COMPARISON OF TWO CONCEPTS AND METHODS TO DECIDE WHEN TO END TEMPORARY SHELTER-IN-PLACE PROTECTION

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Prepared for:

Federal Emergency Management Agency
Office of National Preparedness
Technological Services Division
Chemical Preparedness Branch

July 26, 2003, Version 9.2

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ACKNOWLEDGMENTS

The authors recognize the collaboration of Jack Long, Ted Lemke, Neeraj Mainkar, Gary Hilbert, and Steven Stage from Innovative Emergency Management, Inc., in the effort described in this report. Their contributions were essential to the results.

The authors appreciate the support of the Chemical Stockpile Emergency Preparedness Program Shelter-In-Place Work Group led by Marianne Rutishauser Andrus, and especially the information and advice on chemical hazard prediction offered by Michael Myirski from the U.S. Army Chemical Materials Agency, and shelter-in-place protection offered by John Sorensen from Oak Ridge National Laboratory.

The authors also appreciate the comments and suggestions from Ed Tanzman, Leslie Nieves, Tony Policastro, Paul Hewett, and Ken Lerner from Argonne National Laboratory during the internal review of the draft report. Their support and advice were invaluable.

SUMMARY

This report compares the current concept and method used to decide the best time to end temporary shelter-in-place (SIP) following an accidental release of hazardous vapors with a new concept and method being considered by managers of the Chemical Stockpile Emergency Preparedness Program. The report also discusses the sensitivity of the new method to the variables used in the calculation.

The current concept is to end SIP in an emergency response zone when the plume of hazardous vapor dissipates within the zone or passes out of the zone, i.e., the plume tail-time. The method to implement this concept is to use a dispersion model (e.g., the D2-Puff™ computer model) to calculate the tail-time of the vapor plume at all relevant locations within the zone, and use the latest plume tail-time to define when the plume has dissipated or passed from the zone. The new concept is to end SIP in an emergency response zone when the area of the highest levels of toxic effect in the zone is predicted to be the smallest. The method to implement this concept is to use the Terminate Shelter-In-Place (TSIP) routine, along with the agent vapor concentration-time history calculated from a dispersion model (e.g., the D2-Puff™ computer model as considered in this report), to determine the time to end SIP that results in the smallest area of impact for the highest levels of toxic effect within a zone. In doing so, the TSIP routine considers relationships among the conditions and circumstances of the release, and accounts for the relative concentrations of hazardous vapors both within and outside of shelters.

The report shows that the TSIP routine usually calculated times to end SIP that reduced the area where the most severe toxic effects were predicted, as compared with the plume tail-time method. Using the TSIP routine eliminated areas of severe toxic effects entirely in some zones for some cases.

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COMPARISON OF TWO CONCEPTS AND METHODS TO DECIDE WHEN TO END TEMPORARY SHELTER-IN-PLACE PROTECTION

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1 INTRODUCTION

1.1 PURPOSE

This report was prepared to help the Chemical Stockpile Emergency Preparedness Program (CSEPP) Shelter-in-Place Work Group (SIPWG) and managers from the Federal Emergency Management Agency (FEMA) and the U.S. Army decide about the development of a program called the Terminate Shelter-in-Place (TSIP) routine as a planning and decision tool for use in the CSEPP.

This report compares the current concept and method used to decide the best time to end temporary shelter-in-place (SIP)[1] following an accidental release of hazardous vapors with the new decision concept and method (the TSIP routine) being considered by the SIPWG and CSEPP managers. The report also discusses the sensitivity of the new method to the variables used in the TSIP routine calculations. The concepts and methods that are compared are:

- The Plume Tail-Time Departure concept and the Plume Tail-Time method, and
- The Reduction of Areas of High Levels of Effects concept and the TSIP Routine method.

The important question to answer when looking at this report is whether the results from using the TSIP routine are enough of an improvement over the plume tail-time method to warrant the development of the TSIP routine as a planning and decision tool for use in the CSEPP. The primary consideration in this comparison is the extent to which the TSIP routine helps to avoid the risk of fatalities.

1.2 CONTEXT FOR THIS REPORT

CSEPP managers are continually looking for ways to enhance protection of the population at and around Army chemical stockpile storage sites in the event of a chemical accident. Of particular interest are ways to improve the protection provided by temporary

[1] The acronym SIP used in this report is pronounced "sip."

SIP. FEMA asked Argonne National Laboratory to identify a concept and method for determining the best time to end SIP that considered the potential for the infiltration of hazardous vapors into structures used as temporary shelters, and that would help to avoid fatalities. This concept and method, in turn, could serve as the basis for site-specific operational guidelines for ending SIP at each of the Army chemical stockpile storage sites and in the off-post communities surrounding them. The project consists of the following three tasks:

- *Task 1:* Collect and analyze existing literature of relevance to making decisions about the termination of SIP. Yantosik et al.(2001a) documented the results of Task 1. In the report, the authors concluded that although a decision to end SIP was sometimes based on the departure of a hazardous vapor plume from an emergency response zone (ERZ),[2] "no off-the-shelf decision-making methods [were] available for determining when and how sheltered populations should act to minimize exposure to accumulations of hazardous vapors within the shelter."

- *Task 2:* Develop a concept to decide the best time to end SIP and work out a corresponding methodology for making this decision. The product was a proof-of-concept model of a program called the TSIP routine, which demonstrated the new concept and methodology. The TSIP routine is a copyrighted computer algorithm that examines the relationships among the major conditions and circumstances that influence the exposure of a population in a given ERZ, and calculates the smallest area of a chosen level of toxic effect in that ERZ for the conditions and circumstances. The best time to end SIP in that ERZ is the time for which the smallest area is predicted for that level of toxic effect. The results of Task 2 are described in Yantosik et al. (2001b).

- *Task 3:* Explore the potential to develop the TSIP routine, linked with an approved atmospheric dispersion model, as a decision-making tool to help decide when to end SIP at Army chemical stockpile storage sites and in nearby communities. A report by the CSEPP SIPWG endorsed this effort (CSEPP 2001). Subsequent to the report by the CSEPP SIPWG, the FEMA CSEPP Program Manager asked that Task 3 include a report that (1) compared the TSIP routine with the plume tail-time method of deciding when to end SIP, and (2) discussed the sensitivity of the TSIP routine to the variables used in the calculation. The current document will be provided to the SIPWG to allow them to reaffirm or reconsider their original endorsement of the development of the TSIP routine.

1.3 BACKGROUND

1.3.1 Acute Exposure Guideline Levels

Acute exposure guideline levels (AEGLs) are used as the toxicity criteria for

[2] The acronym ERZ used in this report refers to a locally defined sub zone of a CSEPP emergency planning zone.

mustard and nerve agents for emergency planning and response within the CSEPP. The U.S. Environmental Protection Agency (EPA)-sponsored National Advisory Committee on Acute Exposure Guideline Levels developed AEGLs for these agents, as well as for hundreds of hazardous materials that are around us every day. AEGLs consider the sensitivity of the general population to short-term, one-time exposure to these chemical warfare agents, the duration of the exposure, and the extent to which bodies can withstand some nerve agent exposure. AEGLs provide three thresholds of anticipated health effects:

- AEGL-1 is the threshold at which minor, temporary discomfort (eye effects) are possible in a percentage of the population.

- AEGL-2 is the threshold at which impairment of the ability to escape and other serious long-lasting effects become a possibility. Protective action is required at this threshold.

- AEGL-3 is the threshold at which exposure can cause severe health effects and fatalities become a possibility.[3]

1.3.2 The Benefit of Temporary Shelter-in-Place

Temporary SIP involves prompt sheltering of a population in enclosed structures to minimize initial exposure to a plume of hazardous vapors, followed by timely termination of SIP when the air outside becomes less hazardous than the concentration of vapors that infiltrated the shelters. Temporary SIP is supported by laboratory experiments and is endorsed by experts in emergency response (Sorensen, Shumpert, and Vogt 2002, Blewett and Arca 1999, Blewett et al. 1996, and Chester 1988). Temporary SIP is a public protection tool used by communities in the United States and around the world, and is touted as protection when the chemical release is expected to last for a short time, or when the chemical has a low health hazard and its release does not warrant an evacuation or there is not enough time to evacuate (NICS undated).

Figure 1 illustrates the benefit of SIP. It shows the profile of a hypothetical outside concentration of a plume of hazardous vapor over time, and relative concentrations of hazardous vapor inside shelters with varying Air Changes per Hour (ACH) at a specific location in an ERZ (Myirski 2000). Note the protection that a shelter can provide while the vapor plume is passing (the difference indicated by the height of the curves for each ACH) and how much difference a shelter with low ACH can make.

[3] Information about AEGLs for nerve and mustard agent can be found in the (Federal Register 2000 and Federal Register 2001), and in a publication titled: Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 3 (See www.nap.edu). Authors of the report also considered information about AEGLs presented at the AEGL Conference in August 2002 (Hauschild 2002), and in the CSEPP policy paper on the adoption of AEGLs (CSEPP 2003).

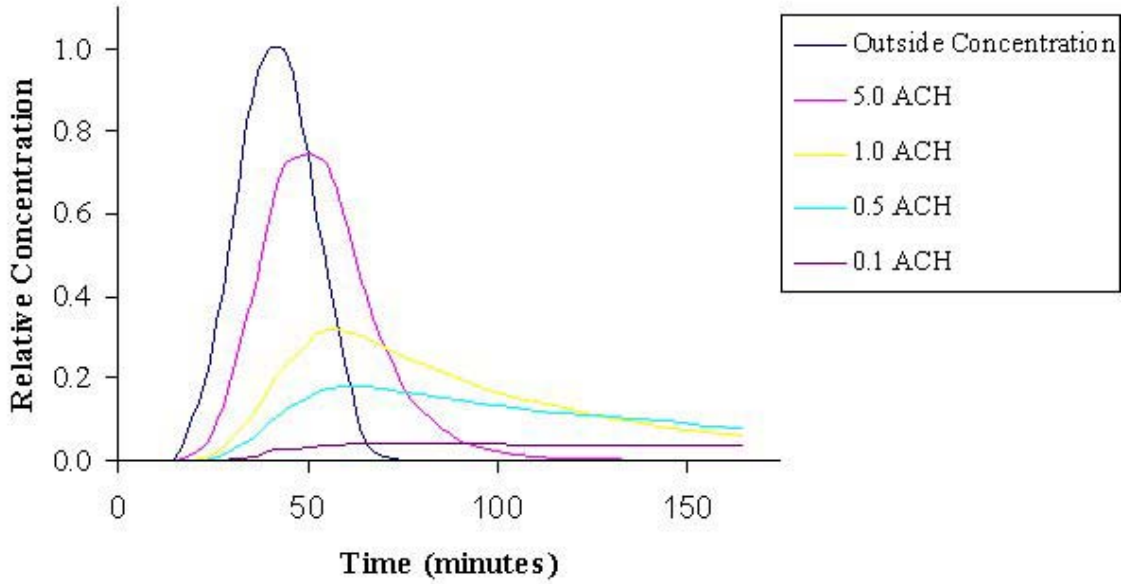

FIGURE 1 The Benefit of Temporary Shelter-in-Place

The *Planning Guidance for the CSEPP* (CSEPP 1996) and Army guidance on chemical accident response (U.S. Army 2003) also identify SIP as an appropriate protective action. Appendix D in the *Planning Guidance for the CSEPP* advises, "Shelter feasibility is determined by the infiltration rate into the structure and the duration that the structure is in the plume. In general, sheltering is not a good protective action when the accident is of a long duration or if the structure has a high infiltration rate. Moreover, people must vacate or air out the shelter when the plume has passed in order to minimize exposure to chemical vapors that entered the shelter while it was in the plume."

1.3.3 The Challenges of Temporary Shelter-in-Place

Shelter-in-Place usually offers only temporary protection because hazardous vapors accumulate in shelters when air is exchanged between the shelter and the exterior environment as the vapor plume passes. In Figure 1 the concentrations indoors and outdoors are equal when the outdoor concentration curve intersects with a curve representing a shelter with a particular ACH. Afterward, the concentration of agent inside is greater than outside. This intersection is the best time for a person in the shelter to end SIP. If people remain in the shelter after this time, they will continue to be exposed to the higher concentration of agent vapors in the shelter (CSEPP 2001). Note that a tighter shelter slows the escape of hazardous vapors that build up inside, turning an initial advantage into a liability. If a person never ends SIP, or even waits until the last of the vapor plume has dissipated or departed from the ERZ in which the shelter is located, he or she might receive almost the same agent dosage that would have been received had the person not taken shelter at all during the event. Figure 1 suggests that a concept and

method that results in ending SIP earlier than the plume tail-time may lessen toxic effects in the sheltered population.

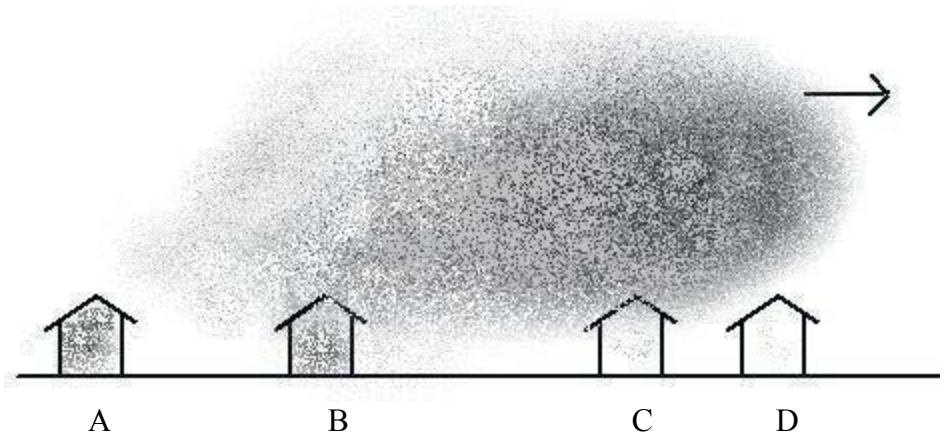

FIGURE 2 The Challenge: Select the One Best Time to End SIP Considering All Shelters in an ERZ

Figure 2 is a snapshot in time of shelters within an ERZ with a plume of invisible hazardous vapor (illustrated in gray shades) traveling from left to right (A to D). Shelters closer to the source of the release will be exposed sooner, and to higher concentrations, than shelters further downwind, because the vapor plume usually expands and rapidly becomes more diluted by clean air as it moves downwind. As Figure 2 shows, the hazardous plume has passed the first shelter on the left (A), leaving a higher concentration inside the shelter than outside. For persons in shelter A, which experienced the highest inside and outside vapor concentrations, ending SIP at or a little before the time of the snapshot would result in a smaller toxic effect than continuing to remain inside. Remaining in this shelter any longer could be fatal in some scenarios. For the shelter that is second from the left (B), the inside concentration is approximately equal to the outside concentration but will soon be greater than the outside concentration once the vapor plume has moved further downwind. Therefore ending SIP at about the time of the snapshot would minimize exposure to persons in shelter B. Delay in ending SIP beyond the time of the snapshot could have dire consequences for them.

For the two shelters on the right (C and D), the inside concentration is less than the outside concentration at the time of the snapshot, and therefore ending SIP at this time could result in more exposure than remaining inside until the outside concentration equals the inside concentration. However, the vapors in the plume outside the shelters on the right are not as concentrated as they were when the plume was passing the shelters on the left, so the potential for life-threatening exposure is less. If no one in the ERZ ends SIP until the vapor plume has dissipated or passed all shelters in the ERZ (minimizing outdoor exposure for even the furthest locations from the source), the sheltered population will suffer the maximum exposure from infiltrated vapors (indoor exposure). The bottom line is that no one time is best for all four shelters.

One approach to deciding the best time to end temporary SIP would be to compare the calculated exterior/interior concentrations at every potential shelter in the total area threatened by the vapor plume, and end SIP on a shelter-by-shelter basis when the outside concentration is less than that predicted inside each shelter. While the modeling calculations needed to support this approach could be constructed, this approach is unworkable because there is no certainty that individual calculations for each of the potentially thousands of shelters could be make quickly enough, even in the unlikely circumstance that data needed to support the calculations could be obtained and maintained current. In addition, there are no communications systems currently available to the CSEPP that would provide for rapid dissemination of shelter-specific protective action information. Lastly, educating the population to be comfortable with ending SIP incrementally on a shelter-by-shelter basis, or even within a group of shelters in a neighborhood, would be a daunting task.[4]

1.3.3.1 Only One Time to End SIP for Each ERZ

In practice, because it is not feasible to construct a suitable arrangement for ending SIP on a shelter-by-shelter basis throughout a threatened area, the CSEPP advocates that decisions to end SIP must be based on entire ERZs on and around chemical agent storage sites (CSEPP 1996). Thus the challenge is how to decide the single best time to end SIP for an entire ERZ, not just a specific location or individual shelter in an ERZ.

1.3.3.2 Shelters Do Not Provide Equal Protection

Another challenge facing decision-makers is that not all shelters in an ERZ will provide the same level of protection against infiltration, and the distribution of actual ACHs of shelters in an ERZ cannot be known with certainty.

1.3.3.3 Effects of Nerve Agent Exposure Are Nonlinear

A third important challenge in deciding when to end SIP involves taking into consideration that the effects of nerve agent exposure are not linear with dosage. In general, the toxic effects of nerve agents, and mustard agent to a much lesser degree, are a nonlinear function of the duration of the exposure and the concentrations experienced during exposure. Therefore, the decision about when to end SIP should consider the ability of the human body to metabolize nerve agent over time in order to maximize the benefit of temporary SIP.

[4] On an exception basis, the best time to end SIP can be calculated for a few select structures in an ERZ where large numbers of persons or special populations might take shelter, and at which extraordinary communications and transportation capabilities would be available.

1.3.3.4 SIP Strategy Should Favor Avoidance of Fatalities

Several possible strategies are available to protect sheltered populations threatened by the release of hazardous chemicals. CSEPP Policy Paper Number 1 (CSEPP 1991) states, "The most important objective of the emergency preparedness and implementation process is the avoidance of fatalities to the maximum extent practicable, should an accidental release of chemical agent occur." This concern for avoiding fatalities was reiterated in CSEPP Policy Paper 20 (CSEPP 2003) which says, "Consistent with CSEPP Policy Paper 1, priority should be to prevent exposures above AEGL-3, which could result in severe, incapacitating, and possible lethal outcomes. To accomplish this, protective actions should be directed toward preventing or minimizing exposures above AEGL-2, i.e., above the threshold where some temporary but potentially escape-impairing effects could occur." Thus, timely termination of SIP to avoid potential fatalities must be an integral component of a SIP strategy in the CSEPP. Other protective action strategies, such as minimizing total population exposure or minimizing the total number of people exposed (Sorensen, Shumpert, and Vogt 2002), can actually result in an increased potential for fatalities.

On the other hand, when the maximum expected concentrations of hazardous vapor in an ERZ presents only a very low health hazard (i.e., AEGL-1), no action is required to protect the public (CSEPP 2003). Therefore, if temporary SIP is used at the discretion of local emergency decision-makers to shelter a population from this low threshold of effects, timing the end of SIP is not critical.

1.3.3.5 Potential for Exposure Before, During, and After SIP

The potential exists for some toxic load to accumulate before persons enter their shelter if they are still outside when the hazardous vapors reach their location. Some additional toxic load can accumulate while persons are in the shelter due to infiltration of hazardous vapors into the shelter. Finally, the potential for additional toxic load accumulation following SIP occurs when persons remain in the building while the shelter ventilates, when persons exit from shelter but remain just outside the building during the ventilation period, or while persons are relocating to an area away from the effects of the plume. All of these circumstances can affect the best time to end SIP.

1.3.3.6 Mitigation of Vapor Hazards in Shelters

Recirculating air filters can reduce agent vapor concentrations within a shelter (Janney et al. 2000). Also, some agent vapor can be adsorbed by a shelter and its contents in certain circumstances (Blewett and Arca 1999). However, validated data that quantifies the percentage of reduction in vapor concentration in shelters due to these mitigating factors are not available.

1.3.3.7 Population Distribution in an ERZ Might Not be Homogeneous

Yet another challenge is to consider the distribution of the population in an ERZ when making decisions about ending SIP, to ensure that appropriate consideration is given to high population concentrations in the ERZ. When current CSEPP ERZs were defined, the criteria did not include consideration for optimizing the decision to end SIP. If an ERZ is large, especially in length with respect to the direction of potential agent vapor travel, and if the population distribution in the ERZ is not reasonably homogeneous, then it is particularly difficult to choose a good time to end SIP for the entire ERZ regardless of the method used. In such cases, consideration should be given to creating additional smaller sub zones within the ERZ that will enhance the timing to end SIP. This is especially important if there is a small area of very dense population at either end of the current ERZ.

1.3.4 Importance of Characterizing the Release

Good information about the release of hazardous material is essential to any initial protective action decision—should a potentially threatened population evacuate immediately, take temporary shelter, or do nothing? Good information about the event is equally important when deciding about the end of temporary SIP, regardless of the method used to make this decision.

