APPENDIX H:

METHODOLOGY FOR ASSESSING THE CONSEQUENCES FROM ACCIDENTS

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The analysis of accidents in this environmental impact statement (EIS) provides an estimate of the upper range of the potential impacts that might occur as a result of a hypothetical accident associated with the proposed action (ACWA pilot testing) or with the no action alternative (continued storage of the chemical weapons). The accidents selected for analysis were the accidents that were shown to have the highest risk in previous Army analyses (SAIC 1996, 1997a-c). The highest-risk accidents are defined as those with the highest combined consequence (in terms of human fatalities) and probability of occurrence.

For proposed operations and for existing continued storage conditions (no action), the highest-risk accidents would involve the release of chemical agent; release of other materials would result in lower consequences and risks. In general, the accidents considered in this EIS would have a fairly low frequency of occurrence, on the order of 2×10^{-3} per year or less (i.e., one occurrence in about 500 years or less). In most cases, the effects of any emergency response or spill mitigation actions that would likely occur following an accidental release were not taken into consideration in the impact assessment. These actions would reduce the number of fatalities and injuries that might occur below the numbers estimated here.

Because detailed information on facility process design and related process hazards for assembled chemical weapon (ACW) destruction systems is not yet available (and may not be available until the systems have been pilot tested), this EIS does not present a detailed process safety analysis or risk assessment. These types of analyses assess each process and estimate the probabilities of process failures at each step in each process. The probabilities and accident consequences are multiplied to obtain risk estimates. (Risk is defined as the product of probability and consequence.) The presentation of the single highest-risk accident consequences for each site in this EIS is intended to aid in the comparison of potential accident impacts for the proposed action and no action alternatives, and it should not be considered a detailed process safety analysis.

H.1 SCENARIOS

An assessment of accident consequences was conducted for both externally and internally initiated events for the ACW destruction systems. Externally initiated events could include earthquakes, aircraft crashes, or lightning strikes; internally initiated events could include handling accidents, process equipment failure, or operator error.

For this ACWA EIS, two possible scenarios were identified as being highest-risk during pilot testing activities (proposed action). (1) For ANAD and PBA, the scenario is a handling accident in a GB- or VX-rocket-containing storage igloo, with a subsequent fire and release of agent from all the munitions in the igloo. (2) For PCD and BGAD, it is an earthquake impacting the unpack area in the pilot testing facility. During continued storage (no action), the highest risk accident identified for ANAD, PBA, and BGAD is a lightning strike on a GB- or VX-rocket-containing igloo, with a subsequent fire and release of agent from all the munitions in the igloo. However, for PCD, the highest-risk continued storage accident is an aircraft crash into a storage igloo. For all four sites, the continued storage accident modeled would result in the entire contents of a single storage igloo being subject to release.

For ANAD and PBA, the consequences of the highest-risk accidents during continued storage (no action) and pilot facility operations (proposed action) would be the same, because under both alternatives, the entire contents of a single GB or VX rocket storage igloo are assumed to be subject to release. There is one special case for ANAD, which is mustard-only processing. If Neut/Bio was selected as the ACWA technology to be used at ANAD, then the pilot facility accident would be an earthquake impacting the unpack area during mustard processing (since no GB or VX would be processed, and therefore the handling accident would not be applicable), and the accident consequences from the no action and proposed action alternatives would differ.

For the earthquake pilot facility accident scenarios, data given in the ANAD, PCD, and BGAD Phase I quantitative risk assessments for a baseline incineration facility (SAIC 1996, 1997a,b) were used to estimate the maximum amount of agent that could be released during an earthquake. The ACWA technology providers would use a modified baseline process for ACW access (General Atomics 1999; Parsons and Allied Signal 1999; AEA/CH2M Hill 2000; Foster-Wheeler 2000); therefore, it was assumed that the unpack area configuration would not deviate significantly from that of the baseline. For ANAD and PCD, it was assumed that the maximum number of munitions in the unpack area would be the contents of four on-site containers (ONCs) containing 155-mm projectiles at the time of the crash. For BGAD, it was assumed that the maximum number of munitions in the unpack area would be the contents of four ONCs containing either VX M55 rockets, GB 8-in. projectiles, or mustard 155-mm projectiles at the time of the earthquake. (These assumptions resulted in the largest possible amounts of chemical agent present in the unpack area among the munition types present at each facility.) Additionally, for each of the four facilities, the accident modeling assumed that the pilot facility or impacted storage igloo would be at the location closest to areas of highest on-post or off-post population density.

Impacts from accidents occurring during transport of agent from the storage igloos to the pilot testing facility were not assessed for this EIS, because the impacts would be less than those from the accidents considered. Accident scenarios and probabilities from on-post transportation are discussed in a PEIS support document (GA Technologies 1987).

