCWM program. While some of the policies that govern the program were enacted by Congress and others were implemented by the Executive Branch through Executive Orders or regulations, most of the regulations and policies for the RCWM program are internal to the Department of Defense. Other policies and regulations relevant to the program are national rather than state based and cover a broader spectrum of environmental or life/safety policy. Given the potential severity of health impacts if agent is released from buried chemical weapons munitions, these policies and regulations are very risk averse.

The organizations that are charged with implementing these statutes, policies, and regulations are broad, diverse, and complex. The relatively small and specialized RCWM organizations that have been created for the program are hidden deep within the DOD hierarchy. The U.S. Army, having been assigned by OSD as EA for the stockpile and non-stockpile programs, is the most involved of the Services in the program. This chapter provided a detailed examination of several of the more important RCWM players, each of which has a specific role to play. Close coordination among these organizations is vital to ensure that the threat to public health and safety is minimized as the remediation of RCWM continues.

This chapter concluded with a brief overview of the management practices that apply to the RCWM program. These management practices are very complex by the nature of the DOD PPBES, which applies to all DOD programs, as well as the specialized functions of the RCWM program itself. The processes must also be designed to apply to several possible scenarios depending on where, when, and how buried chemical weapons munitions are discovered.

# 3

# Treaty and Regulatory Framework and Public Involvement Considerations

As mentioned in the introduction, the Army must clean up large quantities of buried chemical warfare materiel (CWM). Whether the cleanup involves containment on the one hand or the recovery and destruction of CWM on the other will impact the scope and costs of the program.

The first subsection of this chapter discusses the treaty and regulatory requirements that influence whether buried CWM that may exist in pits and trenches will be contained or destroyed.

The next subsection discusses the other federal and state environmental regulatory requirements that may be critical-path items in determining the ultimate total cost, the cost-effectiveness, and time frames for the remediation of buried CWM and the committee's suggestions on how to address these requirements.

The last subsection discusses public involvement issues since, historically, public involvement has affected the remedial approaches selected by the Army and regulators.

This chapter provides only a very general overview of the environmental regulatory programs applicable to discarded chemical warfare materiel, with a focus on those legal and regulatory issues that have the most significant impact on implementation of the buried CWM remediation program. More detailed information on these regulatory programs and how they apply to the Army's overall remediation responsibilities (i.e., the cleanup of munitions and industrial hazardous wastes) is provided in Appendix D.

## TREATY AND REGULATORY REQUIREMENTS THAT DETERMINE SCOPE AND COST OF CLEANUP

The scope and costs of the CWM cleanup program are largely driven by (1) the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (CWC, or "the Treaty");[1] (2) the federal Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) hazardous substance cleanup program (EPA, 1980); and (3) the federal Resource Conservation and Recovery Act (RCRA) corrective action program (EPA, 1976).

### Treaty Obligations

The CWC and related U.S. enabling legislation require the destruction of recovered chemical warfare materiel (RCWM) (NRC, 2003). Nothing in the CWC requires the United States to recover buried CWM munitions. However, once removed and determined to fall into one of the categories of chemicals covered in the treaty, steps must be taken to declare and destroy the items in accordance with the requirements of the CWC.[2]

### CERCLA

#### *Overview*

CERCLA is a federally implemented hazardous waste cleanup program and has been used to clean up hazardous waste sites all over the United States, including military sites that contain CWM. The Environmental Protection Agency (EPA) promulgates the regulations and has issued many guidances governing the investigation, remedy selection, and cleanup of CERCLA sites, whether the responsible entity is the government or a private company.

The decision to contain or recover and destroy buried CWM is made in the context of a complex set of laws, regulations, guidance, and implementing Department of Defense (DOD) cleanup programs. Under CERCLA, the Army performs the site investigations, evaluates the reme-

[1] Available at http://www.opcw.org/chemical-weapons-convention/. Last accessed March 15, 2012.

[2] Lynn M. Hoggins, Director, Chemical and Biological Weapons Treaty Management, Office of the Deputy Assistant Secretary of Defense, Nuclear, Chemical and Biological Defense, personal communication to Nancy Schulte, NRC study director, January 6, 2012.

dial alternatives, and proposes an action (Section 120 of CERCLA; EPA, 1988, 1990a, 1999). However, the process, program, and funding for DOD remediation differs from a nonfederal CERCLA cleanup and depends on the type of DOD cleanup site.

The precise oversight role at DOD sites depends somewhat upon the program: (1) sites no longer owned or controlled by DOD are handled by the formerly used defense sites (FUDS) program[3] (U.S. Army, 2009b); (2) active bases are addressed by the Defense Environmental Restoration Program (DERP); and (3) sites on closing bases are addressed by the base realignment and closure (BRAC) program.

Some sites are placed on EPA's National Priorities List (NPL), which means, as its name implies, that these cleanups generally receive a higher priority and a greater degree of EPA oversight. At NPL sites, EPA and DOD must negotiate a federal facility agreement (FFA), which provides a detailed agreement concerning the process and timing by which the site investigation is performed, the remedy selected, and the remedial action implemented, including the regulatory review (EPA, 1988, 1999.)

As of 2010, EPA and DOD had successfully negotiated FFAs at 136 out of 141 facilities (GAO, 2010), and additional agreements have been entered since 2010. However, at a small number of installations, disputes between EPA and DOD concerning implementation of FFAs have arisen (GAO, 2010). DOD has in rare cases failed to obtain EPA's prior approval for key cleanup decisions, leading EPA not to recognize them and warn that additional work may be required (GAO, 2010; Ferrell and Prugh, 2011). According to GAO, "when an agency refuses to enter into an . . . [FFA] and cleanup progress lags because of statutory and other limitations, EPA cannot take steps—such as issuing and enforcing orders—to compel CERCLA cleanup as it would for a private party" (GAO, 2010). EPA may seek to have DOD perform additional work (EPA, 1988).[4] Thus, disputes must be resolved through interagency discussions (GAO, 2010). Since Section 120 of CERCLA also contains a waiver of sovereign immunity, individuals and states may bring citizen suits if an agency is not adhering to a CERCLA mandate (EPA, 1999; GAO, 2010; EPA, 2011b).

At non-NPL sites, EPA's role is less direct and the cleanup may be more flexible. For the most part, state agencies oversee DOD cleanup activities at non-NPL sites, which are the majority of DOD sites (U.S. Army, 2009b).

Section 120 of CERCLA requires federal agencies, such as Army facilities containing CWM, to comply with CERCLA "in the same manner and to the same extent, both procedurally and substantively, as any nongovernmental entity, including liability" (EPA, 1980). The DERP statute requires that DOD "carry out a program of environmental restoration at facilities under the jurisdiction of the Secretary," including response actions that are "subject to, and in a manner consistent with, section 120," which in turn, requires compliance with CERCLA in the same manner as any nongovernmental entity. The Army final military munition guidance applies the CERCLA remedy selection process to munitions response sites, although explosive safety (which is generally not addressed at CERCLA sites) is the "paramount priority" during a munitions response (U.S. Army, 2009b). U.S. Army guidance, in effect, treats NPL and non-NPL sites the same with regard to coordination with regulators and meeting regulatory requirements.[5] Thus, CERCLA remedy selection criteria apply to DOD sites and are discussed in detail below.

### *CERCLA Remedy Selection Factors*

CERCLA remedial actions are selected using nine criteria. The mandatory threshold remedy selection criteria are "overall protection of human health and the environment" (EPA, 1980) and "compliance with federal and state regulatory requirements found to be applicable or relevant and appropriate" (EPA, 1990a). Protectiveness is essential. CWM responses address "the chemical safety; explosives safety, when applicable; human health; or environmental risks presented by chemical-agent-filled munitions or agents in other than munitions configurations" (U.S. Army, 2009b). Risks posed by agent-filled munitions are "assessed through a baseline risk assessment that adheres to the requirements of CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (U.S. Army, 2009b).

The final remedy is generally selected from protective and applicable, relevant, and appropriate requirement (ARAR)-compliant alternatives based on long-term effectiveness and permanence; the reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost (EPA, 1990a).

State and community "acceptance" must be considered, but it does not provide either the state or local citizens the right to veto a remedy (EPA, 1990a). U.S. Army guidance is clear that regulatory agencies and local governments must be part of the CERCLA planning process and must be consulted in key decisions (U.S. Army, 2005). However, as a practical matter, the exact process utilized and role of the state and community depends largely on whether the site is an NPL site or not.

[3]DOD, Environmental Restoration Program, web site. Available at https://www.denix.osd.mil/denix/Public/Library/Cleanup/CleanupOfc/derp/index.html. Last accessed March 16, 2012. See also Army Regulation 200-1, Environmental Protection and Enhancement (February 21, 1997); AR 200-1 (para 3-3b) requires facilities to include a contingency/response plan for hazardous substances as part of an SPCCP.

[4]Paragraph J Subsequent Modifications of Final Reports, subparagraph 3 of the 1988 Model Federal Facility Agreement.

[5]Deborah A. Morefield, Environmental Management, Office of the Deputy Under Secretary for Installations and Environment Department of Defense, "Remediation Operations from an OSD Installations and Environment Perspective," presentation to the committee on November 2, 2011.

### *Balancing the Criteria Case by Case*

On a case-by-case basis, the relevant criteria are "balanced in a risk management judgment as to which alternative provides the most appropriate solution for the site" (EPA, 1990a). Under CERCLA, EPA "expects to use treatment to address the principal threats posed by a site, wherever practicable" (EPA, 1996c, p. 2). Practicability, however, is "based on the balancing of trade-offs among alternatives that are conducted during the selection of remedy" (EPA, 2009b). In upholding the NCP against challenges seeking to require only permanent remedies, the Court of Appeals for the D.C. Circuit held that "nothing in CERCLA §121 . . . suggest[s] that selecting permanent remedies is more important than selecting cost-effective remedies."[6] Rather, the emphasis on permanent solutions and treatment is balanced by the coequal mandate for remedies to be cost-effective (EPA, 1996c). As a result, 65 percent of EPA CERCLA source control records of decision published from FY 1998 to FY 2008 have included a containment component, and treatment was "not practical" at 56 percent of the Superfund sites in which the record of decision (ROD) was issued from 2005 to 2008 (EPA, 2010c).

## RCRA Corrective Action

The Resource Conservation and Recovery Act (RCRA) is primarily a statute regulating how wastes (solid and hazardous wastes) must be managed to avoid potential threats to human health and the environment, as opposed to CERCLA's focus on the cleanup of contamination (EPA, 1976). However, the RCRA corrective action authority is a hazardous waste cleanup program analogous to CERCLA that applies to past disposal locations on RCRA-permitted facilities, and for facilities that are closing without obtaining permits (including DOD facilities). Although RCRA is a federal program, most states have been authorized by EPA to implement the program.

EPA's written policy is that the "RCRA and CERCLA remedial programs should operate consistently and result in similar environmental solutions when faced with similar circumstances," i.e., procedural differences between RCRA and CERCLA should not substantively affect the outcome of remediation (EPA, 1996b, 1997a, and 2011c).[7] EPA uses essentially the same remedy selection criteria and the same expectations for RCRA remediation as for CERCLA, specifically including the preference for "treatment to address the principal threats posed by a site whenever practicable and cost-effective." (EPA, 1996b).[8] Substantively, cleanups required pursuant to CERCLA and RCRA corrective action are equivalent (see Figure 3-1, which compares very generally the CERCLA and RCRA and remediation processes). (See Appendix D for details).

### *State Cleanup Programs*

Because the RCRA cleanup process is driven primarily by guidance rather than regulation, states (and EPA in certain circumstances) have more flexibility in remedy selection and, in fact, some do not follow the EPA guidance (by definition, guidance is not legally binding). The process is described in Appendix D in more detail.

States implement RCRA programs within their boundaries and normally serve as lead regulator for non-NPL installations and are a "regulatory team member" at BRAC sites (U.S. Army, 2009b). Additionally, state requirements can be incorporated into CERCLA cleanups because ARARs may include state regulatory requirements (EPA, 1990a). CERCLA "specifies that state laws 'concerning removal and remedial actions, including state laws regarding enforcement, shall apply to removal and remedial actions at facilities owned or operated by [the federal government] when such facilities are not included on the NPL.'"[9] (U.S. Army, 2009b). Many of the state remediation regulations are similar to the federal approach, but states may adopt (and some have done so) their own cleanup policies or preferences.

Although there may be some states that set different cleanup goals than EPA for the same chemicals or situation, most states use EPA values and guidance and rely upon CERCLA and RCRA authorities for their legal framework. Most states have essentially adopted the federal RCRA corrective action program

Although there is no known large buried CWM site in New York, it is relevant in understanding the overarching state cleanup process to recognize that even the New York state statute (which requires sites to be restored "to predisposal conditions, to the extent feasible") has been interpreted by the highest court in the state to mean that remedies may "reduce rather than completely eliminate dangers" and that this statute "evinces a preference for the most thorough cleanup that makes sense in light of technical feasibility and cost-effectiveness."[10] The New York remediation "may encompass measures that run a gamut from removal of wastes to institutional controls . . . to address harms that

[6]Ohio v. EPA, 997 F.2d 1520, 1533, D.C. Cir. 1993.

[7]EPA uses the Corrective Action Advance Notice of Proposed Rule Making (ANPRM) as its corrective action guidance.

[8]CERCLA includes explicit statutory remedy selection criteria which express, among other things, a preference for treatment (see discussion above). This preference is also incorporated into the CERCLA cleanup regulations (EPA, 1990a). Although the RCRA statute does not contain a statutory preference, EPA directed its staff to use as "guidance" essentially the same remedy selection criteria as provided in CERCLA (EPA, 1997a). In particular, it specified "remedy expectations" that are intended to "guide development of remedial alternatives" (EPA, 1996b). These expectations are "not binding requirements," but are often followed because they "reflect [EPA's] collective experience" (EPA, 1996a). Specifically, "EPA expects to use treatment to address the principal threats posed by a site whenever practicable and cost-effective" (EPA, 1996b).

[9]42 U.S.C. § 9620(a)(4)(2001).

[10]New York State Superfund Coalition Inc. v. New York State DEC at 9-10 (N.Y., No. 189, 12/15/11). Available at http://www.courts.state.ny.us/CTAPPS/Decisions/2011/Dec11/189opn11.pdf.

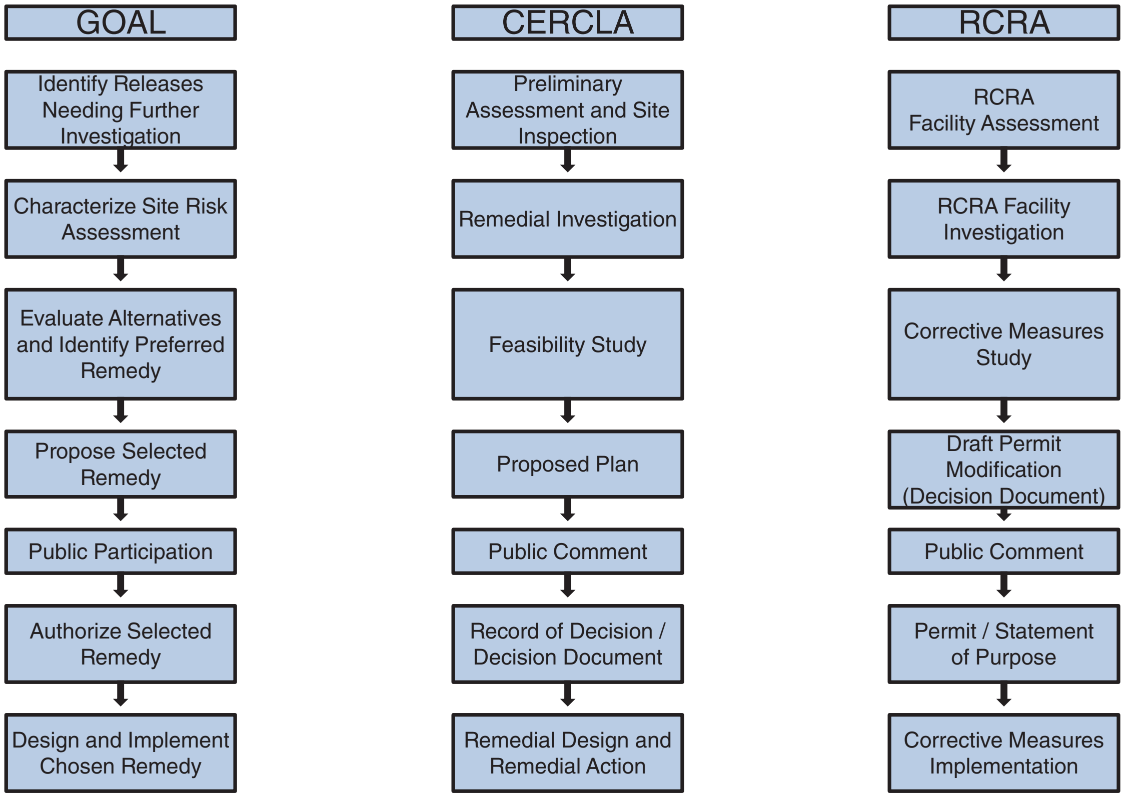


FIGURE 3-1 Comparable CERCLA and RCRA remedial action processes. Final draft Army guidance for Military Munitions Response Program (MMRP) remedial investigation feasibility study (RI/FS). Available at http://www.milvet.state.pa.us/DMVA/Docs_PNG/Environmental/MRRI-FSGuidance.pdf, pp. 1-14 (U.S. Army, 2008c). Accessed April 10, 2012.

range from potential to actual hazards," but the statute would not "compel a reversion to pristine environmental conditions."[11]

### Historic Examples of Cleanup of Buried CWM

Both RCRA and CERCLA have been or are planned to be used to address CWM, as summarized in Table 3-1.

## REQUIREMENTS

A number of regulatory issues (particularly the remedy selection criteria) impact the investigation, remedy design, and remedy implementation of buried CWM. The committee's review documented the reasons that the environmental regulatory programs may require very costly remedial actions and several other regulatory issues that may be obstacles or impact the cost of the remediation of buried CWM. Significant issues that are likely to impact most CWM cleanup operations are discussed below. Issues relevant to Redstone Arsenal are discussed in Chapter 5.

Existing Army guidance for performing remedial investigations at munitions response sites, detailed in the Army's Final Munitions Response Remedial Investigation/Feasibility Study Guidance (MMRP RI/FS Guidance) (U.S. Army, 2009b) is both adequate and appropriate. This guidance recommends following the Technical Project Planning (TPP) process, which requires identifying and bringing decision makers and technical personnel together (TPP Phase I), determining data needs (TPP Phase II), developing data collection options (TPP Phase III), and finalizing the data collection program (TPP Phase IV). All of this planning activity is designed to be front-loaded to identify potential conflicts and decisionmaking before field activities begin. While the existence of this guidance is a significant positive step for expediting the buried CWM portion of the munition response mission, as a matter of law, guidance is not legally binding[12] and, in the experience of many of the committee members, agencies do not always follow their own guidance. Moreover, some agency personnel may not be aware of all of the agency guidance.

[11]New York State Superfund Coalition Inc. v. New York State DEC at 9-10 (N.Y., No. 189, 12/15/11). Available at http://www.courts.state.ny.us/CTAPPS/Decisions/2011/Dec11/189opn11.pdf. Id. at 10-12.

[12]McLouth Steel Products Corp. v. Thomas, 838 F. 2d 1317 (DC Cir. 1988).

TABLE 3-1 Examples of CWM Cleanups

| Site | Cleanup Program | Containment/ Destruction | Technology | Other |
|---|---|---|---|---|
| Rocky Mountain Arsenal (NRC, 2002) | CERCLA. Approved through a CERCLA record of decision and it met the requirements of the state's RCRA order because it was a CERCLA emergency removal action | Destruction selected | EDS | A large CERCLA cleanup has been under way since the 1980s. A small quantity of sarin bomblets in publicly accessed area Rocky Mountain Arsenal was already listed on the CERCLA NPL and had an ongoing remedial program for non-CWM; the sarin bombets are a small portion of overall cleanup. |
| Spring Valley, D.C. (EPA, 2011a) | CERCLA | Destruction selected to date. Future CWM remedy not decided. | EDS | Residential neighborhood, included soil Investigation is ongoing. |
| Camp Siebert | CERCLA | Destruction selected | EDS | Near a farm |
| Redstone Arsenal[a] | State issued a RCRA permit requiring cleanup. EPA is negotiating a CERCLA FFA, which would result in an EPA lead. The Army prefers one regulatory decision maker. Who is the lead regulatory authority is not decided. | State policy: destroy. State has ordered destruction of all CWM. Final remedy not decided | Not determined | On a munitions range on an active base. Residential areas are encroaching on the base. Groundwater is shallow and contaminated groundwater is entering the Tennessee River. |
| Tooele, Utah | RCRA | Not decided. State prefers destroying CWM on surface, but contained buried | Not determined | These CWM are buried on an Army base that is remote from populated areas. |
| Dugway Proving Ground (RCRA Permit 2011)[b] | RCRA | While there were some removals, most sites involved containment remedies. | Covers with land use controls and continued monitoring. | Over 200 solid waste management units were identified at Dugway Proving Ground (DPG); corrective action was implemented at most units during the 1990s. There are no active RCRA corrective action activities at DPG except for postclosure care, including land use controls and continued monitoring. |
| Aberdeen, Md. (U.S. Army, 2008d) | CERCLA | Contained. Five-year reviews in 1999, 2002, and 2008. | A cover was placed on CWM in the O-field landfill using remote technology and ground water pumping | This was just one operable unit on a large active Army base. Munitions were unstable. For the remedy to be protective in the long-term, containment of the waste must continue and LTM and 5-year reviews conducted until site conditions allow for unlimited use and unrestricted exposure. |

[a]Presentations to the committee and conference calls with EPA Enforcement (December 5, 2011).
[b]Utah, RCRA Permit Module VII, SMU 200 Post-Closure Plan. Available at http://www.hazardouswaste.utah.gov/HWF_Section/Docs/DPG/DPG7_Attach22_HWMU200.pdf.

**Finding 3-1.** The Army MMRP RI/FS Guidance document (U.S. Army, 2009b) describes how to implement a transparent and coordinated strategy for identifying stakeholders and including them in the MMRP decision-making process.

**Recommendation 3-1.** Army managers of CWM projects should fully implement the TPP process as described in the MMRP RI/FS Guidance as early as possible when planning and implementing CWM cleanups.

The exact amount of cleanup required and the time frame over which the remedy will be implemented cannot be predicted with accuracy because the ultimate scope can only be determined through the regulatory cleanup process; it is out of the Army's complete control.

### The Need for Flexibility in CWM Remediation

A "multitude of challenges make the RI/FS at CWM sites unique," including the "potential for exposure to toxic chemical agents," the presence of explosive material, and the co-location with nonchemical munitions or hazardous wastes (U.S. Army, 2009b). The presence of explosives requires unique procedures to ensure safety. In addition, soil and other media may be contaminated.

Each site where CWM is buried may also be unique with respect to other factors. Factors include disposal conditions (e.g., depth of disposal, cover soil), location (e.g., floodplain, shallow groundwater, operational range), and exposure pathways (e.g., distance from installation boundary), in addition to other factors. The diversity of conditions at each facility, many with multiple CWM disposal areas, argues for a flexible approach toward site assessment, investigation, conduct of removals or interim actions, final remedy selection and remedy implementation. This is especially the case since it is often difficult to know exactly what is buried in disposal sites or the condition of the items in the burial site until the site is actually investigated.

The CERCLA and RCRA processes provide flexibility to conduct a tailored approach to assessment, investigation, and eventual cleanup that still meets the substantive requirements of both RCRA and CERCLA regulatory programs (i.e., discovery, adequate characterization of the scope of the problem, determination of the risk, and balancing of the remedy selection factors).

With regard to CWM burial sites, and assuming that an exhumation and destruction approach is taken, test burial pits, for example, may be dug as a removal or interim action in a first attempt to start the cleanup process but also to better understand what may be present in the remainder of the disposal site and its condition. Once more is learned about specific disposal sites, additional removal or interim actions may be taken to further reduce risk and better understand the materials present and their condition. More definitive remedial actions (CERCLA) and corrective measures (RCRA) should only be taken once the site is fully understood with regard to nature and extent of contamination, exposure pathways, and risk to human health and the environment.

Specifically, the committee notes that in some cases, adequate data about some CWM burial sites may be available without having to perform a full-blown remedial investigation (CERCLA) or RCRA facility investigation (see Appendix D). They may come from historical information, geophysical investigations, limited test-pits, and some sampling to enable development of a combined investigative and cleanup approach. The conventional approach in cleanup programs would entail completion of a full-blown remedial investigation or RCRA facility investigation even if insufficient data are available to enable evaluation of cleanup options and a cleanup decision. An expedited approach would entail the evaluation of cleanup options and selection of a cleanup technology based on minimal but still sufficient data. The advantage of the expedited approach is that funding can be applied toward risk reduction even if not enough data are available to fully characterize the nature and extent of the source of the contamination and the release and migration pathways. Where a leave-in-place remedy is selected, available funds can be applied toward cap design and the design of a continued media monitoring program, and eventual emplacement of the cap and monitoring system. Where a remove-and-destroy remedy is selected, removal can be conducted in parallel with the remedial investigation so that as the site is characterized, identified surface and buried munitions are exhumed and treated. This is similar to what the Army did at the Spring Valley site, where it took a remove-and-destroy-as-you-characterize approach. Risk has been reduced as the investigation proceeds.

**Finding 3-2.** The CERCLA and RCRA processes are flexible enough to address the unique situations that buried CWM sites may represent.

**Finding 3-3.** In some cases, sufficient data are available for some CWM burial sites to be able to evaluate and select remedial approaches and technologies without having to fully investigate the nature of the source or the extent of releases and migration pathways.

**Recommendation 3-2.** DOD and the appropriate regulatory authorities, with opportunity for input of the interested public, should use the flexibility inherent in RCRA and CERCLA to tailor the overall response to address unique attributes of individual buried CWM sites.

**Recommendation 3-3.** The Army should consider emphasizing the implementation of risk reduction activities as early as possible, even if there are not enough data to fully characterize the nature of the source and the extent of the release and migration pathways.

## Know Before You Go

During the investigative phase of RCRA and CERCLA munitions sites cleanups, field investigative teams may encounter surface-disposed munitions as well as munitions that were buried. Under RCRA's waste management requirements, once a buried munition is uncovered, it is considered having been "actively managed" and becomes newly generated waste. Similarly, a surface-disposed munition that has been undisturbed for many years would also become waste once it is actively managed. If these munitions are determined to be hazardous waste, they are subject to RCRA's waste management requirements.

In addition, and as indicated previously, should the munition be determined to be CWM, the CWC also comes into play. Once confirmed to be chemical warfare materiel, the CWC would require that munition to be destroyed, although there is no specific time limit for achievement of destruction. Considering both RCRA and CWC requirements, uncovered CWM may not be placed back onto or into the ground. The Army RI/FS guidance, EPA guidance, and Army practice are to develop and obtain approval of plans for such activities. The Army may wish to develop, after consultation with federal and state regulators and other stakeholders, a consensus systematic approach for how to process items that may be CWM. The approach should be site-specific and might include specific steps for further evaluation to identify the type of munition and chemical content, interim storage, and eventual disposition, to include destruction either on-site or off-site, and management of secondary wastes and other residuals. Approval by the regulatory authority and involvement of the public is a regulatory requirement.

### Clean Islands in the Middle of Contaminated Operational Ranges

Operational ranges at most of the Army's installations have been in use for many years, most for decades. These operational ranges are used for multiple purposes, primarily training and research and development. Through use over many years, these operational ranges have become contaminated with munitions-related constituents, including munitions-related chemicals (e.g., trinitrotoluene, perchlorate) the breakdown products of munitions-related chemicals (e.g., dinitrotoluene, heavy metals), and unrelated chemicals, such as those used to decontaminate chemical munitions (e.g., bleach solutions, caustics, and organic solvents). These operational ranges have been determined by the Army as safe for soldiers and other personnel involved in intermittent training and research and development, but the contamination at these ranges is a concern nonetheless.

As indicated above, one of the options for cleaning up waste disposal or treatment units located on operational ranges is removal of exploded munition bodies and decontaminated chemical munitions and the removal and destruction of intact munitions, including both conventional and chemical munitions. Presumably, contaminated media may also be removed and either treated or disposed of.

The committee notes that while the removal and destruction of exploded munition bodies and decontaminated chemical munitions and the removal and treatment of intact munitions, including both conventional and chemical munitions, and the removal and treatment and/or disposal of contaminated media may be appropriate for FUDS and BRAC sites, the removal and treatment option should be carefully evaluated for operational ranges. The committee is concerned that the removal and treatment option for old disposal units located on operational ranges could result in cleaned-up islands in the middle of historically contaminated operational ranges that through continued use for training and other purposes into the future, would only become contaminated again.

**Finding 3-4.** By their very nature, the Army's operational ranges are contaminated from prior and ongoing training, research, development, and other uses. Continued use of the range will result in low-level or moderate contamination.

**Recommendation 3-4.** In assessing the appropriate remedy for buried CWM on operational ranges, the Army and the regulators who approve or concur in the remedy for such sites, should continue to consider the unique circumstances presented by operational ranges.

### Corrective Action Management Units

Management of remediation waste is a highly complex subject. Also, because RCRA is largely state-implemented, the states often implement the requirements pertaining to the remediation of wastes differently. Very large amounts of remediation wastes may be generated from the active remediation of some CWM disposal sites. Such wastes include contaminated and uncontaminated empty munition bodies, intact chemical and conventional munitions, disposed manufacturing and processing equipment, and contaminated soil and debris. While, it is beyond the scope of this report to evaluate the intricacies of the regulations for the remediation of wastes that may come out of CWM sites, it is nevertheless important to mention the options for managing such waste.

Historically, EPA interpreted any movement of waste or contaminated soil at a site as the "generation of hazardous wastes," which in turned triggered RCRA waste management requirements, including the requirement to treat the wastes and, if necessary, contaminated soil and debris to meet standards established under the RCRA land disposal restrictions (LDR) program. EPA established a number of different types of units to allow flexibility in the selection of the approach for managing remediation waste and contaminated soil, other media, and debris. As indicated in Appendix D, remediation wastes can be managed in corrective action management units (CAMUs), temporary units, and in designated "areas of contamination" without having to meet all the restrictive requirements for what is known as "as-generated waste," including the requirement to treat remediation waste to meet the same LDR requirements as "as-generated" wastes.

CAMUs in particular are intended for situations where large amounts of remediation waste are expected to be generated from one or more units, and where the wastes can be safely and securely managed in the same on-site location or at an acceptable off-site location. CAMUs include units intended for storage and treatment of remediation waste as well as for disposal of these wastes. Whereas storage and treatment CAMUs are temporary facilities, CAMUs intended for disposal are permanent waste management units. Disposal CAMUs would therefore likely be limited to active installations where the Army is expected to maintain ownership into the future. They could also be employed at BRAC locations where a federal land manager becomes the new landowner for the facility.

Contaminated or decontaminated chemical and conventional munitions and other remediation wastes could be managed in a CAMU. Indeed, any kind of remediation waste can be managed in a CAMU, as long as it can be shown to be protective of human health and the environment. The CAMU could also be used for treatment, storage, or disposal of contaminated debris and soil. Since the CWC would require the destruction of intact chemical weapons, these materials could not be managed in a CAMU. Secondary wastes remaining after such destruction, however, could be managed in a CAMU.

Similar to CAMUs, Areas of Contamination, as described in Appendix D, could also be used to manage remediation wastes. If the concept of an Area of Contamination can be shown to be protective of human health and the environment, and pending regulatory acceptance, remediation wastes, including contaminated soils, could also remain in such Areas. This would be the case, for example, if a decision is made to leave remediation waste in place, with appropriate engineering controls (e.g., landfill cap, leachate collection system), monitoring (e.g., groundwater monitoring), and land use controls. These types of remedies have been employed, for example, at Aberdeen Proving Ground (Edgewood Area) and at Rocky Mountain Arsenal. The review of regulatory programs in Appendix D provides information on the decision-making process for remedy selection under RCRA and CERCLA. In particular, the section in Appendix D on types of remedies addresses the choice of active removal/destruction vs. leave-in-place or containment remedies.

Similarly, Temporary Units, as described in Appendix D, could also be used for the management of remediation wastes. Such units would be ideal for an interim holding facility (IHF), for example, but could also be used for treatment units like the Explosive Destruction System (EDS) or any of the explosive destruction technologies (EDTs).

Setting up such units for the many "empty" munition bodies and scrap metals and for contaminated soil and debris that may be present in large disposal pits would have many advantages over other RCRA or CERCLA remedies.

**Finding 3-5.** Corrective Action Management Units, Temporary Units, or the designation of Areas of Contamination for management of remediation wastes are possible solutions for management of the large amounts of remediation waste that will be generated at RCRA or CERCLA CWM disposal sites.

**Recommendation 3-5.** The Army should make increased use of Corrective Action Management Units in situations where large amounts of remediation waste are expected, although the committee recognizes the need to retain the flexibility to make determinations based on site-specific circumstances.

### The Problem Posed by RCRA Storage Requirements

One complication that the Army could encounter during CWM investigations and also during large-scale removal operations might be the storage of the munition(s) awaiting evaluation or destruction. RCRA requires a hazardous waste storage permit for waste in storage for longer than 90 days. While a 90-day extension to this deadline might be issued by the regulatory authority, it is likely that RCWM would need to be stored for much longer. At Spring Valley, for example, RCWM were stored for approximately 2 years in an IHF before the EDS was brought on-site and operated.[13] Similarly, at the Camp Sibert, Alabama, FUDS, RCWM have been in storage for over a year in an IHF awaiting eventual treatment in an EDS or EDT.[14] RCRA corrective actions would be considered to be an ARAR under CERCLA, and only the substantive aspects of RCRA regulations would be considered applicable.[15] Storage in excess of 90 days is typically not an issue at sites being addressed under CERCLA, because permitting would be considered an administrative (nonsubstantive) requirement. The more likely issue would be if the cleanup is being conducted pursuant to RCRA corrective action. In this case, the 90-day storage criterion would apply. The regulatory authority in this case could direct the installation to initiate action to permit the IHF as a RCRA storage facility.

The committee visited and examined an IHF at the Spring Valley site. In addition, the committee is aware of the regulatory requirements imposed by the U.S. Army Technical Center for Explosives Safety (USATCES) and the Department of Defense Explosives Safety Board (DDESB) on the management of munitions in such containers. The committee believes that establishing additional regulatory requirements through the RCRA permit is unnecessary to protect human health or the environment. The requirement to obtain a storage permit in this case is similar to a situation that emerged as the Military Munitions Rule was being developed by EPA, with input from DOD. Here, EPA and DOD realized that munitions, both conventional and chemical, might be in storage for an extended period of time prior to undergoing demilitarization. EPA agreed, after reviewing DOD regulatory requirements, that requiring DOD installations to obtain RCRA permits for such storage was unnecessary (EPA, 1997b). In recognizing that obtaining a storage permit in this case was unnecessary, the "igloo door" policy was established (DOD, 1998). In accordance with this policy, munitions destined for demilitarization did not become defined as waste subject to RCRA until they exited the igloo on their way to demilitarization. This same concept can be applied to RCWM in storage awaiting destruction. Another approach would be to approve the IHF as a Temporary Unit under RCRA (see Appendix D).

[13]Steven Hirsh, Remedial Project Manager, Region 3, Environmental Protection Agency, "Protecting the Public: An EPA Perspective," presentation to the committee on November 1, 2011.

[14]Karl E. Blankenship, FUDS Project Manager, Mobile District U.S. Army Corps of Engineers, "Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective," presentation to the committee on November 3, 2011.

[15]The committee notes, however, that the definition of what is and what is not applicable and appropriate is subject to regulatory interpretation.

### Regulatory Approval and Permitting of the EDS and EDTs

The EDS and two of the three types of explosive destruction technology (EDT) have now been deployed to a number of locations within the U.S. and have been operated successfully. At CERCLA sites, such as Schofield Barracks in Hawaii and Spring Valley in Washington, D.C., destruction technology was established as part of CERCLA documentation. Regulators were given the opportunity, through the CERCLA process, to review the technology documentation and to comment on operating conditions or controls for these containers. The process has worked very well. At some CERCLA locations, such as at the Rocky Mountain Arsenal in Colorado, the regulatory authority sought an additional level of control over operations to destroy recovered sarin bomblets, so it set its own conditions by formulating state versions of RCRA's emergency order provisions.

In addition to CERCLA sites, the EDS and one of the EDTs have also been used at installations operating under a RCRA permit. Examples include the Pine Bluff Arsenal for the destruction of various types of chemical munitions, and Anniston Chemical Depot, Alabama, where a static detonation chamber (SDC) was used experimentally on waste chemical munitions in anticipation of its use at the Pueblo Chemical Depot. Regulatory approval in these cases was not through the conventional RCRA permitting process, but through alternative regulatory approval mechanisms available under RCRA, such as Research Development and Demonstration (RD&D) permits. The EDS or any of the EDTs may also be approved as a Temporary Unit, mentioned above for approval of the IHF. Use of these alternative regulatory approval mechanisms can work well as a means of allowing the regulatory authority to review documentation and approve use of the devices for RCWM in a timely manner. Another alternative for regulatory approval would be to pursue a conventional RCRA operating permit for a hazardous waste management unit or, in the case of the EDS or the EDTs, a permit for a miscellaneous unit under RCRA Subpart X. Obtaining such permits can be a very long and expensive process, however, taking one or more years and many dollars to finalize.

**Finding 3-6.** Some states may wish to employ the conventional RCRA permitting process as a means of approving use of the EDS or one of the EDTs at a RCRA CWM munitions response site (MRS). Alternative approaches for regulatory approval might save time and money.

**Recommendation 3-6.** The Army should urge the Environmental Protection Agency or the state regulatory authority, as applicable, to employ the existing alternative approval mechanisms and flexibility available under the Resource Conservation and Recovery Act in lieu of the typical permitting process for use of the explosive destruction system or explosive destruction technologies.