At Army chemical stockpile storage sites, initial protective action decisions (evacuate or SIP) may justifiably be based on an appropriate worksite maximum credible event (MCE) in the absence of detailed information about the release for an accident at a worksite (U.S. Army 1993). However, using initial assumptions about the event to decide about ending SIP can result in bad timing of that decision if these assumptions are inaccurate, and thus lessen the protection offered by SIP. Even safe-sided assumptions about the event (i.e., those that are generally thought to be conservative) can have this negative effect. Therefore, source-term observational data (from eyewitnesses at the accident site) and source-term monitoring data (from monitors at and near the accident site), along with the latest meteorological information, are essential to any method of deciding about ending SIP. Ideally, this information will be collected quickly and analyzed promptly, so that a sheltered population can be notified in time to take advantage of the best time to end SIP.

1.4 ORGANIZATION OF THIS REPORT

The body of this report is divided into several sections. Section 2 describes the use of plume tail-time calculations to decide when to end SIP. Section 3 describes the use of the TSIP routine calculations based on D2-Puff™ model release profiles to decide when to end SIP. Section 4 discusses the comparison of the two methods. Section 5 summarizes the results of the comparison. Section 6 discusses the sensitivity of the TSIP

routine to the variables used in calculating the time to end SIP. Section 7 presents conclusions and recommendations.

Appendix A lists references cited in this report. Appendix B defines acronyms used in this report. Appendix C lists the variables and values considered in the report. Appendix D discusses best practices for an effective SIP termination strategy. Appendix E is the tabulated results of the model runs made for the report.

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2 USE OF PLUME TAIL-TIME CALCULATIONS TO DECIDE WHEN TO END SIP

The current concept in the CSEPP is to decide to end SIP in an ERZ when the vapor plume dissipates or passes out of the ERZ, regardless of the protection afforded by shelters or the protective action taken by the population. The CSEPP is currently supporting the D2-Puff computer model to calculate the vapor plume tail over time at all relevant distances from the point of release (the concentration-time history of the vapor plume), and predict when the tail of the vapor plume will leave a given ERZ. The latest predicted plume tail-time in the ERZ is considered to be the time to end SIP. The D2-Puff model is described in an Innovative Emergency Management, Inc. (IEM) technical manual. (Prater, Stage, and Weltman 1998).

The use of the D2-Puff model to calculate the latest plume tail-time for an ERZ, and the use of this time to end SIP, is a continuation of prior CSEPP procedures that used the time when the outside vapor plume concentration had been reduced to a level that was three standard deviations below the plume's trailing centerline concentration (i.e., the definition of plume tail-time) as the time to end SIP when the D2PCw model was used for hazard analysis. The logic was that the plume had passed out of the ERZ at the 3-sigma tail- time, so it is safe to go outside. In D2-Puff, puffs extend a distance 3-sigma in all directions from the centroid, and the plume tail-time for a zone is the time when all of the puffs in the plume have permanently left the zone.

Emergency managers are aware that some agent vapors will seep into shelters as the plume passes by, thus contaminating the air within the shelters and making it important to leave the shelters at an appropriate time. However, D2PCw was not able to model concentrations within shelters (CSEPP 1996, 1999). The D2-Puff model uses a simple mathematical model to find concentrations and dosages within individual shelters.[5] However, the D2-Puff model's capability of estimating the concentrations and dosages within individual shelters does not directly provide a solution for deciding the best time to end SIP for every shelter in a given ERZ. In addition, the plume tail-time method does not consider the dose-response relationship of the agent, shelter air change rates, or the protective actions taken by the population in the ERZ.[6]

In theory, vapor plume tip-times and tail-times can be calculated using a concentration criterion higher than zero. This would effectively reduce the size of the plume that is of concern because it ignores times when low concentrations of vapor are just entering or have not yet departed an ERZ. The resulting delay in the estimated arrival of plume tip-time might provide a few extra minutes for initial evacuation if that decision is based on plume tip-time. Similarly, the plume tail-time produced by this calculation might provide some improvement in the decision to end SIP based on the

[5] The computational module of D2-Puff that IEM used in their Quantitative Emergency Management analysis was also used by IEM to calculate the concentration-time histories used in this report. There were no known bugs in this module as of 2 December 2002.

[6] Neeraj Mainkar (IEM) provided information about D2-Puff model plume tail-time calculations on 27 September 2002.

current plume tail- time method as regards vapor infiltration into shelters. However, current CSEPP policy does not allow this, and the potential to improve on the plume tail-time method by adjusting the concentration criterion has not been studied.

3 USE OF TSIP ROUTINE CALCULATIONS TO DECIDE WHEN TO END SIP

3.1 HOW TSIP ROUTINE CALCULATIONS ARE MADE

The new concept is to decide to end SIP in an ERZ when the area of the highest levels of toxic effect is predicted to be smallest. The method to implement this concept is to use the TSIP routine along with the concentration-time history calculated from a dispersion model (e.g., the D2-Puff computer model as considered in this report) to determine the end SIP time that results in the smallest area of the highest levels of toxic effect within an ERZ. The TSIP routine considers the relationships among the conditions and circumstances of the release and the options to end SIP. The main feature of this routine is consideration of the relative concentrations of vapor within and outside shelters as the plume passes through an ERZ. The TSIP routine also considers the potential for exposure before and after a population takes shelter when making this calculation.[7]

The major conditions that influence the exposure of a population are the source term values of the agent release, meteorological conditions, shelter air change rates, the size and the distance of the ERZ from the source, and the dose-response relationship of the hazardous material. The circumstances that contribute to overall exposure associated with a SIP strategy involve exposure during the time before taking shelter, exposure while sheltered due to vapor infiltration, and additional exposure (if any) following the termination of SIP. Options to end SIP are to relocate to a safer location, exit from the shelter and remain nearby, or ventilate the shelter but remain indoors. Section 4.3 has more information about these conditions, circumstances, and options.

First, the D2-Puff model calculates the outside agent concentration-time histories at a large number of points along the downwind plume centerline. The TSIP routine takes this information and uses it to calculate the agent concentration-time histories inside hypothetical shelters along the downwind plume centerline.[8] Agent concentration-time histories are required input to the IEM routine that is embedded in the TSIP routine to calculate AEGLs. The shelter air-change rates used in the calculation are values predetermined by the user.

The TSIP routine then calculates the SIP end time for each ERZ where the outside (unprotected) effects are AEGL-1 or higher, according to the following protocol:

- The TSIP routine calculates the time to end SIP that results in the smallest area in an ERZ where the AEGL-3 level of toxic effects is predicted, and considers this to be the best time to end SIP. If the calculated best time to minimize the area of

[7] The TSIP routine, an algorithm developed by Argonne, is described in the Argonne publication titled: *When and How to End Shelter-In-Place Protection From a Release of Airborne Hazardous Material: Report on a Decision-making Concept and Methodology* (Yantosik et al. 2001b).

[8] The exchange of D2-Puff concentration-time histories with the TSIP routine was done using a batch file for this report, because the TSIP routine is not yet linked directly to the D2-Puff model.

AEGL-3 effects extends over a period of several minutes (two or more time-steps in the calculation), then the TSIP routine will seek the point in time within this range that minimizes the area where the AEGL-2 level of toxic effects is predicted, and consider that to be the best time to end SIP in that ERZ. If the calculated best time to minimize the area of AEGL-2 effects extends over a period of several minutes (two or more time-steps in the calculation), then the TSIP routine will seek the point in time within this range that minimizes the area where the AEGL-1 level of toxic effects is predicted, and consider that to be the best time to end SIP in that ERZ. If the calculated best time to minimize the area of AEGL-1 effects extends over a period of several minutes, then the TSIP routine will consider the latest time within this range to be the best time to end SIP in that ERZ.[9]

- If the AEGL-3 toxic effects level extends the entire length of an ERZ, and cannot be minimized to anything less than the full length of the ERZ, the TSIP routine calculates the time to end SIP in that ERZ based on when the concentration outside of a hypothetical shelter located at the point on the ERZ boundary that is farthest from the point of release is less than the concentration inside the hypothetical shelter.[10] This is referred to in this report as the Indoor/Outdoor Concentration Technique.

- If no part of an ERZ is affected at the AEGL-3 level of toxic effects, the TSIP routine attempts to find the best time to end SIP in the ERZ beginning with the AEGL-2 level of toxic effects, following the same process described above for AEGL-3.

- If no part of an ERZ is affected at AEGL-3 or AEGL-2 levels of toxic effects, the TSIP routine attempts to find the best time to end SIP in the ERZ beginning with the AEGL-1 level of toxic effects, following the same process described above for AEGL-3 and AEGL-2.

In application, when computing the minimum area of a selected threshold of effects when the area of the AEGL contour of interest extends to more than one ERZ, the area of the AEGL-x contour that lies within each ERZ will be calculated separately.

[9] Timing of the end of SIP to minimize the area where higher levels of toxic effect are predicted can result in some increase in the size of areas where lower levels of toxic effect might occur. However, the trade-off to minimize the areas of AEGL-2 and/or AEGL-1 effects at the expense of the size of the area of AEGL-3 effects is not acceptable (CSEPP 1991).

[10] In application, when using the D2-Puff Risk Envelope, the time to end SIP will be based on the latest time for any shelter in the ERZ, rather than on the farthest point in the ERZ. The TSIP routine would use the same concentration-time history represented by the D2-Puff Risk Envelope.

3.2 HOW THE TSIP ROUTINE ADDRESSES THE CHALLENGES OF SHELTER-IN-PLACE

The TSIP routine addresses many of the challenges of SIP described in Section 1.3.3 of this report by a combination of its design features and the way it can be applied in practice. These are discussed below.

- *How to decide the single best time to end SIP for an entire ERZ, not just a specific location or individual shelter in an ERZ?*[11] The solution to this challenge is a design feature of the TSIP routine. The TSIP routine does this by calculating when the area of the highest levels of toxic effects in an ERZ is predicted to be the smallest, and ending SIP at this time.

- *How to decide the best time to end SIP when not all shelters in an ERZ provide the same level of protection against vapor infiltration and the actual ACH of shelters in an ERZ cannot be know with certainty?* The TSIP routine works best when the assumed shelter ACH that is used as input to the decision tool is equal to the actual ACH of a shelter. The greater the difference between the assumed ACH and actual ACH, the less helpful the tool will be in minimizing the highest levels of toxic effects throughout the ERZ. In some cases at the extremes of a mismatch between assumed and actual shelter ACH, the tool may offer no advantage at all over the plume tail-time method. The solution to this challenge is a design feature of the TSIP routine. This is done by allowing the user the option to apply the TSIP routine to a range of shelter ACHs to represent the range of actual ACHs in shelters throughout the ERZ. To illustrate how this feature of the TSIP routine can accommodate the potential for a range of actual shelter ACHs in an ERZ, this report used a range of ACHs as input (e.g., a range from approximately 0.2 ACH through 2.0 ACH, as described in Table C-6 in Appendix C) to account for these variations. This is a practical compromise, in that the results from using a range of input ACHs are somewhat less helpful than the results that could be obtained if the actual shelter ACH and input ACH were the same, but using a range of input ACHs can eliminate the effects of a large mismatch between the assumed and actual ACH in an ERZ.[12]

- *How to consider that the effects of nerve agent exposure are not linear with dosage when deciding the best time to end SIP?* The solution to this challenge is a design feature of the TSIP routine. The TSIP routine does this by using the

[11] To the extent that arrangements are already under consideration in some CSEPP jurisdictions to decide the time to end SIP at a few select receptors or facilities within an ERZ, the time that the vapor plume tail passes the receptor or facility is usually considered the time to end SIP at that location. A variation of the TSIP routine designed for individual shelters could also be used to help decide when to end SIP at a specific location, and might provide better results.

[12] It was assumed that nearly all shelters will provide 2.0 ACH or less, most will provide 1.0 ACH or less, and 0.5 ACH is easily achievable. Expedient shelter protection (0.2 ACH or less) is the preferred level of protection, and the expected protection to be used by a population educated about SIP and equipped to install expedient shelter measures. This report considered all of these possibilities, as well as shelters with an ACH of 5.0.

plume concentration-time history from the D2-Puff model in combination with IEM's AEGLs dose-response relationship algorithm, because the AEGLs gives a better indication of the expected toxic effects of nerve agent than dosages.

- *How to avoid fatalities to the maximum extent practicable when deciding the best time to end SIP?* The solution to this challenge is a design feature of the TSIP routine. As described above, the TSIP routine does this by giving priority to using AEGL-3 toxic effects when calculating the area of the highest levels of toxic effect in an ERZ, and ending SIP at a time to minimize AEGL-3 effects in an ERZ.

- *How to consider the potential for exposure before, during, and after SIP when deciding the best time to end SIP?* The solution to this challenge is a design feature of the TSIP routine. The user is allowed to select inputs (by default or in real time) that reflect the time taken by a population to begin SIP and the action taken by the population when ending SIP. The time to begin SIP is based on the elapsed time from the release until the notification to take SIP is implemented. The action when ending SIP is based on the user's choice of options that the population either remained inside while shelters ventilated, exited from shelters but did not relocate, or relocated to an area away from the effects of the plume after exiting from the shelters. While the TSIP routine considers the potential for exposure before, during, and after sheltering, by definition there is no exposure after sheltering with the plume tail-time method because the population ends SIP only after the tail of the plume has departed completely from the ERZ.

- *How to consider mitigation of vapor hazards in shelters when deciding the best time to end SIP?* The effects of potential agent vapor adsorption by shelters and their contents, and the reduction of hazardous vapor by using recirculating filters in shelters, were not considered in the report because there is not enough information available to quantify the reduction in airborne vapor concentrations in shelters due to these mitigating factors. If such data becomes available, the TSIP routine is capable of using this information to refine the calculation of the best time to end SIP.[13]

- *How to decide when to end SIP in an ERZ where the population distribution is not homogeneous, especially if there is a small area of very dense population at either end of the current ERZ and subdividing the ERZ is not an option?* This is a difficult challenge regardless of the method used for decision-making.[14] To

[13] For example, if validated tests show that using a recirculating air filter in a room configured to provide expedient protection reduces concentrations of hazardous vapors by 50%, then the indoor concentrations used by the TSIP routine can be reduced by 50% when calculating the time to end SIP in an expedient shelter with a recirculating filter operating.

[14] Theoretically, it would be possible to weigh the distribution of all of the shelters in an ERZ and the number of people in each. However, to do so would require near real-time information about the locations of all potential shelters and the expected number of persons in each shelter at various times of the day and night throughout the year. This "shelter and people counting" arrangement is not practical. However, the concept behind the TSIP routine could be extended to consider population distribution data (if available)

partially address this challenge, the TSIP routine uses area as a surrogate for the distribution of a sheltered population. The TSIP routine seeks the conditions and circumstances that produce the smallest area within an ERZ where a specific threshold effect is expected, and considers this to be the best time to end SIP for the ERZ. If the population distribution within an ERZ is reasonably homogeneous, then there is a direct relationship between population distribution and area. If the distribution of the population is not homogeneous, then the results from the TSIP routine, as described in this report, may be less than a perfect solution, but one still superior to using plume tail-time in the majority of cases. Thus, this application of the TSIP routine as described herein is a practical approach to accommodate the reality of the current CSEPP alert and notification systems, ERZ boundaries, and the paucity of available demographic information. An alternative to this approach would be to use the TSIP Routine to decide the best time to end SIP for a geographically definable area within an ERZ, e.g., a small community, an apartment complex, a shopping mall or an industrial facility.

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and then seek to minimize the number of people affected instead of the area. While this population distribution-based implementation of the TSIP routine might not be practical for CSEPP, it might be useful for other hazardous materials release situations.

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4 COMPARISON OF THE TWO METHODS

4.1 SUMMARY OF EFFORT BY ARGONNE AND IEM

This report was a collaborative effort by Argonne and IEM. The following summarizes that effort.

4.1.1 Argonne Effort

The initial proof-of-concept TSIP model was a manually operated algorithm of limited scope, and needed further development to represent a decision tool for comparison with the plume tail-time method. The following first three steps were undertaken by Argonne to upgrade the TSIP routine for this purpose:

- Expanded the TSIP routine to include values for persistent nerve agent (VX) and mustard vapor. (The proof-of-concept TSIP model supported only non-persistent nerve agent (GB) vapor source terms.)

- Added a calculation to automatically select the shelter termination time that minimizes the area of a selected threshold of effect in the ERZ.

- Developed the TSIP routine decision protocol when the area of a standard toxic effect level (e.g., AEGL-1, AEGL-2, AEGL-3) is never reduced within an ERZ that is touched by the projected hazard area, and integrated this decision protocol into the TSIP routine, as discussed in Section 3.1.

- Identified the specific values of all of the variables that were considered in the report, in consultation with the SIPWG. See Section 4.3.

- Developed a methodology for comparing the plume tail-time results with the TSIP routine. See Section 4.4.

- Developed a batch routine to automate the process of comparing the two methods for each case considered in this report.[15] The routine automatically constructed all of the agent release scenarios from the component release scenarios (see Section 4.4.1), and then generated all of the cases used in this report by considering all of the combinations of variables that were investigated. (See Section 4.3.) In addition, the batch routine integrated (1) the TSIP routine, (2) IEM's AEGL algorithm, and (3) the specific calculations required to compare the two methods for this report. As a part of this process, the batch routine read the D2-Puff model plume centerline

[15] The term "case" used here and later in the report refers to a combination of a given agent release scenario, a set of meteorological conditions, and a hypothetical ERZ.

concentration files and the release scenario datasets. Finally, the batch routine generated the comparison tables presented in Appendix E.

4.1.2 IEM Contribution

- Provided downwind vapor plume centerline concentrations as a function of time for each source term-meteorological condition combination.
- Provided the algorithm to calculate AEGL values from vapor plume concentration-time histories.[16]
- Provided a list of source term values and meteorological conditions associated with base cases prepared by IEM for protective action planning.
- Described the methodology to decide when to end SIP using the plume tail-time concept with the D2-Puff model.
- Reviewed the report to ensure accurate representation of IEM products and effort.

4.2 SUMMARY OF CORE ASSUMPTIONS USED IN THIS REPORT

Several assumptions were made to ensure that both methods to decide when to end SIP were treated equally in the report. These assumptions are summarized below. Details are provided elsewhere in this report, as cited.

- The primary objective of temporary SIP was to avoid severe, incapacitating, and possibly fatal exposures. See Section 1.3.3.
- The population distribution was homogeneous throughout an ERZ. See Section 3.2.
- All ERZs were flat terrain (i.e., the D2-Puff dispersion model was run with the terrain feature off). See Table C-1 in Appendix C.
- All releases were detected immediately, the warnings to the population were timely, and the population in the ERZ took temporary SIP as recommended by CSEPP guidance. See Section 4.4.2 and Table C-7 in Appendix C.

[16] The collaboration between Argonne and IEM required that Argonne calculate AEGLs for each case considered in the report. AEGL calculations considered both the raw concentration data provided by IEM and the range of protective actions considered for each case and each method. Therefore, in addition to the raw concentration data, IEM also provided Argonne with the same algorithm to calculate AEGLs as is used in the D2-Puff model.

- Shelters in the ERZ had air change rates within the range used for CSEPP planning. See Section 4.3.3 and Table C-6 in Appendix C.

- The wide range of hypothetical release scenarios and hypothetical ERZ configurations that were considered were sufficiently representative to draw conclusions. See Section 4.3 and Appendix C.

- Ignoring aerosol releases (including deposition) did not invalidate the conclusions drawn in the report. Only vapor releases were considered. The unlikely potential for aerosol infiltration into shelters was not. See Section 4.3.2.

- Ignoring the instantaneous release dispersion model parameters (i.e., the dispersion parameters considered in this report were all for a point source and assumed a release duration of no less than one minute) did not invalidate the conclusions drawn in the report. Explosive (i.e., instantaneous) releases were all modeled assuming a one-minute release duration from a point source. See Section 4.3.2 and Tables C-2 and C-3 in Appendix C.

- The best practices to ensure an effective SIP termination strategy described by the CSEPP SIP Work Group (CSEPP 2001) were followed by decision-makers and the population at risk. See Appendix D.

- The population at risk was given timely notification about ending SIP, and exited shelters when advised to do so. This population did not relocate to another place after exiting shelters. See Section 4.4.2 and Table C-8 in Appendix C.

4.3 VARIABLES CONSIDERED IN THE REPORT

This section introduces the variables and values considered in this report. Additional details on the variables and values are in Appendix C. The variables and values considered in the report can be categorized into three groups: variables specific to storage sites, variables specific to scenarios, and variables unique to the TSIP routine. The first two groups are common to both decision methods. The third group, as the name implies, are variables that figure in the calculation of time to end SIP using the TSIP routine, but not by the plume tail-time method.

4.3.1 Variables Specific to Storage Sites

Emergency Planning Zone Size and Relative Distance from the Source. Because the report is not based on any one site, values for different sizes of ERZs and their relative distances from the source were based on representative values within the

range of actual ERZ sizes and distances from possible sources at the storage sites. See Table C-1 in Appendix C.

