ANL/DIS-18/3

Pre-Event Recovery Sampling and Analysis Framework for Blue Grass CSEPP Community

Decision and Infrastructure Sciences Division

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ANL/DIS-18/3

Pre-Event Recovery Sampling and Analysis Framework for Blue Grass CSEPP Community

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November 2018

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CHEMICAL STOCKPILE EMERGENCY PREPAREDNESS PROGRAM

Chemical Stockpile Emergency Preparedness Program (CSEPP)

Pre-Event Recovery Sampling and Analysis Framework (RSAF)

Blue Grass CSEPP Community

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November 2018

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FOREWORD

In April 2008, the Chemical Stockpile Emergency Preparedness Program (CSEPP) released the *Final CSEPP Recovery Sampling and Analysis Plan (RSAP) Protocol for Chemical Warfare Agent Accidents/Incidents*. The 2008 protocol was state of the art at the time, laying out a logical and well-planned approach to developing sampling and analysis plans geared toward determining when it was safe to re-enter areas off-post impacted by a chemical agent release. However, it is now 2018 and much has changed since the 2008 protocol was developed.

First, chemical warfare agent demilitarization operations are complete at six of the eight chemical storage depots across the United States. The only remaining facilities are the Pueblo Chemical Depot east of Pueblo, Colorado, and Blue Grass Chemical Activity (BGCA) east-southeast of Richmond, Kentucky.

Second, there are additional (new) resources available to plan a more efficient and effective sampling and analysis program in response to a chemical agent release. These include updated regulations, guidance documents, plume models, sample design tools, field and analytical methods, remote sensing technologies, and federal and state resources.

The Blue Grass CSEPP Community, noting these changes, decided to develop an updated sampling and analysis framework tailored to the BGCA. The initial working draft took approximately 18 months to develop through a cooperative effort led by a Blue Grass CSEPP Community workgroup and supported by technical subject matter experts (SMEs) from Argonne National Laboratory (Argonne).

The workgroup held four “Big Picture Issue” sessions to present and discuss issues and develop a path forward. The workgroup incorporated input from these sessions into an initial draft Recovery Sampling and Analysis Framework (RSAF). The RSAF was reviewed in a series of conference calls and in a workshop held in January 2018. This document reflects the judgment and conclusions of the workgroup as expressed in the review sessions, calls and workshop.

The Blue Grass CSEPP Community RSAF reflects the unique aspects of the BGCA’s storage operation, the specific chemical agents present at BGCA, the environment and climate of the Blue Grass area, and the Community’s input and preferences.

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Chemical Stockpile Emergency Preparedness Program (CSEPP) Pre-Event Recovery Sampling and Analysis Framework (RSAF) Blue Grass CSEPP Community

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Chemical Stockpile Emergency Preparedness Program (CSEPP) Pre-Event Recovery Sampling and Analysis Framework (RSAF) Blue Grass CSEPP Community

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ACRONYMS AND ABBREVIATIONS

ACWA	Assembled Chemical Weapons Alternatives
AEGL	acute exposure guideline level
AFN	access and functional needs
AL	Action Level
APHC	Army Public Health Center
AR	Army Regulation
Argonne	Argonne National Laboratory
BGAD	Blue Grass Army Depot
BGCA	Blue Grass Chemical Activity
BGCAPP	Blue Grass Chemical Agent-Destruction Pilot Plant
BPI	Big Picture Issue
CAC	Citizens Advisory Commission
CAI	chemical accident or incident
CAIRA	Chemical Accident or Incident Response and Assistance
CAM	chemical agent monitor
CASARM	Chemical Agent Standard Analytical Reference Material
CDCAB	Chemical Destruction Citizens Advisory Board
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CMA	Chemical Materials Activity
COC	constituent of concern
CSEPP	Chemical Stockpile Emergency Preparedness Program
CSM	Conceptual Site Model
CST	Civil Support Team (KYNG)
CWA	chemical warfare agent
DA	U.S. Department of the Army
DAAMS	depot area air monitoring system
DA PAM	Department of the Army Pamphlet
DHS	U.S. Department of Homeland Security
DL	detection limit
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQO	data quality objective
DTRA	Defense Threat Reduction Agency
DU	decision unit

EA-2192	A degradation product of VX
ECBC	Edgewood Chemical Biological Center
EDD	electronic data deliverable
EMPA	ethylmethyl phosphonic acid (a degradation product of nerve agents)
EMA	emergency management agency
ENVU	environmental unit
EO	Executive Order
EOC	Emergency Operations Center
EOP	Emergency Operations Plan
EPA	U.S. Environmental Protection Agency
ERZ	emergency response zone
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
gal	gallon(s)
GB	sarin (a type of nerve agent)
GD	soman (a type of nerve agent)
GIS	Geographic Information System
GPS	Global Positioning System
H	mustard, undistilled
HAPSITE	Hazardous Air Pollutant Site
HASP	Health and Safety Plan
HD	mustard, distilled
HHS	Department of Health and Human Services
HT	mustard, mixture of mustard
ICS	Incident Command System
ICP	Incident Command Post
IDW	investigation-derived waste
IMPA	isopropyl methylphosphonic acid (a degradation product of nerve agents)
IRZ	immediate response zone
IPT	Integrated Process Team
JEM	Joint Effects Model
JIC	Joint Information Center
KDEP	Kentucky Department for Environmental Protection
KY EEC	Kentucky Energy and Environmental Cabinet
KYEM	Kentucky Emergency Management Agency
KYNG	Kentucky National Guard
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate

LIMS	Laboratory Information Management System
MACG	Multi-Agency Coordination Group
MACS	Multi-Agency Coordination System
MINICAM	Miniature Chemical Agent Monitor
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
mg/m^3	milligram(s) per cubic meter
MPA	methylphosphonic acid (a degradation product of nerve agents)
MS	matrix spike
MSD	matrix spike duplicate
NCP	National Contingency Plan
NELAC	National Environmental Laboratory Accreditation Council
NELAP	National Environmental Laboratory Accreditation Program
NIMS	National Incident Management System
NRF	National Response Framework
NRT	National Response Team
OSC	on-scene coordinator
OSHA	Occupational Safety and Health Administration
PAD	Protective Action Decision
PAR	protective action recommendation
PAZ	Protective Action Zone
PCB	polychlorinated biphenyl
PCD	Pueblo Chemical Depot
PEO	Program Executive Office
PHILIS	Portable High-Throughput Integrated Laboratory Identification System
PIO	Public Information Officer
PNNL	Pacific Northwest National Laboratory
PPE	personal protective equipment
PRG	preliminary remediation goal
QA	quality assurance
QAP	quality assurance plan
QAPP	quality assurance project plan
QL	quantitation limit
QRG	quick response guide
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
RRT	Regional Response Team
RSAF	Recovery Sampling and Analysis Framework
RSAP	Recovery Sampling and Analysis Plan or Protocol
RSL	Regional Screening Level

RTAP	real-time analytical platform
SAM	sampling and analytical method
SAP	sampling and analysis plan
SIP	shelter-in-place
SME	subject matter expert
SOP	standard operating procedure
SPP	Systematic Planning Process
TDG	thiodiglycol (a degradation product of mustard)
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UC	unified command
UFP	Uniform Federal Policy
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventative Medicine
USCG	U.S. Coast Guard
VSP	Visual Sampling Plan
VX	a type of nerve agent

1 INTRODUCTION

Congress created the Chemical Stockpile Emergency Preparedness Program (CSEPP) in 1985 (U.S. Department of Defense [DOD] Authorization Act, 1986, Public Law 99-145) to provide emergency preparedness assistance and resources to communities surrounding Army chemical warfare agent stockpiles. CSEPP is a partnership between the Federal Emergency Management Agency (FEMA) and the U.S. Department of the Army (Army), and includes elements of the federal, state, and local government at each of the stockpile sites.

Chemical munitions have been stored at the Blue Grass Army Depot (BGAD), located near Richmond, Kentucky since the 1940s. The Army's Blue Grass Chemical Activity (BGCA), a tenant organization on BGAD, manages the stockpile. The munitions consist of projectiles and rockets and contain the chemical agents mustard (H), VX, and sarin (GB). Pursuant to the Assembled Chemical Weapons Alternatives (ACWA) program, the Army is preparing to demilitarize the chemical weapons onsite at BGAD using a combination of technologies designed to destroy the chemical agents and neutralize energetic materials, including explosives and propellants. Operations are slated to begin in 2019 and end in 2023 (see https://www.peoacwa.army.mil/).

The Blue Grass CSEPP Community includes BGCA and BGAD, the 10 counties surrounding BGAD, elements of state government including the Governor's office, the Kentucky Emergency Management Agency (KYEM), and the Kentucky Department for Environmental Protection (KDEP), along with public health agencies, local hospitals, and many others. These entities work together to help ensure local communities are prepared for, can respond to, and can recover from the effects of a chemical accident or incident (CAI), should one occur at BGAD.

This Recovery Sampling and Analysis Framework (RSAF) is a technical guide for the Blue Grass CSEPP Community to help investigate possible chemical agent vapor travel and deposition, examine options for temporary and unconditional re-entry and recovery, and determine the potential need for removal or other actions following an accident or incident at BGAD.

The RSAF consists of nine chapters and six appendices, as follows:

- Chapter 2 presents background information. It reviews the 2008 RSAP Protocol, discusses relevant new developments within the federal and Army communities, and compares emergency response sampling and analytical activities to those associated with more conventional hazardous material release investigations.

- Chapter 3 discusses legal and regulatory context for recovery sampling and analysis.

- Chapter 4 discusses the structure of sampling and analysis response at BGAD under the National Contingency Plan (NCP) and the Incident Command System (ICS), summarizes the Concept of Operations, and identifies roles and responsibilities of the various stakeholders within the Blue Grass CSEPP Community, including federal, state, and local organizations.

- Chapter 5 reviews aspects of BGAD and the surrounding area that influence sampling and analytical planning, re-entry, and recovery following a CAI. It includes discussions on agent persistence and its effect on sampling and analytical planning, the physical environment including critical infrastructure, the political and regulatory environment within Kentucky, the surrounding human population and demographics, and the surrounding natural environment.

- Chapter 6 presents the basics of the RSAF. It consists of 15 sections that discuss issues including but not limited to sample planning and design, health and safety of field sampling teams, field and laboratory analytical methods, decision-making, and potential actions based on sample results.

- Chapter 7 discusses the special case of temporary re-entry, where short-term incursions into potentially contaminated areas may be necessary for various reasons. Examples include care of pets, feeding of livestock, and evacuation of people that have sheltered in place.

- Chapter 8 presents a systematic approach to actions to take if an event actually happens. It provides instructions on how to use the RSAF to create a situation-specific sampling and analytical plan that addresses unique aspects of the event, including its initiating factors (e.g., explosion, leak), plume depictions, weather conditions during and following the event, affected protective action zones, and the impacts of time and weathering on agent persistence.

- Chapter 9 lists references used to develop the RSAF.

Appendices:

- Appendix A – RSAF development process
- Appendix B – U.S. Environmental Protection Agency (EPA) National Response Team Quick Response Guides for the agents stored at BGAD
- Appendix C – Behavior of agents HD, GB, and VX in the environment
- Appendix D – Example conceptual site model (CSM) of a release following a CAI
- Appendix E – Chemical agent air exposure values
- Appendix F – Sample logbook forms

2 BACKGROUND AND TECHNICAL APPROACH

This document is intended to create a framework for recovery sampling and analysis planning, in a way that meets the needs of the Blue Grass CSEPP Community and is consistent from a scientific, technical, and practical standpoint. To meet this goal, the workgroup reviewed previous planning documents and current regulatory, technical, and programmatic reference materials; held structured technical and policy discussions with the Blue Grass CSEPP Community; and conducted outside peer review.

This chapter provides an overview of the 2008 RSAP Protocol prepared in support of the CSEPP (USACHPPM 2008), summarizes changes in the regulatory environment that have occurred since the 2008 protocol was prepared, and lastly summarizes how conventional hazardous substance removal site evaluations differ from those involving chemical warfare agent (CWA).

2.1 Overview of 2008 RSAP Protocol

The 2008 RSAP Protocol was prepared specifically to support the CSEPP and pointed out the need to have a sound basis for post-emergency decisions to allow reentry to affected areas. That in turn depends on having a well-developed CSM and defensible data. The 2008 Protocol outlined potential sampling strategies, data evaluation strategies, and supporting documentation that would be needed to guide sampling and analytical response.

The 2008 Protocol further recommended a probabilistic sample design based on static or adaptive sampling grids, but also allowed for judgmental sampling locations, where sample locations were to be selected based on best judgement of subject matter experts (SMEs). Various types of samples (air, water, soil, wipes) would be collected from grid nodes located in or immediately adjacent to the projected plume area. Samples would also be collected from inside structures (homes and businesses), at sensitive population locations (e.g., schools, nursing homes) and at farm locations. The 2008 protocol also recommended that, where probabilistic sampling is selected, a 90–95% confidence level for a sampling approach should be used in determining the number of samples to be collected. In general, the higher the confidence level selected, the greater the sample number and the larger the sampling/analytical effort. A higher confidence level also increases the expense and duration of the sampling/analytical effort. Duration may be of special concern since populations that have been directed to evacuate or relocate will want a rapid decision about when restrictions can be lifted.

2.2 Relationship of RSAF to 2008 Protocol

The 2008 protocol informed the development of the present RSAF. However, the current RSAF differs from the 2008 protocol in several ways. This RSAF:

- Is specific to the Blue Grass CSEPP Community.
- Incorporates doctrinal and technological developments since 2008, including refinements of the national incident management system (NIMS) and Incident Command System (ICS); advances in geographic information systems, modeling and analysis software; and significant advances in mobile communication and data capabilities.

- Addresses the relationship between confidence in a decision and sample numbers, and sampling/analytical expense and time. While stakeholders will want a high degree of certainty their location is safe for unrestricted use (either re-entry or cessation of SIP), they may not be willing to remain under restrictions during the time needed to collect the number of samples needed to achieve a high degree of certainty. The present RSAF allows decision-makers to weigh the desired confidence in a decision about whether or not contamination is present against the sampling requirements (time and resources) needed to achieve that level of confidence.
- Accounts for risk mitigation resulting from natural degradation of the agents and degradation products over time. Chapter 5 and Appendix C present more on agent degradation characteristics.

2.3 Comparison to other Hazardous Substance Responses

The bulk of experience that the nation has with site characterization and cleanup has been associated with conventional hazardous material spills and waste sites. A number of site characterization and cleanup operations have resulted from emergency response operations in the past, but there have been comparatively few. Most of these resulted from emergency response to train derailments, pipeline ruptures, and industrial accidents, with various types of industrial chemicals and materials, such as chlorine and crude oil.

Site evaluation and removal for a chemical warfare agent release would be generally similar to that for other hazardous materials, with some significant differences.

First, and probably most significant, is the acutely toxic nature of the chemical agents. Many conventional hazardous substance removal or remedial operations involve chemicals that pose a chronic hazard, rather than the acute hazard presented by CWA. The possible presence of chemical agents affects many different aspects of site characterization—everything from the personal protective equipment (PPE) used by field sampling teams to the types of laboratories that are qualified to perform analyses. In addition, because the chemical agents are regulated materials, many different requirements apply, ranging from surety and security to transportation of samples.

Most sampling and analytical technologies for conventional hazardous substance constituents also apply to the agents and degradation products. There are, however, specialized procedures for air monitoring, sample screening, sampling and analysis, and very specific types of chemicals and materials that decontaminate affected environmental media and surfaces, including soils, concrete, buildings, windows, and vehicles. There are also special considerations for other types of contaminated materials, such as farm crops. In some cases, disposal may be preferred to decontamination.

Many conventional hazardous substance constituents are persistent in the environment. Chemical warfare agents will degrade in the environment, so it is important to consider the toxicity of the daughter products and the effects of time and weather conditions before, during, and after the event in determining what to sample and what analyses to perform. For example, because GB degrades so rapidly, if one does not analyze for degradation products one may not even know

that an area was ever contaminated. This is also true, although to a lesser degree, with both HD and VX. Chapter 5 and Appendix C contain additional information about degradation of chemical warfare agents in the environment.

Another significant consideration is the protective action decisions (PADs) made for portions of the population. Those who sheltered in place may need to be relocated, and those who evacuated will be anxious about their property. There will be pressure on decision-makers to allow the evacuated public back to their property. At the same time, the public will want reassurance that the areas are safe for occupation. There likely will also be claims for property damage, evacuation costs, lost business, and other types of damage. The results of sampling and analysis may become evidence in the adjudication of such claims.

All this translates to a sampling and analytical planning effort that must be scientifically valid, well thought out, and implemented in a carefully controlled but efficient manner. Although interim goals may be adequate for site characterization and effective removal and remediation operations, the ultimate goal must be to conduct operations in a manner that clear areas for safe, unconditional re-entry as quickly and efficiently as possible using defensible data and informed decision-making.

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3 LEGAL AND REGULATORY STRUCTURE

A number of statutory and regulatory requirements apply to cleanup and recovery from a chemical event. Some *authorize* response actions, some *require* response actions, and some *direct or guide* procedures for carrying out response actions, including interagency cooperation, public input, and other aspects of the activity. This chapter summarizes applicable requirements and guidance at the federal, Army, and state level.

3.1 Federal Laws and Regulations

3.1.1 CERCLA/NCP

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986, authorizes and requires response to hazardous materials releases, including those that occur on federal installations. Among other things, CERCLA specifically authorizes hazard assessment. When there is reason to believe a release has occurred or may be about to occur, the U.S. President may "undertake such investigations, monitoring, surveys, testing, and other information gathering as he may deem necessary or appropriate to identify the existence and extent of the release or threat thereof, the source and nature of the hazardous substances, pollutants or contaminants involved, and the extent of danger to the public health or welfare or to the environment," (42 USC 9604(b)(1)).

In Executive Order (EO) 12580 (Superfund Implementation), the President delegated certain functions and responsibilities vested in him by CERCLA and other statutes to the DOD. Specifically, the DOD is the lead agency for "a release of a hazardous substance, pollutant, or contaminant, where the release is on, or the sole source of the release is from, any facility or vessel under the jurisdiction, custody, or control" of the DOD. EO 12580 makes the DOD responsible for providing the on-scene coordinator (OSC) to oversee response and cleanup under the National Contingency Plan (NCP) (40 CFR 300).

Through a series of DOD and Army regulations (DOD 2013; AR 200-1; AR 525-27), authority and responsibility for cleanup of hazardous material spills at Army installations is assigned to the installation commander. The installation commander is in turn responsible for predesignating an OSC to coordinate response under the NCP. The OSC coordinates all aspects of response, including immediate actions to mitigate the release and actions to assess any hazard to the public (U.S. Army 2007, paragraphs 11-4.b[10] through 11-4.b[12]; U.S. Army 2012b, paragraph 1-15.g[6]).

CERCLA distinguishes between removal and remedial programs. Short-term (typically, less than twelve months) actions to address the hazard are considered *removal* actions under the NCP, with a relatively simple set of documentation requirements. Under the NCP, the Army OSC can request assistance from the EPA and other federal agencies through the Regional Response Team (RRT) and National Response Team (NRT). Through the U.S. Department of Homeland Security (DHS) ICS, a unified command (UC) structure, perhaps within a Multi-Agency Coordination Group (MACG), would most likely be used to engage state and local officials and

help them come to consensus on removal decisions. Longer term cleanup, if necessary, would be accomplished under the CERCLA remedial program, with the U.S. Army Corps of Engineers (USACE) the Army's lead organization. USACE would provide the OSC and assign an Army Remedial Project Manager (RPM) to oversee the cleanup. Under CERCLA's remedial program, state and local jurisdictions have a more significant role in determining future actions, as opposed to a removal action.

3.1.2 Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA), as amended, addresses proper management of hazardous waste. The installation is subject to RCRA requirements and holds a permit for hazardous waste storage from the Commonwealth of Kentucky. Chemical munitions destruction at the Blue Grass Chemical Agent-Destruction Pilot Plant (BGCAPP) and other facilities will also be conducted under RCRA permit requirements. The EPA authorized Kentucky to administer RCRA regulations within the state. Under RCRA regulations, in the event of an emergency, after immediate emergency response actions have been performed, the facility emergency coordinator must "provide for treating, storing, or disposing of recovered waste, contaminated soil or surface water, or any other material that results from a release, fire, or explosion at the facility" (40 CFR 264.56(g)). Within 15 days after the event, a report is due detailing the incident. This report includes the identity and quantity of the material involved, the extent of any injuries, assessment of actual or potential hazards to human health or the environment, and the estimated quantity and disposition of recovered materials (40 CFR 264.56(j)).

The KDEP, in the Kentucky Energy and Environmental Cabinet (KY EEC), has promulgated hazardous waste regulations that reflect the federal RCRA standards (401 Kentucky Admin. Regulations [KAR] 32–38). However, as directed by statute (Kentucky Revised Statutes [KRS] 224.50–130(2)), the KDEP has designated chemical agents GB, VX, and Mustard as hazardous wastes (see 401 KAR 31:040; Haffenden and Kimmell 2002). The statute also establishes standards for permitting the demilitarization facility (BGCAPP) to operate, including a requirement that the process be 99.9999% effective in destroying the chemical agent. In addition, the statute requires that KYEM certify that emergency planning is adequate to protect the public from a credible worst-case release.

In the event of a release, as the permit-issuer, Kentucky may issue an administrative order-requiring cleanup, known as a "corrective action order" under RCRA.[1] Corrective actions are generally negotiated between the permit-issuer (the state) and permit-holder (BGAD/BGCA), although the public has a number of opportunities to influence cleanup decisions. The state has the authority to compel cleanup under RCRA corrective action, and in so doing, has more control over cleanup decisions. It is conceivable that cleanup could occur in parallel under both CERCLA and RCRA corrective action.[2] In any case, the procedures for coordination and unified

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1 See RCRA Section 3004(u) or (v) and 40 CFR Part 264.

2 The EPA encourages a collaborative approach to avoid duplication of effort when a cleanup may be subject to both RCRA and CERCLA. "EPA continues to stress that, generally, cleanup conducted pursuant to RCRA corrective action or CERCLA will substantively satisfy the requirements of both programs" (EPA 2005).

command outlined in chapters 4, 6 and 8 represent the sort of negotiated solution that EPA envisions.

3.2 Army Requirements and Guidance

Army Regulations (ARs) assign responsibilities and set requirements, and Department of the Army Pamphlets (DA PAMs) provide detailed guidance on particular topics. Army Directives also set policy and assign responsibilities for particular functions.

Army publications including ARs, DA PAMs, and other documents are found on the Army Publishing Directorate webpage (https://www.apd.army.mil). Some of the more directly relevant publications are summarized below.

3.2.1 Chemical Agent-Specific Documents

AR 50-6, Chemical Surety, April 2018. This regulation prescribes policies, procedures, and responsibilities for the Army Chemical Surety Program. Along with AR 190-59 and DA PAM 385-61, it implements DOD safety, accountability, inventory, and physical security requirements pertaining to chemical surety matters (per DODI 5210.65). Chapter 6 addresses chemical accident or incident response and assistance (CAIRA).

DA PAM 385-61 (Toxic Chemical Agent Safety Standards), November 2012. This document describes minimum safety criteria, guidance, and procedures for use in processing, handling, storage, transportation, disposal, and decontamination of chemical agents. It includes relevant information about the chemical agents and addresses monitoring, protective equipment, laboratory safety, and other safety criteria for working with chemical agents.

DA PAM 40-8 (Occupational Health Guidelines for the Evaluation and Control of Occupational Exposure to Nerve Agents GA, GB, GD, and VX), December 1990. This pamphlet establishes a medical surveillance program for all personnel potentially exposed to nerve agents GA, GB, GD, and VX, and provides occupational health guidance for the evaluation and control of exposures to the nerve agents in industrial, depot, and laboratory operations.

DA PAM 40-173 (Occupational Health Guidelines for the Evaluation and Control of Occupational Exposure to Mustard Agents H, HD, and HT), June 2003. This pamphlet provides procedures for the occupational health aspects of the Chemical Surety Program established in AR 40-5 (Preventive Medicine) and AR 50-6 for all personnel potentially exposed to Levinstein mustard (H), distilled mustard (HD), or HT (mixture of 60% HD and 40% bis(2-chloroethylthioethyl) ether). It also provides occupational health guidance for the evaluation and control of exposures to mustard in industrial, depot, and laboratory operations.

3.2.2 General Safety, Environmental and Emergency Management Regulations/Guidance

AR 200-1, Environmental Protection and Enhancement, December 2007. This regulation addresses waste management, hazardous materials spills, and environmental cleanup, among other topics.

AR 385-10, Army Safety Program, November 2013. This regulation implements requirements of the Occupational Safety and Health Act of 1970 as implemented in EO 12196; 29 CFR 1960; and DODIs 6055.1, 6055.04, and 6055.07. It provides new policy on Army safety management procedures with special emphasis on responsibilities and organizational concepts.

AR 525-27, Army Emergency Management Program, March 2009. This regulation prescribes an all-hazard approach to planning, preparation, response, and recovery. It establishes policy and assigns responsibility for Army installation protection and related activities.

DA PAM 525-27, Army Emergency Management Program, September 2012. This pamphlet provides procedures for implementing AR 525-27, including hazard assessment, planning, incident management, and other topics.

CSEPP Guidance, December 2012. This is the base guidance document for implementation of the CSEP Program.

4 ROLES AND RESPONSIBILITIES, INCIDENT COMMAND, AND RESOURCES

Identifying priorities and making decisions regarding monitoring and sampling will involve many jurisdictions and organizations. The results of sampling and monitoring will determine the degree of cleanup required under the NCP, and may also enter into decision making regarding protective actions for the public. County and state CSEPP plans anticipate a collaborative process for post-CAI hazard assessment, in coordination with Army and federal agencies and resources.

In addition, it should be expected that any chemical event severe enough to result in protective actions will attract intense scrutiny from the media and public. Therefore, the process of determining the extent of agent travel, possibility of residual hazard, and the need for protective action will involve a number of agencies and authorities at the federal, state, and local level. This section provides a brief overview of key roles and responsibilities, and then goes into further detail on authorities, responsibilities, resources, and command structure.

4.1 Overview of Roles and Responsibilities

4.1.1 U.S. Army

The BGCA is a tenant facility on the BGAD. BGCA is under supervision of the CMA, headquartered in Edgewood, Maryland, at the Aberdeen Proving Ground. BGAD is under the Joint Munitions Command, headquartered at the Rock Island Arsenal in Illinois. The Blue Grass Chemical Agent-Destruction Pilot Plant (BGCAPP) is a contractor-operated tenant facility that is located on BGAD and overseen by the Program Executive Office (PEO), ACWA, which reports to the Office of the Secretary of Defense.

Note that in an emergency, the Army OSC can obtain all available U.S. Army resources through requests up the chain to higher headquarters. In addition, the OSC can obtain other federal resources through the RRT.

4.1.2 Commonwealth of Kentucky

Management of off-post areas affected by the emergency, including choice of protective actions for the public and control of access to the area, is the responsibility of local and state government.

State law governs emergency powers and agency roles in emergency planning and response. Responsibility for state emergency planning and management is delegated to the Division of Emergency Management. At the local level, each “city, county, urban-county or charter county government of this Commonwealth shall create, support, and maintain a local emergency management agency, which shall serve the public safety interest of the local government within the territorial boundaries of the city or county where the agency is created,” (KRS Section 39B.010).

In an actual or threatened emergency, the governor may declare a state of emergency, activating certain supplemental powers. During the state of emergency, the governor may direct and control all emergency response forces and seize (subject to compensation) certain types of private property needed for the response effort, including means of transportation and communication, stocks of fuel, food, clothing and medical supplies, and facilities such as buildings and industrial plants. The governor may also "exclude all nonessential personnel" from the scene of the emergency, declare curfews, request assistance from the federal government, and "perform and exercise such other functions, powers, and duties as may be deemed necessary to promote and secure the safety and protection of the civilian population" (KRS Section 39A.100). Similar powers are accorded to the local chief executive at the county level upon his or her declaration of a local state of emergency. The governor can also request a presidential declaration of disaster under the Stafford Act.

Key state-level agencies for response and recovery from a chemical event include (all located in Frankfort, Kentucky):

- KYEM, which is responsible for coordination of emergency preparedness and management under the state emergency management statute. KYEM is a division of the Kentucky Department of Military Affairs.

- KDEP is part of the Energy and Environment Cabinet and is responsible for environmental protection, including administration of applicable RCRA permits and other environmental permits for BGAD and BGCAPP.

- The Kentucky Department for Public Health is part of the Cabinet for Health and Family Services. It would advise key decision makers during response and recovery from a chemical event on matters pertaining to public health hazards.

4.1.3 Kentucky Counties

Kentucky counties most at risk from a chemical event include Madison and Estill in the Immediate Response Zone (IRZ), and Clark, Fayette, Garrard, Jackson, Powell, and Rockcastle in the Protective Action Zone (PAZ).

Under the state emergency management statute (see KRS 39B.020), the County Judge or Executive appoints the director of the county emergency management agency (EMA) who in turn has direct responsibility for the organization, administration, and operation of the county EMA. The County EMA Director is responsible for the coordination of response activities and acts as liaison with other local, county, regional, state, and federal emergency management agencies.

The County Judge Executive, or a city mayor, may declare a local state of emergency, allowing the suspension of local rules and regulations in order to expedite emergency operations.

Each county has a local emergency planning committee organized under the Emergency Planning and Community Right-to-Know Act.

4.1.4 Federal Agencies

FEMA coordinates federal emergency response assistance to states and localities and with processing requests from state governors for presidential disaster declarations. FEMA has a CSEPP office located in the District of Columbia and has CSEPP-dedicated personnel in the Region IV office in Atlanta, Georgia, servicing Kentucky.

The EPA receives notifications and administers response to hazardous materials incidents under the NCP. Assistance with assessment and recovery from a chemical event at BGAD would be coordinated through the Region IV RRT, jointly chaired by the EPA and the United States Coast Guard (USCG).

4.2 Incident Management and Coordination under the National Contingency Plan

The NCP implements federal law. It identifies the National Response System (NRS) as the mechanism for coordinating response actions by all levels of government in support of the Federal OSC. The NRS is composed of the NRT, RRT, the OSC, and Special Teams and related support entities. The NRS is capable of expanding or contracting to accommodate the response effort required by the size or complexity of the release.

The NCP (40 CFR 300.100(d)) sets the expectation that OSCs will use Incident Command System (ICS) concepts to manage removal operations. It identifies using either UC or a Multiagency Coordination System (MACS), depending on incident scale, in situations where there are multiple agencies and organizations with different legal, geographic, and functional responsibilities that need to coordinate and plan elements of a removal action. UC is appropriate for coordinating and developing the post-event environmental sampling plan (ESP) because it brings together the federal, state, and local government entities to meet community needs while allowing the OSC to fulfill federal incident commander requirements under the NCP. Figure 4-1 depicts this UC relationship with the NCP's National Response System.

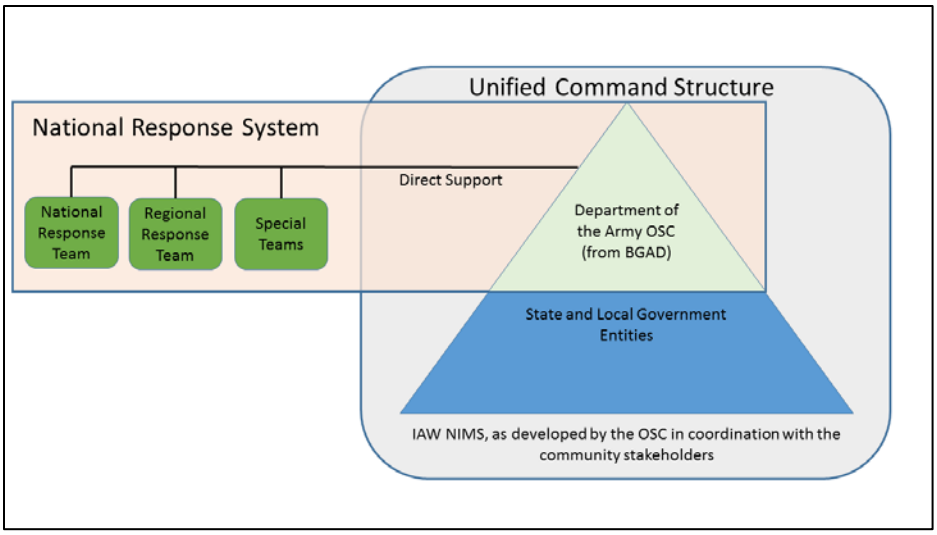

Figure 4-1. Unified Command's Relationship with the National Response System

The UC structure answers the question of "who is in charge" in events with inter-jurisdictional coordination and legal authority challenges such as a release of chemical agent from BGAD. Generally, under CERCLA removal authority, roles and responsibilities relate to the Army meeting its requirements under the NCP and state and local government entities fulfilling their civil protection duties, as summarized below:

- **Army:** Provides the federal OSC. Responsible for all immediate response efforts and for all efforts directed toward physically addressing the hazard (e.g., firefighting, decontamination, and cleanup). Notifies state and local governments and federal agencies. Coordinates with state and local governments. Has the legal authority and duty to take/support actions to protect life, environment, and property outside of the installation boundary, within the limitations imposed by the NCP and federal law. Responsible for sampling and analysis operations.

- **State and Local Government:** Warns and protects the public. Implements emergency operations plan (EOP). Coordinates with federal OSC regarding off-post sampling and analysis operations and cleanup activities. Makes decisions regarding public reentry and use of any areas affected by the incident.

The OSC, in conjunction with state and local authorities, will establish a UC to coordinate response, share situational awareness and reach consensus decisions on response actions. In accordance with the National Incident Management System (NIMS), the UC will establish objectives that drive incident operations. One operational objective will be to develop and execute a SAP that:

- Meets all applicable or relevant and appropriate requirements (ARARs);
- Considers "how clean is clean" factors (e.g., long versus short time, permanent versus temporary, protectiveness);
- Properly leverages science;
- Considers cost;
- Reflects the needs and viewpoints of the community;
- Considers future use;
- Considers the political climate;
- Considers whether specialized sampling (e.g., in-home air sampling, ambient air sampling, biota sampling) should occur;
- Addresses site access; and
- Considers changing site circumstances (e.g., agent degradation over time).

4.3 Sampling and Analysis Incident Command

Post-release sampling and analysis operations are part of removal site evaluations (RSEs) conducted under 40 CFR 300, the NCP. The Army as lead agency will develop an ESP composed of a field sampling and analysis plan (SAP) and a quality assurance project plan (QAPP). The RSE's purpose is to determine the actual or potential exposure of nearby human populations, animals, and the food chain to chemical agent and related degradation products. The

QAPP ensures that collected sampling data will adequately support decision-making. Chapter 6 provides details on developing both the SAP and the QAPP.

The release's severity and complexity will drive the type of IC/UC staff structure the OSC uses to develop and execute the SAP. For simple releases, the OSC may use only an environmental unit (ENVU) to develop the SAP and guide sampling and analysis operations. As release severity and complexity increases, the OSC will most likely establish a full ICS command and staff structure. In this case, the ENVU would fall under the ICS Planning Section. In both cases, the ENVU prepares the SAP under the direction of the OSC/UC and with input from stakeholders. The ENVU identifies what samples to take, where to take the samples, methods for sample analyses, and what laboratories to engage to conduct the analyses. The ENVU may consist of some combination of the following staff positions:

- ENVU leader, responsible for environmental matters associated with the response, including strategic assessment, modeling, surveillance, environmental monitoring and regulatory approvals, as needed.

- Scientific support coordinator, the principal advisor to the OSC for scientific issues and responsible for providing expertise on chemical hazards, field observations, trajectory analysis, resources at risk, environmental tradeoffs of countermeasures and cleanup methods, and information management. The scientific support coordinator can also serve as the ENVU leader.

- Sampling technical specialists, responsible for providing the sampling plan for the coordinated collection, documentation, storage, transportation, and submittal to appropriate laboratories for analysis or storage.

- Hazard analyst, responsible for providing to the UC projections and estimates of the movement and behavior of the release using a combination of visual observations, monitoring and sampling data, computer modeling, and weather data.

- Data management specialist, responsible for sample tracking, data deliverables, database management, data collation, and data visualization.

- Waste management specialist responsible for providing the OSC/UC with a disposal plan that details the collection, sampling, monitoring, temporary storage, transportation, recycling, and disposal of all anticipated response wastes, including investigation-derived waste (see Chapter 6, Section 6.11.7).

Other potential staff positions to support the sampling operations may include:

- Operation section: Establishes sampling teams to carry out the sampling activity, delivering samples to qualified analytical laboratories, and reporting results back to the Planning Section and UC. Specific assigned positions may include hazardous materials group leader, entry leader, decontamination leader, site access control leader, sampling

group supervisor, technical specialist group supervisor, field sampling teams, sample protocol team, sample tracking team, and sample dissemination team.

- Planning section: Situation unit, resource unit, field observers, and documentation unit.
- Logistics Section (ensures that equipment and resources are available to help carry out the SAP): Communications unit, medical unit, supply unit, and ground support unit.
- Finance and administration section: Tracks costs associated with carrying out the SAP.
- Command staff: PIO and safety officer address public communications and worker safety, respectively.

The OSC or the Operations Section Chief should consider the need to train sampling teams on Army-specific chemical agent sample screening processes prior to their deployment in the field (see Chapter 6, Section 6.6.3). In addition, the OSC or the Operations Section Chief needs to determine access-credentialing requirements for teams to pass access control points into restricted areas.

4.4 Sampling and Analytical Resources

The choice of which sampling and analysis methods are used is directly related to available resources. All sampling methods use similar resources, for example: sample bottles, coolers, ice, distilled water, deionized water, sampling equipment, sample labels, various forms, drinking water, global positioning equipment, cameras and/or video equipment, communications equipment, portable monitoring equipment, decontamination equipment (for both personnel and equipment), cleaning solutions, sampling stations, vehicles, tubs and containers, mailing materials, medical supplies, and several levels (Level A, B, C, D) of PPE. In addition, executing sampling operations requires sufficient trained sampling and sample support personnel (e.g., team leaders, quality control specialists, health and safety specialists, and decontamination personnel).

As a rule, using more sampling teams increases the number of samples per day for analysis. However, more sampling teams also means more sampling supplies needed. Typically, the resourcing effort focuses on major sampling and analytical systems; however, the unavailability of expendable sampling supplies may hinder sampling operations significantly. Thus, maintaining an adequate stock of expendable supplies is a critical resource problem for the OSC/UC group to solve. In any case, sampling equipment, analytical laboratories, materials, and personnel must be readily available for the duration of operations and the rate of sampling should not exceed the throughput of the laboratory or laboratories involved in analysis.

Under the NCP, the OSC has the authority and duty to obtain the necessary resources to conduct sampling and analysis operations. The OSC will first determine whether resource needs can be met by other Army locations or units, the other military services, or federal agencies. In addition to using existing military command structures, the OSC may engage the RRT and the NRT to obtain other service and federal agency resources. For example, through the RRT the OSC could

request that the EPA provide one or more of their mobile Portable High-Throughput Integrated Laboratory Identification System (PHILIS) laboratories to support analysis efforts. Similarly, through either the UC or RRT the OSC could request use of KYNG Civil Support Teams to support both sampling and analysis operations. Potential sources of sampling and analytical support include:

- Army Chemical Materials Activity (CMA) (Aberdeen Proving Ground, Maryland);
- Army 48th Chemical Brigade (Fort Hood, Texas);
- Edgewood Chemical Biological Center (Aberdeen Proving Ground, Maryland);
- Army Public Health Center (Aberdeen Proving Ground, Maryland);
- Army Material Command (Redstone Arsenal, Alabama);
- Joint Munitions Command (Rock Island, Illinois);
- U.S. Northern Command (Colorado Springs, Colorado);
- Other Army bases in Kentucky, other DOD installations in Kentucky;
- EPA Region IV RRT (Atlanta, Georgia);
- U.S. EPA Environmental Response Teams (ERTs) (Edison, New Jersey and Erlanger, Kentucky);
- U.S. Coast Guard (USCG) Gulf Strike Force Coordination Center (Elizabeth City, North Carolina)
- National Guard Civil Support Teams
- U.S. Department of Energy (DOE) facilities, including national laboratories; and
- Special teams available to the OSC through the RRT.

BGAD, as the installation that will provide the OSC, may establish MOUs/MOAs regarding the provision of sampling teams with the listed organizations. If sufficient resources are not available through the sources identified above, the OSC may contract, rent, or lease supplies, equipment, and personnel. Pre-identified sources for contract support for removal operations include:

- USCG Basic Ordering Agreement (www.uscg.mil/SILC/emergency.asp); and
- USACE Indefinite Delivery Indefinite Quantity (IDIQ) (www.sam.gov).

4.5 Specific Roles and Responsibilities

4.5.1 BGAD/OSC

1. Provides the federal OSC.
2. Completes all NCP and AR 50-6 notification requirements.
3. Requests the establishment of an incident-specific RRT. Chairs the incident-specific RRT (if formed). Identifies federal agencies for membership based on their ability to provide advice and support for proposed removal actions.
    a. Identifies officials that represent different jurisdictions, legal authorities and functional areas of responsibility to participate in the UC structure. At minimum, the structure should include:
        i. EPA, FEMA, and other incident specific RRT members;
        ii. KYEM and KDEP; and
        iii. Impacted immediate response zone (IRZ) county EMAs.

   b. Establishes an appropriate incident command and staff structure to manage all removal-related tactical activities, including SAP execution.
   c. Appoints an incident safety officer responsible for coordinating and implementing safety measures, including approving temporary re-entry into restricted areas; establishing personnel protection procedures and controls; and ensuring use of appropriate PPE.
4. Using OSC authorities under the NCP, requests and provides personnel and equipment resources to support monitoring, sampling, and analysis.
5. Leads environmental monitoring, sampling, and analysis in accordance with the NCP and consistent with CSEPP Policy.
6. Meets NCP public information and community engagement requirements (see 40 CFR 300.155).
7. Provides pre-deployment training for sampling teams, as needed.

4.5.2 EPA Region IV

1. When requested, provides technical assistance to the Army OSC, either directly or through the incident-specific RRT.
2. Participates in SAP development and review.
3. Coordinates use of EPA sampling and analysis resources when requested by the OSC.
4. Participates in NCP-driven public information and community engagement activities.