### Recycling of Treated Munition Bodies, Fragments, and Other Metals

Recycling of metal fragments has been addressed in prior NRC reports (NRC, 2007, 2010a). However, the number of such metal parts will be much greater at buried CWM sites. For this reason, it would be appropriate to summarize lessons learned. All types of EDT and the EDS will produce a significant amount of metallic secondary waste, consisting of the treated munition body, fragments, and, in some cases, the explosive fragmentation protection system. Currently, the project manager for non-stockpile chemical materiel (PMNSCM) plans to landfill these metal materials as hazardous waste at a RCRA-permitted treatment, storage, and disposal facility (TSDF).[16] They could also be managed in a CAMU, as described above. Such secondary wastes, however, could instead be recycled as scrap metal. Experience has shown that EDT and EDS treatment can produce scrap metal that is <1 vapor screening level (VSL) (NRC, 2009a). The Dynasafe unit produces metal that may be released to the private sector for recycling or other uses. However, all the units are expected to be capable of completely removing and destroying the chemical agent.

The committee reiterates its prior view that the scrap metal produced from these devices should be cleared of chemical agent and should be recyclable as well. Recycling the metal from these other technologies might, however, involve demonstrating to federal and/or state regulatory authorities that the metals should no longer be classified as hazardous waste. While recycling from small and moderate MRSs will not result in the recycling of a significant amount of metal, the amount of metal that could be recycled from large MRSs (which are likely to involve hundreds or even thousands of munitions) could be substantial. The committee expects that the Army will continue to explore potential recycling of scrap metal resulting from RCWM treatment.

### Extending the Pine Bluff Model

In the same fashion that NSCMP designated Pine Bluff Arsenal, Arkansas, as the location of its EDSs to destroy the non-stockpile inventory at Pine Bluff and to be available for emergency response, one or more of the large remediation sites could be used for this purpose in the future. Each of the large buried CWM sites will require investigation and some level of remediation (containment or treatment) of buried or recovered CWM and other related contaminated media. If a portion of the CWM emergency response team and equipment were located at one of these large sites, cost savings are likely to accrue because personnel could be engaged in remediation of buried CWM when they are not working on emergency responses, and their skills and training can be

[16] Franklin D. Hoffman, Chief, Operations Team, NSCMP, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview," presentation to the committee on September 27, 2011.

maintained in between emergency responses. Indeed, the Army achieved just these benefits when it located several EDSs at Pine Bluff (NRC, 2004).

**Finding 3-7.** Potential cost savings are likely to be realized by co-locating resources on one of the large burial sites, so that emergency response functions can be deployed efficiently.

**Recommendation 3-7.** The Army should evaluate and select one of the buried CWM sites as the location/repository for its emergency response operations in order to increase the cost-effectiveness of the overall program and maintain flexibility (NRC, 2004).

## THE IMPORTANCE OF PUBLIC INVOLVEMENT

The importance of constructive and open engagement of the public by the U.S. Army in its policy decisions regarding non-stockpile materiel has been emphasized in several earlier reports from the National Research Council (NRC, 1994, 1999, 2001a, 2001b, 2002) and other organizations (EPA, 2001, 2002b, 2009a, 2010b; U.S. Army, 2007d). Indeed, many of the alternative treatment technologies for chemical agents owe their existence to public concerns and the influence of the public on Congress and the states.

Munitions response actions are governed by a number of laws at the federal, state, tribal, and local levels. As noted above, public involvement is embedded in RCRA and CERCLA (U.S. Army, 2005; EPA, 2005). In addition, the Emergency Planning and Community Right-to-Know Act (EPCRA) requires military installations reporting releases of listed hazardous substances to complete and make public the Toxic Release Inventory annually if the quantities exceed the reporting threshold.[17]

These regulatory frameworks detail the community engagement and stakeholder participation activities to be followed by the lead agency at MRSs. Further, DOD and Department of the Army regulations and policies provide a framework to guide military decision makers—installation commanders as the executive agent on active DOD installations, and the U.S. Army Corp of Engineers (USACE) as executive agent at FUDS—on requirements for conducting public outreach and involvement activities (U.S. Army, 2004a, 2004c, 2005, 2009c, 2009d). The Non-Stockpile Chemical Materiel Program (NSCMP) never has primary responsibility,[18] but it does play a support role—for example, by providing literature for distribution and meeting with residents of impacted neighborhoods.

Feedback from stakeholders, reported in an earlier committee report (NRC, 2002), indicates that the U.S. Army has made considerable progress in providing information to the public and improving communications with stakeholders. Stakeholder feedback has identified a number of issues that typically are of high concern to members of the community. For example, there has been widespread opposition to importing out-of-state wastes that could result in a site becoming a dumping ground, with a correspondingly high preference for mobile destruction technologies. In addition, nonincineration technologies have received broad acceptance as an advance over open detonation, but some community members have expressed concern about the costs associated with the new technologies (NRC, 2002).

The approach taken at different sites may vary, based on the level of public interest. For example, Spring Valley, in Washington, D.C., has a very active restoration advisory board (RAB), while at Camp Sibert, Alabama, the public has not shown any interest in having such a board. Both sites hold public meetings, offer literature to the public, and provide information to the media. The key issue facing the Army as it starts to remediate large buried CWM sites is whether to keep its public involvement program modest in size, in proportion to the limited public interest expressed, or to expand its efforts in case public concern materializes as the buried CWM remediation program grows.

**Finding 3-8.** The U.S. Army project managers at current CWM sites have recognized the importance of public engagement and are supported appropriately by NSCMP.

**Recommendation 3-8.** As the U.S. Army undertakes remediation at the larger CWM sites, project managers should anticipate that there will be more public concern and continue to seek proactive public engagement. They should take steps to ensure that communications from the different participating organizations are coordinated.

[17]David Lyon, Environmental Specialist, Environmental Division, Assistant Chief of Staff for Installation Management/Supply Directorate, personal communication to Derek Guest, committee member, on November 23, 2011.

[18]Laurence G. Gottschalk, PMNSCM, personal communication, to Richard Ayen, committee chair, November 29, 2011.

# 4

# Technologies for Cleanup of CWM Sites

## TECHNOLOGY WORK FLOW

This chapter describes the current supporting technologies that might be used for the cleanup of sites containing chemical warfare materiel (CWM). To put these technologies in context, a scenario is developed for a site with known or suspected CWM.

Suspected subsurface CWM is located by geophysical technologies, typically magnetometers or active electromagnetic sensors, which are in common use for the detection of conventional munitions and explosives of concern (MEC). U.S. Army Corps of Engineers (USACE) contractors erect a containment structure over the detected anomaly and dig toward the object by mechanical or manual means, or both, that are commonly used for conventional MEC. Upon discovery of a suspected CWM, work stops in the area until military explosive ordnance disposal (EOD) technicians or Chemical Biological Radiological Nuclear (enhanced) Analysis and Remediation Activity (CARA) civilian personnel respond. EOD/CARA personnel complete the removal and evaluation of the suspected CWM and package it in a container approved for on-site transport to an interim holding facility (IHF).

Typically, the initial characterization by EOD/CARA will involve using field X-ray equipment to determine whether the ordnance is filled with liquid before it is placed in the overpack and stored in an IHF.

If the recovered chemical warfare materiel (RCWM) is a chemical agent identification set (CAIS), the single CAIS access and neutralization system (SCANS) is used to treat it and the SCANS is then sent off-site to a Resource Conservation and Recovery Act (RCRA) treatment, storage and disposal facility (TSDF).

Otherwise the suspected CWM is removed from the IHF and a mobile munitions assessment system (MMAS) is sent to the site to provide a nonintrusive assessment of the contents of the suspected RCWM. The key MMAS tools are these:

- Digital radiography and computed tomography (DRCT),
- Portable isotopic neutron spectroscopy system (PINS), and
- Raman spectrometry.

If chemical agent fill is determined, the RCWM is again placed in interim storage to await assessment by the Materiel Assessment Review Board (MARB). In this case, the next IHF may be off-site, so the RCWM is packaged into a multiple round container (MRC), which has been certified by the U.S. Department of Transportation, and transported on public roads by CARA.

After review by the MARB, destruction or treatment occurs by one of the following destruction technologies:

- Explosive destruction system (EDS),
- Transportable detonation chamber (TDC),
- Detonation of ammunition in a vacuum integrated chamber (DAVINCH), or
- Static detonation chamber (SDC).

Secondary waste is transported to a commercial facility for final disposal.

These topics are presented in sequential order, from the point of initial detection through excavation and initial evaluation; packaging, storage, and transportation; treatment by SCANS if CAIS items are found; spectroscopic or X-ray assessment; assessment by the Army's Materiel Assessment Review Board; destruction; and treatment of secondary waste. Three overarching topics—personal protective equipment (PPE), air monitoring, and air control systems—are presented between detection and excavation because that is where they first come into play. That is, geophysical detection is completely nonintrusive, so PPE and air monitoring are typically not required. As soon as a shovel is put in the ground, however, PPE and air monitoring must be considered in view of the potential for exposure to CWM from contaminated media or shell fragments.

## GEOPHYSICAL DETECTION

Under the definitions associated with the Defense Environmental Restoration Program (DERP) Munitions Response Program (MRP), CWM can be found as intact munitions and within partially exploded shells and fragments that may still contain MEC or munitions constituents.[1]

MEC CWM includes the CWM that is contained in ordnance, and it has both a chemical agent and an explosive hazard component. The munitions constituent would include agent found outside the ordnance, for example, agent leaked into and absorbed by soil; it would also include other hazardous constituents associated with the munition, including heavy metals, energetic compounds—TNT, for instance—and breakdown products of both agent and energetic compounds.

MEC CWM presents the greatest hazard because it contains both an explosive and a chemical agent hazard. Because the ordnance casing is made of steel, it is easily detected using common geophysical techniques.

The geophysical sensors used to detect MEC CWM are the same as those used for detecting conventional (high-explosive) MEC. The sensors used include magnetometers and active electromagnetic systems.

Government and private research has resulted in consistent improvements in the ability to detect MEC. These advances include improved sensors and signal processing, which in some cases allow us to "classify" or determine whether a buried object contains MEC or is a non-MEC object based only on the object's geophysical signal without having to excavate it and identify it visually.

MEC CWM can be found individually or in mass burials. An example of where individual MEC CWM has been found is the former Camp Sibert, Alabama, Site 8, which was a CWM ordnance impact area. Some of the 4.2-in. mortars that were fired into Site 8 failed to function and remained in the subsurface to be detected individually, excavated, and disposed of.

Other MEC CWM is found in mass burials from previous disposal operations, as was the case at the Spring Valley site in Washington, D.C. Such mass burials are relatively easy to detect using geophysics because the multiple MEC CWM buried together present a large geophysical target. However, it is usually not possible to determine the contents of the subsurface-buried mass from the geophysical data because individual objects cannot be distinguished within the large buried mass.

CWM projects employ the geophysical technologies used for conventional MEC, which are adequate for detection of both individual MEC CWM and mass burials.

Munitions constituents that may be associated with CWM, on the other hand, are much more difficult to detect because the metal casing of the MEC is not present. Typically, sampling and either field or laboratory analysis is required to detect munitions constituents. Munitions constituents consisting of, for example, chemical agents, heavy metals, energetic compounds, or breakdown products of agent or energetic compounds that are absorbed onto or into soils, can be detected only by field or laboratory analytical techniques.

The suite of CWM agent detectors and monitors used in the field for detecting chemical agent and some breakdown products are described later in this report.[2,3]

## PERSONAL PROTECTIVE EQUIPMENT

PPE required to be worn on non-stockpile CWM projects is the same as the PPE approved by OSHA for other hazardous and toxic material handling operations. The various OSHA levels of PPE (Levels A, B, C, and D and OSHA-approved modifications) have been demonstrated to be adequate on numerous non-stockpile CWM projects, including projects at Camp Sibert, Alabama; Spring Valley, Washington, D.C.; and Schofield Barracks, Hawaii; and for VX building demolition at Newport, Indiana.

## AIR MONITORING DURING EXCAVATION, INTERIM STORAGE, AND DESTRUCTION

Air monitoring for chemical agent is conducted whenever there is a risk that workers or the general public could become exposed to chemical agent during or due to site operations and whenever it is included as part of a comprehensive Work Plan to establish the policies, objectives, procedures and responsibilities for the execution of a site-specific response action. Detailed policies and safety and health requirements for RCWM response actions are contained in U.S. Army publications, including manuals, regulations, and pamphlets (U.S. Army, 2004c, 2004b, 2006, 2007b, 2007c, 2008b, 2008e). A large part of the RCWM response process uses the same response procedures required for other MEC. Therefore, RCWM response actions are conducted in accordance with MEC response procedures (U.S. Army, 2006, 2007b).

[1]Formal definitions of MEC and munitions constituents are in the Site Prioritization Protocol (SPP) at http://www.denix.osd.mil/mmrp/Prioritization/MRSPP.cfm.

[2]Karl E. Blankenship, FUDS Project Manager, Mobile District U.S. Army Corps of Engineers, "Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective," presentation to the committee on November 3, 2011.

[3]Herbert H. Nelson, Manager, Munitions Response Program Strategic Environmental Research and Development Program, Environmental Security Technology Certification Program, Department of Defense, "Geophysical Detection of RCWM: Capabilities and R&D," presentation to the committee on January 17, 2012.

When a client organization—say, the Non-Stockpile Chemical Materiel Project (NSCMP)—identifies the need for new analytical or operating procedures for its chemical operations, the Edgewood Chemical Biological Center (ECBC) is generally responsible for their development. At the U.S. Army Engineering Support Center, Huntsville (USAESCH) RCWM projects, ECBC is typically responsible for preparing the plan for air monitoring and analysis methodologies for chemical agents (and other hazardous chemicals, if required) in accordance with U.S. Army standards (U.S. Army, 2007c, 2008e) for setting up stations that monitor the air for chemical agents during all phases of the response action, supporting USACE to maintain any filter units for vapor containment and conducting on-site analysis for headspace samples collected from media suspected of being contaminated with chemical agent. The committee judges vapor containment facilities and filtering techniques to be adequate and thus does not discuss them in detail in this chapter.

## Monitoring Equipment

The choice of monitoring equipment is based on the type of monitoring to be performed and the types of agent involved. Air monitoring equipment systems have been described in detail previously (NRC, 2005a). Monitoring systems and their associated operating procedures used at non-stockpile sites must be appropriately certified before use. The following monitoring equipment systems may be used for the detection of chemical agents present in the air at non-stockpile disposal sites, at stockpile disposal sites, and at storage facilities (U.S. Army, 2004c; NRC, 2005a):

- The Miniature Chemical Agent Monitoring System (MINICAMS) is an automatic air monitoring system that collects compounds on a solid sorbent trap (typically a porous polymer) and thermally desorbs them into a capillary gas-chromatography column for separation and detection. It is a lightweight, portable, near-real-time, low-level monitor with alarm capability, designed to respond to G-series nerve agents, VX nerve agent; mustard; nitrogen mustard; and lewisite. Alarm levels for MINICAMS used at non-stockpile sites are typically set at 0.70 of the appropriate airborne exposure limit (AEL)[4] (NRC, 2005a). MINICAMS was used at Camp Sibert, Alabama, with mixed results.[5] It is expected that a similar experience will be encountered during other remediation efforts.
  - —The MINICAMS was used in the location of an anomaly as that anomaly was being investigated and removed. As part of the MINICAMS calibration procedure, a midday challenge was used. This procedure can cause a delay in field operations of 2 to 3 hours if the initial calibration is unsuccessful.
  - —The MINICAMS is not sufficiently robust to be moved from anomaly to anomaly. This results in long downtimes. A more rugged, portable system for near-real-time air monitoring is needed.
  - —In a certain part of Camp Sibert called the "mustard soaking pit," the presence of trichloroethylene (probably used as a decontamination fluid or as a component of decontamination fluid) interfered with determination of mustard by MINICAMS.
- Open-path systems such as fence-line Fourier transform infrared spectrometry air monitoring (OP-FTIR) send a beam of light through the open air, to a reflector and then back to a receiver. If gases that absorb light are present in the beam path, they can be identified and quantified. This technology will have limited applicability to nonstockpile cleanup operations because of its limited sensitivity. It is marginal for detection at the short-term exposure limit (STEL) level (NRC, 2005b).
- The depot area air monitoring system (DAAMS) is a portable air-sampling unit that is typically used for agent confirmation sampling (following a positive result using MINICAMS, for example). It is designed to draw a controlled volume of air through a glass tube filled with a solid sorbent collection material. After sampling for the predetermined period of time and flow rate, the tube is removed from the vacuum line and transferred to a suitable laboratory facility[6] for gas chromatography analysis to determine the presence, type, and quantity of agent. This technique is sufficiently sensitive and will allow analysis down to the appropriate AEL for the relevant agent.
- A new air monitoring system, the multiagent meter, is being developed by Sandia Livermore under NSCMP sponsorship (Rahimian, 2010). This is a handheld device that can simultaneously analyze for mustard

[4]Airborne exposure limits (AELs) are levels of exposure to hazardous materials to which workers and the unprotected general population can be exposed without experiencing adverse health effects. AELs are established by the Centers for Disease Control and Prevention (CDC). They include the short-term exposure limit (STEL), the level at which an unprotected worker can operate safely for one or more 15-minute periods (depending on the agent) during an 8-hour workday; the worker population limit (WPL), the concentration at which an unprotected worker can operate safely 8 hours a day, 5 days a week, for a working lifetime, without adverse health effects; the general population limit (GPL), the concentration at which the unprotected general population can be exposed 24 hours a day, 7 days a week, without experiencing any adverse health effects; and the immediately dangerous to life or health (IDLH) limit, the level of exposure that an unprotected worker can tolerate for 30 minutes without experiencing escape-impairing or irreversible health effects.

[5]Karl E. Blankenship, FUDS Project Manager, Mobile District U.S. Army Corps of Engineers, "Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective," presentation to the committee on November 3, 2011.

[6]One example of a suitable analytical laboratory facility is the mobile analytical platform used by ECBC.

agent and G-series agents at levels near the AELs. The cycle time is 10 minutes, and (reportedly) no calibration is needed unless the detector is replaced. Testing near the short-term exposure limits (STELs) has been carried out, and the meter will be used with the steam injection testing in the new EDS-2 test fixture during 2012.[7] See the EDS discussion later in this chapter for more information on the test fixture and the multiagent meter.

### Types of Monitoring

Monitoring can be classified into the following types:

- *Background monitoring*. This monitoring is conducted prior to initiation of site operations to provide a baseline reference for subsequent analyses and to determine if there is any interference in the area. DAAMS tubes and/or MINICAMS are generally used for this type of monitoring for the chemical agents of concern.
- *Area monitoring*. General area monitoring provides an early warning to personnel that there is a problem and that action must be taken. The monitoring device or sampling port is placed in strategic locations in the work area where there is a potential for encountering agent vapors. The sample locations are determined based on factors such as the agent involved, the airflow patterns in the area, the operation(s) being performed, and the location of the source of the potential release. A MINICAMS and/or commercially available monitors are used for this type of monitoring. The new multiagent meter (see the last bullet item in the previous section) may also prove valuable for area monitoring. DAAMS may be used to confirm a positive MINICAMS result.
- *Perimeter monitoring*. This type of monitoring is not designed to give rapid warning of hazardous conditions but is instead used to document conditions over time and to confirm a hazardous condition as alarmed by the MINICAMS. DAAMS tube sampling stations and/or the OP-FTIR are placed at the perimeter of the work area to record any chemical agent release beyond the safety zone established around the MEC work area (exclusion zone).
- *Mobile area monitoring*. This is a method of sampling airborne levels of contaminants in the workplace. Samples are taken over the entire workday using a sampling train of DAAMS tubes that are connected to a dual-port sampler attached to a portable air pump calibrated to a specified airflow rate.
- *Decontamination monitoring*. Personal decontamination station monitoring is used to verify that complete decontamination of a worker or piece of equipment has been conducted. Decontamination monitoring will typically be conducted using a MINICAMS.
- *Surface monitoring*. Performed on equipment and remediation waste that is suspected of being contaminated by chemical agent, in accordance with U.S. Army standards (U.S. Army, 2007b, 2008e).
- *Headspace monitoring*. This is conducted on environmental samples suspected of being contaminated with chemical agent before they are shipped off-site for analysis. This type of analysis is conducted to prevent samples contaminated above the vapor screening level (VSL) from being shipped by commercial carrier.[8]

## EXCAVATION EQUIPMENT AND TECHNIQUES

Excavation equipment for use on CWM projects can be classified into two categories: conventional and robotic.

### Conventional Excavation Equipment

Conventional methods of excavation, including by hand and using mechanical equipment, are routinely used on MEC projects to access conventional MEC. The same tools and techniques are used on CWM projects to access subsurface CWM. When accessing shallow-buried, single-item CWM (for example, at Camp Sibert, Alabama, where CWM 4.2-in. mortars were fired into target areas for training), hand tools, such as shovels and hand trowels, are used by trained technicians to uncover the subsurface anomalies that were detected by geophysical methods.

For mass burial sites, mechanical equipment will most likely be used. USACE regulations allow mechanical equipment, such as backhoes and excavators, to be used to excavate MEC with the caveat that the mechanical excavator may not work closer than 1 ft from the MEC (U.S. Army, 2004a). In this case the mechanical excavation equipment is used to remove the bulk of the overburden soil from the MEC/CWM and the final 1-ft. of soil is removed using hand excavation tools.

Applying conventional equipment excavation to CWM projects requires that the project managers determine the appropriate PPE to be used by the field teams to ensure their safety in the event that there is an unexpected release of CWM during the excavation process. Appropriate PPE has been selected and successfully used on numerous projects,

[7]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Status and Update," presentation to the committee on September 27, 2011.

[8]A VSL (vapor screening level) is a control limit used to clear materials for off-site shipment based on agent concentration in the atmosphere above the packaged waste materials. The VSL depends on the permit for the particular facility involved but is often set at either the short-term exposure limit (STEL) or at the short-term limit (STL), which is numerically the same as the STEL but does not have the 15-minute time component (see NRC, 2007).

including Camp Sibert, Alabama; Spring Valley, Washington, D.C.; and Schofield Barracks, Hawaii.

### Robotic Excavation Equipment

Robotic excavation equipment makes site workers safer by separating them from the hazard. The operator can be far enough away from the excavation location to be out of harm's way in the event of a CWM release or accidental detonation. Another benefit of robotic excavation equipment is that the operator can be located in the comfort of a building, protected from the elements, and not required to wear PPE.

Many commercial and Department of Defense (DOD) programs are working on developing and fielding robotic excavators for CWM and conventional MEC excavation.[9]

New robotic excavation equipment is being made more reliable and robust through DOD and privately funded research and has been available for use on CWM projects since it was extensively used on the Old O-Field CWM encapsulation project at Aberdeen Proving Ground, Maryland, in 1995.[10]

There have been rapid strides in the use of conventional and robotic systems to perform a variety of complex industrial tasks. For example, robotics systems are now used in medical applications, in civilian bomb removal, and for surveillance and disarming of improvised explosive devices in combat. Future developments in robotic systems are expected to improve the ability to perform a wide variety of tasks.

## PACKAGING, TRANSPORTATION, STORAGE (ON-SITE AND INTRASTATE)

Frequently, non-stockpile CWM must be packaged, transported, and placed in storage prior to disposal. Packaging, transportation, and storage of CWM has been classified by the Army as an "inherently governmental operation"[11] and, as such, is performed by military service member experts and specialized civilian federal government employees.

### CWM Packaging and Transportation

Packaging of CWM is also an "inherently governmental operation" and is performed by CARA. Prior to packaging, non-stockpile CWM containers must be checked for leaks and, if found to be leaking, sealed. CARA personnel are the acknowledged experts in performing this function in both emergency and planned CWM removal scenarios. CARA is dedicated to this mission, its personnel are well trained, and they perform the packaging and transportation function adequately.

The non-stockpile CWM is then overpacked in one of three types of containers used for this purpose:[12]

- *Propelling charge canisters*. These are reused carbon steel canisters originally designed for shipping individual 8-in. projectile smokeless powder propelling charges. They have an O-ring sealed lid designed to keep moisture and dirt from entering the canister and they serve as an inexpensive CWM overpack; in this application, the O-ring seal keeps minor leaks of agent inside the canister. However, they are not designed for this purpose, are not Department of Transportation (DOT)-certified for off-site transportation of CWM, and, while commonly used, are best suited to short-term storage and limited transportation to an on-site IHF.
- *Single round containers (SRCs)*. These are DOD-designed military specification (MIL-SPEC) overpacks designed and intended for the containerization of CWM. SRCs were tested to DOT and DOD requirements but are not DOT certified (Teledyne Brown, 1998). They are made of carbon steel and are O-ring sealed to prevent vapor leakage. Several sizes are used in the chemical stockpile destruction program and are considered to be an all-purpose CWM overpack option for on-site transportation and storage.
- *Multiple round containers (MRC)*. MRCs are DOD-designed MIL-SPEC overpacks specifically designed to accept various sizes of CWM covering most of the potential non-stockpile CWM. Table 4-1 lists the MRCs and their intended contents. They are made of stainless steel and are designed to contain any leakage and vapors from an overpacked CWM. MRCs are transported in a wood overpack shipping box for handling convenience and for blocking and bracing considerations. The MRCs in their wooden overpack have been tested to meet DOD and DOT requirements. (See for example 12-in. by 56-in. Multiple Round Container Approval Documentation, Defense Ammunition Center, A02-0003.1, August 1998.) As the only DOT-certified overpacks for CWM, they are required for off-site transportation and are the preferred overpack when shipping over a significant distance is required.

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[9]Available at http://www.globalsecurity.org/military/systems/ground/aoe.htm, http://www.army.mil/article/16473/U_S_Army_Demonstrates_Robotic_Technologies/, http://roboticrangeclearance.com/uploads/R2C2_Robo_Clearance.pdf. Each site last accessed April 11, 2012.

[10]Available at http://pubs.usgs.gov/wri/wri00-4283/wrir-00-4283.pdf. Last accessed March 30, 2012.

[11]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Status and Update," presentation to the committee on September 27, 2011.

[12]Franklin D. Hoffman, Chief, Operations Team, NSCMP, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview," presentation to the committee on September 27, 2011.

TABLE 4-1 Multiple Round Containers

| MRC Type[a] | Maximum Contents Weight (lb) | Potential Contents |
|---|---|---|
| 5 × 25 | 32 | 4-in. Stokes and 4.2-in. mortars; 75-mm projectiles; M139 and M125 bomblets |
| 7 × 27 | 100 | 4.2-in. mortar; 75-mm and 4.7-in. projectiles; 155-mm and 2.36-in. rockets |
| 9 × 41 | 200 | Livens, 155-mm, 175-mm, and 8-in. projectiles |
| 12 × 56 | 200 | CAIS PIGs; M47, E46, E52, M70, M70A1, and M113 bombs |
| 18 × 5.5 | 61 | Mines |
| 26 × 79 | 1,000 | 500- and 1,000-lb bombs |
| 30 × 40 | 850 | 50-gal drums |

[a] The first number is the inner diameter in inches and the second is the length in inches. NOTE: PIG, package in-transit gas shipment container. SOURCE: Individual MRC fact sheets provided by NSCMP.

Currently the CWM must be removed from the overpack prior to treatment in an explosive destruction system (EDS). NSCMP is developing a universal munitions storage container (UMSC) made of high-density polyethylene that will allow the overpacked CWM to be treated in an EDS without removal from the overpack.[13] The UMSC will contain an internal centering system to consistently position the CWM within the overpack. Then the explosive shaped charges can be placed on the outside of the overpack and the prepared overpack will be placed in the EDS. The UMSC will be sacrificed upon detonation of the shaped charges. When fielded, the UMSC will offer improved safety because it eliminates the need to manually remove the CWM from the overpack prior to placement of the explosive shaped charges and placement in the EDS. The USMC is not intended to be DOT certified—it will only be used on-site but will fit into a DOT-certified container if off-site shipment is required.

None of the above overpacks are able to contain an accidental detonation. Therefore, part of the CARA mission is to ensure the explosive safety of the CWM prior to overpacking and shipping. Transportation of CWM is also performed by CARA as one of the "inherently governmental operations."

## CWM Storage

When buried munitions or other hazardous materials are removed from the ground, they are preferably placed in an existing magazine (bunker or igloo) or in an IHF (Figure 4-1). Details of the IHFs currently used by NSCMP are given in "Property Identification Guide, Revision 0" (U.S. Army, 2011e) and "Interim holding facility overview fact sheet" (U.S. Army, 2011c). Construction and safety features were developed by NSCMP (U.S. Army, 2011e). Very detailed information on the construction design, safety issues, citing, physical security planning, and vulnerability assessment for an IHF are given by USACE (U.S. Army, 2004c). Information on IHF features and past use were provided by Laurence G. Gottschalk, PMNSCM, in a presentation to the committee on September 27, 2011.

The primary reason for using IHFs is to provide security for RCWM. To this end, high security locks, fencing, and a lighting system can be employed, and the IHF is constructed from fireproof and corrosion-resistant materials. Munitions placed in IHFs are first placed in an appropriate overpack (a propelling charge canister, an SRC, or an MRC).

For environmental protection, the interiors include secondary containment in the form of a sump beneath the floor grating to collect liquids should leaks occur in waste containers. Electrical switches and fixtures are of nonexplosive design to reduce the possibility of fires. Agent monitoring and the use of air pollution control systems, e.g., activated carbon adsorption systems, can be used to reduce the risk that chemical agent or hazardous fumes are released to the environment. Air conditioning can be provided to control vapor pressures. Monitoring ports are provided to allow measuring the concentrations of materials of interest—for example, chemical warfare agents—in the vapor space before the RCWM enters the IHF.

IHFs are factory-built and are purchased by NSCMP from Carber-Rambo Associates, Inc.; HAZ SAFE; and United States Chemical Storage. They feature a steel frame, with interior surfaces constructed from unpainted 304 stainless steel. The exteriors are constructed from carbon steel and are painted. IHFs can be purchased in various sizes, but are all designed to be transported by truck without special permits. IHFs are inspected periodically, and repairs are documented.

The NSCMP has used IHFs at its operations at Spring Valley, Washington, D.C.; Dover Air Force Base, Delaware; and Camp Sibert, Alabama. Future deployment of IHFs is planned at Fort Glenn, Alaska, and Black Hills, South Dakota.[14] The NSCMP has used igloos approved for storage of RCWM at several other sites.

Three holding facilities are used at Spring Valley.[15] When first recovered, a munition is placed in the assessment holding facility. It remains there until the MMAS arrives on site and the data needed for assessment of the munition are recorded. The munition is then placed in a second holding

[13] Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the NRC Committee on Chemical Demilitarization on November 30, 2011.

[14] Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 30, 2011.

[15] Dan G. Noble, Project Manager, Spring Valley, Baltimore District, U.S. Army Corps of Engineers, comments to committee members during the committee's tour of the Spring Valley site on November 2, 2011.

FIGURE 4-1 Interim holding facility. SOURCE: Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 27, 2011.

FIGURE 4-2 A typical DRCT scan. SOURCE: Franklin D. Hoffman, Chief, Operations Team, NSCMP, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview Equipment and Capabilities to NRC," presentation to the committee on September 27, 2011.

facility, the MARB holding facility. It remains there until the assessment is complete, whereupon it is placed in the third holding facility, called the interim holding facility. The munition is held there for up to 2 years, awaiting destruction in an EDS.

## SINGLE CHEMICAL AGENT IDENTIFICATION SET ACCESS AND NEUTRALIZATION SYSTEM

The single CAIS access and neutralization system (SCANS) is a small polyolefin unit for detoxifying intact ampoules and bottles from CAIS. These approximately 4-oz bottles are placed in the unit with a 1-gal bottle of reagent, normally dichlorodimethylhydantoin in solution. After the unit is sealed, the bottles are ruptured with a mallet and plunger. The ingredients are mixed by manually shaking the unit (U.S. Army, 2011e). The system has been successfully used numerous times; the committee judges that it requires no further research.

## SPECTROSCOPIC AND X-RAY ASSESSMENT

### Digital Radiography and Computed Tomography

Digital radiography and computed tomography (DRCT) is a technology similar to a CAT scan. It uses X-rays to vertically scan a suspect CWM on a rotating platform. It produces a digital view of the munition interior, even through an overpack container. The DRCT requires an X-ray source and a detector. The detector records radiation that passes through the object being scanned. The intensity of the radiation arriving at the detector is attenuated by the objects in its path as a function of their density: The thicker, more dense the object, the greater the attenuation of the X-ray intensity. The object being scanned can be rotated or tilted to produce various views of the munition and its internals. A difference in level from tilt view to level view is useful in determining the presence of liquids in the suspected CWM. The DRCT can be operated from a remote location, allowing objects to be scanned from a safe distance (U.S. Army, 2011a).

A typical DRCT scan is seen in Figure 4-2. The container on the left shows that by tilting the container, the presence of liquid can be verified by a shift in the liquid level.

DRCT is a robust, proven technology. It is portable, can be operated remotely, can determine the presence of liquids, and can be used even if the suspected CWM is in an overpack. It cannot be used to determine the type of chemicals in a container.

The PMNSCM has mentioned that NSCMP is updating the DRCT with newer, commercial capabilities and integrating PINS and DRCT.[16] However, the committee did not receive any detailed information on these development activities.

Although the portable isotopic neutron spectrometer (PINS) is considered the most effective tool for determining the presence of CWM inside a chemical munition or

[16]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 30, 2011.

container, DRCT has several capabilities that make it an important part of the MMAS.

### Portable Isotopic Neutron Spectroscopy

PINS is regularly deployed in the field to identify the contents of sealed munitions suspected of containing chemical warfare materiel. Developed by Idaho National Laboratory, the PINS system has been patented and is commercially available through AMETEK, Inc., in Oak Ridge, Tennessee.[17] This self-contained, nondestructive investigative tool is the first step in determining the proper neutralization procedure for found non-stockpile chemical weapons.

The PINS system contains a neutron source, californium-252. The neutrons pass through a polyethylene block and two tungsten plates, which serve to both slow the neutrons and absorb gamma radiation generated by the neutron source before passing through the munition mounted within the instrument (Caffrey et al., 1992). The neutrons pass through the steel walls of the munition and interact with the chemicals inside, generating a spectrum of gamma radiation via neutron capture, followed by prompt gamma-ray emission (Skoog et al., 1998). The gamma-ray emissions are detected using a multichannel analyzer that is able to filter the gamma radiation generated by the steel or aluminum casing. Data are displayed as a spectrum of counts versus the emitted gamma-ray energy, which is element- and isotope-specific (shown in units of kiloelectron volts, or keV). The emission energy peaks are analyzed by the software to generate an elemental ratio, or empirical formula, for the chemical materiel. The spectrum is then compared against a library of known spectra of chemical agents to identify the contents of the munition (Caffrey et al., 1992).

Significant advantages of the PINS system include portability and user-friendly automation. The setup for this system includes a daily background scan to account for local environmental factors, such as high hydrogen concentrations in wetland areas, high chlorine concentrations in coastal areas, and so on. In addition, the peak energies and relative intensities are unaffected by the possible degradation or polymerization of the chemical materiel, rendering the technology applicable to any intact chemical weapon. Lastly, PINS does not generate low-level radioactive material. The neutron capture method generates only very short-lived radionuclei (Caffrey et al., 1992).

While PINS is an essential tool in the assessment of recovered munitions, it is not totally reliable. See Chapter 7 for a discussion of this subject and for findings and recommendations related to PINS.

[17]Available at http://www.inl.gov/research/portable-isotopic-neutron-spectroscopy-system/. Accessed on March 15, 2012.

### Raman Spectroscopy

Raman spectrometry is used only to analyze liquids in recovered glass containers.[18] These include the vials and ampoules from CAIS. Raman spectra are generated by the detection of scattered visible radiation. A sample is irradiated with monochromatic visible or near-infrared light, which is absorbed by the electrons. The electrons reemit the absorbed energy as infrared light, which is detected at an angle perpendicular to the light source. The spectrum that is generated yields structural information about the sample, as shown by the wavelength and intensity of the emitted infrared radiation.

## MOBILE MUNITIONS ASSESSMENT SYSTEM

The MMAS is a transportable system equipped to analyze and provide on-site information about the contents of unidentified munitions without opening them (U.S. Army, 2011d). It was designed and built by the NSCMP to take instruments into the field, provide analysis, and communicate information to response personnel.

As shown in Figure 4-3, the MMAS is an operational platform that transports and contains the support needed to analyze the content of items. It contains nonintrusive assessment equipment such as instrumentation for PINS, DRCT, and Raman spectroscopy to assess conventional or chemical-filled munitions. It contains an onboard darkroom to process X-ray film and is equipped with sensors to constantly monitor weather conditions and cameras to monitor site activities. It includes a portable electric generator, which provides a constant power supply.

Data generated by the MMAS are stored in redundant computer systems equipped with battery backup. Satellite links, cellular phones, and shortwave radio ensure local emergency responders can be contacted in the case of an emergency. The MMAS contains equipment for decontamination of personal protective equipment (U.S. Army, 2005).

The MMASs are operated by CARA on behalf of NSCMP. There are three MMAS units located in the United States, two of which are at Aberdeen Proving Grounds in Maryland and one at Pine Bluff Arsenal in Arkansas.[19]

The DRCT and PINS data, pictures of munitions, and historical and other data are evaluated by the Materiel Assessment Review Board (MARB), which then recommends a method of disposing of the CWM. Chapter 2 describes the MARB's activities.

[18]Laurence G. Gottschalk, PMNSCM, "Non-Stockpile Chemical Materiel Project Program Status and Update," presentation to the committee on September 30, 2011.

[19]Franklin D. Hoffman, Chief, Operations Team, NSCMP, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview," presentation to the committee on September 27, 2011.