4.3.2 Variables Specific to Scenarios

Source Term Values. The report considered source terms values (quantity released and release rate profile) for GB, VX, and mustard. See Tables C-2 and C-3 and Section C.2 in Appendix C. Explosive (i.e., instantaneous) releases were all modeled assuming one-minute release durations from a point source using the "semi-continuous" dispersion model parameters. Similarly, only vapor releases were considered, and the unlikely potential for aerosol infiltration into shelters was not. Ignoring aerosol infiltration for this report was a decision based on information provided by Michael Myirski, an Army expert on dispersion modeling of chemical warfare agent releases. He said, "In the absence of dependable quantitative calculations about the potential for aerosol deposition associated with a chemical accident, there is little choice but to use qualitative estimates to judge the potential for aerosol deposition. Initial judgments should be based on the best available information about the release, atmospheric conditions at the accident site and down wind, and the expert knowledge of Army hazard analysts. These informed judgments should be adjusted immediately as new information becomes available. This is not unreasonable, considering that the generation of aerosol deposition beyond the installation boundary is such a remote possibility, and the conditions that would generate aerosol deposition are easily identified.[17] The absence of these indicators justifies ignoring aerosol deposition completely when making temporary SIP decisions. If aerosol deposition is indicated, Army hazard analysts should make an informed judgment based on the best available information. Reports from surface monitoring teams can help if they are obtained quickly. Regardless, the analysis of any release should consider the potential for an aerosol deposition hazard, and Army protective action recommendations (PARs) should always include an assessment of this potential." (Yantosik, Lerner, and Maloney 2001a)

- **Meteorology.** Wind speed and atmospheric stability class are the key variables that are used within dispersion models to predict the movement and dissipation of hazardous vapors. Numerous combinations of wind speed and stability class were considered in the report. While each case considered constant meteorological conditions, the use of variable release rate profiles produced variations in plume concentration-time histories that were similar to variations in plume

[17] An unusual combination of factors is needed to make aerosol deposition a possible health risk beyond the immediate accident site. It requires many explosively configured munitions filled with persistent agent (VX or mustard) to create large particles or aerosols upon detonation, a fire hot enough to cause the munitions to detonate, and atmospheric conditions that will transport the aerosol significant distances.

concentration-time histories produced by meteorological changes during the life of the vapor plume. See Table C-4 in Appendix C.

4.3.3 Variables Unique to the Use of the TSIP Routine

- **Dose-Response Relationship.** The toxic effects model and methodology used to determine the toxic effect from a chemical warfare agent release is of special importance in determining when to end SIP. The report considered toxic effect threshold levels AEGL-1, AEGL-2, and AEGL-3 for GB, VX, and mustard agent. See Section 1.3.1.

- **Shelter Air Change Rates.** The duration that a given shelter will provide useful protection for a given release scenario will depend in part on the shelter's air change rate as expressed in ACH. The authors of the report considered Oak Ridge National Laboratory Report ORNL-6615 (Rogers et al. 1990), and the *Report of the CSEPP Shelter-In-Place Work Group* (CSEPP 2001) to help select shelter air change rates to use in the report. See Table C-6 in Appendix C for specific ACH values considered in the report.

- **SIP Protective Actions.** The circumstances that contribute to the overall effects of exposure associated with a SIP strategy involve potential exposure before taking shelter, exposure while sheltered due to vapor infiltration, and potential additional exposure following the termination of SIP. The latter depends on whether persons remain inside while the shelter ventilates, exit from shelters but remain just outside the building, or relocate to an area entirely away from the effects of the plume. The SIP protective action taken in an ERZ is a user-selected input in the TSIP routine. See Tables C-7 and C-8 in Appendix C.

4.3.4 Source of Variables and Values Considered in This Report

Argonne drafted a plausible range of values for each variable that influences the timing of decisions to end SIP. These variables and values were reviewed by the CSEPP SIP Work Group and by Mr. Michael Myirski from the U.S. Army Chemical Materials Agency at Aberdeen Proving Ground MD in Maryland. The data were also distributed for comment at the CSEPP National Conference in Lexington, KY. All feedback from these sources was considered when the final set of tables was developed.

To ensure objectivity in the selection of the release scenario values, the report also considered input provided by IEM that its staff derived from a Quantitative Risk Assessment (QRA) at one of the chemical stockpile storage sites. There was some overlap and duplication in these scenario datasets, but the use of two separate scenario datasets increases the confidence in the results of the report. The variables and values considered in the report are described in Appendix C.

4.3.5 Use of Variables in This Report

The TSIP routine considered all of the variables listed above when calculating the best time to end SIP, and all variables were considered for both methods when comparing the TSIP routine and the plume tail-time method.

TABLE 1 Summary of Variables Considered in This Report

	Used in Calculating…		Used in Comparing…	
Variable	**TSIP Routine End SIP time**	**Plume Tail-time**	**TSIP Routine Method**	**Plume Tail-time Method**
ERZ size and location	X	X	X	X
Source term values	X	X	X	X
Meteorology	X	X	X	X
Dose-response relationship	X		X	X
Shelter ACH	X		X	X
SIP protective actions	X		X	X

4.4 COMPARISON METHODOLOGY

4.4.1 Development of Agent Release Scenarios

In order to compare the two methods, Argonne developed a series of 241 agent release scenarios in consultation with IEM and the CSEPP SIP Work Group. Any of these scenarios could potentially occur at Army chemical stockpile storage sites. Each scenario was composed of an agent (GB, VX, or HD) and a mass release time-history. These agent release scenarios are listed in Appendix C.

A small set of component release scenarios was then developed by IEM that could be used as building blocks to construct each of the 241 release scenarios used in the report. That is, each of the release scenarios used in the report could be constructed by taking one or more component release scenarios, scaling them, applying time offsets to them, and then summing them. The component release scenarios are listed below.

1 kg agent released in 60 seconds
1 kg agent released in 300 seconds
1 kg agent released in 900 seconds

1 kg agent released in 1,800 seconds
1 kg agent released in 2,700 seconds
1 kg agent released in 3,600 seconds
1 kg agent released in 5,400 seconds
1 kg agent released in 7,200 seconds
1 kg agent released in 10,800 seconds
1 kg agent released in 14,400 seconds

For each combination of a component release scenario and a meteorological condition, IEM ran a modified version of D2-Puff that produced a file containing the predicted agent concentration at a grid of downwind plume-centerline locations and times. Argonne interpolated this grid to obtain concentrations at other locations and times. The files created by D2-Puff also contained a list of the plume tail-times (as calculated by D2-Puff) for a large number of plume-centerline downwind locations.

4.4.2 Use of Baseline Values

In order to ensure consistent comparison of variables and values throughout the report, it was determined that baseline values were needed to represent the time that a population would take to implement SIP, to represent the actual ACH of shelters in an ERZ, and to represent the way to end SIP. A baseline value is one that was considered to be the most representative value in the range of values considered, and one that when combined with values from other variables, produced information to determine the sensitivity of the other variables. The baseline values used were:

- The population entered shelters 16 minutes after the initial release of hazardous vapors. This value was chosen as the baseline because it is consistent with the results expected by the implementation of CSEPP guidance (CSEPP 1996). See Table C-7 in Appendix C and Section E.3.5, Table E-9, and Table E-24 in Appendix E for information about this baseline value compared with other times that were also considered in the report.

- Shelters in the ERZ had an ACH of 1.0. This value was chosen as the baseline because it represents post-1950 housing construction without enhancements, a level of protection that can be achieved in most shelters (Vogt et al. 1999). See Section E.3.3 and Table E-7 in Appendix E for information about this baseline value compared with other ACHs that were also considered in the report.

- The sheltered population exited shelters but did not relocate when they ended SIP. See Table C-8 in Appendix C and Section E.3.4 and Tables E-8 and E-23 in Appendix E for information about this baseline value action to end SIP compared with other options to end SIP that were also considered in the report.

4.4.3 Additional Considerations

An almost infinite number of combinations of conditions and circumstances would have to be considered in order to calculate the best time to end SIP for every possible contingency. However, to produce valid comparisons between the two methods in a reasonable time and at a reasonable cost, the authors selected logical and justifiable

assumptions and bounds to produce defendable conclusions about the two methods. The assumptions are summarized in Section 4.2. The bounds of the report are described below.

4.4.3.1 Sampling Variables

While it takes only seconds for a computer to calculate an agent plume concentration-time history using D2-Puff and seek an optimal time to end SIP using the TSIP routine for any one scenario at a specific site, calculating multiple combinations of conditions and circumstances becomes a very computationally intensive effort. In order to bound the report to stay within time and budget, yet represent the wide range of variables needed to obtain valid results, all combinations of 241 release scenarios developed for the report by Argonne, nine sets of meteorological conditions, and 18 ERZ configurations described in Section C.1 of Appendix C were considered. In addition, a second set of runs was made using the quantitative risk assessment (QRA) data subset provided by IEM, which included 37 release scenarios, nine sets of meteorological conditions, and 18 ERZ configurations described in Section C.2 of Appendix C. While these runs covered the range of credible combinations, the trends identifiable in the tables in Appendix E are not as smooth as they would have been had an infinite number of combinations of variables and circumstances been considered.

4.4.3.2 Weighing Variables

The values for each variable considered in the report are not weighted as to their likelihood of actually occurring. For example, in this report a 344-kg release is considered as likely as a 0.5-kg release. Sufficient information was not available to assign realistic probabilities to the values within each variable used in the report.

4.4.3.3 Correction for Explosive Releases of VX

The D2-Puff model is capable of applying a correction factor to its predicted concentrations for explosive releases of VX. This correction factor accounts for the contact hazard of liquid VX droplets. The correction may be less applicable when considering SIP issues, as vapor infiltration is the primary concern for tight shelters. The concentration data provided by IEM for explosive releases of VX for this report did not include a correction factor to account for an aerosol component. Therefore, for the purposes of comparing the two methods, explosive releases of VX were assumed to be 100% vapor releases.

4.4.3.4 Evacuation Versus SIP

It was found that the TSIP routine can calculate that the timely end of SIP for certain combinations of conditions and circumstances should occur before the vapor plume will penetrate very far into an ERZ, i.e., a population should end SIP at the same time that this population is entering shelter, if not before. In this case, the TSIP routine is effectively determining that the best protective action should have been to evacuate initially, if possible, rather than to take shelter in the first place. However, it is also recognized that some people will not be able to evacuate, and hopefully those people will shelter-in-place. Therefore, directions to end SIP in ERZs covered by an evacuation order will still be required. For this reason, and also to ensure a fair comparison between the time to end SIP using the TSIP routine and D2-Puff plume tail-time, results from the TSIP routine that suggest that evacuation would have been preferable to SIP were excluded from this report. Thus, for the purposes of this report, the TSIP routine never considers a time to end SIP before the later of (1) the time at which sheltering takes place or (2) the time when the agent plume first reaches the ERZ (i.e., the plume tip time).[18]

4.4.3.5 Weighting Population Distribution Variables

The report did not measure the impact that variations in population distribution in an ERZ would have on the times to end SIP using either the TSIP routine or the plume tail-time method, because the report was based on generic ERZs with an assumed homogeneous population distribution. It would be possible to study the impact of variations in population distribution in site-specific ERZs and recommend changes to actual ERZ boundaries to optimize decisions to end SIP, if the CSEPP program managers thought this would be desirable.

4.4.4 Calculating the Size of Affected Areas

The concept of the hazard wedge, which is currently used in the D2PCw program, was used to calculate the sizes of areas affected by the vapor plume and the differences in the size of areas affected by the vapor plume, when calculations were made using the TSIP routine and the plume tail-time. Argonne and IEM agreed that the hazard wedge would be the most appropriate way to consider the affected area, since generic ERZs without terrain features were used to compare methods (this is comparable to using D2-Puff with terrain tracking off), and constant meteorological conditions were used for each release considered in the report. Thus, areas affected by the vapor plume were calculated as: Area= π * (wedge angle/360) * ($r2^2 - r1^2$), where wedge angle = 60 degrees for A, B, and C stability and 40 degrees for D, E, and F stability; r2 = distance of AEGL-1, -2, -3

[18] When used as a real-time decision tool without the constraints used in the report as to the times that will be considered, a modified TSIP routine can also identify when evacuation would result in a smaller area of a specified threshold of toxic effect in an ERZ than would temporary SIP. However, in order to be used as a tool to help decide between initial evacuation and SIP, the TSIP routine would need to be modified to include consideration of evacuation time estimates for each ERZ.

contour from the point of release; and r1 = distance of closest point in the zone from the point of release. The area reduction using the TSIP routine was calculated as: Area Reduction = 100% * (1 – [area from TSIP routine time/area from plume tail-time]).

4.4.5 Batch Routine Calculations

Argonne developed a batch routine that used the TSIP routine to automatically perform the following calculations for every combination of the 241 release scenarios, nine meteorological conditions, and 18 representative ERZs:

- One or more component release scenario files was read, and these were scaled, time-offset, and summed to create a representation internal to the model of the concentration-time history for that release scenario. The TSIP routine was used to determine the best time to end SIP.

- The performance of both the TSIP routine and plume tail-time was then evaluated by calculating (1) the areas in each ERZ that would experience AEGL-1, AEGL-2, and AEGL-3 impacts, and (2) the area-weighted time-integrated dosage in each ERZ. This information was saved in a temporary impact table.

- Once all release scenario/meteorological condition combinations had been processed, the impact table was further processed by the batch routine to produce the tables in Appendix E.

Similar calculations were made using another set of release scenarios provided by IEM. These were based on a set of QRA release scenarios that they had available (SAIC 1997). The set consisted of 37 release scenarios that were based on stockpile storage accidents, excluding scenarios that were based on accidents during demilitarization.[19]

For every combination of the 37 release scenarios and nine meteorological conditions, IEM ran the D2-Puff model and produced a file containing the concentration-time history. Argonne considered these concentration-time histories along with the 18 representative ERZs in the report. These files were then analyzed by the TSIP routine using the method described in Section 3.

4.4.6 Distinguishing a Practical Difference between the Methods

When both methods are using the same variables and values, the output of the TSIP routine always results in either the same or a smaller impact area than the area

[19] Source terms associated with demilitarization scenarios were not used because they duplicated storage source terms, or were too small to produce plumes that would be relevant to the report, or were too facility-specific for a report that is intended to be relevant to a typical Army chemical storage site.

calculated for the plume tail-time for the highest threshold of effects of interest when a representative input shelter ACH is used.[20] However, in order to determine if using the TSIP routine makes a difference that affects real-world outcomes, i.e., is "significant," the comparison was based primarily on instances when the time to end SIP using the TSIP routine was calculated to be fifteen minutes or more sooner than the time associated with the D2-Puff model plume tail-time. This fifteen-minute improvement in the timing of the end of SIP was deemed "significant" because it represented a real-world difference in the application of these methods as decision tools, i.e., it can be expected to result in a different announced time to end SIP.

The occasions when the times to end SIP using the TSIP routine are fifteen minutes or more earlier than the time associated with the D2-Puff model plume tail-time are then examined in two ways. First, the percentage of time that this "significant" improvement in the timing of the end of SIP is found among the cases considered was calculated. Second, the percent reduction of the area in an ERZ where the highest toxic effect threshold levels are predicted, based on the use of the TSIP routine versus the D2-Puff model plume tail-time, was calculated. The percent reduction of this area was considered to be the most important measure of the improvement in the protection obtained from SIP using the TSIP routine versus the plume tail-time method. It was also the most relevant measure, since the objective of the TSIP routine is to calculate the time to end SIP that results in the smallest area in an ERZ where the highest toxic effect levels are expected.

4.4.7 Criteria for Comparison

Two measures of the percent reduction of an area of toxic effect were considered: (1) the percent reduction in the total area summed over all cases and (2) the average of the percent area reductions for each case considered. Each of these calculations provides useful information, but looking at them side-by-side, as shown in the tables in this report, is even more informative because neither statistic is a perfect representation of the advantage of using the TSIP routine. The "percent reduction in total area" tends to underweight area reductions that are large in the relative sense but small in the absolute sense (e.g., what would tend to happen in small ERZs), while the "average percent reduction" tends to underweight those area reductions that are large in the absolute sense but small in the relative sense (e.g., what would tend to happen in large ERZs). These statistics are summarized in Section 5 and displayed in a more detailed tabular format in Appendix E.

[20] A representative input shelter ACH is a value close to the actual shelter ACH when one actual shelter ACH is suitable for an entire ERZ. A representative input shelter ACH can also be a range of input shelter ACH values when a range of input shelter ACHs is used that includes all of the actual shelter ACHs of concern in an ERZ.

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5 SUMMARY OF THE COMPARISON OF THE TWO METHODS

One of the purposes of this report is to compare the two concepts and methods for deciding when to end temporary SIP. Tables of data describing the comparison using various combinations of variables and values are in Appendix E.

In summary, the potential for life threatening effects or death (AEGL-3 effects) was present in more than 40% of the 32,609 cases examined in the report. The TSIP routine identified a time to end SIP that was different from the plume tail-time method by at least 15 minutes in more than 80% of the AEGL-3 cases, and typically reduced the area of potential AEGL-3 effects by about a third for those who were sheltered effectively within an ERZ. Similar results were observed for lower thresholds of toxic effects. The results for shelters with higher ACH were also improved when using the TSIP routine. A separate analysis of the cases where AEGL-3 effects were possible showed that the TSIP routine eliminated predicted effects at this threshold in an ERZ in more than 20% of the cases when compared with plume tail-time results.

Table 2 and Table 3 below illustrate the percent reduction in total AEGL-3 and AEGL-2 areas and average percent reduction in AEGL-3 and AEGL-2 areas when the population takes timely expedient shelter as expected; and when various shelter ACHs are used as input to the TSIP routine. See Table C-6 in Appendix C for expedient shelter ACH. Table 2 uses Argonne scenario datasets and Table 3 uses IEM scenario datasets.

TABLE 2 Extract from Table E-1

Comparison of the TSIP routine and plume tail-time method for AEGL-3 and AEGL-2 effects when the population takes timely expedient shelter as expected, i.e., the actual ACH used in the calculation is that of expedient shelter. The input ACH used by the TSIP routine is varied as shown. The calculations assumed baselines of 16 minutes to take shelter and ending SIP by exiting shelter but not relocating.

The 29,711 cases considered for this table were based on Argonne scenario datasets	Input ACH				
	Expedient	0.5	1.0	2.0	5.0
Percent of total cases when AEGL-3 effects were possible	43%	40%	37%	35%	32%
Percent of AEGL-3 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	84%	86%	88%	90%	92%
Percent reduction in total AEGL-3 area	33%	35%	37%	36%	32%
Average percent reduction in AEGL-3 area	36%	34%	34%	32%	24%
Percent of cases when the AEGL-3 area increased	0%	0%	0%	2%	7%
Percent of total cases when AEGL-2 effects were possible	21%	20%	19%	18%	16%
Percent of AEGL-2 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	83%	84%	85%	87%	88%
Percent reduction in total AEGL-2 area	62%	71%	64%	56%	44%
Average percent reduction in AEGL-2 area	37%	33%	31%	27%	19%
Percent of cases when the AEGL-2 area increased	0%	0%	1%	4%	8%

TABLE 3 Extract from Table E-16

Comparison of the TSIP routine and plume tail-time method for AEGL-3 and AEGL-2 effects when the population takes timely expedient shelter as expected, i.e., the actual ACH used in the calculation is that of expedient shelter. The input ACH used by the TSIP routine is varied as shown. The calculations assumed baselines of 16 minutes to take shelter and ending SIP by exiting shelter but not relocating.

The 2,898 cases considered for this table were based on IEM scenario datasets	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Percent of total cases when AEGL-3 effects were possible	41%	38%	36%	34%	31%
Percent of AEGL-3 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	76%	78%	81%	83%	91%
Percent reduction in total AEGL-3 area	25%	29%	30%	29%	25%
Average percent reduction in AEGL-3 area	38%	37%	36%	33%	17%
Percent of cases when the AEGL-3 area increased	0%	0%	0%	3%	16%
Percent of total cases when AEGL-2 effects were possible	14%	14%	13%	13%	12%
Percent of AEGL-2 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	76%	79%	80%	81%	90%
Percent reduction in total AEGL-2 area	88%	88%	88%	86%	80%
Average percent reduction in AEGL-2 area	37%	34%	34%	29%	8%
Percent of cases when the AEGL-2 area increased	0%	0%	2%	4%	15%

In Table 2 and Table 3 above, the percent of cases where the AEGL-3 or AEGL-2 area increased is a measure of the cases where the time to end SIP calculated by the TSIP routine results in a time that is too soon to minimize exposures for certain shelter ACHs, and therefore results in a larger area of a specific effects threshold in the ERZ than does the plume tail-time method. This parameter is always zero when the input ACH is the same as the actual ACH, but can be non-zero when there is a difference between these two values.

Table 4 and Table 5 below illustrate the percentage reduction in total AEGL-3 and AEGL-2 areas and average percentage reduction in AEGL-3 and AEGL-2 areas for cases when a range of shelter ACH is used as input to the TSIP routine to account for uncertainty about the actual ACH of shelters in an ERZ, as discussed in Section 3.2. Table 4 uses Argonne scenario datasets and Table 5 uses IEM scenario datasets.

The results summarized in Table 4 and Table 5 represent a conservative application of the TSIP routine because the input shelter air change rate is given to the TSIP routine as a range, rather than as a single optimal input ACH, with the TSIP routine then selecting the latest time for all shelter ACHs between approximately 0.2 ACH and 2.0 ACH. Had the calculations been based on a single shelter ACH as in Table 2 and Table 3, or a tighter range of ACHs for shelters, the percent area reduction would have increased noticeably.

TABLE 4 Extract from Table E-7

Comparison of the TSIP routine and plume tail-time for AEGL-3 and AEGL-2 effects for various shelter ACHs, when the input ACH used by the TSIP routine is a range from ~ 0.2 ACH to 2.0 ACH. The calculations assumed 16 minutes to take shelter and ending SIP by exiting shelter but not relocating.