4.5.3 FEMA Region IV

1. When requested, provides technical assistance to the Army OSC, either directly or through the incident-specific RRT.
2. Provides a federal resource coordinator when requested by the OSC.
3. Participates in NCP-driven public information and community engagement activities.

4.5.4 Kentucky Department of Emergency Management

1. Manages and coordinates state-level emergency response and recovery actions in support of local governments in Kentucky.
2. Coordinates use of Commonwealth assets when requested by the OSC.
3. Participates in NCP-driven public information and community engagement activities.
4. Coordinates participation with the KYNG Civil Support Team, or other Title 32 Military Forces, if approved by The Adjutant General.

4.5.5 Kentucky Department for Environmental Protection (KDEP)

1. Provides technical input for SAP development.
2. Provides advice on meeting applicable or relevant and appropriate requirements (ARARs).
3. In accordance with CSEPP Policy, participates in or observes field sampling activities and ensures they are conducted in accordance with the SAP.
4. Coordinates with agricultural agencies to determine sampling and analysis needs to assess pasture, grazing lands, and agricultural products, as appropriate.
5. Participates in NCP-driven public information and community engagement activities.

4.5.6 KYNG Civil Support Team

1. The KYNG 41st Civil Support Team is trained for operations in response to chemical, biological, radioactive or nuclear materials (CBRN) incidents.
2. Provides survey, sampling and analysis capabilities.
3. Advises civilian emergency response authorities.
4. Can also provide logistical and staging recommendations.

4.5.7 Immediate Response Zone (IRZ) Counties

1. Provides county services to persons and organizations affected by the emergency.
2. Coordinates emergency medical service, fire, police, and medical support for the sampling and analytical operation as needed.
3. Makes decisions regarding re-entry to off-post restricted areas and establishing/lifting of general population protective actions. Per local planning, recommendations to re-enter areas that may have been exposed to chemical agent will be made jointly by the Department of the Army, Federal Region IV Regional Response Team, the State Emergency Response Team (ERT), and local officials.
4. Establishes traffic control points and access controls, in coordination with other state and local officials.
5. Assists with resolving access issues in local communities.
6. Coordinates with agricultural concerns as needed.
7. Participates in NCP-driven public information and community engagement activities.

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5 RE-ENTRY AND RECOVERY CONSIDERATIONS

5.1 Chemical Agents and Persistence

The RSAF addresses the unique properties of the chemical agents stored at BGCA, and in particular their propensity to degrade in the environment. The EPA refers to this process as "natural attenuation." Natural attenuation accounts for a chemical's persistence in the environment; the more persistent a chemical is, the longer it will remain.

The Army describes two of the agents as persistent. For example, the Army has said that VX is "a persistent, terrain denial military compound with the potential to off-gas toxic vapor for days following surface application." Similarly, the Army has indicated that mustard "can be persistent in the environment" (CSEPP 2012).

In a military application, delivery would occur via some type of munition that causes heavy agent concentrations at targeted locations. The Army's perception of persistence relates to when soldiers can safely enter those targeted areas. From this viewpoint, persistence of VX especially, and to a lesser extent mustard, is high, especially following a relatively heavy application. In contrast to the military application, a CAI with an off-post release would cause an agent plume that mixes with and becomes diluted by air. Over time, this settles in a large area, possibly resulting in aerosol droplets depositing on surfaces in a relatively thin layer.

It is important to put environmental persistence into perspective. A good example is polychlorinated biphenyls (PCBs), one of the more common contaminants at hazardous waste sites. PCBs are associated with very high persistence; they last for many years, even decades, in the environment before eventually being broken down by natural attenuation. In contrast, mustard and VX persistency is typically measured in weeks or months, in some climates perhaps a year or more. In this context, mustard and VX would actually be considered moderately persistent; GB would disappear in a matter of hours or days and would be considered non-persistent. Appendix B presents Quick Reference Guides for the agents, which the EPA's NRT developed to address some of these properties. Appendix C presents a detailed discussion of the persistence of the agents stored at BGAD.

The rate of degradation of the agents if released to the environment depends upon release characteristics (e.g., vapor presence, droplet size). It is also a function of ambient conditions, primarily temperature and moisture, including relative humidity, rain, ice, snow, wind speed, and sunlight. Higher temperatures and the presence of moisture will increase the rate of degradation. Agent degradation products in turn degrade over time, and the rate of degradation will increase as a function of temperature and moisture. Hence, several realities must be considered in designing and implementing the RSAF:

- It may take up to several days or more to organize sampling teams, garner resources needed to support sampling operations, and arrange for analytical laboratories. During this time, and depending on the agent and weather conditions, it becomes important to target both agent and degradation products.

- The concentrations of agent and degradation products, assuming they are detected above action levels in samples submitted to the laboratory, will decrease over time, perhaps to the point of being below action levels or even limits of detection sometime after the initial CAI.

- Should a hotspot of agent or degradation product be found on some parcel of land during initial sampling, results from sampling teams sent to the same area for more samples at a later date are likely to show lower concentrations of both agent and degradation products.

- The action levels developed for the agents and degradation products are predicated on long-term "chronic" exposure (see Chapter 6, Section 6.3). However, there is no reasonable scenario in which the affected population would be exposed to agent or degradation products over their lifetime. Application of chronic health-based action levels (see Section 6.3) to a CAI release scenario may be considered highly conservative in this sense.

- Should agent or degradation product be detected above action levels and decision makers determine that some sort of removal or remedial action is warranted, an additional option to consider is whether allowing a period of time to pass—allowing natural attenuation to occur—might be effective in reducing concentrations to below action levels.

With respect to this last item, it is important to evaluate the time it takes to develop a removal or remedial approach, get it approved by decision makers, hire contractors to carry it out, complete the action, and determine its effectiveness. By the time all of this is accomplished, time and natural attenuation may have reduced agent and degradation products to lower levels, perhaps below levels of concern. Also consider that active removal, such as scooping up and disposing of the top layers of soil, or active remediation, such as applying decontamination fluid over an area, is likely to be highly destructive to the natural environment. On the other hand, allowing time and natural attenuation to reduce agent and degradation product to below action levels could keep the evacuated public from their properties for an extended period. Regardless of the ultimate approach taken, time and natural attenuation should be considered in designing a sampling plan and in determining removal or remedial actions.

5.2 Environment and Critical Infrastructure

Much of the information presented in this section is taken from a recent environmental assessment performed in support of emplacement of explosive destruction technologies for the disposal of mustard munitions at BGAD (BGAD 2013).

Figure 5-1 shows the location of BGAD in east-central Kentucky. The terrain surrounding BGAD consists of gentle rolling hills. BGAD itself is located on nearly 15,000 acres east-southeast of Richmond, Kentucky, and is composed mostly of open fields and woodlands.

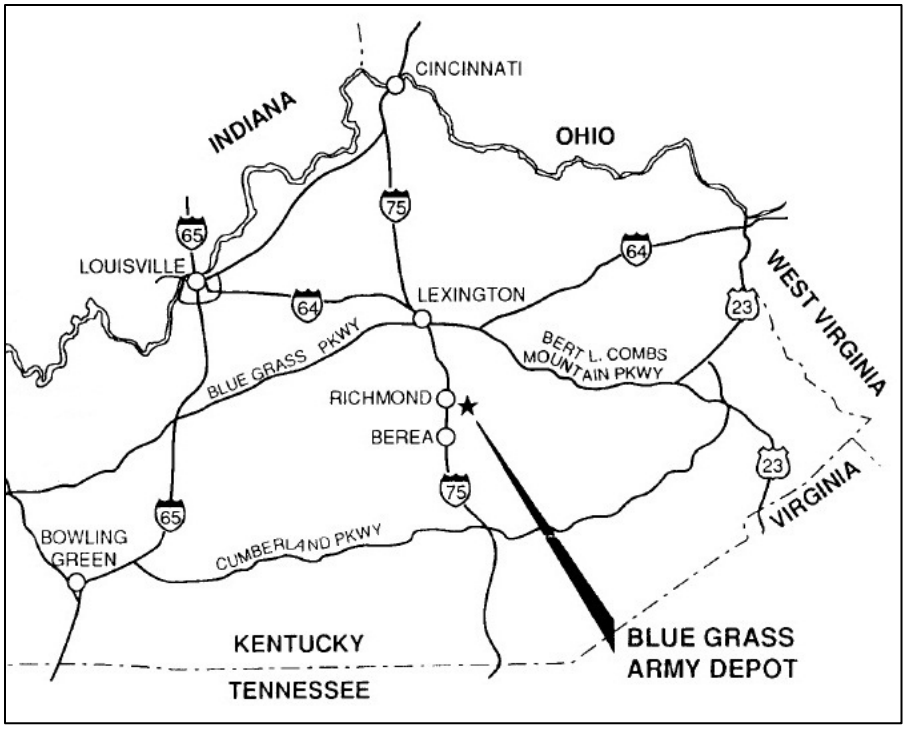

Figure 5-1. Location of BGAD within the Commonwealth of Kentucky (from BGAD 2013)

BGAD is within the Kentucky River basin and is drained by the tributaries of three shallow-water creeks that flow intermittently and are typically dry during the late summer and into early fall (BGAD 2013).

The climate in this area is a humid subtropical climate characterized by hot, humid summers and generally mild to cool winters. The average annual rainfall is 45 inches, spread evenly throughout the year. Average snowfall is 13 inches. From April through October, relative humidity percentages are in the upper 50s. In November through February, relative humidity percentages are higher, in the mid-70s. The average daily temperature is 36.6°F in January and 77.0°F in July. The maximum observed temperature on record is 108°F, and the minimum observed temperature is -24°F.

Vegetation in the area ranges from grassland species to forest trees typical of the Cumberland Mountains to the east of the installation. The three main woodland types are upland, riparian, and flatwood.

Wildlife includes animals typical of the Cumberland Mountains, including white tail deer, rabbits, squirrels, other mammals, amphibians, soil invertebrates, and many insect and bird species (BGAD 2013). Of special concern are threatened or endangered species that are present in the area; sampling activities should avoid interfering with them. These species are reviewed in the aforementioned environmental assessment (BGAD 2013).

A release of chemical agent off-post from BGAD will affect different areas. Which areas are affected will depend primarily on the characteristics of the release, and prevailing winds and weather conditions immediately before, during and, after the release.

Figure 5-2 presents a wind rose for BGAD, showing the distribution of wind speeds and directions during the hours when chemical munitions are transported. The prevailing winds are from the southwest to the northeast. However, the wind rose shows that winds can come from other directions as well.

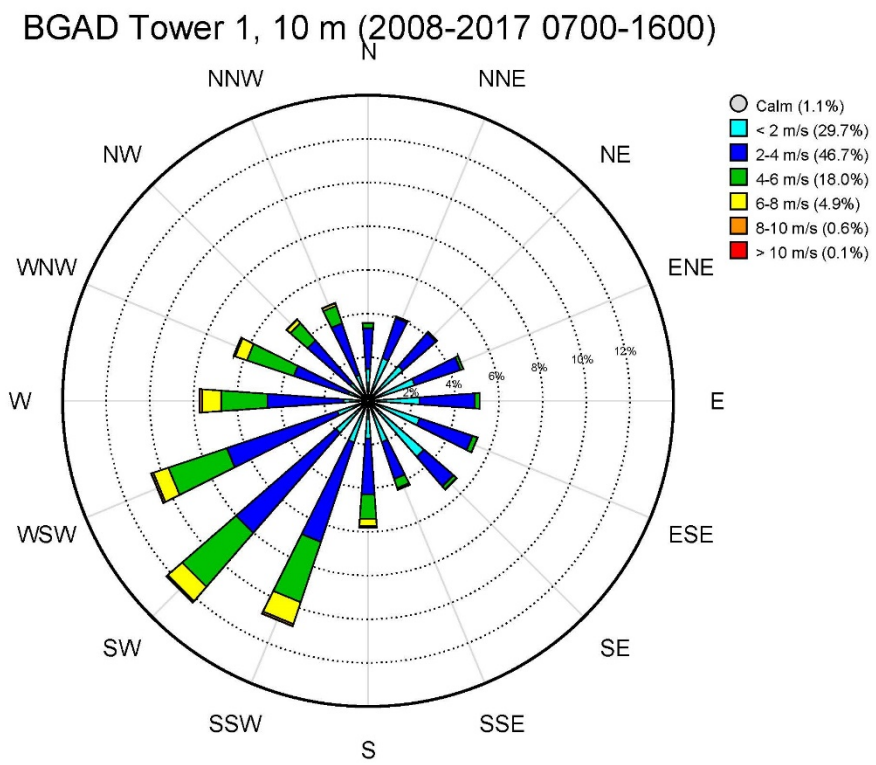

Figure 5-2. Wind Rose for BGAD

Following a CAI at BGAD, the plume could go in any direction and for any distance, depending on the wind direction, speed, and turbulence at the time. Hence, it is important to understand the physical environment and critical infrastructure in a 360° circle around the installation.

Figure 5-3 shows BGAD and the 26 CSEPP emergency response zones (ERZs) established around it, along with evacuation routes and relocation centers. These ERZs cover ten counties in Kentucky. Madison County, where BGAD is located, and the northwest portion of Estill County are closest to BGAD and make up the IRZ. Areas in Clark, Estill, Fayette, Garrard, Jackson, Powell, and Rockcastle counties are included in the Protective Action Zone (PAZ). Jessamine and Laurel Counties are host counties, in which citizens of the IRZ or PAZ may be temporarily relocated should a CAI occur at BGAD.

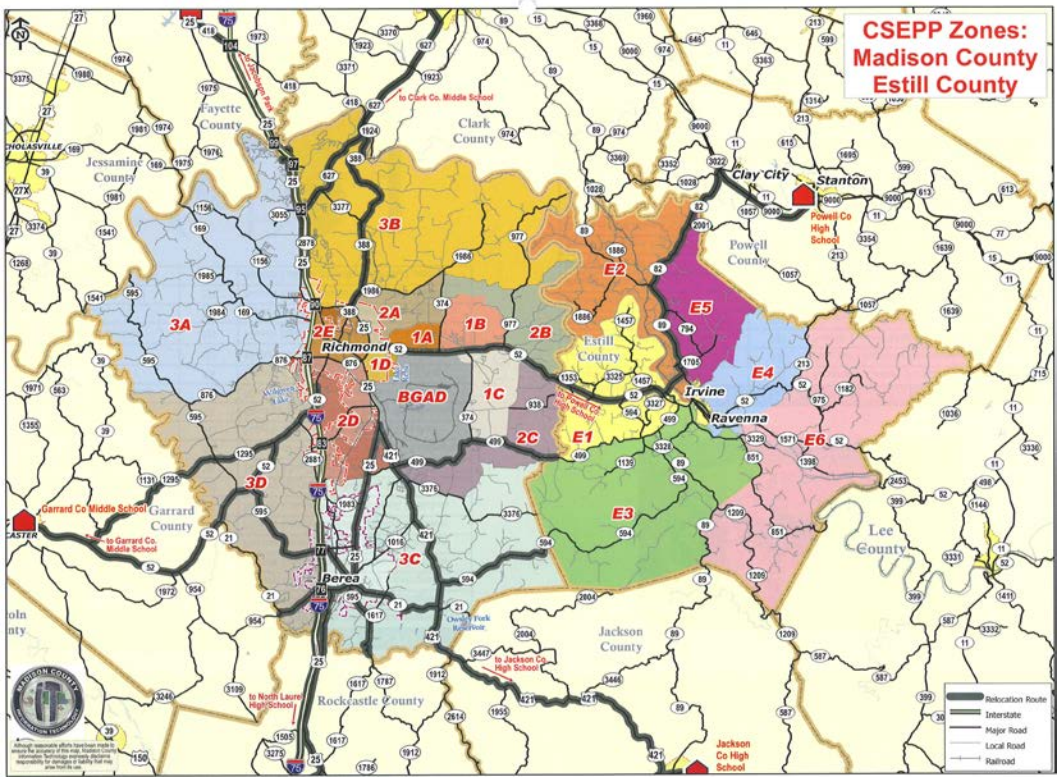

Figure 5-3. ERZs, Madison and Estill Counties (from CSEPP 2017)

The 26 CSEPP ERZs contain a number of residential communities. The city of Richmond, located within Madison County, lies just to the northwest of BGAD. The city of Berea, also located within Madison County, lies south and southwest of BGAD. There are many smaller towns as well. There are numerous farms and woodlands, and many small streams within each of the zones. Some of the zones contain lakes and reservoirs. There are also two interstate highways, many main and secondary roads, and rail lines. Many of the zones also contain government centers, schools, childcare facilities, adult day care, nursing homes, assisted living facilities, and police and fire stations. Eastern Kentucky University is located within Richmond and Berea College within Berea. There are many small and large businesses, several utility locations, and substations throughout the general area.

Should a CAI originate from BGAD, the plume is most likely to move in a northeasterly direction, but it could travel in any direction. What this means for the sampling operation is that the Blue Grass CSEPP Community needs to be prepared to sample in all areas, with potentially different strategies for communities, neighborhoods, individual houses, business areas, roads, streams and lakes, farm areas, woodlands, government centers, utility locations, and sensitive population locations, especially schools and nursing homes. Further, different sampling strategies may be developed to sample the outside and inside of homes and buildings. Sample design is discussed in Chapter 6, Section 6.4. BGAD's location within a humid continental climate with warm summers and cool winters with abundant rainfall makes any release from a CAI particularly susceptible to agent degradation.

5.3 Political Environment

In the aftermath of a CAI at BGAD, officials should expect a high degree of public interest in, and scrutiny of, the process of determining the safety of affected areas. Apart from public officials representing their constituencies, nongovernmental groups and individuals in the area would follow events and provide input and commentary through public hearings (if conducted) and through social and traditional media.

Specific groups that would likely provide feedback regarding post-emergency hazard assessment and recovery measures include the CAC/CDCAB and Kentucky Environmental Foundation Chemical Weapons Working Group.

The Citizens Advisory Commission (CAC), established by Kentucky statute in 1994, comprises nine members appointed by the governor. The Chemical Destruction Citizens Advisory Board (CDCAB) was formed in 2003 and functions as a subcommittee of the CAC to provide broader stakeholder involvement from a range of local organizations. These include government, civic, medical, emergency management, university, and school representatives. Of these CDCAB members, 24 are voting members and seven are representatives of the agencies being advised by the body. The CAC/CDCAB members meet jointly four times a year (National Academy of Sciences 2106, pp. 21-22; PEO ACWA 2017). The CAC/CDCAB has had a longstanding advisory role representing local public interests during design and implementation of the chemical demilitarization process at Blue Grass.

The Kentucky Environmental Foundation Chemical Weapons Working Group, likewise, has a long-established role as a public interest group that monitors the chemical demilitarization process. The group (formerly two separate groups) lobbied to avoid incineration of the weapons at Blue Grass, in favor of the current alternative technology, which it considers safer (KEF CWWG 2018).

5.4 Surrounding Human Population

CSEPP has designated off-post areas that are potentially at risk from a chemical event at BGAD. These areas are the subject of chemical-specific emergency preparedness plans and preparedness measures. As mentioned above, the off-post area of concern is divided into zones. The IRZ is the close-in zone; it includes BGAD itself along with portions of Madison County and Estill County, and extends up to 12.1 miles from the chemical storage areas at BGAD. This area would have less than one hour to implement protective actions in the event of a release. Short response time in this area requires rapid notification, public awareness of emergency guidelines, and significant emergency response training. Evacuation may not be possible (Madison County 2014a, p. 6).

The PAZ surrounds the IRZ and extends approximately 10 to 30 miles from chemical storage areas at BGAD. One hour or more may be available to implement protective actions in this area in the event of a release. Evacuation should be feasible under most circumstances (Madison County 2014a, p. 6). The PAZ includes portions of eight counties: Madison, Estill, Clark, Fayette, Garrard, Jackson, Powell, and Rockcastle. All of Madison County is in either the IRZ or PAZ. All of Estill County is in either the IRZ or PAZ.

5.4.1 Madison County Demographics

5.4.1.1 General Population

Madison County has a total population of about 83,000 residents, based on the 2010 census. The two largest cities in the county are Richmond (population 31,360) and Berea (population 13,561). Richmond is in the IRZ and Berea is in the PAZ.[3]

5.4.1.2 Special Populations

Schools: Detailed information and mapped locations are contained in specific Implementing Guidelines and in Standard Operating Guide documents located in the Madison County Emergency Operations Center (EOC).

- K–12 Schools—The Madison County EOP lists 19 county system schools (elementary, middle, and high schools) with a combined total of 12,365 students. In addition, the EOP indicates the Berea Community School System has approximately 1,200 students in grades K–12, and there are five private schools within the Richmond city limits. One private school has approximately 750 students and the others each have 150 or fewer students.

- Colleges—Eastern Kentucky University has approximately 16,000 students and 2,100 employees in Richmond. Its 14 residence halls house approximately 4,300 students. Berea College has approximately 1,500 students and 550 employees in Berea. Its 16 resident halls house approximately 1,300 students.

Childcare Facilities: At any one time, 35–40 childcare facilities operate throughout Madison County, caring for 2,500–3,000 children from infants through pre-school age. The Madison County EMA tracks these facilities and maintains detailed information regarding their emergency plans, relocation/evacuation routes, point-of-contact information, and population statistics. This information is maintained in Implementing Guidelines, Standard Operating Guidelines, and other "job aid" documents located in the Madison County EOC. Daycare coordinators (volunteers from the professional daycare staffs) report to the EOC as requested when the EOC is activated and daycare populations may be affected.

Access and Functional Needs Population: The Madison County EMA Access and Functional Needs (AFN) Coordinator maintains a database of people with access and functional needs. Members of the community voluntarily submit information to be included in the database. In addition, MEPCO Home Health, which is under the Madison County Health Department, provides its list of home health patients to be included in the AFN database.
Access and functional needs people are defined in the Madison County EOP (Madison County 2014b) as, "Persons who may have additional needs before, during and after an incident in functional areas, including but not limited to: maintaining independence, communication,

[3] Population information and information about schools, childcare facilities, healthcare facilities, and AFN populations is from the Madison County EOP (Madison County 2014b).

transportation, supervision, and medical care. Individuals in need of additional response assistance may include those who have disabilities; live in institutionalized settings; are seniors; are children; are from diverse cultures; have limited English proficiency or are non-English speaking; or are transportation disadvantaged." The AFN Coordinator is included in the alert roster for emergencies and follows specific implementing guidelines maintained in the Madison County EOC to ensure care of persons with access and functional needs during an emergency.

Based on reports provided from the Madison County Health Department, home health agencies, and the voluntary database maintained at the Madison County EMA Office, the population of people with access and functional needs can vary between approximately 500 and 1,000 individuals.

Madison County is also home to a number of assisted living centers in which the majority of residents have access and functional needs, and daytime adult care centers. Fifteen such facilities are listed in the EOP.

5.4.2 Estill County Demographics

General population: The county population in July 2009 was 14,859, of which 27% was urban and 73% was rural.[4]

Special populations living in group situations include 93 people in nursing homes, 24 people in local jails and other confinement facilities (including police lockups), and 21 people in other non-institutional group quarters.

Estill County has one hospital, Marcum and Wallace Memorial, in Irvine, and 76 churches. The County EOP mentions two schools, Estill Springs Elementary School and Estill County High School. The Estill CSEPP Incident-Specific Plan indicates that known daycare centers in the county have received all-hazards alert radios (weather radios) and SIP kits to aid in SIP operations.

4 Estill County demographics are from the Estill County EOP (Estill County 2016a) or the Estill County CSEPP Incident Specific Plan (Estill County 2016b).

6 PRE-EVENT RSAF

This chapter presents all the elements of the sampling and analysis effort. Primary considerations in focusing the effort include the following:

- Agent involved;
- Magnitude of the event (e.g., confirmed agent deposition);
- Extent and dimensions of plume offsite and deposition footprint;
- Jurisdictions affected;
- Whether populations SIP, evacuate, or both;
- Need for temporary re-entry;
- Time of year and time of day; and
- Weather conditions before, during, and after the event.

Figure 6-1 presents the general approach for using the RSAF. Following a CAI, BGCA hazard analysts would use WebPuff to model agent dispersion. Discrete areas potentially affected by an agent plume would then be subject to sampling and analysis to determine whether there is measurable deposition and whether contamination is above action levels. If contamination is not above action levels, then community officials can consider unconditional re-entry. If contamination is found above action levels, community officials would consider some form of removal or remediation (including natural attenuation) and implement access controls to preclude exposure during implementation. Once contamination has been reduced to below action level concentrations, as determined through more sampling and analysis, community officials could consider unconditional re-entry. The subsections that follow provide details for this decision-making process.

One can assume that those involved in developing and implementing the sampling activity will operate under some form of an ICS structure, as described in Chapter 4. Therefore, this chapter uses the term “Planning Section” to identify the staff who produce the sampling design and develop the sampling plan.

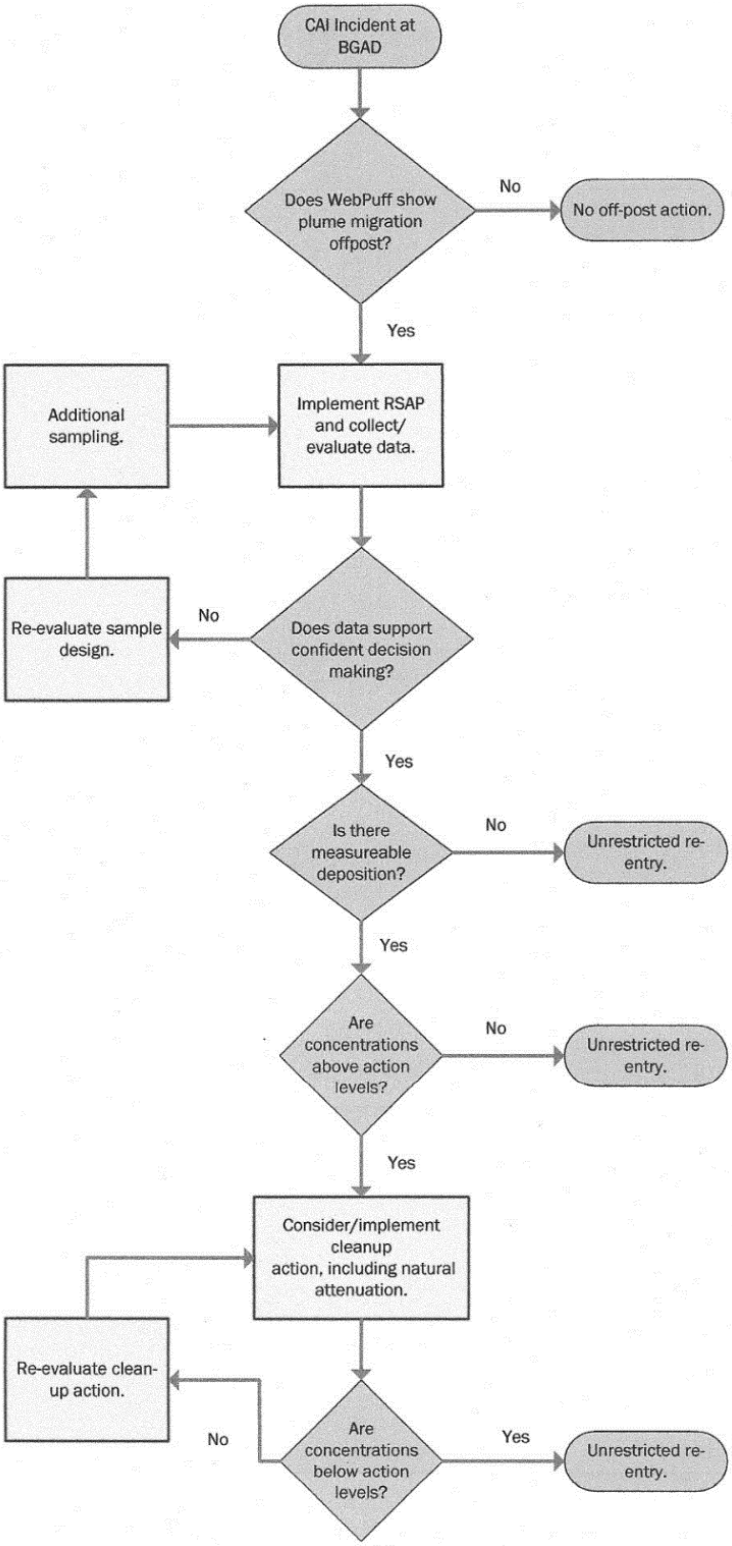

Figure 6-1. General Depiction of RSAF Response

6.1 Develop the CSM and Establish Decision Units (DUs)

A CSM provides information about a hazardous material release and the area affected by it. It is a qualitative tool, incorporating quantitative data (as needed), that will help the Blue Grass CSEPP Community understand the nature of the CAI and what may have been impacted, and serve as a foundation for the sampling and analysis plan. A CSM identifies:

- COCs;
- Sources of COCs (the source term);
- Release mechanisms (nature of the CAI);
- Extent of possible contamination (plume footprint) over a base map;
- Contamination transport mechanisms (wind, rain, runoff);
- Media impacted (air, water, soil, sediment, vegetation);
- PADs;
- Potentially impacted communities, transportation routes, farms, woodlands, surface waters, homes, buildings, and other structures;
- Traffic control points; and
- Potentially affected critical infrastructure.

There are different types of CSMs. They can consist of text, tables, figures, graphs, maps or combinations of these. For the purposes of this RSAF, an exposure-based CSM should be developed. The CSM represents, in a conceptual way:

- Ambient weather conditions (e.g., relative humidity, precipitation, temperature, wind speed and direction) prior to, during, and after the release;
- Agent released and degradation products;
- Accident or incident and release characteristics (explosion, fire, etc.);
- Area encompassed by the plume showing potential vapor and depositional areas;
- PAZs transected by the plume;
- Potentially exposed areas and populations;
- Exposure routes;
- PADs;
- Likely agent concentrations in vapor plume/depositional areas; and
- Passage of time and COC degradation.

Passage of time and COC degradation is a key concern to depict in the CSM. As noted in Chapter 5 and Appendix C, upon release into the environment, the agent begins to change via natural attenuation processes, forming degradation products. Because both the agents and degradation products degrade over time, adjustments to the CSM should occur periodically so that it represents current conditions. The CSM is therefore dynamic and requires periodic updates, as the CAI hazard is assessed, evaluated, addressed, and mitigated.

An example CSM based on a CAI at BGAD appears in Appendix D.

6.1.1 Establish Plume Footprint/Potential Depositional Areas

The CSM is initially based on plume modeling (WebPuff). The Kentucky CSEPP workgroup discussed plume modeling at length. The WebPuff model, developed by Innovative Emergency Management, Inc. (IEM undated), is a fully developed and approved plume model that has been in use within the CSEPP program for many years. WebPuff provides a conservatively safe estimate of the agent concentrations in air resulting from the CAI. It uses human health-based AEGLs developed for agents in air with three different contours. The AEGL 3 footprint is most severe, the AEGL 2 footprint is of moderate concern, and the AEGL 1 footprint is of minor concern. AEGLs for the agents are presented in Appendix E.

WebPuff output is used to make protective action recommendations (PARs) and PADs. The AEGL contours from WebPuff can also be used as the starting point for bounding the sampling plan and determining the deposition footprint. However, since the WebPuff model is designed to be conservatively safe, it will tend to overestimate the extent of affected areas, and may include areas that are very unlikely to have been impacted by agent deposition. Use of WebPuff depictions in support of creating and updating the CSM for recovery sampling may therefore result in a CSM that over predicts areas actually impacted by deposition and could unnecessarily waste time and resources by prompting sampling in outlying areas unlikely to have been impacted by deposition.[5]

The Army's Joint Effects Model (JEM) was also discussed during the BPI sessions as a means of supplementing WebPuff. The JEM was developed for use when facing release situations similar to a CAI. JEM can model ground contamination caused by chemical weapons incidents (Joint PEO, Chemical and Biological Defense 2017). More complex and time-consuming to run than WebPuff, the JEM model would more accurately depict areas impacted by the deposition of agent resulting from a release (i.e., the deposition footprint). The JEM model would use the same release terms and meteorological conditions that serve as inputs to WebPuff but would result in a deposition footprint that is likely to be smaller than and within the WebPuff AEGL 2/3 footprint. JEM can be run at the Defense Threat Reduction Agency (DTRA) but is currently unavailable at the installation level or at county EOCs. Nevertheless, JEM has been selected to be used in conjunction with WebPuff to allow refinement of the CSM. WebPuff would continue to be used as a conservative model to facilitate development of PARs and PADs.

Running JEM as a basis for determining where to sample would be appropriate. However, if sampling in the outer areas identified by JEM results in agent or degradation product detections, areas included within the WebPuff AEGL 2/3 plume beyond the JEM footprint should be sampled as well. Hence, sampling could take place outside the JEM footprint in these instances.

The primary inputs into the dynamic CSM will therefore be both the WebPuff and the JEM footprint depictions. After an incident occurs, WebPuff depictions of the incident will be

[5] Note that a WebPuff vapor deposition function is being developed and may at some point in the future be considered for use in place of or as a supplement to JEM. The WebPuff deposition component was not, however, discussed with the Kentucky CSEPP workgroup during the BPI presentations.

generated by the on-post EOC. The WebPuff depiction is transmitted to off-post EOCs. Similarly, JEM model deposition footprint outputs can be transmitted to off-post EOCs.

The Planning Section can then incorporate these plume model depictions into the CSM, showing the footprint that will be the focus of the sampling and analytical effort. In addition, the CSM can then identify what are termed "focus areas." Focus areas could be incorporated into the sampling plan but may not necessarily be located inside the JEM-depicted depositional footprint. Focus areas can include, but are not limited to the following:

- Vulnerable populations (e.g., schools, nursing homes, daycare facilities, and hospitals);
- Property with livestock;
- Government centers;
- Critical infrastructure; and
- Major employers.

Focus areas may not always be located within a plume footprint. An awareness of the location of the focus areas is necessary to inform those developing the sampling plan during refinement of the CSM and the development of the sampling and analytical plan.

6.1.2 Evaluate Data and Information Collected During Response

The Planning Section will also take into consideration other information sources while refining the CSM and creating a sampling and analysis plan. Valuable information will be available for consideration including:

- The results of any visual/physical examination of the CAI site by BGAD personnel;
- Closed circuit television or traffic camera footage of the incident;
- Depot area air monitoring system (DAAMS) results;
- On-post real-time analytical platform (RTAP) monitoring results;
- Observations by the general public and emergency responders; and
- Observations as relayed by unmanned aerial vehicles (UAVs), stationary cameras, or helicopter flyovers.

The Planning Section can combine this information with the WebPuff and JEM footprint depictions to serve as a starting point for the use of the software sampling design platform VSP. The Planning Section will use VSP to develop and guide sampling efforts to characterize the agent release. Section 6.4 provides a detailed discussion about the mechanics of using VSP.

6.1.3 Consider Possible Secondary Hazards

As part of any planning process for implementing a sampling and analysis plan, the Operations Section and Safety Officer will need to identify other (non-agent) hazards that sampling teams may be subject to during implementation of the sampling effort. Examples include traffic hazards; wildlife; slips, trips, or falls; drowning hazards (if sampling in Lake Reba or other water bodies); electrical hazards; hazards due to extreme temperatures; and hazards from conventional non-agent contaminants at industrial facilities. In accordance with a health and safety plan

(HASP) (see Section 6.6), the sampling team will wear PPE that will afford protection from both agent and from most conventional hazards.

6.1.4 Define Nature and Extent of Release—the Source Term

The CSM should be used to help define the source term—the site of the CAI. The CSM will continue to be refined as more information is gathered. The VSP-directed sampling efforts may involve several iterative sampling events with later events informed by the results from prior events. The initial sampling event will involve the collection of samples from agreed-upon locations within the JEM deposition footprint and other areas. Information gathered during the initial sampling event will involve both hard data and other information that will used to make subsequent decisions regarding re-entry.

6.1.5 Consider Implemented Protective Actions

The possible protective actions implemented after a release include SIP and evacuation. The case has been made within the Blue Grass CSEPP Community that should a CAI originate from BGAD, there is insufficient time within the IRZs (Madison and Estill counties) to support an effective, timely evacuation (CSEPP 2016a). Instead of evacuation, the affected populations would be directed to SIP (see Figure 6-2).

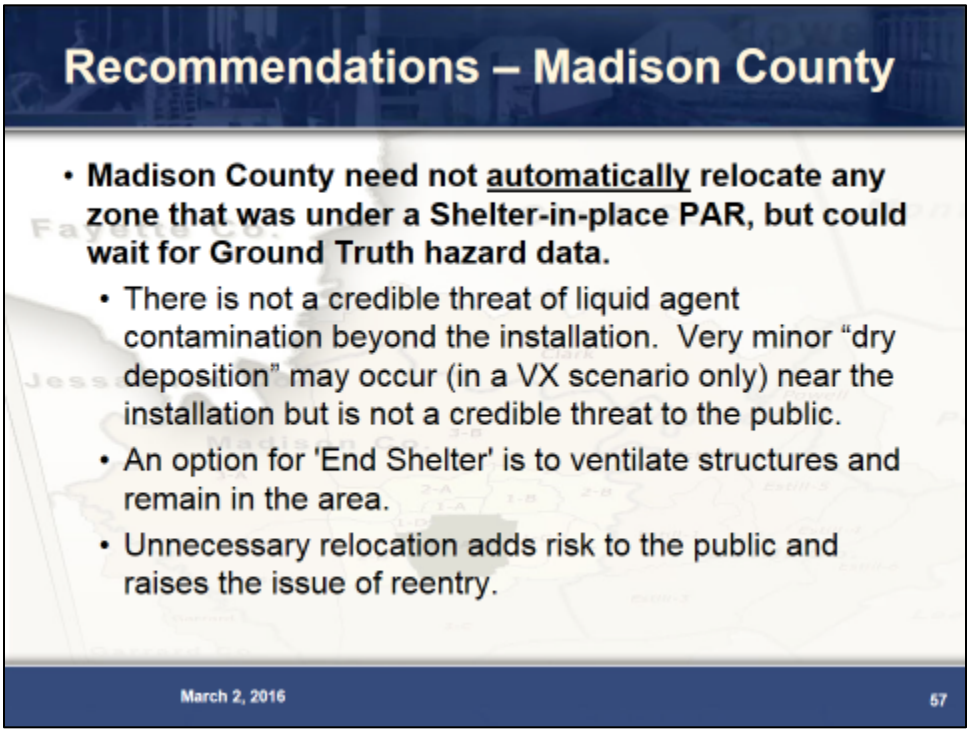

Figure 6-2. Recommendations—Madison County (CSEPP 2016a)

As indicated in Figure 6-2, those who SIP would eventually be directed to end shelter, ventilate the house or building, and remain in the area. Though unlikely, another scenario might involve relocating those who SIP.

The CSM should identify locations where SIP and relocation or evacuation has been implemented. A different sample design may be developed for these areas. For example, decision makers may want a higher sample density in locations where hot spots of contamination have been confirmed and/or people have evacuated.

6.1.6 Consider Influence of Season, Weather, and Timing (Natural Attenuation)

As indicated in Chapter 5 and Appendix C, the natural processes that cause a compound to degrade are typically referred to as “natural attenuation.” The rate at which agents and degradation products disappear from the environment depends on chemical properties and on environmental factors. Most notably, an increase in temperature and humidity increases the degradation rate. Here are some examples:

- GB is the most volatile and least persistent of all the agents stored at BGCA, with a half-life on concrete and soil of two hours and two days, respectively.
- VX also degrades in the environment, with a half-life of 99 days at pH 6, and a half-life of 41.5 days at pH 7.
- In a wet (e.g., rain or fog) or moist environment (moderate to high humidity), mustard in the dispersed form is known to hydrolyze (break down in water) rapidly.

Even the degradation products from the agents will degrade after a period of weeks or months. Because these COCs attenuate in the environment, the Planning Section will need to factor natural attenuation into the CSM. The ratio of agent to degradation product is relevant while the CSM is being refined post-release and comes into play for making decisions about post-release actions, including re-entry and removal or remedial (remediation) actions. For example, nature could be allowed to take its course. Agent and degradation products would diminish over time to safe levels in lieu of performing active remediation.

6.1.7 Put It All Together in a CSM

Appendix D includes an example CSM. The CSM leads to the identification of areas and environmental media that must be sampled to be able to make re-entry decisions (Figure D-1).

The graphic depiction of the CSM will include four visual mapping elements. The first element is a base map with all needed information, including focus areas, pre-plotted. This base map can be generated ahead of time. Use of the ESRI Geographic Information System (GIS) or similar software is recommended for this purpose (see https://www.esri.com/en-us/home).

The remaining three elements would be generated at the time of and during the incident. These three elements are the WebPuff plume, the JEM deposition footprint, and iterations of output from the VSP software. Section 6.4 presents more about the VSP is presented.

The plume depictions are laid over the base map and would be brought into the VSP. This fusion of the base map, plume models, and VSP output will serve as the graphic representation of the CSM. Along with text descriptions and other information (weight of evidence), these constitute the CSM, which can then subsequently be broken down into what are known as decision units (DUs) (see Section 6.1.8).

6.1.8 Break CSM Down into Manageable DUs

Given the potentially large area encompassed by a plume footprint, the area is typically broken down into smaller parts called decision units (DUs). Establishing decision units promotes efficient sampling strategies, data management, and decision making.

DUs can be established for relatively large or small areas. Examples include a residential lot, a portion of a neighborhood, an entire neighborhood, a portion of a town or county, an entire town or county, and an evacuation zone or portions of a zone. A DU could also be based entirely on statistics and the size of the sampling grid, irrespective of what is included within.

Initially, DUs based on the 26 PAZs would be established for the area surrounding BGAD. Additional, smaller sub-decision units (SDUs) would then be established for residential lots, individual communities, relocation routes, water bodies, farms, woodlands, and similar areas within each DU. The DUs and SDUs will be identified post-incident based on the JEM footprint, AEGL concentrations, zones affected, and individual characteristics of these zones.