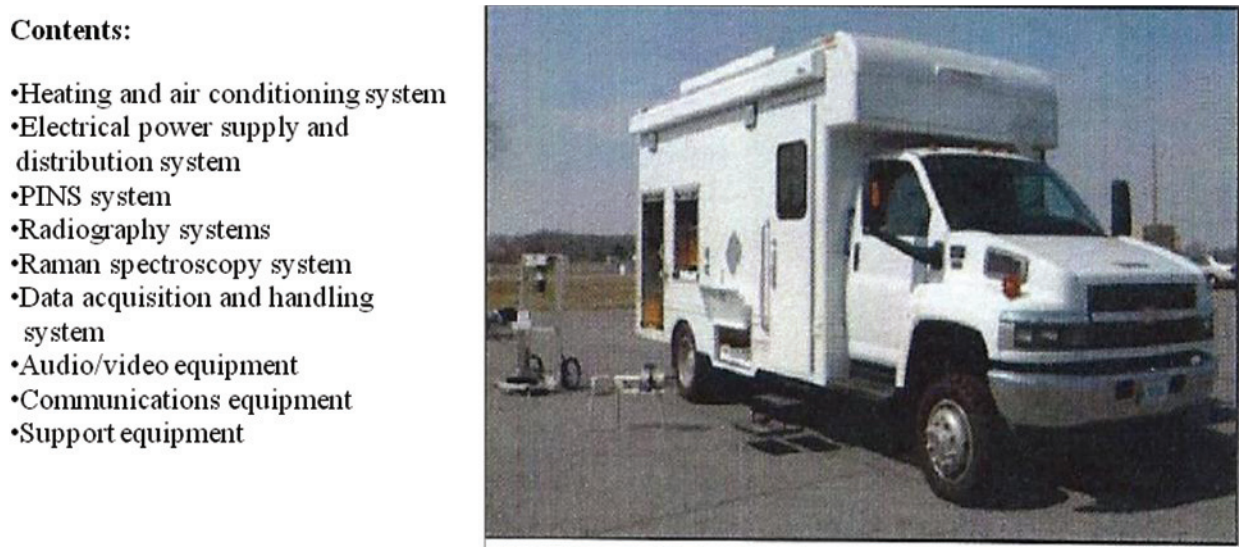



FIGURE 4-3 Mobile munitions assessment system. Contents include heating and air conditioning system; electrical power supply and distribution system; PINS system; radiography systems; Raman spectroscopy system; data acquisition and handling system; audio/video equipment; communications equipment; and support equipment. SOURCE: Laurence G. Gottschalk, PMNSCM, “Program Status and Update to NRC,” presentation to the committee on September 27, 2011.

## DESTRUCTION TECHNOLOGIES

In this section, four systems, each employing one of three technologies that have been used to destroy chemical munitions are described. Each has been used abroad and/or in the United States. One system, the EDS, uses explosive charges only to access the agent cavity in the munition body and uses a liquid reagent to neutralize the agent. Secondary wastes include a liquid neutralent, rinsates, and metal fragments. Another system, the SDC, does not use external explosives at all but depends on electric heating or heat from previous detonations to detonate or deflagrate the munition and destroy the agent in a sealed chamber. Primary effluents are metal fragments, treated off-gases, and dry spent scrubber solution salts from the spray dryer.

The remaining two systems, the TDC and the DAVINCH, are similar in that they both use external charges to access the agent cavity in a sealed chamber (as does the EDS), but unlike the EDS, they also use the detonation to destroy the agent. These technology variants differ in terms of detonation conditions, off-gas treatment, explosion containment capacity, and other operating parameters. Their primary effluents are metal munition fragments, treated off-gases, and, in the case of the TDC, also gravel dust and spent lime.

An overview of the four systems, showing several key differences and similarities between them, is provided in Table 4-2. In the text that follows, the systems are described in greater detail and their experience to date in destroying chemical munitions is summarized.

At sites where some RCWM consists of munition bodies, containers, and scrap metal that contain only traces of agent and where there is no need for placing donor and shaped charges to access the agent cavity in munition bodies, the use of the EDS, TDC, or DAVINCH may not be warranted. At such sites, it is probably more practical to use an alternative method—for example, metal parts treatment, heating in an SDC, or chemical neutralization—to destroy remaining agent residue and heels. For sites at which some of the RCWM consists of munitions and containers that are still filled with agent, one or more of the technologies summarized above may be used, depending on site-specific needs and technology capabilities.

### Explosive Destruction System

The EDS is a system designed by NSCMP. Sandia National Laboratories has built five to date, for on-site destruction of recovered chemical weapons or treatment of other chemical warfare materiel. Two versions, the EDS Phase 1 (EDS-1) and the EDS Phase 2 (EDS-2) (see Figure 4-4), have been built and operated, with the EDS-2 being a later design and, in general, able to destroy more and larger munitions than the EDS-1. Information on the two systems is available from several sources, including NRC, 2006, 2009a, and 2010b.

Both EDS-1 and EDS-2 employ shaped cutting charges to explosively open one or more containers or munitions placed within a closed, sealed containment vessel, thereby releasing the agent contained within the container(s) or munition(s). Any energetics contained within a munition before treatment will be destroyed by the explosive shaped charge. Chemical

TABLE 4-2 Comparison of Destruction Technologies

| | Technology Type | | | |
|---|---|---|---|---|
| | Neutralization | Explosive Destruction | Explosive Destruction | Thermal Destruction |
| Technology Attribute | EDS Sandia, NSCMP | TDC CH2M HILL | DAVINCH Kobe Steel | SDC Dynasafe |
| Agent contained in: | Sealed cylindrical vessel on truck bed | Rectangular detonation chamber | Double walled cylindrical detonation vessel | Spheroid double walled static kiln |
| Agent in munition accessed by: | Shaped charges on munition or munition overpack | Donor charge placed around munition or munition overpack | Shaped and donor charges on munition or munition overpack | Heating of munition, followed by deflagration or detonation |
| Agent destroyed by: | Reaction with reagent[a] in vessel at 60°C for 1 hr followed by 2-hr hot water rinse | Detonation: Heat and pressure from controlled detonation at 700°-1000°C | Detonation: Shock wave, compression, thermal destruction in fireball at 2000°C | Heating to 550°C resulting in agent decomposition |
| Typical cycle time (varies with munition) | 48 hr | 35-40 minutes | 100 minutes[b] | 20-30 minutes |
| Off-gas treatment | None. Agent and reagent react until agent is destroyed. No off-gas produced. | Catalytic oxidizer with max temperature of 1095°C; reactive bed filter with hydrated lime or sodium bicarbonate for acid neutralization; carbon adsorption system; ceramic filter and HEPA for particulates | Cold plasma oxidizer (Glid-Arc) at 600°C, 0.5-1.0 sec residence time; in-line gas scrubber with NaOH washdown to neutralize the gas; sulfur-impregnated carbon and activated carbon; HEPA filters for particulates | Thermal oxidizer at 1100°C, 2 sec residence time; acid scrubber at approx. 80°C; IONEX filter containing HEPA filter, sulfur-impregnated carbon, and activated carbon; baghouse filter and HEPA for particulates[c] |
| Waste streams | Liquid neutralent and rinsate, scrap metal (munition fragments). Discharged scrap metal is ≤1 VSL[d] (formerly 3X) | Exhaust gas, metal fragments, gravel dust, spent lime, activated carbon. Discharged scrap metal is ≤1 VSL (formerly 3X) | Metal fragments, exhaust gas, dust, activated carbon, scrubber condensate water. Discharged scrap metal is ≤1 VSL (formerly 3X) | Metal fragments, scrubbed off-gas, dust, salts, activated carbon. Scrap metal suitable for release for unrestricted use (formerly 5X) |
| Ability to recycle or further treat off-gas | N.A. No gas stream is produced. | None. Has expansion tank for off-gas but no ability to recycle | Yes. Can recycle off-gas through cold plasma oxidizer after holding and testing in off-gas retention tank | Yes. If operated in batch mode, off-gas in the static kiln can be held at 550°C and tested until agent is not detected |
| Transportability | Transportable on one trailer | Transportable on 8 trailers, 10 days | Fixed facility but vessel can be moved on three flatbed trailers (one each for the outer chamber, the inner chamber, and the lid) plus two trailers for the off-gas treatment unit and additional trailers as needed for supporting equipment | Fixed facility but can be moved in 20-25 ISO containers |
| Explosive containment capacity, TNT-equivalent | 5 lb for EDS-2, including shaped charges | 40 lb including donor charge | 99-143 kg, including donor and shaped charges | 5 lb in munition |
| Largest munition | 155-mm projectile | 210-mm projectile | 8-in. projectile, overpacked M55 rocket | 8-in. projectile |

NOTE: ISO, International Standards Organization; HEPA, high-efficiency particulate air filter; NaOH, sodium hydroxide; IONEX, a research company; 3X, level of agent decontamination suitable for transport for further processing (obsolete); 5X, level of agent decontamination suitable for commercial release (obsolete); TNT, trinitrotoluene.

[a]Reagent is monoethanolamine for mustard and NaOH for phosgene and other fills.

[b]Based on experience to date of six cycles per 10-hr day.

[c]In this report, IONEX refers to an off-gas treatment system that contains particulate filters and activated carbon adsorbers (NRC, 2010b).

[d]VSL is a control limit used to clear materials for off-site shipment based on agent concentration in the atmosphere above the packaged waste materials. The numerical value of the VSL can depend on the permit issued by the regulatory authority for the particular facility involved, but it is often set at either the STEL or the short-term limit (STL), which is numerically the STEL but without the 15-min time component. See Chapter 3 of reference NRC, 2007 for an in-depth discussion of the issues surrounding off site shipment of partially decontaminated waste.

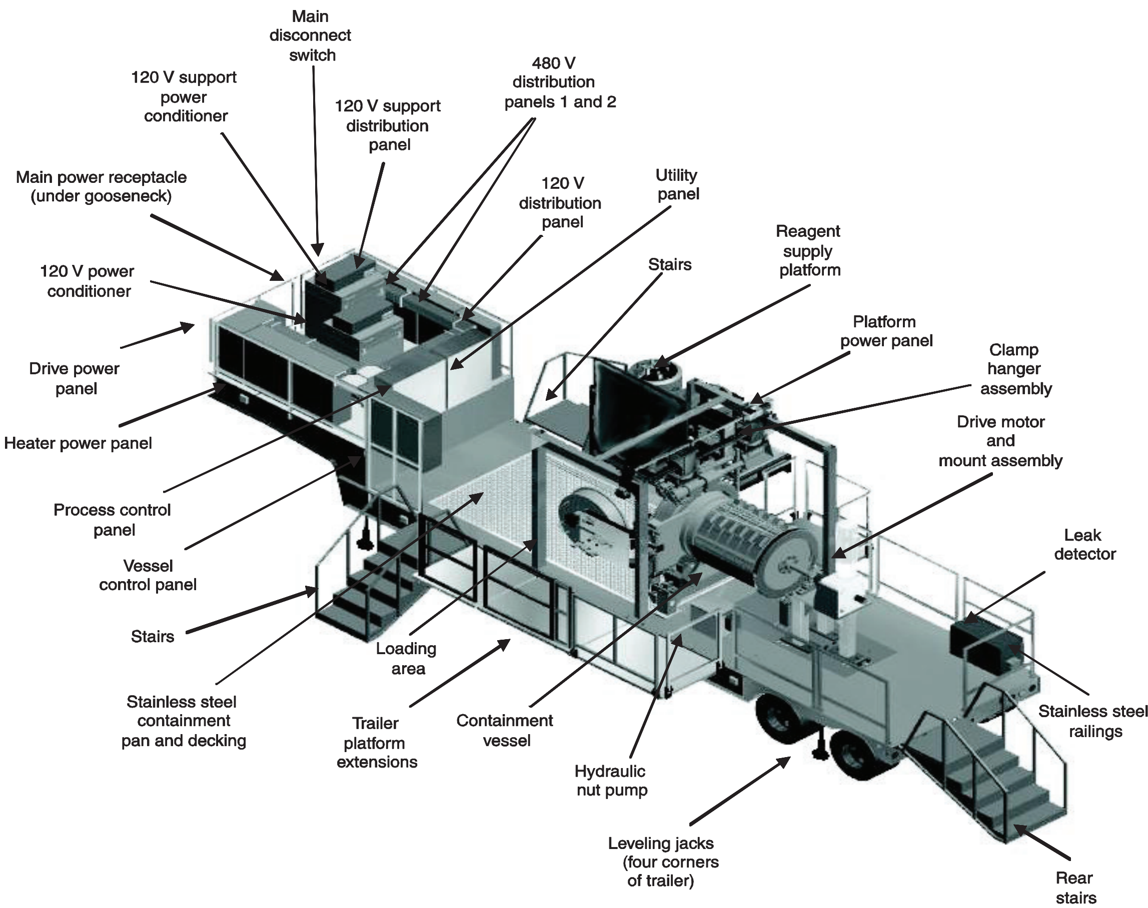



FIGURE 4-4 The EDS-2 vessel on its trailer. SOURCE: NRC, 2009a.

reagents are then added to the vessel to neutralize the agent released from the munition. The EDS-1 containment vessel has a 1-lb TNT-equivalent net explosive weight (NEW) limit, with the NEW limit including both the explosives contained in the munition and those in the cutting charges; the EDS-2 containment vessel has a 4.8-lb TNT-equivalent NEW limit.

The EDS-1 has been used in a number of field operations, including those at Rocky Mountain Arsenal, Colorado [10 sarin (GB) bomblets]; Camp Sibert, Alabama [11 munitions]; and Spring Valley in Washington, D.C. [16 mustard agent (HD) 75-mm artillery projectiles, 1 lewisite 75-mm projectile, and 3 arsine-containing 75-mm projectiles]. One EDS-1 and two EDS-2s were then employed at the Pine Bluff Arsenal to destroy 1,227 recovered chemical munitions. Many of the munitions at Pine Bluff were degraded from burial and not considered safe for dismantling.

Several steps in the EDS operational procedures involve waiting for analytical results or for heating and cooling, resulting in a cycle time of 2 days.

Relative to other transportable whole-munition destruction systems, such as the Dynasafe static detonation chamber, the CH2M HILL transportable detonation chamber, and the DAVINCH system, the EDS-1 and -2 have long cycle times. In the EDS, the munition is opened with a shaped explosive charge. For HD, most of the agent is destroyed by reacting it with a 90 percent MEA/10 percent water solution at 60°C while rotating the vessel for 1 hr. In a subsequent step, water at 60°C is added to the vessel, the vessel contents are heated to 100°C, and the vessel is rotated for 2 hr. This step is needed to disperse or dissolve the solid or semisolid heels that occur in many mustard-filled munitions and to remove the mustard from the chunks or globules of heel and other solid residues. The water-mustard chemical reaction is very fast, with a half-life of about 2.3 sec at 90°C (NRC, 1993), but the diffusion operations involved in this step are much slower, often resulting in a much slower rate of destruction of mustard than implied by the mustard-water chemical reaction. Further, use of still higher temperatures or changing other operational parameters will not appreciably increase the rate of these diffusion operations.

The entire mustard destruction step takes 9 to 10 hr. The equivalent steps in the TDC and DAVINCH are practically instantaneous. Changes can be made to speed up some of the steps in the EDS process—for example, steam injection to reduce vessel heating time—but it will always be slow relative to the TDC and DAVINCH.

To address the slow processing rate and other issues, the NSCMP has begun product improvements to the EDS:

- *Impulsively loaded vessels*.[20] The chambers of all existing EDS chambers are certified as pressure vessels. The American Society of Mechanical Engineers has established a new category, impulsively loaded vessel, with a code stamp U3. Future EDS-2 vessels will have the U3 stamp and will have a 9-lb NEW rating. The Department of Defense Explosives Safety Board (DDESB) will require testing with explosive charges to certify this rating.
- *EDS-2 test fixture*. This is a functional but nonmobile EDS-2 that will allow for more rapid testing of product improvements. It utilizes an existing EDS-2 vessel. Construction was completed in the fourth quarter of 2011. Testing with agent was planned for the first quarter of 2012.
- *Three-piece clamp*. This is a previously designed but never implemented end closure for the EDS. It offers automated bolt tightening. Its advantages over the current design include less operator stress, better alignment between the end closure and the vessel, and a significant saving of time. A clamp of this design is to be installed on the new EDS-2 test fixture.
- *Liquid analyzer*. A near-real-time analyzer that determines whether or not the neutralizing reactions are sufficiently complete to allow EDS vessel draining is being developed. A 10-sec cycle is anticipated. Semi-quantitative testing was reported to be successful for mustard and lewisite agents. Plans called for using the analyzer during the testing of steam injection in the first quarter of fiscal year 2012. These tests were also to include the addition of cold water to more rapidly cool the vessel after the 2-hr water rinse at 100°C. This will decrease the duration of the 1-hr liquid analysis time, which now starts at 1145 and ends at 1245 on Day 1.
- *Use of a laser for surface decontamination*. A commercially available laser from ADAPT Laser is being evaluated for removal of heavy metals from the EDS vessel interior and for similar applications elsewhere. Testing on moderately contaminated surfaces was successful. As of September 2011, testing on more heavily contaminated surfaces was planned.
- *Processing munitions in overpacks*. Use of improved linear shaped charges to cut through the overpack and the munition was planned as of September 2011. This could allow the processing of leaking munitions more safely.
- *Steam injection*. Injection of steam into the EDS vessel is to be tested. Expected advantages of using steam injection include faster heating than is now obtained, by heating with external band heaters only, and reduced liquid waste. Steam injection is being installed and tested on the EDS-2 test fixture mentioned above. Testing with live agent was planned for 2012.
- *The EDS-3*. Simulation studies and modeling are under way on a potential new EDS design, termed the EDS-3. It would be similar to the EDS-2 but would be able to accommodate a complete M55 115-mm rocket contained within an overpack.

In addition to these product improvements, efforts are under way on the identification of a reagent that will be effective for all agents. Testing of 10 reagents on mustard and GD (soman) agents has begun, with results pending.

### Transportable Detonation Chamber

The TDC was first described in the NRC report on international technologies for destruction of RCWM (NRC, 2006). A subsequent report outlined the updates, with an emphasis on the Blue Grass and Pueblo chemical agent destruction pilot plants (NRC, 2009a). The TDC was designed by CH2M HILL Demilitarization, Inc.

The TDC is a true explosive destruction system, as it uses the heat and pressure generated by an explosion to destroy most of the chemical agent fill. The current system was extensively tested and modified between 2003 and 2006 at Porton Down, England. This system evolved into the TC-60, with a DDESB NEW rating of 40 lb TNT-equivalent. The TC-60 unit was used in 2008 to destroy several dozen munitions at the Schofield Barracks in Hawaii. It was then returned to the Aberdeen Proving Ground for substantial additional testing and development work. It was most recently employed in Columboola, Queensland, Australia. The current configuration of the TC-60 system is shown in Figure 4-5. The system has demonstrated the ability to destroy mustard, phosgene, chloropicrin, white phosphorus, smoke, and the vomiting agent Clark.[21]

As shown in the figure, the detonation chamber is followed by an extensive pollution control system, including a catalytic oxidizer, a heat exchanger, carbon filters, and a HEPA filter. The gas is discharged into the system enclosure, which has an additional carbon filtration system, before exhausting into the atmosphere. The munitions are wrapped in an explosive charge and oxygen is injected prior to detonation.

[20]Impulsive loading is defined as a "loading whose duration is a fraction of the periods of the significant dynamic response modes of the vessel components. For the vessel, this fraction is limited to less than 35 percent of the fundamental, membrane-stress dominated (breathing) mode." From ASME Case 2564-1. Available at http://cstools.asme.org/csconnect/pdf/R081171.pdf.

[21]Brint Bixler, Vice President, CH2M HILL, "Controlled Detonation Chamber," presentation to the committee on December 13, 2011.

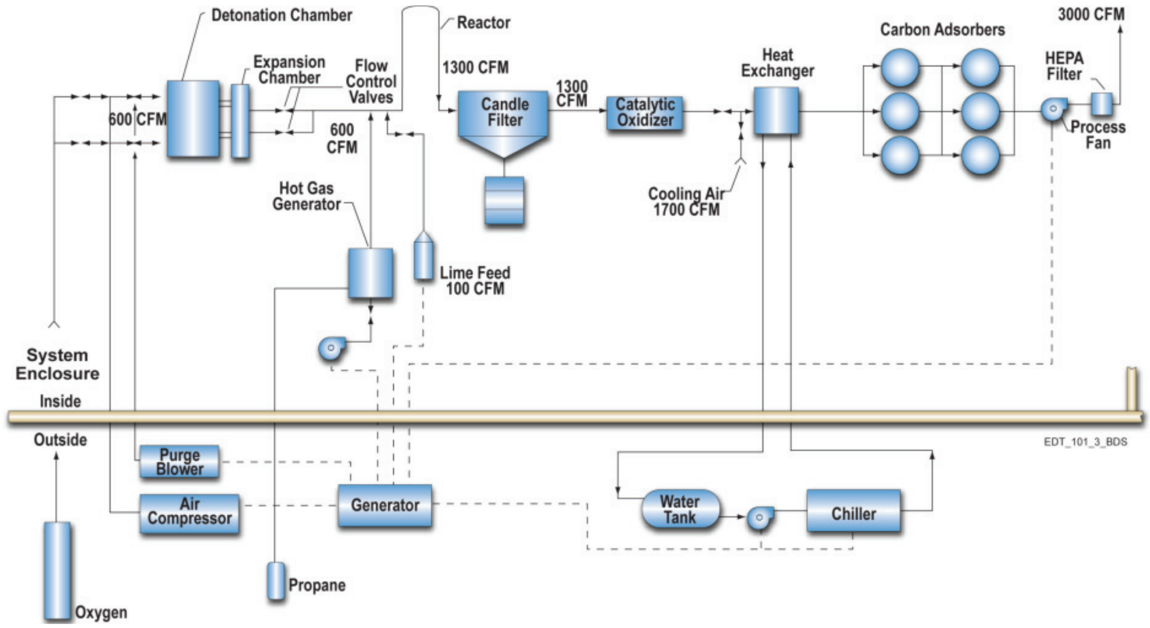



FIGURE 4-5 Process flow in the large mobile transportable detonation chamber TC-60. SOURCE: Brint Bixler, Vice President, CH2M HILL, "Controlled Detonation Chamber," presentation to the committee on December 13, 2011.

There have been a number of lessons learned and upgrades to the system, including the following:[22]

- Additional chamber floor protection was added.
- The efficiency of the final filtration was improved with the addition of a HEPA filter.
- Internal welds for the fasteners attaching the armor plate to the chamber walls were upgraded.
- The firing system was improved by changing the firing plug/cable design and replacing the system every 70 detonations.

At Aberdeen Proving Ground, 29 cylinders of HD were destroyed, for a total of 282 lb HD between March 2009 and March 2010. Included were two cylinders in double overpacks, with 11.7-lb of HD (155-mm projectile equivalent). Overpack test results showed that the outer and inner overpacks had been penetrated and that there was sufficient heat to destroy the chemical fill.

An additional upgrade was made just prior to transport to Columboola. Improved bearings were added to two control valves, one 3-in. and the other 10-in. The unit had been in storage for a while and moisture buildup was causing the valves to seize. The unit was set up in Columboola and ready within 10 days. The typical schedule included 2 days of destruction followed by one-half day of "scrap management." Operations then continued. Destruction rates stabilized at eight munitions per day. Scrap was removed from the detonation chamber twice per week. The campaign ended with treatment of 144 mustard-filled munitions, many with heels.[23] ECBC staff who observed its use in Columboola praised it as "elegant" to operate.[24] There were no problems with the unit other than the cracked welds. The operator believed the unit was a good transportable system with a throughput midway between that of the EDS (slower) and that of the Dynasafe SDC (faster).

[22]Ibid.

### Dynasafe Static Detonation Chamber

The SDC was described in three earlier reports (NRC, 2006, 2009a, and 2010b). It is the only one of the four systems that does not require any preparation of the CWM prior to destruction, which gives it an important safety advantage over the other systems. Moreover, the scrap metal produced is suitable for release for unrestricted use (formerly termed "5X"), and no donor explosives are required.

The design and operation of the SDC 2000 system in Munster, Germany, were described in detail in previous NRC reports (NRC, 2006 and 2009a). An SDC 1200 was delivered to the JFE Steel Corporation in Japan in 2009.[25] It will be used for the destruction of RCWM in Chiba Prefecture, Japan. Another SDC 1200 was delivered to Kawasaki Heavy

[23]Ibid.

[24]Timothy A. Blades, Deputy Director, Directorate of Program Integration, ECBC, teleconference with Richard Ayen, committee chair; Doug Medville and JoAnn Lighty, committee members; and Nancy Schulte, NRC study director, January 4, 2012.

[25]Harley Heaton, Vice President-Research, UXB International, "Dynasafe Static Detonation Chamber," presentation to the committee on December 13, 2011.

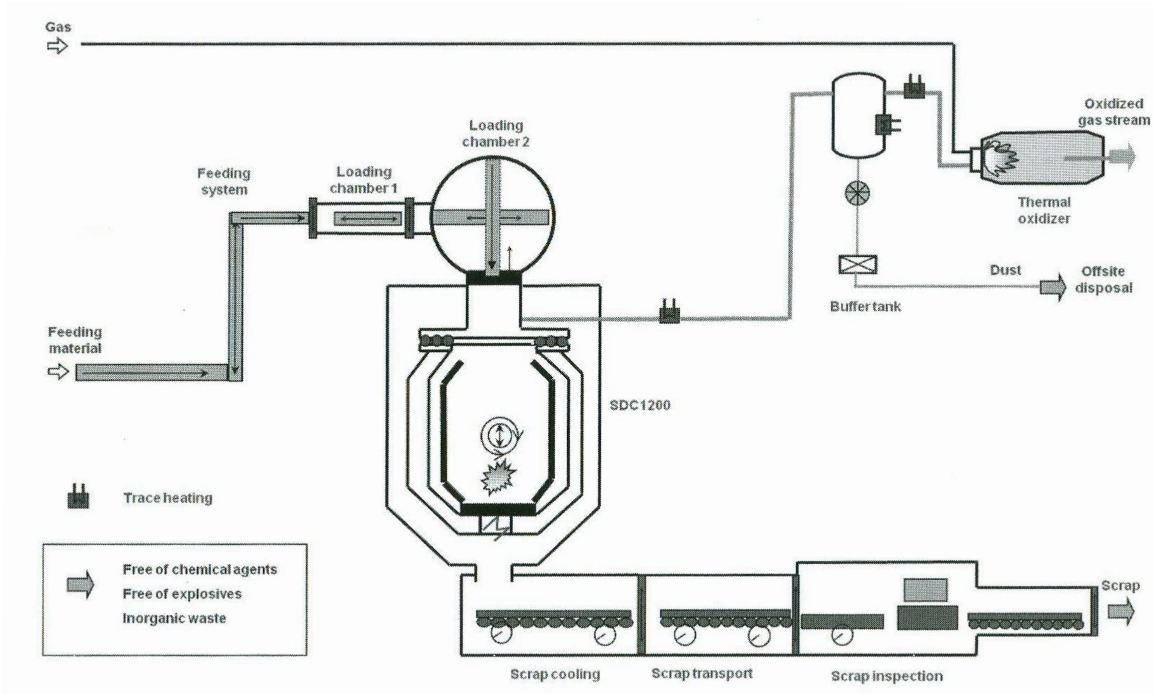



FIGURE 4-6 Process flow diagram for front components of the Dynasafe SDC 1200 installation for Anniston Army Depot. SOURCE: Adapted from personal communication between Holger Weigel, Vice President, Dynasafe International, and Managing Director, Dynasafe Germany, and Richard Ayen, committee chair, May 12, 2010.

Industries and is now undergoing systemization. It will be used for the destruction of Second World War–era Japanese RCWM in Haerba-ling, China.

The NRC letter report "Review of the Design of the Dynasafe Static Detonation Chamber (SDC) System for the Anniston Chemical Agent Disposal Facility-August 25, 2010" describes the Dynasafe SDC 1200 system now installed at the Anniston Chemical Agent Disposal Facility (ANCDF), in Alabama (see Figure 4-6).

The Dynasafe 1200 used at ANCDF had a NEW containment capacity of 5 lb, all of which consists of explosives in the munition since no donor charge is needed. As of September 1, 2011, this system had destroyed 2,322 munitions, consisting of normally configured and overpacked 4.2-in., 105-mm, and 155-mm mustard-filled rounds.[26]

During operations at ANCDF, a number of problems with the system became evident, the most significant being agent migration into secondary containment.[27] Agent was leaking at a number of locations. The actions taken to alleviate the leaking were these:

- Agent leaks from the buffer tank into the solids collection drum below the buffer tank were eliminated by blind-flanging the connection to the solids collection drum from the buffer tank.
- The leaking of agent from loading chamber 2 into the process air system was alleviated by modifying the loading chamber 1/loading chamber 2 pressure equalization procedure during munitions feed to the detonation chamber.
- Agent was detected at the process air monitors during emptying of the detonation chamber. This was alleviated by controlled venting of loading chamber 2 and the detonation chamber before beginning to empty the chamber.
- Agent was escaping from one or more of the flange connections between the detonation chamber and the thermal oxidizer. This was being investigated as this report was being written, with emphasis on different gasket materials or use of sealants.

The unsteady nature of events in the detonation chamber during operations in 2011 appeared to be causing CO excursions in the off-gases from the thermal oxidizer. The short residence time in the thermal oxidizer might also have been contributing to the problem (NRC, 2010b). The instability in the detonation chamber was apparently causing unsteady flow through the thermal oxidizer: The problem was allevi-

[26]Timothy K. Garrett, Site Project Manager, ANCDF, "Dynasafe Static Detonation Chamber," presentation to the committee on September 29, 2011.

[27]Charles Wood, ANCDF Deputy Operations Manager, URS, ANCDF, presentation to the committee on September 29, 2011.

ated by installing a smaller orifice between the detonation chamber and the thermal oxidizer to smooth flow to the oxidizer. Also, the flow rates of the spray dryer atomizing air and the barrier air were reduced, allowing more air at the thermal oxidizer. (See the fourth bullet item in the list of issues being addressed for further discussion of this topic.)

Rapid depletion of carbon was attributed to the presence of sulfur dioxide in the offgases fed to the carbon beds. The excessive sulfur dioxide emissions problem, and hence the rapid carbon depletion problem, was resolved by adjusting the pH in the scrubbers.

As of January 2012, effort was continuing at the ANCDF to eliminate or further alleviate the problems described above, as well as to satisfy other identified development needs.[28] Conventional munitions were of necessity being employed in this critical development effort since Anniston no longer had any chemical munitions. This work was being carried out jointly with Dynasafe, and the lessons learned and the resulting design changes were being incorporated into future SDC 1200 systems. As of January 2012, the following issues were being addressed:

- Process gases were leaking through the knife valves at the bottom of the buffer tank. New valves of an improved design had been received and were to be installed before start-up of an assessment of throughput, reliability, availability, and maintainability (TRAM) for the system.
- Agent vapor from the upper portion of the detonation chamber was escaping to the process air system as the chamber was emptied. In addition to implementing a controlled venting procedure, as previously described, a new nozzle was being installed to keep the top of the chamber hotter, minimizing agent vapor generation at the interface between loading chamber 2 and the detonation chamber.
- Agent was escaping from one or more of the flange connections between the detonation chamber and the thermal oxidizer. It was planned to inspect, measure, and adjust all connections to ensure proper alignment and gasket seating before the start of the TRAM assessment.
- CO excursions in the offgases from the thermal oxidizer were being experienced. The problem was greatly reduced by the actions already described. In addition, design studies were begun aimed at providing additional gas flow through the system by upgrading the induced draft fan and the fan in the filter system between the induced draft fan and the stack (the IONEX Research Corporation system). Since the ANCDF SDC was manufactured, Dynasafe has enlarged the thermal oxidizer for its SDC 1200s.[29] This is expected to allow better control of excess oxygen and hence more reliable combustion of CO.
- Occasional failure of loading gate 2 seals was being investigated.
- Degradation of the spray dryer temperature control valve was addressed by installing a redundant system to be tested during the TRAM assessment.
- A process water piping degradation problem was addressed by upgrading materials to stainless steel. The new piping was to be installed before the TRAM assessment.
- Bridging of solids in the baghouse was being addressed by designing and installing an automated vibrator.
- Accumulation of solids in the spray dryer was alleviated by system tuning and better pH control. The situation was to be monitored and further evaluated during the TRAM assessment.
- The bypass between loading chamber 2 and the detonation chamber occasionally became clogged. This situation was still being evaluated as of January 2012.

This unit completed its intended operation on chemical munitions at ANCDF and is available for use by NSCMP for the destruction of RCWM.

### Detonation of Ammunition in a Vacuum Integrated Chamber

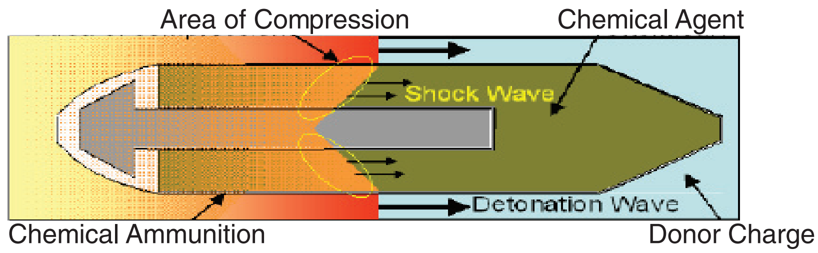
DAVINCH is a controlled detonation system for the disposal of chemical munitions. It is yet another destruction system where an explosion consumes most of the agent.

The DAVINCH technology was developed by Kobelco, a subsidiary of the Japanese company Kobe Steel, a manufacturer of large steel pressure vessels. DAVINCH was developed to destroy Japanese chemical bombs, some containing a mustard/Lewisite mixture and others containing vomiting agents. Munitions placed in the DAVINCH vessel are detonated in a near vacuum using linear shaped charges and a donor charge that is placed on the munitions overpack to open the munitions and access the chemical agent (see Figure 4-7).

The agent is destroyed by the high temperatures (3000°K) and pressures (10 GPa) that result from the detonation and from the fireball in the chamber. The use of a vacuum reduces noise, vibration, and blast pressure, thus increasing vessel life. The off-gases that are produced are treated in a cold plasma oxidizer followed by treatment in activated carbon filters. The explosion containment capability of DAVINCH chambers varies from 99-143 lbs TNT-equivalent NEW, depending on the application. Detailed descriptions of the

[28]Timothy Garrett, Site Project Manager, Anniston Chemical Agent Disposal Facility, personal communication to Nancy Schulte, study director, National Research Council, January 26, 2012.

[29]Harley Heaton, Vice President-Research, UXB International, personal correspondence to Nancy Schulte, NRC study director, March 16, 2012.




| Step | Chemical Agent Destruction Mechanism |
|---|---|
| 1 | Instant compression by propagating shock wave pressure of 10 GPa. A similar phenomenon is observed in cavitation bubbles when bubbles collapse (sonochemistry). |
| 2 | High-speed mixing of chemical agent with detonation gas at high pressure and high temperature. |
| 3 | Thermal decomposition by the long-lasting fireball at 2000°C for 0.5 sec. |

FIGURE 4-7 DAVINCH three-stage destruction mechanism. SOURCE: NRC, 2006.

DAVINCH technology were provided in previous NRC reports (NRC, 2006 and 2009a).

### *United States*

To date, the DAVINCH technology has not been used in the United States. A DV60 (60-kg TNT-equivalent explosion containment capacity) had been leased from Kobelco by the U.S. Army for use at the Tooele Chemical Agent Disposal Facility (TOCDF), in Utah. However, an alternative method of destroying the munitions became available before the DAVINCH was due to start up in early 2012. Because this alternative was successful, it was decided in late 2011 not to use the DAVINCH at TOCDF.

### *Japan*

The DAVINCH technology was used at Kanda Port in Japan to destroy recovered Second World War–era bombs containing chemical warfare materiel. Some of the bombs contained a mixture of mustard agent and lewisite; others contained Clark I and Clark II vomiting agents (DC/DA). As of 2009, 2,050 of these bombs had been destroyed (NRC, 2009a).

### *Belgium*

The Belgian Ministry of Defense has installed a DAVINCH system having a 50-kg TNT-equivalent explosion containment capacity at a Belgian military facility at Poelkapelle. By December 2011, over 4,000 munitions containing chemical agent had been destroyed.

### *People's Republic of China*

DAVINCH units are being used in the People's Republic of China (PRC) to destroy Second World War–era Japanese chemical munitions filled with blister, choking, vomiting, and other agents. These munitions are primarily artillery shells and bombs ranging in size from 75 mm to 150 mm. The site with the most RCWM, Haerba-ling (northeastern China), contains an estimated 300,000-400,000 munitions; another 47,000 munitions have been recovered at 26 other locations. At Haerba-ling, both a DAVINCH and a Dynasafe SDC will be used to destroy munitions recovered from pits where they are buried. The second largest site in the PRC is in Nanjing, where 36,000 chemical munitions have been recovered. At this location, two DAVINCH DV-50 units, operating in tandem, are in use. Between September 1, 2010, and June 10, 2011, 25,000 overpacked and boxed munitions were destroyed.

In addition to these transportable (but barely so) units, Kobelco states that a lighter, more mobile version of DAVINCH, called DAVINCH$^{lite}$, is being developed. The committee believes that, as of early 2012, the DAVINCH$^{lite}$ had not even been manufactured much less used to destroy any RCWM in the PRC.

## SECONDARY WASTE STORAGE AND DISPOSAL

As indicated previously, the treatment technology for RCWM will involve either the EDS, one of the EDTs, or perhaps a combination of these technologies. Each of these technologies will produce a number of secondary waste streams (see Table 4-2) that will then need to be managed in accordance with regulatory requirements. The regulatory requirements pertain primarily to the Resource Conservation and Recovery Act (RCRA) and its implementing regulations. RCRA is summarized in Appendix D, along with other regulatory programs.