The 29,711 cases considered for this table were based on Argonne scenario datasets	Actual ACH				
	Expedient	0.5	1.0	2.0	5.0
Percent of total cases when AEGL-3 effects were possible	43%	43%	43%	43%	43%
Percent of AEGL-3 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	83%	83%	83%	83%	83%
Percent reduction in total AEGL-3 area	31%	21%	16%	13%	4%
Average percent reduction in AEGL-3 area	35%	33%	29%	23%	11%
Percent of cases when the AEGL-3 area increased	0%	0%	0%	0%	2%
Percent of total cases when AEGL-2 effects were possible	21%	21%	21%	21%	21%
Percent of AEGL-2 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	82%	82%	82%	82%	82%
Percent reduction in total AEGL-2 area	59%	36%	28%	16%	7%
Average percent reduction in AEGL-2 area	35%	39%	40%	35%	26%
Percent of cases when the AEGL-2 area increased	0%	0%	0%	0%	0%

TABLE 5 Extract from Table E-22

Comparison of the TSIP routine and plume tail-time for AEGL-3 and AEGL-2 effects for various shelter ACHs, when the input ACH used by the TSIP routine is a range from ~ 0.2 ACH to 2.0 ACH. The calculations assumed 16 minutes to take shelter and ending SIP by exiting shelter but not relocating.

The 2,898 cases considered for this table were based on IEM scenario datasets	Actual ACH				
	Expedient	0.5	1.0	2.0	5.0
Percent of total cases when AEGL-3 effects were possible	41%	41%	41%	41%	41%
Percent of AEGL-3 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	75%	75%	75%	75%	75%
Percent reduction in total AEGL-3 area	25%	18%	15%	14%	6%
Average percent reduction in AEGL-3 area	37%	31%	28%	23%	12%
Percent of cases when the AEGL-3 area increased	0%	0%	0%	0%	2%
Percent of total cases when AEGL-2 effects were possible	14%	14%	14%	14%	14%
Percent of AEGL-2 cases when the TSIP routine calculated a time to end SIP that differed from plume tail-time by at least 15 minutes	75%	75%	75%	75%	75%
Percent reduction in total AEGL-2 area	88%	59%	35%	16%	4%
Average percent reduction in AEGL-2 area	37%	46%	38%	30%	16%
Percent of cases when the AEGL-2 area increased	0%	0%	0%	0%	0%

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6 SENSITIVITY OF THE TSIP ROUTINE TO SIP VARIABLES

6.1 SENSITIVITY TO VARIABLES

Another purpose of this report was to examine the sensitivity of the TSIP routine to the variables considered in the report. This was done by inspecting the data in the tables in Appendix E. Two types of trends are of special interest: (1) changes in values for a given variable that resulted in changes in the percentage of cases with significant end SIP time differences at the AEGL-3 effects level in an ERZ and (2) changes in values for a given variable that resulted in changes in the area reduction of the AEGL-3 effects level in an ERZ.

Sensitivity to Differences Between Input ACH and Actual Shelter ACH

The data in Tables E-1 through E-6 and Tables E-16 through E-21 were developed primarily to examine how well the TSIP routine works when the input ACH and the air tightness of actual shelters do not match. The data in these tables show that when there are differences between the input ACH and the actual ACH, the time to end SIP calculated by the TSIP routine sometimes results in a time that is too soon to minimize exposures for certain shelter ACHs, and therefore results in a larger area of a specific effects threshold in the ERZ than does the plume tail-time method. This parameter is always zero when the input ACH is the same as the actual ACH, but can be non-zero when there is a difference between these two values. (See Section E.3.2 in Appendix E)

Sensitivity to a Range of Input ACH Versus Various Actual Shelter ACH

The data in Tables E-7 and E-22 were developed primarily see if using a range of input ACH would offer better results when there was uncertainty about the actual ACH of shelters in an ERZ. This technique did reduce the effects of a mismatch between input ACH and actual ACH. It was deduced that the tighter the actual shelter, the greater the relative area reduction (total and average) between the TSIP routine and the plume tail-time method for the AEGL-3 effects level. (See Section E.3.3 in Appendix E.)

Sensitivity to Relocation Time after SIP

Tables E-8 and E-23 were inspected for the sensitivity of the TSIP routine to the relocation time after ending SIP, as compared with the plume tail-time. It was noted that the sooner the population relocates, the greater the relative area reduction (total and average) between the TSIP routine and the plume tail-time method for the AEGL-3 effects level. (See Section E.3.4 in Appendix E.)

Sensitivity to Time Taken to Enter Shelter

Table E-9 and Table E-24 were inspected for the sensitivity of the TSIP routine to the time taken to enter shelter after the release, as compared with the plume tail-time

method. It was deduced that the TSIP routine is not very sensitive to the "enter shelter time" when compared with the plume tail-time method. (See Sections E.1 and E.3.5 in Appendix E.)

Sensitivity to Wind Speed

Tables E-10 and E-25 were inspected for the sensitivity of the TSIP routine to wind speed, as compared with the plume tail-time method. It was noted that the percent of cases with a significant time difference between the TSIP routine and the plume tail-time method for the AEGL-3 effects level generally decreases with increasing wind speed. (See Section E.3.6 in Appendix E.)

Sensitivity to Stability Class

Tables E-11 and E-26 were inspected for the sensitivity of the TSIP routine to stability class, as compared with the plume tail-time method. It was deduced that the TSIP routine is not very sensitive to the stability class when compared with the plume tail-time method. (See Section E.3.7 in Appendix E.)

Sensitivity to Agent Dose-Response Characteristics

Table E-12 was inspected for the sensitivity of the TSIP routine to the dose-response characteristics of the agent involved, as compared with the plume tail-time method. It was noted that mustard agent had a relatively greater area of AEGL-3 effects level reduction (total and average) between the TSIP routine and the plume tail-time method than the other agents. Table E-27 did not present AEGL-3 effects for mustard. (See Section E.3.8 in Appendix E.)

Sensitivity to the Length of the ERZ

Tables E-13 and E-28 were inspected for the sensitivity of the TSIP routine to the length of the ERZ, as compared with the plume tail-time method. It was noted that the longer the ERZ, the higher the percent of cases with significant end SIP time differences between the TSIP routine and the plume tail-time method for the AEGL-3 effects level. (See Section E.3.9 in Appendix E.)

Sensitivity to the Distance of the ERZ from the Release

Tables E-14 and E-29 were inspected for the sensitivity of the TSIP routine to the distance of the ERZ from the point of release, as compared with the plume tail-time method. It was noted that the further the ERZ was from the release, the higher the percent of cases with significant end SIP time differences between the TSIP routine and the plume tail-time method for the AEGL-3 effects level. (See Section E.3.10 in Appendix E.)

Sensitivity to the Duration of the Release

Table E-15 was inspected for the sensitivity of the TSIP routine to the duration of the release, as compared with the plume tail-time method. It was noted that the TSIP routine is not very sensitive to the release duration when compared with the plume tail-time method. (See Section E.3.11 in Appendix E.)

6.2 CONCLUSIONS ABOUT SENSITIVITY

As discussed above, data in the tables in Appendix E can suggest the extent to which the TSIP routine can increase the percentage of cases with significant end SIP differences and reduce the total and average area of a selected threshold of effect, compared to the plume tail-time method. However, care must be taken in drawing conclusions from these inferences. The TSIP routine is sensitive to many variables, which sometimes interact to produce counterintuitive sensitivity results. The optimum time to end SIP based on TSIP routine calculations is the product of a non-linear, and occasionally discontinuous, function of the many input variables. The authors advise against devising simple rules for analyzing release scenarios, such as: "If the wind speed drops, the difference between the time to end SIP using the TSIP routine versus the plume tail-time method will always increase."

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7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Use of the TSIP routine can reduce mortality risks among a population vulnerable to the effects of a chemical accident. The analysis shows that the TSIP routine usually calculated times to end SIP in an ERZ that reduced the area where the most severe toxic effects were predicted, as compared with the plume tail-time method. Use of the TSIP routine eliminated areas of severe toxic effects entirely in some ERZs for some cases.

7.2 RECOMMENDATIONS

The SIPWG should consider the results of this report with a view to reaffirming or reconsidering the following recommendations made in their *Report of the CSEPP Shelter-In-Place Work Group* on December 3, 2001 (CSEPP 2001).[21]

- Recommend that the FEMA and the Army develop the routine used in the TSIP proof-of-concept model as a component of the decision tool to decide when and how to end SIP, in order to incorporate the conditions, circumstances, and options that will provide the best decision.

- Recommend that the TSIP routine be linked with a CSEPP-approved atmospheric dispersion model, and be automated to calculate the best time to end SIP for a given level of toxic effect on the sheltered population for each subzone.

- Recommend that the enhanced dispersion model with the TSIP routine be integrated in the management information system used to support the local CSEPP community's emergency responses.

- Recommend that the concept of linking the TSIP routine with the approved dispersion model be applied first at one Army chemical storage site as a pilot project. After review of the results of this pilot effort, this concept and methodology should be modified as appropriate and applied at the other sites.

[21] As of the date of this draft report the CSEPP Shelter-In-Place Work Group was being reconstituted as the CSEPP Protective Action Integrated Process Team.

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APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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APPENDIX B

LIST OF ACRONYMS

APPENDIX B

ACRONYMS

ACH	air changes per hour
AEGL	acute exposure guideline level
Argonne	Argonne National Laboratory
CSEPP	Chemical Stockpile Emergency Preparedness Program
D2PCw	Army computer dispersion model
D2-Puff™	Army computer model developed by IEM
EAS	emergency alert system
ERZ	emergency response zone
GB	nonpersistent nerve agent
HD	mustard agent
IEM	Innovative Emergency Management, Inc.
I/O	indoor/outdoor
kg	kilogram(s)
km	kilometer(s)
m	meter(s)
MCE	maximum credible event
PAD	protective action decision
PAR	protective action recommendation
QRA	quantitative risk assessment
s or sec	second(s)
SIP	shelter-in-place (refers primarily to normal, expedient, and enhanced shelter)
TAR	tone alert radio
TSIP	Terminate Shelter-In-Place (refers to an Argonne computer routine to analyze temporary shelter-in-place strategies)
VX	persistent nerve agent

APPENDIX C

VARIABLES AND VALUES CONSIDERED IN THIS REPORT

APPENDIX C

VARIABLES AND VALUES CONSIDERED IN THIS REPORT

This appendix consists of two sections. The first section lists the variables and values developed by Argonne specifically for this report. The second section lists a second set of scenario values provided by IEM, based on extracts from a QRA (SAIC 1997). All calculations to compare the methods used the same IEM AEGL algorithm and the same D2-Puff model plume concentration-time history.

C.1 ARGONNE VARIABLES AND VALUES CONSIDERED IN THE REPORT

The following tables list the variables that Argonne identified as influencing the timing of decisions to end SIP and, therefore, were considered in the report. The tables also list the values that were used for each variable in various combinations to calculate when to end SIP using the TSIP routine and the D2-Puff model plume tail-time method. The report did not run all possible combinations of variables and values—only those that were credible (as discussed in the tables) and that provided information about the utility of the TSIP routine versus the plume tail-time method.

Table C-1 lists the emergency planning zone sizes and distances from the source that were used to represent the range of possibilities on and around Army chemical storage sites.

TABLE C-1 ERZ Lengths and Distances from Source

VARIABLES	VALUES	REMARKS
ERZ length	1 km, 3 km, 5 km, 15 km, and 25 km	The distance in kilometers in any one ERZ from the closest point to the release to the furthest point from the release.
ERZ distance from release	1 km, 2 km, 10 km, 20 km, and 25 km	The distance in kilometers from the release to the closest point in an ERZ.

The report did not consider any combination of ERZ length and distance from the release that exceeded 27 km for off-post ERZs. Only combinations of 1 km, 3 km, 5 km, and 15 km ERZ lengths with 1 km and 2 km ERZ distances from the release were considered to be representative of area of consideration for on-post decisions. Also, site-specific terrain variables that the D2-Puff model is capable of accommodating were not considered in this report because the TSIP routine has not yet been linked with a D2-Puff model that incorporates site-specific ERZ terrain features. However, this did not detract from the results, because the effect of terrain features on concentration profiles impact equally on the plume tail-time and TSIP routine results.

Table C-2 lists the source term values for GB and VX that were used to develop the release profiles used in the report.

TABLE C-2 GB and VX Source Terms

VARIABLES	VALUES	REMARKS
Instantaneous releases	A range of 1 to 4 rocket warheads detonating	Warhead detonations are outside of a storage structure.
Continuous releases (spill or fire)	A range of releases of up to 547 kg from munitions or bulk containers	The report considered release durations of 5, 15, 30, 45, 60, 90, 120, 180, and 240 minutes.
Variable releases (e.g., combined instantaneous and continuous releases)	Credible combinations of releases (e.g., an explosion or fire followed by a spill)	For example, the report considered 2 rocket warheads detonating simultaneously, combined with 13 warheads leaking. Another example was 4 rocket warheads detonating simultaneously, combined with 26 warheads leaking.

The probabilities associated with various release scenarios were not considered directly. Accidents producing short-duration releases (<60 minutes) are considered to be more probable, and are well represented in the report. Catastrophic accidents capable of producing long-duration releases are considered less likely to occur, but are still represented in some of the combinations of conditions and circumstances in the report.

In developing the continuous release scenarios, the goal was to cover a wide range of release durations and quantities. The range of release durations considered in the report is presented in Table C-2. The range of release quantities included small, medium, and large values. Selection of the upper release quantities considered catastrophic fire and spill scenarios, where the fire scenarios provided the upper limit in all but a few cases. The lower limits on the release quantities were selected by considering releases that could produce at least AEGL-1 effects at least to 2 km under some sets of meteorological conditions. The medium releases were selected by considering releases that could produce AEGL-3 effects at least to 2 km under some sets of meteorological conditions.

Combinations of releases included front-end peak releases (i.e., the majority of the agent is released quickly and at the beginning of the release, with the rest of the agent released at a slower rate and over a longer time), mid-time peak releases (i.e., the majority of the agent is released quickly during the middle of the release, with the rest of the agent released at a slower rate and over a longer period of time), and tail-end peak releases (i.e., the majority of the agent is released quickly at the end of the release, with the rest of the agent released at a slower rate and over a longer time. In practice, it is expected to be very difficult to identify the source term profile of variable releases in near

real time in a fire scenario. It is less difficult to do this in the more probable worksite accidents, when finite numbers of containers or munitions are involved and their condition is more easily ascertained.

The 102 Argonne GB source terms used in the report were:

GB – 0.17 kg in 5 min
GB – 0.25 kg in 15 min
GB – 0.25 kg in 15 min, 60.5 kg in 5 min beginning at 15 min, 0.25 kg in 15 min beginning at 20 min
GB – 0.25 kg in 15 min, 8.5 kg in 5 min beginning at 15 min
GB – 0.25 kg in 15 min, 8.5 kg in 5 min beginning at 15 min, 0.25 kg in 15 min beginning at 20 min
GB – 0.4 kg in 30 min
GB – 0.4 kg in 30 min, 60.5 kg in 5 min beginning at 30 min, 0.4 kg in 30 min beginning at 35 min
GB – 0.4 kg in 30 min, 8.5 kg in 5 min beginning at 30 min
GB – 0.4 kg in 30 min, 8.5 kg in 5 min beginning at 30 min, 0.4 kg in 30 min beginning at 35 min
GB – 0.5 kg in 45 min
GB – 0.5 kg in 60 min
GB – 0.5 kg in 60 min, 60.5 kg in 5 min beginning at 60 min, 0.5 kg in 60 min beginning at 65 min
GB – 0.5 kg in 60 min, 8.5 kg in 5 min beginning at 60 min
GB – 0.5 kg in 60 min, 8.5 kg in 5 min beginning at 60 min, 0.5 kg in 60 min beginning at 65 min
GB – 0.7 kg in 90 min
GB – 0.8 kg in 120 min
GB – 0.8 kg in 120 min, 60.5 kg in 5 min beginning at 120 min, 0.8 kg in 120 min beginning at 125 min
GB – 0.8 kg in 120 min, 8.5 kg in 5 min beginning at 120 min
GB – 0.8 kg in 120 min, 8.5 kg in 5 min beginning at 120 min, 0.8 kg in 120 min beginning at 125 min
GB – 0.9 kg in 180 min
GB – 0.9 kg in 180 min, 8.5 kg in 5 min beginning at 180 min
GB – 1 kg in 240 min
GB – 1 kg in 240 min, 8.5 kg in 5 min beginning at 240 min
GB – 11.5 kg in 15 min
GB – 11.5 kg in 15 min, 60.5 kg in 5 min beginning at 15 min, 11.5 kg in 15 min beginning at 20 min
GB – 12.62 kg in 1 min, 0.34 kg in 5 min beginning at 1 min
GB – 12.62 kg in 1 min, 0.8 kg in 30 min beginning at 1 min
GB – 12.62 kg in 1 min, 1 kg in 60 min beginning at 1 min
GB – 12.62 kg in 1 min, 1.6 kg in 120 min beginning at 1 min
GB – 12.62 kg in 1 min, 1.8 kg in 180 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 120 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 180 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 240 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 30 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 5 min beginning at 1 min
GB – 12.62 kg in 1 min, 126 kg in 60 min beginning at 1 min
GB – 12.62 kg in 1 min, 17 kg in 5 min beginning at 1 min
GB – 12.62 kg in 1 min, 2 kg in 240 min beginning at 1 min
GB – 12.62 kg in 1 min, 40 kg in 30 min beginning at 1 min
GB – 12.62 kg in 1 min, 48 kg in 60 min beginning at 1 min
GB – 12.62 kg in 1 min, 66 kg in 120 min beginning at 1 min
GB – 12.62 kg in 1 min, 80 kg in 180 min beginning at 1 min
GB – 12.62 kg in 1 min, 90 kg in 240 min beginning at 1 min
GB – 14.5 kg in 1 min
GB – 182 kg in 15 min
GB – 2.43 kg in 1 min
GB – 20 kg in 30 min
GB – 20 kg in 30 min, 60.5 kg in 5 min beginning at 30 min, 20 kg in 30 min beginning at 35 min
GB – 22 kg in 45 min
GB – 24 kg in 60 min
GB – 24 kg in 60 min, 60.5 kg in 5 min beginning at 60 min, 24 kg in 60 min beginning at 65 min
GB – 29 kg in 90 min
GB – 33 kg in 120 min
GB – 33 kg in 120 min, 60.5 kg in 5 min beginning at 120 min, 33 kg in 120 min beginning at 125 min

GB – 363 kg in 30 min
GB – 40 kg in 180 min
GB – 410.3 kg in 45 min
GB – 45 kg in 240 min
GB – 547 kg in 120 min
GB – 547 kg in 180 min
GB – 547 kg in 240 min
GB – 547 kg in 60 min
GB – 547 kg in 90 min
GB – 6.31 kg in 1 min
GB – 6.31 kg in 1 min, 0.17 kg in 5 min beginning at 1 min
GB – 6.31 kg in 1 min, 0.4 kg in 30 min beginning at 1 min
GB – 6.31 kg in 1 min, 0.5 kg in 60 min beginning at 1 min
GB – 6.31 kg in 1 min, 0.8 kg in 120 min beginning at 1 min
GB – 6.31 kg in 1 min, 0.9 kg in 180 min beginning at 1 min
GB – 6.31 kg in 1 min, 1 kg in 240 min beginning at 1 min
GB – 6.31 kg in 1 min, 20 kg in 30 min beginning at 1 min
GB – 6.31 kg in 1 min, 24 kg in 60 min beginning at 1 min
GB – 6.31 kg in 1 min, 33 kg in 120 min beginning at 1 min
GB – 6.31 kg in 1 min, 40 kg in 180 min beginning at 1 min
GB – 6.31 kg in 1 min, 45 kg in 240 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 120 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 180 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 240 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 30 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 5 min beginning at 1 min
GB – 6.31 kg in 1 min, 63 kg in 60 min beginning at 1 min
GB – 6.31 kg in 1 min, 8.5 kg in 5 min beginning at 1 min
GB – 60.5 kg in 5 min
GB – 60.5 kg in 5 min, 0.25 kg in 15 min beginning at 5 min
GB – 60.5 kg in 5 min, 0.4 kg in 30 min beginning at 5 min
GB – 60.5 kg in 5 min, 0.5 kg in 60 min beginning at 5 min
GB – 60.5 kg in 5 min, 0.8 kg in 120 min beginning at 5 min
GB – 60.5 kg in 5 min, 0.9 kg in 180 min beginning at 5 min
GB – 60.5 kg in 5 min, 1 kg in 240 min beginning at 5 min
GB – 60.5 kg in 5 min, 11.5 kg in 15 min beginning at 5 min
GB – 60.5 kg in 5 min, 20 kg in 30 min beginning at 5 min
GB – 60.5 kg in 5 min, 24 kg in 60 min beginning at 5 min
GB – 60.5 kg in 5 min, 33 kg in 120 min beginning at 5 min
GB – 60.5 kg in 5 min, 40 kg in 180 min beginning at 5 min
GB – 60.5 kg in 5 min, 45 kg in 240 min beginning at 5 min
GB – 8.5 kg in 5 min
GB – 8.5 kg in 5 min, 0.25 kg in 15 min beginning at 5 min
GB – 8.5 kg in 5 min, 0.4 kg in 30 min beginning at 5 min
GB – 8.5 kg in 5 min, 0.5 kg in 60 min beginning at 5 min
GB – 8.5 kg in 5 min, 0.8 kg in 120 min beginning at 5 min
GB – 8.5 kg in 5 min, 0.9 kg in 180 min beginning at 5 min
GB – 8.5 kg in 5 min, 1 kg in 240 min beginning at 5 min