Decision making should proceed by SDU as soon as sufficient data of adequate quality are available to support decision making. Decisions should also consider any specific property owner requests, even if they are outside specific DUs or SDUs. Samples should also consider focus areas (e.g., schools, hospitals, utilities, government centers) within a DU even if they are outside the plume depositional footprint.

Due to high demand for sampling support and potentially limited sampling and analysis resources, prioritizing sampling and analysis actions based on defined established criteria should be considered. An example of such triaging follows (note, this is only an example; priorities would be determined at the time based on event-specific circumstances):

- High-priority samples—Areas within the JEM depositional plume footprint.
- Moderate-priority samples—Evacuation or SIP zones with at least one portion of the zone within the JEM depositional plume footprint.
- Low-priority samples—Evacuation or SIP zones that have no portion of the zone directly within the JEM depositional plume footprint.

6.2 Data Quality Objectives (DQOs)

6.2.1 Introduction to DQOs

The EPA developed and refined the DQO process as a means of ensuring that the type, quality, and quantity of environmental data collected during an environmental investigation will support

decision making (EPA 2006b). The process is a systematic procedure consisting of seven steps that establish criteria for project data quality that inform the development of data collection strategies. Resulting DQOs guide data collection strategies. Use of the DQO process helps to improve the effectiveness, efficiency, and defensibility of decisions throughout the course of an environmental investigation. It is especially useful for complex applications, such as those that would take place following a CAI release off-post. The Army has adopted the DQO process to facilitate the planning of environmental data collection activities (USACE 2014).

The primary outcomes of the DQO process are descriptions of what data to collect, where to collect samples, when to collect samples, a means of dealing with the uncertainty in the data to be collected, and ultimately, a general design for data collection. Figure 6-3 presents the seven-step DQO process.

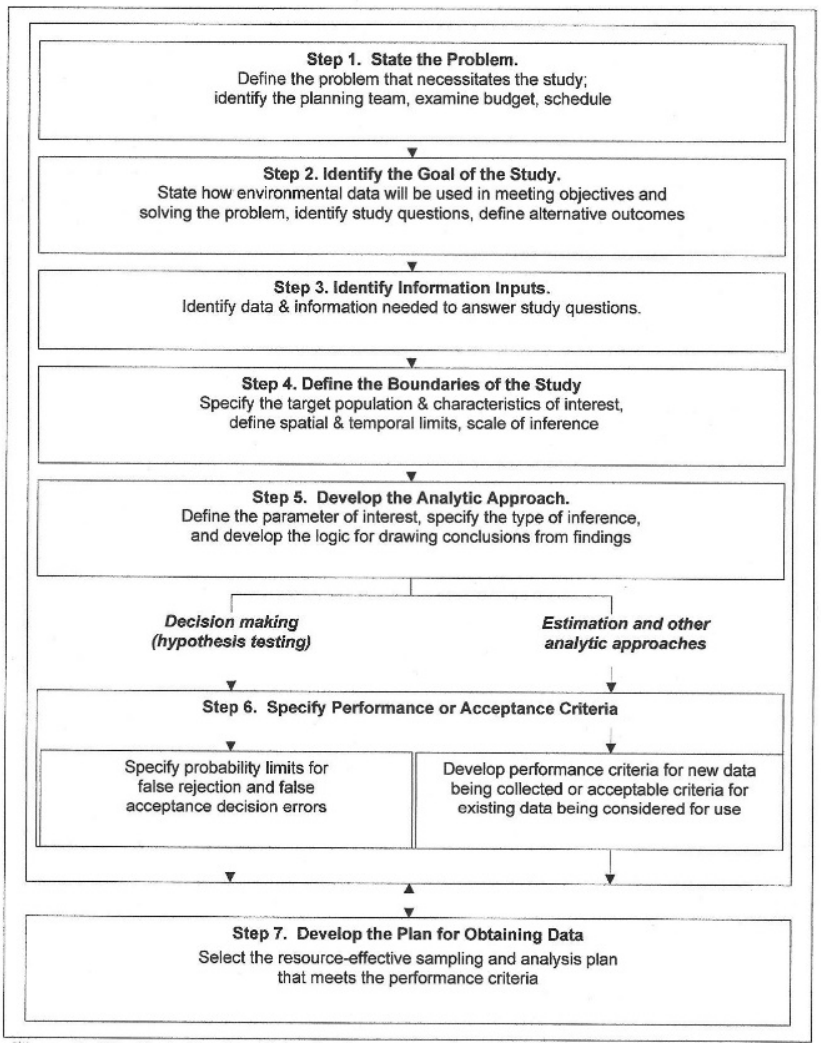

Figure 6-3. DQO Seven-Step Process (as shown in EPA 2006b)

The following sections summarize how the seven steps would be carried out in response to a BGAD CAI that results in an off-post plume.

6.2.2 Step 1—State the Problem

In the off-post CAI scenario, the problem may be simply stated:

> A CAI has occurred at BGAD within the chemical limited area, and WebPuff modeling shows that the plume has migrated off-post. The plume extends into one or more PAZs. Deposition of the agent as a vapor or small aerosol droplets may have occurred onto soil, vegetation, surface water, and into populated areas, both residential and commercial. Sampling and analysis is required to determine potential deposition.

By the time sampling and analysis begins, it is likely one or more days will have passed after the event and the plume has dissipated. By this time:

- Some portion of the population may have SIP and others may have evacuated;
- An off-post response would have been established under the DHS's ICS, and an OSC would have been identified;
- The Planning Section would have established an initial CSM based on WebPuff and JEM, showing potentially impacted PAZs and DUs/SDUs, and would be beginning to plan the sampling and analytical effort;
- The Planning Section would have set up initial hot, warm, and cold boundaries based on WebPuff and JEM concentration contours; and
- The Logistic Section would have begun to mobilize resources (discussed in Chapter 4) to carry out the RSAF effort.

It is also important here to identify the decision makers. It is most likely that a UC structure or a MACG would be used to engage state and local officials and help come to consensus on sample designs, re-entry, and related decisions (see Chapter 4).

Note that if any areas are evacuated or relocated beyond a few hours' duration, some form of temporary re-entry may need to be considered. Short-term excursions may be required to assess critical infrastructure, tend to livestock, or carry out some other essential function. Temporary re-entry is addressed in Chapter 7.

6.2.3 Step 2—Identify the Decision

The primary goal of the investigation is to determine, in as little time as possible, whether impacted areas are safe for unrestricted re-entry or whether some type of removal or remedial action should be considered before granting unrestricted re-entry. Considering the tendency of the agents to degrade, natural attenuation may be considered as a replacement for or in addition to more active forms of removal (e.g., removal of the top several inches of soil) or remedial action (e.g., chemical decontamination). A secondary goal may be to determine what areas were affected by the chemical agent plume, although they are now safe.

The re-entry determination revolves around action levels (Section 6.3) and considers other evidence, such as stressed vegetation, birds, insects, and other animals. Decision rules may be established as follows:

1. If agent or degradation product concentrations do not exceed action levels, allow unrestricted re-entry.
2. If agent or degradation product concentrations equal to or exceed action levels, consider other actions, such as removal, remediation, and natural attenuation, and maintain access controls until actions have been successfully completed.
3. Once removal, remediation, or natural attenuation actions have been completed, and agent or degradation product concentrations do not exceed action levels, allow unrestricted re-entry.

6.2.4 Step 3—Identify Inputs to Decision

The basic data that are needed to support the decisions that need to be made, per Step 2 above, are concentrations of chemical agent and degradation products within the various media that will be sampled. The samples needed are identified as part of this step. These may include air, soil, water, vegetation, windows/windshields/mailboxes (wipe samples), and potentially, tissue from live or dead animals. Note, however, that by the time sampling teams are activated, it is likely that agent concentrations in air would have decreased to undetectable levels; it is premature to consider re-entry if agent remains in air. Hence, air samples would not be needed to evaluate re-entry. They would be needed, however, to support health and safety of the sampling teams.

In DQO Step 3, the agent and degradation products are identified; these are termed constituents of concern, COCs. Action levels are also established (Section 6.3); sampling teams and analytical resources are identified (Chapter 4); and means of collecting, organizing, and evaluating data are established (Sections 6.5, 6.6, 6.7, and 6.12). Analytical methods are also identified, including both field techniques (Section 6.8) and laboratory techniques (Section 6.9).

As indicated previously, analytical methods should be sensitive enough to reliably measure COCs at or below the action levels. Note, however, that even state of the art analytical methods may not be able to “reach” action levels. Levels may be set very low or there may be matrix interferences in samples that preclude being able to reach the action levels. Section 6.13 discusses these considerations.

Other information may be used to supplement actual data. This information includes personal observations by emergency responders, the public that have SIP, and those who have been evacuated. Remote sensing may also be employed, including information collected by helicopter, UAVs, or drones.

6.2.5 Step 4—Define Site Boundaries

The logical “boundary” in the off-post CAI scenario for sampling would be the plume depositional footprint, as established using JEM. Sampling would be conducted primarily within this footprint. As noted in 6.1.1 above, there may also be focus areas beyond the model-

predicted footprint that are priorities for sampling due to the presence of vulnerable populations, critical infrastructure, major public gathering places, or other discretionary factors.

It is important not just to establish the boundaries of what will be sampled, but also to define DUs and SDUs, as discussed in Section 6.1. DUs/SDUs, however, would need to be established based on impacted areas; they could include individual properties, multiple properties within a community, parcels in farmland or wooded areas, water bodies, and streambeds. Section 6.1 touches on this issue area

Establishing boundaries also entails deciding whether to sample structures (inside or out). Efficiency would be most important here, because it could be very time consuming to sample multiple units, inside and out. A minimalistic approach can be taken to sampling structures, relying on wipe samples of impervious surfaces (automobile windshields, mailboxes, exterior windows, interior countertops). Considering weight-of-evidence here may be especially important; if there is no visual evidence of agent deposition, structure sampling may be limited to wipe sampling of exterior mailboxes and vehicle windshields, for example. Only if agent is detected in these locations would sampling be conducted indoors.

A related issue deals with legal access; permission may be needed, or a police escort could be required to allow entry into private property and unoccupied areas. The Kentucky CSEPP working group debated this issue, ultimately determining that it may be necessary to sample private property, and possibly structure interiors (Appendix A). Section 6.4 discusses access.

Another “boundary” consideration would be time. Time is especially important because of the tendency of the agents to degrade. Hence, the planning team may decide to focus analyses on degradation products after a certain point in time. Times when data may be collected should also be established. Although lighting may be used to allow sampling at night, it would be best for health and safety purposes to limit sampling to the daylight hours. Additional sampling teams may be utilized in this case to decrease the amount of time between sample collection and decision making.

Other practical constraints may also be considered, such as how to deal with weather events like thunderstorms and snowstorms. Would sampling occur during such events? Or might it be delayed until the events were over? To protect the health and safety of the sampling teams, sampling should be suspended during such events.

A final boundary consideration may include whether to sample groundwater. As indicated within the original 2008 sampling and analysis protocol (USACHPPM 2008):

> *It is even more unlikely that ground water would be impacted. In the process of being transported from the surface through the soil to underlying ground water, the chemical agents will likely undergo rapid hydrolysis. Even in the event chemical agents were to reach ground water, they will in all likelihood not pose an immediate or long-term threat due to the advection-dispersion properties that control the fate and transport of contaminants within the subsurface. All potential ground-water contamination must be evaluated on a very limited, site-specific basis.*

Therefore, generally groundwater need not be sampled. Groundwater sampling is not further discussed in this RSAF.

6.2.6 Step 5—Develop Decision Rules

In DQO Steps 5–7, the DQO process becomes a bit more technical. Step 5 leads to the establishment of decision rules. These are simply statements of what actions will be taken based on results obtained. However, these are not simple to develop because this is where decisions really begin to have consequences, in terms of risk and public policy. This is also where we begin to weigh time and effort against resources and uncertainty.

It may help to discuss the term "uncertainty." Uncertainty represents a level of confidence that the data that is collected represents the total population within the sample area. In the environmental world, uncertainty will always exist because sample data only represent a portion of the population and are subject to sampling and analytical error and variability. The only way to avoid this situation would be to collect 100% of all the samples within the DU or SDU, which would be take a very long time, and the resource and cost implications would be astronomical. Instead, one identifies a number of samples that is assumed, using a statistical parameter of interest, to represent the total population. Uncertainty is controlled by understanding the nature of the total population, sources or error and variability, and the statistical variation within the population.

Decision makers need to be able to select a level of uncertainty (or a level of confidence) in the data to be collected, while understanding the number and type of samples that need to be collected and analyzed, the amount of resources (personnel, equipment, and funding) involved, and the time necessary to complete sampling and analysis and related activities. Political pressure to make decisions with a high degree of confidence will be very high, but so too will the pressure to allow people back to their properties within as short a time as possible.

The Planning Section should consider developing an easy-to-understand visual presentation of the level of certainty/confidence versus resources and time for decision makers; Figure 6-4 presents an example of this. This figure clearly shows that as the level of certainty/confidence increases, the number of samples grows considerably, as do the level of resources and the time it will take to eventually come to a re-entry decision.

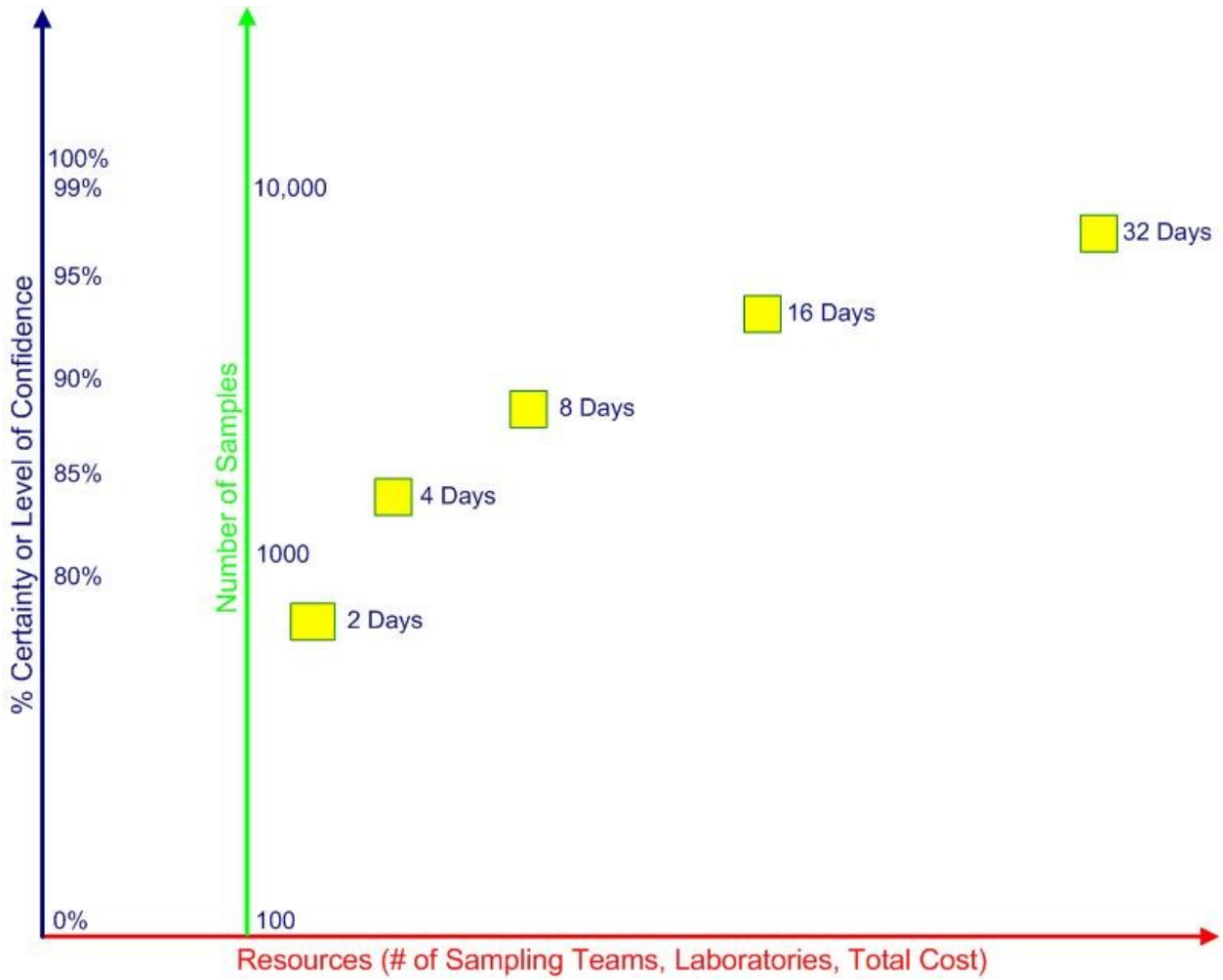

Figure 6-4. Re-Entry Sampling and Analysis Decision Evaluation (Example for Presentation Purposes—Not Based on an Actual Situation)

Different types of decision rules may also need to be established. For example, it could be beneficial to establish decision rules for each media sampled. Different decision rules can also be established for different DUs/SDUs or populations. A simple decision rule may be:

> If the COC is determined to be present in the media sampled (soil, water) below the action level, allow unrestricted re-entry. Otherwise, consider removal or remedial action, including natural attenuation over some period of time.

As discussed in Section 6.3, there are no established, agreed-upon action levels at present for wipes or for plant or animal tissue samples. Here, decision rules can be:

> If the COC is determined to be present in the wipe samples or plant and animal tissue samples above analytical DLs, do not allow unrestricted re-entry. Consider taking soil and water samples in the area using VSP's hot spot routine and compare data against action levels.

The above example decision rules suggest that even one sample exceeding an action level within a DU (or SDU), even one sample out of a hundred or more, would mean that the entire DU (or SDU) would be subject to further action (e.g., additional sampling, removal, or remediation, including natural attenuation).

Instead of looking at whether an action level is merely exceeded in any one sample, the planning team may select a statistical parameter of interest. A statistical parameter of interest is a descriptive measure (e.g., a mean, proportion, or percentile) that represents a level of confidence or certainty that a decision is correct. In this case, the characteristics or attributes of the sample population are compared as a whole to the action level. Here, the decision rule can be:

> If the mean concentration of the COC is determined to be present in the media sampled (soil, water) below the action level, allow unrestricted re-entry. Otherwise, consider removal or remedial action, including natural attenuation over some period of time.

Using a mean, or any proportion or percentile, would imply that the bulk of the results obtained are below the action level, but there may be some portion of the sample population that exceeds the action level. This is the downside of selecting any statistical parameter of interest, as opposed to merely stating that any exceedance of an action level of any sample means that some form of action (natural attenuation, removal, or remediation) will be considered. However, a mean or average statistic within an area of interest or DU likely more accurately reflects overall exposure concerns than single sample values.

6.2.7 Step 6—Specify Limits on Decision Errors

At this point in the DQO process, the focus is on determining the most efficient means of producing sufficient data over the established DUs and SDUs so as to allow decision makers to make decisions with some level of confidence in their decision. Here, a level of acceptable uncertainty in making an incorrect decision is made using the limited amount of sample data collected from within the DU or SDU. Uncertainty, in this case, takes into account the consequences of falsely accepting or rejecting a presumed baseline condition. The possibility of making an incorrect decision cannot be eliminated, but it can be controlled by selecting an appropriate tolerance for making an incorrect decision.

Section 6.4 presents more on this step of the DQO process, as applied to the off-post CAI scenario.

6.2.8 Step 7—Optimize the Design for Obtaining Data

The last step in the DQO process leads to the sample design. Here, VSP is used to evaluate decision errors (Step 6) and various sample designs that meet criteria established in Step 6. This leads to a number of sample design approaches and choices that can then be presented to decision makers. Because each sample design will have implications for the number of samples, number of analyses, resource requirements, and cost and time, the ultimate choice of sample design should rest with the decision makers.

Section 6.4 presents more on this step of the DQO process, as applied to the off-post CAI scenario.

6.3 Determine Data Needs and Means to Obtain Data

In this section, the types of data and information needed to evaluate re-entry are determined and the means for obtaining and managing the data are established.

6.3.1 Determine COCs

COCs were one of the BPIs presented to the Blue Grass CSEPP Community (Appendix A). COCs include the agents stored at BGCA, mustard (H), GB, and VX. Because the agents degrade in the environment, COCs would also include agent degradation products that are of concern for human health, and for environmental toxicity and risk. Appendix C discusses degradation products and their formation. They are also mentioned briefly in the EPA NRT Quick Reference Guides (Appendix B).

Each agent and munitions configuration (GB, VX, and H) is segregated and stored separately in agent-specific igloos. Munitions headed for destruction in the BGCAPP facility are also phased one agent type at a time. Hence, COCs during any one CAI event would very likely be limited to only one agent (and its degradation products)and it is reasonable to base planning for sampling and analysis on single agents and their degradation products.

For GB (also known as sarin) and VX, the degradation products of concern are well established. The principal degradation products of GB decomposition include isopropyl methylphosphonic acid (IMPA) and methylphosphonic acid (MPA), both of which are moderately persistent; they last for a period of months to a year or more in the environment (see Appendix C). Under most conditions, GB will first degrade to IMPA, and then the IMPA will degrade to MPA. However, due to the speed of the reaction, both IMPA and MPA will typically be present at the same time in most release scenarios. These are the degradation products most often assayed for at hazardous waste sites known to have had GB present at one time.

VX degradation products of concern include ethyl methylphosphonic acid (EMPA), MPA (MPA is a degradation product of both GB and VX), and a chemical known as EA-2192 (EA stands for Edgewood Arsenal, where the compound was first discovered). The chemical name of EA-2192 has several configurations, one of the most common of which is O-ethyl S-[2(diisopropylamino)ethyl] methylphosphonothioate. These are the degradation products most often assayed for at hazardous waste sites known to have had VX present at one time.

For mustard (H), the degradation products of concern are also well established. The primary degradation product is Thiodiglycol (TDG). For mustard, however, additional degradation products and some other chemicals can also be included, including stabilizers, impurities, heavy metals, and chlorinated hydrocarbons. The issue of which COCs should be considered for mustard was debated during one of the BPI sessions. The debate revolved around whether, in the event of a mustard release, these additional chemicals should be analyzed for. The consensus was

that if mustard or TDG were detected, then other COCs should be included, as noted above, although this may require resampling in some areas.

The primary COCs addressed are shown in Table 6-1.

Table 6-1. Agents and Degradation Products Identified as RSAF COCs

Parent Agent	Degradation Products
Mustard (H or HD)	TDG
Sarin (GB)	• MPA • IMPA
VX	• MPA • EMPA • EA-2192

6.3.2 Determine Action Levels

In the RSAF context, action levels are concentrations of COCs in various media, such as soil or water, above which some type of action is considered. Action levels are sometimes referred to as criteria levels, clearance levels, or cleanup levels. Examples of actions that may be taken if action levels are exceeded include allowing natural attenuation to reduce COC concentrations over a period of time to below action levels, or conducting removal or some type of remedial action (remediation) to reduce COCs to below the action level.

Various organizations have developed action levels for chemical agents and degradation products. Two organizations in particular are notable. One is the CSEPP itself, which has published these types of action levels for years. They are shown, for example, in the draft Kentucky Recovery Plan (CSEPP 2005), as well as in the Colorado Recovery Plan (CSEPP 2016b). CSEPP only developed these levels for the agents; they were not developed for any of the degradation products.

The EPA has published similar levels for use in cleanup programs under RCRA and CERCLA. These were initially developed by EPA Region 3 (risk-based concentrations, or RBCs), and by EPA Region 9 (preliminary remediation goals, or PRGs). These levels were applied for years in cleanup efforts within these EPA regions, and other EPA regions adopted them as well. More recently, EPA Headquarters adopted these levels, and terms them regional screening levels (RSLs). RSLs can be examined on EPA's RSL website (EPA undated h). The Region 3 RBCs and the Region 9 PRGs are no longer available, because the EPA RSLs replaced them.

The new EPA RSLs have been determined for several of the degradation product COCs (TDG, MPA, and IMPA), but are not shown for the agent COCs or for the COC degradation products EMPA or EA-2192. As explained by Watson et al. (2011b), RBCs and PRGs were initially available for the agent COCs. However, Watson et al. estimated RSLs for the agent COCs using an RSL calculator available on the EPA's RSL website.

Also, note that these levels are published for soil for two types of exposure scenarios, industrial and residential. In the cleanup world, industrial levels are typically applied in an industrial setting (including, for example, on an army base in non-cantonment [nonresidential] areas), and residential levels are applied in residential areas (e.g., housing). Action levels for water are usually published without reference to exposure scenario, but rather the rate at which water is consumed.

The RSAF employs EPA action levels, including those estimated by Watson et al., using EPA's RSL calculator but also shows CSEPP action levels for comparison. Regarding the industrial versus residential determination, the workgroup decided to select soil residential levels for all off-post applications. However, the HASP developed for workers—in this case the sampling team, or perhaps those involved in removal or remedial actions—might specify use of the industrial-based soil action levels for worker protection. Tables 6-2 and 6-3 present CSEPP and EPA residential and industrial action levels for the COCs in soil and in water.

Table 6-2. CSEPP Action Levels for Agent COCs (CSEPP 2016b)

COC	Soil Residential (mg/kg)	Soil Industrial (mg/kg)	Tap Water (µg/L)
H (Mustard)	0.01	0.3	47
GB (Sarin)	1.3	32	4
VX	0.042	1.1	4

Table 6-3. RSAF Action Levels for COCs (See Footnotes)

COC	Soil Residential (mg/kg)	Soil Industrial (mg/kg)	Tap Water (µg/L)
H (Mustard)	0.55[a]	68[b]	46[c]
GB (Sarin)	1.6[a]	32[b]	9.3[c]
VX	0.047 [a]	1.1[b]	5[c]
TDG	5,400[d]	79,000[d]	1,400[d]
MPA	3,800[d]	49,000[d]	1,200[d]
IMPA	6,300[d]	82,000[d]	2,000[d]
EMPA	6,300[e]	82,000[e]	2,000[e]
EA-2192	0.047[f]	1.1[f]	5[f]

[a] EPA RSL from Watson et al. (2011b).
[b] EPA PRG from Watson et al. (2011b).
[c] DOD Tri-Service Standard from Watson et al. (2011b), based on 15 L/day consumption.
[d] EPA RSL (EPA undated h).
[e] No action level available; value shown is for IMPA, a structurally similar chemical.
[f] No action level available; value shown is for VX, a structurally similar chemical.

Action levels do not exist for surface wipes or for vegetation or animal tissues. The exposure assumptions involved in determining action levels for soil and water are quite complex but are

generally accepted within the scientific community. Should these types of samples be taken during an RSAF event, action levels may be established at analytical DLs. The “action” that may be prompted by detecting a COC above the analytical DL on a wipe sample would be to collect additional samples (e.g., soil or water) in proximity to where the positive wipe or vegetation sample was collected.

The action levels in the tables above assume low-level chronic exposure over a lifetime. Since the agent and degradation products break down over a period of days to months, application of the action levels noted above may be considered very conservative.

Action levels also exist for the air media. These are shown in Appendix E, which is taken from the 2016 Recovery Plan developed for the PCD (CSEPP 2016b). This table (Appendix E) also appears in the 2005 Draft Recovery Plan developed for BGAD (CSEPP 2005). The action levels for air come into play for establishing plume contours (WebPuff), for determining worker exposure levels, for use in waste management, and for temporary re-entry missions (see Chapter 7). These action levels are not considered for unrestricted re-entry, however, because if any agent remains in the air, it is premature to even consider sending sampling teams out to evaluate unrestricted re-entry. The action levels for air are, however, used to support the HASPs developed for sampling teams, and may be used in the unlikely event that agent is detected indoors at businesses or residences following a CAI.

Action levels are typically considered screening levels, above which further action would be considered. Actual cleanup levels may be different if they consider different exposure assumptions than those used for the action levels. Should some form of removal or remediation, including natural attenuation, be determined to be necessary, decision makers may choose to examine different exposure assumptions and develop cleanup levels tailored to the situation.

6.3.3 Consider Field and Laboratory Analytics and Capabilities

For the COCs in the environmental media that will be sampled, it is important to determine whether proven, accepted analytical methods are available that are sensitive enough to quantify the concentration of COCs at or below the action levels. DLs of the methods available should be at or below action levels; otherwise it would be impossible to determine whether the action level was exceeded, warranting further action.

Figure 6-5 illustrates the relationship between action levels and DLs.

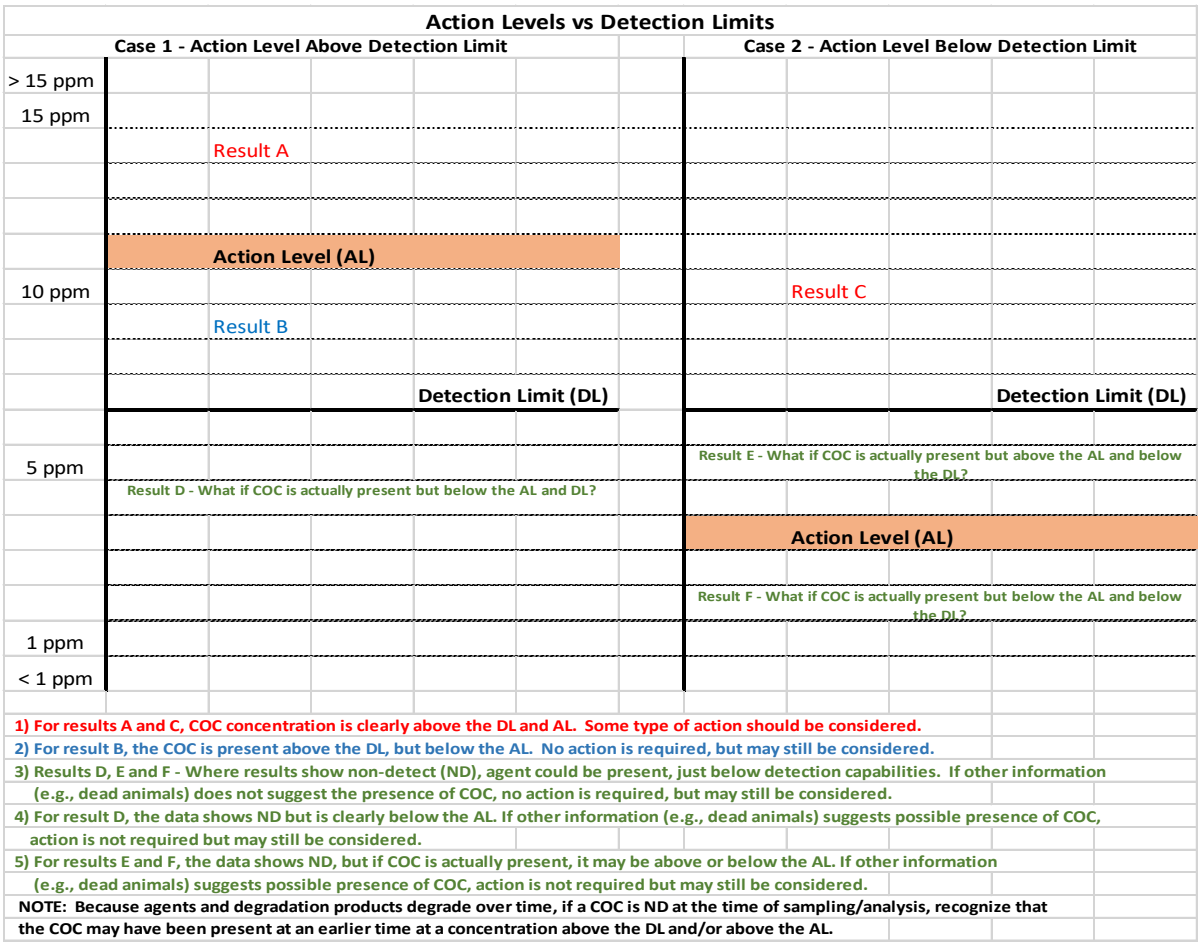

Figure 6-5. RSAF Demonstration, Action Levels vs. DLs

It is critical to consider whether the methods used to measure COC concentrations are sensitive enough to detect the COCs at or above the action levels. This includes both field and laboratory methods. Field and laboratory methods are further discussed in Sections 6.8 and 6.9.

6.3.4 Select Field Sampling Platforms

Effective and efficient sampling operations require advance planning and coordination. Supplies and equipment needed for multiple sampling teams taking large numbers of samples over multiple consecutive days must be arranged ahead of time. Sampling teams and the sampling methods require similar resources, as shown in the following list:

- Sample bottles
- Coolers
- Ice
- Distilled water
- Deionized water,
- Sampling equipment,
- Sample labels,

- Various forms,
- Drinking water,
- Global positioning equipment,
- Several levels (Level A, B, C, D) of PPE,
- Cameras and video equipment,
- Communications equipment,
- Portable monitoring equipment,
- Decontamination equipment (for both personnel and equipment),
- Cleaning solutions,
- Sampling stations,
- Vehicles,
- Tubs and containers,
- Mailing materials, and
- Medical supplies.

An additional, very important consideration is the need for properly trained sampling and sample support personnel (such as team leaders, samplers, quality control specialists, health and safety specialists, decontamination personnel) to execute the sampling design. In addition, some type of mobile sampling platform is necessary to establish a logical base for sampling operations. There is too much equipment for samplers to hand-carry all their supplies into potentially contaminated zones. The platform, in this case, might include tents, decontamination stations (for decontaminating sampling equipment between samples), and the supplies and equipment noted above, which would be carried on vehicles, likely all-terrain.

The more sampling teams there are, the more samples per day can be collected, processed, and transported to the laboratory. A minimum size for sampling teams is three to five experienced and trained personnel. Depending on the magnitude of the event, two or more sampling teams may be operating at the same time in different locations.

Samplers must be aware that the chemical agents will all degrade with time. Hence, sample preservation (using coolers and ice) after collection and during transport to the laboratory is very important. In addition, certain constituents in certain samples will have a shelf life (also known as sample holding time) between sampling and sample preparation/analysis that should not be exceeded. This is especially important for the agents that degrade or evaporate rapidly, such as GB.

6.3.5 Select Onsite, Offsite, and Mobile Laboratories

The Army has published and applied analytical methods for chemical agents and degradation products for many years. These methods are all based on the same general technology, but different methods are applied at different locations (e.g., Edgewood Chemical Biological Center [ECBC] at Aberdeen, Maryland; BGCA; and other sanctioned laboratories such as Lawrence Livermore National Laboratory, in California). These methods have all evolved over the years and are considered state of the art.

More recently, the EPA has published analytical methods for chemical agents and degradation products out of its National Homeland Security Research Center in Cincinnati, Ohio (EPA 2007). These methods are intended to be applied for any incident of national significance involving chemical agents and may also be considered state of the art.

The question is, which suite of methods should be applied? This issue is discussed in Section 6.9. If laboratories expected to support the off-post response can be selected in advance, it will save time during the CAI response.

6.3.6 Prepare for Data Collection, Optimization, and Evaluation

Once samples are collected and sent to laboratories for analysis, data begins to become available for decision making. It is important to plan for collecting and organizing the data that comes in. This allows data from, potentially, multiple laboratories to be readily assessed, verified, and validated (see Section 6.10), combined into a common database, exported into data visualization software programs, and presented to decision makers. More on this is presented in Section 6.12.

6.4 Sampling Design (Step 7 of the DQO Process)

Sampling design was introduced above (Sec. 6.2.8) as Step 7 of the DQO process, and is elaborated in this section. Sampling design leverages the CSM as developed for the release event and organizes data collection around the decision rules and DUs/SDUs defined using information contained in the CSM and the prior steps. This section provides a brief background on alternative data collection strategies and tools that can be used to support data collection program design, and presents the recommended sampling approach.

6.4.1 Biased/Judgmental Approaches

Biased (also known as judgmental) sampling approaches are approaches that rely on the opinion of technical experts combined with supporting site information to select the number and location of sampling points. When the technical expertise exists and supporting site information is sufficient, biased sampling can be a very efficient and effective means of determining the presence or absence of contamination at levels of concern. The primary drawback of this type of sampling approach is the lack of reproducibility; an alternate “expert” might come up with a significantly different sampling program, either in terms of the locations to be sampled or the number of samples required. A second drawback is that biased sampling techniques do not provide a quantitative means for assessing the confidence level at which decisions are made.

One approach to addressing the primary drawback is to have a team of two or three experts independently select sampling numbers and locations. The resulting sampling strategies are then compared; where there is concurrence, there is relatively high confidence that the locations and numbers are appropriate. Where there is divergence, the differences could be triaged among the experts to determine why the differences exist, and whether a particular expert brought a piece of knowledge or experience that the others lacked and that would alter their conclusions. Ideally, the result would be consensus that harmonizes divergences. When a technical disagreement

among the experts is unresolvable, a conservative approach would be to include all the sampling locations in question.

A well-formulated CSM is especially critical to the success of a biased sampling program. Ideally, it would incorporate all of the supporting information an "expert" requires to determine sample numbers and locations. For example, a well-formulated CSM would articulate the transport, depositional, and degradation processes that would lead to measurable COC concentrations in the environment, and release-specific details (i.e., amount, nature of the release, type of agent, weather conditions) that would affect the understanding of where contamination is likely to be found and where it is not.

A biased sampling program typically focuses on those locations that the experts believe have the highest probability of contamination being present and measurable, if in fact contamination (deposition) exists, for an area of interest. However, biased sampling can also focus on locations where, if contamination were present, the consequences would be the most severe (e.g., at a daycare). The decision rule is typically this:

> If contamination is not encountered above action levels at biased sampling locations within a DU or SDU, then it is safe to conclude that the balance of the unit is also free from contamination above levels of concern.

6.4.2 Statistical Approaches

Statistical approaches rely on either a statistical or probabilistic analysis to determine the sample numbers required for a particular area. Advantages of statistical/probabilistic approaches are that they provide a quantitative and reproducible method for calculating sample number requirements, and a measure of confidence in the decision based on the resulting datasets. The primary disadvantages are that these approaches typically require assumptions about underlying statistical distributions that may be difficult to substantiate—or in fact may be incorrect—and the fact that there may be no good way to incorporate important information into the statistical analysis captured in the CSM. Most statistical/probabilistic approaches are also location agnostic; in other words, within an area of interest or DU/SDU, every location would be considered equally likely to yield measurable contamination at levels of concern. An outcome of this is that sampling programs based on statistical/probabilistic methods typically place sampling locations on a regular grid laid over the area of interest/DU or randomly place sampling locations within the DU/SDU.

A common example of a probabilistic approach is the use of probability methods to determine the density of samples required to identify a "hot spot" of given size and shape within a larger area of interest. A common example of a statistical approach is the use of statistics to determine the number of samples required to confidently determine whether a key parameter (for example, the average agent concentration across a DU) is above or below some significant threshold.

Within the world of statistical and probabilistic approaches, there is a wide variety of methods that vary based on what decisions they are designed to support and the underlying assumptions

that must be true in order for the results to be valid. In this sense, statistical and probabilistic approaches are no different than biased sampling; both require SMEs to correctly apply them.

6.4.3 EPA's Triad Approach

The EPA's triad approach to site characterization and remediation is based on three components: systematic planning, dynamic work plans, and real-time measurement systems (see https://triadcentral.clu-in.org/over/index.cfm). The motivator behind the triad approach is the recognition that characterizing environmental contaminant releases often involves unexpected sample results that indicate the original CSM was incorrect to some degree; the best way to resolve these surprises is to leverage real-time measurement systems (when they exist) and dynamic work plans that allow field work (including sample collection) to adjust to results as they become available. Agreement with stakeholders is established ahead of time through systematic planning.

A dynamic work plan is one that does not specify sample numbers and locations completely up front, but instead defines the decision-making logic that will be used to adjust sample numbers and locations going forward with fieldwork as results become available. A real-time measurement system is one that can return sample results quickly enough to affect the progression of a sampling program as part of a dynamic work plan. This sample result turnaround time could be minutes, hours, or even be days if data collection is spread across a significant period of time. A real-time measurement system could take the form of a field-deployable instrument, a mobile laboratory, or a rapid-turnaround traditional laboratory.

Emergency response efforts to significant environmental releases will by nature incorporate triad approach concepts; this would be the case in the event of an off-post release from BGAD. The early stages of an emergency response are typically fluid as decision makers attempt to quickly understand the nature and scope of a possible release. In the later stages of the response, where return and reuse decisions are being made for affected areas, work plans are typically more rigid and formulaic. The EPA's triad approach advocates flexibility and responsiveness to data results throughout the characterization and remediation (if needed) processes to keep decision-making timely and cost-efficient.

6.4.4 Hybrid Approaches

The most effective approach to designing a sampling program often involves hybrid approaches that combine the elements from one or more approaches best suited to the problem at hand. For example, a statistical or probabilistic method might be used alongside limited judgmental sampling to provide both a technical basis for sample numbers and to ensure that the locations most likely to yield contamination are in fact sampled. Alternatively, a work plan might fix a baseline number of samples and locations per DU/SDU, but also incorporate decision logic for collecting additional samples in response to unlikely but possible sample analytical results.

6.4.5 Available Tools

Software tools exist to assist in the design of sampling programs. Probably the most widely used free software package is VSP, developed by researchers at PNNL (PNNL 2014).

VSP includes a wide variety of statistical and probabilistic sampling design tools for different applications, from supporting the closure of sites contaminated with radioactivity to identifying buried explosives, to monitoring groundwater contamination. VSP uses published statistical routines and methods and provides a user interface to facilitate the use of those routines and methodologies when designing a sampling program.

As with any higher-end modeling package (in this case statistical), simplifying the use of complex mathematical, statistical, and probabilistic routines is not a substitute for understanding the nature of the routines being used, the underlying assumptions upon which they are based, and the ramifications of parameter values. Although training is available for VSP, the training offered is not a substitute for the support of an environmental statistician, at least on a consultative basis, if VSP is used.

6.4.6 Pre-Determined Sampling Locations

In the case of BGAD and the potential for an off-post chemical agent release, enough is known about the facility, the surrounding environs, and the agents that could possibly be released to allow an *a priori* determination of sampling sites based on an initial CSM for the site. An advantage to having predetermined sampling sites for specific sectors is that this allows the OSC to quickly mobilize data collection efforts while the CSM and subsequent overall sampling strategy are updated to reflect the details of what happened. Examples of predetermined sampling sites include facilities serving vulnerable populations, critical infrastructure, and critical transportation corridors—the focus areas discussed previously. An additional advantage is that the process of selecting these predetermined locations requires careful thought be given to what constitutes a high-priority sampling location.