The secondary wastes produced by the various types of EDTs are similar; they consist of metal casings and fragments, explosive fragmentation protective materials, carbon filter material, baghouse dusts, miscellaneous wastes (used O-rings, fittings, etc.), and liquid waste streams coming from off-gas treatment, from periodic cleaning and decontamination of the device, or from closure between deployments. The EDS will generate not only the above materials but also a substantial volume of liquid wastes (hydrolysates and various dilute rinsates). CAIS containing dilute or neat agent are treated and disposed of in a SCANS unit, as discussed above.

Secondary waste from EDS operations was stored at both the Spring Valley and Camp Sibert sites and then shipped off-site.[30,31] At both sites, the project managers followed the Army's general practice of treating the waste only to the point at which it can be safely shipped off-site to commercial treatment, storage, and disposal facilities (TSDFs) (NRC, 2004). At both places, the waste was stored in a less-than-90-day hazardous waste storage area. The waste was placed in an enclosed trailer (Spring Valley) or in a vapor containment structure (Camp Sibert). The enclosures were within fences, with security guards present. Liquid waste was placed in 55-gal steel drums.

For the past several years, NSCMP has maintained a waste management contract with Shaw Environmental, Inc. As explained in NRC, 2004, the waste management contractor is responsible for teaming with one or more commercial hazardous waste TSDFs to transport and dispose of hazardous secondary and neutralent wastes from the various NSCMP projects. Shaw Environmental fulfilled this responsibility for EDS operations at both Spring Valley and Camp Sibert. The project manager at Spring Valley reported that he received some questions and expressions of concern from the regulators and the community about the nature and amounts of reagents and waste entering and leaving the facility, but that this was "nothing really significant."

Otherwise, there were no problems with waste storage or disposal at either Spring Valley or Camp Sibert. As a consequence, the committee could not identify any need for targeted research and development in this area.

[30]Karl E. Blankinship, FUDS Project Manager, Mobile District U.S. Army Corps of Engineers, personal communication to Nancy Schulte, NRC study director, April 4, 2012.

[31]Dan G. Noble, Project Manager, Spring Valley, Baltimore District, U.S. Army Corps of Engineers, personal communication to Nancy Schulte, NRC study director, March 30, 2012.

# 5

# Redstone Arsenal: A Case Study

## INTRODUCTION

Although its tasks are addressed in detail in the individual chapters of this report, the committee believes that the challenges facing the Non-Stockpile Chemical Materiel Project (NSCMP) can be examined in a more holistic manner by conducting a case study of one of the small number of sites that contain especially large quantities of chemical warfare materiel (CWM). There are 249 known and suspected sites in the United States that contain CWM (DOD, 2007), including several sites that could contain large quantities of CWM: Black Hills Air Force Base, South Dakota; Deseret Chemical Depot, Utah; and Redstone Arsenal (RSA), Alabama. RSA in Huntsville, Alabama, has 17 suspected CWM sites for which the state regulatory authority is requesting removal as an interim measure to satisfy the Resource Conservation and Recovery Act (RCRA). RSA is also believed to be the largest and most challenging of the sites in terms of estimated quantities, the condition and variety of items, operational complexity, regulatory issues, and potential remediation costs.

In this chapter, the committee uses RSA to illustrate the technological and operational challenges and community relations issues faced by NSCMP as it proceeds with the cleanup of large CWM sites. It also offers recommendations to improve the efficiency and effectiveness of the remediation activities.

## THE CHALLENGES AT REDSTONE ARSENAL

The cleanup at RSA is a huge challenge for a number of reasons. The site comprises some 38,300 acres of land containing over 300 solid waste management units (SWMUs), 17 of which are designated by the regulatory authority as subject to interim measures involving CWM removal. Each of these units not only is likely to require a customized approach but also has more than 5 mi of disposal trenches and various burn and disposal areas for chemical munitions and related wastes as a result of operations that began in the early 1940s.[1,2] Further, the combination of active and former operational areas supports a large number of tenants and is situated in a region with a growing economy and a growing population. The magnitude of the problem is illustrated to some extent in Figure 5-1. Note especially the large size of the facility and the many CWM sites within its 38,000 acres.

These factors and others discussed below call for a very carefully considered and deliberate approach to remediation.

## CHEMICAL WARFARE MATERIEL INVENTORY

From 1940 until 1945, this was the site of three chemical agent plants at the Huntsville Arsenal, where toxic agents such as mustard (H/HS), lewisite, phosgene (CG), and adamsite (DM) were produced and where the RSA Ordnance Plant assembled and packaged chemical munitions such as 75-mm to 155-mm shells and 30-lb and 100-lb chemical bombs. These plants also produced many munitions filled with smoke and incendiary chemicals. Examples of the items produced are listed in Table 5-1.

Following the Second World War, the Ammunition Returned from Overseas (ARFO) program brought up to 1 million munition items to RSA for evaluation and demilitarization. These munitions came from Germany, Japan, and Great Britain and contained agents not produced in the United States, such as British mustard (HT), the German nerve agent tabun (GA), German mustard, thickened German mustard, and nitrogen mustard (HN-3). Destroying these agents presented challenges to the Army at the time.

[1]Stephen A. Cobb, Chief, Government Hazardous Waste Branch, Land Division, ADEM, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

[2]Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, U.S. Army, "Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager's Perspective," presentation to the committee on November 2, 2011.

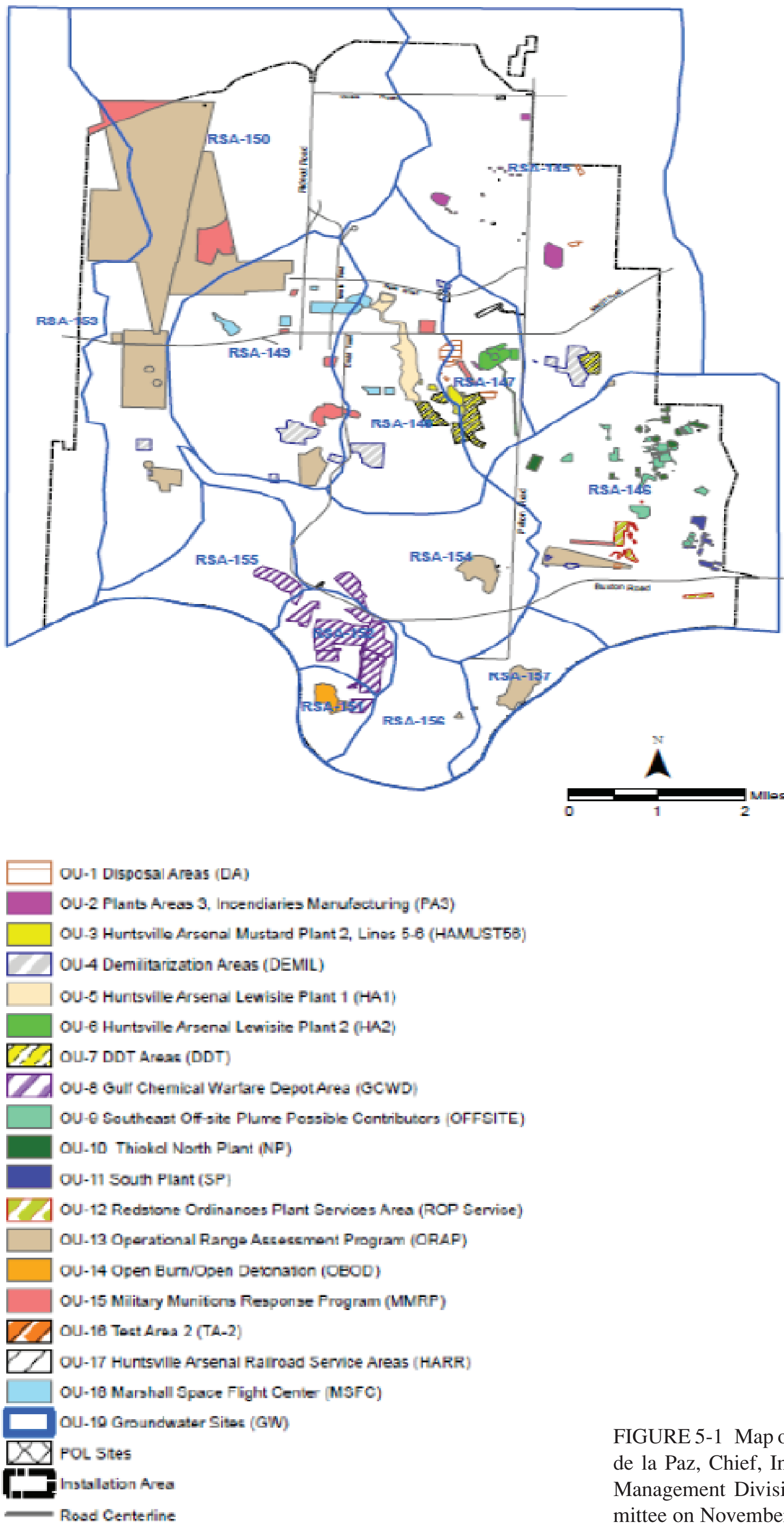



FIGURE 5-1 Map of Redstone Arsenal, Alabama. SOURCE: Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, presentation to the committee on November 2, 2011.

TABLE 5-1 Partial List of Chemical Items Produced at RSA Ordnance Plant During the Second World War

| Agent | Item | Quantity |
|---|---|---|
| Mustard (H/HS) | 105-mm M60 rounds | 1,770,000 |
| | 155-mm M105, M104, M110 rounds | 31,000 |
| | 4.2-in. mortar rounds | 54,000 |
| | 100-lb. M47 and M70 bombs | 560,000 |
| | Ton containers, 30- and 55-gal drums | Unknown |
| Lewisite | Ton containers | Unknown |
| Phosgene | 500-lb bombs (M78) and 1,000-lb bombs (M79) | Unknown |
| White phosphorus | 4.2-in. shells, 75- and 155-mm shells | 4,194,000 |
| | 100-lb bomb (M46, M47) | 162,000 |
| | M15 hand grenades | 951,000 |

SOURCE: Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, "Remediation of RCWM from Burial Sites," presentation to the committee on November 2, 2011.

Between 1945 and 1950, major disposal actions were taken to destroy chemical munitions and agents, with most of the toxic chemical agents being processed by 1949. The agent production and ordnance plants at RSA were decontaminated and demolished, and the post-Second-World-War overseas ordnance, reject munitions produced at RSA, and "good" munitions produced there were disposed of, usually by burning in trenches.

Although mustard munitions in pits were burned twice with subsequent refilling of the pits, large quantities of contaminated and potentially contaminated materiel remain at 17 sites, where today there is still a possibility of encountering CWM. Based on excavation of a similar pit at Pine Bluff Arsenal Site 12 in 1987, about 10 percent of the original mustard-filled munitions may have survived the burning and might still need to be destroyed.[3] Other munitions may have been partially destroyed, with residual quantities of toxic chemical agent remaining in the munitions, on metal surfaces, or within the soil or other fill materials.

Examples of chemical items that could remain in trenches and pits at RSA include the following:[4]

- Rubberized mustard residue from thickened German mustard in burned 250-kg bombs: 1,660 bomb bodies with probable residue are estimated to remain;
- H/HS in burned 250-kg and 500-kg bombs: 40-50 lb of heel may remain in each of an estimated 9,000 bomb bodies;
- Possible concrete-encased 500-kg H/HS-filled bombs;
- Large quantities of agent-contaminated metal such as burned-out bomb bodies, 55-gal drums, British land mines, and plant production equipment;
- Over 10,000 CAIS bottles, both intact and damaged, containing surviving H/HS, and
- Small quantities of CG-filled items.

The total quantities of remaining items cannot be known until source removal action is taken and disposal begins. However, based on archival research and interviews with former employees, there is a potential for significant quantities of munitions, both conventional and chemical, and chemical warfare-related items (e.g., drums and production equipment) to be found in various states within burial sites at RSA.[5] These quantities have been assigned to the various SWMUs at RSA and each lot has been characterized by munition or container type (e.g., bomb, canister, mortar) and by agent content (e.g., H, GA, CG). The quantities that could be encountered are divided into three categories, which are defined in the footnotes, and are estimated as follows:

Intact items: 85,000-92,000[6]
Empty contaminated items: 844,000-855,000[7]
Empty noncontaminated items: 1,971,000-1,975,00[8]

German Traktor rockets being prepared for disposal in a pit are shown in Figure 5-2.

## Processing of Unusual Items at Redstone Arsenal

The burial pits at RSA are expected to contain many items that NSCMP may not have encountered previously. For example, the "empty contaminated" category in the inventory of buried items includes these:[9]

- Production plant equipment, chemical with HS, L, and WP: 91,400 items,
- German Traktor rockets with GA and HN-3: 54 items,

[3]William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, "Non-Stockpile Chemical Materiel Project Redstone Arsenal (RSA) Interim Historical Report," presentation to the committee on January 18, 2012.

[4]Ibid.

[5]Ibid.

[6]An intact item is physically intact enough to hold most or all of the original agent content of the munition. These items will require agent destruction by a suitable technology (e.g., an EDS or an EDT).

[7]An empty contaminated item is a munition that has been opened and partially burned or decontaminated but can still provide a detectable air monitoring reading. These items will require further treatment to destroy any remaining quantities of chemical agent, smoke, or incendiary fill.

[8]An empty noncontaminated item is a munition that has been physically opened and burned or decontaminated to a point where no chemical agent, smoke, or incendiary chemical can be detected by air monitoring equipment. These items should be clean enough to not require further processing and can be disposed of as nonhazardous waste or sent to a smelter or other commercial disposal facility.

[9]William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, "Non-Stockpile Chemical Materiel Project Redstone Arsenal (RSA) Interim Historical Report," presentation to the committee on January 18, 2012.

FIGURE 5-2 German Traktor rocket pit at Huntsville (now Redstone) Arsenal, Alabama (photo from 1948). SOURCE: William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, "The Redstone Arsenal Archival Review," presentation to the committee on January 18, 2012.

- 55-gal drums with CNS, CNB, HS, HT: 21,046 items,
- Bombs, chemical, 100-lb M47, HS fill: 11,032 items,
- Bombs, chemical, 115-lb, M70, HS fill: 33,514 items,
- Bombs, chemical, German, 250 kg, GA fill: 750 items, and
- Bombs, chemical, German, 500 kg, GA fill: 692 items,

where HS is 60 percent sulfur mustard and 40 percent bis[2-(2-chloroethylthio)ethyl]ether, CNS is phenyacyl chloride (CN) tear gas mixed with chloropicrin and chloroform, and CNB is CN tear gas mixed with carbon tetrachloride and benzene.

## TECHNICAL AND OPERATIONAL ISSUES

Remediation at RSA is complicated by a number of technical and operational factors. The arsenal contains a large number and wide variety of munition types (see preceding section) in different stages of degradation and was used for many years as a disposal site for toxic chemicals.[10] Additional processing capacity may be needed to safely and efficiently process such quantities of munitions and contaminated materials and media if they are removed. The conventional approach for identifying the contents of a sealed munition suspected of containing CWM is to use portable isotopic neutron spectroscopy (PINS) to collect data that are then analyzed by the Materiel Assessment Review Board (MARB). While PINS is a valuable tool, it has not been completely reliable for identifying chemical fills or small quantities of explosives in recovered munitions,[11] and the MARB review process is likely to result in long delays when large numbers of items are being processed at RSA (see "Assessment of Recovered Munitions" in Chapter 7 for more information on this issue).

As described in the preceding section, large numbers—perhaps as many as 1 million—of empty but still contaminated items exist at RSA.[12] While many of these may be further decontaminated using existing destruction technology equipment such as the explosive destruction system, these technologies are not expected to have the capacity to destroy such a large number of items in a reasonable time frame. Other options, such as soaking in a decontamination solution or heating in a furnace, may be preferable, especially if the energetics have been removed and the munition casing has already been opened, thus eliminating the need for an explosive destruction technology to access the agent cavity. This would be particularly true for decontaminating the many pieces of production plant equipment that are expected to be found in several of the pits at RSA.

Other solutions that may be examined include disposal-in-place or consolidated disposal in a suitable location on-site, with land use controls and continued monitoring as appropriate. The suitability of these cleanup options at RSA will depend on the applicable laws, regulations, and U.S. Army policies as well as the development of a constructive relationship between the various stakeholders (including the Army, the state of Alabama, EPA, tenants, and local community groups). A flexible approach to remediation and risk management at RSA has the potential to expedite cleanup while reducing its overall cost.

The strengths and limitations of the current supporting technologies for use in the cleanup of CWM sites are discussed in Chapter 4. The legal and regulatory issues associated with the various options are presented in Chapter 3, with background information presented in Appendix D.

The 17 interim-action sites at RSA with known or suspected CWM fall into two categories when it comes to restoration funding, which complicates and potentially delays the overall remediation process. Of these 17 sites, 5 are eligible for the Defense Environmental Restoration Program (DERP), while the remaining 12 are classified as operational ranges and must seek funding from the Compliance Cleanup Program of the Army's Operations and Maintenance (OMA) program. Since OMA funding is limited (less than $20 million is available each year), these sites may require many

[10]Ibid.

[11]Dan G. Noble, Project Manager, Spring Valley Baltimore District, U.S. Army Corps of Engineers, "Project Management of Spring Valley: A Corps of Engineers Perspective," presentation to the committee on November 1, 2012.

[12]William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, "Non-Stockpile Chemical Materiel Project Redstone Arsenal (RSA) Interim Historical Report," presentation to the committee on January 18, 2012.

years for complete remediation.[13,14] Overall, it has been estimated that it could take up to 15 years and between $1 billion and $3 billion to complete restoration.[15] The committee believes that the current management approach and funding constraints for operational ranges greatly complicate the task of cleanup there. For more details on operational issues that may impact the effectiveness of cleanup operations at RSA and recommendations for operational improvements, see Chapter 6.

RSA is home to more than 130 landowners and tenants, including the Army, NASA, the Tennessee Valley Authority, and the Wheeler National Wildlife Refuge; in addition, an ongoing cleanup program for dichlorodiphenyltrichloroethane (DDT) is being conducted by Olin Corporation. Also, given its location in the Tennessee Valley, on a partial flood plain having a complex hydrogeology, it should be expected that the cleanup program will draw a great deal of scrutiny from regulators and community groups concerned about the protection of the region's environment.

Coordinating access to all of these facilities and land areas and gaining the cooperation of the tenants will be a significant challenge for NSCMP. The committee believes that community and general stakeholder engagement will be critical for a successful remediation program at RSA, and it points to the important lesson learned at the formerly used defense site (FUDS) of Spring Valley in Washington, D.C. Notwithstanding the difficulties experienced in the early days of the cleanup effort, a collaborative partnership eventually developed that simplified decision making and made it more acceptable to all parties (see the later section "Community Concerns" for more information).

## MATCH OF TECHNOLOGY NEEDS WITH NSCMP CAPABILITIES

As indicated earlier in this chapter, it is expected that 85,000-92,000 intact chemical munitions and 844,000-855,000 empty but contaminated items will be encountered. If a remove-and-treat approach is selected, the key technological responsibilities for NSCMP will be to (1) assess the intact munitions, (2) destroy the intact munitions, and (3) decontaminate (remove agent and energetics from) the empty contaminated items.

[13]Stephen A. Cobb, ADEM, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

[14]James D. Daniel and Tim Rodeffer, "USACE Operations of Recovered Chemical Warfare Material from Burial Sites: Cleanup and Munitions Response Division," presentation to the committee on December 12, 2012.

[15]Stephen A. Cobb, ADEM, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

### Assessment of Intact Munitions

The PINS/digital radiography and computed tomography (DRCT)/MARB approach has never been used on a project involving the large number of munitions expected to be found at RSA, where tens to hundreds of thousands of items may still contain detectable quantities of agent and energetics. The current approach would be overwhelmed, and changes to it will be needed to prepare for this massive effort involving diverse agents and energetics. See Chapter 6 for findings and recommendations on this topic.

### Destruction of RCWM-Containing Energetics

Technologies are available to NSCMP for the destruction of the intact munitions. The Dynasafe SDC is suited for this purpose because of its high throughput rate and because it can produce scrap metal that is suitable for release for unrestricted use (formerly termed "5X"). The CH2M HILL TDC or the DAVINCH could also be used, but they have slower throughput rates and produce scrap metal that is not suitable for release for unrestricted use. Again, the items expected to be found at RSA are anticipated to contain a wide variety of chemical agents and chemicals, including H, HD, HT, HS, L, WP, CNS, CNB, HN-3, CG, and GA (see Finding 5-2 and Recommendation 5-1).

Some of the munitions, including any intact 500- and 1,000-lb bombs, might be too large to be destroyed in the available EDTs. However, the large item transportable access and neutralization system (LITANS) is an NSCMP-developed technology that could be used for this purpose (U.S. Army, 2011e). LITANS throughput may be too low, however, if a great many items are found.

### Processing of Nonenergetic RCWM

Between 844,000 and 855,000 items that are empty but contaminated with agent and energetics, including burned and opened munition bodies, are expected to be encountered. These items will require treatment to the ≤1 VSL (formerly 3X) level or suitable for release for unrestricted use (formerly 5X) level. Processing them through a Dynasafe SDC appears to be a good approach that produces scrap metal suitable for release for unrestricted use. Other candidate technologies include the CH2M HILL TDC, a high-temperature furnace similar to the Blue Grass (BGCAPP) metal parts treater or the Pueblo (PCAPP) metal treatment unit; a commercial transportable hazardous waste incinerator; a car bottom furnace; and treatment with decontamination solution. Any technology selected must be able to destroy the wide range of expected agents while also meeting the applicable waste management and emission requirements. A study to evaluate and rank these technologies is needed and should consider the option of containment in lieu of treatment.

Dynasafe has said that its SDC 2000 system has been used in Germany for decontaminating large quantities of agent-contaminated metal, including opened contaminated munitions.[16] Some of the munitions also contained energetics, agent-contaminated in some cases. To decontaminate these and similar materials in the SDC 1200, no changes would need to be made to the hardware; up to 330 lb of metal could be fed per cycle as long as the agent quantity does not exceed 2 lb per feed. The cycle time would be 7 min. Dynasafe expects that optimal use of the SDC 1200 at RSA or a similar site would involve mixing contaminated scrap with explosively configured recovered rounds for each feed cycle.

Finally, very large items, such as the bodies of the 500- and 1,000-lb bombs, sections of the agent production facilities, and 55-gal drums, may require decontamination. These items may be too large to be fed to existing treatment technologies. Means of treating these large items should be to investigated; such a study should consider a containment option in lieu of treatment.

The items expected to be found at RSA are anticipated to contain or be contaminated with a variety of chemical agents and chemicals, including H, HD, HT, HS, L, WP, CNS, CNB, HN-3, CG, and GA. It is not clear that the available explosive destruction technologies (EDTs) would be able to effectively treat all these chemical agents and chemicals without changes to the operating procedures or the equipment. For example, lewisite (L) contains 37 weight percent arsenic, and the air pollution control system would have to be able to remove large amounts of arsenic oxides from the detonation chamber off-gases (NRC, 2009a). Similarly, the entire chemical charge of a munition containing WP would be converted to $P_2O_5$, which means that the off-gas treatment system would need to remove and neutralize vastly larger quantities of $P_2O_5$ than when the munition contains any other chemical agent or chemical. These technologies include those used for destroying intact munitions and those used for decontaminating agent-contaminated items.

However, the NSCMP cannot be expected to spend huge amounts of money to modify a high-volume destruction or decontamination technology, such as the Dynasafe SDC, to treat small numbers of unusual items, such as munitions containing WP or L. Logically, NSCMP will make these determinations as a matter of course and already has an option—the EDS—for destroying small volumes of problematic items. Also, as discussed earlier in this chapter, it can use decontamination solution for decontaminating problematic items.

**Finding 5-1**. Many items that are expected to be found at RSA are anticipated to contain agent or to be agent-contaminated but too large to be fed to commonly used decontamination technologies.

**Finding 5-2**. The items expected to be found at RSA are anticipated to contain or be contaminated with a wide variety of chemical agents and chemicals. The technologies selected to destroy or decontaminate these items must be able to destroy the chemical agents and chemicals while producing air emissions within acceptable limits.

**Recommendation 5-1**. The Non-Stockpile Chemical Materiel Project should conduct a study of the ability of currently available or other candidate technologies to destroy or contain the wide range of unusual items, including large items or munitions containing chemical agents and chemicals such as H, HD, HT, HS, L, WP, CNS, CNB, HN-3, CG, and GA, while meeting waste management requirements and producing air emissions within acceptable limits. The technologies include those used for destroying intact munitions and those used for decontaminating agent-contaminated items.

**Finding 5-3.** The overall cleanup at RSA, which will involve conventional munitions, chemical munitions, and conventional pollutant contamination both on operational ranges and on other areas of the installation, will make it one of the largest, most complex, most long-lasting, and costliest responses ever mounted for CWM munitions in the United States.

**Recommendation 5-2.** The Army should develop organizational, operational, and funding plans for a complex, long-term, costly cleanup project at Redstone Arsenal, with the plans based on the programmatic recommendations discussed in Chapter 7.

## REGULATORY ISSUES

In addition to the 17 sites discussed above, the RSA has hundreds of old disposal locations containing chemical and conventional munitions; some locations are also contaminated with industrial chemicals, including pesticides.[17] Federal facilities with Resource Conservation and Recovery Act (RCRA) permits or those undergoing RCRA closure are subject to hazardous waste cleanup requirements under both RCRA and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). However, in accordance with a policy memo issued by EPA in 1996 to RCRA/CERCLA National Policy Managers, "in most situations, EPA RCRA and CERCLA site managers can defer cleanup activities for all or part of a site from one program to another with the expectation that no further cleanup will be required under the deferring program" (EPA, 1996c, p. 2). Hence, oversight authority can be deferred, partially or wholly, from one program to the other. Either the CERCLA federal facility agreement (FFA) can delegate authority to the

[16]Harley Heaton, Vice President-Research, UXB International, personal correspondence to Nancy Schulte, NRC study director, March 16, 2012.

[17]See Appendix D for the regulatory background.

state under RCRA, or state RCRA permit documentation can delegate authority to the EPA under CERCLA.

### CERCLA Actions at Redstone Arsenal

#### *Background*

CERCLA remedy investigation, selection, and implementation related to RSA has been ongoing since 1983, when the state of Alabama, EPA, and Olin Corporation entered into a consent decree requiring Olin to implement a DDT sediment cleanup.[18] The facility was first placed on the National Priorities List in 1994.[19]

At least 10 CERCLA remedies have been or are being implemented at RSA, including the dismantling of the lewisite manufacturing plant sites (RSA-122) and closing the arsenic waste ponds (RSA-056)[20] (Shaw, 2009).

#### *Regulatory Oversight*

At RSA an FFA has been drafted but not yet agreed upon, primarily owing to a disagreement about the role of the Alabama Department of Environmental Management (ADEM).

According to GAO, "when the Army refuses to enter into an Interagency Agreement and cleanup progress lags because of statutory and other limitations, EPA cannot take steps—such as issuing and enforcing orders—to compel CERCLA cleanup as it would for a private party" (GAO, 2010). Disputes must be resolved through interagency discussions and ultimately, if necessary, would be decided by the Office of Management and Budget.

It is EPA's goal for RSA to enter into an FFA with the Army (see Chapter 3 and Appendix D) in order to implement the remaining cleanup of the site, including the remediation of the CWM. Oversight authority may be provided by EPA or the state of Alabama, or both. It appears that the role of the state in this oversight is one of the bones of contention.[21, 22] However, no agreement is yet in place.[23] RSA is continuing cleanup of contamination including, but not limited to, CWM sites.

### RCRA Action at Redstone Arsenal

The state of Alabama issued a RCRA permit with corrective action requirements in 2010 (EPA, 2010a). The RCRA permit lists over 300 SWMUs, with 17 of these units requiring interim actions under RCRA. Most of these 17 units are located on operational ranges at RSA. They consist of munitions burial sites containing a mix of conventional and chemical munitions and probably conventional pollutants as well.

### Cleanup Decision

No action to clean up buried CWM has been taken at these units under CERCLA. While most of the buried munitions are actually remnants of exploded munition bodies and previously decontaminated chemical munitions that may still contain detectable quantities of agent, some explosively configured munitions and unexploded bursters and fuzes can be expected.[24,25]

In 2011, ADEM mandated interim action at the 17 units that would consist of the immediate removal of the buried CWM.[26] Once removed from their interment, the chemical munitions would need to be destroyed, as required by the Chemical Weapons convention (CWC). Additional site investigations are likely to be performed, and it appears that a final RCRA Facility Investigation (RFI) under RCRA has not yet been conducted at these SWMUs. Army guidance requires a risk assessment for final cleanup decisions at all locations, including on and off operational ranges to ensure that the remedy is protective (U.S. Army, 2009b; also, see Chapter 3).

The remedy selection process normally considers many factors, including, but not limited to, the following:

- Existing land use—for example, whether the material is located on an operational range;
- Potential future uses (U.S. Army, 2009b)—for example, whether the Army can control access to the

[18]Available at http://epa.gov/region4/superfund/sites/npl/alabama/triatenval.html. Accessed February 22, 2012.

[19]Available at http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0405545. Accessed February 22, 2012.

[20]Final Record of Decision RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Area Disposal Area, Operable Unit 6.

[21]SMITH/Associates, facilitators. Meeting minutes of the Alabama Tier II Restoration Partnering Team meeting, November 8 and 9, 2011. Available at http://www.altier2team.com/index.cfm/linkservid/A042ACA5-3B10-425D-BA0949A34DBF3747/showMeta/0/. Accessed February 22, 2012.

[22]Doug Maddox, EPA Federal Facilities Restoration and Reuse Office (FFRRO), conference call with Todd Kimmel and William Walsh, committee members, and Nancy Schulte, NRC study director, on November 21, 2011; Sally Dalzell, EPA Enforcement, Harold Taylor, Region 4 Federal Facilities Branch Chief, and other EPA staff, conference call with Todd Kimmell, Jim Pastorick, and William Walsh, committee members, and Nancy Schulte, NRC study director, on December 5, 2011; Stephen A. Cobb, ADEM, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

[23]Stephen A. Cobb, ADEM, presentation to the committee on November 2, 2011.

[24]Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, U.S. Army, "Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager's Perspective," presentation to the committee on November 2, 2011.

[25]Harley Heaton, Vice President-Research, UXB International, personal communication to Nancy Schulte, NRC study director, March 30, 2012.

[26]Hazardous Waste Facility Permit AL7 210 020 742, issued by ADEM to U.S. Army Garrison-Redstone, September 30, 2010. Available at http://www.epa.gov/epawaste/hazard/tsd/permit/tsd-regs/sub-x/redstone-final.pdf. Accessed April 18, 2012.

site and the potential for exposure for as long as the buried CWM remain on-site; and

- Short-term and long-term risk.

The final remedy is selected from the protective alternatives. The parties appear to be proceeding in good faith, but whether the cleanup will proceed via a CERCLA FFA or the RCRA corrective action or both regulatory authorities is unresolved as of the drafting of this report. The committee notes that these delays could increase the overall cost of whatever actions are taken at RSA.

### Maximizing Regulatory Flexibility

As discussed in Chapter 3, remediation policies provide that the amount and kind of data and the choice between interim action and remedial action are determined on a site-specific, case-by-case basis. The committee believes that, consistent with such policies, the cleanup decision should be based on the regulatory factors just described, including a scientific evaluation of the site-specific risks. What constitutes adequate data will therefore vary. Adequate data may consist of historical information, and be based on geological investigations, limited test-pitting, sampling, and experience with evaluations of the various remediation technologies. At Redstone, site-specific factors have led to the selection of remediation based on interim actions rather than on the conclusions of a feasibility study, and the Army and the state are developing work plans. Particularly at sites containing buried CWM, the committee judges that extensive, new data may not be required to select the remedies. At sites where the efficient use of data allows expeditious decisions on the remedies to be employed, available funding can be focused on risk reduction.

### Corrective Action Management Units, Temporary Units, and Area of Contamination Concept

As indicated in Chapter 3 and in Appendix D, the management of remediation waste is complex. While the present discussion is intended to provide broad suggestions on the regulatory issues that pertain to RSA, it is beyond the scope of this report to delve into the intricacies of the regulatory requirements for the wastes that may be generated there. However, the concept of establishing corrective action management units (CAMUs), temporary units (TUs), and areas of contamination, as discussed in Chapter 3 and in Appendix D, is very appealing for a site as large and complex as RSA. Assuming that acceptable locations can be identified for them, the establishment of CAMUs, TUs, and areas of contamination could be a cost-effective approach for RSA. For example, remediation waste placed in a disposal CAMU may include large amounts of contaminated and noncontaminated empty munition bodies, empty agent containers, debris such as equipment from the demolition of agent manufacturing and handling facilities, and contaminated soils and debris. The management of remediation waste in such units and areas may help mitigate the risks and costs of treating materials removed from the trenches and of dealing with residuals from that treatment.

## COMMUNITY CONCERNS

Alabama's Madison County and the town of Huntsville, which surround the RSA, are experiencing significant economic development.[27] While some of the area's recent construction activity can be attributed to RSA's status as a BRAC "gaining facility," much of the community's economic expansion began before that impact. Indeed, the area's economic growth has been identified as an important factor in ADEM's preference for a removal and cleanup remedy rather than a leave-in-place remedy.[28]

Contaminants have been identified in the vicinity of the RSA site, including solvents, metals, pesticides, CWM, and hazardous remnants from rocket fuel R&D and testing, such as perchlorate. These contaminants have impacted groundwater, soil, sediments, and surface waters in the region[29] and are of concern for both public health and economic prosperity. The proximity to the Tennessee River, which is used for drinking water and recreation, increases the importance of selecting the best remediation approach.[30]

Public engagement and education will be critical during the protracted and complex cleanup of RSA. It will be important that the Army, the state of Alabama, the federal regulatory agencies, and the community work closely together to maximize the efficiency of the cleanup program and protect the health and environment of the community.[31,32]

The committee judges that the long-term cleanup at the Spring Valley FUDS in Washington, D.C., offers an important lesson to be learned for remediation efforts at RSA. The committee received briefings on the Spring Valley FUDS; from EPA Region 3; the Army Corps of Engineers, Baltimore District; the District of Columbia Department of

[27]Huntsville Regional Economic Growth Initiative, 2007. Available at www.huntsvillealabamausa.com/HREGI/hregi_report.pdf. Accessed April16, 2012.

[28]Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, U.S. Army, "Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager's Perspective," presentation to the committee on November 2, 2011.

[29]U.S. EPA Superfund Record of Decision: U.S. Army/NASA Redstone Arsenal. EPA/ROD/R04-04/662. 09/29/2004. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r0404662.pdf. Accessed April 16, 2012.

[30]Ibid.

[31]Stephen A. Cobb, Chief, Government Hazardous Waste Branch, Land Division, ADEM, "Remediation of Buried CWM in Alabama: The State Regulator's Perspective," presentation to the committee on November 2, 2011.

[32]Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, U.S. Army, "Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager's Perspective," presentation to the committee on November 2, 2011.

the Environment; and a representative of the Spring Valley Restoration Advisory Board established to facilitate public involvement. These briefings spoke of conflict in the early days of the cleanup effort but also of the collaborative partnering that eventually emerged, with all parties having had a voice in determining cleanup objectives, processes, and procedures. While a partnering environment was established, all acknowledged that there were technical, practical, and monetary limitations and that while the path forward was not always agreed on by all parties, all parties at least understood why decisions were made the way they were. One of the most important lessons learned by all parties was the concept of partnering, education of the public, the involvement of all stakeholders, and public participation in bodies like restoration advisory boards and community outreach groups.

# 6

# The Path Forward: Recommendations for Targeted Research and Development

The organizational and technical approach taken to date by the Army in recovering, assessing, processing, transporting, storing, and destroying recovered chemical warfare materiel (RCWM) has been effective, although some problem areas have been identified by those involved in the process—for example, at Camp Sibert, in Alabama, determination of RCWM fill required a “significant amount of equipment” and was a “lengthy process,” destruction operations were “costly,” and waste management and disposal were “difficult.”[1]

For sites at which large numbers of items—in the tens to hundreds of thousands—must be processed and where the destruction of more than a few each day may be required, existing procedures and technologies may be inadequate. An example is Redstone Arsenal (RSA), where there are 17 sites requiring interim measures and source removal[2] in over 20,000 linear feet of burial trenches[3] and where up to 1 million potentially contaminated items could be found,[4] as described in Chapter 5.

Similar quantities of buried CWM may exist at Deseret Chemical Depot, in Utah, and elsewhere. Existing analytical and assessment methods and destruction technologies such as digital radiography and computed tomography (DRCT), portable isotopic neutron spectroscopy (PINS), Raman spectroscopy, the explosive destruction system (EDS), and explosive destruction technologies (EDTs) may not be able to keep up with the requirements at a large burial site if tens or hundreds of items are recovered each day.

Existing administrative procedures, organizational responsibilities, lines of reporting, and sources of funding may also not be sufficient to cope with the magnitude of this problem. One estimate of the scope of the RCWM effort at RSA alone was that initial cost projections were in the $1 billion to $3 billion range and that it was expected to take up to 15 years to complete the remediation.[5]

Similarly, existing destruction hardware may not have the capacity to destroy the required number of items. The highest throughput rates per 10-hr day reported to an earlier committee for a representative small and commonly recovered item, a 4.2-in. mortar round, were 40 per day in a TDC TC-60, 36 per day in a detonation of ammunition in a vacuum integrated chamber (DAVINCH) DV-65, and 120 per day in a Dynasafe static detonation chamber (SDC) SDC 2000 (NRC, 2006). More recently, the SDC 1200 in Anniston, Alabama, achieved a processing rate of 100 4.2-in. mortar rounds per 10-hr day.[6] Throughput, however, may not be an issue since multiple EDT or EDS units can be used if need be.

Of some significance is whether the CWM to be recovered are buried or are above ground in, for example, open trenches. If the former, they must be located, unearthed, and their content assessed, preferably while still in the ground but otherwise following placement in a container, monitoring, and storage. These items are expected to be in a more deteriorated condition than those that have been above ground in open disposal pits or trenches. Potentially agent-contaminated soil must also be assessed and disposed of.