The 76 Argonne VX source terms used in the report were:

VX – 0.005 kg in 5 min
VX – 0.007 kg in 15 min
VX – 0.007 kg in 15 min, 0.25 kg in 5 min beginning at 15 min
VX – 0.007 kg in 15 min, 0.25 kg in 5 min beginning at 15 min, 0.007 kg in 15 min beginning at 20 min
VX – 0.007 kg in 15 min, 38 kg in 5 min beginning at 15 min, 0.007 kg in 15 min beginning at 20 min
VX – 0.012 kg in 30 min
VX – 0.012 kg in 30 min, 0.25 kg in 5 min beginning at 30 min
VX – 0.012 kg in 30 min, 0.25 kg in 5 min beginning at 30 min, 0.012 kg in 30 min beginning at 35 min
VX – 0.012 kg in 30 min, 38 kg in 5 min beginning at 30 min, 0.012 kg in 30 min beginning at 35 min
VX – 0.012 kg in 45 min
VX – 0.014 kg in 60 min

VX – 0.014 kg in 60 min, 0.25 kg in 5 min beginning at 60 min
VX – 0.014 kg in 60 min, 0.25 kg in 5 min beginning at 60 min, 0.014 kg in 60 min beginning at 65 min
VX – 0.014 kg in 60 min, 38 kg in 5 min beginning at 60 min, 0.014 kg in 60 min beginning at 65 min
VX – 0.017 kg in 90 min
VX – 0.021 kg in 120 min
VX – 0.021 kg in 120 min, 0.25 kg in 5 min beginning at 120 min
VX – 0.021 kg in 120 min, 0.25 kg in 5 min beginning at 120 min, 0.021 kg in 120 min beginning at 125 min
VX – 0.021 kg in 120 min, 38 kg in 5 min beginning at 120 min, 0.021 kg in 120 min beginning at 125 min
VX – 0.025 kg in 180 min
VX – 0.025 kg in 180 min, 0.25 kg in 5 min beginning at 180 min
VX – 0.03 kg in 240 min
VX – 0.03 kg in 240 min, 0.25 kg in 5 min beginning at 240 min
VX – 0.25 kg in 5 min
VX – 0.25 kg in 5 min, 0.007 kg in 15 min beginning at 5 min
VX – 0.25 kg in 5 min, 0.012 kg in 30 min beginning at 5 min
VX – 0.25 kg in 5 min, 0.014 kg in 60 min beginning at 5 min
VX – 0.25 kg in 5 min, 0.021 kg in 120 min beginning at 5 min
VX – 0.25 kg in 5 min, 0.025 kg in 180 min beginning at 5 min
VX – 0.25 kg in 5 min, 0.03 kg in 240 min beginning at 5 min
VX – 0.3 kg in 15 min
VX – 0.3 kg in 15 min, 38 kg in 5 min beginning at 15 min, 0.3 kg in 15 min beginning at 20 min
VX – 0.5 kg in 30 min
VX – 0.5 kg in 30 min, 38 kg in 5 min beginning at 30 min, 0.5 kg in 30 min beginning at 35 min
VX – 0.55 kg in 45 min
VX – 0.65 kg in 60 min
VX – 0.65 kg in 60 min, 38 kg in 5 min beginning at 60 min, 0.65 kg in 60 min beginning at 65 min
VX – 0.75 kg in 90 min
VX – 0.85 kg in 120 min
VX – 0.85 kg in 120 min, 38 kg in 5 min beginning at 120 min, 0.85 kg in 120 min beginning at 125 min
VX – 1 kg in 180 min
VX – 1.1 kg in 240 min
VX – 115 kg in 15 min
VX – 18.16 kg in 1 min, 0.88 kg in 30 min beginning at 1 min
VX – 18.16 kg in 1 min, 1.76 kg in 60 min beginning at 1 min
VX – 18.16 kg in 1 min, 3.54 kg in 120 min beginning at 1 min
VX – 18.16 kg in 1 min, 5.3 kg in 180 min beginning at 1 min
VX – 18.16 kg in 1 min, 7.06 kg in 240 min beginning at 1 min
VX – 18.2 kg in 1 min
VX – 229 kg in 30 min
VX – 344 kg in 45 min
VX – 38 kg in 5 min
VX – 38 kg in 5 min, 0.007 kg in 15 min beginning at 5 min
VX – 38 kg in 5 min, 0.012 kg in 30 min beginning at 5 min
VX – 38 kg in 5 min, 0.014 kg in 60 min beginning at 5 min
VX – 38 kg in 5 min, 0.021 kg in 120 min beginning at 5 min
VX – 38 kg in 5 min, 0.025 kg in 180 min beginning at 5 min
VX – 38 kg in 5 min, 0.03 kg in 240 min beginning at 5 min
VX – 38 kg in 5 min, 0.3 kg in 15 min beginning at 5 min
VX – 38 kg in 5 min, 0.5 kg in 30 min beginning at 5 min
VX – 38 kg in 5 min, 0.65 kg in 60 min beginning at 5 min
VX – 38 kg in 5 min, 0.85 kg in 120 min beginning at 5 min
VX – 38 kg in 5 min, 1 kg in 180 min beginning at 5 min
VX – 38 kg in 5 min, 1.1 kg in 240 min beginning at 5 min
VX – 4.54 kg in 1 min
VX – 458 kg in 120 min
VX – 458 kg in 180 min
VX – 458 kg in 240 min
VX – 458 kg in 60 min
VX – 458 kg in 90 min
VX – 9.08 kg in 1 min
VX – 9.08 kg in 1 min, 0.44 kg in 30 min beginning at 1 min
VX – 9.08 kg in 1 min, 0.88 kg in 60 min beginning at 1 min

VX – 9.08 kg in 1 min, 1.77 kg in 120 min beginning at 1 min
VX – 9.08 kg in 1 min, 2.65 kg in 180 min beginning at 1 min
VX – 9.08 kg in 1 min, 3.53 kg in 240 min beginning at 1 min

Table C-3 lists the source term values for mustard agent that were used to develop the release profiles used in the report.

TABLE C-3 HD Source Terms

VARIABLES	VALUES	REMARKS
Continuous steady releases (spill or fire)	A range of releases of up to 1,220 kg from munitions or bulk containers	The report considered release durations of 5, 15, 30, 45, 60, 90, 120, 180, and 240 minutes, outside of a storage structure.
Variable releases	Credible combinations of releases	

In developing the continuous-release scenarios for mustard, the goal was to cover a wide range of release durations and quantities, as was done for GB and VX. The range of release durations considered in the report is presented in Table C-3. The range of release quantities included small, medium, and large values. Selection of the upper release quantities considered catastrophic fire and spill scenarios, where the fire scenarios provided the upper limit in all but a few cases. The lower limits on the release quantities were selected by considering releases that could produce at least AEGL-1 effects at least to 2 km under some sets of meteorological conditions. The medium releases were selected by considering releases that could produce AEGL-3 effects at least to 2 km under some sets of meteorological conditions.

Only a small fraction of available liquid mustard is expected to be converted instantaneously to a vapor during an explosive release.[22] In order for explosive mustard releases to produce a relatively large vapor hazard, the agent must evaporate after being dispersed by the explosion. While D2PCw and D2-Puff models have a unique method for treating mustard releases, the authors assumed that considering only steady releases was sufficient for the purposes of the comparison discussed in this report (i.e., explosive releases per se were not considered).

The 63 Argonne HD source terms used in the report were:

HD – 101 kg in 5 min
HD – 101 kg in 5 min, 13 kg in 120 min beginning at 5 min
HD – 101 kg in 5 min, 13 kg in 15 min beginning at 5 min
HD – 101 kg in 5 min, 13 kg in 180 min beginning at 5 min
HD – 101 kg in 5 min, 13 kg in 240 min beginning at 5 min
HD – 101 kg in 5 min, 13 kg in 30 min beginning at 5 min
HD – 101 kg in 5 min, 13 kg in 60 min beginning at 5 min
HD – 101 kg in 5 min, 200 kg in 15 min beginning at 5 min

[22] This is based on an analysis of the D2PCw and D2-Puff routines that model explosive mustard releases, where approximately 2% of the agent is released instantaneously and the rest is potentially available to be released by evaporation.

HD – 101 kg in 5 min, 350 kg in 30 min beginning at 5 min
HD – 101 kg in 5 min, 400 kg in 120 min beginning at 5 min
HD – 101 kg in 5 min, 400 kg in 180 min beginning at 5 min
HD – 101 kg in 5 min, 400 kg in 240 min beginning at 5 min
HD – 101 kg in 5 min, 450 kg in 60 min beginning at 5 min
HD – 120 kg in 5 min
HD – 120 kg in 5 min, 13 kg in 120 min beginning at 5 min
HD – 120 kg in 5 min, 13 kg in 15 min beginning at 5 min
HD – 120 kg in 5 min, 13 kg in 180 min beginning at 5 min
HD – 120 kg in 5 min, 13 kg in 240 min beginning at 5 min
HD – 120 kg in 5 min, 13 kg in 30 min beginning at 5 min
HD – 120 kg in 5 min, 13 kg in 60 min beginning at 5 min
HD – 1220 kg in 120 min
HD – 1220 kg in 180 min
HD – 1220 kg in 240 min
HD – 1220 kg in 60 min
HD – 1220 kg in 90 min
HD – 13 kg in 120 min
HD – 13 kg in 120 min, 101 kg in 5 min beginning at 120 min, 13 kg in 120 min beginning at 125 min
HD – 13 kg in 120 min, 120 kg in 5 min beginning at 120 min
HD – 13 kg in 120 min, 120 kg in 5 min beginning at 120 min, 13 kg in 120 min beginning at 125 min
HD – 13 kg in 15 min
HD – 13 kg in 15 min, 101 kg in 5 min beginning at 15 min, 13 kg in 15 min beginning at 20 min
HD – 13 kg in 15 min, 120 kg in 5 min beginning at 15 min
HD – 13 kg in 15 min, 120 kg in 5 min beginning at 15 min, 13 kg in 15 min beginning at 20 min
HD – 13 kg in 180 min
HD – 13 kg in 180 min, 120 kg in 5 min beginning at 180 min
HD – 13 kg in 240 min
HD – 13 kg in 240 min, 120 kg in 5 min beginning at 240 min
HD – 13 kg in 30 min
HD – 13 kg in 30 min, 101 kg in 5 min beginning at 30 min, 13 kg in 30 min beginning at 35 min
HD – 13 kg in 30 min, 120 kg in 5 min beginning at 30 min
HD – 13 kg in 30 min, 120 kg in 5 min beginning at 30 min, 13 kg in 30 min beginning at 35 min
HD – 13 kg in 45 min
HD – 13 kg in 5 min
HD – 13 kg in 60 min
HD – 13 kg in 60 min, 101 kg in 5 min beginning at 60 min, 13 kg in 60 min beginning at 65 min
HD – 13 kg in 60 min, 120 kg in 5 min beginning at 60 min
HD – 13 kg in 60 min, 120 kg in 5 min beginning at 60 min, 13 kg in 60 min beginning at 65 min
HD – 13 kg in 90 min
HD – 200 kg in 15 min
HD – 200 kg in 15 min, 101 kg in 5 min beginning at 15 min, 200 kg in 15 min beginning at 20 min
HD – 305 kg in 15 min
HD – 350 kg in 30 min, 101 kg in 5 min beginning at 30 min, 350 kg in 30 min beginning at 35 min
HD – 400 kg in 120 min
HD – 400 kg in 120 min, 101 kg in 5 min beginning at 120 min, 400 kg in 120 min beginning at 125 min
HD – 400 kg in 180 min
HD – 400 kg in 240 min
HD – 450 kg in 30 min
HD – 450 kg in 45 min
HD – 450 kg in 60 min
HD – 450 kg in 60 min, 101 kg in 5 min beginning at 60 min, 450 kg in 60 min beginning at 65 min
HD – 450 kg in 90 min
HD – 610 kg in 30 min
HD – 915 kg in 45 min

Table C-4 lists the meteorological conditions that were considered in the report.

TABLE C-4 Meteorological Conditions

VARIABLES	VALUES	REMARKS
Stability class and wind speed	Stability class B with wind speeds of 1 m/s and 2 m/s. Stability class D with wind speeds of 1 m/s, 2 m/s, 5 m/s, 10 m/s, and 15 m/s. Stability class F with wind speeds of 1 m/s and 2 m/s.	The report did not directly consider changing meteorology during the duration of the release, but variable release rates, which are considered (see Tables C-2 and C-3), offer similar utility for the report because both produce variable concentration profiles.

Table C-5 lists the dose-response relationships that were considered in the report.

TABLE C-5 Dose-Response Relationships

VARIABLE	VALUES	REMARKS
Dose-response relationship	AEGL-1, AEGL-2, and AEGL-3	The IEM AEGL algorithm was used for all cases in the report.

AEGLs are used as the toxicity criteria for mustard and nerve agents within the CSEPP for emergency planning and response. AEGLs considers the sensitivity of the general population to short-term, one-time exposure to these chemical warfare agents, the duration of the exposure, and the extent to which bodies can withstand some nerve agent exposure. (See discussion in Section 1.3.1.)

Table C-6 lists the air changes per hour, or ACH, that were considered in the report.

TABLE C-6 Shelter Air Change Rates

VARIABLE	VALUES	REMARKS
Shelter air change rates	Approximately 0.2 ACH (expedient shelter), 0.5 ACH, 1.0 ACH, 2.0 ACH, and 5.0 ACH	See notes below and the *Report of the CSEPP Shelter-In-Place Work Group* (CSEPP 2001).

Expedient shelter was represented in the report by an ACH of 0.5 for the first 15 minutes in shelter while installing expedient measures (plastic and duct tape to seal openings in a room), followed by an ACH of 0.2 for the duration of the time in shelter

(Sorensen 1988 and Rogers et al. 1990). This is also referred to as "approximately 0.2 ACH" in the report to indicate that 0.2 ACH is not obtained immediately upon entering shelter.

0.5 ACH represents homes that are weatherized or built since the 1970s, but without expedient measures taken.

1.0 ACH represents typical construction built in 1950-1970 without enhancements, or lower ACH construction under conditions of moderate wind speeds or temperature differentials.

2.0 ACH represents leaky residential structures.

5.0 ACH represents well-ventilated structures, or lower ACH construction under conditions of high wind speeds or temperature differentials. This value was used in the report to represent structures occupied by the percentage of the population who were unaware of the hazard until they were notified to end SIP, and thus made no special effort to enhance their protection during the passage of the plume. This value was also used in this report to represent the ventilation rate of shelters that remained occupied by persons whose action to end SIP was to ventilate shelters but remain inside.

Table C-7 lists the times to implement SIP that were considered in the report.

TABLE C-7 Times to Implement SIP

VARIABLE	VALUES	REMARKS
Time to take normal shelter after release	0 minutes, 8 minutes, 16 minutes, 21 minutes, and 30 minutes	The time to take normal SIP in an ERZ can be a locally determined default value, but the TSIP routine will allow for manual input during the response to replace the default.
Time to add expedient protection to normal shelter protection	15 minutes	This time assumes that all preparations to install expedient protection are in place and that the population knows how to do this quickly. Adding expedient protection was considered equal to reducing the ACH in the shelter to 0.2.

0 minutes represents an assumption that most of the population is already indoors at the time of the release.

8 minutes represents an assumption of immediate detection of the release, 5 minutes for the Army to make a protective action decision (PAD) and alert and notify the affected post population, and 3 minutes for a knowledgeable and prepared on-post population to take shelter in a building with 0.5, 1.0, or 2.0 ACH but without expedient

enhancements.

16 minutes represents an assumption of immediate detection of the release, 5 minutes for the Army to send a protective action recommendation to off-post jurisdictions, 8 minutes for the off-post population to be alerted and notified about the need to SIP, and 3 minutes for a knowledgeable and prepared population to take shelter in a building with an 0.5, 1.0, or 2.0 ACH but without expedient enhancements.[23]

21 minutes represents an assumption of immediate detection of the release, 10 minutes for the Army to send a protective action recommendation to off-post jurisdictions, 8 minutes for the off-post population to be alerted and notified about the need to SIP, and 3 minutes for a knowledgeable and prepared population to take shelter in a building with 0.5, 1.0, or 2.0 ACH but without expedient enhancements.[24]

30 minutes represents additional time to take SIP because of an unexpected delay in alert and notification.

Table C-8 lists the actions upon ending SIP that were considered in the report.

TABLE C-8 Actions upon Ending SIP

VARIABLE	VALUES	REMARKS
Time outside the shelter after ending SIP	Infinite	The population in an ERZ exits from shelters when notified to end SIP, but does not relocate away from the vicinity of the shelter. This could allow additional exposure outside the shelter until the plume has dissipated at that location.
Time taken to relocate to a safe distance away from the shelter after ending SIP	15 minutes and 20 minutes	In practice, the time a population in an ERZ takes to relocate following SIP will be a locally determined default value, but the TSIP routine will allow for manual input during the response to replace the default. This could involve some additional exposure while relocating, until the population is away from the plume.

[23] Information about the estimated time needed to take shelter after alert and notification, to include time to close doors and windows and turn off HVAC, was developed from information presented by Dr. John Sorensen at a CSEPP National Conference (Sorensen 2002).

[24] The selection of 5 and 10 minutes for the Army to provide a PAR to off-post jurisdictions reflect the guidance that the Army has less time to provide a PAR for a jurisdiction where the off-post population is close to the installation.

The report considered two of four possible options discussed below for ending SIP. These are to relocate immediately to a designated safe facility or to exit from the shelter but remain nearby.[25]

Exit and relocate. Local officials may direct that upon the termination of SIP, sheltered populations should relocate to designated facilities to be accounted for and medically screened for agent exposure symptoms (CSEPP 1996). In this case, the instructions would be to exit from shelters and proceed immediately to a place where this follow-up can occur. Instructions should identify the routes to take to avoid re-encountering the plume and to avoid traffic bottlenecks. Designated routes and facilities for relocation might not be the same as for an initial evacuation. In dire circumstances, such as if the duration of the release is longer than originally expected and SIP is no longer a good choice, sheltered persons might be asked to relocate immediately to a safer place. This option was considered in this report as an option in Tables E-8 and E-23, but not as a baseline in the report. It is expected that a sheltered population will have some advance notice to relocate, versus a no-notice initial direction to evacuate or SIP (see Section 4.4.6). Persons leaving shelter should be able to move away from any hazardous vapors within 15 to 20 minutes, though it might take longer for them to reach their ultimate relocation destination. This option reflects the recommendation by the SIP Work Group (CSEPP 2001) to end SIP by using direct routes to quickly move away from residual hazardous vapors, to avoid catching up with the vapor plume, and their informal estimates of how long this might take if the sheltered population had immediate access to suitable transportation.

Exit and remain nearby. To decrease the overall exposure, local officials might instruct the public not to take the time to open windows, remove tape, turn on ventilation equipment, etc., prior to leaving the building. Rather, they should simply go outside and let the building ventilate itself gradually. The potential for aerosol deposition should be a minor consideration since it is such a remote possibility, and not likely to be a safety factor at great distances from the source even if an agent aerosol is generated by the event. This might also be the best option for persons who lack transportation to relocate. This option was considered in this report as the baseline action for ending SIP.

Ventilate shelter and remain indoors. In some cases, the only option to end SIP might be to remain indoors but ventilate the building by opening doors and windows, turning on ventilation equipment, and moving to the part of the building where the air exchange with the outside is the greatest. This might be the only option for disabled persons or special populations who lack the mobility to exit the shelter. This option also might apply when the weather is so dangerous that remaining outside for an extended period is inadvisable or there is believed to be some other hazard outdoors to be avoided. The TSIP routine is capable of considering the option to ventilate a

[25] If persons are going to exit or relocate, ventilation of the shelter after everyone has exited is not that important, and might result in additional harmful exposure in the process. Also, some people might be reluctant to leave their homes unsecured, and delay their exit and relocation while they secure their valuables or collect their valuables to take with them.

shelter but remain inside. This option was considered in the report, but not as the baseline action for ending SIP. Ventilating a shelter at 5.0 ACH was considered for 5,184 randomly selected cases based on 32 release scenarios, to test the effect of exercising this option. Of these, 4,023 cases were relevant to the report.[26] The results were similar to exiting shelter but not relocating, but the average reduction in the size of areas affected at various thresholds of effect was less, relative to the plume tail-time method.

Resume normal activity. Resuming normal activity with no restrictions would be an appropriate action for persons who were never in danger, but who were sheltered as a precaution. This is the usual interpretation of "all clear." This option did not warrant inclusion in the report because the time to end SIP is not a factor for a population that was never in danger.

C.2 IEM QRA VALUES CONSIDERED IN THE REPORT

IEM provided a list of source term values to consider in the report separate from the list developed by Argonne.