ONCs are used for transportation of munitions at the Tooele Chemical Agent Disposal Facility, but the Army is investigating the feasibility of using modified ammunition vans (MAVs). A change in the transport system used might also entail changes in the dimensions and capacity of the unpack area or a similarly functioning building or area. Such changes should not invalidate the impact estimates for pilot facility earthquake accidents given here, because the assumption about the number of ONCs stored in the unpack area represents a high-end estimate of the amount of agent that could be released in an earthquake. These accident impact estimates should be representative for either type of transportation system.

For the continued storage accident scenarios, it was assumed that the lightning strike or aircraft crash could lead to the release of the entire contents of a storage igloo. For these scenarios, the maximum amount of agent at risk was obtained from estimates of the maximum amount of agent stored in any single igloo at each of the four storage locations (Burdell 2000a; DeMers 1999; Hancock 2000; Harris 2000). For the lightning strikes into rocket storage igloo scenarios (for ANAD, BGAD, and PBA), it was assumed that 100% of the agent released would be involved in the resulting fire, on the basis of current assumptions made in the Army's modeling in support of the quantitative risk assessments being conducted under the PMCD Program. For the PCD aircraft crash scenario, it was assumed that after the airplane crashed into an igloo, the resulting fire would cause 25% of the munitions to detonate and 75% to burn. It was also assumed that the fire would consume all but 5%, 2.5%, or 10% of the HD, VX, or GB agent (respectively) in the burned munitions (Innovative Emergency Management 1993). The remaining agent would be lofted by the heat of the fire through the breach in the structure caused by the accident and dispersed into the atmosphere.

H.2 METHODS OF ANALYSIS

Potential accidental releases of chemical agent to the atmosphere and the impact distances associated with the releases were analyzed with the D2PC atmospheric dispersion model (Whitacre et al. 1987). The model simulates several agent/munition release modes (detonation, fire, and/or evaporation), downwind dispersion, dosages, and deposition. Although no explicit formulation or treatment of fire or explosion phenomena is incorporated into D2PC, the model relies on experimental data that are input either by the user or from an empirical database within the code. The D2PC model, developed by the U.S. Army Chemical Research, Development, and Engineering Center (now the U.S. Army Edgewood Chemical and Biological Center), has been used by the Army primarily to support and evaluate emergency preparedness and response at its eight chemical depots. It has also been used in assessing chemical agent accident impacts in all of the EISs with Records of Decision (RODs) prepared by the Program Manager for Chemical Demilitarization (PMCD). The estimated consequences derived with D2PC, along with the modeling assumptions used in the analysis conducted for this EIS, should be considered conservative. Highlights of some of these and other assumptions and model limitations are given below:

- The model assumes steady-state diffusion over open, flat terrain. It does not account for topography, vegetation, or buildings. The effects of terrain and vegetation can create more turbulence, or mixing, which reduces the expected downwind dispersion distances.

- The assessment assumes that wind speed and direction are uniform over the entire accidental release dispersion period modeled. In reality, wind shifts would probably cause the plume to meander (drift) as it moved downwind. Meandering would spread (dilute) the plume over a wider area and reduce the expected hazard distance of the plume.[1] Typically for Chemical Stockpile Emergency Preparedness Program (CSEPP) planning exercises, an additional degree of conservatism is added by using a “wedge” covering an angle left and right of the centerline to help ensure that the estimated area contains the entire hazard width. A 40° to 60° wedge (20° to 30° each side of the plume center) is recommended: 40° for stability classes D, E, or F, and 60° for stability classes A, B, or C.[2] The wedge angle was not used in the accident impact assessments conducted for this EIS.

- The model estimates the peak, centerline concentration and dosage. Exposure to a plume away from the center would be expected to produce fewer effects.

- The D2PC model assumes total exposure and dosage; that is, it assumes that a person exposed to the chemical agent at a given distance stays at that location and is exposed to dosages equivalent to exposures for a person at center of the plume until the entire plume passes.

- The model assumes a (default) constant breathing rate (25 L/min) equivalent to moderate work activity. Lower breathing rates would reduce a person’s intake of the chemical agent, thereby reducing the effects of exposure.

- D2PC assumes the exposure occurs outdoors, without mitigation from sheltering structures.

- While terrain conditions usually mitigate the effects of a release, at least two specific terrain conditions exist that could cause D2PC to underestimate the effects:

    1. A plume trapped in a depression (low-lying area) with insufficient wind to ventilate the area, and

    2. A plume released into a narrow valley that restricts the natural spreading (and dilution) of the plume.

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[1] Imagine that the plume is following a line of fixed length. If the line is wavy, going left and right, it will cover a wider area, but it will not go as far downwind as if the line were straight.