If the CWM items are above ground, as is the case with open disposal pits, processing can proceed more rapidly

[1]Karl E. Blankenship, Formerly Used Defense Sites (FUDS) Project Manager, Mobile District U.S. Army Corps of Engineers, “Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager’s Perspective,” presentation to the committee on November 3, 2011.

[2]Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, RSA, Alabama, “Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager’s Perspective,” U.S. Army, Presentation to the committee on November 2, 2011.

[3]Steven A. Cobb, Chief, Governmental Hazardous Waste Branch, Land Division, Department of Environmental Management (ADEM), “Remediation of Buried CWM in Alabama: The State Regulator’s Perspective,” presentation to the committee on November 2, 2011.

[4]William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, “Non-Stockpile Chemical Materiel Project Redstone Arsenal (RSA) Interim Historical Report,” presentation to the committee on January 18, 2012.

[5]Ibid.

[6]Harley Heaton, Vice President-Research, UXB International, to Nancy Schulte, NRC study director, personal correspondence on March 16, 2012.

since the subsurface location, excavation, and soil treatment steps are not needed.

For sealed munitions, it is expected that DRCT (X-ray) and PINS will be used to determine the quantity of fill and the chemical content of the munition. For munitions that have been previously opened and burned or otherwise treated, as well as for potentially contaminated scrap metal, it is expected that agent monitors will be used to determine whether further treatment is required. Finally, it is expected that recovered items for which no agent is detected will be disposed of in accordance with environmental regulations.

It is not possible know in advance the processing needs for every RCWM at every site. Therefore, the committee cannot recommend site-specific treatment options. It can only identify and recommend general needs for modifications to the supporting technologies listed in the second bullet item of the statement of task. The committee hopes that these modifications will enable the supporting technologies to better meet the Army's needs at RCWM sites, based on the very limited information about the quantities and characteristics of the CWM at these sites.

Also, it may well be that modifications to existing technologies—for example, a more accurate PINS, a faster EDS, or more easily transported EDTs—may be necessary but not sufficient to meet the Army's needs, especially at the large burial sites, where hundreds of thousands of potentially contaminated items will have to be assessed and treated and where existing procedures, while effective, may prove to be too slow or cumbersome for the quantities involved. It is possible that at these sites, it will be necessary to design and construct facilities where recovered items, whether found in burial pits or in the open, can be efficiently assessed for agent content and remaining contamination and treated accordingly.

The existing approach has been effective in disposing of small quantities of RCWM, and processing rates and urgency in identification of fill have not been an issue. For example, at the Pine Bluff Explosive Destruction System (PBEDS) facility in Arkansas, between June 2006 and April 2010, two EDS units destroyed 1,225 4.2-in. mortar rounds and Second World War–era German Traktor rockets (an average processing rate of nearly 27 munitions per month). For those sites containing tens to hundreds of thousands of potentially chemically contaminated items, processing at this rate may not be sufficient. For these sites, new technology capabilities may well be required. Technology research that could lead to the development of such capabilities is described below, and technology-related findings and recommendations are provided.

## TECHNOLOGIES WITH NO TARGETED R&D RECOMMENDATIONS

**Finding 6-1.** The committee finds that the following technologies are sufficiently developed and identifies no research and development needs for them:

- Other organizations have large R&D programs under way in geophysical detection. The best policy for NSCMP is to simply track developments in these programs.
- Personal protective equipment.
- Conventional excavation equipment.
- CWM storage (interim holding facilities, igloos, bunkers).
- Vapor containment facilities and filtering techniques.
- Single Chemical agent identification set Access and Neutralization System (SCANS).
- Digital radiography and computed tomography.
- The CH2M HILL transportable detonation chamber (TDC).
- The DAVINCH.
- The explosive destruction system (EDS).
- Secondary waste storage and disposal.

## TECHNOLOGIES WITH TARGETED R&D NEEDS

### Robotic Excavation Equipment

As discussed in the section on robotic excavation equipment in Chapter 4, robotic technology has continued to grow in versatility and reliability. To reduce risk to workers, its use in the remediation of buried chemical materiel should be investigated and developed.

**Finding 6-2.** The committee believes that existing robotic systems are capable of accessing and removing buried CWM, resulting in improved safety.

**Recommendation 6-1.** The Army should demonstrate that robotic systems can be reliably utilized to access and remove buried chemical warfare materiel, and, where applicable, it should use them.

### CWM Packaging and Transportation

As described in Chapter 4, the Non-Stockpile Chemical Materiel Project (NSCMP) is developing a universal munitions storage container. It is fabricated from high-density polyethylene, and its use will allow the destruction of overpacked munitions in the EDS without removing them from the overpack.

**Finding 6-3.** Existing overpacks for the EDS may require removal and additional handling of the contained munition prior to destruction.

**Recommendation 6-2.** The Non-Stockpile Chemical Warfare Materiel Project should complete the development and testing of a universal munitions storage container.

## Assessment of Recovered Munitions

Before RCWM can be destroyed, an assessment must be carried out on each item to determine the nature of the contained agent and energetics. The noninvasive analytical method used for this purpose is PINS, which is described in Chapter 4. While PINS is an essential tool in the assessment of recovered munitions, it is not totally reliable. For example, during the destruction of 71 recovered munitions at Schofield Barracks in Hawaii in 2008, a 75-mm projectile was mistakenly identified as containing phosgene but actually contained chloropicrin (NRC, 2009a). Another example is at the Spring Valley remediation effort, where, sometime in 2002 or 2003, three munitions were incorrectly identified as containing diphenylcyanoarsine when they actually contained arsine.[7]

When destroying munitions in an EDS or by another EDT, it is important to know the TNT-equivalent net explosive weight in order to assess the type and quantity of contained energetics.[8] The U.S. Army Corps of Engineers (USACE) project manager at Spring Valley expressed his belief that some of the munitions processed as "explosively configured" at Spring Valley did not, in fact, contain explosives.[9] Processing a munition as explosively configured places additional stress on the operators.[10] The Spring Valley project manager said that PINS "was not very good" at identifying explosives in recovered munitions and that a better method was needed for this purpose—particularly for small amounts—owing to low sensitivity for nitrogen, a key element in explosive materials.[11]

After conducting the PINS analysis for fill and explosive content, the Materiel Assessment Review Board (MARB) reviews all available information for each RCWM and presents its assessment. The procedure is complicated and lengthy, and the Camp Sibert project manager said that the results "are often qualified to the extent that regulators cannot be satisfied that an item is, or is not, RCWM, thus limiting the disposal options."[12] The manager also commented that a better tool is needed to determine whether a munition is CWM or not.

The NSCMP has R&D projects under way to address some of these PINS-related issues. These R&D efforts are aimed at generating more definitive analytical results and lowering the detection limit, plus replacing the radioactive neutron source with a neutron generator to facilitate transportation of the PINS equipment.

**Finding 6-4.** Improvements are needed in the portable isotopic neutron spectroscopy (PINS) data processing to provide more definitive information for the identification of chemical fills in recovered munitions.

**Recommendation 6-3.** Research and development should continue on the processing of data from portable isotopic neutron spectroscopy to provide more definitive information for the identification of chemical fills in recovered munitions.

As explained in Chapter 4, mixed results were obtained at Camp Sibert when using the Miniature Chemical Agent Monitoring System (MINICAMS) for air monitoring in the area of a detected subsurface object as the object was being investigated and removed. It is expected that a similar experience will be encountered during other remediation efforts. The problems encountered were as follows:

- As part of the MINICAMS calibration procedure, a midday challenge was used. This procedure can delay field operations a few hours.
- The MINICAMS is a relatively fragile system, not intended to be moved around on a remediation site, resulting in a significant amount of downtime. A more rugged system is needed.
- In certain parts of Camp Sibert, the presence of trichloroethylene interfered with determination of mustard by MINICAMS.

**Finding 6-5a.** The MINICAMS is a fragile system, not sufficiently robust to be moved from site to site. This lengthens downtime.

**Finding 6-5b.** A more rugged and portable system for near-real-time air monitoring is needed to reduce downtime.

Fewer than 100 munitions have been assessed at Spring Valley and Camp Sibert. Future large remediation projects—

[7]Dan G. Noble, Project Manager, Spring Valley Baltimore District, USACE, personal correspondence to Nancy Schulte, NRC study director, February 3, 2012.

[8]Dan G. Noble, Project Manager, Spring Valley Baltimore District, USACE, "History of the American University Experiment Station," presentation to the committee on November 2, 2011.

[9]Dan G. Noble, Project Manager, Spring Valley Baltimore District, USACE, personal correspondence to Nancy Schulte, NRC study director, February 3, 2012.

[10]Karl E. Blankenship, FUDS Project Manager, Mobile District, USACE, "Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective," presentation to the committee on November 3, 2011.

[11]Dan G. Noble, Project Manager, Spring Valley Baltimore District, USACE, "History of the American University Experiment Station," presentation to the committee on November 2, 2011.

[12]Karl E. Blankenship, FUDS Project Manager, Mobile District, USACE, "Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective," presentation to the committee on November 3, 2011.

for example, RSA—might entail assessing tens or hundreds of thousands of munitions or opened munitions that might still contain small amounts of agent and energetics. As discussed above, the PINS/DRCT/MARB assessment approach has both problems and limitations. If the approach is applied to the assessment of tens or hundreds of thousands of munitions, it may be unable to generate assessment opinions in a sufficiently timely fashion, and the assessment results may not be sufficiently definitive and accurate to guarantee the safety of those who operate the treatment equipment. This issue needs to be addressed before munitions remediation is begun at RSA or at other large burial sites.

**Finding 6-6.** When dealing with tens or hundreds of thousands of munitions or opened munition bodies that contain agent and energetics, the current PINS/DRCT/MARB approach may not be able to carry out its assessments in a sufficiently timely fashion, and the results may not be sufficiently accurate to guarantee the safety of treatment equipment operators.

**Recommendation 6-4.** The Non-Stockpile Chemical Materiel Project should recommend modifications to the current PINS/DRCT/MARB assessment approach or adopt an alternative approach that will function more quickly and with more definitive and more accurate results when tens of thousands or hundreds of thousands of munitions are to be assessed at a single site.

## DESTRUCTION OF CONTAMINATED RCWM

As noted in Chapter 5, RCWM can be placed into three broad categories: agent contaminated and still containing energetic components such as fuzes and bursters; agent contaminated but not containing energetics; and agent noncontaminated and suitable for unrestricted release. In the text below, technology options and possible R&D needs are described for RCWM in the first two categories. There are no technology needs for the third category, and items in that category can be sent off-site for recycling or, if they contain a listed waste, sent to a hazardous waste treatment, storage, and disposal facility (TSDF) for management in accordance with the state's hazardous waste disposal regulations.

### Destruction of RCWM That Contains Energetics

Some of the RCWM to be destroyed will still contain energetic components. For most of these items, existing EDTs are expected to be adequate. (There are exceptions; see "Processing of Unusual Items at Redstone Arsenal" in Chapter 5.) Possible developmental needs for these technologies are described below.

#### *Explosive Destruction System*

The EDS has been very effective in destroying munitions where the processing rate has not been a key factor and where the munitions were well characterized—that is, the net explosive weight and chemical fill to be treated were known. These conditions may not prevail, however, when processing RCWM where small quantities of residual agent might exist that are not easily identified by PINS. To increase the capabilities of the EDS, the Project Manager for Non-Stockpile Chemical Materiel (PMNSCM) is carrying out a product development program with two key elements:

- *Steam injection*. Injection of steam into the EDS vessel is to be tested. Its expected advantages are twofold: (1) faster heating than is now obtained by heating with external band heaters only and (2) less liquid waste. This will reduce the 1-hr, 15-min needed to heat the rinse water from 60°C to 100°C, which originally took from 1315 until 1430 on Day 1. Steam injection is being installed and tested on the EDS-2 test fixture mentioned above. Testing with live agent was planned for 2012.
- *Universal reagent*. Research has been begun on the identification of a reagent that will be effective for all agents. Testing of 10 reagents on mustard and GD (soman) agents has begun, with results pending.

#### *Dynasafe SDC 1200*

The committee judges that the Dynasafe technology is a viable approach to processing large numbers—tens or hundreds of thousands—of burned and open chemical munition bodies that might contain residual agent or energetics. In fact, this technology may be an optimal approach, especially if a munition destruction process is also needed at a large burial site such as RSA to destroy intact munitions. A Dynasafe static detonation chamber (SDC) system could then process both types, easily shifting back and forth between intact munitions that contain energetics and previously opened munition bodies that do not. The SDC is the only one of the four technologies that produces scrap metal that is suitable for release for unrestricted use (formerly "5X").

As described in Chapter 4, many problems were encountered when the SDC 1200 was operating on chemical munitions at the Anniston Chemical Agent Disposal Facility (ANCDF), and work was begun on correcting these problems. This effort was continuing as this report was being written, with conventional munitions of necessity being employed since Anniston no longer has any chemical munitions. The continued effort has been designated as a throughput, reliability, availability, and maintainability (TRAM) study. The committee believes that this study is well planned and will increase both the throughput rate and the reliability of the process. Dynasafe, the vendor, is involved in the effort and is incorporating the design improvements developed at Anniston into future units. As also noted in Chapter 4, since the SDC for Anniston was manufactured, Dynasafe has enlarged the thermal oxidizer for its SDC 1200s.[13] This will allow better control of excess oxygen and hence more reliable combustion of CO.

**Finding 6-7.** Dynasafe has enlarged the thermal oxidizer in its standard SDC 1200 design. Installation of this larger oxidizer is expected to aid in controlling excess oxygen and hence result in more complete and consistent combustion of CO.

**Recommendation 6-5.** The Non-Stockpile Chemical Materiel Project should investigate the benefits of the larger thermal oxidizer now used in Dynasafe's standard SDC 1200. If, as expected, the larger oxidizer aids in controlling excess oxygen, leading to the more complete and consistent combustion of carbon monoxide, the project should consider replacing the current thermal oxidizer with the larger oxidizer.

The committee, however, continues to be concerned about the performance of the spray dryer used at the ANCDF. The vendor of the SDC 1200 claimed that the spray dryer would minimize the formation of dioxins (polychlorinated dibenzo-p-dioxins) and furans (polychlorinated dibenzofurans) as the hot gases exiting the thermal oxidizer were cooled in the dryer (NRC, 2010b). Dioxins and furans are highly toxic materials. Because they accumulate in the human body, they are of great concern to the public. Emissions of dioxins and furans are regulated by the state of Alabama (NRC, 2010b) and other regulatory authorities. Since the SDC system was started up, it has become clear that the spray dryer does not prevent the formation of dioxins and furans, and the activated carbon adsorbers in the off-gas treatment system must be depended on to capture the dioxins and furans formed there. Also, the solids formed in the spray dryer sometimes accumulate on its interior walls. Eliminating the spray dryer and using a heat exchanger to cool the hot gases from the detonation chamber, as is done in the CH2M HILL TDC process, might improve the reliability of the process. The existing activated carbon adsorbers would continue to capture the dioxins and furans formed as the off-gas from the thermal oxidizer is cooled. The committee notes that neither the CH2M HILL TDC nor the DAVINCH system employs a rapid quench to minimize the formation of dioxins and furans, instead relying on activated carbon adsorbers to capture the dioxins and furans that are formed. However, the larger Dynasafe system installed at Munster, Germany, does employ a venturi quench for that purpose. Elimination of the spray dryer would result in generation of a liquid waste stream, the spent scrubber solution. If this is a problem, the use of dry lime scrubbing, as done in the CH2M HILL TDC, could be considered.

**Finding 6-8.** The SDC spray dryer does not prevent the formation of dioxins and furans, and solids sometimes accumulate on the interior walls of the dryer.

**Recommendation 6-6.** The Non-Stockpile Chemical Materiel Project should evaluate the costs and benefits of improving the reliability of the Dynasafe static detonation chamber system by replacing the spray dryer with a water-cooled heat exchanger and continuing to rely on activated carbon adsorbers to capture the dioxins and furans formed as off-gas from the thermal oxidizer is cooled. If disposal of liquid waste (i.e., spent scrubber solution) becomes a problem, the Project Manager for Non-Stockpile Chemical Materiel should consider replacing the caustic scrubbers with a dry lime injection system.

**Finding 6-9.** The ongoing development program for the Dynasafe SDC 1200 system at the ANCDF is well justified and well planned. It is expected to increase the reliability of the process. The throughput rate of the process, already high, is also expected to increase.

**Recommendation 6-7.** The Non-Stockpile Chemical Materiel Project should continue its efforts to improve throughput and reliability of the Dynasafe static detonation chamber system.

### *The Kobe Steel DAVINCH and the CH2M HILL Transportable Detonation Chamber*

The DAVINCH and the TDC are similar in that they both use external donor charges to access munition bodies and destroy agent fill. Both technologies have been extensivly used to destroy chemical munitions, and both have been modified by their respective developers in light of this experience. Consequently, the committee has not identified any key R&D needs that could make these technologies more suitable for processing intact RCWM that still contains an agent fill. The primary solid waste produced by both technologies is scrap metal from munition bodies that has been decontaminated to ≤1VSL but not to a more stringent level that would allow the scrap metal to be released for unrestricted use. Additional development work on both technologies could be carried out to allow this to happen.

For the DAVINCH, the need for R&D to make it more suitable for RCWM destruction will depend on site-specific requirements. For example, if the DAVINCH is used to destroy RCWM, a reduction in the quantity of donor and shaped charges could reduce both costs and risks associated with explosives handling. For larger and heavier munitions, it takes a long time to manually load the munition into the DAVINCH vessel, and use of robotic equipment, as practiced in Japan,

[13] Harley Heaton, Vice President-Research, UXB International, personal correspondence to Nancy Schulte, NRC study director, March 16, 2012.

could reduce the loading time and any safety issues associated with manual handling of the overpacked munitions.

Both the DAVINCH and the CH2M HILL TDC system have suitable air pollution control systems and are already designed to withstand detonations of energetics. Although both technologies use donor explosives to access the munition bodies and destroy the agent fill, it may be possible to use only enough donor charges to access the munition cavities (as is the case with the EDS) and to then use an external source of hot gas to destroy the agent rather than using the donor charge to do this. This could alleviate safety concerns associated with the handling of energetics and would reduce stresses on the containment vessels associated with the detonations. An approach of this nature was once used to eliminate residual agent from the TDC (NRC, 2006).

### Processing of Nonenergetic RCWM

Some of the RCWM at large burial sites will not contain energetics such as bursters and fuzes but may still contain detectable quantities of agent. This materiel includes previously opened and drained munition bodies, scrap metal, and former production plant equipment, as is expected to be found at RSA, for example. Rather than destroying residual agent using donor charges in explosive containment vessels such as the TDC or the DAVINCH, other options exist. These include, but are not limited to, the following:

- Processing through high-temperature furnaces similar to the Blue Grass metal parts treater or the Pueblo metal treatment unit or the metal parts furnaces used at the now-closed U.S. chemical munition incineration facilities. In all cases, the systems would need to be gas tight and have appropriate air pollution control trains.
- Processing through a commercial transportable hazardous waste incinerator with a rotary kiln. These systems are gas-tight and are equipped with suitable air pollution control systems.
- Processing through a car bottom furnace. Such furnaces feature cars (carts) on which the munitions would be loaded that can be rolled on rails into and out of the furnace. A car bottom furnace used for the munition body application would need to be of gas-tight construction and have an air pollution control train for discharge of the off-gases.
- Treating with decontamination solution and then analyzing the headspace. This is repeated until the headspace concentration is below the VSL. The decontaminated waste can then be shipped off-site for recycling.[14]
- Using the Dynasafe SDC 1200 as noted above. The SDC 1200 relies on heat to destroy agent in munitions still containing an agent fill, whether explosively configured or not. It can also be used to destroy residual quantities of agent in previously opened and treated munitions and to treat contaminated scrap metal, assuming that the metal can fit into the SDC loading chambers.

**Finding 6-10.** A program to investigate technologies such as the SDC that can process burned and opened munition bodies that might still contain residual agent and energetics is justified.

**Recommendation 6-8.** NSCMP should evaluate the Dynasafe static detonation chamber for its ability to destroy recovered chemical warfare materiel, including burned and previously opened munition bodies that still contain detectable traces of agent and agent-contaminated scrap metal. This evaluation should include possible modifications to the SDC feed system, changes in the residence time in the SDC chamber, and changes to its off-gas treatment system.

**Recommendation 6-9.** If a Dynasafe static detonation chamber is not available for destroying agent in recovered open munition bodies, or is needed full time for the destruction of intact munitions, the Project Manager for Non-Stockpile Chemical Materiel should evaluate available alternatives for decontaminating non-energetic recovered chemical warfare materiel.

**Finding 6-11.** Many items that are expected to be found at Redstone Arsenal are anticipated to contain agent or to be agent-contaminated. At the same time, they will be too large to be fed to available or commonly used decontamination technologies.

**Recommendation 6-10.** The Non-Stockpile Chemical Materiel Project should begin preparations for treatment of unusually large agent-contaminated or agent-filled items at Redstone Arsenal.

Soil and sludge contaminated with agent, degradation products from agent and energetics and, as mentioned in Chapters 4 and 5, industrial chemicals, including pesticides and solvents, will be found at CWM remediation sites. In the remediation projects at Camp Sibert and Spring Valley, contaminated soil was sent to commercial TSDFs for disposal. The Camp Siebert project manager briefed the committee on one waste analysis issue, difficulties in obtaining toxicity characteristic leaching procedure analyses on soil contaminated with agent; these difficulties caused delays. TSDFs require such analyses before accepting the soil for land disposal. The Edgewood Chemical Biological Center laboratories do not perform these analyses, and commercial

[14]Raymond Cormier, Director, Mission Support, Deseret Chemical Depot, personal communication to Nancy Schulte, NRC study director, April 2, 2012.

laboratories cannot accept agent-contaminated samples.[15] The committee is passing along these comments, which impact the timing and cost of a remediation project, but without presenting any findings or recommendations.

[15]Karl E. Blankenship, FUDS Project Manager, Mobile District USACE, “Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager’s Perspective,” presentation to the committee on November 3, 2011.

# 7

# The Path Forward: Recommendations for Policy, Funding, and Organization

## INTRODUCTION

As discussed in the introduction to this report and the preceding chapters, the Department of Defense (DOD) mission for the destruction of the U.S. stockpile of lethal chemical agents and munitions and of non-stockpile chemical materiel, for both of which the Army is executive agent (EA), is becoming more complex and longer lasting than had once been envisioned as the program for the remediation of recovered buried chemical warfare materiel (RCWM) transitions into a significant large-scale program that greatly exceeds the scope of the existing smaller-scale munitions and hazardous substance cleanup programs on active and former defense sites and ranges.

The existing structure utilized by the Army, in its capacity as EA for the destruction of non-stockpile chemical materiel, must now be reconfigured to prepare for the remediation of RCWM at over 250 sites in the United States. Different organizations design and acquire the specialized chemical warfare materiel (CWM) destruction and related equipment, other organizations operate the equipment, another organization transports the equipment and personnel, and various organizations within the Army Corps of Engineers and the offices of the Secretary of the Army and of the Secretary of Defense play significant roles in setting policy, obtaining federal funding from three separate budget accounts, prioritizing sites for remediation, and participating in state decisions on selecting remedies.

Since May 2005 the Under Secretary of Defense for Acquisition, Technology and Logistics [USD(AT&L)] has been considering assigning the responsibility for the recovery and destruction of buried CWM in the United States to the Secretary of the Army and consolidating the characterization, recovery, and destruction responsibilities for buried CWM under a single organization within the Army.[1]

[1]USD(AT&L) Memorandum for Secretary of the Army, "Designation of Responsibility for Recovery and Destruction of Buried Chemical Warfare Material (CWM)," May 3, 2005.

In response to the Army's request to the National Research Council to suggest ways to improve coordination among organizations involved in conducting investigations, recoveries, and cleanup activities for non-stockpile CWM, the committee received a number of briefings and reviewed a number of planning documents related to the proposed policy planning, organization, and funding for the RCWM program. Chapter 2 traced the history of remediation of chemical warfare materiel up to July 2007. This chapter reviews evolving DOD and Army policy and their organization and programs for the recovery and destruction of buried CWM and makes recommendations that, if adopted, should lead to improvement.

## CHRONOLOGY, 2007 THROUGH THE PRESENT

### RCWM Program Implementation Plan of 2007

On September 20, 2007, the Secretary of the Army responded to the tasking in the USD(AT&L)'s May 2005 memorandum (see Chapter 2). The Secretary's report "Recovered Chemical Warfare Material (RCWM) Program Implementation Plan (Recovery and Destruction of Buried Chemical Warfare Material), July 2007" (DOD, 2007), hereinafter referred to as RCWM Plan 2007, is the only RCWM document provided to the committee that has been formally approved by the Secretary of the Army. As such, it establishes an authoritative baseline for development and implementation of the RCWM program unless it is superseded by a subsequent plan approved by the Secretary.

In his memorandum forwarding the plan, the Secretary expressed the belief that consolidating responsibilities for the program under the Army would provide for consistency in approach, avoid the duplication of programs, and make more efficient use of limited resources. The Secretary also expressed the view that "while the enclosed plan addresses preliminary implementation procedures, additional coordination will be required within DOD and among the Services to determine precise resource requirements and finalize roles and responsibilities."[2]

Although the USD's tasking was specific to the recovery and destruction of buried CWM, the Secretary of the Army's report addressed all situations involving the recovery and destruction of buried CWM, regardless of the circumstances of recovery, and expanded the scope of the plan to provide a comprehensive approach for addressing RCWM, including unexploded ordnance and other materials of interest, such as munitions that have unknown liquid fill and chemical agent identification sets (CAIS).

The plan was developed by a buried CWM integrated product team (IPT) and an overarching integrated product team (OIPT) formed by the Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health [DASA(ESOH)]) with representatives from his office, the Deputy Assistant Secretary of the Army (Elimination of Chemical Weapons) [DASA(ECW)], the Assistant Chief of Staff for Installation Management (ACSIM), the Army G-3, the U.S. Army Corps of Engineers (USACE), the Chemical Materials Agency (CMA), CMA's Non-Stockpile Chemical Materiel Project (NSCMP), and the U.S. Army's Forces Command (FORSCOM) 20th Support Command (CBRNE). It states, in part, as follows:

> During this plan's development the need for an Executive Agent (EA) for the RCWM program was made clear. Multiple agencies are currently responsible for various aspects of a response that involves or potentially involves CWM (e.g., planning, budgeting, execution). The agencies have independently developed costs for various aspects of the RCWM program. These estimates have been highly variable. . . . An integrated approach is needed to address these issues. The designation of an EA with responsibility for ensuring an integrated consistent approach to the oversight and management of all aspects of the RCWM is recommended.

The IPT made almost a dozen determinations:

a. The assignment of EA responsibility to the Army would provide the DOD with visibility for total requirements and an integrated consistent approach for addressing (1) the RCWM aspects of responses conducted at DERP-funded munitions response sites (MRS); (2) range clearance and other activities conducted on operational ranges where CWM material is known or suspected to be present, or where it is encountered; and (3) explosives or munitions emergency response where a munition with an unknown liquid fill or CWM is encountered.
b. The scope of the EA's responsibilities and the RCWM program should be broadened to make the EA responsible for the support of all circumstances that could involve RCWM including: addressing the discovery and assessment of munitions with unknown liquid fills; UXO determined to be chemical-filled munitions; CWM commingled with conventional munitions; and providing an approach for addressing CWM on operational ranges and other areas that are outside the DERP.
c. Overall, the RCWM program should be managed as part of DOD's Installations and Environment (I&E) program, not as an acquisition program. In addressing CWM recovered under a variety of situations (e.g., during munitions response on active, BRAC, and FUDS properties, during range clearance activities, and during explosives and munitions emergencies) multiple funding sources might be involved.
d. Planning and management of CWM responses should remain integrated with the Service I&E programs, not managed as a separate program.
e. RCWM should be handled as nonsurety material.
f. The roles and responsibilities for compliance with the Chemical Weapons Convention (CWC) were not expected to change should the Army be made EA for the RCWM program.
g. NSCMP's equipment and associated personnel for assessment of recovered munitions and destruction of RCWM personnel should transition from the NSCMP-managed acquisition-related program to an Army operational activity.
h. Any estimate for the RCWM program's total estimated cost should include specific funds to support:
    - NSCMP's sustainment of operational crews, staff, and equipment.
    - Research, development, test and evaluation (RDT&E) required to support the RCWM program.
    - Necessary archival research.
    - The U.S. Army Forces Command (FORSCOM) 20th Support Command (Chemical, Biological, Radiological, Nuclear and High Yield Explosives) (CBRNE)'s two chemical battalions [Technical Escort (TE)] (formerly U.S. Army Material Command's Technical Escort Unit) support of explosive and munitions emergency responses.
i. Funding and management of CWM responses should be consolidated to the extent practical. However, separate funding—a separate appropriation—should be established for those activities collectively referred to as emergency.
j. I&E programs of the respective Services should continue to prioritize, plan, and fund CWM response actions, less assessment and destruction; and should coordinate with the EA to obtain prioritization based on Defense-wide needs and to ensure that assessment and destruction requirements can be met.

[2]RCWM Plan 2007.

k. If a separate appropriation is not established, the costs associated with these functions should be absorbed by the I&E programs of the respective Services. However, due to the complexity of the requirements, the uncertainties of costs at specific installations, the high-level of public concern, and the risk to the I&E programs of the respective Services, the best approach was believed to be a separate appropriation.[3]

The OIPT recommended as follows:

a. The Secretary of Defense [should] assign the Secretary of the Army as the EA for the DOD RCWM program,
b. The Secretary of the Army [should]:

- Delegate the EA responsibilities to the Assistant Secretary of the Army for Installations and Environment [ASA(I&E)], allowing for further delegation authority as ASA(I&E) determines necessary.
- Designate the U.S. Army Corps of Engineers (USACE) as the RCWM Response Executor.

c. The EA [should] establish an RCWM Program Management Office (PMO) to manage the resources and develop policy necessary to respond to and destroy any RCWM, and guide the transition process
d. U.S. Army CMA [should] support development of a separate appropriation to fund the emergency response functions.[4]

The RCWM Plan 2007 has provided the basis for Army and Office of the Secretary of Defense (OSD) changes to the RCWM program. Approval of the Secretary's report and development and approval of a final implementation plan for the recovery and destruction of RCWM have been the subject of a continuing series of Army and OSD staff actions since the report was submitted to the Deputy Under Secretary of Defense for Installations and Environment [DUSD(I&E)] on September 20, 2007.

A step forward in this regard occurred on April 1, 2009, when DASA(ESOH) recommended the immediate implementation of a draft Army regulation that provided interim guidance for chemical warfare materiel response and related activities (U.S. Army, 2009a). The interim guidance prescribed Department of the Army procedures to be taken should CWM or munitions with an unknown liquid fill be encountered either during a planned CWM response or during another environmental response or during construction or other activities. It included procedures for the protection of human health and the environment and stressed the importance of working with environmental regulators and safety officials and of implementing a public outreach program during response activities. The draft regulation also provided information on compliance with CWC requirements. The draft regulation did not, however, contain new policy guidance or assign responsibilities for the program.

On March 1, 2010, the USD(AT&L) formally designated the Secretary of the Army as EA for the RCWM program (see Appendix C). In 2011 the Army established a provisional RCWM integrating office to integrate, coordinate, and synchronize the DOD's RCWM response program and related activities.[5]

On September 19, 2011, a draft document prepared by the Assistant Secretary of the Army for Installations, Energy and Environment ASA(IE&E) was issued as Secretary of the Army memorandum "Delegation of Executive Agent Responsibilities for DOD's Recovered Chemical Warfare Materiel Program (RCWM-P)." This draft document, if implemented, would transfer EA responsibility for the program for RCWM from ASA(ALT) to ASA(IE&E). This essentially would make the ASA(IE&E) the line manager in charge of the program. Neither a detailed program management plan nor a program organization was presented to the study committee during its review.[6]

On April 17, 2012, the ASA(I&E) sent a memorandum to the USD(AT&L) requesting that the USD either reevaluate the direction provided in its memorandum (Appendix C) relating to the source of funding for the RCWM program or finalize the directed action. The letter recommended that a separate nonacquisition program element be established under the Chemical Agent and Munitions Disposal, Defense (CAMD,D) budget account to make transparent the costs associated with the RCWM program and that OSD identify a near- and long-term funding profile for the program from DOD's Total Obligation Authority. The letter further requested that the Assistant to the Secretary of Defense for Nuclear, Chemical and Biological Defense [ASD(NCB)] programs continue to manage the CAMD,D account, including the new program element for the RCWM program, with the DUSD(I&E) providing general environmental policy oversight (U.S. Army, 2012).

**Finding 7-1.** As of April 30, 2012, neither the responsible officials within OSD—namely, the DUSD(I&E), the Office of the OSD comptroller, and the Assistant Secretary of Defense (Nuclear, Chemical, and Biological Defense) [ASD(NCB)]—nor the responsible officials in the Army had completed the task assigned to them by the USD(AT&L) memorandum of March 1, 2010.

[3]Adapted from paragraph 4, Executive Summary to RCWM Plan 2007, pp. ii-iv.

[4]Adapted from paragraph 5, Executive Summary to RCWM Plan 2007, p. iv.

[5]J.C. King, Assistant for Munitions and Chemical Matters, Office of the DASA-ESOH, "The Army RCWM Program: A Policy Perspective," presentation to the committee on September 29, 2011.

[6]Memorandum for the Assistant Secretary of the Army for Installations, Energy and Environment, draft document dated September 19, 2011, provided to the committee by J.C. King on September 27, 2011.

**Recommendation 7-1.** The Army should formally approve, then submit, a final implementation plan for the recovery and destruction of buried chemical warfare materiel as required by the Under Secretary of Defense for Acquisition, Technology and Logistics in its memorandum of March 1, 2010.

### The Army's RCWM Implementation of Plan 2010

The USD(AT&L) memorandum "Final Implementation Plan for the Recovery and Destruction of Buried Chemical Warfare Materiel, March 1, 2010" (Appendix C) designated the Secretary of the Army as the DOD EA for the destruction of non-stockpile chemical warfare munitions, agents, and by-products.

The memorandum delineated the Secretary's authorities and responsibilities as EA as including the following function among others:

> (a) maintaining DOD's inventory of locations known or suspected to contain CWM and chemical agent identifications sets (CAIS); (b) the execution of CWM response or other actions, such as range clearance activities, needed to address these sites; (c) supporting explosives or munitions emergency response that may involve recovered chemical warfare materiel (RCWM) or CAIS; (d) addressing, regardless of the circumstances under which found, RCWM and munitions and other materials that have an unknown liquid or chemical agent fill (munitions and materials of interest); (e) planning, programming and budgeting for the EA functions for the assessment of the fill of RCWM and munitions and other materials of interest, the destruction of RCWM, and those functions and equipment related to such assessment and destruction; and (f) integrating and coordinating the RCWM Program with all DOD Components. Collectively, these and related functions make up the RCWM Program.

Quoting almost directly from the RCWM Implementation Plan, 2007, and clearly reflecting the intent of that plan, the USD(AT&L) memorandum observed:

> This EA designation ensures a comprehensive approach for addressing RCWM and determining whether munitions and other materials of interest are RCWM. Under the EA determination, the Army's execution of the RCWM program will provide consistency, avoid duplication, and provide for the efficient use of those limited resources that support the assessment of liquid and chemical agent fills and the destruction of RCWM.

The memorandum directed the DUSD(I&E) and the Under Secretary of Defense (Comptroller), in coordination with the Army and the ASD(NCB), to determine an appropriate funding profile for a new RCWM account that would include the following:

- The funding source for the assessment of RCWM and munitions and other materials of interest, the destruction of RCWM, the sustainment of crews and equipment and the maintenance of related equipment will be the Chemical Agent and Munitions Destruction, Defense (CAMD,D) appropriation pending establishment of a single, focused RCWM program account. Once implemented and funded, the RCWM program account will be resourced from the DOD's Total Obligation Authority and will be separate and distinct from the CAMD,D account used for other portions of the chemical demilitarization program.
- Those functions and activities not related to the assessment of RCWM and munitions and other materials of interest and the destruction of RCWM will be funded by the DERP accounts or other appropriations normally available to fund such functions and activities.
- Once established, the RCWM program account will fund:

  a) the assessment of RCWM to determine the most likely chemical agent fill;
  b) the assessment of munitions and other materials of interest to determine whether they are RCWM;
  c) destruction of RCWM;
  d) the sustainment and maintenance of required crews and equipment; and
  e) program management and other necessary functions of the EA.

Finally, the memorandum requested that the Army, within 180 days of receipt of the memorandum, develop and submit to the USD(AT&L) timelines and milestones that are coordinated with DUSD(I&E), ASD(NCB), and the other DOD components at least for the following activities:

- Delineate program management roles and responsibilities to ensure seamless work flow and funding at the sites currently identified as being CWM response sites;
- Determine the funding required for support of the RCWM program for consideration in the planning, programming, and budgeting process for the fiscal year 2012 through 2017 Program Objective Memorandum; and
- Provide technical advice and support the planning, programming, and budgeting process for environmental response actions that may involve RCWM under the DERP.

### Army Role and Responsibilities

#### *September 19, 2011, Draft*

On September 27, 2011, at its first meeting, the committee was briefed on a draft memorandum prepared by ASA(IE&E) for approval by the Secretary of the Army.[7] This draft memo acknowledged the Secretary's designation as the DOD RCWM EA by the USD(AT&L) memorandum of March 1, 2010. The draft memo delegated the Secretary's EA responsibilities, functions, and authorities to ASA(IE&E), with further delegation authorized as the ASA(IE&E) might direct. The Secretary's memorandum also stated that the

[7] Ibid.