The 17 IEM GB source terms used in the report were:

GB – 0.463 kg 3600 sec, 0.340 kg 7200 sec
GB – 0.485 kg 3600 sec
GB – 0.499 kg 3600 sec
GB – 0.508 kg 60 sec, 5.2 kg 11640 sec
GB – 0.953 kg 3600 sec
GB – 0.971 kg 3600 sec
GB – 13.381 kg 60 sec, 126.099 kg 11640 sec
GB – 2.037 kg 60 sec, 20.638 kg 11640 sec
GB – 2.177 kg 3600 sec
GB – 2.404 kg 3600 sec
GB – 360.606 kg 300 sec
GB – 4.808 kg 3600 sec
GB – 4.808 kg 3600 sec
GB – 539.774 kg 300 sec
GB – 6.713 kg 60 sec, 63.049 kg 11640 sec
GB – 6.713 kg 60 sec, 8.391 kg 21600 sec
GB – 721.211 kg 300 sec

The 11 IEM VX source terms used in the report were:

VX – 12.156 kg 60 sec, 0.158 kg 21600 sec
VX – 12.156 kg 60 sec, 0.161 kg 21600 sec
VX – 15.422 kg 60 sec, 0.118 kg 21600 sec
VX – 2.431 kg 60 sec, 0.020 kg 21600 sec
VX – 301.639 kg 300 sec
VX – 452.685 kg 300 sec
VX – 6.849 kg 60 sec
VX – 603.277 kg 300 sec

[26] A case is relevant in this report only when AEGL-1 toxic effects or greater are possible in an unsheltered population in an ERZ.

VX – 7.711 kg 60 sec, 0.004 kg 21600 sec
VX – 7.711 kg 60 sec, 0.060 kg 21600 sec
VX – 7.711 kg 60 sec, 0.061 kg 21600 sec

The nine IEM HD source terms used in the report were:

HD – 1.066 kg 60 sec, 0.640 kg 21600 sec
HD – 0.721 kg 3600 sec
HD – 4.191 kg 60 sec, 2.463 kg 21600 sec
HD – 0.753 kg 3600 sec
HD – 2.150 kg 60 sec, 1.234 kg 21600 sec
HD – 2.150 kg 60 sec, 1.275 kg 21600 sec
HD – 0.785 kg 3600 sec
HD – 8.845 kg 3600 sec
HD – 5.126 kg 3600 sec

APPENDIX D

BEST PRACTICES FOR ENDING SHELTER-IN-PLACE

APPENDIX D

BEST PRACTICES FOR ENDING SHELTER-IN-PLACE

This section discusses best practices to support an effective SIP termination strategy from the report published by the CSEPP SIP Work Group (CSEPP 2001). These best practices apply to any concept and method to end SIP and are especially relevant to the two concepts and methods discussed in this report.

D.1 USE OF MODELING TO SUPPORT A SHELTER TERMINATION STRATEGY

A single model should be used to help decide when and how to end SIP. This model should consider all of the conditions, circumstances, and options that will provide the best decision. In addition, the best decision is one that:

- Is based on when the plume concentration outside becomes less than that inside shelters.
- Considers the dose-response relationship that is most relevant to the effects of the agent on a sheltered population.
- Considers exposure before, during, and after SIP.
- Provides information to minimize fatalities.

D.2 USE OF A PUBLIC EDUCATION PROGRAM TO SUPPORT A SHELTER TERMINATION STRATEGY

Public education must explain the vapor infiltration concern; yet convince the potentially affected population that SIP is a viable action if this protection is ended at the appropriate time. The education program should include specific information about how the public will be told when to end SIP, and that this instruction might come very soon after the initial direction to take shelter. It is also important that the actual SIP notification messages are consistent with the public education program that explains the SIP protective action messages, so the public will not be confused or misunderstand what they are being asked to do. The public also needs to be educated about what actions to take to end SIP. It is too simplistic to announce "All Clear." A program of pre-emergency public education should convey the following to ensure timely and effective public response to end SIP during an actual emergency.

- The hazard of concern is primarily a vapor. The hazard will most likely be an invisible and odorless vapor that is transported downwind as a plume that expands and dilutes as it travels, and eventually dissipates.

- Vapor infiltration can reduce the protection of a shelter over time. A population can reduce the risk of exposure to hazardous vapor by going indoors and shutting off ventilation to the outside. However, every building leaks air, and outside vapors will infiltrate shelters that are in the path of the plume. Thus, as outside air infiltrates the shelter, the protection afforded by the shelter gradually declines. Eventually, sometime after the highest concentration of the vapor plume has passed the shelter, outside air will be cleaner than the air inside the shelter. Officials will consider this fact when instructing the sheltered population to ventilate or leave their shelters.

- The public will be notified about shelter-in-place protective actions. The Army will notify local officials promptly if a chemical accident occurs. These officials will alert and notify the affected population quickly, and instruct them on initial protective actions. Persons who have taken shelter will be told when and how to end SIP when officials have decided that it is time to do so.

- Shelter-in-place is a temporary, two-step process. First, a population must quickly take the best shelter available. Then, the population must end this protective action when instructed.

- Timing is important in both steps of this process. Taking shelter-in-place immediately when instructed will minimize exposure to toxic vapors, provided that one also ventilates or leaves the shelter immediately when told to do so.

- Shelter-in-place must include an exit strategy. When taking shelter, one should bring a radio tuned to the local emergency alert system (EAS) station, in order to receive instructions about when and how to end shelter-in-place. (This direction might be modified to accommodate tone alert radios (TARs) in those jurisdictions where TARs are installed.) When local officials have decided that shelter-in-place should be ended in an area, the sheltered population may be instructed to resume normal activity without restrictions, ventilate shelters but remain indoors, exit from shelters but remain nearby, or relocate to a designated facility for reasons such as accountability or medical screening.

D.3 USE OF EMERGENCY INSTRUCTIONS TO SUPPORT A SHELTER TERMINATION STRATEGY

An effective shelter termination strategy must include emergency instructions that meet the following criteria:

- Emergency instructions must be consistent with public education materials, and vice versa. Instructions during an emergency should describe actions and choices that have been previously introduced in public education materials, and use the exact terms and phrases used in these materials. Due to the short time available for messages on the EAS, sirens, and TARs, there is no opportunity for these messages to explain the practical meaning of terms such as "shelter-in-place" or "relocate." Their meaning must be explained and the groundwork laid for action ahead of time through an effective and comprehensive public education program.

- Actual emergency instructions must be as clear and concise as possible, regardless of the scope and effectiveness of the public education program, because the affected population will probably include some who were not reached by the SIP public education program, such as transients and new arrivals. In addition, local officials and other credible community leaders should provide supplemental emergency information and explanation through media outlets to reinforce emergency instructions broadcast on alert and notification systems.

- Instructions to the public while in shelters should be repeated at frequent intervals. The sheltered population should be encouraged to sustain this protection and remain alert for directions on when and how to end their SIP. Instructions should also direct persons to take SIP immediately if they have not yet done so, and reiterate basic SIP instructions. This includes how to use SIP kits, if provided, or how to improvise other expedient measures to improve the protection of the shelter.

- Instructions to the sheltered population should include the best time for ending SIP, the preferred way to end SIP, and alternatives if the preferred option is not possible. It should be remembered that instructions to end SIP are appropriate even for areas where evacuation was recommended, in the event that some persons could not or would not evacuate.

D.4 USE OF AGREEMENTS TO SUPPORT A SHELTER TERMINATION STRATEGY

Army and off-post authorities should formally agree on what information concerning SIP will be exchanged among organizations during an emergency to ensure that this action will be timed and implemented effectively. Agreements should cover protocols and practical details about how the information will be communicated, comparable to arrangements currently in place for making initial protective action recommendations (PARs) and PADs. This exchange could be addressed in separate agreements, or incorporated into existing agreements such as those pertaining to alert and notification or mutual aid. The following should be considered:

- The Army should provide projections of optimal shelter termination times for each ERZ affected by the release as soon as possible after making the initial PAR,

regardless of whether the initial PAR was to evacuate or SIP. These estimates should be used by local officials to anticipate SIP termination PARs and PADs.

- All emergency response officials should immediately share PADs made within their jurisdiction with all other jurisdictions involved in the response to the accident. This includes sharing of Army PADs with off-post officials, and vice versa. This will enable all jurisdictions to anticipate the impact that a PAD in one ERZ will have on other ERZs regarding mutual assistance with relocating and medically screening persons who were sheltered-in-place. Off-post officials should also inform the Army when the direction to SIP was broadcast in each ERZ, and how long the officials believe it took or will take the population to execute this PAD. This will enable the Army to provide better PAR updates.

- The Army should provide PARs to end SIP for each ERZ affected by the appropriate, agreed-upon toxic hazard levels of concern as soon as possible, so off-post officials have time to consider the PARs and implement corresponding PADs. These updated PARs to end SIP should be provided regardless of whether the initial PARs were to evacuate or SIP, because some individuals might have taken shelter instead of evacuating. These PARs should be based on current information about conditions at the accident site and information from off-post officials about the implementation of PADs to evacuate or SIP in each ERZ.

D.5 USE OF PLANS TO SUPPORT A SHELTER TERMINATION STRATEGY

The Army and each off-post jurisdiction should expand their emergency response plans to cover the essential elements of a temporary SIP effort. The following should be incorporated in these plans:

- All plans should describe and discuss the concept and methodology to decide when and how to end SIP in a timely and appropriate manner. The concept and methodology should incorporate consideration for all of the important variables that bear on decisions to end SIP, and implement the CSEPP policy (CSEPP 1991) that fatalities will be avoided to the maximum extent possible.

- All plans should discuss education of the public to understand and respond to instructions to end SIP.

- All plans should include protocols for sharing SIP termination information with other jurisdictions as described in formal agreements. This includes feeding information to the Joint Information System and to the Joint Information Center.

- All plans should include procedures for the timely broadcast of instructions to end SIP, consistent with the public education effort and preplanned emergency instructions. This should include consideration for broadcasting the direction to end SIP selectively within certain large ERZs or in special facilities, especially if

that will minimize the potential for fatalities. Consideration also should be given to broadcasting instructions to end SIP in ERZs where the original PAD was to evacuate, to accommodate those persons who could not or would not evacuate.

- All plans should provide for support of the sheltered population upon termination of SIP. This includes the selection of relocation routes to avoid areas that might remain potentially hazardous, and the establishment of relocation and medical screening facilities that might be different from those set up to support an initial evacuation effort.

- In addition, the Army plan should describe how to expedite the collection of eyewitness information, and the results of monitoring at or near an accident site, to obtain real-time data about source term values in time for this information to be used for deciding about terminating SIP. Any method to decide when and how to end SIP will depend on the most current information available about meteorology and the source term. Using worst-case assumptions about these variables in lieu of near real-time data will likely skew the estimate of the optimal time to end SIP, regardless of the decision tool used. Underestimating the source term value (less likely under current guidance) can also skew the estimate of the optimal time to end SIP. Thus, the Army must make every effort to obtain and use the best meteorological and source term information to support PARs and PADs to end SIP. (CSEPP 1996) The Army plan also should address how to collect eyewitness information and monitoring results to determine the potential for aerosol deposition, if the circumstances of the release suggest that this is a possibility. These Army plans should be explained to off-post officials to ensure their understanding of how the Army will decide PARs to end SIP.

- The Army plan also should cover the need to calculate SIP termination PADs for the on-post population (employees, contractors, visitors, and residents) immediately upon deciding the initial on-post PADs, regardless of the initial PADs implemented on-post. Similarly, the Army plan should provide for the calculation of SIP termination PARs immediately after issuing initial PARs (SIP or evacuate) to off-post officials. These calculations should be based on updated reports from the accident site to quantify the source terms more accurately than using a maximum credible event (MCE) default source term.

D.6 USE OF EXERCISE ENHANCEMENTS TO SUPPORT A SHELTER TERMINATION STRATEGY

It would be beneficial to practice SIP termination decision-making and the dissemination of public instructions and emergency information during CSEPP exercises.

The scenario design and extent-of-play agreements in CSEPP exercises should be expanded accordingly.[27] Key SIP elements to exercise include the following:

- Collecting and assessing eyewitness information from the accident site and monitoring results from the vicinity of the accident site, to support SIP termination recommendations and decisions.

- Deciding when and how to end SIP.

- Translating SIP termination decisions into clear and timely public instructions and emergency information.

- Broadcasting public instructions via alert and notification systems (e.g., sirens, TARs, and EAS).

- Providing supplemental emergency information and explanation through media other than sirens, TARs, and the EAS.

- Simulating feedback from the public and the media through the public inquiries system and the mock media. Feedback should reflect probable public concerns and questions based on the local public education program and information generated by players during the exercise response.

[27] Sections 3.3.2 and 4.2.4 of the *Exercise Policy and Guidance for the CSEPP* (CSEPP 2003a) should be interpreted to include the key elements of SIP when planning for the exercise and developing extent-of-play agreements.

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APPENDIX E

TABULATED RESULTS OF MODEL RUNS MADE FOR THIS REPORT

APPENDIX E

TABULATED RESULTS OF MODEL RUNS MADE FOR THIS REPORT

This section presents a series of tables that compare the use of the TSIP routine with the plume tail-time method to determine when to end temporary SIP after a chemical agent release. The tables are designed so that individual variables of interest are considered separately in the comparison of the two methods. The variables of interest in the report are those variables that are important in determining the area of toxic effects from a chemical agent vapor plume. In general, the data associated with the "AEGL-3 technique" in the tables are of the greatest interest since this represents the scenarios where lives would potentially be saved by using one method versus the other.

E.1 INTRODUCTION

The purpose of this section is to:

- Present the rationale for the baseline values selected for the shelter infiltration and shelter action variables that were used.
- Illustrate the difference in potential impacts between using the TSIP routine and the plume tail-time method to determine when to end SIP.
- Investigate how sensitive the variables of interest are when comparing the TSIP routine with the plume tail-time method.

For the purposes of this section, the variables of interest are categorized as either shelter infiltration and sheltering action variables or release scenario and receptor location variables.

Shelter infiltration and sheltering action variables are:

- Assumed shelter air-tightness measured as ACH.
- Actual shelter air-tightness measured as ACH.
- Enter shelter time.
- Terminate shelter action/relocation time.

Release scenario and receptor location variables are:

- Wind speed.

- Stability class.
- ERZ size.
- ERZ location.
- Source terms.

All applicable combinations of the specific values for the release scenario and shelter location variables outlined above were analyzed with the D2-Puff concentration data files to determine the effects on all of the hypothetical ERZs. This resulted in the creation of 39,042 cases (a combination of 241 sources, nine sets of meteorological conditions, and 18 ERZs) using Argonne scenario datasets. Of these, 29,711 cases were relevant to the report.[28] Similarly, 5,994 cases (a combination of 37 sources, nine sets of meteorological conditions, and 18 ERZs) were created using IEM scenario datasets. Of these, 2,898 were relevant to the report. The 29,711 relevant Argonne cases and 2,898 relevant IEM cases were then analyzed with the TSIP routine to determine times to end temporary SIP for each case, considering select values from the shelter-infiltration and shelter-action variables.

Due to the large number of relevant cases, it became apparent that in order to keep the report from becoming too complex, yet still allow examination of any individual variable of interest, it was necessary to establish baseline values for the shelter-infiltration and shelter-action variables. In doing this, care was taken to ensure that the baseline values would represent a wide range of values among the applicable variables, yet not be biased toward the use of the TSIP routine.

The discussion associated with Tables E-1 through E-7 below outline the rationale for the baseline values that were ultimately selected for the level of shelter air tightness, both the assumed or input shelter air tightness used by the TSIP routine (i.e., the "input ACH") and the shelter air tightness used for evaluating the TSIP routine versus plume tail-time (i.e., the "actual ACH"). See Table C-6 in Appendix C for additional information about shelter ACH.

The baseline "enter shelter time" of 16 minutes was selected as the most representative time to use in the report. Tables E-9 and E-24 show that the TSIP routine versus the plume tail-time method is not very sensitive to the "enter shelter time." This supports the use of "16 minutes to take shelter" as the baseline value in this report. See Table C-7 in Appendix C for additional information about times to take SIP.

[28] A case is relevant in this report only when AEGL-1 toxic effects or greater are possible in an unsheltered population in an ERZ. In some relevant cases, when AEGL-1 effects are possible in an unsheltered population, this threshold level of effect might not be expected if the population took timely and effective shelter. This criterion was used because it represents ERZs that would typically be included in a PAR or PAD, or might otherwise be of interest to planners and decision-makers.

The baseline value for the terminate shelter action/relocation time was set as "exit shelter but do not relocate." As Tables E-8 and E-23 show, the TSIP routine performs best, as compared with the plume tail-time method, when the population relocates after exiting the shelter (and the sooner the better). Therefore, in order to avoid a bias favoring the TSIP routine, the baseline value was to simply exit the shelter, remain outside the shelter, and NOT relocate. See Table C-8 in Appendix C for additional information about actions upon ending SIP.

E.2 DEFINITIONS USED IN THE TABLES

In order to understand the comparison of the TSIP routine with the plume tail-time method made in this report, it is necessary to know the following definitions of the terminology used in the tables.

Number of Cases – This parameter represents the number of cases applicable to the column of interest. A total of 29,711 relevant cases of Argonne scenarios in Tables E-1 through E-15 are used to compare the method using the TSIP routine with the plume tail-time method, but not all cases apply to every table. Tables E-1 through E-14 consider all of the relevant cases, while Table E-15 considers a special subset of these cases. There are a total of 2,898 relevant cases considered for the IEM scenarios in Tables E-16 through E-29.

Input ACH – The ACH (or range of ACHs) selected by the user of the TSIP routine to represent the *assumed* air tightness of the shelters in the ERZ. The use of a range of ACHs as input to the TSIP routine is discussed in Section 3.2. The TSIP routine uses the "input ACH" value as a variable to calculate the best time to end SIP in the ERZ.

Actual ACH – The ACH used in the report to represent the *actual* air tightness of the shelters in the ERZ. This value is used, along with the input ACH value, to evaluate the relative benefit of using the TSIP routine end shelter time versus the D2-Puff plume tail-time method.

Max End Shelter Time from Input of Approximately 0.2 ACH (expedient shelter) to 2.0 ACH – A special technique that used the TSIP analysis in which the optimal end SIP time for a range of input ACHs is computed and the latest end SIP time is selected. This technique is designed to account for potential differences between the input ACH and the actual ACH. See the discussion in Section E.3.3 for more details on this technique.

AEGL-3 Technique – A case in which minimizing the AEGL-3 impact area was the most important criteria in selecting the time to end SIP using the TSIP routine. If a range of times result in a minimum AEGL-3 area, then the TSIP routine may select a time within that range that is calculated from one of the other techniques (i.e., AEGL-2, AEGL-1, or Indoor/Outdoor [I/O] Concentration). See Section 3.1 for details.

AEGL-2 Technique – A case in which minimizing the AEGL-2 impact area was the most important criteria in selecting the time to end SIP using the TSIP routine. This occurs

when the AEGL-3 impact area remains constant for all potential times to end SIP or when there is no AEGL-3 impact in the ERZ. If a range of times result in a minimum AEGL-2 area, then the TSIP routine may select a time within that range that is calculated from one of the other techniques (i.e., AEGL-1 or I/O Concentration). See Section 3.1 for details.

AEGL-1 Technique – A case in which minimizing the AEGL-1 impact area was the most important criteria in selecting the time to end SIP using the TSIP routine. This occurs when the AEGL-3 and AEGL-2 impact areas remain constant for all potential times to end SIP or when there are no AEGL-3 or AEGL-2 impacts in the ERZ. If a range of times result in a minimum AEGL-1 area, then the TSIP routine may select a time within that range that is calculated from the I/O Concentration technique. See Section 3.1 for details.

Indoor/Outdoor Concentration Technique – A case in which the TSIP routine calculates the time to end SIP by finding the time when the outside concentration falls below the inside concentration at a hypothetical shelter at the furthest point in the ERZ that is also within the hazard wedge. This occurs when the AEGL-3, AEGL-2, and AEGL-1 impact areas remain constant for all potential times to end SIP in the ERZ or when there are no AEGL-3, AEGL-2, or AEGL-1 impacts in the ERZ. In some relevant cases, when AEGL-1 effects are possible in an unsheltered population, this threshold level of effect might not be expected if the population took timely and effective shelter. The I/O Concentration technique was used for these cases. See Section 3.1 for details.

% of total cases – Of the total number of cases in a table column, the percent that were calculated by a particular TSIP technique. The "% of total cases" is a combined measure of the number of cases where a given toxic threshold exists (e.g., the AEGL-3 level) for the conditions represented in the given column, combined with the cases where that toxic threshold level could be minimized. Differences in the "% of total cases" from one column to another on a given table does not necessarily provide useful information in comparing the method using the TSIP routine with the plume tail-time method.

% cases with significant time difference – For all cases in a table column that were calculated by a particular TSIP technique, the percent for which the time to end SIP as calculated by the TSIP routine was significantly different from the time to end SIP as calculated by the plume tail-time method. A significant time difference was assumed to be 15 minutes or more, as described in Section 4.4.6.

% reduction in total AEGL-[1,2,3] area – For all cases in a table column that were calculated by a particular TSIP technique, and for which there was a significant time difference, the percent reduction in the sum of the AEGL-[1,2,3] impact areas for each case when using the TSIP routine time to end SIP, as compared with the sum of the AEGL-[1,2,3] impact areas for each case when using the plume tail-time to end SIP.