6.4.7 Tailor the Sample Design to the CSM and DUs/SDUs

DUs and SDUs were discussed in Section 6.1. In the case of BGAD, each of the 26 protective action zones surrounding the facility is considered a DU. In the case of an actual release, the characteristics of the release and associated weather patterns will determine which of the zones are carried forward as DUs that must be addressed by data collection.

As indicated in Section 6.1, DUs can be broken into multiple SDUs. SDUs allow for variability in sampling strategies to address their particular sensitivities and sampling needs. For example, a single sample from an appropriate location might suffice for an industrial facility, while a community might have a set of samples collected from a grid laid across the area it encompasses.

If an off-post release were to occur at BGAD, the initial CSM (based on modeling and observations) would dictate which PAZs were activated as DUs, and which of those DUs/SDUs would require sampling. As the CSM evolves to reflect changing weather conditions and

information gained by additional observations, further release details, sampling results, and other factors, additional DUs might be disaggregated into SDUs (reflecting an impacted area larger or spatially different than initially thought), or SDUs might be aggregated back into their DUs (reflecting the apparent absence of contamination as work progressed). Sampling approaches for particular SDUs might depend on the nature of the sub-unit. For example, clearing access at a hospital might be different from demonstrating the absence of contamination over a large spatial area, such as a farm.

The connection between the CSM, DUs, and sampling designs is not linear. Instead, these mutually evolve as the CSM feeds forward into the selection of DUs/SDUs and appropriate sampling designs, and sampling results feed backward, resulting in modifications to the underlying CSM.

6.4.8 Confidence (Uncertainty) as a Function of Time, Cost, and Resources

Step 5 of the DQO process (see Section 6.2), establishes the analytical approach and decision rules. As indicated in Section 6.2, decision rules are simply statements of what actions will be taken based on results obtained. This is where decisions really begin to have consequence in terms of risk and public policy. Therefore, decision rules should be established by the OSC, with the input and concurrence of the UC or MACG. Although decision rules can be established ahead of time, as in this document, decision makers should have the flexibility to adjust the decision rules based on circumstances.

Assuming that a statistical approach is taken for the sample design, perhaps in combination with biased sampling, the key determination for decision makers is the level of certainty or confidence in the data to be collected. The level of certainty or confidence selected directly affects the number and distribution of samples that need to be collected and analyzed, the amount of resources (personnel, equipment, and funding) involved, and the time that it will take to complete sampling, analysis, and related activities (see Figure 6-4). Although all decision makers would naturally like to have a high degree of certainty in the data, for example 99.99%, such a high level of certainty can add hundreds of thousands of dollars to the sampling/analytical effort, and can add days, weeks, or longer to sample collection and analysis. Additional sampling and analytical resources can be obtained to shorten this time, but there comes a point when additional resources become less and less efficient.

Establishing a level of certainty involves identifying a statistical parameter of interest for the population sampled, such as a mean, proportion, or percentile. Common levels of certainty employed at hazardous waste site investigations (see Section 2.4), include 95%, 97.5%, and 99%. Each of these affects the magnitude of the sampling/analytical effort, resources, and time. The VSP allows users to evaluate the implications of level of certainty versus resources versus time with several key strokes. VSP will show the number of samples required over a DU or SDU to achieve the desired level of certainty and will estimate the costs of sampling and analysis. It will not show the time required to complete the sampling and analysis, however.

Time may be quickly estimated by examining several key elements:

- Time required to garner the resources for coordinated, efficient sampling operation. This is estimated at two to three days following the CAI.
- Number of sampling teams, made up of three to five people each, that can be used effectively and efficiently. This is estimated at two to four sampling teams, depending on the magnitude of the event (see Section 6.6).
- Each sampling team would operate during daylight hours only, estimated at 12 hours. These teams would be able to sample an estimated 15 to 30 locations per 12-hour period, resulting in from 45 to 90 samples per day. More samples could be collected if additional sampling teams were employed.
- Time required for sample transport to an approved analytical laboratory (see Section 6.9). If one or more mobile laboratories are brought to BGAD, sample transport time may be less than an hour. Otherwise, sample transport time could be significant.
- The current proposal is to engage the EPA PHILIS laboratory from Edison, New Jersey, for analytical support. An additional PHILIS laboratory, located in Castle Rock, Colorado, could also be called in to support analysis. The EPA indicates that each PHILIS laboratory operates 24 hours per day and can analyze from 100 to 200 samples per day (see Section 6.9).
- And finally, collection of data from multiple sources, feeding such data to programs that can consolidate the data and present it in meaningful ways for decision makers (e.g., data visualization; see Section 6.13). The time required to collect, tabulate, and present data is estimated at several hours. This becomes inconsequential when compared to analytical throughput.

As can be deduced from the above, the limiting factor seems to be laboratory throughput, which is estimated at 100–200 samples per day for one PHILIS laboratory. Sampling time would only become a limiting factor if fewer sampling teams were employed. However, assuming only one PHILIS laboratory is brought in, and adding three days to garner the sampling and analytical resources, Table 6-4 estimates time required for 100, 200, 400, 800, 1,600, 3,200, and 6,400 samples.

Table 6-4. Time Required for Sampling and Analytical Results (Assumes 3 days for Sampling/Analytical Mobilization)

Number of Samples (Total of Water, Soil, Wipes and, Vegetation)	Minimum/Maximum Analytical Time (Assuming 100–200 Samples/Day)	Total Time (Days)
100 Samples	1 Day/1 Day	4 Days
200 Samples	1 Day/2 Days	4–5 Days
400 Samples	2 Days/4 Days	5–7 Days
800 Samples	4 Days/8 Days	7–11 Days
1,600 Samples	8 Days/16 Days	11–19 Days
3,200 Samples	16 Days/32 Days	19–35 Days
6,400 Samples	32 Days/64 Days	35–67 Days

Table 6-4 emphasizes the importance of time when weighing the appropriate level of uncertainty against the number of samples. Although most decision makers would want to have an extremely high level of confidence in the analytical results, the resources, and more importantly, the time required (especially where people are asked to be away from their homes and livelihoods) must also be considered. Decision makers should ask the Planning Section to show several different VSP iterations using different assumptions that impact certainty or level of confidence. Decisions can then be made considering certainty, resources, and time.

6.4.9 Recommended Sampling Approach

This section describes the recommended sampling approach, focusing on the selection of sampling locations and the determination of sample numbers. The recommended sampling approach reflects a combination of judgmental and systematic sampling, driven by the CSM and identification of DUs and SDUs developed in response to the release.

The recommended sampling approach as described in this section is based on the following assumptions:

- Predictive modeling results using WebPuff and JEM are available and sufficiently accurate to provide an acceptable level of confidence that the absence of measurable environmental contamination within the modeled footprints would indicate an acceptably low probability of measurable contamination existing outside these footprints.
- Post-event air sampling conducted by emergency response personnel did not identify airborne agent outside the plume footprints as defined by predictive modeling.
- Sampling needs are greater than sampling resources can immediately address; in other words, sampling will take place over a period of time to completely clear areas for re-use, and will require prioritization.
- Predefined sampling locations (focus areas) for critical infrastructure/sensitive locations are established and plotted on a CSM base map.
- Hot spots are defined as quarter-acre (10,890 ft^2) areas (about the size of a typical small home property in a densely populated area).
- Hot spots are of initial concern within the JEM plume deposition footprint.
- For hot spot identification, sampling locations can be selected that are conservative for their immediate surrounding area (i.e., if contamination is not detected at the sampled location, then it is highly unlikely it would be detected in samples from the immediately surrounding area).

The implications of these assumptions not being true are discussed at the end of this section.

In the event of a potential off-site release of agent, sampling to determine re-entry of potentially affected areas will take place in three stages, as shown below beginning is Section 6.4.9.1. The sampling design presented represents a 95% confidence level that the sampling program will identify a hot spot of some specified size, if it indeed exists. It also assumes that there are no false negatives. In other words, if sampling is conducted within a hot spot footprint, the sample result would correctly identify the presence of the hot spot all of the time; if it did not, it would be a false negative. Another way to describe the false negative is if the sampling approach

wrongly determines that there is no contamination. This is as opposed to a false positive, which is like a false alarm; it wrongly determines that an area is contaminated when it is not.

The Planning Section can present this design to the OSC, UC, or MACG decision makers. If assumptions like the 95% confidence level are acceptable, resources are available to support the sample design, and the time required for sampling and analysis is acceptable, then the design can be implemented. If resources and time considerations are unacceptable, alternate designs based on different assumptions can be presented. Figure 6-6 presents the implications of different designs based on different confidence levels in terms of resources and time required.

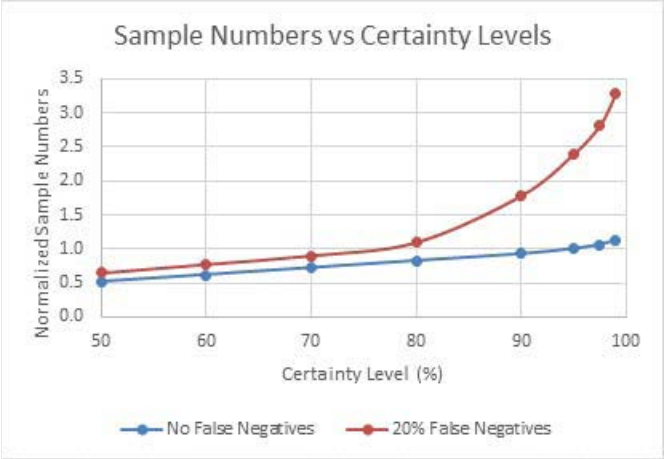

Figure 6-6. Sample Numbers vs. Certainty Levels

In Figure 6-6, the blue curve is based on the assumption that there are no false negatives for samples, and the red curve assumes 20% of sample results are false negatives. This simply means that more samples are needed at a particular confidence level as the false negative rate increases. Put another way, examining the 2 on the y-axis, twice as many samples would be needed at the baseline 95% confidence level case for 20% false negatives as compared to no false negatives. Also shown in Figure 6-6, the additional number of samples needed increases significantly as required confidence levels increase. Recalling that each sampling team can likely sample from 15 to 30 sample locations per day, and assuming three sampling teams, laboratory processing of samples becomes the limiting time factor. The EPA's mobile PHILIS laboratory (see Section 6.9) can process between 100 and 200 samples per day. It may be assumed that laboratory results will be available within one or two days of sampling.

The three-stage sampling approach is described below.

6.4.9.1 Stage 1

The purpose of Stage 1 sampling is to determine whether there is evidence of off-post deposition of agent and/or degradation product above action levels. Stage 1 sampling will begin as soon as emergency response personnel determine that the plume has dissipated, and when adequate resources to begin implementing the sample design are available.

Stage 1 sampling will be split into two campaigns: one will address hot spots within the JEM depositional footprint and a second will target focus areas that fall outside the JEM footprint but within DUs subject to protective actions (evacuation or SIP).

- JEM depositional footprint campaign. Samples will be taken every 127 ft. along the centerline of the JEM depositional footprint. This is equivalent to the hot spot definition at 95% confidence for a circle approximately one-quarter acre in size. In addition, samples will be taken for each property (including focus areas) outside the sampled plume centerline but within the JEM depositional footprint. For properties approximately equal to or less than one-quarter acre in size, a single sample will be taken using best judgement as to the location most likely to exhibit contamination, were it to occur. For properties greater than one-quarter acre in size, VSP's hot spot algorithm will be used to define a triangular sampling grid pattern appropriate for each property assuming a circular hot spot one-quarter acre in extent.
- Focus areas campaign. Focus areas that fall outside the JEM depositional footprint, but within DUs subject to protective actions, will be prioritized for sampling based on emergency response, immediate access, and criticality of function needs post-release. A single sample will be taken using best judgement as to the location most likely to exhibit contamination, were it to occur.

At each sampling location, four samples will be collected (wipe, soil, water, and vegetation). In the event that any COC is detected in any focus area outside the JEM footprint, this will also likely result in a reconsideration of the CSM and potentially in a redefinition of DUs and SDUs.

If neither sampling campaign identifies the presence of COCs above action levels, decision makers may consider releasing the area for unrestricted re-entry. If contamination above action levels is identified by either sampling campaign, Stage 2 sampling will begin.

6.4.9.2 Stage 2

Stage 2 sampling will occur only if COCs are detected above action levels during Stage 1. The purpose of Stage 2 sampling is to bound the contaminated areas encountered in Stage 1.

If a hot spot sampling location along the plume centerline has measurable contamination at levels of concern, the following activities will take place:

- The location may be resampled to confirm the result was not a false positive. Time following initial sampling and weather conditions during that period of time will need to be considered, because COC degradation will likely have occurred during this timeframe.
- If the hot spot is along the depositional centerline and surrounding hot spot samples failed to find contamination, then the contamination may be considered localized. However, if the location is near the perimeter of the JEM footprint boundary and/or adjacent focus area samples indicate a more widespread depositional footprint, hot spot sampling will be extended beyond the JEM boundary until the contamination extent has been confidently bounded.

- Depending on the initial results (proximity to JEM footprint perimeter and level of contamination observed), decision makers may opt to begin an "outside-in" approach to hot spot sampling, beginning at the boundary of what an updated CSM would consider to be a plausible contamination extent footprint and then working in toward the plume centerline.
- For properties with a hot spot sample detection, systematic (gridded) sampling will take place within the property. Per-property sample numbers will be determined using VSP, with the goal of comparing average sample results against action levels.
- At each sampling location, soil, water, and vegetation samples will be collected if possible. The exact sampling locations will be selected using best judgment.

Any property with measurable contamination above action levels will be systematically sampled to determine whether average concentrations exceed action levels. The number of samples required will be calculated using VSP. Decision makers may choose, however, to examine alternate statistical parameters of interest other than the average concentration, such as the median, a proportion, or a percentile. The implications of selecting an alternate statistical parameter of interest can be examined using iterations of VSP. Engaging the technical support of an environmental statistician is highly recommended.

If the results of systematic sampling at an affected property show an average concentration below the action level, then decision makers can consider releasing the property for unrestricted re-entry. If the results of systematic sampling at one or more affected properties demonstrate action levels have been exceeded, Stage 3 will be initiated.

6.4.9.3 Stage 3

Stage 3 sampling would be implemented post-removal or after active remediation, or it may be implemented after sufficient time has passed to allow for the degradation of COCs to below action levels. The purpose of Stage 3 sampling is to demonstrate that properties that previously had contamination above action levels are suitable for re-entry. The protocols used would be identical to those used for Stage 2: systematic sampling across each affected property, with the average sample results (or an alternate statistical parameter) compared to the action level. Here again, new sample designs may be needed, depending on the areas of concern.

6.4.9.4 Validity of Assumptions and Implications

At the beginning of Section 6.4.9, assumptions behind the recommended sample approach were identified. The implications of these assumptions not being true are discussed below.

- Accuracy of Predictive Modeling Results—The sampling strategy assumes that areas defined by predictive modeling are sufficiently conservative (conservatively safe) so as to capture all areas with a potential for depositional concerns. If this assumption is not correct, the CSM could be inaccurate and will need to be re-examined.
- Immediate Post-Event Air Sampling Results—The sampling strategy assumes that post-event sampling off-post does not identify agent outside the JEM depositional footprint. If contamination is encountered in samples taken outside the JEM depositional footprint,

then the CSM will need to be modified to reflect the fact that the JEM footprint is likely not conservative enough to address hot spot concerns.

- Sampling Resources—The sampling strategy assumes limited sampling resources and hence the need to prioritize. If abundant sampling resources are available, then sampling should proceed in a manner that makes the most sense considering efficient use of resources.
- Focus Areas—This sampling strategy assumes focus areas exist that can be prioritized and sampled as part of Stage 1 activities. If that list does not exist, or if there no focus area locations fall within the modeled footprint for a release, then focus area location sampling is unnecessary.
- Hot Spot Definitions—The sampling strategy presumes a hot spot definition has been determined by the stakeholder community that can be used in VSP to develop an appropriate hot spot identification sampling grid.
- Hot Spot Location Concerns—The sampling strategy presumes that hot spots are only a concern within the JEM footprint, unless subsequent sampling proves otherwise. If hot spot concerns extend beyond this footprint, then an equivalent boundary will need to be defined based on the CSM.

6.4.10 Access to Private Property

Off-post, sampling location will invariably fall on private property. Entry to private property generally requires permission under the law. Options include getting permission to enter, entering without permission, omitting or moving the troublesome points, or choosing a different system for selection of sampling points.

6.4.10.1 Permission to Enter

Where a desired sampling point falls on private property, one obvious option is to obtain entry permission from the property owners or tenants. Although permission is a simple concept, it is worth breaking the process down, especially if many such permissions must be obtained:

- Contact the owner or tenant. This may be done with a visit—knocking on the door—although it may require multiple visits at different times of day to make contact. Emergency management officials may be able to obtain contact information for residents based on property address from existing records, for example, if individuals have registered to obtain a tone-alert radio or a SIP kit. In addition, the need for access can be communicated to the public through emergency public information channels such as news releases, social media, or reverse-911 systems.

- A minimally invasive sampling method may be helpful in obtaining permission. In addition, if sampling were limited, at least initially, to outside locations, permission may be easier to obtain.

- For areas that where the public has been evacuated or relocated, tracking down residents may be more difficult. If they have visited a reception center or mass care shelter, there should be a record of their address and contact information.

If permission cannot be obtained, other options include entering without permission, omitting (or adjusting) the troublesome grid points, collecting wipe samples from adjacent accessible surfaces (such as mailboxes or fire hydrants), or using a non-grid-based system to determine sampling locations. The relative attractiveness of these options may depend on the number of troublesome locations, potential for agent deposition, desire for a scientifically defensible result, time pressure, and other factors.

6.4.10.2 Entry without Permission

Authority to enter property and take samples without permission is available based on CERCLA or on state emergency management law.

CERCLA and the NCP provide authority to enter property to assess contamination. The NCP, section 300.400, authorizes access to any properties where there is a reasonable basis to believe the property has been affected by a release, or access is needed to execute a response action (40 CFR 300.400(d)). This section of the NCP outlines a procedure to issue an administrative order for access if consent is not obtained.[6] The EPA has used this authority many times. However, following this procedure would add considerable time to the sampling process and a separate order would likely be needed for each property. Also note that the NCP specifies, "Force shall not be used to compel compliance with an order" (40 CFR 300.400(d)(v)).

Apart from CERCLA/NCP authority, Kentucky state law provides extensive emergency powers to the governor once a state of emergency has been declared, including the ability to direct evacuations, remove uncooperative people, and seize property needed for emergency response, subject to later compensation (KRS 39A.100). These extraordinary powers presumably could be used to enforce access to properties to conduct monitoring and sampling. However, that would be a policy decision on the part of the governor at the time, potentially with input from other decision makers.

6.4.10.3 Adjusting Sampling Points

Sampling points can be omitted or adjusted to a different (nearby) location to avoid sampling where access is problematic. This is a familiar problem in sampling design because grid points may fall in places where it is impractical to take some types of samples, such as lakes or parking lots. Depending on the number of points in the desired grid, the number of problematic points, and other factors, the decision can be made to move sampling locations or to live with a grid that has some "holes." If all samples in area are coming back "nondetect," then missing grid points is likely not a significant issue. However, if some positive readings are found, filling the grid becomes more important.

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6 EPA, or the appropriate federal agency, may issue an order pursuant to section 104(e)(5) of CERCLA directing compliance with the request for access made under § 300.400(d)(1). EPA or the appropriate federal agency may ask the Attorney General to commence a civil action to compel compliance with either a request for access or an order directing compliance (40 CFR 300.400(d)(4)(i)).

Since property owners do not actually "own" their mailboxes, if located outside, a fallback position may be to take wipe samples on mailboxes or to take soil or vegetation samples in the vicinity of the mailboxes. Fire hydrants or similar locations may also be considered.

6.4.10.4 Alternative Scheme for Locating Samples

This relates back to the purpose of sampling. A grid-based sampling plan can provide a statistically defensible estimate of residual hazard. However, it is not the only way to provide assurance of safety.

Modeling indicating significant potential for agent deposition off-post would suggest a sampling grid is appropriate. If modeling does not so indicate, another system for sampling may be appropriate. Sampling could be conducted along roads, at locations of particular concern such as schools and daycare centers, or the like. Local residents and businesses could be offered sampling on an as-requested basis.

6.5 Sampling and Methods

Sampling methods have been used at many locations during conventional hazardous waste site investigations under RCRA and CERCLA since the 1980s. The sampling methods for soil, water, and other media improved greatly in the early RCRA and CERCLA days, but have not changed significantly in recent years. From a sampling perspective, there is nothing unique about chemical agents or degradation products that would warrant new or different methods. However, the Army has developed specific techniques for agent air monitoring, both within BGCA and the BGCAPP, that will be applied in this RSAF. Both conventional sampling techniques and those applied at BGAD are discussed in this section.

6.5.1 Sampling Standard Operating Procedures (SOPs)

As indicated in Chapter 4, several different organizations will supply experienced personnel to support and be part of sampling teams. Each of these "sampling partners" will likely have standard operating procedures (SOPs) that are based on conventional sampling methods. These address step-by-step procedures for sampling environmental media. During the BPI sessions (Appendix A), the Kentucky CSEPP RSAF workgroup discussed whether the sampling partners should use their own sampling SOPs, or whether an attempt should be made to harmonize all of the SOPs from each partner into a single set of RSAF-specific SOPs. Such an effort would take time, but it would remove one variable that could eventually influence the produced data and its interpretation.

The workgroup discussed the fact that it would probably be time consuming to develop a common set of SOPs and for sampling partners to become familiar with them. They also surmised that the SOPs from each organization are very likely to be substantially equivalent, and that applying SOPs for the same methods from different organizations should not significantly influence the data obtained. The workgroup concluded that it is acceptable to use sampling partner-specific SOPs.

6.5.2 Media Sampling (e.g., Soil, Water)

Media sampling includes primarily soil and water but may also include sediment and similar materials. The media sampled is scooped up in a prescribed fashion with some sort of sampling device (e.g., spatula, spoon, spade, flask), placed in a sample container, and sent to the laboratory for analysis.

There are more advanced procedures for certain applications. One example is sampling water at a certain depth within a lake or stream. These types of methods are not likely to be applied during the implementation of this RSAF.

6.5.3 Air Sampling (e.g., Buildings, Homes)

Sampling partners will also have SOPs that address air sampling methods. To a large extent, these SOPs address combined sampling and analytical devices. These devices are discussed in Section 6.8.

One exception to the above may be the agent-specific methods applied at BGAD. These include use of the Miniature Chemical Agent Monitor (MINICAM) applied for agent monitoring, as well as the Depot Area Agent Monitoring System (DAAMS) sampling systems. The MINICAM is a combined sampling/analytical system. DAAMS tubes need to be sent back to a laboratory for analysis. Both the MINICAMs and DAAMS can be deployed from BGAD's RTAP systems.

RTAPs are mobile vehicles that house or carry MINICAMs, DAAMS, and/or other equipment. All are equipped with radios. These vehicles can take air samples while in transit, but this is not recommended; the RTAPs should be stationary when monitoring or sampling the air. Two technicians are needed to operate each RTAP when deployed off the installation.

BGAD maintains 13 RTAPs with MINICAM capabilities, and one configured with DAAMS. In the event of a CAI, most if not all of the RTAPs are likely to be deployed on post until the source is under control (i.e., the plume has stopped and the agent is no longer being released to the atmosphere). However, these RTAPs are anticipated to be available for temporary re-entry missions (see Chapter 7) and are anticipated to eventually become available to support off-post sampling. Figure 6-7 provides a fact sheet from the PCD on MINICAMs, DAAMS, and RTAPs.

U.S. ARMY PUEBLO CHEMICAL DEPOT

FACT SHEET

REAL TIME ANALYTICAL PLATFORM

Chemical Agent Monitoring

The Real Time Analytical Platform (RTAP) is a self-contained mobile monitoring and detection system. Pueblo Chemical Depot (PCD) RTAPs use gas chromatographs called Miniature Continuous Air Monitoring Systems (MINICAMS®) that can detect agent within six to nine minutes.

The RTAP can detect chemical agent vapors at levels lower than those that would cause effects to unprotected persons. These levels are equal to the Department of Health and Human Services requirements for the levels of agent unmasked workers can be exposed to for a 40-hour work week with no harmful effects.

The RTAP is used to support personnel with real-time monitoring requirements for chemical agent storage operations. The units are also used to support Chemical Stockpile Emergency Preparedness Program requirements.

Proper operation of the RTAP is verified using strict quality control procedures.

MINICAMS®

PCD primarily uses the MINICAMS.® These near-real-time monitors sample the air every six to nine minutes and are capable of 24-hour operation when monitoring igloos. Near-real-time data collection is the ability to collect data automatically and have the data delivered and analyzed quickly enough to affect monitoring and control decisions. MINICAMS® are very sensitive and can detect extremely low levels of chemical agent vapor by using a process called gas chromatography.

DAAMS

The Depot Area Air Monitoring System (DAAMS) is a portable air sampling unit that draws a controlled volume of air through a glass tube filled with a sorbent material. Chemical agent vapors are collected on the sorbent material. Sampling times vary from as few as 30 minutes to 12 hours. After sampling is complete, the tubes are removed from the DAAMS station and sent to the laboratory for analysis within 72 hours.

RTAP monitoring a chemical agent storage structure

MINICAMS®

DAAMS

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Figure 6-7. RTAPs, MINICAMs, and DAAMS (U.S. Army 2017)

6.5.4 Wipe Sampling (e.g., Buildings, Vehicles, and Windows)

Data input for making a decision about re-entry may involve the collection and analysis of wipe samples. Wipes are used to take samples from non-absorptive surfaces such as glass windows, vehicle windshields, vehicle roofs or hoods, house siding, mailbox surfaces, tile, and countertops. They involve dousing an absorptive cloth or filter paper (as used in many analytical laboratories) with solvent (for example, methanol) and then wiping the surface of the material with the wipe in a prescribed fashion. The wipe picks up the chemical contaminant, which is placed in a sample bottle with the same solvent used in the wipe and then sent to the laboratory for analysis.

Wipe samples can be useful since agent deposition, should it occur, can settle on various outdoor surfaces. If agent is detected outdoors via air monitoring or media sampling, sampling inside adjacent homes and inside other structures may also be performed with wipes. Another advantage of wipes is that they will not damage or destroy surfaces as part of the sampling event. Some of the solvents used on the wipes may damage painted surfaces, however.
One benefit of wipe samples is that they can be readily composited. For example, should a vehicle be subject to wipe sampling, the front windshield can be wiped. The wipe would be placed in a sample vial with solvent, and then the back windshield could also be wiped and placed in the same sample vial. Wipe samples from multiple vehicles in the same location can similarly be composited. Mailboxes in an area could be composited the same way.

One additional concern with wipe sampling deals with direct sunlight and potentially hot surfaces. Wipe sampling would presumably take place some days after the plume has passed. If an agent actually settled on surfaces, direct sunlight and the heat it produces could significantly decrease COC concentrations over time. If this is a concern, wipe samples might be taken in shaded areas when possible. Caution should be exercised, however, because shaded areas—for example under trees—may not have received as much deposition as open areas.

6.5.5 Biota Sampling (e.g., Flora, Fauna)

Approaches for sampling biota such as flora and fauna may differ for each of the sampling partners participating in recovery sampling and analysis. Differences in SOPs are not likely to be significant. In general, biota are sampled by simply collecting them; for example, leaves, grass clippings, and edible plant portions can be harvested, placed in containers, and then stored to await shipment and analysis.

6.5.6 Composite Sampling

Compositing samples other than wipes may affect concentrations detected during analyses due to analyte loss during the compositing process. The primary concern here has to do with volatile chemicals, which include some of the agents, especially GB. However, considering the lack of data on compositing samples containing agent or degradation product, the Blue Grass CSEPP Community determined it would not employ compositing. However, with wipe samples, data suggests there should be no detrimental effects on analyte concentrations during the compositing process (Hess et al. 2016).

6.5.7 Sampling Equipment

Sampling equipment will be called out in the relevant SOP. Because soil sampling will target surficial soil layers, a stainless steel or plastic shovel or scoop will work best. Surface water samples can be collected by dipping the sample container into the water feature to be sampled. Air can be sampled and analyzed directly using direct-sensing field analytics. Air can also be sampled using MINICAMs and DAAMS tubes.

6.5.8 Decontamination Operations

Decontamination operations are needed in order to have "clean" sampling equipment for each sample, so that COCs from one sample do not contaminate subsequent samples. In other words, sampling equipment must be decontaminated between samples. As for sampling, partners will have SOPs for equipment decontamination. Decontamination procedures are also likely to be substantially equivalent. Decontamination, however, is tedious and time-consuming, and there is always a chance that inadequate decontamination will result in cross-sample contamination. Hence, in lieu of decontamination, RSAF sampling partners should try to rely on single-use, disposable equipment, thus avoiding the need for decontamination. Disposable items must be handled according to established waste handling protocols (see Section 6.11).

The procedure followed for decontamination depends on the item being decontaminated. The exterior surfaces of sample bottles should be wiped with a paper towel to remove gross (visible) contamination. If reusable water samplers are used, they should be decontaminated by removing gross contamination using brushes, approved water, and non-phosphate detergent. The samplers should then be rinsed with reagent-grade alcohol followed by a rinse with approved water. The decontaminated sampler should then be wrapped in clean aluminum foil prior to reuse. Solids material samplers and knives or scissors used to clip vegetation for sampling have the potential to become significantly contaminated after use. These items should be rigorously decontaminated before being reused.

6.6 Sampling Teams and Support Organizations

Support for sampling operations will come from a number of different organizations, both federal and state. These organizations were reviewed in Chapter 4. Individuals from them are likely to make up sampling teams, or may be involved in supporting sampling teams.

6.6.1 Organize Sampling Teams and Operations

With so many individual organizations potentially involved in sampling, organization of the sampling effort becomes key. Proper organization ensures that:

- Adequately trained sampling teams are in place;
- Resources needed to support sampling teams are available before they begin sampling operations;
- Staging area(s) for operations are identified, staffed, supplied, and prepared; and
- Sampling teams understand their daily assignments.

In addition, adherence to the principles of the ICS is paramount. The ICS was reviewed in Chapter 4. With respect to the sampling and the ICS:

- The Incident Commander (in accordance with the NCP, this would be OSC) is the ultimate decision maker, supported by decision makers within the UC or MACG;
- The Planning Section designs the sampling plan;
- The Operations Group carries out the sampling plan;
- Within the Operations Group, individual task forces make up the sampling teams;
- The Logistics Group ensures that all resources are in place to support sampling;
- The Finance and Administration Group tracks resources and expenditures; and
- The Safety Officer establishes health and safety requirements.

Sampling teams should consist of a minimum of three to five individuals, as follows:

- Team leader;
- Actual samplers (one or two);
- Person responsible for sample handling (decontamination, labeling, packaging, transport);
- Person responsible for air monitoring and health and safety; and
- A communications person/runner (someone who is assigned communications with those in the sampling staging area and, if necessary, can run samples back to the staging area for screening and eventual transport to the laboratory).

Note that personnel on the sampling team may assume more than one role.

If possible, each sampling team should consist of people within one organization (e.g., KYNG, KDEP, BGCA, EPA). These people are all used to following their own SOPs and to working with each other in the field. As needed, field sampling teams may consist of people from more than one organization, but this practice should be limited.

6.6.2 Training Field Sampling and Support Teams

Candidates for sampling and support teams must be properly trained and experienced with sampling operations involving hazardous chemicals. In addition, candidates should have basic ICS training and Occupational Safety and Health Administration (OSHA) and Hazardous Waste Operations and Emergency Response training (29 CFR 1910.120). Although the Operations Group leaders should not be expected to go as far as to demand credentials for each individual involved in sampling operations, the organization supplying samplers and support personnel should be able to document training and experience of personnel who staff the sampling teams and support operations. Credentials for sampling teams may need to be provided, however, for access beyond traffic control points and into sampling areas.

In addition to the above, pre-deployment training for sampling teams may need to be provided prior to beginning sampling operations. Pre-deployment training is especially warranted for individuals who may not be experienced with sampling in potentially chemical agent-impacted

areas, and for Army-specific procedures for air monitoring and sample screening for the chemical agent.

6.6.3 Staging Areas for Sampling Operations

With a potentially multiple-sampling-team, multiple-day operation, it is important to set up a staging area for sampling operations. This may be set up adjacent to or near the ICP, but should be a separate location dedicated to sampling operations. In accordance with accepted health and safety practice, the sampling staging area should be established with a hot zone (leading into the potentially contaminated area), a personnel decontamination (intermediate) zone, and a support (clean) zone. Sample screening for the presence of agents (see Section 6.11) should be conducted at the site of sampling or just inside the hot zone. The decontaminated sample bottles/coolers should be brought into the decontamination zone by the samplers. The support zone is for stockpiling sampling equipment and materials and is also used for health and safety, medical and other support.

Ideally, a mobile analytical laboratory can be brought in (e.g., EPA's PHILIS laboratory) and located near or adjacent to the staging area and ICP. The shorter the time for transport of samples to the laboratory, the better, as discussed earlier. A good location for the sample staging area (and ICP/mobile laboratory) would be just inside the BGAD boundary, in an area that is confirmed free of contamination.

Note that for an exceptionally large release, or if samplers are approaching the potential depositional area from different directions (e.g., outside-in versus inside-out sampling approach) multiple staging areas may be identified. Staging areas may also be moved as parts of the potential depositional area are determined to be free of contamination or determined to have been impacted by the release (e.g., positive identification of agent or degradation products).

6.6.4 Health and Safety and PPE

Within the ICS Command Group, the Safety Officer is responsible for establishing the requirements to ensure the health and safety of sampling teams, and of those staffing the sample staging area—including the personnel decontamination operation. A Health and Safety Plan (HASP) must be established to address not only hazards presented by the agents and degradation products, but also typical hazards faced by samplers at conventional hazardous waste sites. These include, but are not limited to, cold, heat, insects, snakes, and trips and falls.

6.6.5 Air Monitoring

Because it would be premature to send out samplers while a plume is still present or potentially present, it would be unlikely that samplers would encounter agent in air during sampling operations. However, for health and safety reasons, portable air monitors should be employed prior to approaching and while within potentially contaminated areas. Samplers should be prepared to exit areas immediately if they discover that they are not wearing the proper level of PPE.

6.7 Field Communications and Other Tools

During the course of a response to a potential off-post release, field communication devices and field-deployable handheld and/or aerial devices can play important roles, such as:

- Maintaining communication between sampling teams and the command post, OSC, UC, and decision makers;
- Providing field teams access to interactive maps and datasets that may be important to the sampling that needs to be conducted;
- Allowing for the capture of evidence of potential significance to field work, including photographs, short video clips, and voice recordings;
- Determining and verifying the coordinates of field sampling locations; and
- Capturing field data in electronic forms and facilitating the submittal of that data for review, analysis, and archiving.

Information technology changes rapidly. The purpose of this section is to describe generic functions that field-deployable technology can play in a response, recognizing that the tools available at the time of the event may be significantly different from those available to responders today.

6.7.1 Personal Communication Devices

For this section's purposes, communication devices primarily refer to personal smart phones, but can also include communication devices issued by the Army, DHS, FEMA, or state and local agencies. The primary purpose of these devices is to maintain communication links between field personnel and the ICP. However, personal smart phones also can serve other purposes, such as providing interactive maps that can be used to find routes to sampling locations, overlaying imagery to provide situational awareness, and roughly determining location coordinates. Smart phones can also act as Wi-Fi hotspots, allowing other types of internet-enabled equipment to connect when those connections serve a purpose.

Use of personal smart phones assumes that cell towers are operational. If an off-post release is associated with a significant natural event (e.g., a severe storm), cellular networks may be either damaged and/or overwhelmed with use in response to the event. However, by the time a post-event sampling effort is underway, it is reasonable to assume that cellular coverage will be available to support responders.

6.7.2 Tablets for Data Collection and Submission

Field-deployable handheld devices also include tablets. These devices can serve other purposes beyond simply communication, including the capture, retention, and transmittal of data important to the field effort. These data can include contextual data such as photographs, video clips, voice annotations, Global Positioning System (GPS) coordinates for a particular location, written notes, and text data captured in forms. These types of data can be stored for later retrieval, or submitted immediately to the ICP for review, analysis, and archiving.

There is currently software that can be used to develop and customize form-based data collection using tablets and smart phones. This includes building in entry constraints that check for common data collection issues and enhance data capture quality (i.e., forcing numeric entries when those are the only valid entries). The focus areas mentioned earlier may be preloaded on tablets and include GPS coordinates and forms for entering observations and data.

This is a rapidly changing technology; for example, it is now common to use the camera associated with handheld devices as a barcode reader. In the case of sample collection, this can be used to associate pre-labeled sampling containers with other information such as a sampling location and photographs. One would expect the rapid rate of change to continue, producing additional opportunities to integrate field-deployable technology in field sampling efforts.

6.7.3 Use of Unmanned Aircraft Systems (UASs) in Sampling Operations

Small unmanned aircraft systems (UASs) are another emerging technology that could play a significant role in an offsite release response. The Federal Aviation Administration (FAA) defines small UASs as systems that weigh less than 55 pounds. The FAA currently allows flight of these systems under three different paradigms: as recreational systems by individuals, for commercial purposes by businesses, or by public agencies for public applications. The rules governing the use of small UASs vary significantly depending on the paradigm under which one is operating.

For an off-post release, one would expect that an application of UAS to the data collection effort would take place either through the use of a contractor, in which case the FAA's Part 107 rules would likely apply, or by government entities, in which case use may be governed by a public Certificate of Authorization (COA) granted by the FAA to the government entity. FAA UAS regulations are rapidly evolving.

Small UASs typically fly at low altitudes (less than 400 feet) and are commonly powered by batteries, which limits their flight time to about an hour or less. Their use requires de-conflicting potential airspace issues where manned aircraft are also in operation through coordination with local airports and/or other entities operating manned aircraft in the areas. Currently, UASs are typically used to collect aerial imagery (in either the visual or the infrared spectrum). In this context, they can provide rapid coverage of areas where visual clues visible from low altitudes may be provide valuable insight into what occurred. Technology is currently available to stream video collected from a UAS to a wider audience in real time. Research is underway using UASs to collect environmental samples such as soil or surface water from locations where, for whatever reason, access by a sampling team is problematic. Although these types of systems are not commercially available at the moment, at the rate of technology change these may be available if an off-site release happens at some point in the future.

6.8 Field Analytical Methods

6.8.1 Select Field Analytical Methods

Field analytical methods that might be deployed post-incident include the following:

- Liquid detection using M-8 paper (Luxfer Magtech 2017d) or M-9 tape (Luxfer Magtech 2017e);
- Vapor detection using the M18A3 (Luxfer Magtech 2017a) or M-256A1 kits (Luxfer Magtech 2017b);
- Water testing kit M272 (Luxfer Magtech 2017c);
- Chemical agent monitors (CAMs) (Smiths);
- Proengin AP2C (Proengin undated b);
- DAAMS (Markes International undated);
- MINICAMs (OI Analytical 2017);
- Joint contaminated surface detector (U.S. Army undated);
- Joint chemical agent detector (JCAD) (U.S. Army Acquisition Support Center);
- Hazardous Air Pollutant Site (HAPSITE) chemical identification system (Inficon undated);
- MATCAD detector (Msaga, undated);
- ChemPro 100i (Environics); and
- HAPSITE ER (Inficon, undated).

M-8 paper and M-9 tape have sensitive indicator dyes that react and produce agent-specific colors when exposed to liquid containing agent. Note that some household chemicals may react with M-8 or M-9 paper to produce a positive response.

The M-18A3 chemical agent detector kit also reacts to chemical agents by producing specific color changes when exposed to chemical agents. The device responds to vapor, aerosol, and liquid. Response time is two minutes to four minutes (Luxfer Magtech, Inc. 2017a).

The M256 sampling kit is also a colorimetric test kit. The detector kit reacts to agent in the air (Luxfer Magtech, Inc. 2017b).

The M272 water testing kit determines whether water has been contaminated with agent. It uses colorimetric techniques to qualitatively determine whether agent is present or absent. In general, under the release scenario being planned for under this RSAF, some of the agents in water would more than likely degrade into degradation products. Hence, the results of the M272 would have to be backed up with other analytical methods that target degradation products (Luxfer Magtech, Inc. 2017c).

The CAM detects nerve and mustard agent vapors. It has near-real-time response capability (one minute) to detect 0.03 mg/m^3 (GB), 0.1 mg/m^3 (VX), and 0.1 mg/m^3 (mustard). The CAM may be considered a real-time gross level detector (Smiths 2017).

MINICAMs are used at BGAD and are low-level monitors that can detect agent in air within three to five minutes. The MINICAM is designed to respond to 0.0001 mg/m^3 for GB, 0.00001 mg/m^3 for VX, and 0.003 mg/m^3 for mustard. It typically provides results in less than 15 minutes and has alarm capability (OI Analytical 2017).

The DAAMS technique involves drawing air through a tube filled with sorbent material over a set period of time. The tube is then analyzed in a laboratory, so it is not a real-time system. However, results may be obtained within a few hours after receipt at the laboratory and could support a triad approach to sampling. DAAMS can provide low-level detection capability for all the agents stored at BGAD. As discussed in Section 6.5, both this system and MINICAMs can be mounted in the RTAPS maintained at BGAD.

The ChemPro 100i relies on an open-loop ion mobility spectrometry sensor. The device samples ambient air, or it can be used to sample a surface (such as sampling PPE after decontamination). Readings from the device are compared to “library” readings. The low alarm (think of low alarm as a DL) for nerve agent is 0.00004 mg/m^3 and the low alarm for mustard is 0.0005 mg/m^3. The ChemPro 100i functions as a real-time gross level monitor (Environics USA 2017).

The HAP SITE ER system used by the KDEP ERT is an air monitoring system as well but can be also used for headspace analysis of environmental media. It uses a thermal desorption subsystem linked to the analytical component of the HAP SITE ER tool. The HAP SITE ER system compares data derived during the analysis to a “library” of results, including agent results, to qualitatively identify agent contamination (Inficon undated).