[2] The effective wedge angle may end up much larger than 40° or 60° because a wedge line through any portion of a zone would cause a protective action to be taken for the entire zone.

The Army has completed the development, validation, and verification of a new model (D2Puff) intended to address many of the above limitations with D2PC. Accreditation and conditional approval of the D2Puff model for use at continental U.S. Chemical Stockpile sites was issued on June 22, 2000. The conditions for approval (i.e., training for use by hazard analyst in emergency operations centers [EOCs] during CSEPP exercises) are to be met over a transition period during which D2PC would remain in use. The Army's goal is to fully accredit the use of the D2Puff model, which is an ongoing process. The model is approved for use at five of the eight sites in training, exercises, and planning, but not in response situations. Most of the hazard analysts at each of the Army chemical depots have now been trained to use the new model. The new model is installed at Umatilla, Deseret, Blue Grass, Pine Bluff, and Anniston. As of 2001, the only fully accredited model for use at all of the CSEPP sites is the D2PC model. This includes use in actual emergency situations. Although the Army's goal is to replace the D2PC model with D2Puff, D2PC will continue to be used as directed by the Department of the Army's Safety Office in support of the CSEPP for the foreseeable future. Given this status, the accident consequence assessments reported in this EIS continue to be based on estimates from the D2PC model.

Impacts were estimated on the basis of atmospheric dispersion of the chemical agents mustard, GB, and VX under credible bounding meteorological conditions that would inhibit the vertical and horizontal dispersion, or rate of growth, of the vapor cloud. The bounding meteorology represents credible conditions that could transport agent for long distances downwind from the release point. A slightly stable atmosphere (stability class E) and very light wind speeds (on the order of 1 m/s) were chosen as the bounding meteorological conditions (referred to below as E-1). These conditions are typical at night. Although these conditions are consistent with the modeling performed in support of previous PMCD EIS accident assessments, the EPA is now recommending slightly less conservative assumptions for worst-case accidents (Class E and 1.5 m/s) in guidance issued under the EPA's Risk Management Program (EPA 1999). The impacts under typical daytime conditions with neutral atmospheric stability (stability class D) and a wind speed of 3 m/s (referred to below as D-3) were also assessed. When D-3 meteorological conditions are assumed, the size of the estimated plume is smaller, but the amount of agent deposited within the plume area is greater in locations close to the release point. In conducting D2PC modeling, it was assumed that no plume depletion by agent deposition would occur. This is a conservative assumption for estimating the area potentially affected by an accidental release, because assuming that more agent remains in the plume allows farther plume travel before concentrations are diluted below the toxicological endpoint levels. The D2PC model default mixing height assumptions were used for modeling D-3 meteorological conditions, and per EPA guidance (EPA 1995), an unlimited mixing height was assumed for modeling E-1 meteorological conditions. A mixing height of 5,000 m is used as a default in D2PC to represent unlimited mixing.

For modeling mustard agent instantaneous releases, the "time after functioning" (TAF) parameter was assumed to be 20 hours. (The TAF was applicable only for accident modeling involving mustard agent instantaneous releases; it is defined as the time after detonation required to remove the agent source by decontaminating it or by containing it so it would no longer enter the atmosphere [Whitacre et al. 1987]).

The developers of the D2PC model have limited its application to accident release scenarios that could produce impacts at distances of less than or equal to about 30 mi (50 km). This distance is consistent with EPA guidance (EPA 1996) on the application of straight-line Gaussian models, with the limitations inherent in the experimental data used in developing and validating these models, and with the historical model regulatory applications.

H.3 EXPOSURES AND DEPOSITION

For each of the accident scenarios assessed, the impacts of agent release were modeled by using D2PC-generated plumes with dosages estimated to result in adverse impacts for a certain percentage of the human population exposed (i.e., LCt_{50} = dosage corresponding to 50% lethality; LCt_{01} = dosage corresponding to 1% lethality; no deaths = dosage below which no deaths are expected in the human population exposed; no effects = dosage below which no adverse impacts are expected in the human population exposed). The assumed dosages corresponding to these distances for each of the chemical agents assessed are provided in Table H.1. The distances to which these various plumes were predicted to extend and the amount of agent deposited within the plumes were used in this EIS as the starting point for the analysis of impacts on the various resources of concern under the proposed action and no action alternatives.