ASA(ALT) would remain responsible for the chemical demilitarization program except that for demilitarization and any related functions required to support the DOD's RCWM program. The ASA(IE&E) was also given responsibility for safeguarding RCWM involved in an explosives or munitions emergency or recovered during planned munitions responses or range clearance activities. The memorandum established supporting roles in the RCWM program for FORSCOM, the Army Materiel Command, and USACE, as agreed to by the ASA(IE&E).

An accompanying draft enclosure to the Secretary's memorandum[8] further delegated EA authority to DASA(ESOH), delineated its roles and responsibilities and those of supported DOD components and supporting elements of the Army Secretariat and Staff, major commands, agencies, and offices. The assigned responsibilities of DASA(ESOH) included these:

- Providing policy and guidance for the DOD RCWM program;
- Providing centralized oversight of the RCWM program;
- Ensuring cross-functional coordination among the Services' environmental program managers and the Army program managers;
- Ensuring cost-effective and efficient use of limited resources that support the RCWM program;
- Developing and compiling funding requirements for support of the program using input from the military services, environmental program managers, Army program execution managers, and the Army Materiel Command;
- Establishing a provisional RCWM Integrating Office;
- Ensuring the development and maintenance of an inventory of known or suspected CWM and CAIS sites and other locations of potential interest;
- Approving an annual work plan for the RCWM program, including CWM responses and other planned activities—for example, range clearance activities developed by the provisional RCWM Integrating Office in coordination with the military departments' environmental program managers, the Army's program execution managers, and the Army Materiel Command); and
- Providing oversight of activities of the Center for Treaty Implementation and Compliance to ensure compliance with the CWC.

### *Provisional RCWM IO*

The assigned roles, responsibilities, and guidance, including the establishment of the provisional RCWM Integrating Office (RCWM IO), conformed to the guidance outlined in the RCWM Plan 2007. The draft enclosure to the Secretary's memorandum provided general scope and responsibilities of the proposed provisional RCWM IO. The memorandum did not propose who should chair the IO.

During the course of the committee's review, CMA gave the committee the draft of a charter for the IO.[9] Under this charter, CMA is the acting chair of the provisional RCWM IO on behalf of DASA(ESOH). The RCWM IO is composed of representatives of relevant Army organizations, including AMC, CMA, ACSIM, USACE, the 20th Support Command, the Naval Facilities Engineering Command, the Air Force Center for Engineering and the Environment, and critical subdivisions of those organizations such as NSCMP, ECBC, the Chemical Biological Applications and Risk Reduction Agency (CARA), the U.S. Army Engineering and Support Center/Chemical Warfare Design Center (in Huntsville, Alabama), and the U.S. Army Technical Center for Explosives Safety.

The committee notes that the IO is, as its name implies, operating on an interim basis, awaiting formal approval by higher Army and DOD authorities. The provisional IO plays an important role in the RCWM program by coordinating planning, programming, and remediation requirements and resolving issues across DOD. The committee believes, however, that despite its important role, the provisional IO lacks the authority required to execute its mission.

**Finding 7-2.** As an advisory and coordinating office, the provisional IO has no authority to direct any of its members to comply with its decisions.

## FUNDING

### Background

As discussed in Chapter 2, Congress authorizes programs and appropriates funding for the express purpose of implementing those programs consistent with its direction. In most cases, a program's funding is directed to be expended solely for that program—that is, it must not be mixed with funding for any other program (commingled). In the case of the RCWM program, while chemical weapons munitions remediation is funded separately by CAMD,D, two other important funding programs frequently come into play during some aspects or phases of the overall effort: DERP and Operations and Maintenance (O&M).

Congressionally mandated restrictions on the use of these funding programs require the Executive Branch (primarily DOD) to carefully coordinate and account for their use. The fact that RCWM might be buried along with conventional munitions at many sites means that properly accounting for

[8] Ibid.

[9] From a draft of proposed charter for the establishment of an RCWM IO provided to the committee via e-mail from W.R. Betts III to Nancy Schulte, January 13, 2012.

the activities and funding in each case can become costly and complex. An additional complication for RCWM requirements is that the CAMD,D funding program was established primarily to destroy large quantities of stockpiled chemical weapons, and funding for RCWM remediation accounts for only a small portion of that effort. Once the stockpiled weapons have been destroyed and their demilitarization sites remediated, CAMD,D funding could be eliminated, making future funding for RCWM problematic.

The CAMD,D budget account, as discussed in Chapter 2, includes funding for two major defense acquisition programs (MDAPs): (1) Chemical Demilitarization—U.S. Army CMA and (2) Chemical Demilitarization—Assembled Chemical Weapons Alternatives (ACWA). The CMA MDAP for which the Army is EA includes funding for the Chemical Stockpile Elimination (CSE) project, the Chemical Stockpile Emergency Preparedness Project (CSEPP), and the NSCMP.

CMA has completed the destruction of the 90 percent of the U.S. stockpile for which it is responsible and is remediating the demilitarization sites themselves. As those activities are completed, the CMA's responsibilities are expected to lessen to those necessary to support stockpile storage and CSEPP at the two ACWA sites and sustainment of the NSCMP. The CAMD,D funding is anticipated to be reduced accordingly.

As the ACWA program and remediation of the ACWA demilitarization sites is completed in the 2021 to 2023 time frame, the need for funds for CAMD,D could be eliminated entirely.[10] As is the case for other budget elements, the President's budget request for the project is authorized and appropriated annually by Congress. The President's budget request includes annual budget estimates for the following 4 years, and, when available, the estimated cost to complete the project. All are subject to change. Annual funding for the program beyond 2017 has not been determined; however, the cost and time to complete the program were recently estimated to exceed the previous estimate by about $2 billion and 2 years.[11]

DERP is a very broad program encompassing funding for early site investigation and characterization through funding for remediation, including, by definition, chemical warfare agents and chemical munitions. DERP funds are commonly used for conventional munitions cleanup at RCWM sites, comprising site characterization and remediation up to the point of identifying the RCWM munitions. According to a briefing from DUSD(I&E),[12] once an RCWM is discovered, DERP funding can no longer be used, and CAMD,D funding must be used for the assessment and remediation of the RCWM. The committee notes, as described in Chapter 2, that according to Army guidance, funds appropriated for the Military Munitions Response Program (MMRP) in the Environmental Restoration, Army (ER,A) budget account can be used to conduct identification, investigation, removal, and remedial actions to address unexploded ordnance (UXO), discarded military munitions (DMM), and munitions constituents. By definition under this guidance, DMM and military munitions include chemical munitions and materiel.

The committee notes further that under Section 2703 of Title 10, U.S. Code, all funds appropriated to carry out the Secretary of Defense's function relating to environmental response are appropriated to what is essentially a transfer account, ER,A, and are subsequently transferred to an appropriate account (e.g., O&M, Military Construction) for conducting environmental responses. It seems, then, to the committee that the various budget accounts currently used by the Army or OSD for funding RCWM activities could be more flexible.

O&M funding, in the context of RCWM, is used for the O&M of active training ranges for each of the military services, including environmental restoration of the ranges. Like funding for DERP, O&M funding is not used to remediate RCWM on active training ranges. Rather, CAMD,D funding is employed.

**Finding 7-3.** The committee could not ascertain whether the current practice of prohibiting the use of DERP and O&M funding for RCWM assessment and remediation is based on a statute or on DOD policy.

The operational limitations imposed by the Army's practice of allowing only funds from the CAMD,D budget account to be used for the processing and remediation of RCWM and the inability of the OSD staff and the Army to reach agreement on the establishment of a separate budget account for RCWM remediation, as directed by the USD(AT&L) (DOD, 2010), support the committee's consensus view that the Secretary of Defense should seek a legal interpretation of the current practice of using only CAMD,D funding and prohibiting the use of DERP and O&M funding for RCWM assessment and remediation. If the legal interpretation affirms the current practice, the consensus of the committee is that the Secretary should consider seeking legislative relief from these restrictions.

**Recommendation 7-2.** The Secretary of Defense should seek a legal interpretation of the perceived prohibition on spending Defense Environmental Restoration Program (DERP) and Operations and Maintenance (O&M) funds to assess and remediate recovered chemical warfare materiel. If it is determined that only Chemical Agents and Munitions Destruction, Defense (CAMD,D) funds may be used for

[10]FY 2013 Budget Estimate, CAMD,D, OSD Comptroller, February 2012.

[11]U.S. Army Element, ACWA, press release "Department of Defense approves new cost and schedule estimates for chemical weapons destruction plants." Aberdeen Proving Ground, Md., April 17, 2012.

[12]Deborah A. Morefield, Manager, DERP, Environmental Management, Office of the DUSD(I&E), Remediation Operations from an OSD Installations and Environment Perspective, presentation to the committee on November 1, 2011.

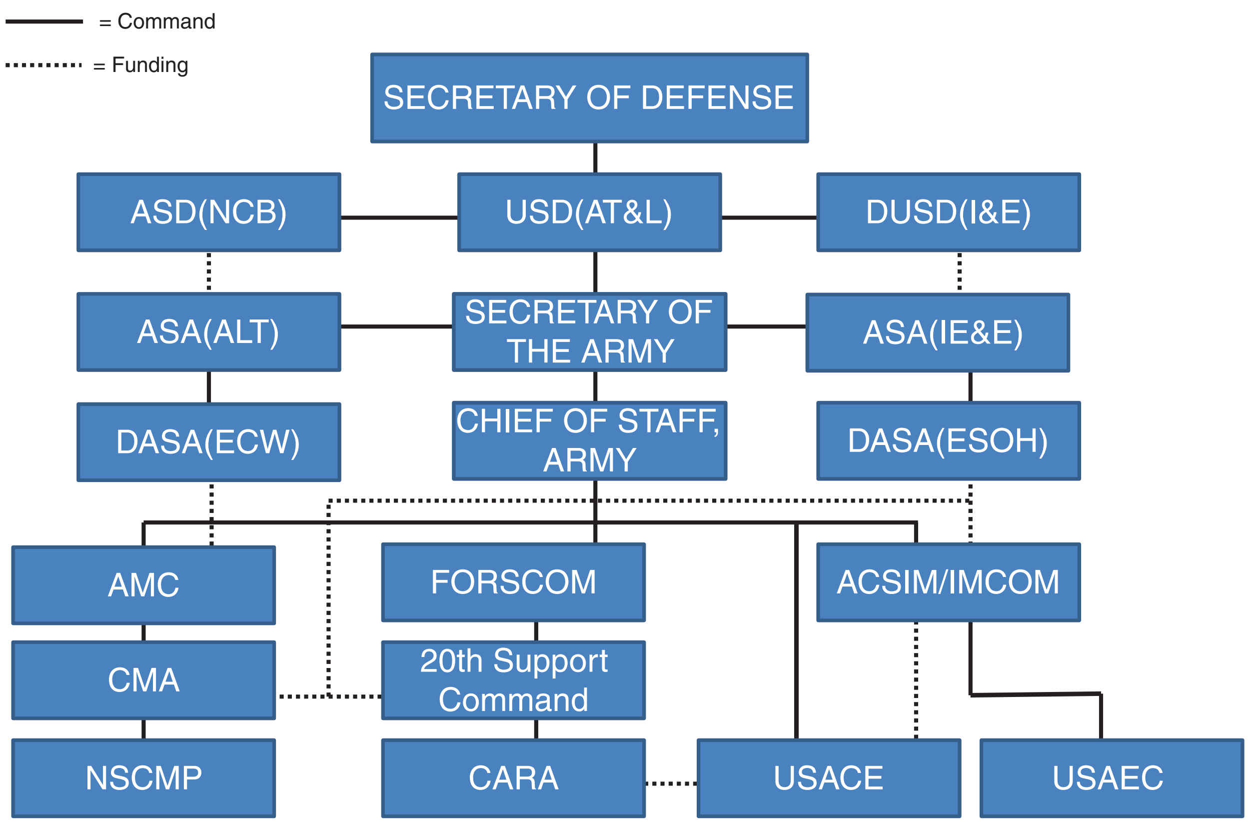



FIGURE 7-1 Current organization for policy, oversight, and funding for RCWM. USAEC, U.S. Army Environmental Command.

RCWM assessment and remediation, the Secretary should seek legislative authority to change this stricture in order to permit the commingling of DERP, O&M, and CAMD,D funding for these RCWM activities.

Depending on how and where CWM is discovered, authority and funding for RCWM activities emanate from two OSD offices and two Army Secretariat offices. The two OSD offices are ASD(NCB) for CAMD,D and DUSD(I&E) for DERP and O&M. The two Army Secretariat offices are ASA(ALT) for CAMD,D and ASA(IE&E) for DERP and O&M, as shown in Figure 7-1. Thus, there is no single advocate for the program. In addition, at present the NSCMP must compete annually for funding from the CAMD,D budget account, which is also the source of funding for the much larger chemical stockpile destruction program. Not only have estimates for completing the stockpile program been pushed out to 2021-2023, they have also increased significantly.[13] As the stockpile program nears completion, the CAMD,D account can be expected to come under increasing pressure for significant reductions, if not total elimination. The long-term funding and oversight issues inherent in a growing and enduring RCWM remediation mission need to be addressed by establishing an enduring funding stream that is integrated with other long-term environmental remediation programs.

The CAMD,D appropriation, being tied to the completion of the stockpile program, is a problematic long-term source of funding for RCWM requirements, including the stockpile's derivative NSCMP. Because the stockpile program is expected to complete its mission by 2021-2023, that portion of the CAMD,D funding that supports RCWM requirements will need to be retained and moved to other enduring funding streams.

**Finding 7-4.** Authority and funding for RCWM activities, depending on how and where CWM is discovered, emanate from two OSD offices and two Army Secretariat offices. There is no single proponent for the program. In addition, the non-stockpile chemical materiel program is a derivative of the stockpile program which is expected to complete its mission by 2020. A portion of CWM's funding and oversight will need to be retained and moved to other enduring funding programs.

**Recommendation 7-3.** The Office of the Secretary of Defense and the Army should each select a single office to champion and fund remediation of all RCWM.

[13]U.S. Army Element, ACWA, press release "Department of Defense approves new cost and schedule estimates for chemical weapons destruction plants." Aberdeen Proving Ground, Md., April 17, 2012.

As previously noted, on March 1, 2010, the USD(AT&L) approved and sent to the Secretary of the Army a memorandum designating the Secretary of the Army as the DOD EA for the destruction of non-stockpile chemical warfare munitions, agents, and by-products. The Army has not yet submitted a final implementation plan for the recovery and destruction of buried chemical warfare materiel as required by that memorandum.

### RCWM Program Funding Requirements

The committee has been provided information from various sources regarding the overall costs of completing the RCWM program. The cost estimates vary greatly. Moreover, they are often presented as ranges, with extensive caveats. For example,

- In 2003, the DOD Inspector General (DOD IG), in reviewing the increased costs for the stockpile and non-stockpile chemical materiel disposal program (D-2003-128),[14] found that the NSCMP did not have the information needed to prepare a reliable estimate of the cost and a schedule for disposing of buried CWM. The PMNSCM estimated that, in addition to the $1.6 billion in the FY2003 cost estimate for the disposal of non-stockpile CWM declared under the CWC and in order to continue research, development, and testing of non-stockpile chemical warfare disposal technologies, a further $11.7 billion would be required for disposal of the buried munitions. As noted in the DOD IG's report, according to the Acting DASA(ECW), the $11.7 billion cost estimate was based on an estimate that had not been updated since 1996 except for an adjustment reflecting the inflation indices. The DOD IG recommended that the USD(AT&L) issue directions to the environmental offices of the DOD components to identify, schedule, and fund the disposal of buried chemical warfare materiel from active installations and BRAC installations. The DOD IG also recommended that NSCMP update the plan and the cost estimate for disposal of buried munitions after the environmental offices implement the USD(AT&L) directive.[15]
- The Army RCWM Program Implementation Plan (DOD, 2007) approved by the Secretary of the Army in July 2007 projected the total cost of the RCWM program over a 30-year period as a range:
  - —Program startup (including training staff and developing appropriate cost estimate tools) was estimated at approximately $10 million for assessment and destruction, $36 million per year for emergency response functions, $5 million per year for RDT&E, and $10 million for archival research over 4 years. The total emergency response cost is $41 million per year, which reaches $43.5 million per year during the first 4 years when $2.5 million for the archival research effort is included.
  - —The low end of the cost estimate is $2.5 billion, including $765 million for investigation; cleanup, minus assessment and destruction; and site closeout, and $1.5 billion for assessment and destruction and emergency response functions.
  - —The high end of the cost estimate is $17 billion, reflecting the projected cost of complete removal of all munitions at CWM sites where there is no record of decision. This amount includes (1) $1 billion for investigation; cleanup, less assessment and destruction; and site closeout, and (2) $16 billion for assessment and destruction and other emergency response functions.
  - —The cost of remediating any additional discovered munitions.

As described earlier in this subsection, the cost of completing the RCWM is difficult to predict. A key reason for this difficulty is the lack of reliable information about the nature of the chemical munitions and materiel to be found at RCWM sites, including an estimate of the total number of munitions requiring remediation. As was just seen, some sources estimate the cost of the program at as low as $2.5 billion and others put it as high as $17 billion. The FY13 President's budget request for RCWM operations has increased to $133 million. Even if Congress approves this funding level, completing the RCWM program would take a minimum of 25 years and a maximum of 128 years (at the current annual funding level in uninflated dollars).[16] In discussing this estimate, many committee members shared the view that dragging the program out for such a long period would present an unacceptable long-term cost and risk to the nation. Uncertainty about the amount of long-term funding needed for the RCWM program will adversely impact planning and programming for the program. This situation is problematic not only at the Army level, but also at OSD.

The committee received briefings on the Army's experience at Pine Bluff Arsenal and its ongoing preparations for operations at Redstone Arsenal. The information amassed by the Army will allow it to develop a 5-year level-of-effort program on which it can base its request for RCWM fund-

[14]Office of the Inspector General, "The Chemical Demilitarization Program: Increased Costs for Stockpile and Non-Stockpile Chemical Disposal Programs." D-2003-128, September 4, 2003. Available at http://www.dodig.mil/audit/reports/fy03/03-128.pdf. Accessed June 6, 2012.

[15]Office of the Inspector General, Corps of Engineers Equipment Reporting on Financial Statements for FY 2002. D-2003-123, August 20, 2003. Available at http://www.dodig.mil/audit/reports/fy03/03-123.pdf. Accessed June 6, 2012.

[16]Committee estimate.

ing in the FY 2014-2018 Program Objective Memorandum (POM).[17]

**Finding 7-5.** The Army has a basis for developing a 5-year level-of-effort program that would in turn provide a basis for setting RCWM funding requirements in the FY 2014-2018 POM.

**Finding 7-6a.** Long-range policy for the remediation of buried munitions, including CWM, is not clearly defined, in part because the inventory of suspected buried munitions and sites is incomplete.

**Finding 7-6b.** The lack of an accurate inventory of the buried munitions and of a reliable cost estimate for the RCWM program severely limits the ability of the DUSD(I&E) and the Under Secretary of Defense, Comptroller, in consultation with the ASD(NCB) and the Army, to establish budget requirements and draw up an appropriate funding plan for a new and separate RCWM account. The consensus of the committee is that the overall RCWM program is substantially underfunded and that an inventory estimate is urgently required to provide a quantitative basis for overall program funding.

**Recommendation 7-4a.** The Secretary of Defense should, as a matter of urgency, increase funding for the remediation of chemical warfare materiel to enable the Army to complete the inventories of known and suspected buried chemical munitions no later than 2013 and develop a quantitative basis for overall funding of the program, with updates as needed to facilitate accurate budget forecasts. Pending establishment of a final RCWM management structure, this task should be assigned to the director of the CMA as chair of the provisional RCWM integrating office.

**Recommendation 7-4b.** As the RCWM executive agent, the Secretary of the Army should establish a policy that addresses all aspects of the remediation of chemical warfare materiel and that prioritizes remediation requirements, and the Secretary of Defense should identify a new long-term funding source to support the program.

The committee's recommendation to increase funding is important and necessary. Though the exact amount of the nation's liability is not presently determinable with precision, it is known that, at a minimum, the contents of these sites must be identified and that there will very likely be significant costs for treating at least portions of some sites. It is beyond the scope of the committee's task to arrive at a more refined cost estimate. As with the DOD Installation Restoration Program, the FUDS program, and the munitions remediation program, a number of inherent uncertainties, making the exact amount and timing of the expenditures not yet determinable. Unlike determining the cost of a tank or of operating a military base, determining the cost of environmental remediation projects has historically been quite difficult. In the case of buried chemical materiel, the materiel is not only buried and exact numbers of agent-filled materiel unknown, but the remediation technology is relatively new and highly specialized. Costs can vary by an order of magnitude based on the case-by-case determination of the regulators. Based on the committee's review, the ultimate costs far exceed existing funding levels. However, the committee recognizes that the ultimate rate of expenditure will be constrained by the existing budget realities facing the Army.

The USD(AT&L) memorandum stated that the source of funding for the assessment and destruction of RCWM and the sustainment of crews and related equipment would be the CAMD,D appropriation pending the establishment of an RCWM program account.

The committee notes the ASA(IE&E) memorandum (U.S. Army, 2012) requesting that the USD(AT&L) either reevaluate his direction regarding the funding source for the RCWM program or finalize the directed action. The committee believes that the actions requested by the ASA(I&E) would not relieve either the currently bifurcated budget structure [management of the RCWM budget by ASD(NCB) and of the DERP budget by DUSD(I&E)] or the multiple-headed management structure of the current RCWM program, and that it essentially maintains the status quo in the program. The committee does agree with the ASA that whatever the directed action, it needs to be finalized. That is, a separate RCWM budget account should be established and the management of the program unified.

**Recommendation 7-5**. The Deputy Under Secretary of Defense for Installations and Environment and the Under Secretary of Defense, Comptroller, in coordination with the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Programs and the Army, should proceed immediately to establish a separate budget account for recovered chemical warfare materiel, as directed by the memorandum of the Under Secretary of Defense for Acquisition, Technology and Logistics dated March 1, 2010, and to ensure that funding requirements for the recovered chemical warfare materiel program are included in the FY 2014-2018 Program Objectives Memorandum (POM).

## COMMITTEE FINDINGS AND RECOMMENDATIONS ON THE ORGANIZATION OF RCWM ACTIVITIES

Chapter 2 described in detail the key players within DOD who are involved to one degree or another with the policy, planning, programming budgeting, and execution functions of the RCWM program. Organizations at every level of DOD

[17] William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation, "The Redstone Arsenal Archival Review," briefing to the committee on January 18, 2012.

have a role to play in the program. In some cases multiple offices at a given level are involved.

At the OSD level, two main offices, ASD(NCB) and DUSD(I&E), work on RCWM policy and funding matters in coordination with the USD(Comptroller) (Figure 7-1). As was briefed to the committee and discussed earlier in this chapter, these offices have not yet completed the action to establish a separate funding account for RCWM as directed by the USD(AT&L).

Within the Department of the Army two secretariat (i.e., policy) offices—ASA(IE&E) and ASA(AL&T)—have been very involved with the RCWM program. The Army has, to its credit, assigned responsibility to one of these offices [ASA(IE&E)], which has enabled the Army to begin setting up a long-term organization to lead the program. At the Army staff level, the main player is the ACSIM office and its field operating agency, the Installation Management Command (IMCOM). The committee judges that the ACSIM and IMCOM are performing a creditable job of integrating the Army's cleanup requirements (including DERP and CAMD,D) and presenting them in a defendable POM and budget request. Some remaining duplication of effort on the part of IMCOM's AEC and of USACE merits the Army's attention.

**Finding 7-7.** The Army has assigned responsibility for the RCWM program to an appropriate secretariat level organization, the ASA(I&E). The ACSIM is developing a credible program for Army cleanup including RCWM.

**Recommendation 7-6.** The Army should examine the RCWM roles and responsibilities to determine where money can be saved by eliminating duplication of functions, such as those of the Army Environmental Command and the U.S. Army Corps of Engineers.

The Army offices executing the RCWM program are shown in Figure 7-2. The committee evaluated the strengths and weaknesses of this "baseline" RCWM organization in light of the charge in the Statement of Task. An important feature of the baseline organization is the provisional RCWM IO, which is composed of representatives from several Army organizations, as well as from appropriate offices in the Air Force (AFCEE) and the Navy (NAVFAC). A chart of the RCWM offices, including the provisional IO (in highlighted oval) is provided in Figure 7-2.

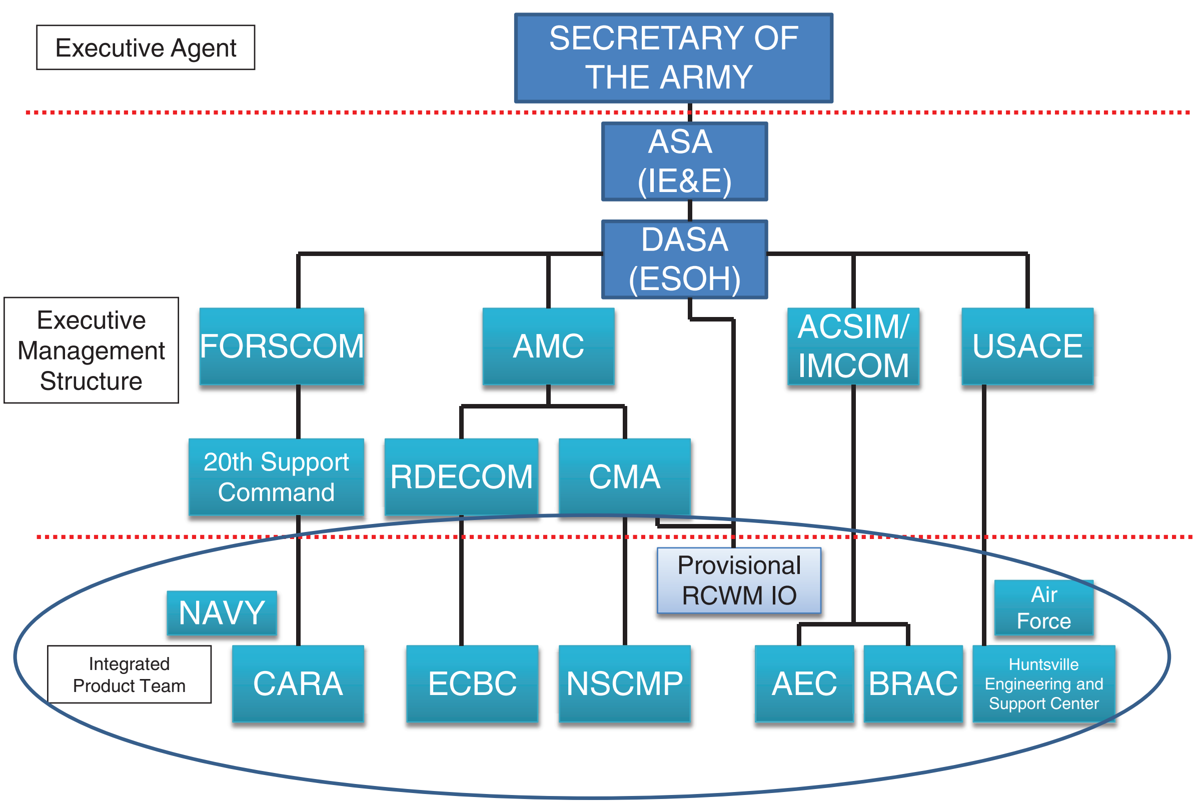



FIGURE 7-2 RCWM Army execution structure. RDECOM, Research, Development, and Engineering Command. SOURCE: Adapted from the presentation of J.C. King to the committee on September 26, 2011.

The provisional RCWM IO coordinates emergency responses and planned RCWM projects for DOD in keeping with the Army's role of RCWM executive agent. The provisional IO has met several times while it awaits formal approval by the Army and DOD. The committee considers the establishment of the provisional IO to be a step in the right direction in the overall management of the program but has some significant concerns with it conceptually:

- The provisional IO is temporarily led by a senior civilian at CMA. By being placed at this level in the hierarchy of the Army bureaucracy, subordinated to a deputy assistant secretary of the Army, the provisional IO leader is seriously handicapped when it comes to influencing decisions and practices of such a disparate group of individuals spread throughout DOD.
- The target grade of the provisional IO leader is GS-15, and as of April 12, 2012, the Army was still trying to fill this position. While the grade is senior in the federal civilian General Schedule, the person who fills it will lack the authority and status called for by the scope and visibility of the RCWM program.
- The provisional IO is a coordinating body without formal tasking or decision-making authority. Once the larger RCWM projects (see Chapter 5 on Redstone Arsenal) begin in earnest, the provisional IO may be overwhelmed by the responsibility, especially if a series of emergency response events were to coincide with planned projects.

**Finding 7-8.** The provisional RCWM IO leader lacks directive authority, is too low in the Army staff bureaucracy, and is too junior in rank to be held accountable for the execution of the RCWM program.

At the major command level, FORSCOM, AMC, and USACE share RCWM program execution roles. Two of their subordinate offices, ECBC (part of AMC) and CARA (part of FORSCOM) have specialized missions, only some of which are devoted to the RCWM program. Briefings provided to the committee indicate that these two offices have some overlapping functions that may add to the cost of the program, particularly during emergency response activities. The committee judges, however, that the overlap is not significant enough to warrant a major reorganization of either office.

**Finding 7-9.** ECBC and CARA perform important activities in support of the RCWM program. In practice, however, they operate with some redundancy in the field.

**Recommendation 7-7.** The Army should reexamine the roles and responsibilities of Edgewood Chemical Biological Center and the Chemical Biological Radiological Nuclear (Enhanced) Analysis and Remediation Activity with the objective of eliminating any overlapping functions, particularly on emergency response activities.

The CMA's NSCMP and the USACE's Huntsville Engineering and Support Center are key players for the execution of both emergency responses and planned RCWM projects. As described in Chapter 2, both PMSNCM and USACE have a long history of working separately and together on the program. NSCMP has depth in project planning and technology utilization, while USACE has hands-on technical skills in RCWM project management, construction management, and contract management.

NSCMP, which reports to CMA, has several organizational layers (see Figure 2-11). Further, it is more of an operational organization, lacking sufficient program and project management capability to manage large projects such as Redstone Arsenal. The committee is also concerned that CMA may not have a continuing role in the Army once the stockpile program winds down in the next several years, leaving NSCMP without an enduring higher authority to report to. These factors introduce significant risk and uncertainty to the RCWM program, raising the possibility that emergency responses or large planned remediation projects will not have adequate or sustainable management and funding support.

**Finding 7-10.** CMA may be disestablished or downsized in anticipation of the completion of the stockpile program.

**Recommendation 7-8.** The Army should review the long-term requirements for executing the RCWM program with the objective of making organizational changes that will eliminate duplication of effort and ensure sustainable management support.

## Organizational Alternatives

Based on the discussion, findings, and recommendations above, the committee recommends two significant changes to the baseline organization (Figure 7-2) to improve the efficiency, effectiveness, and accountability of the RCWM program and its leadership.

### *Organizational Change One*

The first change addresses the challenges facing the provisional IO and the accountability and effectiveness of his or her leadership. As concluded in Finding 7-8, the IO and its leadership lack directive authority and are placed too low in the Army organization. As discussed above, an individual at the GS-15 level will not be able to effectively lead the program. The committee concluded that the position should be upgraded and filled by a member of the Senior Executive Service (SES) or by a military general officer.

This person would have directive authority over other program participants within the Army and, through agreements with the other Services, within the appropriate RCWM activities of the Air Force and Navy. He or she and would establish, chair, and direct a new OIPT for RCWM. The new RCWM OIPT, composed of higher-level representatives of the organizations in the current provisional RCWM IO along with appropriate members from OSD, would replace the provisional RCWM IO. OIPT members should be fairly senior in their grade, and in their knowledge and experience, and their parent organizations should give them authority to make decisions. One example of a senior executive with tasking authority[18] to direct a large, expensive program of national interest, but having potential risk is the executive of the Army's highly successful chemical stockpile demilitarization program. In this case, the senior executive reported directly to ASA(RDA)—now known as ASA(ALT), the Army's acquisition executive.

The level in the Army organization to which the new SES or general officer executive reports is important because it affects that individual's ability to lead the organization. The reporting office for the new program executive needs to have the authority and breadth of mission commensurate with the responsibilities of the position.

The committee evaluated assigning the new SES/general officer program executive to one of the following: (1) Army major command (such as AMC, FORSCOM, or USACE, (2) Army staff (e.g., ACSIM), or (3) an Army secretariat office.

Alternative 1 would assign the RCWM program executive to an Army MACOM, placing the executive at an operational execution level. Organizations at this level usually lack reach outside their defined mission areas and are weak candidates for an office expected to have directive authority across the entire Army and to leverage the OSD, the Navy, and the Air Force. For this reason the committee determined that this alternative was not acceptable.

Alternative 2, an RCWM program executive reporting to an Army staff organization such as ACSIM, places the official at a higher level in the Army organization. As described in Chapter 2 and above, ACSIM has the greatest Army Staff responsibilities for the RCWM program, being the integrating office for RCWM CAMD,D funding as well as for other major funding programs such as DERP and Army-installation-related O&M. ACSIM, though, does not have significant Army staff authority over organizations such as AMC or FORSCOM, much less over related Navy or Air Force organizations. Accordingly, the committee does not believe that ACSIM, or any other Army staff organization, has the authority needed for an RCWM program executive to be accountable and effective.

Alternative 3, an RCWM program executive reporting to an Army secretariat office, provides the authority, the breadth of responsibilities, and the stature the program demands. As described in Chapter 2, the Army secretariat is a policy-level set of organizations led by political appointees. They oversee a very broad segment of Army programs and requirements. As the Secretary of the Army has directed, the appropriate Army secretariat office for leading the RCWM program is the ASA(IE&E). Because of its policy and its directive authority within the Army structure, the committee concluded that ASA(IE&E) was the appropriate reporting office for the new RCWM program executive. In addition, the visibility of the RCWM program and the risks it entails also demand that the SES or general officer assigned to lead the program should have a level of authority paralleling that of the deputy assistant secretaries within the ASA(IE&E). Accordingly, the committee determined that it would be best if the RCWM program executive reports directly to the ASA(IE&E).

**Finding 7-11.** To have the organizational reach and authority needed to lead the program effectively, the new SES or general officer RCWM program executive should report to a high level in the Army.

**Recommendation 7-9.** The Secretary of the Army should establish a new position at the level of the Senior Executive Service (civilian) or a general officer (military) to lead the RCWM program. The person who fills this position would report directly to the Assistant Secretary of the Army (Installations, Energy and Environment). The Secretary should delegate full responsibility and accountability for RCWM program performance to this person, including for programming, planning, budgeting, and execution and for day-to-day oversight, guidance, management, and direction of the program.

### *Organizational Change Two*

The second organizational change considered by the committee involved the organizations executing the RCWM program. Consistent with the discussions in the preceding section, the committee was very concerned about the current placement of NSCMP within the Army structure. The committee evaluated several alternatives for the long-term reporting relationship for NSCMP. The alternative reporting offices that the committee considered are as follows:

(1) Retain NSCMP with CMA,
(2) Assign NSCMP to the USACE Huntsville Engineering and Support Center,
(3) Assign it to ECBC,
(4) Assign it to the Army AEC,
(5) Assign it to DASA(ESOH), or
(6) Assign it to the ACWA Program Executive Office.

[18]Tasking authority is the authority of the RCWM program executive with respect to day-to-day oversight, guidance, management, and direction of the program and to budget planning and allocation, and program and budget execution and performance by the RCWM commands, agencies, and organizations.

The committee carefully selected a set of criteria to evaluate the six alternatives:

(A) Ease of implementation,
(B) Functional organization (size, budget, scalability),
(C) Efficiency,
(D) Compatibility with organization's mission,
(E) Technical expertise,
(F) Accountability through clean lines of authority,
(G) Longevity of program (durable chain of command).

In applying the above criteria, the committee concluded that alternatives 4, 5 and 6 rated poorly against criteria A-D:

- Alternative 4, assign to AEC, was eliminated because AEC's mission did not line up well with NSCMP and would not result in improved efficiency.
- Alternative 5, assign to DASA(ESOH), was eliminated because the Army Secretariat's role is predominately policy making, while that of NSCMP is operational.
- While ACWA (alternative 6) has significant technical expertise, the committee eliminated this alternative because of a congressional mandate that placed ACWA under the DOD and the CMA under the Army's chain of command. ACWA is expected to be disestablished at the completion of its program, leaving no long-term reporting office for NSCMP.

Alternatives 1, 2, and 3 were more suitable than 4, 5, and 6:

- Alternative 1, retain NSCMP with CMA, rated positively with respect to criteria A, D, and F. The committee believed, however, that the status quo would not improve efficiency or allow NSCMP to manage a large RCMA program. And, as stated in the last section, CMA is expected to be phased out as the stockpile program winds down, leaving NSCMP without a long-term higher headquarters to report to (criterion G). Undoubtedly, the staff of NSCMP has the relevant chemical technical skills (criterion E). However, other technical skills required for nonstockpile operations, such as civil engineering, soil mechanics, and explosives, must be tasked to other organizations. By definition, the NSCMP could exist for a long time, but its long-term suitability as a relatively small, highly specialized operational element without a functioning, higher-level headquarters and its dependence on other organizations is questionable. The committee concluded that this alternative is weak with respect to the overall criteria.
- Alternative 2 was realignment of the NSCMP with another key Army organization that is required to accomplish RCWM neutralization, such as USACE. In this arrangement, NSCMP could provide chemical expertise and program planning and management skills to that organization.
- Alternative 3, assignment to ECBC, was viewed positively with respect to criteria D, E, and G but was viewed negatively for criteria B (scalability), C (improved efficiency) and F (accountability). In the committee's judgment, assigning NSCMP to ECBC did not result in sets of skills and responsibilities needed to effectively execute the RCWM program.

The committee determined that alternative 2—assign NSCMP to USACE Huntsville Engineering and Support Center—would result in the best long-term fit for NSCMP. This alternative was rated negative only against criterion A (ease of implementation) but positive for criteria B, C, D, F, and G (criterion E was rated no change to negative). In the committee's judgment, this alternative would provide continuity of program execution and cost-effective synergy between NSCMP and USACE and would mean an enduring reporting organizational relationship for NSCMP.