The EPA ERT is likely to have access to the following field analytical equipment: CAM/ICAM, AP2C/AP4C, APD-2000, Draeger (CDS Kit), M256/M256A1, and M272 (water) (as referenced in the NRT Quick Reference Guides for HD [EPA and ERT 2015a], GB [EPA and ERT 2015b], and VX [EPA and ERT 2015c]). Devices not described above include the AP2C, Smiths Detection APD 2000, and Draeger Civil Defense Simultaneous-Test Set.

The AP2C has a fast response time and is suitable for monitoring GB, VX, and H in vapor or aerosol form (Proengin 2015). The Smiths Detection APD 2000 is capable of monitoring for agents and hazardous chemicals in air at what is reported to be relative concentrations. The APD 2000 is no longer available. The Draeger Civil Defense Set Simultaneous-Test Set (Draeger CDS-Test) uses colorimetric detector tubes for the detection of mustard in air, but not the two nerve agents present at BGAD (Draeger 2017).

6.8.2 Limitations of Field Analytical Methods

By helping to verify the adequacy of decontamination, these methods can substantiate that field sampling teams can perform sampling activities safely. However, field analytical methods have limited capability. For example, they will not be useful in determining the extent of contamination caused by aerosol deposition on soil, vegetated surfaces, automobiles, buildings, and roads. In addition, field methods are designed to assay for agent, not for degradation products. Because both agents and degradation products are COCs, use of the field agent

detectors is mostly limited to temporary re-entry missions (see Chapter 7) and health and safety support of field sampling teams.

6.9 Laboratory Analytical Methods

A key component of the RSAF is to pre-identify available laboratory resources that may be called upon to analyze samples for chemical agents and degradation products in the event of a CAI. This section addresses laboratories that can perform definitive analyses (as opposed to screening or field analyses) for the agents and degradation products. It includes fixed laboratories (laboratories located in buildings) as well as full-service mobile laboratories. Mobile laboratories more recently came online after 9-11 for the express purpose of providing onsite support in the event of an Incident of National Significance as defined under the DHS National Response Plan (DHS 2004).

The great advantage that laboratory analyses have over field analyses is that laboratory analysis provides an additional level of confidence that the results are definitive and can be used more confidently for decision-making.

6.9.1 Requirements for Laboratory Analytical Methods

There are many government and commercial laboratories operating throughout the United States. Many of these are accredited in some fashion, but not all are pre-dispositioned to analyzing chemical agents and degradation products. This is especially true for the chemical agents, because these chemicals are regulated under international treaty, federal regulations, and ARs. Obtaining standards is key to performing chemical agent analyses so that positive identification of the agents can be confirmed. These standards emanate from the Army's Chemical Agent Standard Analytical Reference Material (CASARM) program, which is run out of the Army's CMA at Aberdeen Proving Ground, Maryland (http://www.cma.army.mil/).

There are also chemical surety (security) concerns regarding the agents. Laboratories must adhere to stringent requirements to meet CASARM standards. Hence, relatively few laboratories maintain the ability for agent analyses. Many more labs are situated to perform agent degradation product analyses. Sample screening (see Section 6.11) is required of all samples that leave a potential contaminated area. Only those samples that do not contain agent above worker protection standards can be sent to the labs performing degradation product-only analyses.

Another key consideration is laboratory accreditation. The National Environmental Laboratory Accreditation Council (NELAC) has established stringent QA and other requirements for accreditation (NELAC and NELAP undated). Laboratories performing analyses pursuant to RCRA and CERCLA hazardous waste requirements must be NELAC-accredited. Part of the accreditation involves showing proficiency for conducting specific analyses prior to receiving samples. Proficiency testing applies to the laboratory as well as individual analysts. In addition, proficiency testing must be performed periodically, typically yearly. Hence, even for labs that are pre-accredited for chemical agent or degradation product analyses, if these sorts of analyses are not performed routinely, proficiency testing may be needed prior to running samples. This could delay sample analyses if a CAI were to actually occur at BGAD. Because agent and degradation

product samples have a shelf life after which analyses should not be performed, the time between sampling and analysis must be evaluated. This means that sampling may need to be delayed to allow time for laboratories that do not normally perform these analyses to ramp up.

In addition, there are several other factors to consider. For comparability, laboratories that perform sample analyses should perform them using the same analytical methods. This is not mandatory, however, because many of the methods applied are still based on common instrumentation (e.g., gas chromatography/mass spectrometry) and procedures (sample preparation and extraction). However, if laboratories use the same methods, this removes one more variable from the interpretation of results from multiple laboratories.

In addition, laboratories should maintain a common Laboratory Information Management System (LIMS). This produces laboratory deliverables in compatible formats so that sample results from multiple laboratories can be efficiently combined, evaluated, reviewed, and interpreted using common software applications.

6.9.2 Select Laboratory Analytical Methods

One set of methods and resources should be identified as the primary resource to be used off-post. It was recognized that Army methods/resources would likely be used on-post; however, the OSC could request other resources, including, for example, EPA laboratory resources. The most likely choice is to use EPA analytical resources and methods and request the PHILIS located in Edison, New Jersey, and, depending on the magnitude of the incident, possibly also the other PHILIS located in Castle Rock, Colorado. The Army laboratory and analytical resources could also be used to supplement EPA resources, and could analyze split samples for QA (see Section 6.10).

Complicating the decision on which method to use is the fact that analytical methods and resources are very much related. In other words, if Army methods are used, Army laboratories must be used. It follows that if EPA methods are used EPA laboratories must be used. As mentioned in Chapter 4, EPA maintains two mobile laboratories (PHILIS) that can travel to any location in the United States in a matter of hours. One is located in Edison, New Jersey, and the other is in Castle Rock, Colorado. EPA and several states also maintain fixed laboratories that are approved for these analyses.

6.9.3 Potential Analytical Resources

PHILIS units are the EPA’s mobile laboratory assets under the Environmental Response Laboratory Network (ERLN), designed to detect agent and other chemicals in environmental samples (EPA 2009). There are also five fixed EPA laboratories that are part of the low-level chemical agent standard program. These EPA regional laboratories are located in Regions 1 (New York), 3 (Philadelphia), 6 (Dallas), 9 (San Francisco), and 10 (Seattle). There are also two state laboratories, one in Virginia and another in Florida. All of these laboratories are equipped to CASARM standards and are NELAC accredited, and they are all part of the National Environmental Response Laboratory Network. They would run the EPA National Homeland

Security Research Center sampling and analytical methods (SAMs), as discussed earlier, and they all have compatible LIMS and data deliverables.

Additional labs that can be accessed include Battelle's facility in Columbus, Ohio, and one at Lawrence Livermore's facility in California. The Army's ECBC lab in Aberdeen, Maryland, routinely runs agent analyses and can be accessed as well. BGAD and PCD (including the chemical agent pilot plants located there) also both operate smaller labs that are set up to run agent analyses. However, the PCD lab is only set up to run mustard analyses. Although these labs all meet CASARM standards, they are not NELAC accredited. These labs may use methods that are similar to but not the same as the EPA SAM methods. Results would nevertheless be comparable to EPA SAM methods, as discussed above. In addition to performing agent analyses, these labs would be capable of analyzing samples for degradation products.

A number of NELAC-accredited commercial analytical laboratories are also capable of performing agent degradation product analyses. Many of these laboratories routinely perform these types of analyses; for example, they analyze samples taken from current and former defense sites that had a history of agent testing or disposal. Were these laboratories to receive samples from a CAI site, the samples would need to be prescreened for chemical agent to ensure that they do not contain agent above worker protections standards (see Section 6.11).

All told, and excluding commercial laboratories, there are 14 CASARM and NELAC-accredited laboratories capable of performing agent analyses. Therefore, capacity exists to perform analyses in the event of a CAI. However, there are great advantages to using a mobile laboratory that can be located near the site of potential contamination. EPA's mobile PHILIS laboratories can operate 24/7 and indicate they can analyze between 100 to 200 samples a day (EPA undated a). In comparison, sample throughput at the BGCA laboratory might be 12 to 20 samples per day. Sample throughput is important because samples need to be sent to the laboratories in such a manner so as not to significantly exceed their throughput. The samples have a shelf life and must be analyzed within a set period of time (estimated at seven days). Hence, the selection of analytical methods (and laboratories) must also consider throughput and sample shelf life.

6.9.4 Limitations of Laboratory Analytical methods

There are several limitations to laboratory processing of CAI samples:

- Only select laboratories are pre-approved to conduct agent analyses;
- Laboratory throughput for a single laboratory is limited;
- Fixed laboratories may be located far enough away from the sample site to require shipping; and
- Should sample screening show that the samples contain agent above worker protection standards, controlled escort of these samples may be required.

6.10 Quality Assurance/Quality Control

QA/QC defines the requirements necessary to ensure that the data produced in any environmental investigation is of adequate quality to support decision making. QA/QC requirements are defined for sampling operations, laboratory operations, and data management, and are typically developed as part of the DQO process (see Section 6.2).

The intent of this section is to present the basic QA/QC requirements of the sampling and analysis effort in an abbreviated manner.

6.10.1 Understanding QA/QC Requirements

The EPA has developed the bulk of the guidance available describing elements of QA/QC and presents these on their website (https://www.epa.gov/quality/agency-wide-quality-system-documents). Additionally, the EPA, DOD, and DOE have combined efforts to develop key QA/QC guidance documents. One in particular is pertinent to the RSAF: *The Uniform Federal Policy (UFP) for Quality Assurance Project Plans* (EPA et al. 2005).

The Quality Assurance Plan should identify key stakeholders and project organization, roles, and responsibilities. It should describe the project objectives and schedule and indicate project management. It should address a systematic planning process (SPP) established for these types of projects. Systematic planning originated with the USACE as the Technical Project Planning Process (USACE 2016). SPP is a key part of EPA's triad process, as discussed in Section 6.4.

The remainder of Section 6.10 discusses elements of QA/QC not already addressed.

6.10.2 Measurement Performance Criteria

Measurement performance criteria are established for the environmental media to be sampled (e.g., soil, water, wipes, vegetation) and for the analyses group to be determined (e.g., agents and degradation products). If needed, different criteria are established for each media and analytical group. The criteria are both qualitative and quantitative and relate to what are commonly referred to as data quality indicators. They include precision, accuracy/bias, representativeness, comparability, sensitivity, and completeness. These data quality indicators reflect a combination of requirements that reflect both the adequacy of sampling and analytical performance. They are examined for the RSAF below.

6.10.2.1 Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, percent difference, or range, in either absolute or relative terms. Precision data indicate how consistent and reproducible the field sampling and analytical procedures have been (EPA et al 2005).

Overall project precision is measured by collecting data from co-located field duplicate (or replicate) samples. Precision specific to the laboratory is measured by analyzing laboratory duplicate (or replicate) samples. Comparing overall project precision and laboratory precision will help to identify sources of imprecision if a problem exists (EPA et al. 2005).

If two separate samples are collected from adjacent locations and analyzed, these samples are referred to as co-located field duplicates. If two representative portions taken from a single sample are analyzed by the same laboratory, these are referred to as subsample field duplicates. If two aliquots of the same sample are prepared and analyzed by a laboratory, these samples are referred to as laboratory duplicates. If two aliquots of the same prepared sample are analyzed in duplicate, these samples are referred to as analytical duplicates (EPA et al. 2005).

For the RSAF, precision will be evaluated by calculating a relative percent difference (RPD) of laboratory control samples (LCSs), laboratory control sample duplicates (LCSDs), matrix spikes (MSs), matrix spike duplicates (MSDs), and field duplicates. The LCS/LCSD is an analyte-free matrix spiked with target analytes and is prepared as a check for sample extraction, digestion, and analysis for analytical batches. The MSs and MSDs are actual samples spiked with target analytes, and an MS/MSD is prepared for each analytical batch (typically, 20 samples). The MS is used to evaluate potential matrix interference and sample homogeneity for specific analytes, and the MS/MSD is used to evaluate precision for each analytical batch. When the RPDs among duplicate results exceed established acceptance criteria for the COCs (typically >20% or 30%), the data are qualified (during data verification and validation; see Section 6.10.6) accordingly. If exceedances of the RPDs are identified, the sampling and analytical techniques may be examined to determine whether SOPs are being followed.

6.10.2.2 Accuracy and Bias

Accuracy is the degree of agreement between an observed value (sample result) and an accepted reference value; bias describes the systematic or persistent distortion associated with a measurement process. The terms accuracy and bias are typically used interchangeably (EPA et al. 2005).

Analyte accuracy and bias is evaluated using different types of QC samples. For example, a standard reference material or an LCS that contains a known concentration of analyte(s) spiked into contaminant-free water or another blank matrix provides information about how accurately the laboratory (analysts, equipment, reagents, etc.) can analyze for a specific analyte using a selected method. Single-blind and double-blind proficiency testing (PT) samples also provide information on how accurately the laboratory can analyze for a specific analyte using a selected method. Accuracy and bias are calculated as a percentage (EPA et al. 2005).

Because environmental samples contain interferences (i.e., compounds that may interfere with the analysis of a specific analyte), the accuracy or bias for a specific analyte is evaluated in relation to the sample matrix. This is done by analyzing MS and MSD samples. MS and MSD results are indicative of matrix interference and are used to evaluate potential bias in sample results. The difference between the concentration of the analyte in the unspiked sample and the concentration of the analyte in the spiked sample should be equal to the concentration of the

analyte that was spiked into the sample. Frequently, MS samples are prepared and analyzed in duplicate, especially for organic analyses, to provide sufficient precision and accuracy data to evaluate achievement of quality objectives (EPA et al. 2005).

In some cases, accuracy is also assessed though the use of surrogates. Surrogate standards are non-target compounds added to field and QC samples for organic analyses to evaluate matrix effects and analyst/method performance on an individual sample basis.

For the RSAF, accuracy will be assessed by monitoring LCS, MS, and MSD samples. Where surrogates are used, accuracy will also be assessed through recovery of surrogates from each field and QC sample. The recovery of target analytes is compared with acceptance criteria, typically around 20% to 30%, but sometimes higher depending on the analyte. Accuracy will also be assessed by comparing recoveries to laboratory in-house control limits. If these criteria are not met, sample results will be qualified during data verification and validation (see Section 6.10.6).

6.10.2.3 Representativeness

Representativeness is a qualitative term that describes the extent to which a sampling design adequately reflects the environmental conditions of a site. It takes into consideration the magnitude of the site area and indicates the feasibility and reasonableness of the design rationale. Representativeness also reflects the ability of the sample team to collect samples and the ability of the laboratory personnel to analyze those samples so that the generated data accurately and precisely reflect site conditions. In other words, a discrete sample that is collected and then subsampled by the laboratory is representative when its measured contaminant concentration is comparable to the contaminant concentration of some predefined vertical and horizontal spatial area (e.g. DU or SDU) at the site. Sample homogeneity, sampling variability, and subsampling variability, should all be considered when developing criteria for representativeness (EPA et al. 2005).

6.10.2.4 Comparability

Comparability is the degree to which different methods or data agree or can be represented as similar. It describes the confidence that different datasets, perhaps from multiple sources, can contribute to a common analysis and interpretation (EPA et al. 2005). Comparability is a qualitative evaluation factor. The term “comparability” is an umbrella term that encompasses an array of sampling and analysis characteristics that individually may or may not be comparable when contrasting different sampling or analytical procedures and their results, or different datasets describing the same characteristic.

One common means of evaluating data comparability (or the lack of it) is the use of split samples and regression analysis or correlation coefficients. Should split samples be taken and analyzed by different laboratories, such as by EPA and Army laboratories, comparability will be an important evaluation factor. If datasets produce similar results, there is no issue. If datasets produce varying results, it may be difficult to ascertain which dataset produces the more usable results. In this case, examining the other evaluation factors described herein may provide clues to the reasons

for the differences in results. Data verification and validation, discussed in Section 6.10.6, would also offer some resolution.

6.10.2.5 Sensitivity

Sensitivity refers to the ability of a method or instrument to detect the target analytes at the level of interest, in this case the action level (discussed in Section 6.3). Sensitivity can be determined by examining and quantitation limits (QLs) and DLs. Note that different laboratories often use different terms with similar meanings to describe the same characteristics. For example, laboratories often interpret QLs as reporting levels.

The QL is the minimum concentration of an analyte that a laboratory can routinely identify and quantify above the method detection limit (MDL or simply DL) (EPA et al. 2005). DLs are the lowest levels of an analyte that the laboratory can identify in an environmental sample. A "detection" between the DL and QL typically means that there is a certain degree of confidence (e.g., 99%) that the analyte is present, but that its exact concentration cannot be measured with certainty. DLs are specific to the method and the laboratory and may also be influenced by the analyst. Sometimes DLs can change day to day as well, because certain laboratory instrumentation can be very sensitive to ambient conditions, including temperature and pressure. DLs are typically lower than QLs by a factor of between 3 and 5. When the laboratory detects an analyte between the DL and the QL, the laboratory qualifies the concentration noted as "estimated."

Laboratories will typically report both the DL and the QL (reporting level) in the data report. Sometimes action levels are so low that laboratories, even with the most sophisticated methods, may be unable to actually see concentrations of some analytes at or near the action level. Actions in this case are discussed in Section 6.13.

6.10.2.6 Completeness

Completeness is a measure of the amount of valid data collected using a measurement system (EPA et al. 2005). It is a way to compare the data required by the sample design to the data that was actually collected and is often further broken down into the amount of data that are usable (i.e., not qualified during data verification or validation; see Section 6.10.6) compared to the amount of data that are questionable or unusable. Completeness is often expressed as a percentage or ratio. In addition, completeness can be further broken down into:

- Contractual completeness—Data required by contract versus data received.
- Analytical completeness—Data required versus data qualified as unusable.
- Technical completeness—Data that are useable versus total number of results.

Invariably in environmental investigations, not all samples specified by the sample design can be collected. Often, some portion of the data collected also may be qualified during verification or validation as questionable or unusable. It boils down to the question of whether there are enough data of adequate quality to support an informed and reliable re-entry determination. The determination of completeness therefore comes at the completion of data verification and

validation, when decision makers are advised as to whether the data will support solid decision making.

6.10.3 Field Sampling and Quality Control

Field sampling and quality control are controlled through the prescribed use of SOPs. This includes SOPs for sampling, decontamination, sample screening, chain of custody, and sample handling, from the field to the laboratory. SOPs also describe proper sampling containers and sample preservation requirements, and they address sampling equipment calibration, maintenance, testing, and inspection.

As discussed in Section 6.6, each organization that contributes personnel to sampling teams will come with its own equipment and SOPs. It would not be advisable to require that all organizations use one set of SOPs. These organizations are used to their own SOPs, and as indicated earlier, it is very likely that these SOPs will be substantially equivalent. It is these SOPs that will be used to ensure quality control during field sampling.

6.10.4 Field Quality Control Samples

Field quality control samples include the use of blank samples, duplicate samples, split samples, and MS/MSD samples. These are samples taken along with “actual” samples, and are used to evaluate precision, accuracy, representativeness, and comparability.

Because of potential litigation following any release from BGCA, whether off-post deposition is confirmed or not, the off-post community must maintain stringent QA/QC requirements, including conventional rates established for field QC sampling. Therefore:

- Trip and field blanks will be taken at the rate of one per sampling team outing.
- Equipment blanks will be taken once per sample location.
- Duplicate samples will be taken at a rate of 5%, one out of every 20 samples.
- Samples for MSs will be taken at a rate of 5%, one out of every 20 samples.
- Split samples will be taken as alternate laboratories become available to conduct the same types of analyses under stringent QA/QC controls.

6.10.5 Laboratory Quality Control

Laboratory QA/QC is defined within laboratory QA/QC documentation that is developed in accordance with overarching certification organization requirements (e.g., DOD manuals, laboratory accreditation), and is fairly rigid. Laboratories conducting analyses pursuant to RCRA and CERCLA site investigations are required to be certified under NELAC and National Environmental Laboratory Accreditation Program (NELAP) (NELAC and NELAP undated). EPA’s mobile and fixed laboratory resources, discussed in Section 6.9, are all NELAP certified. This certification documents that the laboratory’s QA/QC program is adequate to support RSAF activities.

Army laboratories, such as ECBC (U.S. Army undated c), adhere to similarly stringent requirements established under the Chemical Material Agency Laboratory and Monitoring Quality Assurance Plan (LMQAP). Adherence to LMQAP requirements also documents that the laboratory's QA/QC program is adequate to support RSAF activities.

6.10.6 Data Quality Evaluation

A data quality evaluation or assessment is an after-the-fact assessment of data produced during field and laboratory activities. The UFP (EPA et al. 2005) describes this assessment as follows:

> *Data review is the process which data are examined and evaluated to varying levels of detail and specificity by a variety of personnel who have different responsibilities within the data management process. It includes verification, validation, and usability assessment. This QAPP element group encompasses the data review activities used to ensure that only scientifically sound data that are of known and documented quality and meet project quality objectives (PQOs) are used in making environmental decisions.*

The basic determination is whether data are of adequate quantity and quality to support decision making.

Data verification and validation are after-the-fact assessments of data produced in the field and in the laboratory to assess overall data quality to determine whether data are of sufficient quality to support decision making. Data verification is more of a screening-type evaluation that takes a minimum amount of time. It consists of an evaluation of the following:

- Trip and equipment blanks;
- Laboratory method blanks;
- Initial and continuing calibration blanks (total metals and anions);
- Sample extraction and analysis holding times;
- Surrogate recoveries;
- LCSs and LCSDs;
- MSs and MSDs;
- RPDs for LCSs/LCSDs, MSs/MSDs, and duplicate samples;
- Inductively coupled plasma (ICP) serial dilutions (total metals only); and
- Initial calibrations and calibration verifications.

Data verification is more of a completeness check than a complete data quality evaluation. However, issues are often noted during the process, which results in the assignment of data verification qualifiers. Modified laboratory data reports showing data verification qualifiers, if assigned, are typically developed by the verifier/validator.

Data validation is a much more in-depth evaluation, often involving examination of data from individual laboratory instruments (hard drive). It is important to confirm that data results between DLs and QLs are valid. Therefore, data validation becomes even more critical with the application of DLs.

Data verification of an RSAF dataset could take a few hours, a day, or more, depending on the number of samples and analytes measured. Data validation is more intense; it could take perhaps two or three times longer than data verification, or even longer if data quality issues are uncovered. Automated programs are available for these types of data quality assessments; however, verification and validation are usually performed "by hand," by qualified individuals. If an automated program is used, experienced SMEs should still be employed to help interpret the results.

Data verification and validation are necessary steps to ensure that data are of sufficient quality to support decision making. Data will become available to support decision making once they are released from the analytical laboratory. The question is, whether decision makers should wait until these data are properly assessed (verification and validation) before making decisions regarding re-entry, or whether decisions should be made as soon as possible after data are released.

Consider that samples will be collected and analyses performed over a period of days, weeks, or even months. Sample data produced over multiple sampling events will become available periodically, perhaps daily or even several times a day. Typically, data quality is assessed after all data are collected, collated, and organized into formal reports. A sub-issue here is whether data verification and validation should wait until all data are collected pursuant to an individual DU or SDU prior to decision making.

It could be argued that if a significant portion of results are close to action levels, then data verification and validation become more important. However, if the opposite were true—if a significant portion of results were far above or far below action levels—then it may not be as critical to determine whether there is a data quality issue that may be affecting the results. Hence, the need for data verification and validation could be dependent on the relation of the data to action levels.

The UFP (EPA et al. 2005) also refers to a final step in the data evaluation process, known as a usability assessment:

> *A usability assessment considers whether data meet project quality objectives as they relate to the decision to be made, and evaluates whether data are suitable for making that decision. All types of data (e.g., sampling, on-site analytical, off-site laboratory) are relevant to the usability assessment. The usability assessment is the final step of data review and can be performed only on data of known and documented quality (i.e., verified and validated data).*

Decision making is discussed further in Section 6.13.

6.11 Sample Handling

Like sampling methods (Section 6.5), the procedures for sample handling have been used at many locations during conventional hazardous waste site investigations under RCRA and CERCLA. These same methods will be applied for this RSAF, with one exception: in accordance with Army requirements, samples potentially containing agent must be screened to determine

agent content, to ensure that samples are handled properly and are sent to laboratories prepared to handle them (see Section 6.11.4).

6.11.1 Maintaining Field Log Books

All information pertinent to sampling should be recorded in field logbooks. Field logbooks are bound, unprinted books such as a surveyor's field book; logbooks that are made for outdoor use in different conditions (e.g., cold, rain, snow) are preferred. Each page or form of the logbook should be consecutively numbered. All entries should be made in indelible ink. All corrections should consist of single line-out deletions that are initialed and dated. Sample locations must be geo-located with a GPS unit, so they can be georeferenced using data visualization software. Documenting sampling locations is also important because some location may need to be revisited later for re-sampling.

Example logbook forms for soil samples, water samples and map files are found in Appendix F.

6.11.2 Sample Labeling

Every sample collected should have a sample label that uniquely identifies the sampling point and the desired analytical parameters. Adhesive on sample labels should be sufficiently robust so that the label will not wash off in water. An indelible pen should be used to complete the information on the sample label. The following steps describe how to use a typical sample label system.

As a sample is collected, fill out a sample label. Enter the following information on each label:

- Project name;
- Project number;
- Location/site identification (including GPS coordinates);
- Date of sample collection;
- Time of sample collection;
- Analyses to be performed;
- Whether the sample is filtered or unfiltered (water samples only);
- Preservatives or wipe solution used; and
- Number of containers for the sample (e.g., 1 of 2).

The completed label should then be applied to the sample container and the sample number and designated sampling point should be recorded in the field logbook, along with the following sample information:

- Time of sample collection (each logbook page should be dated);
- Sampler name and organization;
- The location of the sample (with a sketch and using a GPS device);
- Agent (CAM or similar) meter readings for the sample (when appropriate);
- Any unusual or pertinent observations (oily sheen on groundwater sample, incidental odors, soil color, grain size, plasticity, etc.);

- Number of containers required for each sample; and
- Whether the sample is a quality control sample (split, duplicate, or blank).

Barcode technology offers more expedient data management possibilities. Labels can be purchased with barcodes linked to a blank label. An accompanying identical barcode can then be affixed to the chain-of-custody form to aid in data management. As discussed in Section 6.11.6, Sample and Data Tracking, another possibility to consider is using a software package such as Scribe.net (EPA undated f) that tracks sample information and generates sample labels. Scribe is described more completely in Section 6.11.6.

6.11.3 Sample Integrity and Chain of Custody

Following deliberate chain of custody procedures will prevent sample tampering as they are processed from field to laboratory. Protocols for chain of custody usually involve the use of sample container seals and documentation whereby samplers affirm, in writing, that samples have not been out of their custody between when the sample was collected and when it is delivered to an analytical lab for example. The steps involved and a description of the content of a chain-of-custody form include:

- Give the site name and project name/number;
- Enter the sample label information;
- Indicate the sampling dates for all samples;
- List the sampling times (military format) for all samples;
- Indicate “grab” or “composite” sample with an X;
- Specify the sample location;
- Enter the total number of containers per cooler;
- List the analyses/container volume;
- Obtain the signature of sample team leader;
- State the carrier service and air bill number, analytical laboratory, and custody seal numbers;
- Sign, date, and time the “relinquished by” section; and
- Upon completion of the form, retain the shipper copy and affix the other copies to the inside of the sample cooler, in a zip-seal bag to protect from moisture, to be sent to the designated laboratory.

Another approach to consider is a software package that prepares a chain-of-custody form after the user populates entry screens with sample-specific information. Scribe.net, described in Section 6.11.6, can generate chains of custody while also serving as a central repository for information about the location of sample containers after sample collection.

6.11.4 Sample Screening, Packaging, Security, and Transport

Any sample with the potential to contain agent is required (DA PAM 385-61, November 2012) to go through a screening process. The purpose of the screening process is to insure that samples containing agent are sent only to those laboratories that are prepared to handle them, and that proper surety protocols are maintained during transport. Samples screened and determined not to

contain agent at concentrations that would be a threat to staff “downstream” of the sample collection and transport teams may be sent to other laboratories, for example, for degradation product analyses.

Environmental samples collected by the sampling teams will need to undergo screening in a restricted and controlled fashion, as specified in DA PAM 385-61. Screening involves heating to facilitate off-gassing and collection and analysis of air samples to demonstrate the likelihood of agent being released from the sample at levels of concern. Prior to shipment, the sender documents the chemical agent hazard level.

The Army OSC has control of the screening process in that the screening process must occur while the samples are under government control. Samples that are confirmed to contain some level of agent must also be maintained under government control. Government control includes Army possession, as well as possession by state and federal agencies and their laboratories. For example, possession of samples by KDEP or KYNG would mean that the samples are under government control. Government control would also include analysis at both fixed and mobile government laboratories.

In addition, the sampling program would need to comply with Army requirements for handling samples potentially contaminated with agent. These requirements include training, safety criteria for agent activities, personnel protective practices, surety requirements, and requirements for decontamination and disposal.

Large numbers of samples could overwhelm the analytical capacity of onsite mobile laboratories or nearby fixed laboratories, such as those operational within BGAD. Agent-containing environmental samples could be analyzed on the depot, at a mobile laboratory located onsite (area of contamination) or the site, or at an offsite laboratory that has been qualified and approved to process these samples. Should large numbers of sample overwhelm onsite or nearby resources, samples containing agent above the screening levels can be transported to any of several offsite laboratories (see Section 6.3.7) that have been approved to handle them. However, because of agent-hazard concerns, it may not be possible to transport such samples using commercial carriers. It may be necessary for Army resources to escort such samples.

Samples that represent a threat to laboratory workers (from, for example, an inadvertent unprotected exposure to the sample) must be sent to an approved laboratory (DA PAM 385-61). If an approved laboratory is offsite, the OSC may require any sample that potentially contains agent to be specially escorted and transported using Army staff and Army transport systems. Samples that do not represent a threat could be removed from restricted control and sent to a conventional laboratory. Samples removed from restricted control could be transported via commercial shipping systems.

Packaging and transport requirements for pure or nearly pure agent samples differs greatly from the requirements for agent-related environmental samples. BGAD has in-house capability to perform the agent screening step, laboratory-related analyses, and the low-level agent analyses necessary for risk-based decisions regarding re-entry. Alternatively, mobile laboratories may be brought in. Analytical support was described in Section 6.9.

Considering the agent screening step described above, sampling teams will need to collect multiple samples for each media type at each location. One sample is required for the screening; another sample is required for the agent analyses; and a third sample is required for degradation product analyses. In the case of VX, one sample should be taken for MPA/EMPA and one for EA-2192, because these analytes are analyzed using different analytical methods. In addition, other samples may be needed from the same location for QA (see Section 6.10).

6.11.5 Sampling Handling and Laboratory Operations

Once received at the laboratory, samples go through a very structured log-in and handling process. Sample handling is controlled at the laboratory by SOPs similar to those that exist for the sampling operation. These SOPs ensure that samples are handled properly, that chain of custody is maintained, and that the health and safety of laboratory staff is protected.

6.11.6 Sample and Data Tracking

The post-event RSAF will create large data streams that will lead to decisions regarding re-entry or the need for some type of removal or remedial action. Further, these data streams may emanate from different sources. There will be data from first responders (from restricted/conditional re-entry missions), data from sampling teams (observations, photographs, agent air monitoring, field and sample logs), and data from one or more laboratories. The data streams may include:

- Geo-references for sample locations (GPS, latitude/longitude);
- Sample results from direct-sensing, field-portable instruments;
- Observational cues (dead animals, stained surfaces, UAV video feed, etc.);
- Sample-specific information like sample type, sample time, analytical method, where sample is in the chain of custody (with sampling crew, at the laboratory);
- Sample status results of the agent screen; and
- Analytical results.

Depending on the nature of the CAI, these data streams could become fairly significant, especially if information is flowing to decision-makers from separate entities. To assist in the management and use of these data streams, centralized systems may be used to be sure that the information gathered can be easily managed and applied. Once again, the EPA-developed tool ScribeNet (EPA undated i) is one such centralized data handling tool. The following excerpt from the EPA Environmental Response Team website describes the Scribe product (https://response.epa.gov/site/site_profile.aspx?site_id=ScribeGIS).

> *Scribe is a software tool that assists in the process of managing environmental data. Scribe captures sampling, observational, and monitoring field data. Examples of Scribe field tasks include Soil Sampling, Water Sampling, Air Sampling and Biota Sampling. Scribe can import Electronic Data Deliverable (EDD) files including Analytical Lab Result EDD files and Sampling Location data EDD files such as GPS data.*

Scribe outputs include labels for collected samples, Chain of Custody generation and Analytical Lab Result data reports. Scribe provides a flexible user interface to manage, query and view all this information. Scribe supports exporting electronic data for user services such as GIS tools and spreadsheets so sampling data may be further analyzed and incorporated into report writing and deliverables. Additionally, Scribe's Quickmap feature exports data to KML files that can then be viewed spatially using programs such as ArcGIS and Google Earth.

A system like Scribe allows the granularity of data entry that would be required for RSAF. Information about sampling locations, analyses type, instrumentation, laboratory list, and sampler can be input into the system. The software is already set up to accommodate sample results for media such as air, wipe, biota, soil/sediment, and water sampling. The software also addresses sample management, allowing the creation and monitoring of chain-of-custody and monitoring data. Custom data views accommodate electronic data deliverables (EDDs) and the software also provides for importing and exporting sample results. Figure 6-8 depicts a data entry screen for Scribe.

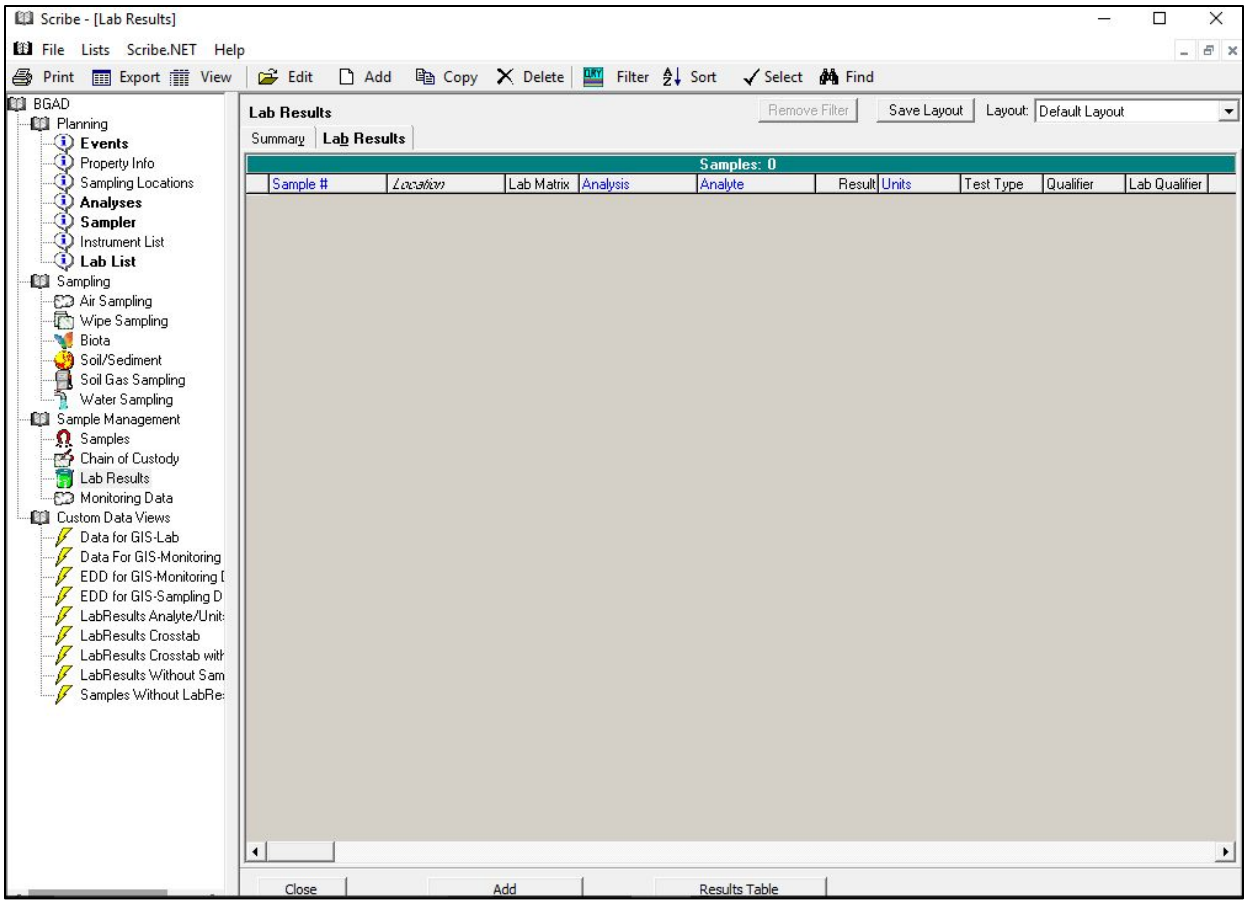

Figure 6-8. Scribe Input Screen

6.11.7 Investigation Derived Waste

A surprising amount of waste is generated during the type of investigation that would follow a CAI event. Waste includes disposable sampling equipment, decontamination fluids and materials, plastic bags, paper towels, disposable PPE, and more. These wastes are collectively termed IDW and some could be characterized as hazardous waste. IDW will need to be handled, labeled, stored, and disposed of according to state waste management requirements and generally accepted practices for management of hazardous or potentially hazardous waste and/or materials.

Each sampling team will generate IDW. The IDW would need to be temporarily stored in an acceptable manner, typically in sealed 55-gallon or smaller drums, or in plastic bags. If IDW is left at optimally located sites, some sort of security may be necessary. If possible, IDW should be transported back to the sample staging area for subsequent handling.

A determination of the final disposition of the IDW generated will be made following laboratory analysis of samples collected during investigation activities or through use of process knowledge. Disposal options will depend on characterization to determine whether the IDW is characterized as hazardous waste or not.

6.12 Data Deliverables

Data deliverables from both the field and the laboratory must be able to be combined easily and efficiently into a common format to support data evaluation, visualization, and subsequent decision making. It is important to identify a data manager who will be responsible for tracking samples, data deliverables, database management, data visualization, and presentation.

6.12.1 Field Data Deliverables and Reporting Formats

Field methods were reviewed in Section 6.8. They range from simple colorimetric techniques with gross detection capabilities to complex MINICAMs that are much more sensitive, providing detection capabilities in the parts per million to the parts per billion range. Data from field monitoring are likely to be transmitted in real time from the field to the OSC and decision makers in the command group. Some devices will maintain data on hard drives contained within them, while others merely enable spot monitoring with no data retention capabilities. Given the wide range of possible field instruments, there is an equally wide range of report formats.

At the same time, data will be coming in from multiple field sampling teams and emergency responders. Data fields that should be included are date, time sampler, device, DL, result, and units. Because data transcription will involve technicians entering data into the database in real time, it will be important, as a data quality check, to back check data at some point after they have been entered into the database. The database should also include fields for data review and verification.

As indicated earlier, in all likelihood most, if not all, results are likely to indicate non-detect. Therefore, it will also be important to be able to highlight any positive results. This action should facilitate the data review and verification step.

6.12.2 Laboratory Data Deliverables and Reporting Formats

Laboratory methods were reviewed in Section 6.9. As indicated, EPA fixed or mobile laboratories will be used as the primary laboratory, and split samples will be sent to Army laboratories. The EPA laboratories use methods from the National Homeland Security Research Center's Selected Analytical Methods manual (EPA 2012), whereas Army laboratories may use slightly different analytical techniques. Each set of laboratories, however, is likely to use the same or similar LIMS, which will enable reporting in common formats.

Laboratory data reports come in several different formats:

- Data summary report;
- Detailed data package; and
- EDD.

The data summary report is a brief report that presents the data collected (results) along with information on the sample, sample date, analysis date, methods used, QLs (reporting limits) and DLs, units, and laboratory-assigned data qualifiers. The data qualifiers are flags that indicate issues with a data point. Qualifiers denote things like analyte detected in blank samples, analyte detected between the DL and reporting level, and sample analyzed beyond holding times. The data report is typically provided as a PDF.

The detailed data package sometimes includes the summary report, but always provides all the supporting data necessary to conduct data verification and validation (discussed in Section 6.10). These reports typically present different levels of detail. They are also typically provided as PDFs. The levels of detail provided in these reports were established initially under the EPA Contract Laboratory Program, which was developed to support CERCLA hazardous waste site investigations. Level III reports provide sufficient supporting data to support data verification and cursory data validation, whereas a Level IV report provides detailed information to support data validation. There is a significant difference in the costs of these reports; however, Level IV reports should always be requested for data in support or RSAF efforts. They are quite detailed, typically spanning hundreds of pages per sample group.

As discussed in Section 6.10, at some point, some level of data validation should be performed. If samples are all coming back with non-detect results, data validation can be confidently performed on a small percentage, for example 5% of the samples. When results vary, including some detections, or where data quality issues are identified as a result of data verification, data validation should be more intense, involving at least 10% of the samples.

The EDDs are data provided on an electronic database, typically in Microsoft Excel or Access format. They are quite detailed and include many fields of information. They present data collected (results) along with fields for the laboratory, the project, the sample number, sample date and time, extraction date and time, the analyst, methods used, QLs (reporting limits), DLs, units, and laboratory data qualifiers. Fields are later added to accommodate data qualifiers added during data verification and validation. EDDs can be generated almost immediately after analysis, but the laboratory typically holds them for one or more days to allow time for internal

laboratory data quality review. Although it is possible to request that the EDD be delivered electronically on an expedited basis, laboratories performing RSAF analysis should also be instructed to phone in positive results to the command group and decision makers as soon as they are detected and confirmed.

EDDs are the reports that will be most useful for RSAF data evaluation, statistical analysis, and data visualization. Given that they are provided in common formats (Microsoft Excel or Access), it should be possible to combine these deliverables into a common database, even when different laboratories generate them.

6.13 Decision Making to Support Unrestricted Return

Two basic courses of action can be taken in response to a CAI that migrates off post. The basic decision that needs to be made is whether to allow re-entry, or whether to take some other action. This section discusses how this decision can be made.