The LCt_{50} dosage levels used in the accident impact assessment were obtained from documentation for the quantitative risk assessments for the stockpile sites conducted for the chemical stockpile disposal program (SAIC 1997d) and related documents (Goodheer 1994; Burton 2001). The draft ACWA EIS had also included accident assessments that used values recommended by the National Research Council (see Table H.1). However, these assessments were not included in this final version, because this version used revised LCt_{50} dosage values that were much more similar to those recommended by the National Research Council, and because the National Research Council's suggested values have not been formally approved for use by the Army. The LCt_{01}, no deaths, and no effects dosage levels used are the default values given in documentation for the D2PC model (Innovative Emergency Management 1993). All the dosage values are based on the responses of healthy young males breathing at the normal rate (25 L/min) for an adult performing moderate activity.

To estimate the potential maximum fatalities among the on-post and off-post populations from a specific accident, the 50%, 1%, and no deaths dose contours from the D2PC atmospheric dispersion model were overlain on the maximum on-post and off-post population angles centered on the destruction facility or storage facility locations closest to nearby population centers. The population within each contour was obtained either from year 2000 census data for the off-post population or from information on locations of noninvolved workers and on-post residents at the storage facilities (Burdell 2000b; Atkinson 2000; Holland 2000; Elliott 2001). To estimate the

TABLE H.1 Accident Impact Assessment Criteria Values for Mustard, GB, and VX[a]

Chemical Agent	Criteria Values (mg-min/m^3)			
	LCt_{50}[b]	LCT_{01}	No Deaths	No Effects
Mustard	600	150	100	2
GB	42	10	6	0.5
VX	18	4.3	2.5	0.4

[a] All values are applicable for breathing rates of 25 L/min or less. LCt_{50} criteria values (i.e., dosage corresponding to 50% lethality) are from Goodheer (1994), SAIC (1997d), and Burton (2001). Other criteria values are from Innovative Emergency Management (1993).

[b] LCt_{50} values of 900, <35, and <15 mg-min/m^3, for mustard, GB, and VX, respectively, are suggested by the National Research Council (1997). These values are applicable for breathing rates of 15 L/min. They were not used for accident assessment in this EIS because they have not been approved for use by the Army.

total potential number of fatalities associated with each accident, it was assumed that the fatality rate for individuals located within the 50% fatality plume would be 75%, the rate for individuals located between the 50% fatality plume and the 1% fatality plume would be 25%, and the rate for individuals located between the 1% fatality plume and the no deaths plume would be 0.5%. These assumptions are consistent with the standard fatality estimation methodology used in assessments of agent incineration impacts (U.S. Army 1997). Because the decrease in dose response is greater than linear with increased distance from the release location, the results derived from this approach will probably overestimate fatalities.

The impacts on involved workers (i.e., those working at the pilot facility) from accidents involving releases of agent were not assessed quantitatively. During an accident, involved workers might be subject to one or more of three sources of harm: severe physical forces, thermal (fire) forces, and exposure to releases of chemicals. The risk to involved workers would be very sensitive to the specific circumstances of each accident: the speed at which the accident developed, exact location and response of the workers, direction and amount of the release, physical and thermal forces causing or caused by the accident, meteorological conditions, and characteristics of the room or building if the accident occurred indoors. Impacts on involved workers under accident conditions would likely be dominated by physical forces from the accident itself, rather than by the effects of the material released.

H.4 ANALYSIS FOR SENSITIVE POPULATIONS

The toxicity levels used to estimate fatalities were originally developed for healthy adult males. If it is assumed that children and/or the elderly are substantially more susceptible to the effects of agent exposure than healthy adult males and all other conservative assumptions remain the same, then the estimated number of fatalities would increase. A method to estimate the increase in fatalities has been derived (U.S. Army 1997). The method involves estimating the proportion of the population within the D2PC-derived plume areas that are in the more "sensitive" (higher-risk) categories, and adjusting the estimated number of deaths in the plume area using that proportion. This method was also used in this EIS to estimate impacts to sensitive populations.

By using 1999 age-specific population data for the regions of influence (ROI) around each of the four ACW storage locations, it was determined that approximately 35%, 35%, 40%, and 30% of the ROI populations around the ANAD, PBA, PCD, and BGAD posts, respectively, would fall into the sensitive category (U.S. Bureau of the Census 2000). Sensitive was defined for this assessment as individuals under age 16 or over age 65. It was further assumed that the sensitive population would be up to 10 times more likely to die from exposure to chemical agent than the general population (U.S. Army 1997). Effectively, this resulted in the assumption that for the proportion of the population that was more sensitive to exposure, 100% lethality would occur within the plume area from the source to the LCt_{50} boundary, 100% lethality would also occur in the area between the LCt_{50} and LCt_{01} boundaries, and 5% lethality would occur in the area between the LCt_{01} and no deaths boundaries. These assumptions, when used to assess the impacts of accidental releases occurring under E-1 meteorological conditions, generally increased the number of estimated fatalities by a factor of 1.3 to 2.6, depending on the site-specific distributions of the populations around the hypothetical accident sites.

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