% with AEGL-[1,2,3] area increase – For all cases in a table column that were calculated by a particular TSIP technique, and for which there was a significant time difference, the percent of cases where the AEGL-[1,2,3] area increased when using the TSIP routine as compared with the plume tail-time method. This parameter is a measure of the small percentage of cases where the time to end SIP calculated by the TSIP routine results in a

time that is too soon to minimize exposures, and therefore results in a larger area of a specific effects threshold in the ERZ than does the plume tail-time method. Note that for the baseline "action upon ending SIP" strategy considered, (e.g., exit but do not relocate) a non-zero value is only possible when the actual ACH does not equal the input ACH (when a single input value is used) or when the actual ACH does not fall within the range of input ACHs (when a range of input values are used). This parameter is only presented in Tables E-1 through E-8 for the Argonne release scenarios and Tables E-16 through E–23 for the IEM release scenarios. All of the other tables would have all zeros because the baseline actual ACH value considered in the report fell within the baseline input ACH range considered in those tables.

% with average dosage increase – For all cases in a table column that were calculated by the I/O Concentration technique, and for which there was a significant time difference, the percentage of cases where the average dosage in the ERZ (the dosage integrated over the area of a zone) increased when using the TSIP routine as compared with the plume tail-time method. This parameter is a measure of the small percentage of cases for which the time to end SIP calculated by the TSIP routine results in a time that is too soon to minimize exposures, and therefore results in a larger area of a specific effects threshold in the ERZ than does the plume tail-time method. Note that for the baseline "action upon ending SIP" strategy considered, (e.g., exit but do not relocate) a non-zero value is possible only when the actual ACH does not equal the input ACH (when a single input value is used) or when the actual ACH does not fall within the range of input ACHs (when a range of input values are used). This parameter is presented only in Tables E-1 through E-8 for the Argonne release scenarios and Tables E-16 through E-23 for the IEM release scenarios. All of the other tables would have all zeros because the baseline actual ACH value considered in the report fell within the baseline input ACH range considered in those tables.

% reduction in area-weighted dosage sum – For all cases in a table column that were calculated by the I/O Concentration technique, and for which there was a significant time difference, the percent reduction in the sum of the area-weighted dosages in the ERZs for each case when using the TSIP routine time to end SIP, as compared with the sum of the area-weighted dosages in the ERZ for each case when using the plume tail-time to end SIP. The area-weighted dosage is computed by integrating the local dosage with respect to location throughout an ERZ. Intuitively, the area-weighted dosage can be thought of as the average dosage in an ERZ multiplied by the area of the ERZ.

average % reduction in AEGL-[1,2,3] area – For all cases in a table column that were calculated by a particular TSIP technique, and for which there was a significant time difference, the average for each case of the percent reduction in the AEGL-[1,2,3] impact areas for that case when using the TSIP routine time to end SIP, as compared with the AEGL-[1,2,3] impact areas for that case when using the plume tail-time to end SIP.

average % reduction in average dosage – For all cases in a table column that were calculated by the I/O Concentration technique, and for which there was a significant time difference, the average for each case of the percent reduction in the average dosage in the

ERZ for that case when using the TSIP routine time to end SIP, as compared with the average dosage in the ERZ for that case when using the plume tail-time to end SIP.

E.3 TABULAR DISPLAY OF RESULTS

Table E-1 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual expedient (~0.2 ACH) shelter, using Argonne release scenarios.

Table E-2 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 0.5 ACH shelter, using Argonne release scenarios.

Table E-3 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.0 ACH shelter, using Argonne release scenarios.

Table E-4 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.5 ACH shelter, using Argonne release scenarios.

Table E-5 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 2.0 ACH shelter, using Argonne release scenarios.

Table E-6 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 5.0 ACH shelter, using Argonne release scenarios.

Table E-7 displays results of the comparison of the two methods when considering a range of shelter ACH inputs (from approximately 0.2 ACH to 2.0 ACH) and various actual shelter ACHs, using Argonne release scenarios.

Table E-8 displays results of the comparison of the two methods when considering various options to end SIP, using Argonne release scenarios.

Table E-9 displays results of the comparison of the two methods when considering various times to enter shelter after the release, using Argonne release scenarios.

Table E-10 displays results of the comparison of the two methods when considering various wind speeds, using Argonne release scenarios.

Table E-11 displays results of the comparison of the two methods when considering various stability classes, using Argonne release scenarios.

Table E-12 displays results of the comparison of the two methods when considering various agent types, using Argonne release scenarios.

Table E-13 displays results of the comparison of the two methods when considering various zone sizes, using Argonne release scenarios.

Table E-14 displays results of the comparison of the two methods when considering various zone distances from the release, using Argonne release scenarios.

Table E-15 displays results of the comparison of the two methods when considering various release durations, using Argonne release scenarios.

Table E-16 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual expedient (~0.2 ACH) shelter, using IEM release scenarios.

Table E-17 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 0.5 ACH shelter, using IEM release scenarios.

Table E-18 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.0 ACH shelter, using IEM release scenarios.

Table E-19 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.5 ACH shelter, using IEM release scenarios.

Table E-20 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 2.0 ACH shelter, using IEM release scenarios.

Table E-21 displays results of the comparison of the two methods when considering various shelter ACH inputs and an actual 5.0 ACH shelter, using IEM release scenarios.

Table E-22 displays results of the comparison of the two methods when considering a range of shelter ACH inputs (from approximately 0.2 ACH to 2.0 ACH) and various actual shelter ACHs, using IEM release scenarios.

Table E-23 displays results of the comparison of the two methods when considering various options to end SIP, using IEM release scenarios.

Table E-24 displays results of the comparison of the two methods when considering various times to enter shelter after the release, using IEM release scenarios.

Table E-25 displays results of the comparison of the two methods when considering various wind speeds, using IEM release scenarios.

Table E-26 displays results of the comparison of the two methods when considering various stability classes, using IEM release scenarios.

Table E-27 displays results of the comparison of the two methods when considering various agent types, using IEM release scenarios.

Table E-28 displays results of the comparison of the two methods when considering various zone sizes, using IEM release scenarios.

Table E-29 displays results of the comparison of the two methods when considering various zones distances from the release, using IEM release scenarios.

E.3.1 Notes about All Tables

Each column or scenario examined in Tables E-1 through E-9 considered all 29,711 relevant Argonne cases applied to a range of shelter types (both input ACH and actual ACH). All 29,711 relevant Argonne cases are also considered in each of Tables E-10 through E-14, although each column considers only a subset of the total relevant cases (sorted by general meteorological conditions, ERZ size, or ERZ location). Table E-15 does not consider all of the relevant Argonne cases because the range of values considered (i.e., release type and durations) represent only a subset of the total possible. Each column or scenario examined in Tables E-16 through E-24 considered all 2,898 relevant IEM cases applied to a range of shelter types (both input ACH and actual ACH). All 2,898 relevant IEM cases are also considered in each of Tables E-25 through E-29, although each column considers only a subset of the total relevant cases (sorted by general meteorological conditions, ERZ size, or ERZ location).

Since the range of values for all of the variables that were considered in the report were both discrete and nonuniform, the display of trends was not always smooth. Similarly, the evaluation method used placed the "results" of a given comparison into a discrete bin (i.e., AEGL-1, AEGL-2, AEGL-3 or I/O Concentration technique) that further reduced the smoothness in any trends that might be realized in a report that considered a much larger set of data. Therefore, when interpreting the results, both the range of values and the effects of binning the results should be considered.

E.3.2 Notes about Tables E-1 through E-6

The purpose of Tables E-1 through E-6 is to see how the TSIP routine works when the air-tightness of the actual shelters does not exactly match the input ACH selected by the user of the TSIP routine. Five input ACHs from approximately 0.2 ACH (expedient shelter) to 5.0 ACH are displayed in these tables. A different actual ACH (from

approximately 0.2 ACH [expedient shelter] to 5.0 ACH) is considered in each table. Entries in columns 2-6 in each table compare the TSIP routine with the plume tail-time method (e.g., percentage of area reduced) for each of the five input ACHs considered. Tables E-1 through E-6 show that regardless of the differences between the input ACH and the actual ACH, the use of the TSIP routine results in total reductions of areas of concern when considering all cases together, as compared with results from using the plume tail-time method.

If there is a mismatch between the input ACH and the actual ACH, then ending temporary SIP at the time calculated by the TSIP routine instead of the plume tail-time could, in some cases, result in an increase in the affected area. This effect can be seen by looking at both the "% with AEGL-[1,2,3] area increase" parameter and the "% with average dosage increase" parameter in Tables E-1 through E-6. In Table E-6, for example, when the input to the TSIP routine is approximately 0.2 ACH (expedient shelter) but the actual shelter air tightness is 5.0 ACH, then there are 3% of the cases where the AEGL-3 technique results in a larger AEGL-3 area than if the plume tail-time method were used. The discussion in Section E.3.3 below describes how this potential problem is addressed in this report, as well as how it can be addressed in practice.

E.3.3 Notes about Table E-7

The results of Tables E-1 through E-6 helped establish a reasonable baseline value (actually a baseline technique) for the input ACH. As shown in Tables E-1 through E-6, the use of the TSIP routine will show the greatest improvement over the plume tail-time method when the input ACH matches the actual ACH. However, a mismatch is possible, and needs to be considered for the purposes of the comparison. Recall that the input ACH is used by the TSIP routine to determine the best time to end SIP, which in turn is then used with the actual ACH to make comparisons with the plume tail-time method for the purposes of this report. The baseline technique that was developed was to consider all of the most reasonable ACH values (approximately 0.2 ACH [expedient shelter] to 2.0 ACH) for each case and then select the latest TSIP routine time to end SIP for this range.

Establishing and using the "approximately 0.2 ACH (expedient shelter) to 2.0 ACH range" as the input ACH technique addressed the potential problem of the TSIP routine producing a larger area than the plume tail-time method when there is a mismatch between the input ACH and the actual ACH. (See discussion in Section E.3.2.) Recall that the "% with AEGL-[1,2,3] area increase" parameter provides a measure of the percentage of times when the TSIP routine results in a larger area than the plume tail-time method. Using a range of input ACH values effectively removes the mismatch between the input ACHs and the actual ACH. The range of "approximately 0.2 ACH (expedient shelter) to 2.0 ACH" was used because it represents the expected level of shelter air tightness within CSEPP ERZs. (See Section 3.2 and Table C-6 in Appendix C) In practice, the range of values to consider for the input ACH could be adjusted to reflect information from a specific ERZ, but for the purposes of this report "approximately 0.2 ACH (expedient shelter) to 2.0 ACH" was considered appropriate. When 5.0 ACH is considered as the actual ACH in this report (e.g., representing very leaky shelters with no enhancements), there is still the

potential for cases where the area calculated using the input ACH range of "approximately 0.2 ACH (expedient shelter) to 2.0 ACH" with the TSIP routine might be larger than if the plume tail-time method were used. This is because the 5.0 ACH falls outside of the "0.2 ACH (expedient shelter) to 2.0 ACH" range used as the input ACH.

Table E-7 shows how using this technique for the input ACH compares with the plume tail-time method for a range of actual ACHs. The use of the TSIP routine results in improvement over the plume tail-time approach for almost all of the actual ACHs considered when the latest time to end SIP from the "0.2 ACH (expedient shelter) to 2.0 ACH" (i.e., the input ACH technique) is used. As Table E-7 shows, the tighter the "actual" shelter the better the TSIP routine works for all four area minimization techniques (e.g., AEGL-3 technique) when using this "approximately 0.2 ACH (expedient shelter) to 2.0 ACH" input ACH technique. Additionally, using this "0.2 ACH (expedient shelter) to 2.0 ACH" input ACH technique prevents the potentially adverse situation of a larger affected area with the TSIP routine end SIP time, as outlined in the discussion in Section E.3.2 for some cases when there is a mismatch between the input ACH and the actual ACH. Note that when 5.0 ACH is used as the actual ACH, there are still some cases where the "% with AEGL-[1,2,3] area increase" parameter is not zero, indicating that in a small percentage of cases where the shelter ACH is very high and outside the input ACH range, the area calculated using the TSIP routine will be larger than if the plume tail-time method were used.

Note that the "percent of total" and the "% of subcases with significant time differences" remains the same regardless of the actual ACH. This is because for each case considered, the time to end SIP calculated by the TSIP routine, and therefore the area minimization techniques used, is based on the input ACH technique and not the actual ACH in the ERZ. The actual ACH in the ERZ is used only to evaluate how well the end SIP times (TSIP routine versus plume tail-time method) compare for each case.

Table E-7 is also is useful in exploring an appropriate actual ACH to use as a baseline value against which other variables can be considered. By far the best results for the TSIP routine in Table E-7 are for the approximately 0.2 ACH (expedient shelter), and the poorest results are for the 5.0 ACH shelter. An actual ACH of 1.0 was used as a baseline value in the report, as explained in Section 4.4.2. Based on trial runs, and supported by the full set of runs, the TSIP routine would have produced more beneficial results had a lower baseline ACH been used, but the conservative approach in selecting this value as the baseline enhances the validity of the conclusions.

E.3.4 Notes about Table E-8

Table E-8 shows the effect on the TSIP routine versus plume tail-time comparison of three different sheltering actions taken once the time to end SIP using the TSIP routine is reached. The baseline terminate shelter action used for this report is to exit the shelter and not relocate. All 29,711 cases, representing all combinations of meteorological conditions/release scenarios/ERZ configurations that resulted in an AEGL-1 or higher, were examined for each of the three sheltering actions shown. As Table E-8 illustrates,

relocating after terminating shelter improves the results of using the TSIP routine versus the plume tail-time approach. Additionally, the less time it takes to relocate after ending SIP, the greater the advantage of using the TSIP routine versus the plume tail-time method.

E.3.5 Notes about Table E-9

Five different times to enter shelter are displayed in Table E-9 (0, 8, 16, 21, and 30 minutes). All combinations of meteorological conditions/release scenarios/ERZ configurations were examined for each of the five times to enter shelter that are shown. The improvement seen by using the time to end SIP calculated by the TSIP routine over the plume tail-time method does not appear to be strongly affected within this range of times to enter shelter. Thus the median baseline value of 16 minutes to enter the shelter used in this report was reasonable because this value would not bias the comparison of the two methods.

E.3.6 Notes about Table E-10

Five wind speeds are displayed in Table E-10 (1, 2, 5, 10, and 15 m/s). All combinations of meteorological conditions/release scenarios/ERZ configurations were examined for this table, for a total of 29,711 cases. These cases are sorted by wind speed, with the greatest number of cases associated with the lowest wind speeds. The greatest number of cases are associated with the lowest wind speeds because (1) more stability class-wind speed combinations were investigated with the lower wind speeds and (2) all else being equal, the lower wind speeds tend to cause a larger number of ERZs to be affected by any given release. Regardless of the area minimization technique used to calculate the TSIP routine time, the percent of cases with significant time differences is greater for the lower wind speeds. No noteworthy trends appear to exist in the percent area reductions listed for the various techniques when comparing the five different wind speeds.

E.3.7 Notes about Table E-11

Three stability classes are displayed in Table E-11 (B, D, and F). All combinations of meteorological conditions/release scenarios/ERZ configurations were examined for this table, for a total of 29,711 cases. The 29,711 total cases are sorted by stability class, with the greatest number of cases associated with the D stability, simply because there were more wind speeds considered with D stability than with B or F. The improvement seen from using the TSIP routine time versus the plume tail-time method does not appear to be strongly affected within this range of stability classes.

E.3.8 Notes about Table E-12

Three agent types are displayed in Table E-12 (GB, mustard, and VX). All combinations of meteorological conditions/release scenarios/ERZ configurations were

examined for this table, for a total of 29,711 cases. These cases are sorted by agent type, with the greatest number of cases associated with the GB releases, simply because there were more GB release scenarios considered in this report. The results with mustard agent tend to show a greater percent area reduction using the TSIP routine compared with results using the plume tail-time method. This can be explained by the fact that the dose-response relationship for mustard tends to be more linear than for nerve agents, and therefore the "penalty" for remaining in shelter after the mustard vapor concentration outside becomes less than inside is greater for mustard than nerve agents. See Section 1.3.3.

E.3.9 Notes about Table E-13

Five ERZ sizes are displayed in Table E-13 (1, 3, 5, 15, and 25 km). All combinations of meteorological conditions/release scenarios/ERZ configurations were examined for this table, for a total of 29,711 cases. These cases are sorted by ERZ size, with the greatest number of cases associated with the smallest ERZ size. The main trend is that the percentage of cases where the time difference is significant between the TSIP routine and plume tail-time method increases with increasing ERZ size, with 100% of cases having significant differences in the 25 km ERZ. No trends are seen in the sensitivity of the ERZ sizes on the percent area reduction using the TSIP routine versus plume tail-time method.

E.3.10 Notes about Table E-14

Five ERZ distances are displayed in Table E-14 (1, 2, 10, 20, and 25 km from the release). All combinations of meteorological conditions/release scenarios/ERZ configurations were examined for this table, for a total of 29,711 cases. These cases are sorted by the distance of the ERZ from the point of release, with the greatest number of cases associated with ERZs closest to the release. The percent of cases where there is a significant time difference between the TSIP routine end SIP time and the plume tail-time increases with increasing distance from the release. The percentage area reduction using the TSIP routine versus the plume tail-time method tends to decrease with increasing distances.

E.3.11 Notes about Table E-15

All combinations of meteorological conditions and ERZ configurations, but only steady-state releases (i.e., a uniform release of agent over a given time period) are shown in Table E-15, for a total of 9,292 cases. These cases are sorted by release durations (1, 5, 15, 30, 45, 60, 90, 120, 180, and 240 minute durations). The percent of cases where there is a significant time difference between the TSIP routine end SIP time and the plume tail-time increases with increasing release duration. No trends are noteworthy concerning the sensitivity of the release durations on the percent area reduction using the TSIP routine versus plume tail-time method.

E.3.12 Notes about Tables E-16 through E-29

Tables E-16 through E-29 represent the same comparisons made in Tables E-1 through E-14, respectively, with the one exception, that the scenario data is from the IEM database of scenarios. There is no corresponding IEM table for the Argonne Table E-15, since there were not enough uniform releases in the IEM database to provide a meaningful dataset.

TABLE E-1 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual expedient (~0.2 ACH) shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = Expedient; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	33%	35%	37%	36%	32%
AEGL-3 Technique: average % reduction in AEGL-3 area	36%	34%	34%	32%	24%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	2%	7%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	62%	71%	64%	56%	44%
AEGL-2 Technique: average % reduction in AEGL-2 area	37%	33%	31%	27%	19%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	1%	4%	8%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	67%	69%	65%	59%	31%
AEGL-1 Technique: average % reduction in AEGL-1 area	34%	31%	28%	21%	4%
AEGL-1 Technique: % with AEGL-1 area increase	0%	0%	2%	5%	10%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	17%	21%	23%	23%	23%
I/O Conc. Technique: average % reduction in average dosage	35%	37%	36%	32%	20%
I/O Conc. Technique: % with average dosage increase	0%	0%	1%	4%	22%

TABLE E-2 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 0.5 ACH shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 0.5; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	17%	34%	36%	35%	33%
AEGL-3 Technique: average % reduction in AEGL-3 area	32%	40%	39%	37%	31%
AEGL-3 Technique: % with AEGL-3 area increase	2%	0%	0%	1%	6%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	36%	63%	67%	63%	55%
AEGL-2 Technique: average % reduction in AEGL-2 area	39%	45%	43%	39%	33%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	3%	7%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	29%	57%	66%	64%	49%
AEGL-1 Technique: average % reduction in AEGL-1 area	23%	43%	40%	34%	23%
AEGL-1 Technique: % with AEGL-1 area increase	5%	0%	1%	4%	10%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	12%	15%	18%	20%	21%
I/O Conc. Technique: average % reduction in average dosage	31%	34%	36%	36%	33%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	2%	6%

TABLE E-3 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.0 ACH shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 1.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	13%	19%	32%	33%	30%
AEGL-3 Technique: average % reduction in AEGL-3 area	27%	32%	41%	39%	36%
AEGL-3 Technique: % with AEGL-3 area increase	1%	1%	0%	0%	2%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	27%	40%	61%	64%	59%
AEGL-2 Technique: average % reduction in AEGL-2 area	39%	44%	54%	52%	48%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	1%	3%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	19%	28%	56%	62%	54%
AEGL-1 Technique: average % reduction in AEGL-1 area	21%	30%	50%	47%	36%
AEGL-1 Technique: % with AEGL-1 area increase	6%	4%	0%	2%	9%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	8%	10%	12%	14%	16%
I/O Conc. Technique: average % reduction in average dosage	26%	29%	31%	33%	34%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	1%	3%

TABLE E-4 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.5 ACH shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 1.5; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	10%	15%	22%	31%	29%
AEGL-3 Technique: average % reduction in AEGL-3 area	25%	29%	34%	40%	37%
AEGL-3 Technique: % with AEGL-3 area increase	1%	1%	1%	0%	1%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	19%	29%	41%	60%	57%
AEGL-2 Technique: average % reduction in AEGL-2 area	38%	42%	48%	57%	53%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	1%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	15%	20%	35%	56%	53%
AEGL-1 Technique: average % reduction in AEGL-1 area	19%	25%	37%	51%	44%
AEGL-1 Technique: % with AEGL-1 area increase	6%	5%	2%	0%	5%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	5%	7%	9%	11%	13%
I/O Conc. Technique: average % reduction in average dosage	22%	24%	26%	29%	31%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	1%