**Finding 7-12.** The Huntsville Center of the U.S. Army Corps of Engineers would be the best long-term fit for a realigned NSCMP.

**Recommendation 7-10.** The Army should realign the nonstockpile chemical materiel program from the Army Materiel Command/Chemical Materials Agency to the U.S. Army Corps of Engineers Huntsville Engineering and Support Center.

**Recommendation 7-11.** To provide for an effective transition, the new program executive should enter into a memorandum of understanding with the Commander of the U.S. Army Corps of Engineers and the Army Materiel Command/Chemical Materials Agency outlining the reporting ladder and transition plan for the realignment of the non-stockpile chemical materiel program.

### Recommended Path Forward

The committee recommends that OSD and the Army review and implement the funding and organizational changes recommended in this chapter in a timely manner. Many of the findings listed above have been known within OSD and the Army for several years, lacking only the completion of the relevant plans, budgets, inventories, and organizational assignments.

The committee believes that the assignment of an SES civilian or general officer RCWM program executive with full authority and responsibility for planning, programming, budgeting, and executing the RCWM program, who has direct access to and visibility at the highest levels of the Department of the Army and the OSD secretariat is abso-

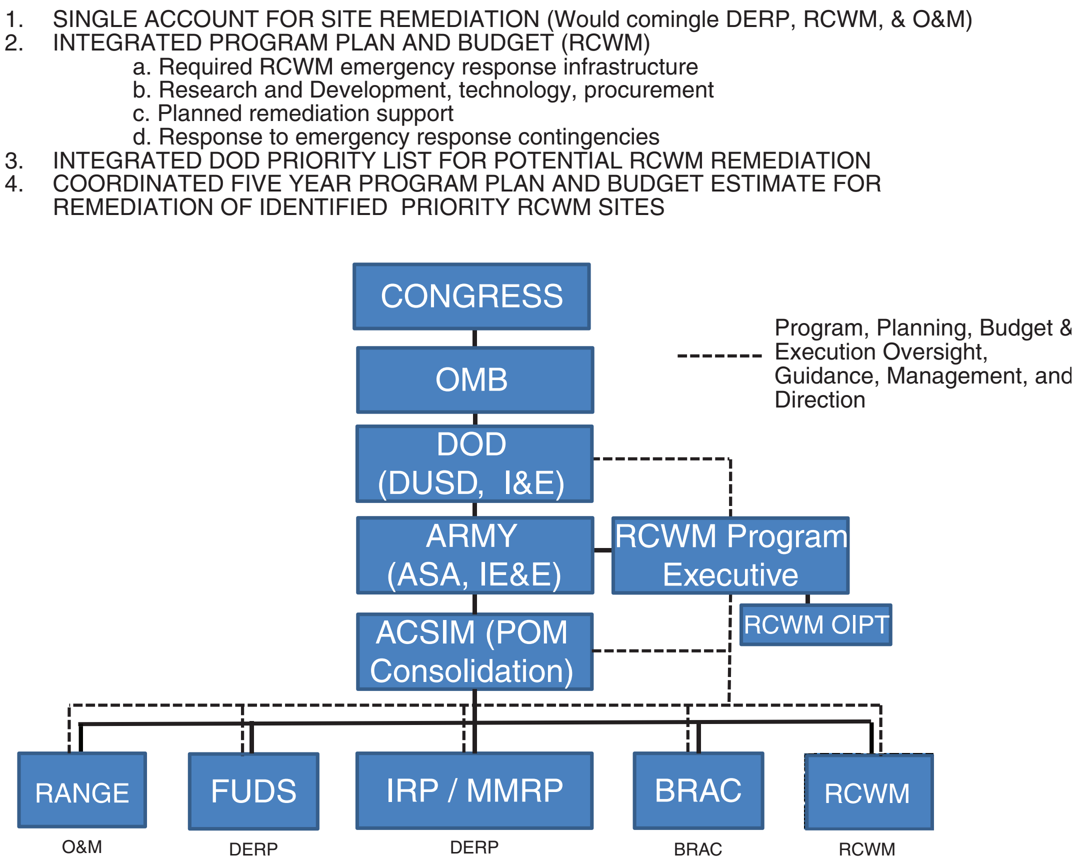



FIGURE 7-3 RCWM program future funding.

lutely critical to the future success of the program. It will be vital for the effectiveness of the program executive and the program itself that the executive possess the authority and ability to exercise oversight and management and to provide fiscal and operational guidance and direction to the operating elements of the RCWM and control the funds for RCWM both during development and defense of the program plan and budget and during the execution of the annual program.

The committee's recommendations for RCWM program and budget planning are illustrated in Figure 7-3.

Owing to the timing of the DOD POM and budget cycles, the committee urges OSD to establish a separate program account for the RCWM program and include the currently estimated funding levels in the FY2014-2018 POM. This would require the Army to program RCWM requirements and OSD to establish the accounts in the summer of 2012 (see Recommendation 7-5).

To allow OSD to formulate and defend long-term RCWM program requirements, the Army's provisional RCWM IO must complete the inventory of known and suspected buried chemical weapons as a first order of business (see Recommendation 7-4a) and submit it to OSD as soon as possible with a target at the end of FY2013. This inventory is a critical element in alerting the administration and the Congress about the extent of RCWM needs. At current funding levels, the risks attending buried chemical weapons munitions will remain for 25 to 128 years.

While the destruction of stockpile chemical weapons nears completion in the current decade, the challenges of the RCWM program continue to increase as more is learned about the magnitude of the problem. The committee is very concerned that the RCWM program lacks the authority, leadership, and accountability demanded by the size, visibility, and risk of the program. The committee recommends that the Army detail a strong SES or general officer to this program immediately in FY2012 and continue to select strong SES or general officer leaders for the positions thereafter. The Secretary of the Army should direct that this new RCWM program executive report directly to ASA(IE&E) and provide the authority needed for the program executive to discharge his or her responsibilities effectively (Recommendation 7-9).

The committee's recommended structure for Army RCWM organization and authority is shown in Figure 7-4, which incorporates the recommended Program Executive with the general-officer-level RCWM program executive reporting to the ASA(IE&E); the RCWM OIPT under the direction of the RCWM program executive; the tasking

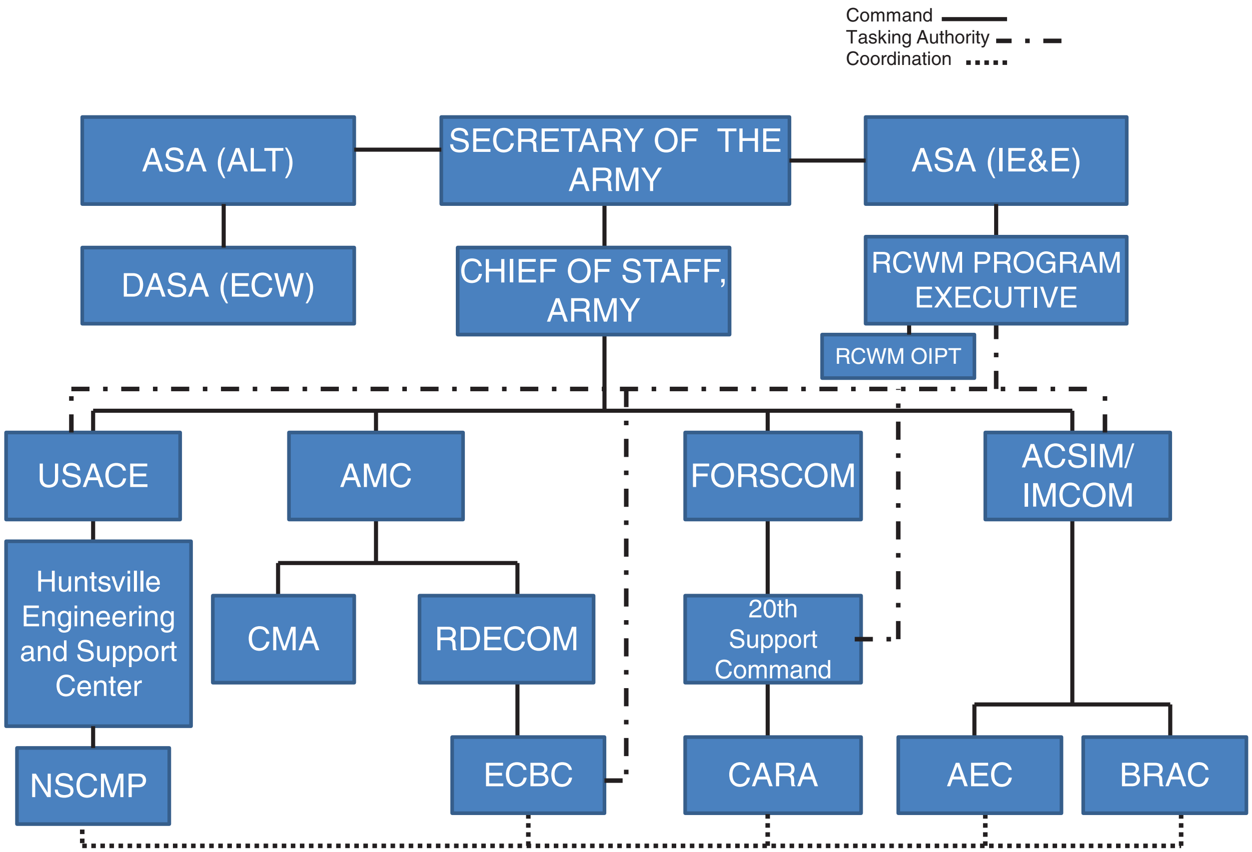



FIGURE 7-4 Army RCWM organization and authority recommended by committee. NOTE: Tasking authority is the authority of the RCWM Program Executive with respect to day-to-day oversight, guidance, management, and direction of Army elements on all RCWM matters, including program and budget planning and allocation, and program and budget execution and performance by the RCWM commands, agencies, and organizations.

authority of the RCWM program executive; and the realignment of NSCMP under the USACE Huntsville Engineering and Support Center. The figure also delineates the lines of command, tasking authority, and coordination among the various elements of the program.

Once assigned, the RCWM program executive should, at a minimum, undertake the following:

- Form and chair a new RCWM OIPT composed of decision makers from key organizations involved in the policy, programming, and execution of the RCWM program. The new RCWM OIPT, composed of higher level representatives of the organizations in the current provisional RCWM IO along with appropriate members from OSD, would replace the provisional RCWM IO. OIPT members should be fairly senior in grade, knowledge and experience, and should be given the authority to make decisions by their parent organizations.
- Develop an integrated DOD priority list of potential RCWM remediation sites for approval by the Secretary of the Army.
- Develop and execute a coordinated 5-yr program plan and budget estimate for remediation of the identified priority RCWM sites.
- Review requirements for RCWM emergency response functions and establish a program plan and budget to support the required capabilities.
  —Required RCWM emergency response infrastructure
  —Research and development, technology, procurement
  —Known remediation support
  —Response to emergency response contingencies
- Develop and defend in the FY2014-2018 POM/budget execution submission a budget program and plan for RCWM remediation that will, assuming approval and funding by Congress, support execution of the approved RCWM plan and support maintenance of an RCWM emergency response infrastructure.

As the new RCWM program executive position and the recommended supporting OIPT are constituted, the committee recommends that the Army begin transitioning the alignment of PMNSCM from AMC/CMA to the USACE Huntsville Center.

**Recommendation 7-12.** As a necessary first step, the Deputy Under Secretary of Defense for Installations and Environment, the Under Secretary of Defense Comptroller, the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Programs, and the Secretary of the Army should proceed immediately to implement the guidelines contained in the March 1, 2010, memorandum from the Under Secretary of Defense for Acquisition, Technology and Logistics.

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# Appendix A

## Biographical Sketches of Committee Members

**Richard J. Ayen** *(Chair)*, now retired, was director of technology for Waste Management, Inc. Dr. Ayen managed all aspects of Waste Management's Clemson Technical Center, including treatability studies and technology demonstrations for the treatment of hazardous and radioactive waste. His experience includes 20 years at Stauffer Chemical Company, where he was manager of the Process Development Department at Stauffer's Eastern Research Center. He received his Ph.D. in chemical engineering from the University of Illinois. Dr. Ayen has published extensively in his fields of interest. Dr. Ayen was a member of the National Research Council Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (I and II) and several committees dedicated to non-stockpile initiatives. Dr. Ayen currently also chairs the Committee on Chemical Demilitarization.

**Douglas M. Medville** *(Vice Chair)* retired from MITRE as program leader for chemical materiel disposal and remediation. He has led many analyses of risk, process engineering, transportation, and alternative disposal technologies and has briefed the public and senior military officials on the results. Mr. Medville was responsible for evaluating the reliability and performance of the demilitarization machines used by the Army to disassemble stockpile chemical munitions and wrote several test plans and protocols for alternative chemical munitions disposal technologies. He also led the evaluation of the operational performance of the Army's chemical weapons disposal facility on Johnson Atoll and directed an assessment of the risks, public perceptions, environmental aspects, and logistics of transporting recovered non-stockpile chemical warfare materiel to candidate storage and disposal destinations. Before that, he worked at Franklin Institute Research Laboratories and General Electric. In recent years, he has participated as a committee member in nine National Research Council studies concerning the Army's non-stockpile and Assembled Chemical Weapons Alternatives programs. Mr. Medville earned a B.S. in industrial engineering and an M.S. in operations research from New York University.

**Dwight A. Beranek** is a retired senior vice president of Michael Baker Jr., Inc., a professional engineering and consulting service for public-sector and private-sector clients worldwide. Previously, he served as deputy director for military programs in the U.S. Army Corps of Engineers, where he was responsible for executive management of its worldwide military programs mission. He is a registered professional engineer and a certified floodplain manager. He served on the National Research Council Committee on Bureau of Reclamation Dam Security and on the Federal Highway Administration–American Association of State Highway and Transportation Officials Blue Ribbon Panel on Bridge and Tunnel Security. Mr. Beranek received his B.S. in mechanical engineering from Northwestern University, an M.S in business administration from Boston University, and an M.P.A. from American University.

**Edward L. Cussler (NAE)** is the Distinguished Institute Professor and professor of chemical engineering at the University of Minnesota. After 13 years of teaching at Carnegie-Mellon University, he joined the University of Minnesota in 1980. Dr. Cussler conducts research on thin films, centering on membranes, with applications in water purification, and corrosion control; and on small-scale energy, with a goal of making individual farms energy self-sufficient. He has written over 220 articles and five books, including *Diffusion: Mass Transfer in Fluid Systems*; *Bioseparations*; and *Chemical Product Design*. He holds a Ph.D. and an M.S. from the University of Wisconsin–Madison and a B.E. from Yale University, all in chemical engineering. Dr. Cussler has received the Colburn and Lewis Awards from the American Institute of Chemical Engineers, which he served as director, vice president, and president. He received the Separations Science Award from the American Chemical Society, the Merryfield Design Award from the American Society of Engineering

Education, and honorary doctorates from the University of Lund and the University of Nancy. He is a Fellow of the American Association for the Advancement of Science and a member of the National Academy of Engineering.

**Gilbert F. Decker**, retired executive vice president of Walt Disney Imagineering, served as assistant secretary of the Army for research, development, and acquisition from 1994 to 1997. When he was assistant secretary of the Army, two of his main responsibilities were research and development for the chemical demilitarization program. Mr. Decker received his B.S. in electrical engineering from Johns Hopkins University in 1958 and served as an armor lieutenant and army aviator until 1964. His active-duty assignments included helicopter pilot, battalion supply officer and company commander in Korea, and test, evaluation, and control officer for the 11th Air Assault Division. He received an M.S. in operations research from Stanford University in 1966. From 1966 to 1994, Mr. Decker worked as a systems and design engineer, engineering project manager, director of marketing, president, or chief executive officer for several companies engaged in electronics systems for defense applications; advanced computing, communications, and information systems; and high-temperature materials and control systems for the aerospace and pollution-control industries. The companies included ESL, Inc; TRW, Inc; Penn Central Federal Systems Company; and Acurex Corporation.

**Clair F. Gill** received a B.S. from the U.S. Military Academy and an M.S. in geotechnical engineering from the University of California, Berkeley. He retired as the chief of staff and deputy director of the Office of Facilities Engineering and Operations of the Smithsonian Institution. In that capacity, he oversaw all facilities maintenance, operations, security, capital construction, and revitalization of the institution's museums and research facilities in Washington, D.C., and at several other locations in the United States and abroad. Immediately before that, he served with the Department of Energy, where he established and led the Office of Engineering and Construction Management. Mr. Gill retired from the U.S. Army in 1999, when he last served as the Army's budget director. Throughout his military career, Mr. Gill was involved directly in various major construction projects, including military school facilities, a hotel complex, two flood-control systems, and reconstruction of a medical center. He was involved in the operational concept, the environmental-impact statement, and the design and startup of construction of nearly one-fourth of a billion dollars of facilities to enable the Army to consolidate three branch schools at Fort Leonard Wood, Missouri.

**Derek Guest** is an independent consultant, providing support to small businesses and community organizations in addressing environmental, public-health, and sustainability issues. He retired from Eastman Kodak Company after working for more than 20 years in health, safety, environment, and sustainability. His most recent position was director of science and technology policy; he was responsible for identifying and addressing emerging environmental regulations and performance standards worldwide to support the company's manufacturing operations and businesses. He received his Ph.D. in biochemical toxicology in the United Kingdom before moving to the United States to complete postdoctoral training in toxicology at the Chemical Industry Institute of Toxicology. He recently served on the Centers for Disease Control and Prevention–Agency for Toxic Substances and Disease Registry National Conversation on Public Health and Chemical Exposures (the Serving Communities Work Group) and is on the Board of Directors of the Rochester-based Center for Environmental Information, which works to address regional environmental issues, such as watershed protection and community health. Dr. Guest is a full member of the Society of Toxicology.

**Todd A. Kimmell** is principal investigator in the Environmental Science Division of the U.S. Department of Energy's Argonne National Laboratory. He is an environmental scientist and policy analyst with more than 30 years of experience in solid-waste and hazardous-waste management, permitting and regulatory compliance, cleanup programs, environmental programs policy development, and emergency management and homeland security. He has supported the Army's chemical and conventional munitions management programs and has contributed to the Army's Assembled Chemical Weapons Assessment Program and Chemical Stockpile Emergency Preparedness Program. Mr. Kimmell also has a strong technical background in analytical and physical–chemical test method development and analytical quality assurance and control. He has served the U.S. Environmental Protection Agency's National Homeland Security Research Center on environmental test methods for chemical, biological, and radiological assessment for emergency response. Mr. Kimmell has also supported a number of environmental permitting programs at Army chemical weapons storage sites and at open burning–open detonation sites. He graduated from George Washington University with an M.S. in environmental science.

**JoAnn Slama Lighty** is professor in and chair of the Department of Chemical Engineering and adjunct professor of civil and environmental engineering at the University of Utah. She received her B.S. and Ph.D. in chemical engineering from the University of Utah. She is currently involved in research on the formation of fine particulate matter from combustion and gasification systems, including soot formation and oxidation, and chemical looping technologies for effective carbon capture. Dr. Lighty is active in the American Institute of Chemical Engineers, of which she was recently selected as a fellow, and the Combustion Institute. She is the author of over 50 peer-reviewed publications and has given over 125 conference presentations. In 2004, she was honored with the Society of Women Engineers Distinguished Engineering Educator Award. Dr. Lighty has served previously on the National Research Council Committee on Technologies for Cleanup of Mixed Wastes in the DOE Weapons Complex.

**James P. Pastorick** is president of UXO Pro, Inc., a technical consulting firm in Alexandria, Virginia, that specializes in providing technical support to state regulators in munitions and explosives of concern (MEC) project planning, management, and quality control, including chemical warfare material MEC. Since retiring from the U.S. Navy as a diving officer and explosive ordnance disposal technician, he has worked for over 20 years in managing MEC investigation and removal projects. He is certified by the American Society for Quality as a manager of quality and organizational excellence (CMQ/OE). Mr. Pastorick has served on several National Research Council committees: the Committee to Review Assembled Chemical Weapons Alternatives Program Detonation Devices, the Committee on Review and Evaluation of International Technologies for the Destruction of Non-Stockpile Chemical Materiel, the Committee on Review and Assessment of the Army Non-Stockpile Chemical Demilitarization Program: Pine Bluff, the Committee for Review and Assessment of the Army Non-Stockpile Chemical Demilitarization Program: Workplace Monitoring, and the Committee for the Review and Evaluation of the Army Non-Stockpile Chemical Materiel Disposal Program.

**Jean D. Reed** is a consultant and Distinguished Research Fellow of the National Defense University's Center for Technology and National Security Policy, where he focuses on chemical–biological defense and the integration of research and development and national security policy. He is also a senior fellow of the Potomac Institute for Policy Studies. He received a B.S. and an M.S. in physics from the University of Oklahoma and a master's of military art and science from the U.S. Army Command and General Staff College. He did postgraduate studies in physics at Georgtown University. He is a graduate of the Army War College and the National War College and was a chief of staff Army fellow at the Army's Strategic Studies Institute. Appointed to the Senior Executive Service in December 2005, Mr. Reed served as deputy assistant to the secretary of defense (DATSD; Chemical Biological Defense–Chemical Demilitarization) in the Office of the Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Matters until April 2010. He exercised overall oversight, coordination, and integration of all aspects of the Department of Defense chemical and biological medical and nonmedical defense program, which totaled about $1.5 billion a year, and of the program for destruction of the U.S. stockpile of lethal chemical agents and munitions, which also totaled about $1.5 billion a year. Before assuming his position as DATSD, Mr. Reed served for 15 years as a professional staff member of the Committee on the Armed Services in the U.S. House of Representatives, where he had principal staff responsiblility for oversight of the Department of the Navy research and development program, defensewide science and technology, and selected programs of other military services and defense agencies, including the Defense Advanced Research Projects Agency; the Defense Threat Reduction Agency; joint experimentation, test, and evaluation; and chemical demilitarization and chemical–biological defense.

**William R. Rhyne** is a retired risk and safety analysis consultant to the nuclear, chemical, and transportation industries, He has over 30 years of experience associated with nuclear and chemical processing facilities and with the transportation of hazardous materials. From 1984 to 1987, he was the project manager and principal investigator for a probabilistic analysis of transporting obsolete chemical munitions. From 1997 to 2002, he was a member of the National Research Council Committees for the Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons I and II. More recently, he has served on committees examining chemical stockpile secondary waste issues. Dr. Rhyne is the author or a coauthor of numerous publications on nuclear and chemical safety and risk analysis and is the author of *Hazardous Materials Transportation Risk Analysis: Quantitative Approaches for Truck and Train.* He received a B.S. in nuclear engineering from the University of Tennessee and an M.S. and a D.Sc. in nuclear engineering from the University of Virginia.

**Tiffany N. Thomas** is an environmental consultant for Tetra Tech, Inc. She has extensive experience in designing and executing novel scientific research in atmospheric chemistry, environmental geochemistry, and materials science–crystal growth chemistry. She has multiple publications in peer-reviewed scientific journals and presentations at various international academic conferences. For the last 5 years, she has worked for Tetra Tech on various projects, including multiple Department of Defense (DOD) sites contaminated by chemical materiel and explosives, geochemical modeling of metals releases from mining sites, and optimization of chlorinated-solvent treatment. She received her Ph.D. in inorganic chemistry from the University of California, Davis and her B.S. in environmental chemistry from Northern Arizona University. Dr. Thomas has worked with Lawrence Livermore National Laboratory, Savannah River National Laboratory, the Department of Energy, DOD, and multiple state and local agencies.

**William J. Walsh** is an attorney in the Washington, D.C., office of Pepper Hamilton LLP. Before joining Pepper Hamilton, he was section chief in the Environmental Protection Agency Office of Enforcement. His legal experience includes environmental regulatory advice and advocacy and defense of environmental-injury litigation involving a broad spectrum of issues pursuant to a variety of environmental statutes, including the Resource Conservation and Recovery Act and the Toxic Substances Control Act. Mr. Walsh holds a J.D. from George Washington University Law School and a B.S. in physics from Manhattan College. He represents trade associations, including the Rubber Manufacturers Association and the American Dental Association, in rule-making and other public-policy advocacy. He has negotiated protective yet cost-effective remedies in pollution cases involving water, air, and hazardous waste and has advised technology developers and users on taking advantage of incentives for, and eliminating regulatory barriers to, the use of innovative environmental technologies. Mr. Walsh has also served on several National Research Council committees: the Committee on Review and Evaluation of International Technologies for the Destruction of Non-Stockpile Chemical Materiel, the Committee on Review and Assessment of the Army Non-Stockpile Chemical Demilitarization Program: Pine Bluff, the Committee for Review and Assessment of the Army Non-Stockpile Chemical Demilitarization Program: Workplace Monitoring, the Committee for the Review and Evaluation of the Army Non-Stockpile Chemical Materiel Disposal Program, and the Committee on Ground Water Cleanup Alternatives.

**Lawrence J. Washington**, recently retired after working for the Dow Chemical Company for over 37 years, where he was corporate vice president for sustainability and environmental health and safety (EH&S). Among his many distinctions, Mr. Washington chaired the Corporate Environmental Advisory Council, the EH&S Management Board, and the Crisis Management Team. In his role as corporate vice president for EH&S, Human Resources, and Public Affairs, Mr. Washington led the creation of the Genesis Award Program for Excellence in People Development. His career included many roles in operations, including being leader of Dow's Western Division and general manager and site leader of Michigan Operations. Mr. Washington earned bachelor's and master's degrees in chemical engineering from the University of Detroit.

# Appendix B

# Committee Meetings and Data-Gathering Activities

## FIRST COMMITTEE MEETING, SEPTEMBER 27-29, 2011, EDGEWOOD, MARYLAND

*Objective*: To introduce National Research Council (administrative actions, including committee introductions and composition, balance, and bias discussions for committee members); to review committee statement of task with sponsor; to receive detailed process and equipment briefing presentations; to review preliminary report outline and report-writing process; to confirm committee writing assignments; and to discuss future meeting dates and next steps.

### Briefings and Discussions

*Discussion with sponsor on scope of statement of task*: Don Barclay, Deputy Director, Chemical Materials Agency; and Laurence G. Gottschalk, Project Manager for Non-Stockpile Chemical Materiel.

*The Army RCWM Program: A Policy Perspective*: J.C. King, Assistant for Munitions and Chemical Matters, Office of the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health (DASA-ESOH).

*U.S. Army Corps of Engineers' Roles, Responsibilities and Capabilities Related to Buried/Recovered CWM*: Chuck Twing, Chief, Chemical Warfare Design Center, U.S. Army Corps of Engineers-Huntsville.

*Non-Stockpile Chemical Materiel Project Program Status and Update*: Laurence G. Gottschalk, Project Manager for Non-Stockpile Chemical Materiel.

*CBRNE Analytical and Remediation Activity Missions*: LTC Charles A. Asowata, Acting Director, and Dalys Talley, Chief of Operations, Chemical Biological Radiological Nuclear (enhanced) Analysis and Remediation Activity (CARA).

*Edgewood Chemical and Biological Center's Roles, Responsibilities and Capabilities in Monitoring and Handling CWM:* Timothy A. Blades, Deputy Director, Directorate of Program Integration, Edgewood Chemical and Biological Center.

*Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview*: David Hoffman, Operations Chief, Non-Stockpile Chemical Materiel Project.

*Site Visit Assessment Equipment/MMAS, PINS, DRCT Scanner and Raman Spectrometer, CAIS and SCANS, EDS Phase I and Phase II, Multiple and Single Round Containers for On- and Offsite Transportation of Munitions*: David Hoffman, Chief, Operations Team, Non-Stockpile Chemical Materiel Project.

*Lessons Learned Program*: Darryl Palmer, Project Engineer, Non-Stockpile Chemical Materiel Project.

*Dynasafe Static Detonation Chamber*: Tim Garrett, Site Project Manager, and Charles Wood, ANCDF Deputy Operations Manager, Anniston Chemical Agent Disposal Facility, Anniston, Alabama (via VTC).

## SECOND COMMITTEE MEETING, NOVEMBER 1-3, 2011, WASHINGTON, D.C.

*Objective*: To receive briefings on Army and DOD policy with regard to RCWM operations; to conduct a site visit to Spring Valley; to receive a briefing on the status installation and plans for systemization of the DAVINCH at TOCDF; to receive a briefing on the conduct of RCWM operations at Redstone Arsenal and Camp Siebert, Alabama; to review preliminary report outline; to confirm committee writing assignments; and to discuss information-gathering requests and next steps.

### Briefings and Discussions

*Remediation Operations from an Army Perspective*: Carmen J. Spencer, Deputy Assistant Secretary for Elimination of Chemical Weapons, U.S. Army.

*Remediation Operations from an OSD Installations and Environment Perspective*: Deborah A. Morefield, Manager, Defense Environmental Restoration Program, Environmental Management, Office of the Deputy Undersecretary for Installations and Environment, Department of Defense.

*Chemical Weapons Convention Treaty Requirements and Policies*: Lynn M. Hoggins, Director, Chemical and Biological Weapons Treaty Management, Office of the Assistant Secretary of Defense for Nuclear, Chemical and Biological Defense Programs/Treaties and Threat Reduction, Department of Defense.

*Project Management of Spring Valley: A Corps of Engineers Perspective*: Dan G. Noble, Project Manager, Spring Valley Baltimore District, U.S. Army Corps of Engineers.

*Protecting the Public: An EPA Perspective*: Steven Hirsh, Remedial Project Manager, Region 3, Environmental Protection Agency.

*Spring Valley: The Regulatory Agency Perspective*: James Sweeney, Chief, Land Remediation and Development Branch, Department of the Environment, District of Columbia.

*Involvement of the Spring Valley Community*: Greg Beumel, Co-Chair, Spring Valley Community Restoration Advisory Board.

*History of the American University Experiment Station*: Dan G. Noble, Project Manager, Spring Valley Baltimore District, U.S. Army Corps of Engineers.

*Site Visit*: Low-probability digging for metallic anomalies, controlled detonation system for conventional items, and interim holding facility.

*Perspectives on Public Involvement*: Henry J. Hatch, former U.S. Army Chief of Engineers, U.S. Army [Retired].

*Remediation of Buried CWM in Alabama: The State Regulator's Perspective:* Steven A. Cobb, Chief, Governmental Hazardous Waste Branch, Land Division, Department of Environmental Management (ADEM).

*Remediation of Buried CWM at Redstone Arsenal, Alabama: The Installation Manager's Perspective*: Terry de la Paz, Chief, Installation Restoration Branch, Environmental Management Division, Redstone Arsenal, Alabama, U.S. Army.

*Installation and Systemization of the DAVINCH Unit at TOCDF (video conference)*: Thaddeus A. Ryba, Jr., TOCDF Site Project Manager.

*Remediation of Contaminated Soil at Camp Sibert, Alabama: The Installation Manager's Perspective (video conference):* Karl E. Blankenship, FUDS Project Manager, Mobile District, U.S. Army Corps of Engineers.

## THIRD COMMITTEE MEETING, DECEMBER 12-14, 2011, WASHINGTON, D.C.

*Objective*: To receive briefings from the Army Environmental Command and the Army Corps of Engineers on the conduct of RCWM operations at Deseret Chemical Depot Utah and on three destruction systems; to review and advance preliminary first full message draft; to confirm committee writing assignments; and to discuss information-gathering requests and next steps.

### Briefings and Discussions

*Roles and Responsibilities of the Army Environmental Command in the Army's Cleanup Program* (*video conference*): James D. Daniel, Chief, Cleanup & Munitions Response Division, Army Environmental Command; and Timothy L. Rodeffer, Oversight East Army Environmental Command.

*USACE Operations of Recovered Chemical Warfare Material from Burial Sites*: James D. Daniel and Tim Rodeffer, Cleanup and Munitions Response Division.

*USACE Effective Engagement with Stakeholders*: Hal E. Cardwell, Director, USACE Conflict Resolution & Public Participation Center of Expertise.

*USACE Military Munitions Support Services for Chemical Warfare Materiel*: Christopher L. Evans, Special Assistant for Military Munitions Support Services Headquarters, U.S. Army Corps of Engineers.

*Dynasafe Static Detonation Chamber*: Harley Heaton, Vice-President-Research, UXB International.

*Controlled Detonation Chamber*: Brint Bixler, Vice President, CH2M HILL.

*DAVINCH*: Joseph K. Asahina, Chief of Technology Nuclear and CWD Division, Kobe Steel, Ltd.

*Remediation of Buried CWM at Deseret Chemical Depot, Utah: The Installation Manager's Perspective (video conference)*: Troy Johnson, Environmental Manager; Raymond Cormier, Director, Mission Support; and Mark B. Pomeroy, Commander Deseret Chemical Depot, Utah.

*Remediation of Buried CWM in Utah: The State Regulator's Perspective (video conference)*: Brad Maulding, Program Manager; David Larsen, Project Manager; and John Waldrip, Project Manager, Division of Solid and Hazardous Waste, Utah Department of Environmental Quality (UDEQ).

## FOURTH COMMITTEE MEETING, JANUARY 17-19, 2012, WASHINGTON, D.C.

*Objective*: To receive briefings from the Chemical Materials Agency and the Hill on geophysical detection from DOD; to receive briefings from the Navy and Air Force on the Redstone Arsenal archival review; to review and advance preliminary first full message draft; to confirm committee writing assignments; and to discuss information-gathering requests and next steps.

### Briefings and Discussions

*Perspectives from the Chemical Materials Agency*: Don Barclay, Deputy Director, Chemical Materials Agency.

*A Congressional Perspective*: Richard Fieldhouse, professional staff member, Senate Armed Services Committee.

*Geophysical Detection of RCWM: Capabilities and R&D*: Herbert H. Nelson, Manager, Munitions Response Program, Strategic Environmental Research and Development Program, Environmental Security Technology Certification Program, Department of Defense.

*Roles and Responsibilities Related to Remediation of RCWM of the Office of the Assistant Chief of Staff for Installation Management*: Bryan M. Frey, Office of the Assistant Chief of Staff for Installation Management, Installation Services Directorate, Environmental Division, Department of the Army.

*The Navy's Roles and Responsibilities Related to Remediation of RCWM*: Robert Sadorra, Manager, Munitions Response Program, Naval Facilities Engineering Command.

*The Air Force's Roles and Responsibilities Related to Remediation of RCWM*: Michele Indermark, Director for Environmental Policy, Office of the Deputy Assistant Secretary (Environment, Safety, and Occupational Health), Department of the Air Force.

*The Redstone Arsenal Archival Review*: William R. Brankowitz, Senior Chemical Engineer, Science Applications International Corporation.

## FIFTH COMMITTEE MEETING, FEBRUARY 29-MARCH 2, 2012, IRVINE, CALIFORNIA

*Objective*: To conduct committee discussions aimed at ensuring that the text of each chapter addresses the statement of task; to perform page-by-page review of text for each chapter; to agree on and/or refine findings and recommendations and necessary supporting text; and to make any necessary work assignments.

## SIXTH COMMITTEE MEETING, APRIL 3-5, 2012, WASHINGTON, D.C.

*Objective*: To conduct committee discussions aimed at ensuring that the text of each chapter addresses the statement of task; to perform page-by-page review of text for each chapter; to agree on and/or refine findings and recommendations and necessary supporting text; and to reach concurrence on study draft and findings and recommendations.

## DATA-GATHERING ACTIVITIES

### Teleconference, November 12, 2011

*Objective:* To gain a better understanding of EPA's involvement in the cleanup at sites that have significant quantities of RCWM.

*Person spoken with:* Doug Maddox, Federal Facilities Office, Environmental Protection Agency Headquarters, Washington, D.C.

*National Research Council participants:* Todd Kimmell, William Walsh, committee members; Nancy Schulte, NRC study director.

### Teleconference, December 5, 2011

*Objective:* To gain a better understanding of EPA's involvement in the cleanup at sites that have significant quantities of RCWM, particularly at Camp Sibert and Redstone Arsenal, both in Alabama, and within EPA Region 4.

*Persons spoken with:* Sally M. Dalzell and Anne Heard, Federal Facilities Enforcement Office, Environmental Protection Agency Headquarters, Washington, D.C.; and Harold Taylor and Michelle Thornton, EPA Region 4 Federal Facilities Branch.

*National Research Council participants:* Todd Kimmell, Jim Pastorick, and William Walsh, committee members; Nancy Schulte, NRC study director.

## Teleconference, January 4, 2012

*Objective:* To gain a better understanding of ECBC's experience with CH2M HILL's TDC.

*Person spoken with:* Tim Blades, Edgewood Chemical and Biological Command.

*National Research Council participants:* Dick Ayen, Doug Medville, and JoAnn Lighty, committee members; Nancy Schulte, NRC study director.

# Appendix C

## Final Implementation Plan for the Recovery and Destruction of Buried Chemical Warfare Materiel, March 1, 2010

**THE UNDER SECRETARY OF DEFENSE**
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

MAR 01 2010

MEMORANDUM FOR SECRETARY OF THE ARMY

SUBJECT: Final Implementation Plan for the Recovery and Destruction of Buried Chemical Warfare Materiel

The Deputy Secretary of Defense designated the Secretary of the Army as the DoD Executive Agent (EA) for destruction of non-stockpile chemical warfare munitions, agents, and by-products on March 13, 1991. This designation is consistent with DoD Directive 5101.1, "DoD Executive Agent," dated September 3, 2002.

The authorities and responsibilities of this EA designation include, among other functions: (a) maintaining DoD's inventory of locations known or suspected to contain chemical warfare materiel (CWM) and chemical agent identification sets (CAIS); (b) the execution of CWM response or other actions, such as range clearance activities, needed to address these sites; (c) supporting explosives or munitions emergency responses that may involve recovered chemical warfare materiel (RCWM) or CAIS; (d) addressing, regardless of the circumstances under which found, RCWM and munitions and other materials that have an unknown liquid or chemical agent fill (munitions and materials of interest); (e) planning, programming and budgeting for the EA functions for the assessment of the fill of RCWM and munitions and other materials of interest, the destruction of RCWM, and those functions and equipment related to such assessment and destruction; and (f) integrating and coordinating the RCWM Program with all DoD Components. Collectively, these and related functions make up the RCWM Program.