6.13.1 The Influence of the CSM and DUs/SDUs

In Section 6.1, the CSM and DUs/SDUs were established. First, it is important to understand that different decisions can be made for different DUs/SDUs at different points in time. Re-entry may be allowed for some DUs/SDUs, and some other action may be taken at other DUs/SDUs.

6.13.2 Data Visualization

Data visualization techniques can be used to present complex information for each DU/SDU in an easily understandable way. As noted in Section 6.1, the fusion of a base map, plume maps (WebPuff and JEM), and VSP representations of planned sampling locations is a data visualization technique. Especially if multiple rounds of samples need to be taken, an approach that allows visual determination of hot spots, concentration contours, and individual data points would be helpful input for decision makers.

Scribe software (or similar software) allows project managers to understand the status of a sample visually as well. Depending on the needs of the OSC and other decision makers, one could also plot the status of a sample on the same GIS platform used to create the base map, plume map, and VSP fusion so that planners can visually distinguish locations that have been sampled but not yet analyzed, versus those with samples that have been analyzed.

Data visualization methods such as GIS can also be used to plot information that is tied to a given location. This type of plot allows decision makers to quickly understand the situation and analysis results.

If all sample results come back as non-detect or below an agreed-upon action level, then visualization programs are probably not needed. However, the real strength of post plots and other GIS-based visualization techniques is realized in situations where hot spot patterns and concentration contours need to be determined.

If analytical results suggest the presence of a hot spot of contamination, another data visualization technique involves geo-statistical analysis. Maps can be prepared to depict concentration estimates and contours, and to show where concentrations are expected to be above and below action levels.

6.13.3 Evaluate Data against CSM, DQOs, and SAP

After data are presented in a manner that allows decision-makers to understand where samples were taken and what the results show, the next step is to evaluate data against the CSM, DQOs, QA/QC requirements, sample design, and SAP. This includes examining data verification and validation results. The key determination is whether the data are of sufficient quality and quantity to support confident decision-making.

Figure 6-9 presents a decision flow diagram of the discussion below.

Evaluation of the data against the CSM entails a judgment call as to whether the data confirm that the CSM is accurate. This call is best made with the input of SMEs. Initial examination of the data, for example, may lead to the conclusion that the CSM does not adequately depict the characteristics of the release, exposure pathways, and/or potential receptors. In this case, the CSM may need to be adjusted, and additional sampling may be needed in some areas within the DU/SDU. A supplemental sample design would be required, followed by a supplemental sampling and analytical plan.

Should the data be determined to adequately “fit” the CSM, the next determination would be whether DQOs have been achieved. Again, this call is best made with the input of SMEs. If DQOs have not been achieved, a supplemental sample design and a supplemental sampling and analytical plan may be needed, followed by additional sampling and analysis.

If the CSM is judged to be adequate and the DQOs have been achieved, the next step would be to determine whether the requirements of the sample design and sampling and analytical plan, including QA/QC criteria, have been met. This includes examining the results of data verification, and if available, data validation. Again, this call is best made with the input of SMEs. If the requirements of the sample design and sampling and analytical plan have not been achieved, a supplemental sample design may be needed, followed by a supplemental sampling and analytical plan.

Once the above is accomplished, the last determination, as referred to in Section 6.10, is to determine whether the data are adequate to support decision-making. This is referred to as a data usability assessment. The basic question is whether, considering all of the above, the data are suitable to support confident decision making.

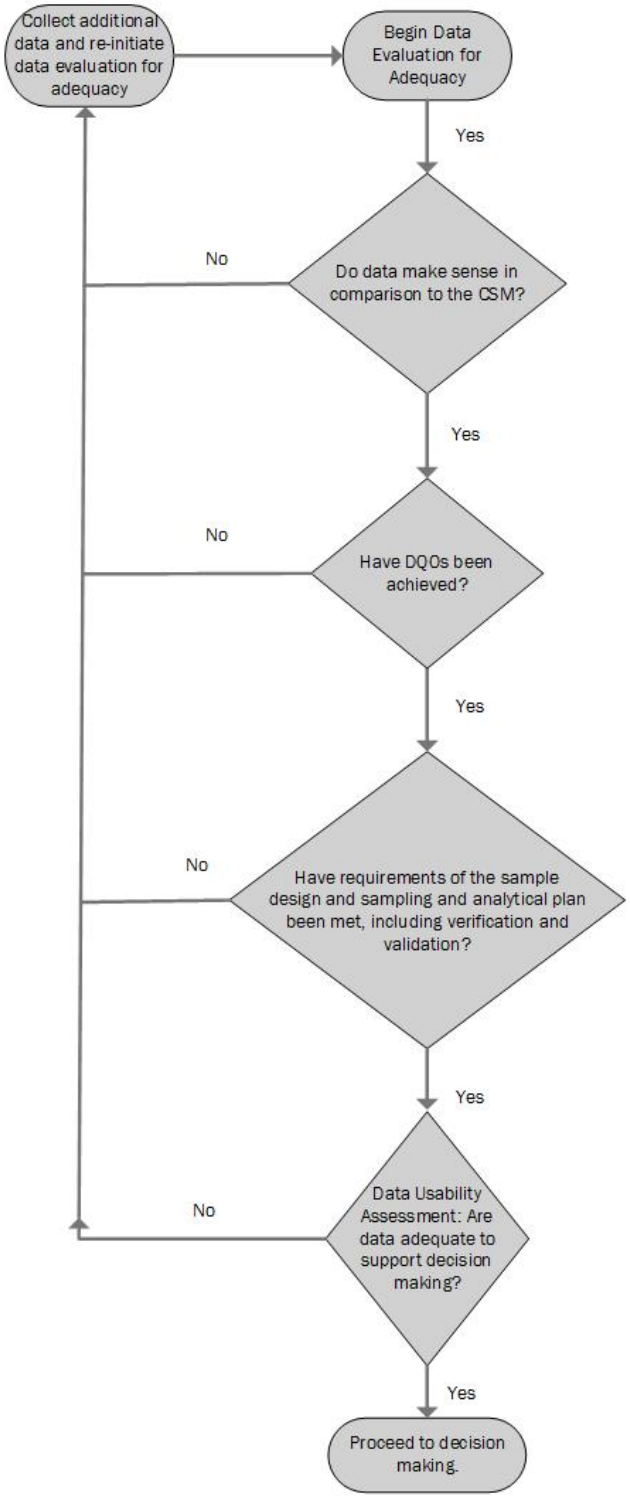

Figure 6-9. Decision Flow Diagram on Data Adequacy

6.13.4 Determine Relationship of Data to Action Levels and DLs

If the data are sufficient to support confident decision-making, the next step is to determine the relationship of the data to action levels and analytical DLs. This was discussed in Section 6.3.3 and depicted in Figure 6-5, which showed the relationship between results, analytical DLs, and action levels. Basically, if all data for a DU/SDU indicate non-detection or presence of agent or degradation product below action levels, and there are no other indications that agent has impacted an area (e.g., considering weight of evidence), then decision-making becomes fairly straightforward. There is no need to proceed further, and re-entry may be allowed. If the opposite is true, then additional action may be considered. Here, review of the decision rules established during the DQO process (Section 6.2) becomes important.

It is important to remember that because agents and degradation products degrade over time, if a COC is not detected at the time of sampling/analysis, the COC may have been present at an earlier time at a concentration above the DL and/or above the action level.

6.13.5 Agent or Degradation Product Detections (Possible False Positives)

One thing to be aware of is that it is not uncommon to obtain false positive results. These are results that show a COC above an analytical DL (a positive result), which is in error (false). False positive results are not uncommon when dealing with chemical agents and degradation products. This is particularly the case if results are between the DL and the QL. For example, GB and VX have chemical structures that are common to some types of pesticides. If pesticides or similar chemicals have been used in the area, it would not be unusual to find positive results for one of these agents. As another example, TDG, a degradation product of concern for mustard, is commonly used in textile dyes and in some pen inks. False positive results could be obtained if ink from a pen contaminates sampling equipment or the sample itself.

If there are many positive results and there is other evidence to suggest that an agent has impacted a DU/SDU (weight of evidence), then in all likelihood, positive data are not all false positives. However, if there are only a few positive results or the positive results are very spotty, the possibility of false positive results should be investigated. Here, assistance from a SME would be advisable.

6.13.6 Determine Safe Unrestricted Return versus Need for Additional Action

If some or all data for a DU/SDU indicate that an agent or degradation product is present above action levels, or detections are negative but the action level is at or below the DL and there is some evidence that agent has impacted an area (e.g., consider weight of evidence), then it is advisable to consider other actions. This is discussed in Section 6.14.

6.14 Removal, Remediation, and Natural Attenuation

If some or all data for a DU/SDU indicate that an agent or degradation product is present above action levels, or where data are negative but the action level is at or below the DL and there is some evidence that agent has impacted an area (e.g., consider weight of evidence), then

consideration of follow-on actions is advisable. This section discusses alternative actions that may be taken.

6.14.1 Evaluate Natural Attenuation versus Removal versus Active Remediation

When an agent or degradation product is present above action levels, the primary alternatives are:

- Conduct a removal action,
- Conduct active remediation, and
- Consider natural attenuation.

Note that natural attenuation can be considered as part of a removal action or as part of a remedial action. These actions can be considered for different DUs and SDUs within the plume footprint. It is also possible that one or more alternatives could be implemented at the same location. For example, removal could be conducted for the top few inches of soil, and then natural attenuation could be allowed to occur.

Removal would likely involve excavation and removal of the top few inches of soil, and possibly vegetation or other materials, including cement, macadam, outdoor furniture, or even structures or vehicles. Therefore, removal would be extremely destructive, and a large amount of remediation waste would be generated, requiring subsequent management.

Active remediation would likely involve spraying chemical decontaminants in contaminated areas. Decontamination fluids for chemical agents are typically caustic, consisting of dilute solutions of sodium hydroxide, sometimes combined with various bleach formulations. These can also be destructive.

Natural attenuation is a form of remediation and can also be considered as part of a removal or remedial action. Natural attenuation would simply to allow time and weather to reduce concentrations of COCs to below the action levels. Access restrictions would need to be imposed were this action to be selected. As discussed in Section 5.1 and Appendix C, the amount of time required would depend on several factors, and on the agent released. Time required could entail several days for GB and up to several weeks, months, or in extreme cases even a year or more for VX and mustard. Degradation products would similarly take several days, weeks, or possibly months to naturally attenuate. These COCs would not need to be completely degraded; degradation would only be required until concentrations dipped below action levels.

Determining which alternative, or combination of alternatives, to apply will typically involve a significant period of time for planning, evaluation, selection, and approval of the selected alternative(s). Selection may also involve public meetings and regulatory (EPA, state, or both) concurrence or approval. In a typical hazardous waste site investigation, for example, the planning and execution involved takes months or even years before action is eventually taken. During this time, natural attenuation will occur. Therefore, the time required to plan and execute removal or remediation alternatives should be considered when selecting among the possible

alternatives. Overall, the amount of time members of the evacuated public are kept from their properties should be a key consideration.

6.14.2 Planning to Conduct the Selected Alternative

First, note that all alternatives will entail some level of access control, including barriers, fencing, and similar devices to deter the public from entering the area of concern until decision makers determine re-entry is safe.

Removal and remediation actions are also regulated under different sections of CERCLA, each dictating different levels of planning and approval and each involving different stakeholders. Removal actions may be implemented by the OSC under CERCLA removal authority, without approval of other stakeholders, although the OSC would most likely seek concurrence from state and local officials through the UC or MACG. Removal actions are typically implemented in a shorter timeframe than are remedial actions. Remediation authority under CERCLA would rest with the Army with concurrence from state and local officials. Removal and remedial options are dictated under EO 12580.

The public, likely represented by the public interest groups discussed in Chapter 5, will likely be actively involved in determining follow-on actions. However, CERCLA provides more opportunities for public involvement under remedial authority as opposed to removal authority.

6.14.3 Completing and Documenting the Selected Alternative

Regardless of which alternative or combination of alternatives is selected, sampling and analysis of affected areas would be required to determine the success of the selected alternative or alternatives. For removal actions, sampling and analysis would be required as each layer of substrate is removed, to determine whether the substrate below meets action levels. Similarly, for active remediation, sampling and analysis would be required to determine the effectiveness of the treatment. It would be necessary to sample the remediation waste and to determine appropriate waste management techniques. Sampling and analysis would continue until concentrations of COCs were determined to be below action levels. For natural attenuation, the affected area would be monitored (through sampling and analysis) until concentrations of COCs were determined to be below action levels.

In all of these situations, the plan elements laid out in the other portions of this chapter would be applied. VSP especially would be useful here as a means of statistically evaluating the effectiveness of the selected alternative or alternatives.

6.15 Reporting Requirements, Archiving and Follow-up

This section summarizes reporting requirements from the NCP, including immediate reporting requirements accompanying a release, community-relations requirements, and reporting of initial site assessment activities. Note if a removal or remediation effort were to be implemented, further reporting requirements would apply beyond those summarized here.

6.15.1 Immediate Notification Requirements

Under the NCP, release of a hazardous substance above the threshold quantity must be reported to the National Response Center (40 CFR 300.125). Where circumstances indicate a potential public health emergency, the Army OSC immediately notifies the Department of Health and Human Services (HHS) RRT representative and may call upon OSHA and HHS for assistance on worker health and safety issues. FEMA would also be advised of potential major disaster situations, and trustees of natural resources should be promptly notified of any releases that might affect those resources. In addition, where a discharge or release may potentially affect endangered or threatened species or their habitat, the NCP requires consultation with the U.S. Department of the Interior, or the U.S. Department of Commerce (National Oceanic and Atmospheric Administration) and, if appropriate, the cognizant federal land managing agency (40 CFR 300.135).

The BGAD Plan and implementing procedures provide for these notifications, along with notifications to the Local Emergency Planning Committee, KDEP, other state agencies, elected officials, and higher Army headquarters (BGAD 2017).

6.15.2 Community-Relations Requirements

When an incident occurs, it is imperative to give the public prompt, accurate information about the nature of the incident and the actions underway to mitigate the damage (40 CFR 300.155(a)). The NCP requires regular communications with local public and private interests, recommending establishment of a Joint Information Center (JIC) to provide information and respond to questions and concerns. The dissemination of information related to natural resource damage assessment would be coordinated through the lead administrative trustee (40 CFR 300.155). Further community relations requirements are described in the NCP sections on removal, remediation, and enforcement actions; these are intended to promote active communication between communities affected by discharges or releases and the lead agency responsible for response actions (40 CFR 300.415, 300.430, and 300.435).

Establishment of a JIC and an emergency public information program are addressed in several CSEPP guidance documents (CSEPP 2012) and in the BGAD CAIRA Plan (BGAD 2017). JIS/JIC functions are regularly practiced during CSEPP exercises.

6.15.3 Site Assessment Reporting

Under the NCP, the OSC “shall submit pollution reports to the RRT and other appropriate agencies as significant developments occur during response actions” (40 CFR 300.135(m)).

In addition, the section on remedial site evaluation provides guidance on “methods, procedures, and criteria the lead agency shall use to collect data, as required, and evaluate releases of hazardous substances” (40 CFR 300.420). This section describes a preliminary assessment (PA) process, the purpose of which is to determine which areas need no further attention and which areas may require removal action, to gather existing data to facilitate analysis, and to set priorities for further inspections—essentially the actions described in this RSAF. It tasks the

OSC with preparation of a PA form (the EPA Preliminary Assessment form, available from EPA regional offices, or its equivalent) and preparation of a PA report, to include the following:

- A description of the release;
- A description of the probable nature of the release; and
- A recommendation on whether further action is warranted, which lead agency should conduct further action, and whether a site inspection, a removal action, or both should be undertaken.

If a removal action will be undertaken, further requirements would apply pertaining to community relations, compiling an administrative record, and taking public comments, as described in 40 CFR 300.415(n).

6.15.4 Archiving Data and Information

A tremendous amount of sampling, analysis, and related data and information will be generated in response to a CAI that migrates off-post. It is important to retain all this data and information in an easily accessible repository. Hard copies of key documents, such as sampling and analysis reports, can be retained in a library; however, archiving the data and information into an electronic repository is recommended.

6.15.5 Follow-on Monitoring

As indicated in Sections 6.13 and 6.14, several different courses of action may be initiated in response to a CAI that migrates off-post. These include:

- Temporary re-entry;
- Unconditional re-entry;
- Removal action;
- Allowing natural attenuation to occur over some period of time; and
- Remedial action (active remediation).

If unconditional re-entry is allowed initially, presumably action levels for COCs were below levels of concern. In this case, there should be no need for follow-on (long-term) monitoring. However, if other actions are taken, it is reasonable to assume that action levels were exceeded at some point. In this case, and regardless of which other action is taken, eventually unconditional re-entry will be allowed after action levels for COCs are shown to be below levels of concern. Even after this, because action levels were exceeded at some point, it is likely that follow-on monitoring will be necessary to determine long-term impacts on human health and the environment.

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7 CONSIDERATIONS FOR RESTRICTED (TEMPORARY) RE-ENTRY

In a restricted area that has been evacuated (or relocated after an initial sheltering period) there may be a need for reentry to perform missions vital to public health and safety. For example, there might be persons who were unable to leave and require assistance, or an emergency repair to over-pressurized facilities. The first priority for monitoring would be to accompany responders performing such missions. In support of such missions, real-time monitoring for residual agent would be performed to allow responders to operate in the area using appropriate personal protective equipment (PPE) and to ensure that persons can be evacuated without encountering an agent hazard.

The following sections review potential temporary re-entry scenarios and discuss technical approaches for monitoring.

7.1 Likely Scenarios

Temporary re-entry addresses several different possible scenarios. One such situation is where people have evacuated and need to get back into their properties for short periods to conduct some task. Examples include:

- Feed and care for pets left behind;
- Retrieve medicines or important possessions such as funds, credit cards, checkbooks, or personal documentation; and
- Tend to or care for livestock (e.g., feed the cows).

Another situation is where people have sheltered-in-place and need to know whether it is safe to stop sheltering or whether they need to relocate. This decision could be made based on plume models alone. However, emergency responders might be directed to reconnoiter some areas to measure agent concentrations in outside air as a basis for making this decision. This may depend on availability of monitoring teams and RTAPs.

A third temporary re-entry situation is where critical infrastructure assessment or repair is required. Examples of infrastructure that may be affected include:

- Major highways, railways, or waterways;
- Water intake and treatment plants;
- Electrical or natural gas generating facilities or substations;
- Positive-pressure systems in schools or hospitals; and
- Communication or other utility structures.

7.2 Technical Approach

In the above situations, the focus is on conducting operations quickly and safely. Only air monitoring is needed — to support both re-entry activity and the health and safety of first responders. A judgmental sampling approach would be employed using handheld air monitoring instrumentation or, if available, RTAPs with MINICAMs.

Although physical samples (e.g., soil, water, wipes) could be taken and analyzed during temporary re-entry missions, there are several reasons this is not advisable:

- First and foremost, temporary re-entry should focus on the task being accomplished. Taking soil, water, or other types of environmental samples might distract first responders from the primary mission.

- Second, proper sampling operations require considerable planning and preparation, as discussed in Chapter 6. Because temporary re-entry would likely need to take place within hours after the incident, it is unlikely that sufficient resources would be available to support sampling of soil, water, or other media concurrent with temporary re-entry missions.

- Obtaining analytical results would take too long to support the immediate decisions that would need to be made.

Nevertheless, one could argue that teams could take samples of soil, water, or other media during temporary re-entry missions. The advantage of doing so would be that data on actual media contamination would become available sooner. Hence, if trained samplers can accompany first responders on re-entry missions and take media samples without jeopardizing the re-entry mission, then it may be acceptable to do so. In this case, the emphasis should be on wipe samples. Wipes would be taken on impervious surfaces, such as car windshields, car hoods, and mailboxes.

8 WHAT TO DO IF AN EVENT HAPPENS

A systematic approach to what to do if a CAI happens is presented below. Note that some of these steps may be conducted in parallel. In addition, the steps would be carried out under the direction of the OSC under an ICS framework (see Chapter 4). The timing of these steps is shown in Table 8-1; they are described in more detail below the table.

Table 8-1. Timing of Sampling and Analytical Response

Response Steps	Timing	Comments
Initiating Event (Step 1)	Instantaneous	Emissions may continue for some time, depending on the nature of the initiating event. For example, a fire may result in continuing emissions for minutes or hours, until extinguished.
Preparation, Planning and Logistics (Steps 2–9)	One to two days or more	Steps 2–9 involve many different activities, most of which can occur in parallel, but may be limited by the number of available experienced personnel. For a complex initiating event, the time required for Steps 2–9 may exceed two days.
Sampling and Analytical Activities (Step 10)	Two to four days or more	The duration of the actual sampling and analytical activity will be highly dependent on the extent of the depositional area, weather, number of experienced sampling teams, nature of the terrain to be sampled (e.g., urban vs. rural, wooded vs. farmland), number and proximity of analytical laboratories, and other factors. In addition, sample results in some areas may dictate additional sampling in the same areas, or sampling in areas beyond the initial depicted depositional area.
Data Management and Evaluation (Steps 11–14)	Less than one day	As data is produced, it should be placed into a database to allow continual quality assessment and evaluation. Evaluation will be more complex if results show the presence of agent or degradation products above action levels in multiple locations.
Decision Making (Steps 15–16)	A few hours or more	Decision-making is easy if all data are coming back as non-detect. However, if results show exceedance of action levels, decision-making will be more complex. The public, perhaps represented by one or more public interest groups, may be expected to have significant input here. While they will want to be able to return to their homes and livelihoods quickly, they will also want assurances that it is safe to do so. Here, public messaging and coordination with PIOs is extremely important.

Response Steps	Timing	Comments
Follow-on Actions (Step 17)	Varies	If a removal or remedial action is warranted, follow-on actions, including contaminated media/materials removal, decontamination, or allowing natural attenuation to occur, may take weeks or even months. Sampling and analytical activities will continue during this period as a means of determining if and when COC concentrations fall below action levels.
Data Report(s) Archive (Step 18)	Continual	Notifications, data, and reports should be placed into a permanent archive as they are generated.

Step 1: Initiating Event. The initiating event is the incident combined with a WebPuff model result indicating off-post migration. The BGAD EOC would relay information to the off-post community regarding the agent involved and the characteristics of the release (e.g., fires, explosions, amount of agent involved). This information would be used to define the source term. For the duration of the event, the off-post community would follow on-post activities to obtain updated assessments of continuing emissions and the amount of agent released, and to ascertain when the source term is under control (i.e., no further emissions).

Step 2: Maintain Situational Awareness and Refine WebPuff and JEM Model Results. Initiate JEM modeling to identify potential areas of deposition. Until the air release ceases, continue running WebPuff and JEM as needed to determine potential changes in the plume over time (e.g., direction, speed, dispersion characteristics). Maintain situational awareness throughout the response. If the plume changes course, be sure to track everywhere the plume may have migrated, to ensure that protective actions are maintained in all areas where the plume may have traveled and that traffic control points are not placed in potentially contaminated areas.

Step 3: Determine Resource Needs. Begin to examine resource needs, including sampling equipment, sampling teams, and analytical laboratories. Refer to Chapter 6 to identify media to be sampled and required analytical suite. Contact Army and CSEPP partners, including KYEM, KDEP, KYNG, FEMA Region IV, EPA Region IV, RRTs, and the NRT to arrange transport of resources as soon as practical. Identify staging areas for field sampling equipment and teams, and locate analytical resources. If mobile laboratories are to be brought in, identify locations with utilities that can be used. Examine sample-to-laboratory transport routes.

Step 4: Gather Information That May Impact Agent Dispersion and Degradation. Gather information on weather conditions before, during, and after the event to gauge plume behavior over time and the potential for deposition to occur, and to estimate degradation rates for agent and degradation products. Adjust WebPuff and JEM modeling as needed. Maintain situational awareness.

Step 5: Develop the CSM. Using information from Step 4, superimpose the WebPuff AEGL 2/3 and JEM plume depictions on the RSAF base map, showing the plume and everywhere it has traveled in relation to PAZs, evacuation routes, roads, highways, communities, traffic control points, surface features, and the locations of focus areas. ESRI or similar tools may be used for

this purpose. The resulting map is a graphical depiction of the CSM. Incorporate changes in wind (speed, direction, variability, turbulence) and weather conditions (sunshine, rain, fog, mist, etc.). Be sure the CSM includes all locations where the AEGL 2/3 plume has migrated (WebPuff), as well as potential depositional areas (JEM).

Step 6: Gather Information in Preparation for Sampling. If first responders and/or monitoring teams are sent out on temporary re-entry missions, gather their information (air monitoring results, observations, video, and photographs). Gather observations from the public. Use UAVs as available to reconnoiter the WebPuff AEGL 2/3 plume and JEM depositional footprints. Use other observational equipment as available to gather information, including traffic cameras, helicopter flyovers, and so forth.

Step 7: Identify Focus Areas to be Sampled. Identify focus areas in the predicted plume footprint that were identified pre-incident as part of RSAF planning, including locations with sensitive populations (schools, nursing homes, daycare facilities, hospitals), property with livestock, critical infrastructure requiring inspection/operation, and major employers. Use the information from Step 6 and the graphical depiction of the CSM from Step 5 to fill in details for the initial CSM, noting potential receptors (exposed people, wildlife) and exposure routes (air, contaminated surfaces, soil, plants).

Step 8: Develop VSP-based Sampling Approach. Use the CSM and the guidance provided in Chapter 6 to develop the initial sampling plan using VSP. Use the following VSP tools to develop a plan for sampling a transect along the centerline of the WebPuff/JEM plume model:

- Locate hot spot (contiguous areas of contamination), assuming no false negatives.
- Parameter to calculate: “I want to solve for # of samples.”
- Input parameters: “I want to have at least a 95% chance of detecting a specified hot spot.”
- Area of hot spot: 0.25 acre.
- Sample spacing every 127 ft. along plume centerline.
- For properties greater than 0.25 acre in size, use the VSP hot spot algorithm to create a triangular grid search pattern.

Other sample design options using different VSP assumptions (e.g., uncertainty, hot spot patterns) can also be used, noting resource needs, costs, and time required to conduct sampling and analysis, and to receive results. Present options to decision makers and have them weigh uncertainty, resources, costs, and time and select the initial sample design.

Step 9: Merge Focus Areas and VSP results. Based on decisions made in Step 8, develop a focused SAP and accompanying QA/QC plan to guide the sampling and analytical effort, using the guidance in Chapter 6.

Step 10: Mobilize Sampling Teams. When resources are gathered and in place, begin to mobilize sampling teams to carry out the sample design. Assign sample collection to teams based on sample locations. Ensure sampling teams operate within the ICS framework and using ICS principles. Ensure sampling teams are directed by a qualified health and safety officer and are

equipped with proper PPE. Coordinate sampling teams with traffic control points and access into restricted areas. Use UAVs as available to reconnoiter designated sampling locations.

Step 11: Initiate Sampling and Track Sampling Progress. Using the agreed-upon methods described in Chapter 6, initiate an efficient process for taking samples, documenting sample locations, preparing sample labels, filling in logbooks, screening samples in the field, and packaging samples for transport to the appropriate laboratories. Coordinate sample delivery to laboratories within the shortest time possible, being careful to not overwhelm laboratories. Keep track of the status of samples including:

- Samples to be collected;
- Samples that have been collected;
- Samples that are in transit to the laboratory;
- Samples that are at the laboratory; and
- Sample results that are available.

Use a software tool such as SCRIBE to aid in tracking sample status.

Step 12: Manage Data and Refine the CSM. As sample results and data deliverables arrive from the laboratories, continually evaluate data adequacy and quality. Evaluate data against the predicted depositional areas in the CSM and adjust the CSM as warranted. If needed, review, revise, or adjust the VSP to come up with supplemental sampling designs, involving decision makers in weighing uncertainty, resources, costs, and time to select the most appropriate supplemental sample design. Run VSP and conduct supplemental sampling until SMEs are comfortable that the data collected, including weight-of-evidence information, reasonably match the CSM and can adequately support decision-making.

Step 13: Evaluate Analytical Suite. Continually evaluate weather conditions and analytical results to determine agent degradation rates, noting if and when agent may be degrading. As agent degrades, begin to consider transitioning from agent and degradation product analyses to just degradation product analyses. Note degradation rates of the degradation products as well. Continually compare data against action levels for both agent and degradation products.

Step 14: Review Data Adequacy. Continually evaluate data against the CSM, DQOs, and QA/QC requirements. Verify and validate data as soon as practical. Continually determine adequacy of data to support confident decision-making.

Step 15: Communicate with Decision Makers. Continually advise decision makers on progress, problems, and data results. When data are determined to “fit” the CSM, to meet quality requirements, and to be adequate to support decision making, brief decision makers on potential decisions regarding re-entry, removal actions, and remedial actions, including natural attenuation. Support decision-making.

Step 16: Keep Stakeholders and the General Public Informed. Throughout the preceding steps, keep stakeholders and the public adequately informed of progress and problems through established communication channels, utilizing PIOs, the JIC, and their resources as needed.

Public information processes established during the emergency response phase should be continued throughout the sampling and analysis effort to keep the public apprised of progress. The importance of public messaging and coordination with PIOs cannot be overstated.

Step 17: Implement Follow-on Actions. Should removal actions and/or remedial actions, including natural attenuation, be determined to be necessary, implement these actions. Utilize VSP to determine sample designs needed to monitor changes in COC concentrations as the action is implemented and completed. Conduct sampling and analysis and determine adequacy of sample results as needed to support confident decision-making. Determine when action has been successfully completed and consider allowing re-entry.

Step 18: Archive Documents. Retain all documentation as needed to support reporting, event response, decision making, and potential litigation.

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APPENDIX A

RSAF DEVELOPMENT PROCESS

This document is intended to create a framework for recovery sampling and analysis planning, in a way that meets the needs of the Blue Grass CSEPP Community and is consistent from a scientific, technical, and practical standpoint. To meet this goal, the workgroup reviewed previous planning documents and current regulatory, technical, and programmatic reference materials; held structured technical and policy discussions with the Blue Grass CSEPP Community; and conducted outside peer review.

A.1 Reference Review and Analysis

Beginning in 2015, the Blue Grass CSEPP community began reviewing the need for an updated and site-specific guide for recovery sampling and analysis. The community reviewed the existing CSEPP sampling and analysis document, *Final CSEPP Recovery Sampling and Analysis Plan (RSAP) Protocol for Chemical Warfare Agent Accidents/Incidents* (2008), with the goal of identifying new and updated regulations, guidance documents, plume models, sample design tools, field and analytical methods, remote sensing technologies, and federal and state resources that could be used to update it. Of 27 key references in the 2008 protocol, 21 had since been updated. In addition, 27 new reference documents were identified, along with important advances in modeling, mobile communications, and other technologies. It was determined that a new, site-specific document should be developed to provide a framework for recovery sampling and analysis in the event of a chemical accident or incident at the Blue Grass Chemical Activity.

A.2 Engagement with the Blue Grass CSEPP Community

A recovery sampling and analysis workgroup was established following an initial meeting with members of the Kentucky CSEPP IPT in June 2016. To lay technical and policy foundations for planning, the workgroup initially discussed and resolved a series of big picture issues (BPIs) for the Kentucky RSAF. The workgroup held four separate BPI sessions, wherein BPIs were presented and discussed, and a path forward was developed. In addition, prior to one of the BPI sessions there was a training session for the Blue Grass CSEPP Community on a sampling program developed by Pacific Northwest National Laboratory (PNNL) called Visual Sampling Plan (VSP) (PNNL 2014).

A.3 BPIs and Their Resolution

BPIs addressed during a workgroup meeting held in August 2016 included the following:

- Validity of CSM;
- Validity of WebPuff footprint;
- Use of the DOD joint effects model (JEM) (U.S. Army 2014);
- Determining constituents of concern (COCs);
- Action levels for demonstrating unrestricted re-entry; and
- Adopting the EPA Radiation Protective Action Guidance approach.

BPIs addressed during a workgroup meeting held in October 2016 included the following:

- CSM (review);
- Establishing decision units;
- Does one size fit all;
- Addressing sampling heterogeneity;
- Use and validity of field screening methods;
- Considering EPA's triad approach;
- Inside-out versus outside-in sampling approach;
- Pre-selecting sampling areas;
- Sampling approaches;
- Use of PNNL VSP (PNNL 2014); and
- Systematic sampling.

BPIs addressed during a workgroup meeting held in November 2016 included the following:

- Natural attenuation and the sampling goal;
- Actions if agent and/or degradation product is detected above an action level;
- Actions if agent and/or degradation product is detected below an action level;
- Actions if analytical detection limits (DLs) are higher than action levels;
- Actions if multiple non-detect results;
- Considering weight-of-evidence;
- Remediation versus natural attenuation;
- Quality assurance/quality control (QA/QC);
- Data verification and validation; and
- Site access issues.

BPIs addressed in February 2017 included the following:

- EPA, Army or other analytical methods;
- Use of analytical DLs versus quantitation or reporting limits;
- Sampling and analytical resources and limitations;
- Nature and availability of Army and other federal resources off-post;
- On-post sampling and analytical resources;
- Sample screening, packaging, labeling, security, and transport; and
- Health and safety for field sampling teams.

Meeting summaries from each of the BPI sessions are archived on the CSEPP Portal.

A.4 RSAF Workshop

A workshop on the working draft version of this document, which was released in June 2017, was held in Richmond, Kentucky, on the afternoon of January 17, 2018. The workshop focused on resources needed to implement the sampling and analytical effort (Argonne 2018). In the summary of discussion following the workshop, the RSAF working group identified the following items for follow-up, which were subsequently addressed in this RSAF:

- Credentialing and certification of sampling teams;
- Pre-deployment training of sampling teams;
- Coordination with traffic control points for access;
- Development of clearance levels;
- Providing a data manager responsible for data collection and management;
- Sample management in terms of handling, labeling, and transport;
- Integration of Kentucky National Guard (KYNG) Civil Support Team capabilities;
- Standing up UC;
- Overall timing of sampling and analysis response (consider Gantt chart or similar);
- Role of emergency medical service, fire, police, hospitals during sampling and analysis;
- Responsibility for investigation-derived waste (IDW) management;
- Stockpiling of supplies for sampling, and disposition of used supplies;
- Use of ESRI for data visualization;
- Coordination with agricultural agencies;
- Importance of public messaging and coordination with public information officers (PIOs); and
- MOUs for involved organizations.

A.5 External SME Technical Review

This document was reviewed by external SMEs from U.S. EPA and the Army Public Health Center (APHC).

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APPENDIX B

U.S EPA National Response Team (NRT) Quick Reference Guides (QRGs) for Chemical Warfare Agents (CWA) Stored at Blue Grass Army Depot

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NRT Quick Reference Guide:
Sulfur Mustard (HD)
[January 2015 Update]

For references, please see Key References Cited/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Chemical Warfare Agents. QRGs are intended for Federal OSC/RPMs.

Agent Characteristics

Agent Classification: Schedule 1 Chemical Warfare Blister (Vesicant) Agent; **CAS:** 505-60-2; **Formula:** $C_4H_8Cl_2S$; **Molecular Weight:** 159.08 g/mol.

Description: Sulfur mustard is sometimes called "mustard gas" but is actually a yellow to brown oily liquid with a garlic, onion, horseradish or mustard-like odor. It is a blister (vesicant) agent that will have delayed health effects on the order of hours, and is reported to be a known human carcinogen. It can be manufactured at different concentrations; with impurities, additives, or thickening materials that will all affect physical properties, appearance, persistence and analytical detection limits. Distilled mustard (HD) is considered the most potent form and is the basis of this QRG. Environmental breakdown products of HD, including thiodiglycol (TDG) and hydrochloric acid, are relatively non-toxic, but some decontamination by-products can be toxic (e.g., sulfones).

Persistence: HD is considered a "semi-persistent" chemical warfare agent with liquid deposition on surfaces lasting for hours to days. Persistence will depend upon amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. Under certain environmental conditions, HD liquid may go through a partial hydrolysis that results in an outer protective coating around "globules" that are resistant to further hydrolysis and can persist for decades if not physically disturbed. Porous, permeable, organic or polymeric materials such as carpets and vinyl tiles can act as "sinks" for absorbing HD vapors and liquids, prolonging persistence.

Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.1538; mg/m³ = ppm x 6.503

Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility
5.4 (air = 1)	0.072 mm Hg (68°F/20°C)	610 mg/m³ (68°F/20°C)	~422°F/217°C	58.1°F/14.5°C	223°F/106°C	1.27 g/mL (77°F/25°C)	0.92 g/L (72°F/22°C)	Common solvents, alcohols, gasoline, oils, fats

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.

Open Areas: HD is difficult to disperse in air due to low volatility; however, it may be possible to disperse HD as a vapor/aerosol plume if an appropriate heat/explosive device is employed. The low volatility of HD would limit the size and extent of plume dissipation, posing localized hazards. **HD has a freezing point at 15°C (58°F), so the re-aerosolization of liquids and solids, as ambient temperatures rise, may present a real hazard.** HD vapors are heavier than air, so vapors can accumulate in lower terrains.

Water/Water Systems: HD released into water may dissolve and hydrolyze with a half-life of about 8.5 minutes at 25°C, but in sufficient amounts (relative to water volume) HD may also form globules surrounded by a protective outer layer resistant to hydrolysis. These globules may settle out or be entrapped, persisting for years and posing a contact hazard to anyone disturbing them. Areas in which the globules may persist include stagnant volumes of water as small as puddles formed by precipitation events. Water systems, plumbing, surfaces and equipment that have contacted HD globules, must be evaluated for decontamination.

Indoor Facility: HD is a semi-persistent agent with low to moderate volatility, and would be difficult to distribute effectively throughout a building or facility from a point source. Liquid HD will result in localized areas of surface contamination. HVAC system intakes near to liquid HD should be investigated for contamination from HD vapors and aerosols. HD vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.

Health Effects

Onset	Onset and severity of effects depend on dose, duration and route of exposure (not all signs/symptoms may develop). The effects caused by HD are not typically fatal immediately, but can require substantial supportive medical care as there is no antidote, and secondary infections from blisters/tissue damage may also be fatal. HD produces effects by causing DNA damage/cell death in seconds (this is not like an acid burn). Despite the immediate DNA damage actual **signs/symptoms are delayed 1-48 hours** after exposure, so those exposed may not be aware.
Signs/ Symptoms	Symptoms will vary depending on exposure route; however, the following is a general list of all possible symptoms. The severity of effects depends upon the dosage. **Mild:** Effects delayed 1-48 hours (severity depends on dose): Eye irritation (tearing, grittiness), runny nose, sneezing, nosebleed, hoarseness, hacking cough. **Moderate:** Effects delayed 1-24 hours: Mild effects plus reddening and swelling of eyelids, severe cough, shortness of breath, reddening of skin. **Severe:** Effects delayed 1-24 hours: Upper respiratory/lung damage may occur at high concentrations and longer exposure durations.
Exposure Routes	**Inhalation:** Injury develops slowly, intensifies over several days. Vapor exposure is absorbed in mucous membranes (mouth, throat and lungs). **Skin:** Direct contact with HD liquid can cause redness or blisters in 2-24 hours. Warm and sweaty skin areas (underarms, groin) are most susceptible to exposure. **Eyes:** Eyes are the most sensitive to HD injury; effects noted after 1-12 hours include irritation, burning, gritty feeling, itching, weeping, reddening, lid swelling, light sensitivity, pain and corneal injury. High concentration effects are extremely painful and generally require extended medical treatment. **Ingestion:** Consumption of contaminated food or drink could cause burning, nausea and vomiting.

Effect Levels

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for HD (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Chemical Warfare Agents):

AEGL Level in mg/m³, at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	0.40	0.13	0.067	0.017	0.0083
AEGL 2: Potentially irreversible effects or impaired ability to escape	0.60	0.20	0.10	0.025	0.013
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	3.9	2.7	2.1	0.53	0.27

Exposure Guidelines: IDLH = 0.7 mg/m³; **STEL** = 3.0 x 10^{-3} mg/m³; **Worker Population Limit (WPL)** [an 8-hr time-weighted average occupational value] = 4.0 x 10^{-4} mg/m³; **General Population Limit (GPL)** [a 24-hr time-weighted average] = 2.0 x 10^{-5} mg/m³. **Soil: Industrial Exposure Scenario** = 0.3 mg/kg (10^{-4} cancer risk); **Residential Exposure Scenario** = 0.01 mg/kg (10^{-6} cancer risk). **Drinking Water:** Provisional Advisory Levels (PAL-1) for HD are not available due to the rapid hydrolysis of dissolved HD to TDG. In the absence of PALs, the U.S. Army's Military Exposure Guidelines (MEGs) may be used; the MEG at 5 L/day, for 7 days = 140 µg/L.

Personnel Safety

Note	Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decontamination may vary depending upon the amount and purity of agent, site conditions and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb. We also recommend that responders check their own internal procedures (i.e., SOPs) if they have them.
Medical	**Pre-incident:** Annual physical and respiratory function exams. **During Incident:** Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per Health Effects section above and treat accordingly as per First Aid section below.
First Aid	Immediately remove person from affected area and remove contaminated clothing and articles. Wash bare skin immediately with water, or warm, soapy water if available, at normal household pressures (~50-60 psi) for three minutes, ensure thorough soaking. Rinse eyes exposed to liquid agent with potable water for 15 minutes. **Antidote: NO ANTIDOTE AVAILABLE.** Send person for follow-up medical attention and evaluation; **be aware effects are delayed 1-48 hours.** If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.
PPE	**GENERAL INFORMATION:** NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, & protective clothing should be used. Pre-incident training & exercises on the proper use of PPE are recommended. Per NIOSH guidance - **LEVEL A:** Recommended for the initial response to an HD incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), & eye protection when the contaminant identity or concentration is unknown. Select Level A when the HD concentration is unknown or above the IDLH or AEGL-2, & when there is a potential of ocular or dermal exposure. **LEVEL B:** Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the HD concentration is unknown or above the IDLH or AEGL-2 & dermal exposure is less of a risk. Level B differs from Level A in that it incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not airtight. **LEVEL C:** Select Level C when the contaminant identity & concentration are known & the respiratory protection criteria factors for the use of APR or PAPR (i.e., < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. **LEVEL D:** Select Level D when the contaminant is known & the concentration is below the appropriate occupational exposure limit or less than AEGL-1 for the stated duration times. **Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.**

Field Detection

Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment. The following is a summary of minimum screening concentration ranges for equipment procured by many EPA and HAZMAT response teams. Other screening tools may be used by these teams & other agencies & responders, some with similar capabilities & limitations.

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of HD at levels as listed below.

Minimum Screening Ranges	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger (CDS Kit)	M256/M256A1	M272 (water)
ppm	0.3	0.03-0.142	0.3	0.15	0.31-0.46	2.0 mg/L
mg/m³	0.1-2	0.2-1	0.22-2	1	2-3	NA

Updated January 2015 (replaced previous version dated 2011)

Sampling	*Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)* **Sampling Concerns:** Detection, sampling equipment and procedures, and analytical techniques will be site-specific and depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. non-porous); 3) the purpose of sampling (e.g., characterization, decontamination efficacy and clearance); and 4) specific laboratory requirements. Few laboratories currently have capability to determine HD, particularly for large numbers of samples and in all types of media. The U.S. Environmental Protection Agency (EPA) has set up mobile and fixed labs and analytical assets for chemical agent analysis of environmental samples under their Environmental Response Laboratory Network (ERLN), see ANALYSIS section below (www2.epa.gov/emergency-response/environmental-response-laboratory-network). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.
	Sample Locations and Planning: Initially consider air monitoring to ensure worker safety and to determine if there is a vapor plume that could impact other areas. Characterization sampling is initiated by targeted or judgmental sampling to identify "hot spots," potential agent flow paths, and media or objects potentially acting as sinks. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify the efficacy of decontamination. More thorough probabilistic sampling (e.g., grid, statistical approach) may be required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because HD is a semi-persistent liquid, sample priorities should include surfaces that are potentially contaminated with aerosol/liquid (e.g., release site, low lying areas) and that humans are likely to contact or where vegetation is used as food.
	Note: HD breaks down in most environmental conditions to numerous breakdown products, especially TDG, which may be used as a marker to determine the extent of contamination of the parent HD. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. **Types of Samples:** **Air (Vapors are heavier than air):** Samples are collected using appropriate solid phase absorbent (tubes) or air sampler (e.g., SUMMA canister) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces. **Water:** Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents and preservatives. **Soil:** For localized hot spot areas where soil deposition may occur (i.e., aerosol or liquid droplets), surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples are typically not necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered. **Surface Wipes:** Wipe samples are often desired to indicate absence of HD on non-porous surfaces. Concurrent air monitoring is recommended. **Bulk:** For hot spot areas where liquid HD deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring or drills) for subsequent laboratory extraction analysis. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of HD into these materials. **Other Sample Matrices:** Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.
	Sample Packaging and Shipping: The packaging and shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA and IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.
Analysis	**CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil).** The ERLN will use uniform, compatible sample prep and analytical methods. (See www2.epa.gov/emergency-response/environmental-response-laboratory-network). For access to the nearest ERLN laboratory specially trained and equipped for HD analysis, contact the EPA/HQ-EOC at 202-564-3850.
Decontamination/Cleanup	**Decontamination/Cleanup Planning:** Once site controls are in place, develop a site-specific decontamination/cleanup plan. Decontamination may require a "tiered approach" using a variety of techniques and products. Call the EPA/HQ-EOC at 202-564-3850 for more information. **General Considerations:** A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service and any socio-economic, psychological, and/or security impacts that may result. Large volumes of decontamination wastes may be generated that will need to be collected, treated and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see Waste Management section below). **Disposal Option:** The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decontamination formulations, or may be cheaper to discard and replace than to decontaminate and restore. **Monitored Natural Attenuation:** HD degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation may require institutional controls (e.g., access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options but is non-destructive to materials. **Fix-in-Place Option:** The contaminated area may be resistant to decontamination products or may be unable or impractical to be treated. Physical barriers can be used to separate and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution. **Decontamination Strategy:** A decontamination strategy can be developed by designating contaminated areas into three broad categories: 1) surfaces or hot spots, 2) large volumetric spaces, and 3) sensitive equipment or items. Areas in each category may be treated using one or more unique decontamination processes in a tiered approach to the overall site-specific decontamination strategy. **Surfaces/Hot Spots:** This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods. In contrast to the rapid hydrolysis when HD is dissolved in water, **the hydrolysis of HD on surfaces is slow.** 1) Hypochlorite solutions are effective but can be very corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards. Household bleach solutions (≥5% sodium hypochlorite) are very effective for HD with efficacy achieved with contact time of 15-60 minutes depending on surface material. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 2) Proprietary decontamination foams and gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® have been reported to be effective against HD on the order of minutes to hours, but not all have been thoroughly tested. Availability, cost and the need for specialized equipment may limit their use early in the response. **Large Volumetric Spaces:** This category is for areas larger in size but with lower levels of agent contamination. They may require less aggressive but more broadly applied decontamination products and methods. 1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination. 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of HD in large volumetric spaces or open areas; efficacy typically can be achieved in hours to days with less waste and adverse impacts to materials. 3) Fumigation with modified vaporous hydrogen peroxide (VHP®) has been reported to be effective against HD. HVAC systems in large indoor spaces may require a separate decontamination strategy that could include the use of Hot Air ventilation or fumigation. **Sensitive Equipment and Items:** 1) Forced or Hot Air ventilation may be used for HD and can be used either in-situ or ex-situ to decontaminate these items. 2) modified VHP® fumigation can be used on these items with less corrosion to electronics than dilute hypochlorite solutions. **CAUTION:** Decontamination products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., bleach results in chlorine vapors). Strong oxidizers, such as hypochlorite, may react violently with organics. Under oxidizing conditions (i.e., bleach), **HD can break down into several toxic by-products, such as mustard and vinyl sulfones.** Hydrolysis of HD releases Cl ions that can affect the pH of solutions. Formulations should be chosen that do not allow the formation of these toxic breakdown products. Dirt, grime and other coatings can reduce the efficacy of decontamination; pre-cleaning surfaces with soap and water may be needed before the application of decontamination formulations **but resulting pre-cleaning rinsates may contain and spread agent.** **Verification of Decontamination:** Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.
Waste Management	**CAUTION:** Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm#hmp. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org. Current resources on packaging, labeling and shipping are available at: www.phmsa.dot.gov/hazmat.
	Waste Management: Under the Resource Conservation and Recovery Act (RCRA), waste generally is classified as hazardous waste (subtitle C) or solid waste (subtitle D). Under RCRA's statutory authority, a waste is considered hazardous if it: (A) causes or significantly contributes to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness or (B) poses a substantial, present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. The RCRA regulations generally define a waste as hazardous if it is: (1) a listed waste (40 CFR§261.21, §261.32), (2) exhibits specific characteristics (§261.21-261.24) or (3) is a spilled or discarded commercial chemical product (§261.33). The States (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements than the Federal program, so it is critical to open a dialogue with regulators as early as possible. Several states (CO, IN, KY, MD, OR, UT) have their own waste designations for CWA, which may be applicable for the cleanup of contaminated residues. HD is not a hazardous waste under the Federal regulations, but state codes may apply for HD-contaminated residues, soils and debris. Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. The EPA has developed I-WASTE, a web-based tool that contains links to waste transportation guidance, treatment and disposal facilities, state regulatory offices, packaging guidance, and guidance to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (www2.ergweb.com/bdrtool/login.asp).

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NRT Quick Reference Guide:
Sarin (GB)
[January 2015 Update]

For references, please see Key References Cited/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Chemical Warfare Agents. QRGs are intended for Federal OSC/RPMs.

Agent Characteristics

Agent Classification: Schedule 1 Chemical Warfare Nerve Agent; **CAS:** 107-44-8; **Formula:** $C_4H_{10}FO_2P$; **Molecular Weight:** 140.10 g/mol.

Description: Colorless and odorless liquid when pure; brown liquid with a fruity odor in impure form. GB is a lethal cholinesterase inhibitor with a mechanism of toxicity similar to organophosphate insecticides, though it is much more potent. GB is more easily generated and more volatile than chemical warfare agents GA, GD, GF, HD, Lewisite, and VX. Environmental breakdown products of GB, including methylphosphonic acid (MPA) and isopropyl methylphosphonic acid (IMPA), are relatively non-toxic. Other breakdown products include fluoride ion, which may exist as hydrofluoric acid (HF) depending on the pH. GB can react violently with strong oxidizers and may decompose when in contact with metals, evolving flammable hydrogen gas. GB vapors can form explosive mixtures with air.

Persistence: GB is considered a "very low persistent" chemical warfare agent. Vapor: minutes to hours; liquid: 2-24 hours. Persistence will depend upon the amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. Porous, permeable, organic or polymeric materials such as carpets and vinyl tiles can accumulate agent by sorbing GB vapors and liquids, acting as "sinks," thereby prolonging persistence.

Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.1745; mg/m³ = ppm x 5.730

Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility
4.86 (air = 1)	2.94 mm Hg (77°F/25°C)	22,000 mg/m³ (77°F/25°C)	316°F/158°C	-69°F/-56°C	>280°F/138°C	1.09 g/mL (77°F/25°C)	miscible	Common solvents, alcohols, gasoline, oils, fats

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.

Open Areas: GB has high volatility relative to other nerve agents but may still be present as a liquid or aerosol, and the primary release/attack scenario is an airborne release. GB is expected to degrade in the environment fairly rapidly; however, liquid GB on surfaces could persist for up to 24 hours. Environmental conditions will affect the degradation and evaporation rates of GB with cooler and drier conditions enhancing persistence. GB vapors are heavier than air, so vapors can accumulate in lower terrains. GB vapors can form explosive mixtures with air.

Water/Water Systems: GB is not typically considered a water release hazard. If released into natural waters or water systems, GB will likely hydrolyze with a half-life of about 39 hours at pH 7, with persistence depending on released amount and environmental conditions.

Indoor Facility: Due to its volatility, GB could potentially be dispersed as a vapor or an aerosol inside a building or facility; HVAC systems could be impacted. GB vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.

Health Effects

Onset	Onset of symptoms is dose and route dependent. After exposure, symptoms may occur within seconds if GB is present in vapor form or within minutes to hours if in liquid form. Even a relatively low dose exposure to GB can be fatal and immediate administration of an antidote is critical (see First Aid below).
Signs/ Symptoms	Symptoms will vary depending on exposure route; however, the following is a general list of all possible symptoms. The severity of effects depends upon the dosage. **Mild:** Runny nose, reduction in pupil size (miosis), dimness of vision, tightness of chest, difficulty in breathing. **Moderate:** Increased miosis (to level of pinpointing of pupils), headaches, confusion, drowsiness, nasal congestion, tightness of chest, nausea, vomiting, diarrhea, cramps, generalized weakness, twitching of large muscle groups. **Severe:** Involuntary defecation and urination, drooling, twitching, staggering, convulsions, cessation of breathing, loss of consciousness, coma, death.
Exposure Routes	**Inhalation:** A primary exposure route; inhalation of very small concentrations can produce health effects. **Skin:** Direct contact with liquid agent is especially toxic. Moderate to severe *signs/symptoms occur at, but are not limited to, the site of contact.* Exposure can also result from absorption of vapors via skin. **Eyes:** Eyes are the most sensitive target organs of nerve agent exposure. Miosis (reduction in pupil size) will typically be the first sign of exposure. **Ingestion:** Contaminated drinking water and foods are the most likely route for ingestion of agent. Target organ from ingestion is the GI tract. **Other:** Females appear to be more susceptible to nerve agent effects. Certain genetic traits may increase susceptibility.

Effect Levels

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for GB (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Chemical Warfare Agents):

AEGL Level in mg/m³, at various exposure durations	**10 min.**	**30 min.**	**1 hr.**	**4 hr.**	**8 hr.**
AEGL 1: Threshold mild effects	0.0069	0.0040	0.0028	0.0014	0.0010
AEGL 2: Potentially irreversible effects or impaired ability to escape	0.087	0.050	0.035	0.017	0.013
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	0.38	0.19	0.13	0.070	0.051

Exposure Guidelines: IDLH = 0.1 mg/m³; **STEL** = 1.0 x 10^{-4} mg/m³; **Worker Population Limit (WPL)** [an 8-hr time-weighted average occupational value] = 3.0 x 10^{-5} mg/m³; **General Population Limit (GPL)** [a 24-hr time-weighted average] = 1.0 x 10^{-6} mg/m³. **Soil: Industrial Exposure Scenario** = 32 mg/kg; **Residential Exposure Scenario** = 1.3 mg/kg. **Drinking Water:** Provisional Advisory Levels (PAL-1) for general public at 2 L/day, for 1, 30, and 90 days = 37, 8.1, and 2 µg/L, respectively.

Personnel Safety

Note	Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decontamination may vary depending upon the amount and purity of agent, site conditions and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb. We also recommend that responders check their own internal procedures (i.e., SOPs) if they have them.
Medical	**Pre-incident:** A baseline cholinesterase activity determination and an annual physical and respiratory function exam. **During Incident:** Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per Health Effects section above and treat accordingly as per First Aid section below.
First Aid	Immediately remove person from affected area and remove contaminated clothing and articles. Wash bare skin immediately with water, or warm, soapy water if available, at normal household pressures (~50-60 psi) for three minutes, ensure thorough soaking. Rinse eyes exposed to liquid agent with potable water for 15 minutes. **Antidote: Atropine, 2-PAM Chloride injections (Duo Dote/Mark II kits). Antidote kit should only be administered as per pre-incident training.** Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.
PPE	**GENERAL INFORMATION:** NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, and protective clothing should be used. Pre-incident training and exercises on the proper use of PPE are recommended. Per NIOSH guidance - **LEVEL A:** Recommended for the initial response to a GB incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the GB concentration is unknown or above the IDLH or AEGL-2, and when there is a potential of ocular or dermal exposure. **LEVEL B:** Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the GB concentration is unknown or above the IDLH or AEGL-2 and dermal exposure is less of a risk. Level B differs from Level A in that it incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not airtight. **LEVEL C:** Select Level C when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e., < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. **LEVEL D:** Select Level D when the contaminant is known and the concentration is below the appropriate occupational exposure limit or less than AEGL-1 for the stated duration times. **Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.**

Field Detection

Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment. The following is a summary of minimum screening concentration ranges for equipment procured by many EPA and HAZMAT response teams. Other screening tools may be used by these teams and other agencies and responders, some with similar capabilities and limitations. NA = not available.

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of a nerve agent at levels as listed below.

Minimum Screening Ranges	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger (CDS Kit)	M256/M256A1	M272 (water)
ppm	0.005-0.02	0.0015-0.003	0.005-0.015	0.025	0.0008-0.0009	0.02 mg/L
mg/m³	0.03-0.1	0.01-0.03	0.025-0.27	0.14	0.005	NA

Updated January 2015 (replaced previous version dated 2011)

Sampling	*Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)* **Sampling Concerns:** Detection, sampling equipment and procedures, and analytical techniques will be site-specific and depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. non-porous); 3) the purpose of sampling (e.g., characterization, decontamination efficacy and clearance); and 4) specific laboratory requirements. Few laboratories currently have capability to determine GB, particularly for large numbers of samples and in all types of media. The U.S. Environmental Protection Agency (EPA) has set up mobile and fixed labs and analytical assets for chemical agent analysis of environmental samples under their Environmental Response Laboratory Network (ERLN), see ANALYSIS section below (www2.epa.gov/emergency-response/environmental-response-laboratory-network). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.
	Sample Locations and Planning: Initially consider air monitoring to ensure worker safety and to determine if there is a vapor plume that could impact other areas. Characterization sampling is initiated by targeted or judgmental sampling to identify "hot spots," potential agent flow paths, and media or objects potentially acting as sinks. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify the efficacy of decontamination. More thorough probabilistic sampling (e.g., grid, statistical approach) may be required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because GB is generally not persistent, air sampling to help to "clear areas" should be included in the sampling plan.
	Note: GB breaks down in most environmental conditions to numerous breakdown products, especially fluoride ion, MPA and IMPA, which may be used as markers to determine the extent of contamination of the parent GB. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. **Types of Samples:** **Air (Vapors are heavier than air):** Samples are collected using appropriate solid phase absorbent (tubes) or air sampler (e.g., SUMMA canister) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces. **Water:** Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents and preservatives. G-agents are unlikely to persist in water. **Soil:** For localized hot spot areas where soil deposition may occur, surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples may not be necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered. **Surface Wipes:** Wipe samples are often desired to indicate absence of GB on non-porous surfaces. Concurrent air monitoring is recommended. **Bulk:** For hot spot areas where liquid GB deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring or drills) for subsequent laboratory extraction analysis. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of GB into these materials. **Other Sample Matrices:** Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.
	Sample Packaging and Shipping: The packaging and shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA and IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.
Analysis	**CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil).** The ERLN will use uniform, compatible sample prep and analytical methods. (See www2.epa.gov/emergency-response/environmental-response-laboratory-network). For access to the nearest ERLN laboratory specially trained and equipped for GB analysis, contact the EPA/HQ-EOC at 202-564-3850.
Decontamination/Cleanup	**Decontamination/Cleanup Planning:** Once site controls are in place, develop a site-specific decontamination/cleanup plan. Decontamination may require a "tiered approach" using a variety of techniques and products. Call the EPA/HQ-EOC at 202-564-3850 for more information. **General Considerations:** A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service and any socio-economic, psychological, and/or security impacts that may result. Large volumes of decontamination wastes may be generated that will need to be collected, treated and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see Waste Management section below). **Disposal Option:** The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decontamination formulations, or may be cheaper to discard and replace than to decontaminate and restore. **Monitored Natural Attenuation:** GB degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation may require institutional controls (e.g., access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options but is non-destructive to materials. **Fix-in-Place Option:** The contaminated area may be resistant to decontamination products or may be unable or impractical to be treated. Physical barriers can be used to separate and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution. **Decontamination Strategy:** A decontamination strategy can be developed by designating contaminated areas into three broad categories: 1) surfaces or hot spots, 2) large volumetric spaces, and 3) sensitive equipment or items. Areas in each category may be treated using one or more unique decontamination processes in a tiered approach to the overall site-specific decontamination strategy. **Surfaces/Hot Spots:** This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods. Decontamination of GB occurs mainly through hydrolysis, which may be catalyzed (sped up), by hypochlorites. 1) Hypochlorite Solutions: Hypochlorite can be very corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards. Household bleach solutions (≥5% sodium hypochlorite) are very effective for GB with efficacy achieved with contact time of 15-60 minutes depending on surface material. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 2) Hydroxide (e.g., sodium, potassium – 10% solution) reacts rapidly with GB but solutions are very damaging to many surfaces and should be rinsed thoroughly after use. 3) Other high pH solutions, such as sodium carbonate (10% solution) have been shown to decontaminate but slower than decontamination with sodium or potassium hydroxide. Proprietary decontamination foams and gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® have been shown to be effective against GB on the order of minutes to hours, but not all have been thoroughly tested. Availability, cost and the need for specialized equipment may limit their use early in the response. **Large Volumetric Spaces:** This category is for areas larger in size but with lower levels of agent contamination. They may require less aggressive but more broadly applied decontamination products and methods. 1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination, especially given GB's relative high volatility. 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of GB in large volumetric spaces or open areas; efficacy typically can be achieved in hours to days with less waste and adverse impacts to materials. **Sensitive Equipment and Items:** Forced or Hot Air ventilation may be used for GB and can be used either in-situ or ex-situ to decontaminate these items. **CAUTION:** Decontamination products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., bleach results in chlorine vapors). Dirt, grime and other coatings can reduce the efficacy of decontamination; pre-cleaning surfaces with soap and water may be needed before the application of decontamination formulations **but resulting pre-cleaning rinsates may contain and spread agent.** **Verification of Decontamination:** Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.
Waste Management	**CAUTION:** Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm#hmp. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org. Current resources on packaging, labeling and shipping are available at www.phmsa.dot.gov/hazmat.
	Waste Management: Under the Resource Conservation and Recovery Act (RCRA), waste generally is classified as hazardous waste (subtitle C) or solid waste (subtitle D). Under RCRA's statutory authority, a waste is considered hazardous if it: (A) causes or significantly contributes to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness or (B) poses a substantial, present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. The RCRA regulations generally define a waste as hazardous if it is: (1) a listed waste (40 CFR§261.21, §261.32), (2) exhibits specific characteristics (§261.21-261.24) or (3) is a spilled or discarded commercial chemical product (§261.33). The States (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements than the Federal program, so it is critical to open a dialogue with regulators as early as possible. Several states (CO, IN, KY, MD, OR, UT) have their own waste designations for CWA, which may be applicable for the cleanup of contaminated residues. GB is not a hazardous waste under the Federal regulations, but state codes may apply for GB-contaminated residues, soils and debris. Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. The EPA has developed I-WASTE, a web-based tool that contains links to waste transportation guidance, treatment and disposal facilities, state regulatory offices, packaging guidance, and guidance to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (www2.ergweb.com/bdrtool/login.asp).

Updated January 2015 (replaced previous version dated 2011)

NRT Quick Reference Guide:
VX
[January 2015 Update]

For references, please see Key References Cited/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Chemical Warfare Agents. QRGs are intended for Federal OSC/RPMs.

Agent Characteristics

Agent Classification: Schedule 1 Chemical Warfare Nerve Agent; **CAS:** 50782-69-9; **Formula:** $C_{11}H_{26}NO_2PS$; **Molecular Weight:** 267.38 g/mol.

Description: Odorless, oily, yellow/amber colored liquid when pure. VX is a lethal cholinesterase inhibitor having a similar mechanism of toxicity as organophosphate insecticides, though it is much more potent. VX is more potent than the G-agents. However, VX has a very low vapor pressure and is difficult to maintain or disperse as vapor in air. Environmental breakdown products of VX, including methylphosphonic acid (MPA) and ethyl methylphosphonic acid (EMPA), may be present. VX **breakdown can result in the formation of compound EA-2192, which is considered almost as toxic as VX by ingestion exposure route.** EA-2192 formation is maximized between pH 7-10, but can be formed in potentially significant amounts outside this range.

Persistence: VX is considered a "persistent" chemical warfare agent. Vapor: hours to days; liquid: hours to months. Persistence will depend upon amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. Porous, permeable, organic or polymeric materials such as carpets and vinyl tiles can act as "sinks" for absorbing VX vapors and liquids, prolonging persistence.

Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.09144; mg/m³ = ppm x 10.936

Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility
9.2 (air = 1)	0.0007 mm Hg (68°F/20°C)	10.5 mg/m³ (77°F/25°C)	568°F/298°C	<-38°F/-39°C	318°F/159°C	1.008 g/mL (77°F/25°C)	30 g/L (temp not reported)	Common solvents, alcohols, gasoline, oils, fats

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.

Open Areas: VX is difficult to disperse in air as a gas due to low volatility, but even small quantities can be lethal. It may be possible to disperse VX as a vapor/aerosol plume if an appropriate heat/explosive device is employed; however, the low volatility of VX would limit the size and extent of plume dissipation, posing localized hazards. VX vapors when present are heavier than air, so vapors can accumulate in lower terrains.

Water/Water Systems: VX released into water will likely hydrolyze with a half-life of about 1,000 hours at pH 7, with persistence depending on released amount and environmental conditions; however, it could potentially persist for weeks depending on overall dilution and breakdown processes. The hydrolysis breakdown product of VX, EA-2192, may be a greater ingestion concern. If released into water systems such as reservoirs, treatment plants, distribution systems, public fountains or pools, treatment processes can further break down agent. For water systems, plumbing, surfaces and equipment that have contacted contaminated water must be evaluated for decontamination along with the bulk water.

Indoor Facility: Due to its low volatility, VX would be difficult to distribute effectively throughout a building or facility from a point source. Liquid VX will result in localized areas of surface contamination. VX vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.

Health Effects

Onset

Onset of symptoms is dose and route dependent. After exposure, symptoms may occur within seconds if VX is present in vapor form or within minutes to hours if in liquid form. Even extremely low dose exposure to VX can be fatal and immediate administration of an *antidote is critical* (see First Aid below).

Signs/ Symptoms

Symptoms will vary depending on exposure route; however, the following is a general list of all possible symptoms. The severity of effects depends upon the dosage.

Mild: Runny nose, reduction in pupil size (miosis), dimness of vision, tightness of chest, difficulty in breathing.

Moderate: Increased miosis (to level of pinpointing of pupils), headaches, confusion, drowsiness, nasal congestion, tightness of chest, nausea, vomiting, diarrhea, cramps, generalized weakness, twitching of large muscle groups.

Severe: Involuntary defecation and urination, drooling, twitching, staggering, convulsions, cessation of breathing, loss of consciousness, coma, death.

Exposure Routes

Inhalation: Inhalation of very small concentrations can produce health effects.

Skin: Direct contact with liquid agent is especially toxic. Moderate to severe *signs/symptoms occur at, but are not limited to, the site of contact.* Exposure can also result from absorption of vapors via skin.

Eyes: Eyes are the most sensitive target organs of nerve agent exposure. Miosis (reduction in pupil size) will typically be the first sign of exposure.

Ingestion: Contaminated drinking water and foods are the most likely route for ingestion of agent. Target organ from ingestion is the GI tract.

Other: Females appear to be more susceptible to nerve agent effects. Certain genetic traits may increase susceptibility.

Effect Levels

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for VX (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Chemical Warfare Agents):

AEGL Level in mg/m³, at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	0.00057	0.00033	0.00017	0.00010	0.000071
AEGL 2: Potentially irreversible effects or impaired ability to escape	0.0072	0.0042	0.0029	0.0015	0.0010
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	0.029	0.015	0.010	0.0052	0.0038

Exposure Guidelines: IDLH = 0.003 mg/m³; **STEL** = 1.0 x 10^{-5} mg/m³; **Worker Population Limit (WPL)** [an 8-hr time-weighted average occupational value] = 1.0 x 10^{-6} mg/m³; **General Population Limit (GPL)** [a 24-hr time-weighted average lifetime chronic value] = 6.0 x 10^{-7} mg/m³. **Soil: Industrial Exposure Scenario** = 1.1 mg/kg; **Residential Exposure Scenario** = 0.043 mg/kg. **Drinking Water:** Provisional Advisory Levels (PAL-1) for general public at 2 L/day, for 1, 30, and 90 days = 2.7, 0.21, and 0.21 µg/L, respectively.

Personnel Safety

Note

Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decontamination may vary depending upon the amount and purity of agent, site conditions and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb. We also recommend that responders check their own internal procedures (i.e., SOPs) if they have them.

Medical

Pre-incident: Annual physical, respiratory function exams and a baseline cholinesterase activity determination. **During Incident:** Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per Health Effects section above and treat accordingly as per First Aid section below.

First Aid

Immediately remove person from affected area and remove contaminated clothing and articles. Wash bare skin immediately with water, or warm, soapy water if available, at normal household pressures (~50-60 psi) for three minutes, ensure thorough soaking. Rinse eyes exposed to liquid agent with potable water for 15 minutes. **Antidote: Atropine, 2-PAM Chloride injections (Duo Dote/Mark II kits). Antidote kit should only be administered as per pre-incident training.** Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.

PPE

GENERAL INFORMATION: NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, and protective clothing should be used. Pre-incident training and exercises on the proper use of PPE are recommended. Per NIOSH guidance - **LEVEL A:** Recommended for the initial response to a VX incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the VX concentration is unknown or above the IDLH or AEGL-2, and when there is a potential of ocular or dermal exposure. **LEVEL B:** Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the VX concentration is unknown or above the IDLH or AEGL-2 and dermal exposure is less of a risk. Level B differs from Level A in that it incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not airtight. **LEVEL C:** Select Level C when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e., < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. **LEVEL D:** Select Level D when the contaminant is known and the concentration is below the appropriate occupational exposure limit or less than AEGL-1 for the stated duration times. **Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.**

Field Detection

Real-time field screening tools (results not confirmatory or quantitative) AND may not specify type of nerve agent. Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment. The following is a summary of minimum screening concentration ranges for equipment procured by many EPA and HAZMAT response teams. Other screening tools may be used by these teams and other agencies and responders, some with similar capabilities and limitations. NA = not available.

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of a nerve agent at levels as listed below.

Minimum Screening Ranges	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger (CDS Kit)	M256/M256A1	M272 (water)
ppm	0.0037-0.02	0.0009-0.0015	0.0037-0.004	0.025	0.002-0.009	0.02 mg/L
mg/m³	0.03-0.1	0.01-0.03	0.25-0.04	0.27	0.005-0.1	NA

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Sampling	*Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)* **Sampling Concerns:** Detection, sampling equipment and procedures, and analytical techniques will be site-specific and depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. non-porous); 3) the purpose of sampling (e.g., characterization, decontamination efficacy and clearance); and 4) specific laboratory requirements. Few laboratories currently have capability to determine VX (or its breakdown product EA-2192), in all types of media. The U.S. Environmental Protection Agency (EPA) has set up mobile and fixed labs and analytical assets for chemical agent analysis of environmental samples under their Environmental Response Laboratory Network (ERLN), see ANALYSIS section below (www2.epa.gov/emergency-response/environmental-response-laboratory-network). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.
	Sample Locations and Planning: Initially consider air monitoring to ensure worker safety and to determine if there is a vapor plume that could impact other areas. Characterization sampling is initiated by targeted or judgmental sampling to identify "hot spots," potential agent flow paths, and media or objects potentially acting as sinks. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify the efficacy of decontamination. More thorough probabilistic sampling (e.g., grid, statistical approach) may be required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because VX is a persistent liquid, sample priorities should include surfaces that are potentially contaminated with aerosol/liquid (e.g., release site, low lying areas) and that humans are likely to contact or where vegetation is used as food.
	Note: VX breaks down in most environmental conditions to numerous breakdown products, especially EA-2192, MPA and EMPA, which may be used as markers to determine the extent of contamination of the parent VX. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. **Types of Samples:** **Air (Vapors are heavier than air):** Samples are collected using appropriate solid phase absorbent (tubes) or air sampler (e.g., SUMMA canister) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces. **Water:** Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents and preservatives. In large volumes of water, VX is expected to dissipate via breakdown, hydrolysis and dilution. To rule out contamination concerns, particularly in small bodies of water, analyses should include EA-2192. **Soil:** For localized hot spot areas where soil deposition may occur (i.e., aerosol or liquid droplets), surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples are typically not necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered. **Surface Wipes:** Wipe samples are often desired to indicate absence of VX on non-porous surfaces. Concurrent air monitoring is recommended. **Bulk:** For hot spot areas where liquid VX deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring or drills) for subsequent laboratory extraction analysis. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of VX into these materials. **Other Sample Matrices:** Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.
	Sample Packaging and Shipping: The packaging and shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA and IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.
Analysis	**CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil).** The ERLN will use uniform, compatible sample prep and analytical methods. (See www2.epa.gov/emergency-response/environmental-response-laboratory-network). For access to the nearest ERLN laboratory specially trained and equipped for VX analysis, contact the EPA/HQ-EOC at 202-564-3850.
Decontamination/Cleanup	**Decontamination/Cleanup Planning:** Once site controls are in place, develop a site-specific decontamination/cleanup plan. Decontamination may require a "tiered approach" using a variety of techniques and products. Call the EPA/HQ-EOC at 202-564-3850 for more information. **General Considerations:** A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service and any socio-economic, psychological, and/or security impacts that may result. Large volumes of decontamination wastes may be generated that will need to be collected, treated and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see Waste Management section below). **Disposal Option:** The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decontamination formulations, or may be cheaper to discard and replace than to decontaminate and restore. **Monitored Natural Attenuation:** VX degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation may require institutional controls (e.g., access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options but is non-destructive to materials. Potential formation of EA-2192 must be considered and addressed. **Fix-in-Place Option:** The contaminated area may be resistant to decontamination products or may be unable or impractical to be treated. Physical barriers can be used to separate and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution. **Decontamination Strategy:** A decon strategy can be developed by designating contaminated areas into three broad categories: 1) surfaces or hot spots, 2) large volumetric spaces, and 3) sensitive equipment or items. Areas in each category may be treated using one or more unique decon processes in a tiered approach to overall site-specific decon strategy. **CAUTION: VX hydrolyzes and forms the toxic breakdown product EA-2192, with greatest yields between pH levels 7 and 10. For decontamination and EA-2192 information, contact the EPA/HQ-EOC at 202-564-3850. It is advisable to choose a decontamination solution containing a strong oxidant, such as chlorine or peroxide, which will help limit EA-2192 formation regardless of pH. Presence of EA-2192 may present significant challenges in waste disposal.** **Surfaces/Hot Spots:** This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods. 1) Hypochlorite Solutions: Hypochlorite can be very corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards. Household bleach solutions (≥5% sodium hypochlorite) are very effective for VX with efficacy achieved with contact time of 15-60 minutes depending on surface material. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 2) Aqueous peroxide solutions may be effective in breaking down VX without the formation of the EA-2192 species. Proprietary decontamination foams and gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® have been shown to be effective against VX on the order of minutes to hours, but not all have been thoroughly tested. Availability, cost and the need for specialized equipment may limit their use early in the response. **Large Volumetric Spaces:** This category is for areas larger in size but with lower levels of agent contamination. 1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination. 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of VX in large volumetric spaces or open areas; efficacy typically can be achieved in days to weeks with less waste and adverse impacts to materials. 3) Fumigation with modified vaporous hydrogen peroxide (VHP®) has been reported to be effective against VX. HVAC systems in large indoor spaces may require a separate decontamination strategy that could include the use of Hot Air ventilation or fumigation. **Sensitive Equipment and Items:** 1) Forced or Hot Air ventilation may be used for VX and can be used either in-situ or ex-situ to decontaminate these items. The low volatility of VX may necessitate high operating temperatures. 2) modified VHP® fumigation can be used on these items with less corrosion to electronics than dilute hypochlorite solutions. **CAUTION:** Decontamination products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., bleach results in chlorine vapors). Strong oxidizers, such as hypochlorite, may react violently with organics. Formulations should be chosen that do not allow the formation of toxic breakdown products such as EA-2192. Dirt, grime and other coatings can reduce the efficacy of decontamination; pre-cleaning surfaces with soap and water may be needed before the application of decontamination formulations **but resulting pre-cleaning rinsates may contain and spread agent and toxic breakdown products.** **Verification of Decontamination:** Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.
Waste Management	**CAUTION:** Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm#hmp. These regulations differ from state-to-state. Detailed state regulations can be found at: www.envcap.org. Current resources on packaging, labeling and shipping are available at: www.phmsa.dot.gov/hazmat.
	Waste Management: Under the Resource Conservation and Recovery Act (RCRA), waste generally is classified as hazardous waste (subtitle C) or solid waste (subtitle D). Under RCRA's statutory authority, a waste is considered hazardous if it: (A) causes or significantly contributes to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness or (B) poses a substantial, present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. The RCRA regulations generally define a waste as hazardous if it is: (1) a listed waste (40 CFR§261.21, §261.32), (2) exhibits specific characteristics (§261.21-261.24) or (3) is a spilled or discarded commercial chemical product (§261.33). The States (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements than the Federal program, so it is critical to open a dialogue with regulators as early as possible. Several states (CO, IN, KY, MD, OR, UT) have their own waste designations for CWA, which may be applicable for the cleanup of contaminated residues. VX is not a hazardous waste under the Federal regulations, but state codes may apply for VX-contaminated residues, soils and debris. Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. The EPA has developed I-WASTE, a web-based tool that contains links to waste transportation guidance, treatment and disposal facilities, state regulatory offices, packaging guidance, and guidance to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (www2.erqweb.com/bdrtool/login.asp).

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APPENDIX C

Behavior of Mustard (HD), Sarin (GB), and VX in the Environment

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APPENDIX C

Behavior of Mustard (HD), Sarin (GB), and VX in the Environment

C.1 Introduction

Developing a sampling and analysis plan requires an understanding of the agents' fate when released into the environment. The environment is defined very broadly here to include air, lakes, rivers, soil, snow, ice, farmland, crops, farm animals, woodlands, wildlife, residential areas, commercial areas, structures, automobiles, roads, highways, and everything in between.

The fate of chemical agents released into the environment has been studied extensively (Small 1984; MacNaughton and Brewer 1994; Rosenblatt et al. 1996; Munro et al. 1999; Watson et al. 2011a, b). Physical and chemical properties of the agents and their primary degradation products are reviewed in detail in Watson et al. (2011a) and that information is not repeated here. This appendix summarizes the environmental fate of the agents currently stored at BGAD and identifies their primary degradation products and pertinent environmental properties.

C.2 Scenario

The most likely scenario for a chemical agent release from BGAD that would prompt development of an RSAP would be a vapor or aerosol plume extending off-post in the direction of wind flow. Unless something truly catastrophic occurs, the release would involve only one of the three agents stored at BGAD. The agents would likely be present as a vapor or aerosol within a plume extending some height and distance from the site of the release. The exact height and distance would depend primarily on the nature of the release event and atmospheric conditions, the most significant factors being wind direction and speed (CSEPP 2012b). The plume would eventually dissipate over time and space, potentially resulting in deposition of agent where the plume travelled. Deposition of the agent would likely occur as a vapor or small aerosol droplets (much smaller than normal raindrops). The agent could be deposited onto soil, vegetation, lakes, and other water bodies, and into populated areas, both residential and commercial. Because it would likely be a day or more before sampling teams could be mobilized to perform sampling to evaluate re-entry, it is likely that the plume will have dissipated long before sampling for the purposes of evaluating re-entry begins. However, deposited agent may still evaporate or off-gas from various surfaces into the surrounding air for some time following plume dissipation. The following discussion is predicated on this scenario.

C.3 Degradation, Persistence, and Time

Persistence of the chemical released and the persistence of its degradation products are key factors in designing an RSAP. It is prudent to put persistence into perspective. For many years, the U.S. Army has described several of the agents as being persistent. For example, the Army has discussed VX as "a persistent, terrain denial military compound with the potential to off-gas toxic vapor for days following surface application." Similarly, the Army has indicated that mustard "can be persistent in the environment" (CSEPP 2012a). The Army's perception of

persistence relates to the fact that when used in a military application, it is applied via some type of munition that is likely to cause heavy loading onto land and water. In addition, as suggested by the Army's description of VX persistency, the Army is concerned with soldiers on the ground. The Army's perception of persistence relates to when soldiers can safely re-enter areas that have been impacted. From this viewpoint, persistence of VX, and to a lesser extent mustard, is high—especially after a relatively heavy application.

In contrast, in the case of a release off-post, a CSEPP scenario would entail a plume of agent that is mixed with and diluted by air that settles in areas over time. This would result in deposition of vapor or aerosol droplets in a relatively thin layer. Exposure would not involve relatively short-term exposure for soldiers on the ground, but rather longer-term exposure of the general public. Therefore, it is important to put the Army's statements about agent persistence into perspective. A good example, and one of the more common contaminants at hazardous waste sites, is polychlorinated biphenyls (PCBs). PCBs are associated with very high persistence; they last for many years, even decades, in the environment before they eventually break down. In contrast, as discussed below, HD and VX persistency is typically measured in weeks or months. In this context, HD and VX would actually be considered moderately persistent. For the RSAF, persistence should be evaluated in the same sense.

Considering this, for very persistent chemicals, analyses of soil and other media to evaluate re-entry may target only the parent chemical, at least initially. If chemicals are known to degrade rapidly, then it would be prudent to sample and analyze media in potentially impacted areas for more stable degradation products. For moderately persistent chemicals—chemicals that will degrade at a slower rate—it may be prudent to focus sampling and analysis on both the parent chemical and degradation products. Because degradation increases with time, and because it may take a day or more after the event to organize and mobilize field sampling teams to evaluate re-entry, it is important to consider the time that has elapsed since the event in determining whether to analyze samples for agent, degradation products, or both.

The U.S. Environmental Protection Agency (EPA) uses the term "natural attenuation" to refer to natural processes that contribute to the disappearance of a chemical over time after it has been deposited in the environment. Natural attenuation, or allowing nature and time to reduce contaminant concentrations to lower levels, is a commonly used remediation technique at many hazardous waste sites. This type of remedy is typically accompanied by various types of institutional controls (e.g., fences, warning signs) designed to preclude direct contact. When natural attenuation and institutional controls are inappropriate, for whatever reasons, more active forms of remediation are considered.

C.4 Mustard (HD)

If released to the environment in bulk form, HD has a tendency to polymerize at the HD/soil/water interface, forming a layer that will, in essence, shield the bulk of the HD from significant degradation (MacNaughton et al. 1994). Hence, HD in bulk form that is buried or that is present in a quiescent aqueous environment can remain in that form for many years, with little degradation (Rosenblatt et al. 1996). Even small droplets of HD that are present beneath the soil surface can remain in that form for a long time (Small 1984). Mustard present in the environment

in a bulk form, especially when buried, can therefore be considered very persistent, taking years to degrade. In addition, because it has very low water solubility, mustard that is present in a bulk form underwater may remain in that form for some time.

However, as discussed above, a release of H from BGAD would most likely occur as a vapor or aerosol cloud or plume. Rosenblatt et al. (1996), in a study referencing Small (1983), noted that field plot and explosion testing using HD munitions showed that HD concentrations dropped to 90% of their original concentration in air in as little as 5 hours, but that time could range to up to 10 days. Rosenblatt et al. (1996) speculated that if concentrations in air can be assumed to have the same effect in soil, then soil concentrations would also drop to 90% of their original concentration with the same time. Fine HD vapor or aerosols deposited on soils would likely be undetectable after about a month, especially in a warm, humid environment.

HD is also relatively volatile. It will begin to volatilize at temperatures above its freezing point (about 56 to 58°F); this accounts for much of its decrease in concentration on soil and other surfaces over time. The volatilized HD can, however, have toxic effects on exposed biota. Because HD is heavier than air, volatilized HD will remain close to the exposed surface unless disturbed by wind or other forces. Munro et al. (1999) indicate that HD is lost from the soil surface primarily via evaporation, and that the rate of loss is a function of temperature, wind speed, and soil type.

In a wet (e.g., rain or fog) or moist environment (moderate to high humidity), mustard in a dispersed form hydrolyzes rapidly. In a relatively dry environment, such as a desert, HD will still hydrolyze, but much more slowly. In both situations, higher ambient temperatures will result in more rapid hydrolysis. Mustard released as vapor or aerosol droplets onto soils in a warm, humid environment may be considered to have low persistence; it lasts a matter of hours or days in that environment. In cold or dry seasons, mustard released as a vapor or aerosol droplets can be considered moderately persistent; it persists for several days or weeks, perhaps even a month or more.