This EA designation ensures a comprehensive approach for addressing RCWM and determining whether munitions and other materials of interest are RCWM. Under this EA determination, the Army's execution of the RCWM Program will provide consistency, avoid duplication, and provide for the efficient use of those limited resources that support the assessment of liquid and chemical agent fills and the destruction of RCWM.

The Army will establish procedures for: (a) the execution of RCWM response or other actions needed to address RCWM; (b) the support of explosives or munitions emergency response actions that may involve RCWM or CAIS; (c) the assessment of both RCWM to determine its chemical agent (CA) fill, and recovered munitions and materials of interest to determine whether the fill is a CA; (d) the destruction of all RCWM in a manner that complies with applicable federal and state laws and regulations and DoD policies; (e) the sustainment of required crews and equipment; and (f) the maintenance of related equipment. As part of the responsibilities under this EA designation, the Army will work with the other DoD Components to develop a proposal for DoD approval that clearly defines the roles and responsibilities of the DoD Components.

The Deputy Under Secretary of Defense for Installations and Environment (DUSD(I&E)) and the Under Secretary of Defense (Comptroller), in coordination with the Army and the Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs (ATSD(NCB)), will determine an appropriate funding profile for a new RCWM Program account. However, the funding source for the assessment of RCWM and munitions and other materials of interest, the destruction of RCWM, the sustainment of crews and equipment, and the maintenance of related equipment will be the Chemical Agent and Munitions Destruction, Defense (CAMD, D) appropriation pending establishment of the RCWM Program account. Once implemented and funded, the RCWM Program account will be resourced from the DoD's Total Obligation Authority and will be separate and distinct from the CAMD,D account used for the other portions of the Chemical Destruction Program. Those functions and activities not related to the assessment of RCWM and munitions and other materials of interest and the destruction of RCWM will be funded by the Defense Environmental Restoration Program accounts or other appropriations normally available to fund such functions and activities. Once established, the RCWM Program account will fund: (a) the assessment of both RCWM to determine the most likely chemical agent fill; (b) the assessment of munitions and other materials of interest to determine whether they are RCWM; (c) destruction of RCWM; (d) the sustainment and maintenance of required crews and equipment; and (e) program management and other necessary functions of the EA.

Within 180 days of receipt of this memorandum, I request the Army develop and submit to me for review timelines and milestones that are coordinated with DUSD(I&E), ATSD(NCB), and the other DoD Components for the following activities – at a minimum:

- Delineate program management roles and responsibilities to ensure seamless work flow and funding at the sites currently identified as being CWM response sites;
- Determine the funding required for support of the RCWM Program for consideration in the planning, programming, and budgeting process for the Fiscal Year 2012 through 2017 Program Objectives Memorandum; and
- Provide technical advice and support the planning, programming, and budgeting process for those environmental response actions that may involve RCWM under the DERP.

My point of contact is Ms. Deborah Morefield at 703-571-9067.

Ashton B. Carter

cc:
Secretary of the Navy
Secretary of the Air Force
Director, Defense Logistics Agency

# Appendix D

# Review of Regulatory Programs

## TWO MAIN PROGRAMS

As indicated in Chapter 3, there are primarily two regulatory programs under which munitions response sites (MRSs), including those containing chemical warfare materiel (CWM), would be assessed, investigated, characterized, and cleaned up: the corrective action program under the Resource Conservation and Recovery Act (RCRA) and the cleanup program under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).[1] The process leading to cleanup under both is fairly well prescribed, is highly complex, is often influenced by the type of facility (active installation, formerly used defense sites [FUDS], or Base Closure and Realignment Comnmission [BRAC]) and the type of action (emergency vs. nonemergency), and depends somewhat on whether the Environmental Protection Agency (EPA) or a state environmental regulator (or both) oversees the cleanup. The process leading to cleanup is also influenced by the level of local government involvement, the landowner (such as military, other federal agency, state or local government, or private sector), adjacent landowners, and the level and intensity of public involvement. The end result, eventual cleanup of the site, is likely to be the same regardless of those factors, but the path to the result can vary widely.

### Resource Conservation and Recovery Act

RCRA (PL 94-580), an amendment to the Solid Waste Disposal Act, was enacted in 1976 to address hazardous-waste management. As required by the statute, EPA created a cradle-to-grave system of regulations for the management of hazardous waste. States could receive authorization to administer the RCRA program within their boundaries if they develop a regulatory program deemed by EPA to be substantially equivalent to the federal RCRA program. It is important for this discussion that in adopting the federal RCRA program, states could also choose to develop regulations that are more stringent than the federal program. For example, although EPA did not identify chemical agents as hazardous waste, most of the stockpile states have specifically listed chemical agents as hazardous waste under their RCRA programs.

Once wastes are defined as hazardous, a complicated system of requirements and permits becomes applicable. Permits are required for treatment, storage, and disposal, and, because RCRA is largely state-implemented, the nature and stringency of the permit can differ from state to state. Specific provisions are established in the RCRA regulations for permitting specific types of units, such as landfills, incinerators, and storage facilities. But EPA also established a catch-all category for units that could not meet a standard type, called a miscellaneous unit.[2] If a full RCRA permit would be required for an EDT or the EDS, a unit would be defined as a miscellaneous unit. Other types of RCRA permits and mechanisms are also available under RCRA for regulatory approval.

RCRA has been amended by Congress several times to add specific provisions. The most significant RCRA amendment pertinent to the present report is the RCRA corrective action program, which came out of the 1984 Hazardous and Solid Waste Amendments (HSWA). Similar to CERCLA, RCRA corrective action requires investigation and cleanup of hazardous waste and constituents released from solid-waste management units (SWMUs) at RCRA facilities, either active facilities with current permits or at facilities that close under RCRA in lieu of obtaining permits. Areas at RCRA facilities in which buried CWM would be found would be regarded as SWMUs.

Cleanup under RCRA is intended to be risk-based. After a preliminary assessment (often referred to as a RCRA facility

[1]In rare cases, the Safe Drinking Water Act and other federal and state authorities may be used as well.

[2]Miscellaneous units are often referred to as Subpart X units because of the designation under 40 CFR 264, Subpart X.

assessment [RFA]), data are collected to define the nature and extent of the release (often referred to as a RCRA facility investigation [RFI]). If the release poses a risk that requires corrective action, a study of alternatives is conducted (often referred to as a corrective measures study [CMS]), and selected measures are then implemented (often referred to as corrective measures implementation [CMI]). In addition, interim measures may be taken at RCRA SWMUs to reduce risk sooner before more comprehensive cleanup approaches are considered. Interim measures can be part of a final corrective measure, but they were intended as a means of stabilizing releases to reduce risk pending more definitive corrective measures (55 FR 30798, July 27, 1990).

An RCRA corrective action is implemented through the permit process. EPA initially proposed the above-described RFA-RFI-CMS-CMI prescriptive process for implementing RCRA corrective actions, but opted instead for a less prescriptive approach that allows for some flexibility. Still, many of the states authorized for RCRA corrective actions require a more structured approach, which, although it has some advantages, can be a deterrent to progress. States differ in how they implement RCRA corrective actions.

Another important RCRA amendment pertinent to recovered CWM (RCWM) involves the Land Disposal Restrictions (LDRs), which were also mandated by the 1984 HSWA. The LDRs establish requirements for hazardous-waste treatment before land disposal. LDRs include application of specific treatment technologies but also establish numerical treatment standards for a number of constituents. Although no LDRs exist for listed chemical-agent wastes, these wastes may exhibit one or more of the RCRA characteristics. Treatment of RCWM that exhibits RCRA characteristics may need to meet LDRs for the applicable characteristics. In addition, and with some exceptions, remediation wastes, such as munition bodies and contaminated media, may need to meet LDRs for debris and contaminated soil.

Another regulatory development pertinent to this discussion is EPA's creation of the corrective-action management unit (CAMU) and temporary unit (TU) (EPA, 2002).[3] A CAMU is a type of waste-management unit that is designed specifically for the management of waste created during the cleanup of RCRA and CERCLA hazardous-waste sites, known as remediation waste. CAMUs can be used for treatment and storage and for disposal of remediation wastes. They are ideal when facilities will be generating a large amount of remediation waste and when such waste can be managed on site near the area from which the remediation waste was removed and in a manner that is protective of human health and the environment. CAMUs can also be established at off-site locations. For example, if a CAMU is established at Redstone Arsenal, pending regulatory approval, remediation waste generated at Camp Sibert could be accepted. A CAMU can be especially effective when wastes from multiple SWMUs or CERCLA units can be managed in the same location. One important advantage of a CAMU is that management of remediation waste within these units would trigger RCRA LDR requirements tailored for remediation wastes.

TUs are used to either treat or store remediation waste on site. They must be shown to be protective of human health and the environment and have an operating life of 1 year, which may be extended for 1 year if that is determined to be necessary. An ideal application of a TU might be for the IHFs used for storage of RCWM.

Another concept that is important to mention in connection with management of remediation waste is what is known as the Area of Contamination Policy (EPA, 1998). This policy was actually introduced in the original preamble to the National Contingency Plan under CERCLA (55 FR 8758, March 8 1990). An area of contamination is a designated area of an RCRA or CERCLA site where management of remediation waste—including treatment, storage, or disposal—is allowed without triggering LDRs or requirements for design of specific types of hazardous-waste management units (such as liners and leachate-collection systems).

Clearly, management of remediation waste—including consideration of CAMUs, TUs, treatment requirements, and areas of contamination—is a highly complex subject. Also, because RCRA is largely state-implemented, the states often implement these types of requirements differently. Although it is important to mention the various options for management of remediation waste, it is beyond the scope of this report to evaluate the intricacies of the regulatory requirements for remediation wastes that may come out of CWM sites.

Emergency provisions and other enforcement mechanisms are available under RCRA to address releases of hazardous waste and constituents. EPA can issue Section 3008(a) compliance orders; Section 3008(h) interim status corrective-action orders; Section 3013(a) monitoring, analysis, and testing orders; and Section 7003 imminent-hazard orders.[4] Many states have incorporated similar emergency provisions and enforcement mechanisms into their state RCRA programs.

Another important RCRA amendment was the Federal Facility Compliance Act of 1992 (PL 102-386), which required EPA, in consultation with the Department of Defense (DOD), to identify when waste military munitions become subject to RCRA and to provide for their safe transport and storage. The Military Munitions Rule (MR) was promulgated in 1997 (62 FR 6622). It defined when conventional and chemical munitions become subject to RCRA requirements. Although the MR provided many clarifications regarding classification of military munitions

[3] 67 FR 2961, January 22, 2002. Available at http://www.gpo.gov/fdsys/pkg/FR-2002-01-22/html/02-4.htm. Accessed April 10, 2012.

[4] http://www.epa.gov/region4/waste/rcra/RCRAAdministrativeOrders.html.

in the RCRA context, one of the important provisions for the present report is that it provided an exemption from RCRA procedures (for example, permitting and waste manifesting) for responses to explosives or munitions emergencies. It also provided an exemption for munitions on what have become known as operational ranges. Another related provision pertinent to buried CWM is that these do not become subject to RCRA waste-management requirements unless they are actively managed (for example, exhumed). DOD developed an interim guidance for implementation of the MR, which was published in 1998 (DOD, 1998), and has been working to develop it into an Army regulation.

RCRA also has well-defined and established procedures for public involvement, especially in the corrective-action process. The public has a number of opportunities to influence site-characterization procedures, interim measures, and the selection of cleanup alternatives.

### Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA is implemented through the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300), which provides a structured process for overall responses. CERCLA can be applied at any site at which hazardous substances, pollutants, or contaminants have been released into the environment, including active installations, FUDS, and BRAC sites. CERCLA can also be applied at permitted RCRA facilities. In both EPA and DOD guidance documents dealing with the cleanup of MRSs, including sites with CWM, there is a clear preference for cleanups that follow the regulatory program under CERCLA (EPA, 2005; U.S. Army, 2006) as opposed to RCRA corrective action.

The CERCLA cleanup process involves a number of steps, initiated through an initial assessment of risk. A preliminary assessment or site investigation is performed to gather data to support a determination of to whether a site qualifies for further action. Sites are scored; if they present a significant risk, they may qualify for placement on the National Priorities List (NPL). Cleanup actions under CERCLA can be required regardless of whether a site is listed on the NPL, but NPL listing places a site in a category that requires a tightly structured process that leads to cleanup. Relatively speaking, few MRSs containing CWM are listed on the NPL. The most prominent examples of CWM sites that are NPL-listed are Aberdeen Proving Ground (Edgewood Area) in Maryland, Rocky Mountain Arsenal in Colorado, and Redstone Arsenal in Alabama. Most of the FUDS and BRAC sites, and active installations that contain buried CWM that are addressed under CERCLA would be in the non-NPL site category.

If it is determined to be necessary to reduce risk in an emergency or immediate timeframe, CERCLA removal actions can be used to mitigate a release or threat of a release. Like RCRA interim measures, removal actions are typically short-term actions intended to reduce risk in an immediate time frame but can also be permanent remedies or parts of more permanent remedies. Regardless of whether a site is NPL-listed, a remedial investigation may be required. A remedial investigation is a detailed site investigation that leads to a determination that a site is sufficiently characterized to support the evaluation of cleanup alternatives. A removal action can be conducted before, during, or even after a remedial investigation is completed.

If a remedial investigation results in a determination that further action is needed to reduce risk, a feasibility study is undertaken to evaluate remedial actions, and alternatives are selected with the goal of permanently reducing "the volume, toxicity, or mobility of hazardous substances, pollutants or contaminants."[5]

EPA is responsible for implementing CERCLA at most sites. However, Executive Order 12580, issued in 1987, delegated response authority to DOD and other federal land managers for both NPL and non-NPL sites. In addition, Section 120 of CERCLA contains specific procedures for applying CERCLA at federal facilities. Most notably, if a site is not listed on the NPL, DOD and other federal land managers must conduct removal and remedial actions in accordance with state laws and requirements. If a site is NPL-listed, EPA must develop an interagency agreement, often referred to as a federal facility agreement (FFA). An FFA is a binding agreement between EPA and the federal land manager, in this case DOD. A state can also choose to be a signatory to an agreement, but at NPL sites EPA must concur with the cleanup decision. U.S. Army guidance is clear that regulatory agencies and local governments must be part of the CERCLA planning process and must be consulted in key decisions (U.S. Army, 2004). U.S. Army guidance, in effect, treats NPL and non-NPL sites the same with regard to coordination with regulators and meeting regulatory requirements.[6]

RCRA corrective action and CERCLA are different, but there are important crossovers. An example important for this discussion is known in the CERCLA program as applicable, relevant, and appropriate requirements (ARARs). Basically, requirements of other federal and state environmental laws that are determined to be either applicable or relevant and appropriate must be complied with. Most RCRA waste-management requirements (for media and debris removed from the site, including RCWM) would be considered either applicable or relevant and appropriate at CERCLA sites. Although RCRA administrative requirements, such as the need to obtain RCRA permits, would not be imposed at

[5]CERCLA remedy-selection factors include threshold criteria, balancing criteria, and modifying criteria and are discussed in many CERCLA guidance documents. (See OSWER Directive 9355.3-01F54, March 1990, available at http://www.epa.gov/superfund/policy/remedy/pdfs/93-55301fs4-s.pdf. Accessed March 21, 2012.)

[6]Deborah A. Morefield, Environmental Management, Office of the Deputy Undersecretary for Installations and Environment Department of Defense, "Remediation Operations from an OSD Installations and Environment Perspective," presentation to the committee on November 2, 2011.

federal CERCLA sites, the federal agency implementing a CERCLA action would be required to meet substantive RCRA requirements.[7]

### Summary

Regardless of regulatory authority or type of MRS, cleanup typically follows the same general flow of initial assessment, site investigation, conduct of removal or interim actions to reduce short-term risk, site characterization, evaluation and selection of alternative cleanup approach or technology to reduce long-term risk, conduct of cleanup, and site closeout. There are also requirements for periodic reviews—5 years under CERCLA and typically 5 or 10 years at RCRA facilities. Removal and treatment of RCWM may occur anywhere during the process, but is most likely during the removal or actual cleanup (remedial) phase. And under both RCRA and CERCLA, cleanups may be determined to be complete even if wastes or hazardous materials are left in place. When hazardous materials are left in place, the remedy typically involves mechanisms designed to control further releases of hazardous waste or constituents from the site (for example, an engineered cap) and typically is combined with land-use controls and continued monitoring.

## OTHER APPLICABLE REGULATORY PROGRAMS

### Munitions Response Site Prioritization Protocol

As of September 2006, DOD had cataloged over 3,300 sites as potentially eligible for the Military Munitions Response Program, as shown in Table D-1.

With so many sites and limited funding for addressing them, a priority-setting system was needed. Development of the Munitions Response Site Prioritization Protocol (MRSPP) was mandated by the 2002 Defense Authorization Act (10 USC 2710), wherein Congress directed DOD to develop a protocol for assigning priority to MRSs for response action. In 2005, DOD finalized its MRSPP.[8] The rule-making required DOD to use the MRSPP to rank MRSs for response action. Priorities are based on potential risk: the highest priority is assigned to sites that contain or potentially contain CWM.

Relative risk weighs heavily in determining priorities for response, but other factors influence which MRSs are next in sequence for response. Those factors include economic development, environmental justice, and stakeholder concerns. Some non-CWM MRSs may be selected for action before CWM MRSs despite a higher risk ranking.

[7]The identification of RCRA requirements that are substantive and included as ARARs can be contentious.

[8]https://www.federalregister.gov/articles/2005/10/05/05-19696/munitions-response-site-prioritization-protocol. Accessed March 21, 2012.

### Defense Environmental Restoration Program

DOD has been conducting cleanups at its hazardous-waste sites since the middle 1970s under its Installation Restoration Program (IRP). The IRP was formalized as the Defense Environmental Restoration Program (DERP) with the passage of the Superfund Amendments and Reauthorization Act in 1986. Congress directed DOD to carry out the DERP in consultation with EPA and with states and tribal authorities; except when situations are determined to constitute emergencies, DOD is required to give state and local governments the opportunity to review and comment on response actions. The DERP also established funding mechanisms for environmental restoration at MRSs; separate accounts are used for active installations, FUDS, and BRAC sites. However, DERP funding cannot be applied at operational ranges.

### Chemical Weapons Convention Treaty Requirements

The Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction was signed by the United States in 1993 and ratified by Congress in 1997. Treaty requirements are overseen by the Organization for the Prohibition of Chemical Weapons (OPCW). Although most of the treaty requirements pertain to destruction of chemical-weapons stockpiles in nations that stockpiled these materials, there are treaty requirements that apply to non-stockpile materials, including RCWM. The treaty requires simply that RCWM be destroyed and provides for oversight of the destruction by the OPCW. There is no treaty requirement to recover buried munitions, and no timeframe is specified in the treaty for destruction of the RCWM. The processes for treaty compliance and OPCW oversight are coordinated by CMA.

## DICTATION OF APPLICABLE REGULATORY PROGRAM BY TYPE OF FACILITY OR RESPONSE ACTION

The type of facility or property where a CWM-containing MRS is can influence whether the response action taken to clean up the site is conducted under RCRA or CERCLA. The following sections review the general types of MRSs and discuss regulatory programs applicable to the sites.

### Active Installations

Many active installations have RCRA-permitted hazardous-waste management units, such as hazardous-waste storage. Some installations may also have RCRA-permitted treatment units, including, for example, open burn–open detonation (OB/OD) units used for treatment of conventional waste munitions. Other installations may have initially sought RCRA permits for hazardous-waste management activities (like OB/OD) but determined later that a permit

TABLE D-1 Number of Munitions Response Sites

| MRSs | Active Installations | BRAC Installations | FUDS Properties |
|---|---|---|---|
| 3,309 | 1,333 | 318 | 1,658 |

SOURCE: http://www.denix.osd.mil/mmrp/upload/MRSPP_Stakeholder_FactSheet_final.pdf. Undated. Accessed March 21, 2012.

was not needed and were required to go through RCRA closure. RCRA-permitted facilities and facilities going through RCRA closure are subject to RCRA corrective action and will probably already be in the process of characterizing or remediating SWMUs on the installation, including SWMUs that are also MRSs.

Nearly all active installations have also been assessed under CERCLA, even those with active RCRA corrective action programs. Some of those installations may have CERCLA non-NPL sites or CERCLA NPL sites. If an active installation with CERCLA units is also an RCRA-permitted facility or is closing under RCRA, RCRA corrective action and CERCLA requirements apply to the same MRS at the same time. Quite often, states with RCRA corrective action authorization will want cleanup of MRSs at active installations that operate under RCRA permit to be conducted under RCRA corrective action so that they can maintain some level of control over cleanup decisions. At the same time, EPA will often want cleanup to be conducted under CERCLA authority so that it can maintain control over cleanup decisions, especially for NPL sites. RCRA vs CERCLA authority is an issue facing active installations, inasmuch as the prospect of being subject to both RCRA and CERCLA cleanup requirements can be problematic. Redstone Arsenal is subject to both RCRA corrective action and CERCLA cleanup requirements; neither EPA nor the state of Alabama has been willing to defer regulatory authority.

### Formerly Used Defense Sites

FUDS are locations where the land may have been used for training, research and development, testing, or disposal of military munitions. Property owners are diverse and may include federal and state agencies, local governments, commercial companies, public or private institutions, and even private landowners. Only in rare cases would a landowner be subject to RCRA requirements. For example, a commercial manufacturer that acquired the land that is now a FUDS MRS may also hold an RCRA permit; in this rare case, it is possible that the FUDS could be addressed under RCRA corrective action requirements. In the likely absence of overarching regulatory structure at most FUDS, the vast majority of FUDS will probably be addressed under CERCLA. In that manner, whereas the military, through the Army Corps of Engineers, will conduct the remedial investigation and eventually identify and carry out removal and remedial actions, the FUDS landowner and adjacent landowners, as well as the general public, will be key participants in the decision-making process. The state regulator also will probably be a key player, and if the FUDS is also a CERCLA NPL site, EPA will become a primary decision-maker. It should also be mentioned that even if MRSs are being addressed under CERCLA, states may issue emergency provisions or orders that are available under RCRA to address cleanup actions.

### Base Realignment and Closure

BRAC installations are similar to active installations with respect to RCRA corrective action vs CERCLA requirements. Some MRSs at BRAC sites will be addressed under RCRA, some under CERCLA (as either NPL or non-NPL sites), and requirements of both programs may apply at some BRAC installations. Given that most BRAC sites will eventually be turned over to the private sector, cleanup at installations going through BRAC will need to consider that the land will in most cases no longer be managed by the federal government.

The provisions of CERCLA 120(h) allow the transfer of contaminated federal property to nonfederal parties, but there are restrictions. Under CERCLA 120(h), EPA (and in some cases a state regulator) performs additional oversight at federal facilities that transfer to nonfederal ownership. Generally, remedial actions must be in place and operating properly and successfully before a parcel is transferred (EPA, 2010), although remedial actions need not be complete before transfer. However, CWM sites at which the remedial action includes a containment (leave-in-place) option are unlikely to be transferred to nonfederal parties.

### Operational Ranges

Another category of MRS where buried CWM may be found is operational ranges. Operational ranges are active ranges where testing, training, and other activities are expected, planned, or going on. The RCRA munitions rule makes it clear that RCRA requirements do not apply to operational ranges themselves but may apply to specific locations on ranges. For example, many RCRA-permitted OB/OD units are on or next to operational ranges. Past disposal units (including RCRA SWMUs) may also be on operational ranges, as is the case at Redstone. In such cases, RCRA or CERCLA cleanup requirements could apply not only to a unit in question but to releases of hazardous waste or constituents from the unit.

As indicated earlier, another limitation with regard to operational ranges is that DERP funding may not be used to fund cleanup at these sites. That limitation can be problematic in that some of the largest locations where CWM is known to be buried are on operational ranges (such as Redstone Arsenal).

### Emergency Response

Emergency response to a situation where a CWM or potential CWM is identified either on or off an installation or at an established BRAC or FUDS is generally "a situation in which there is an imminent and substantial threat to human health or the environment and which requires immediate and expeditious action to eliminate the threat" (EPA, 2010). As indicated previously, the RCRA Munitions Rule provides an exemption from permitting requirements for emergency response. However, the preamble to the final rule indicates that a responder should consult with an applicable state regulator if there is time.

Once an emergency is over, however, depending on the potential for additional munition items (including CWM) and location of the site, the site may become a FUDS. The Spring Valley site in Washington, D.C., was initiated as an emergency response in 1993 and has become one of the longest-active FUDS in the nation.

## TYPES OF REMEDIES

Two types of remedies may be considered for CWM-containing MRSs. CWMs may be left in place with institutional "land-use controls" (LUCs) and continued monitoring, or they may be actively removed and destroyed. In addition, when CWMs are actively removed and destroyed, RCWM destruction may take place onsite (close to the point of extraction), or they may be transported to a specified offsite location for destruction. The types of remedies for CWM-containing MRS are discussed below.

### Leave in Place with Institutional (Land-Use) Controls

Buried CWM can be left in place with LUCs to prevent unauthorized access and with deed restrictions to prevent future uses that are incompatible with buried munitions. Most often, this type of remedy is accompanied by emplacement of an engineered cap and continued monitoring of media (such as groundwater) for an indefinite period to detect migration of contamination or fluctuations in contaminant concentrations. If unexpected migration or contaminant fluctuation is detected, additional remedies may be considered. Sometimes, this type of remedy is accompanied by active treatment, such as pumping and treating of contaminated groundwater.

The leave-in-place remedy is commonly used in both RCRA and CERCLA cleanups. It is used when leaving contamination in place can be shown to be acceptable from a risk perspective and when removal of contamination would be technically impracticable or financially prohibitive. It is also used when the physical removal of contamination and later treatment can be shown to pose a health or environmental risk. That was the case at Old O-Field at Aberdeen Proving Ground, Maryland, where, among other concerns, reactivity of energetic materials was thought to pose an unacceptable risk to workers. CWM at Old O-Field was consolidated and buried on the site with a specially designed cap and indefinite monitoring of air and groundwater. As an NPL site, it is reviewed every 5 years as required by the National Oil and Hazardous Substances Pollution Contingency Plan.

The leave-in-place remedy is typically far less expensive than removal, but there is a continuing cost and liability and, of course, long-term restrictions on land use and associated loss of economic benefit that may be associated with that long-term use. Implicit in this remedy is the need to maintain ownership and control of the affected land area. For that reason, the remedy is limited to active installations. It may also be used at BRAC sites or at non-BRAC closures, such as Rocky Mountain Arsenal, where a federal land manager retains control over future land use. Although the remedy theoretically could be used at FUDS, it is unlikely to be acceptable to landowners, adjacent landowners, and state and local government.

### Active Removal and RCWM Destruction

In accordance with DOD's interim guidancefor CWM responses (U.S. Army, 2009e), "Munitions with an unknown liquid fill that are determined to be CWM and any CWM recovered during a CWM response will normally be treated (destroyed) on site using approved contained destruction technology." With the remove-and-destroy approach, buried CWM is eliminated permanently and, assuming that the remainder of the MRS site (including contaminated soil) is remediated to accepted standards, the land may be returned to beneficial use.

Removal and destruction would entail location of the CWM, removal from the burial site, and then contained destruction. Although it would be most efficient, as indicated in an earlier National Research Council report on international technologies (NRC, 2006), to move the RCWM directly from the burial site to the destruction device, interim storage for some period is sometimes required. Most RCWM can be safely stored in an IHF, as described previously. Destruction of the RCMW with a contained destruction technology would involve the EDS or one of the EDTs, as described previously. The IHF and EDS or EDTs could be approved as TUs with the limitation that they would not be able to be operated for longer than 2 years.

### Emplacement of a Corrective Action Management Unit, a Temporary Unit, or an Area of Contamination

A CAMU can also be considered for management of remediation waste. Using a CAMU for disposal of remediation waste can be considered a type of leave-in-place remedy, but it does not necessarily need to be in or even near an existing SWMU or disposal site. It would be established at a location where remediation waste could be consolidated and managed; this is similar to use of a landfill. However, in contrast with leave-in-place, remediation waste would be moved from the disposal units onsite to the CAMU. In addition, although the CAMU could receive munition bodies and scrap metal from the site and from the EDS or the EDTs, it would not necessarily need to include these metals. It could be used merely to manage contaminated media such as soil). In addition, in combination with designated areas of contamination, CAMUs used for storage and treatment, and possibly TUs, a cost-effective and efficient means of dealing with remediation waste that is protective of human health and the environment and that is tailored to the site in question could be developed.

### On-site Treatment vs Off-site Transportation for Treatment

The DOD interim guidance (U.S. Army, 2009) clearly favors on-site treatment, but it leaves the door open for off-site transportation for treatment:

> Under certain circumstances and after coordination with appropriate state, federal and DOD agencies and, when appropriate, with concurrence by Center for Disease Control's U.S. Department of Health and Human Services (USDHHS), the DASA (ESOH) may authorize other dispositions (e.g., transport and treatment off-site, open detonation).

Off-site transportation would presumably be considered when space or other limitations prevent an onsite approach or when a military installation with EOD capabilities is a reasonable distance from the burial site. There may be circumstances in which off-site transportation for later destruction will be a good option.

### Other Approaches

In the quotation above, DOD leaves open the option of open detonation for RCWM. The DOD interim guidance goes on to say, "When open detonation is authorized, 50 USC, Section 1518 requires Congressional notification." Clearly, open detonation would be used only in highly unusual circumstances when there is no safer way to deal with the RCWM.

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# Appendix E

## Management Practices for U.S. Army Planned RCWM Recovery and Emergency Response

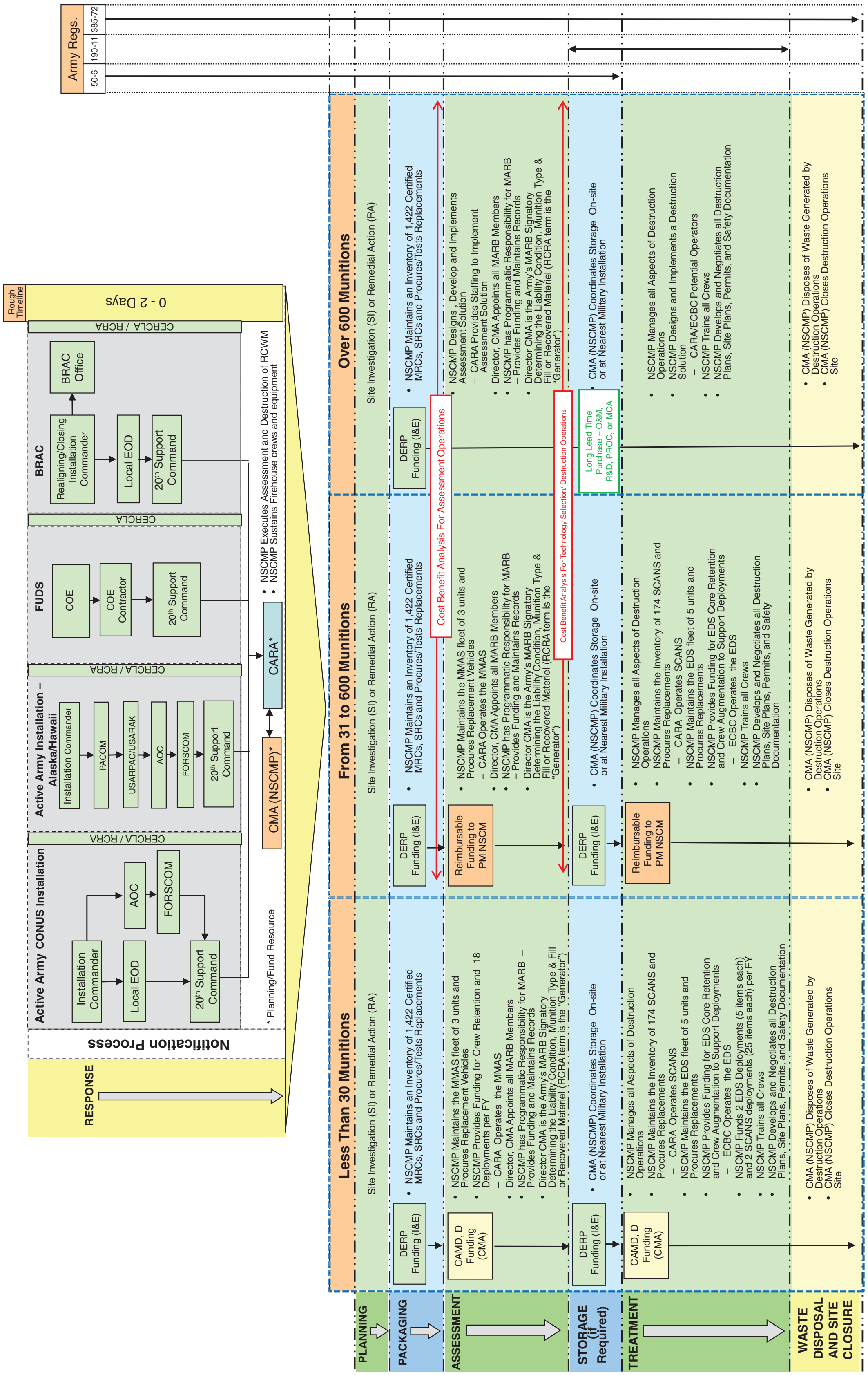


FIGURE E-1 Management practices for U.S. Army planned RCWM recovery at burial locations. SOURCE: David Hoffman, chief, Operations Team, Non-Stockpile Chemical Materiel Project, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview," presentation to the committee on September 29, 2011.

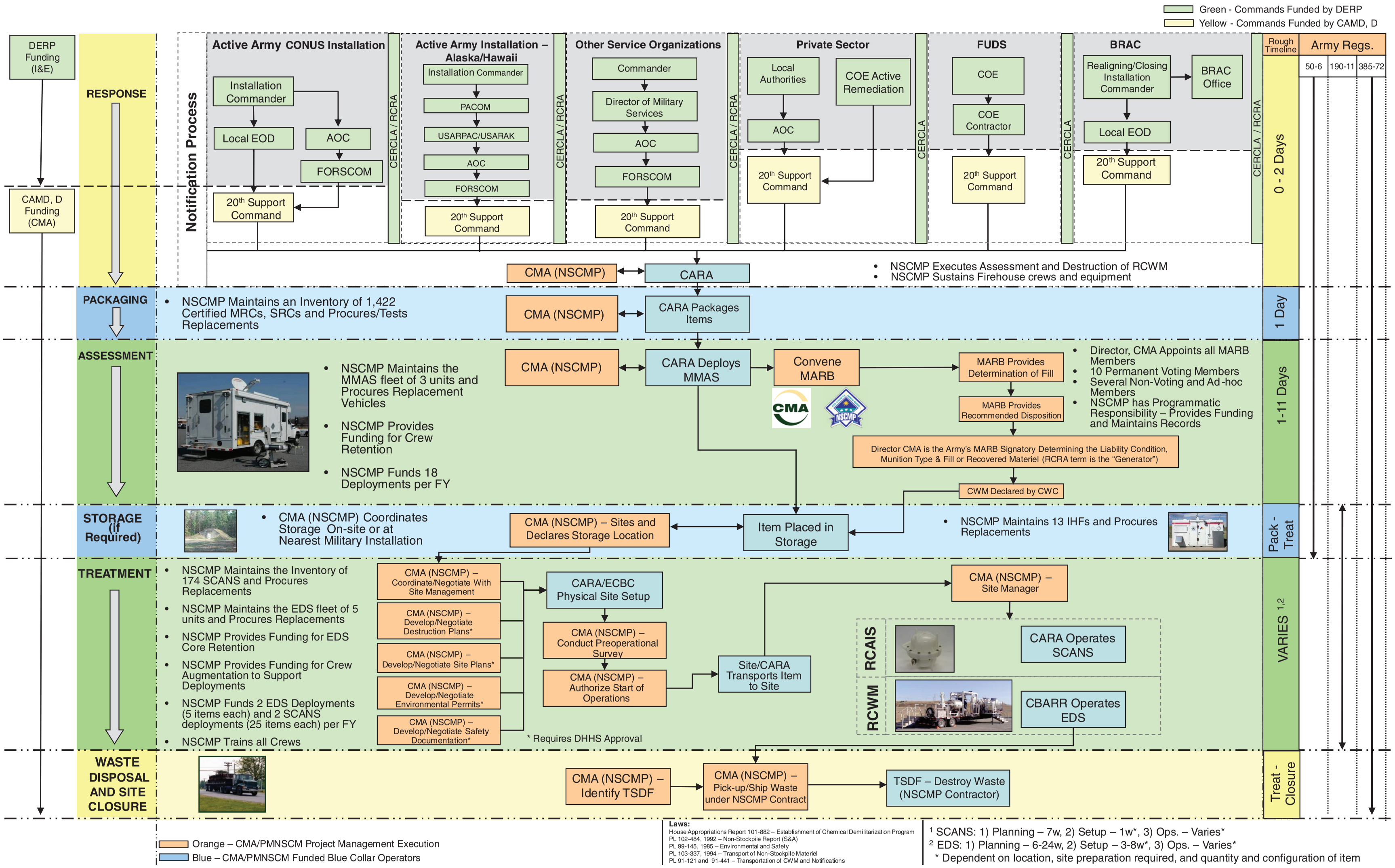


FIGURE E-2 Management practices for U.S. Army RCWM emergency response, executed by DASA-ECW, CMA, and PMNSCM. SOURCE: David Hoffman, Chief, Operations Team, Non-Stockpile Chemical Materiel Project, "Non-Stockpile Chemical Materiel Project Equipment and Capabilities Overview," presentation to the committee on September 29, 2011.