When dispersed as small aerosol droplets, HD is fairly unstable in an aqueous environment; it rapidly hydrolyzes into degradation products. This includes lakes, rivers, streams, and even puddles or wet surfaces (e.g., after a rainfall). However, even on surfaces with some moisture, such as mud, dew-laden surfaces, and moist soils, some degree of hydrolysis will occur. The temperature of the air and medium surface will greatly affect the rate of hydrolysis.

Munro et al. (1999) referenced two studies performed in Norway examining persistence of HD droplets released to a snow surface (Norwegian Ministry of Affairs 1982–1983; Johnsen and Blanch 1984). They observed that HD droplets quickly freeze on snow, but evaporate rapidly. After approximately two weeks, only a fraction remained.

Another factor to consider is the propensity for agent and degradation products to absorb into specific materials, such as soils, vegetation, cement, brick, wood, steel, glass, rubber, vinyl, and other plastics. If the agent and/or degradation products will absorb into these materials, then hydrolysis or natural attenuation processes may not occur or may occur at a lower rate. When

absorbed into a material, the contact hazard of the agent (touching) may be less of an issue unless some of the agent also remains on surfaces.

As reported in Watson (2011a), studies Love et al. (2009) performed for the U.S. Department of Homeland Security (DHS) evaluated the persistence of HD on steel, glass, latex paint (on wall board), and vinyl tile. HD spiked on glass and steel disappeared completely after about 25 hours. Between 20 and 50% of HD spiked on latex paint and vinyl tile remained after about 50 hours. HD did not begin to disappear completely from vinyl tile for more than five to eight weeks, and from latex paint from between 20 and 30 weeks. Watson et al. (2011a) concluded that "with the exception of VX, the residual chemical exposure hazard posed by liquid droplet (aerosol) release of [agent] may be realistically mitigated by natural attenuation within a 24 (hour) period."

Rosenblatt et al. (1996) evaluated absorption of chemical agents onto polymeric surfaces, such as paint, rubber, polystyrene, and chemically protective fabrics. They concluded that HD, like all the agents evaluated in the RSAF, can absorb into these materials but that absorption capacity varies widely by material. Rosenblatt et al. (1996) further concluded that complete decontamination of sorbed agents from thick layers of polymeric materials would be impractical due to time constraints. In other words, using some type of decontamination process to remove or destroy agent sorbed into materials may take a long time. If this is the case, removal and disposal of these types of materials may more efficient.

When HD hydrolyzes, the reaction is typically rapid and results in several degradation products, the primary species of which is thiodiglycol (TDG). At hazardous waste cleanup sites where mustard is known to have been present, TDG is the primary degradation product that is typically analyzed for. Other hydrolysis products may be present as well, including 1,4-oxathiane and 1,4-dithiane (Rosenblatt et al. 1996), but the presence of TDG is typically considered adequate evidence that HD is present or was present at one time. However, TDG is also subject to biodegradation and, dependent on temperature and other conditions, will biodegrade over time. The technology being employed at the Pueblo Chemical Deport Chemical Agent-Destruction Pilot Plant (PCAPP) for treatment of TDG, the primary product of the mustard hydrolysis treatment, is biodegradation (National Research Council 2015a). Talmage et al. (2007), as referenced in Watson et al. (2011a), estimate the persistence of TDG to be moderate, lasting weeks to months in the environment.

TDG itself is also not considered particularly toxic (Watson et al. 2011b). It is analyzed in a mustard release situation primarily as an indicator that mustard is or was present, not because it is a toxic contaminant or constituent. Nevertheless, the EPA has developed a soil regional screening level (RSL) for TDG. The lowest level (most stringent) is based on soil ingestion by a child with a non-carcinogenic toxic endpoint. The level is set at 5,400 mg of TDG per kilogram of soil, which amounts to a little more than 0.5% (EPA 2015). As referenced in Watson (2011b), EPA Region 9 published preliminary remediation goals (PRGs) for TDG, based on adult residential exposure (24,000 mg/kg, or 2.4%) and worker exposure, for both indoor workers (60,000 mg/kg, or 6.0%) and outdoor workers (820,000 mg/kg, or 82%). According to the EPA website, however, PRGs and other preexisting screening levels developed by the EPA and the EPA Regions for hazardous waste cleanup sites have been combined into the EPA's RSL tables (https://www.epa.gov/risk/regional-screening-levels-rsls). However, because TDG is used in

many industrial processes (e.g., it is a common component of various inks and is used heavily in the textile industry), its presence in the environment could be indicative of other pollutant sources. Nevertheless, in a HD release scenario, the presence of TDG can be an indication that HD is or was present. If TDG is encountered only in industrial areas, background concentrations may need to be examined.

What does all this mean for the RSAF? For HD, analyses following a release event should consider weather conditions before, during, and after the event. In most circumstances, analyses should include both HD and TDG. However, if initial analyses in the most likely area of vapor or aerosol deposition result in no HD detections, following analyses should include TDG only. If HD is detected above levels of concern, a reasonably appropriate remediation option would be to wait a few days, perhaps a week or more, until natural attenuation has reduced HD below concentrations of concern. HD degradation can be confirmed by periodically analyzing media for both HD and TDG. Further, if TDG is detected above levels of concern, allowing natural degradation to reduce levels could again be considered. In both cases, where either HD or TDG is present above levels of concern, performing some type of active remediation should be considered only if concentrations are very high (relative to levels of concern) and it is determined that natural attenuation will not occur within a reasonable time. Often, active remediation, such as soil removal or treatment with decontaminants, will take as much time to plan and execute as would allowing natural degradation to take its course, and will cause much more lasting effect on the environment. Of course, if farmland crops or livestock are affected, or if residential or commercial areas are affected, other remedial options will need to be evaluated. However, the effects of weather conditions and time should still be primary considerations.

C.5 Sarin (GB)

GB has the distinction of being the most volatile and least persistent of all the chemical warfare agents. GB evaporates at about the same rate as water and is readily hydrolyzed under both acidic and basic conditions (Rosenblatt et al. 1996). It is also soluble in water, where hydrolysis is the primary mechanism for GB degradation. Rosenblatt et al. (1996) indicated that in water with a pH of 4 to 6.5, GB is at its most stable. Under these conditions, it has a half-life of about 238 hours (about 10 days) at 25°C. At pHs above and below this range, GB hydrolysis increases linearly, which means that hydrolysis increases at a faster rate as conditions become increasingly acidic or basic. Caustic solutions are often used as decontaminants for materials contaminated by GB.

Rosenblatt et al. (1996) cited Cooper et al. (1990), indicating that GB showed 99% disappearance from concrete in 30 minutes or less and that it persisted on concrete for only about two hours. In soils, Rosenblatt et al. (1996) concluded that the half-life of GB rarely exceeded two days and that soil originally contaminated with dispersed GB should be free of detectable GB after a month or less.

Munro et al. (1999) report that GB is more persistent at lower temperatures. Two studies referenced in Munro et al. (1999), Norwegian Ministry of Affairs (1982–1983) and Johnsen et al. (1984), showed that GB can persist on snow from two to four weeks, but will eventually disappear through a combination of evaporation and hydrolysis.

Therefore, it follows that with a GB release incident from any source, if one does not analyze environmental media for GB's degradation products, it could be falsely concluded that the area being evaluated was never exposed to GB at all. In the event of a GB release, one must analyze environmental media for degradation products. Here, as with HD, if analyses of environmental media in the area most suspected of being exposed to agent vapor or aerosols do not detect any GB, further analyses should focus solely on GB's hydrolysis products.

The principal hydrolysis products of GB decomposition include isopropyl methylphosphonic acid (IMPA) and methylphosphonic acid (MPA). Both of these are moderately persistent (Watson et al. 2011a), lasting for a period of months to years in the environment (Talmage et al. 2007, as referenced in Watson et al. 2011a). Under most conditions, GB will first degrade to IMPA, and then IMPA will degrade to MPA. However, due to the speed of the reaction, both IMPA and MPA will typically be present at the same time in most release scenarios.

According to Rosenblatt et al. (1996), soil has a tendency to sorb IMPA. Depending on the soil type, IMPA can quickly hydrolyze to MPA (half-life of 2.9 hours). In other soils, hydrolysis of IMPA to MPA is negligible (Rosenblatt et al. 1996). Nevertheless, the most long-lived hydrolysis product of GB is MPA (Rosenblatt et al. 1996). However, considering the low rate of hydrolysis in some soils, it is important to analyze for both MPA and IMPA when assaying for GB degradation products. IMPA can remain up to 4 weeks in snow after GB has disappeared (Norwegian Ministry of Affairs 1982–1983 and Johnsen et al. 1984, as referenced in Munro et al. 1999).

As with HD, another factor to consider is the propensity for agent and degradation products to absorb into other materials, such as vegetation, brick, wood, steel, glass, rubber, vinyl, and other plastics. If agent and/or degradation products will absorb into these materials, then hydrolysis or natural attenuation processes may not occur or may occur at a lower rate. When absorbed into a material, the contact hazard of the agent (touching) may be less of an issue unless some of the agent also remains on surfaces.

As reported in Watson (2011a), studies Love et al. (2009) performed for DHS evaluated the persistence of GB on steel, glass, latex paint (on wall board), and vinyl tile. GB spiked on glass and steel disappeared completely after about 12 hours. GB spiked on latex paint and vinyl tile began to disappear completely after about 50 hours. Watson et al. (2011a) concluded that "with the exception of VX, the residual chemical exposure hazard posed by liquid droplet (aerosol) release of [agent] may be realistically mitigated by natural attenuation within a 24 (hour) period."

Rosenblatt et al. (1996) evaluated absorption of chemical agents onto polymeric surfaces. Surfaces evaluated included paint, rubber, polystyrene, and chemically protective fabrics. They concluded that GB, like all the agents evaluated in the RSAF, can absorb into these materials but that absorption capacity varies widely by material. However, considering GB's volatility, much of the GB that would be deposited on a surface would be expected to evaporate before much adsorption could occur. Rosenblatt et al. (1996) further concluded that complete decontamination of sorbed agents from thick layers of polymeric materials would be impractical due to time

constraints. In other words, using some type of decontamination process to remove agent sorbed into materials may take a long time. If this is the case, removal and disposal of these types of materials may be more efficient.

As with TDG and HD, the primary degradation products of GB are not particularly toxic. The EPA established a residential PRG for MPA of 1,200 mg/kg and an outdoor worker PRG of 3,000 mg/kg (Watson et al. 2011b). The EPA has since developed RSLs for both MPA and IMPA. The lowest levels (most stringent) are based on soil ingestion by a child with a non-carcinogenic toxic end-point. The level is set at 3,800 mg of MPA per kilogram of soil, and for IMPA the level is set at 6,300 mg per kilogram of soil. These concentrations amount to a little less than 0.5% and 0.75%, respectively (EPA 2015). Although these degradation products are not particularly toxic, they will remain in environmental media considerably longer than GB. Again, according to the EPA website, PRGs and other preexisting screening levels for hazardous waste cleanup sites have been combined into the EPA's RSL tables (https://www.epa.gov/risk/regional-screening-levels-rsls).

What does all this mean for the RSAF? The fate of GB in the environment, due to its high volatility and lack of persistence, is less dependent on weather conditions than either HD or VX. Nevertheless, for GB, analyses following a release event should consider weather conditions before, during, and after the event. If initial analyses in the most likely area of vapor or aerosol deposition result in no GB detections, following analyses should include MPA and IMPA only. As with HD, if GB is detected above levels of concern, a reasonably appropriate remediation option would be to wait a few days, perhaps a week or more, until natural attenuation has reduced GB below concentrations of concern. GB degradation can be confirmed by periodically analyzing media both for GB and for MPA and IMPA. However, if MPA and IMPA are detected above levels of concern, considering that these chemicals are somewhat persistent in the environment, allowing natural attenuation to reduce levels should probably only be considered for nonresidential and noncommercial areas. If exposure to MPA and IMPA is of concern, allowing natural degradation to take its course may keep viable areas from public use for unacceptably long periods of time. Of course, if farmland crops or livestock are affected, or if residential or commercial areas are affected, other remedial options will need to be evaluated. However, the effects of weather conditions and time should still be primary considerations.

C.6 VX

VX has the distinction of being the least volatile and most persistent of all the chemical warfare agents present at BGAD. Studies cited in Rosenblatt et al. (1996) on VX disappearance from various soil types show that VX will degrade in most environments within a matter of weeks or months. Small (1983) cited a study by Demek and Epstein (1959) that showed that VX content in soil decreased by about three orders of magnitude within 17 to 52 days after application. Small (1984) also cited a report by Griffith (1979) that showed that VX dispersed prior to 1969 at an area within Dugway Proving Ground, Utah, showed no remaining VX 10 years later. Studies at the Netherlands TNO laboratories (Verweij and Boter 1976; Kaajik and Frijilink 1977) showed VX applied to soils was reduced by about 99.9% from its original concentration after about three weeks. U.S. Army Test and Evaluation Command (USATECOM) studies (undated)

showed that VX applied to soils containing only about 1% moisture reduced in concentration by 79% after three days and 90% after 15 days.

Munro et al. (1999) reported that VX is soluble in water but is relatively resistant to hydrolysis. Rosenblatt et al. (1996) cited similar studies in water (Epstein et al. 1974), which showed that VX degradation is a function of pH, with a half-life of 2,381 hours (99 days) at pH 6, a half-life of 996 hours (41.5 days) at pH 7, a half-life of 184 hours (7.7 days) at pH 8, and a half-life of 63 hours (2.6 days) at pH 9. Studies conducted by Yang et al. (1990) and Szafraniec (1990) showed similar results. Rosenblatt et al. (1996) concluded that dispersed VX in contact with relatively dry, but not totally water-free, soil would be undetectable in soil after about three months.

Several of the above studies also evaluated the presence of VX degradation products. These include ethyl methylphosphonic acid (EMPA), MPA (MPA is a degradation product of both GB and VX), and a chemical known as EA-2192 (EA stands for Edgewood Arsenal, where the compound was first discovered). The chemical name of EA-2192 has several configurations, one of the most common of which is O-ethyl S-[2(diisopropylamino)ethyl] methylphosphonothioate. These are the degradation products most often assayed for at hazardous waste sites where VX is known to have been present at one time.

In the Griffith (1979) study cited in Small (1984), MPA was detected at concentrations ranging from 14.9 to 23 ppm. In the Netherlands TNO laboratories (Verweij et al. 1976; Kaajik et al. 1977) studies, EA-2192 was detected a day after VX introduction, but had degraded at about the same rate as VX. In this study, EMPA was observed to be the main degradation product, which in turn slowly degraded to MPA. In the water studies conducted by Szafraniec (1990), EA-2192 was the dominant degradation product detected. Rosenblatt et al. (1996) observed that EA-2192 is considerably more stable in water than is VX. As referenced by Munro et al. (1999), EA-2192 does not form in aqueous VX solutions with a pH less than six or greater than 10. Hence, to preclude EA-2192 formation in hydrolysis reactions, the BGAD BGCAPP agent destruction process maintains the pH of VX hydrolysis reactions at well above pH 10 (National Resource Council 2015b). Once released to the environment, however, hydrolysis of VX in the range between pH 6 and 10 can be expected to form EA-2192.

VX also absorbs into the same types of materials discussed for HD and GB. As reported in Watson (2011a), studies Love et al. (2009) performed for DHS evaluated the persistence of VX on steel, glass, latex paint (on wall board), and vinyl tile. VX spiked on glass and steel disappeared completely after about 170 to 200 hours (seven to a little over eight days). VX spiked on latex paint disappeared between 10 and 30 weeks after spiking, while VX spiked on vinyl tile took 40 to 50 weeks to begin to approach complete disappearance. Watson et al. (2011a) concluded that “with the exception of VX, the residual chemical exposure hazard posed by liquid droplet (aerosol) release of [agent] may be realistically mitigated by natural attenuation within a 24 (hour) period.” Hence, VX was of greater concern than the other agents. Rosenblatt et al. (1996) observed that absorption capacity varies widely by material and concluded that complete decontamination of any of the agents from thick layers of polymeric materials would be impractical due to time constraints. In other words, using some type of decontamination

process to remove agent sorbed into materials may take a long time. If this is the case, removal and disposal of these types of materials may be more efficient.

As discussed above for GB, the EPA established a residential PRG for MPA of 1,200 mg/kg and an outdoor worker PRG of 3,000 mg/kg (Watson et al. 2011b). The EPA has since developed a RSL for MPA, but not for IMPA. However, for purposes of the RSAF, it can be assumed that IMPA will have a similar toxicity as EMPA; their chemical structures are similar and both will eventually degrade to MPA. The level is set at 3,800 mg of MPA per kilogram of soil, and for IMPA and the level is set at 6,300 mg per kilogram of soil. These concentrations amount to a little less than 0.5% and 0.75%, respectively (EPA 2015). These degradation products are not particularly toxic, but they will remain in environmental media considerably longer than VX. Again, according to the EPA website, PRGs and other preexisting screening levels for hazardous waste cleanup sites have been combined into the EPA's RSL tables (https://www.epa.gov/risk/regional-screening-levels-rsls).

EA-2192 warrants additional consideration, because it is nearly as toxic as its parent chemical, VX. As discussed in Watson et al. (2011a), EA-2192 is about six times less acutely toxic than its parent VX. On a relative scale, this is still very toxic. The EPA established a residential PRG for EA-2192 of 0.047 mg/kg and an outdoor worker PRG of 0.68 mg/kg (Watson et al. 2011b). To date, the EPA has not developed a soil RSL for EA-2192. Standard practice for some time has been to apply the same toxicological criteria for EA-2192 as for VX.

What does all this mean for the RSAF? Due to its tendency to degrade as a function of pH, the fate of VX in the environment can depend on weather conditions and, in particular, the pH of rainwater. For VX, analyses following a release event should consider weather conditions before, during, and after the event. If initial analyses in the most likely area of vapor or aerosol deposition results in no VX detections, following analyses should include MPA and EMPA as well as EA-2192. As with HD and GB, if VX is detected above levels of concern, a reasonably appropriate remediation option would be to wait a week, perhaps several weeks or months, until natural attenuation reduced VX to below concentrations of concern. Due to EA-2192 toxicity, however, analyses should continue for this compound. VX degradation can be confirmed by periodically analyzing media for VX, for MPA and EMPA, and for EA-2192. If MPA, EMPA, and EA-2192 are detected above levels of concern, considering that these chemicals are somewhat persistent in the environment, allowing natural attenuation to reduce levels should probably only be considered for nonresidential and noncommercial areas. In this case, allowing natural attenuation to take its course may keep viable areas from public use for unacceptably long periods of time. If EA-2192 is detected above levels of concern, since it has about the same level of persistence as VX, a reasonably appropriate remediation option would be to wait a week, perhaps several weeks or months, until natural degradation has reduced EA-2192 to below concentrations of concern. Of course, if farmland crops or livestock are affected, or if residential or commercial areas are affected, other remedial options will need to be evaluated. However, the effects of weather conditions and time should still be primary considerations.

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APPENDIX D

Example Conceptual Site Model

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APPENDIX D

Example Conceptual Site Model

This appendix presents an example Conceptual Site Model (CSM). The foundation for this CSM is a maximum credible event (MCE) for a chemical accident or incident (CAI) emanating from Blue Grass Army Depot (BGAD), within the Blue Grass Chemical Activity (BGCA) chemical limited area where the chemical weapons storage igloos are located. The Planning Section would use this information as a starting point for the development of a sampling plan using the Visual Sampling Plan (VSP). Although planners know some CSM components pre-incident (e.g., a base map depicting evacuation zones, focus areas), they can define other CSM components only after the incident occurs. A situation-specific CSM should be created based on the actual incident and release characteristics. Further, the CSM is dynamic; it is crafted and then refined as more information is gathered.

The CSM includes several elements:

- Representation of exposure pathways. The representation of exposure pathways may be presented as text, as a table, or in figures. This example presents exposure pathways in figures (see Figure D-1). Figure D-1 focuses on exposure and will allow the planning team to identify the constituent(s) of concern (COC[s]), environmental media, and exposure pathways. This representation leads to decisions on what media must be sampled to inform decisions about re-entry or other actions. Figure D-1 should be revisited as more becomes known about the incident, in order to ensure that the proper exposure pathways are captured and that the proper COCs are being selected for analyses. For example, in selecting the mix of COCs for a sampling plan, long lag times between the release and sample collection may cause the planning team to rely more on degradation products than on the agent that was released. As discussed below, areas within the plume footprint may be subject to more than one round of sampling. In the event that no agent is detected in the initial sampling, the planning team may want to focus more on degradation products in subsequent rounds.

- Visual mapping elements. The CSM includes a number of mapping elements. In this example, two maps are presented, Figures D-2 and D-3.

- Plume model outputs. These include both WebPuff and JEM. They may be separate depictions, or they may be superimposed. The plume model output is superimposed on a base map that is pre-populated with information in and around the plume footprint.

In the event of a release, plume depictions of the event would be created and updated as more information is gained. Figure D-2 is an example of an initial WebPuff depiction for a CAI using plume model results from a MCE. As noted in Figure D-2, The WebPuff plume map denotes two zones:

- AEGL-2: The airborne concentration (expressed in parts per million, or milligrams per cubic meter) of a substance at or above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

- AEGL-3: The airborne concentration (expressed in parts per million, or milligrams per cubic meter) of a substance at or above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The areas within the AEGL-2 and 3 areas are of primary concern; however, the JEM plume depositional footprint will be the focus of the sampling effort. Some focus area locations within portions of protective action zones outside the JEM depositional footprint may be sampled as well. This CSM example assumes that the WebPuff depiction for the AEGL-2 and 3 areas mimics the JEM depiction of the plume exactly.

Post-release, the WebPuff and JEM plume depictions would be brought into an existing base map. The information on the base map will include the BGAD protective action zones, evacuation routes, roads and highways, communities, traffic control points, surface features, and the locations of focus areas. Focus areas will include, but not be limited to, locations with sensitive populations (such as schools, nursing homes, daycare facilities, and hospitals), property with livestock, critical infrastructure requiring human inspection or operation, and major employers.

This fusion of WebPuff, JEM, and the RSAF base map will serve as the starting point for the development of the sampling plan using the VSP (Figure D-3). This example CSM uses symbols to represent example focus areas. The VSP will be used iteratively in that initial sample results will be used to generate subsequent sample designs, if needed.

Using this example CSM, a transect down the plume centerline will serve as the basis of target sample locations. Following receipt of sampling and analysis results, the CSM would be updated.

Source	Primary release mechanism	Media impacted by release	Exposure Route	Receptors: Resident	Receptors: Restricted re-entry
Either HD or GB or VX stored on BGAD (all three sources would probably not be involved in a release) Environmental conditions and the passage of time will result in decreasing CWA presence with increasing CWA-degradation compound presence	Maximum Credible Event causing vapor and droplets released by air beyond BGAD boundary	Air	Ingestion/inhalation	• GB	
		Soil	Ingestion	* GB ,IMPA, MPA	
			Dermal	*IMPA, MPA	* IMPA, MPA
		Anthropogenic surfaces	Dermal	* GB, IMPA, MPA	* IMPA, MPA
		Vegetation	Dermal	* IMPA, MPA	* IMPA, MPA
			Ingestion	* GB, IMPA, MPA	
		Surface water and sediment	Dermal	* IMPA, MPA	* IMPA, MPA

* Indicates potential complete pathway. Passage of time and environmental conditions could impact analytes selected for analysis- CWA and/or CWA Degradation compounds

Least Persistent GB and/or isorpropyl methylphosphonic acid (IMPA) and methylphosphonic acid (MPA
HD and/or thiodiglycol (TDG), 1,4-Oxathiane and 1,4-Dithiane
Most Persistent VX and/or Ethyl methylphosphonic acid (EMPA), MPA and EA-2192

Figure D-1 Exposure and Pathway CSM

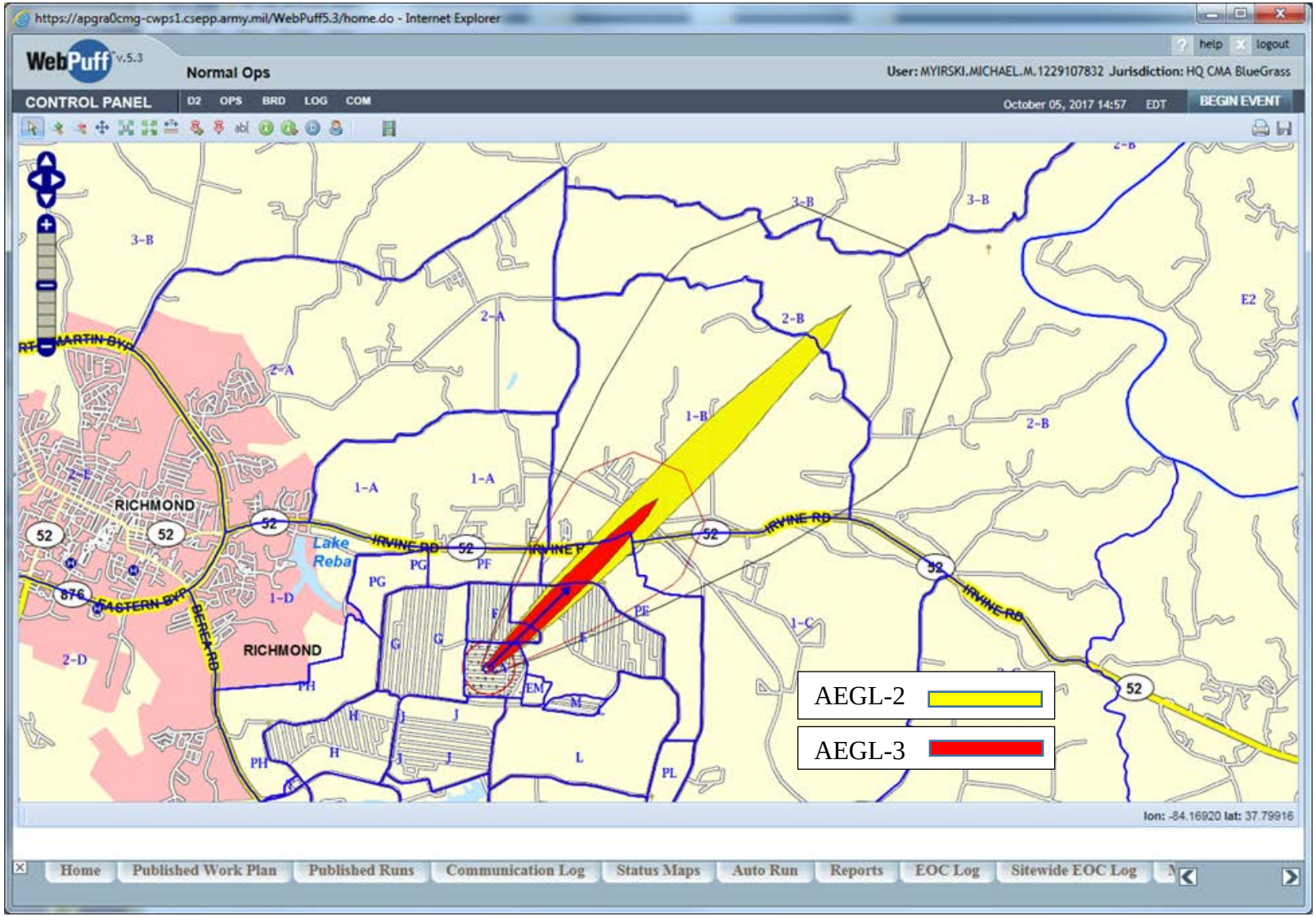

Figure D-2 WebPuff/JEM Output

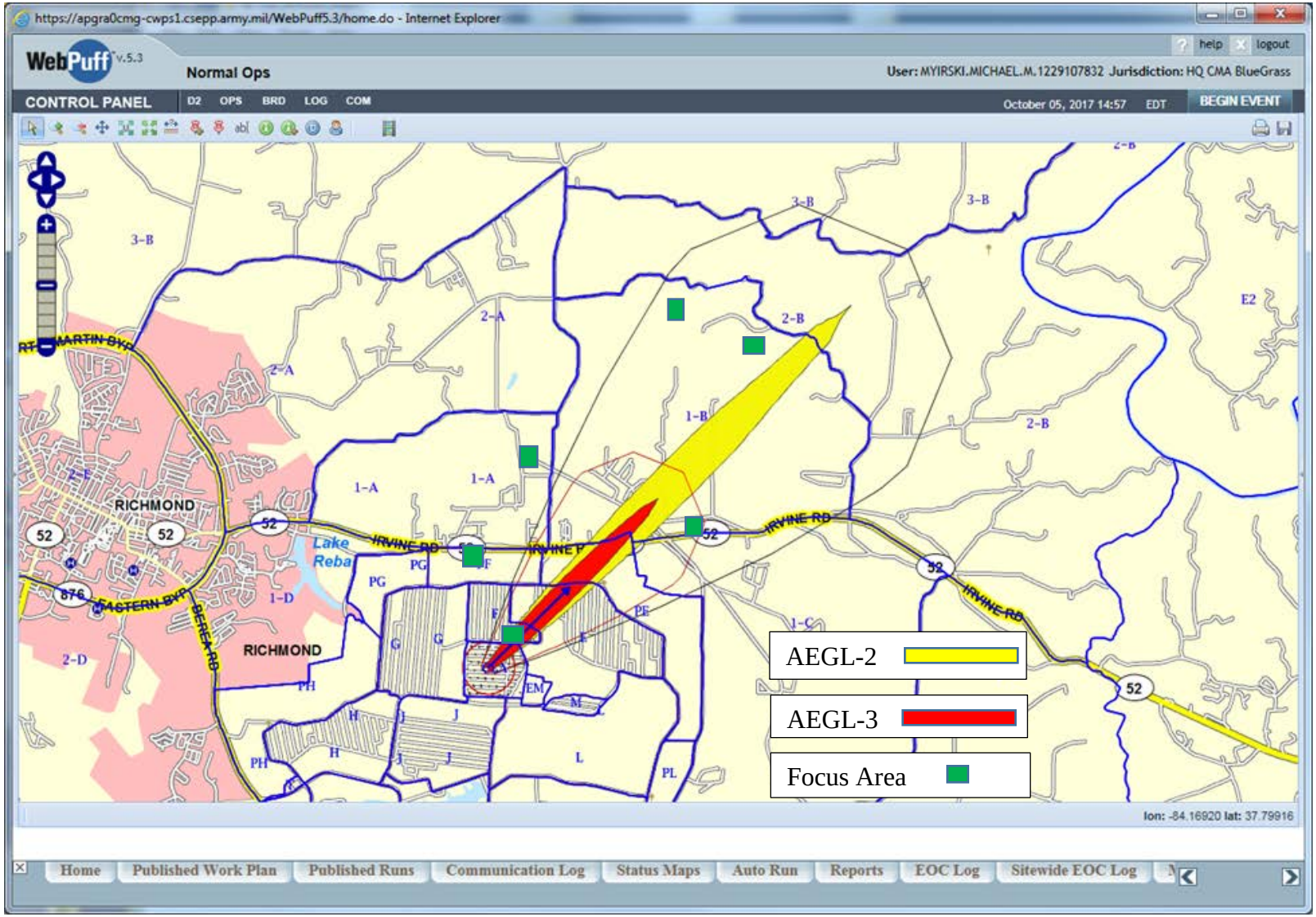

Figure D-3 WebPuff-derived AEGL Delineation and Focus Areas Derived from the RSAF Base Map (see Section 6.1.7) already Prepared by the CSEPP Community

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APPENDIX E

Chemical Agent Air Exposure Values (from APHC, 2018)

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Table 1: Summary of Chemical Agent Air Exposure Values: Existing Information as of 10/26/2018

Media – Air	Standard Name	Population	Exposure Scenario	H/HD/HT (Mustard)	GA (Tabun)	GB (Sarin)	GD/GF (Soman/ Cyclosarin)	VX	L/HL (Lewisite)	Notes
Airborne Exposure Limits (AELs) mg/m^3	IDLH (Immediately Dangerous to Life/Health)	Civilian/ DoD worker	30-min TWA	0.7 (7×10^{-1})	0.1 (1×10^{-1})	0.1 (1×10^{-1})	0.05 (5×10^{-2})	0.003 (3×10^{-3})	0.003 (3×10^{-3})	1, 2, 9, 10
	STEL (Short-Term Exposure Limit)	Civilian/ DoD worker	15-min TWA	0.003 (3×10^{-3})	0.0001 (1×10^{-4})	0.0001 (1×10^{-4})	0.00005 (5×10^{-5})	0.00001 (1×10^{-5})	0.003 (3×10^{-3})	3, 4, 5, 9,10
	WPL (Worker Population Limit)	Civilian/ DoD worker	8-hr TWA	0.0004 (4×10^{-4})	0.00003 (3×10^{-5})	0.00003 (3×10^{-5})	0.00003 (3×10^{-5})	0.000001 (1×10^{-6})	0.003 (3×10^{-3})	6, 9, 10
	GPL (General Population Limit)	Civilian/ General Population	12- or 24-hr TWA (see notes)	0.00002 (2×10^{-5})	0.000001 (1×10^{-6})	0.000001 (1×10^{-6})	0.000001 (1×10^{-6})	0.0000006 (6×10^{-7})		7, 8, 9, 10
Acute Exposure Guideline Levels (AEGLs) mg/m^3	AEGL -1	Civilian/ General Population	10 MIN	0.40	0.0069	0.0069	0.0035	0.00057	NR	11, 12, 13
			30 MIN	0.13	0.0040	0.0040	0.0020	0.00033		
			1 HR	0.067	0.0028	0.0028	0.0014	0.00017		
			4 HR	0.017	0.0014	0.0014	0.00070	0.00010		
			8 HR	0.0083	0.0010	0.0010	0.00050	0.000071		
	AEGL-2		10 MIN	0.60	0.087	0.087	0.044	0.0072	1.3	11, 14
			30 MIN	0.20	0.050	0.050	0.025	0.0042	0.47	
			1 HR	0.10	0.035	0.035	0.018	0.0029	0.25	
			4 HR	0.025	0.017	0.017	0.0085	0.0015	0.070	
			8 HR	0.013	0.013	0.013	0.0065	0.0010	0.037	
	AEGL-3		10 MIN	3.9	0.76	0.38	0.38	0.029	3.9	11, 15
			30 MIN	2.7	0.38	0.19	0.19	0.015	1.4	
			1 HR	2.1	0.26	0.13	0.13	0.010	0.74	
			4 HR	0.53	0.14	0.070	0.070	0.0052	0.21	
			8 HR	0.27	0.10	0.051	0.051	0.0038	0.11	
Military Exposure Guidelines (MEGs) mg/m^3	U.S. Army Public Health Center (APHC) Technical Guide 230 (TG 230) provides MEGs for the agents listed in this table, and application guidance for assessing and characterizing exposure risks to military personnel in deployed settings as required by DoD Force Health Protection policy. The TG 230 was most recently updated in 2013. Information about TG 230 can be obtained by contacting the APHC proponent (usarmy.apg.medcom-aphc.list.racb@mail.mil) or visiting the TG 230 support website (https://phc.amedd.army.mil/topics/envirohealth/hrasm/Pages/TG230.aspx).									

Notes

[1]Immediately dangerous to life or health (IDLH) is a 30–minute TWA. The 30–minute period is not meant to imply that anyone should stay in the environment any longer than necessary; in fact, every effort should be made to exit immediately.

[2]IDLH values are used solely for the purpose of establishing the concentrations at which self-contained breathing apparatus (SCBA) or supplied air respirators (SARs) are required. It is not necessary to establish IDLH values for L because workers will already be required to wear this level of respirator protection at concentrations much lower than what is considered IDLH for L because of concerns over carcinogenicity.

[3]For G-series nerve agent, exposure at the STEL should not be longer than 15 minutes and should not occur more than 4 times per day, and at least 60 minutes should elapse between successive exposures in this range.

[4]For VX nerve agent, exposure at the STEL should not be longer than 15 minutes and should not occur more than once per day.

[5]For sulfur mustards and L, exposure at the STEL should be as short as practical (but no longer than 15 minutes) and should not occur more than once per day.

[6]Exposure below the WPL is safe and not expected to produce any adverse health effect. Acute or subchronic exposure above the WPL is also not expected to produce any adverse health effect since WPL is a chronic exposure limit.

[7]For nerve agents, the general population limit (GPL) is a 24–hour TWA.

[8]For sulfur mustards, the GPL is a 12–hour TWA.

[9]HT is measured as HD.

[10]All concentrations measured as L.

[11]AEGLs are guidelines not regulatory standards. However, there is an Army-FEMA policy letter requiring use of these AEGLs for the Chemical Stockpile Emergency Planning Program (CSEPP)

[12]NR: Not recommended due to insufficient data

[13]AEGL Level 1 is defined as “Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure”

[14]AEGL Level 2 is defined as “Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape”

[15]AEGL Level 3 is defined as “Life-threatening health effects or death”

Definitions

Acute Exposure Level Guidelines (AEGLs): Used by emergency planners and responders worldwide as guidance in dealing with rare, usually accidental, releases of chemicals into the air. AEGLS are expressed as specific concentrations of airborne chemicals at which health effects may occur. They are designed to protect the elderly and children, and other individuals who may be susceptible.

General population limit (GPL): An airborne exposure limit designed to protect the general public.

Immediately Dangerous to Life or Health (IDLH): a situation that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

Short-Term Exposure Limit (STEL): An airborne exposure limit designed to address short-term upward deviations in exposure. Typically, exposures at the STEL should not be longer than 15 minutes and should not occur more than 4 times per day, and at least 60 minutes should elapse between successive exposures in this range.

Time-weighted average (TWA): An average value of exposure over the course of an 8-hour (typically) work shift.

Worker population limit (WPL): An airborne exposure limit designed to protect workers. It is expressed as a time-weighted average (TWA) for exposure over an 8-hour work shift.

References

(1) 68 Federal Register (FR) 54460 (17 September 2003) (corrected in 68 FR 58348 (9 October 2003)), Final Recommendations for Protecting Human Health from Potential Adverse Effects of Exposure to Agents GA (Tabun), GB (Sarin), and VX.

(2) 69 FR 24164 (3 May 2004), Interim Recommendations for Airborne Exposure Limits for Chemical Warfare Agents H and HD (Sulfur Mustard).

(3) 53 FR 8504 (15 March 1988) (corrected in 53 FR 11002 (4 April 1988)), Final Recommendations for Protecting Human Health and Safety against Potential Adverse Effects of Long-term Exposure to Low Doses of Agents: GA, GB, VX, Mustard Agent (H, HD, T), and Lewisite (L).

(4) DA PAM 385-61, Toxic Chemical Agent Safety Standards, 13 November 2012

(5) Acute Exposure Guideline Levels for Airborne Chemicals, https://www.epa.gov/aegl Website accessed 22 October 2018.

(6) U.S. Army Public Health Command (APHC 2013). 2013. Technical Guide 230: Environmental Health Risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel. Available at: https://phc.amedd.army.mil/topics/envirohealth/hrasm/Pages/TG230.aspx

APPENDIX F

Example Logbook Forms

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APPENDIX F

Example Logbook Forms

FIELD PARAMETER LOGBOOK
SOIL, SEDIMENT, and WIPE SAMPLES

HIGH CONCENTRATION EXPECTED? HIGH HAZARD?

INSTALLATION/SITE _____ AREA _____

INST CODE _____ FILE NAME _____

SITE TYPE_____ SITE ID _____
FIELD SAMPLE NUMBER _____

DATE (MM/DD/YY) __/__/__ TIME _____ AM PM SAMPLE PROG.____

DEPTH (TOP) _____ DEPTH INTERVAL _____ UNIT _____

SAMPLING METHOD:

SPLIT SPOON __ AUGER __ SHELBY TUBE __ SCOOP __ OTHER_____

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS
__	_____	_____	__	_____
__	_____	_____	__	_____
__	_____	_____	__	_____
__	_____	_____	__	_____
__	_____	_____	__	_____
__	_____	_____	__	_____

TOTAL NUMBER OF CONTAINERS F

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION : _____

_____

_____

SAMPLE FORM _____ COLOR _____ ODOR ___

_____ UNUSUAL FEATURES _____

_____

WEATHER/TEMPERATURE_____

SAMPLER _____

Figure F-1. Example Soil/Sediment and Wipe Sample Logbook Form

SURFACE WATER SAMPLES

HIGH CONCENTRATION EXPECTED? _____ HIGH HAZARD?_____

INSTALLATION/SITE _____ AREA_____

INST CODE _____ FILE NAME _____ SITE TYPE _____

SITE ID _____ FIELD SAMPLE NUMBER _____

DATE (MM/DD/YY) __/__/__ TIME _____ AM PM SAMPLE PROG.____

DEPTH (TOP) _____ DEPTH INTERVAL _____ UNITS_____

SAMPLING MEASUREMENTS

CAL REF. ____ pH ____ TEMPERATURE °C ____ CONDUCTIVITY ____ OTHER _____

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS
___	_____	_____	___	_____
___	_____	_____	___	_____
___	_____	_____	___	_____
___	_____	_____	___	_____
___	_____	_____	___	_____
___	_____	_____	___	_____

TOTAL NUMBER OF CONTAINERS

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION _____

_____

SAMPLING METHOD _____

SAMPLE FORM _____ COLOR _____ ODOR ____

PID (HNu) _____

UNUSUAL FEATURES _____

WEATHER/TEMPERATURE _____ SAMPLER _____

Figure F-2. Example Surface Water Sample Logbook Form

MAP FILE LOGBOOK

SITE ID _____ POINTER _____

DESCRIPTION/MEASUREMENTS _____

_____

SKETCH/DIMENSIONS :

MAP REFERENCE _____

COORDINATE DEFINITION (X is _____ Y is _____)

COORDINATE SYSTEM _____ SOURCE _____ ACCURACY _____

X-COORDINATE _____ Y-COORDINATE _____ UNITS ____

ELEVATION REFERENCE _____

ELEVATION SOURCE _____ ACCURACY _____ELEVATION _____

_____

SAMPLER ____

Figure F-3. Example Map Logbook Form

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