TABLE E-5 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 2.0 ACH shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 2.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	8%	12%	16%	28%	28%
AEGL-3 Technique: average % reduction in AEGL-3 area	22%	27%	31%	40%	38%
AEGL-3 Technique: % with AEGL-3 area increase	2%	2%	1%	0%	0%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	15%	22%	31%	55%	54%
AEGL-2 Technique: average % reduction in AEGL-2 area	35%	39%	45%	58%	55%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	0%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	12%	16%	26%	50%	51%
AEGL-1 Technique: average % reduction in AEGL-1 area	16%	20%	30%	52%	47%
AEGL-1 Technique: % with AEGL-1 area increase	7%	6%	4%	0%	2%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	6%	7%	9%	11%
I/O Conc. Technique: average % reduction in average dosage	19%	20%	22%	25%	27%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	1%

TABLE E-6 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 5.0 ACH shelter, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 5.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	40%	37%	35%	32%
AEGL-3 Technique: % with significant time difference	84%	86%	88%	90%	92%
AEGL-3 Technique: % reduction in total AEGL-3 area	3%	4%	6%	8%	20%
AEGL-3 Technique: average % reduction in AEGL-3 area	11%	13%	17%	21%	32%
AEGL-3 Technique: % with AEGL-3 area increase	3%	5%	6%	4%	0%
AEGL-2 Technique: % of total cases	21%	20%	19%	18%	16%
AEGL-2 Technique: % with significant time difference	83%	84%	85%	87%	88%
AEGL-2 Technique: % reduction in total AEGL-2 area	7%	9%	13%	18%	38%
AEGL-2 Technique: average % reduction in AEGL-2 area	26%	28%	32%	38%	51%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	1%	2%	0%
AEGL-1 Technique: % of total cases	20%	18%	16%	14%	12%
AEGL-1 Technique: % with significant time difference	90%	89%	90%	90%	92%
AEGL-1 Technique: % reduction in total AEGL-1 area	4%	5%	8%	13%	37%
AEGL-1 Technique: average % reduction in AEGL-1 area	10%	12%	16%	23%	48%
AEGL-1 Technique: % with AEGL-1 area increase	9%	10%	10%	7%	0%
I/O Conc. Technique: % of total cases	15%	22%	28%	33%	39%
I/O Conc. Technique: % with significant time difference	68%	75%	79%	83%	87%
I/O Conc. Technique: % reduction in area-weighted dosage sum	1%	2%	2%	3%	4%
I/O Conc. Technique: average % reduction in average dosage	10%	9%	11%	13%	15%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	0%

TABLE E-7 Results of the comparison of the two methods when considering a range of shelter ACH inputs (from approximately 0.2 ACH to 2.0 ACH) and various actual shelter ACH, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Maximum End Shelter Time from Input of Expedient 2.0 ACH; Actual ACH = Various (as shown); Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Actual ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	43%	43%	43%	43%
AEGL-3 Technique: % with significant time difference	83%	83%	83%	83%	83%
AEGL-3 Technique: % reduction in total AEGL-3 area	31%	21%	16%	13%	4%
AEGL-3 Technique: average % reduction in AEGL-3 area	35%	33%	29%	23%	11%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	0%	2%
AEGL-2 Technique: % of total cases	21%	21%	21%	21%	21%
AEGL-2 Technique: % with significant time difference	82%	82%	82%	82%	82%
AEGL-2 Technique: % reduction in total AEGL-2 area	59%	36%	28%	16%	7%
AEGL-2 Technique: average % reduction in AEGL-2 area	35%	39%	40%	35%	26%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	0%
AEGL-1 Technique: % of total cases	20%	20%	20%	20%	20%
AEGL-1 Technique: % with significant time difference	88%	88%	88%	88%	88%
AEGL-1 Technique: % reduction in total AEGL-1 area	66%	42%	31%	24%	7%
AEGL-1 Technique: average % reduction in AEGL-1 area	34%	39%	40%	37%	16%
AEGL-1 Technique: % with AEGL-1 area increase	0%	0%	0%	0%	5%
I/O Conc. Technique: % of total cases	15%	15%	15%	15%	15%
I/O Conc. Technique: % with significant time difference	68%	68%	68%	68%	68%
I/O Conc. Technique: % reduction in area-weighted dosage sum	17%	12%	8%	4%	1%
I/O Conc. Technique: average % reduction in average dosage	35%	31%	26%	19%	10%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	0%

TABLE E-8 Results of the comparison of the two methods when considering various options to end SIP, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Relocation Time: All Zones; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Various (Select TSIP Time Base Upon "Assumed Action Listed")			
	Action at TSIP End Shelter Time		
	Exit Shelter, Don't Relocate	**Exit Shelter, Relocate (15 min)**	**Exit Shelter, Relocate (20 min)**
Number of Cases	29711	29711	29711
AEGL-3 Technique: % of total cases	43%	49%	48%
AEGL-3 Technique: % with significant time difference	83%	93%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	16%	92%	89%
AEGL-3 Technique: average % reduction in AEGL-3 area	29%	67%	64%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%
AEGL-2 Technique: % of total cases	21%	22%	22%
AEGL-2 Technique: % with significant time difference	82%	92%	91%
AEGL-2 Technique: % reduction in total AEGL-2 area	28%	97%	95%
AEGL-2 Technique: average % reduction in AEGL-2 area	40%	74%	72%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%
AEGL-1 Technique: % of total cases	20%	22%	22%
AEGL-1 Technique: % with significant time difference	88%	94%	93%
AEGL-1 Technique: % reduction in total AEGL-1 area	31%	92%	90%
AEGL-1 Technique: average % reduction in AEGL-1 area	40%	76%	74%
AEGL-1 Technique: % with AEGL-1 area increase	0%	0%	0%
I/O Conc. Technique: % of total cases	15%	7%	7%
I/O Conc. Technique: % with significant time difference	68%	56%	53%
I/O Conc. Technique: % reduction in area-weighted dosage sum	8%	53%	52%
I/O Conc. Technique: average % reduction in average dosage	26%	44%	44%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%

TABLE E-9 Results of the comparison of the two methods when considering various times to enter shelter after the release, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Enter Shelter Time: All Zones; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Various (as shown); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Enter Shelter Time in Minutes				
	0	**8**	**16**	**21**	**30**
Number of Cases	29711	29711	29711	29711	29711
AEGL-3 Technique: % of total cases	45%	44%	43%	43%	42%
AEGL-3 Technique: % with significant time difference	81%	82%	83%	83%	83%
AEGL-3 Technique: % reduction in total AEGL-3 area	17%	17%	16%	16%	16%
AEGL-3 Technique: average % reduction in AEGL-3 area	30%	30%	29%	29%	27%
AEGL-2 Technique: % of total cases	22%	22%	21%	21%	21%
AEGL-2 Technique: % with significant time difference	81%	82%	82%	82%	82%
AEGL-2 Technique: % reduction in total AEGL-2 area	28%	28%	28%	28%	28%
AEGL-2 Technique: average % reduction in AEGL-2 area	39%	42%	40%	40%	38%
AEGL-1 Technique: % of total cases	21%	21%	20%	20%	19%
AEGL-1 Technique: % with significant time difference	88%	89%	88%	89%	89%
AEGL-1 Technique: % reduction in total AEGL-1 area	32%	32%	31%	29%	26%
AEGL-1 Technique: average % reduction in AEGL-1 area	43%	42%	40%	39%	38%
I/O Conc. Technique: % of total cases	12%	13%	15%	16%	18%
I/O Conc. Technique: % with significant time difference	72%	71%	68%	67%	64%
I/O Conc. Technique: % reduction in area-weighted dosage sum	8%	8%	8%	8%	8%
I/O Conc. Technique: average % reduction in average dosage	25%	26%	26%	26%	25%

TABLE E-10 Results of the comparison of the two methods when considering various wind speeds, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Wind Speed: All Zones; All Cases by Wind Speed; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Wind Speed in m/s				
	1	**2**	**5**	**10**	**15**
Number of Cases	10731	10115	3201	2869	2795
AEGL-3 Technique: % of total cases	46%	48%	44%	32%	29%
AEGL-3 Technique: % with significant time difference	90%	84%	72%	67%	65%
AEGL-3 Technique: % reduction in total AEGL-3 area	16%	16%	23%	27%	29%
AEGL-3 Technique: average % reduction in AEGL-3 area	24%	30%	30%	38%	40%
AEGL-2 Technique: % of total cases	21%	20%	18%	30%	27%
AEGL-2 Technique: % with significant time difference	95%	87%	69%	67%	60%
AEGL-2 Technique: % reduction in total AEGL-2 area	19%	36%	55%	45%	31%
AEGL-2 Technique: average % reduction in AEGL-2 area	38%	40%	50%	44%	37%
AEGL-1 Technique: % of total cases	14%	20%	27%	27%	30%
AEGL-1 Technique: % with significant time difference	98%	95%	86%	75%	71%
AEGL-1 Technique: % reduction in total AEGL-1 area	28%	17%	27%	70%	65%
AEGL-1 Technique: average % reduction in AEGL-1 area	48%	33%	26%	51%	51%
I/O Conc. Technique: % of total cases	20%	12%	10%	11%	14%
I/O Conc. Technique: % with significant time difference	83%	62%	49%	44%	44%
I/O Conc. Technique: % reduction in area-weighted dosage sum	7%	10%	28%	36%	36%
I/O Conc. Technique: average % reduction in average dosage	22%	32%	33%	36%	36%

TABLE E-11 Results of the comparison of the two methods when considering various stability classes, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Stability Class: All Zones; All Cases by Stability Class; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)			
	Stability Class		
	B	**D**	**F**
Number of Cases	5245	16082	8384
AEGL-3 Technique: % of total cases	33%	44%	49%
AEGL-3 Technique: % with significant time difference	89%	78%	87%
AEGL-3 Technique: % reduction in total AEGL-3 area	26%	20%	15%
AEGL-3 Technique: average % reduction in AEGL-3 area	35%	29%	25%
AEGL-2 Technique: % of total cases	32%	22%	15%
AEGL-2 Technique: % with significant time difference	89%	76%	91%
AEGL-2 Technique: % reduction in total AEGL-2 area	32%	35%	21%
AEGL-2 Technique: average % reduction in AEGL-2 area	47%	41%	27%
AEGL-1 Technique: % of total cases	30%	24%	6%
AEGL-1 Technique: % with significant time difference	96%	85%	94%
AEGL-1 Technique: % reduction in total AEGL-1 area	21%	41%	15%
AEGL-1 Technique: average % reduction in AEGL-1 area	46%	40%	25%
I/O Conc. Technique: % of total cases	5%	10%	30%
I/O Conc. Technique: % with significant time difference	83%	55%	76%
I/O Conc. Technique: % reduction in area-weighted dosage sum	12%	9%	8%
I/O Conc. Technique: average % reduction in average dosage	23%	31%	25%

TABLE E-12 Results of the comparison of the two methods when considering various agent types, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Agent Type: All Zones; All Cases by Agent Type; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)			
	Agent Type		
	GB	**VX**	**Mustard**
Number of Cases	13200	9781	6730
AEGL-3 Technique: % of total cases	47%	40%	42%
AEGL-3 Technique: % with significant time difference	80%	90%	78%
AEGL-3 Technique: % reduction in total AEGL-3 area	15%	11%	32%
AEGL-3 Technique: average % reduction in AEGL-3 area	27%	28%	34%
AEGL-2 Technique: % of total cases	18%	11%	43%
AEGL-2 Technique: % with significant time difference	79%	81%	84%
AEGL-2 Technique: % reduction in total AEGL-2 area	16%	32%	29%
AEGL-2 Technique: average % reduction in AEGL-2 area	22%	44%	52%
AEGL-1 Technique: % of total cases	24%	26%	6%
AEGL-1 Technique: % with significant time difference	88%	88%	98%
AEGL-1 Technique: % reduction in total AEGL-1 area	22%	36%	95%
AEGL-1 Technique: average % reduction in AEGL-1 area	28%	53%	46%
I/O Conc. Technique: % of total cases	12%	23%	9%
I/O Conc. Technique: % with significant time difference	57%	79%	58%
I/O Conc. Technique: % reduction in area-weighted dosage sum	7%	8%	10%
I/O Conc. Technique: average % reduction in average dosage	21%	31%	20%

TABLE E-13 Results of the comparison of the two methods when considering various zone sizes, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Zone Size: All Zones by Size; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Zone Size (km)				
	1	**3**	**5**	**15**	**25**
Number of Cases	7362	6439	6439	5426	4045
AEGL-3 Technique: % of total cases	29%	39%	42%	54%	65%
AEGL-3 Technique: % with significant time difference	56%	70%	82%	98%	100%
AEGL-3 Technique: % reduction in total AEGL-3 area	14%	17%	15%	16%	17%
AEGL-3 Technique: average % reduction in AEGL-3 area	23%	25%	25%	30%	35%
AEGL-2 Technique: % of total cases	19%	22%	22%	22%	21%
AEGL-2 Technique: % with significant time difference	66%	75%	80%	98%	100%
AEGL-2 Technique: % reduction in total AEGL-2 area	34%	29%	25%	25%	51%
AEGL-2 Technique: average % reduction in AEGL-2 area	33%	38%	40%	40%	50%
AEGL-1 Technique: % of total cases	22%	21%	23%	20%	12%
AEGL-1 Technique: % with significant time difference	81%	85%	89%	98%	100%
AEGL-1 Technique: % reduction in total AEGL-1 area	35%	31%	29%	30%	55%
AEGL-1 Technique: average % reduction in AEGL-1 area	29%	35%	37%	52%	66%
I/O Conc. Technique: % of total cases	30%	17%	13%	4%	2%
I/O Conc. Technique: % with significant time difference	59%	70%	80%	100%	100%
I/O Conc. Technique: % reduction in area-weighted dosage sum	28%	14%	11%	5%	3%
I/O Conc. Technique: average % reduction in average dosage	35%	26%	19%	7%	3%

TABLE E-14 Results of the comparison of the two methods when considering various zones distances from the release, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Zone Distance: All Zones by Distance; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Zone Distance from Release (km)				
	1	**2**	**10**	**20**	**25**
Number of Cases	10265	9960	5524	3039	923
AEGL-3 Technique: % of total cases	60%	50%	22%	15%	13%
AEGL-3 Technique: % with significant time difference	80%	82%	90%	96%	99%
AEGL-3 Technique: % reduction in total AEGL-3 area	18%	18%	11%	12%	7%
AEGL-3 Technique: average % reduction in AEGL-3 area	33%	31%	9%	16%	5%
AEGL-2 Technique: % of total cases	18%	22%	25%	24%	23%
AEGL-2 Technique: % with significant time difference	77%	77%	90%	93%	92%
AEGL-2 Technique: % reduction in total AEGL-2 area	48%	45%	24%	27%	29%
AEGL-2 Technique: average % reduction in AEGL-2 area	48%	45%	32%	29%	27%
AEGL-1 Technique: % of total cases	7%	15%	39%	41%	40%
AEGL-1 Technique: % with significant time difference	82%	84%	91%	92%	94%
AEGL-1 Technique: % reduction in total AEGL-1 area	62%	49%	29%	29%	38%
AEGL-1 Technique: average % reduction in AEGL-1 area	63%	56%	34%	24%	32%
I/O Conc. Technique: % of total cases	15%	13%	14%	20%	24%
I/O Conc. Technique: % with significant time difference	53%	55%	88%	98%	100%
I/O Conc. Technique: % reduction in area-weighted dosage sum	6%	6%	11%	16%	21%
I/O Conc. Technique: average % reduction in average dosage	30%	29%	25%	21%	24%

TABLE E-15 Results of the comparison of the two methods when considering various release durations, using Argonne release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for Argonne Release Scenarios: Sensitivity to Duration of Single-Phase Releases: All Zones; Single-Phase Releases by Duration; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Duration of Release (min)									
	1	**5**	**15**	**30**	**45**	**60**	**90**	**120**	**180**	**240**
Number of Cases	809	870	905	945	948	953	964	964	964	970
AEGL-3 Technique: % of total cases	49%	40%	39%	37%	38%	37%	34%	32%	30%	29%
AEGL-3 Technique: % with significant time difference	59%	60%	69%	72%	71%	75%	76%	73%	74%	75%
AEGL-3 Technique: % reduction in total AEGL-3 area	12%	17%	18%	23%	21%	19%	17%	14%	12%	11%
AEGL-3 Technique: average % reduction in AEGL-3 area	31%	29%	30%	33%	33%	29%	25%	23%	23%	17%
AEGL-2 Technique: % of total cases	17%	24%	25%	26%	25%	25%	25%	25%	26%	25%
AEGL-2 Technique: % with significant time difference	53%	69%	69%	70%	73%	73%	73%	74%	73%	74%
AEGL-2 Technique: % reduction in total AEGL-2 area	30%	24%	31%	43%	33%	32%	31%	26%	19%	14%
AEGL-2 Technique: average % reduction in AEGL-2 area	27%	41%	52%	53%	45%	43%	43%	40%	27%	23%
AEGL-1 Technique: % of total cases	23%	26%	23%	21%	21%	19%	19%	19%	17%	17%
AEGL-1 Technique: % with significant time difference	69%	72%	77%	82%	82%	83%	82%	85%	87%	90%
AEGL-1 Technique: % reduction in total AEGL-1 area	32%	22%	22%	25%	22%	31%	28%	28%	25%	18%
AEGL-1 Technique: average % reduction in AEGL-1 area	34%	39%	41%	45%	40%	43%	38%	39%	36%	26%
I/O Conc. Technique: % of total cases	11%	10%	13%	16%	17%	19%	22%	23%	26%	28%
I/O Conc. Technique: % with significant time difference	17%	29%	36%	40%	43%	49%	52%	53%	58%	60%
I/O Conc. Technique: % reduction in area-weighted dosage sum	5%	6%	6%	6%	7%	7%	7%	6%	5%	4%
I/O Conc. Technique: average % reduction in average dosage	15%	15%	16%	16%	15%	15%	14%	12%	10%	8%

TABLE E-16 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual expedient (~0.2 ACH) shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = Expedient; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	25%	29%	30%	29%	25%
AEGL-3 Technique: average % reduction in AEGL-3 area	38%	37%	36%	33%	17%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	3%	16%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	88%	88%	88%	86%	80%
AEGL-2 Technique: average % reduction in AEGL-2 area	37%	34%	34%	29%	8%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	2%	4%	15%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	81%	87%	87%	82%	75%
AEGL-1 Technique: average % reduction in AEGL-1 area	49%	48%	44%	26%	14%
AEGL-1 Technique: % with AEGL-1 area increase	0%	1%	5%	15%	31%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%
I/O Conc. Technique: % reduction in area-weighted dosage sum	9%	13%	15%	17%	18%
I/O Conc. Technique: average % reduction in average dosage	39%	42%	42%	40%	19%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	3%	27%

TABLE E-17 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 0.5 ACH shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 0.5; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	289	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	17%	27%	27%	25%	23%
AEGL-3 Technique: average % reduction in AEGL-3 area	31%	35%	33%	31%	22%
AEGL-3 Technique: % with AEGL-3 area increase	1%	0%	0%	2%	15%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	59%	84%	84%	86%	80%
AEGL-2 Technique: average % reduction in AEGL-2 area	45%	53%	49%	44%	22%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	3%	15%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	54%	72%	77%	75%	72%
AEGL-1 Technique: average % reduction in AEGL-1 area	31%	54%	52%	38%	-1%
AEGL-1 Technique: % with AEGL-1 area increase	9%	0%	3%	14%	33%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%
I/O Conc. Technique: % reduction in area-weighted dosage sum	7%	10%	12%	14%	16%
I/O Conc. Technique: average % reduction in average dosage	32%	36%	38%	40%	32%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	12%

TABLE E-18 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.0 ACH shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 1.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	14%	19%	26%	27%	24%
AEGL-3 Technique: average % reduction in AEGL-3 area	29%	31%	35%	34%	29%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	0%	7%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	34%	49%	71%	77%	73%
AEGL-2 Technique: average % reduction in AEGL-2 area	39%	43%	55%	52%	39%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	8%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	41%	51%	66%	67%	69%
AEGL-1 Technique: average % reduction in AEGL-1 area	26%	32%	55%	45%	17%
AEGL-1 Technique: % with AEGL-1 area increase	7%	5%	0%	6%	29%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	6%	8%	10%	12%
I/O Conc. Technique: average % reduction in average dosage	27%	30%	32%	34%	33%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	9%

TABLE E-19 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 1.5 ACH shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 1.5; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	12%	15%	20%	28%	25%
AEGL-3 Technique: average % reduction in AEGL-3 area	26%	28%	31%	35%	32%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	0%	2%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	21%	34%	50%	67%	66%
AEGL-2 Technique: average % reduction in AEGL-2 area	33%	37%	45%	53%	42%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	5%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	35%	42%	54%	60%	66%
AEGL-1 Technique: average % reduction in AEGL-1 area	25%	30%	38%	47%	31%
AEGL-1 Technique: % with AEGL-1 area increase	4%	3%	1%	2%	16%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%
I/O Conc. Technique: % reduction in area-weighted dosage sum	3%	5%	6%	8%	10%
I/O Conc. Technique: average % reduction in average dosage	23%	25%	27%	29%	30%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	6%

TABLE E-20 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 2.0 ACH shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 2.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	11%	13%	16%	27%	26%
AEGL-3 Technique: average % reduction in AEGL-3 area	23%	25%	28%	34%	31%
AEGL-3 Technique: % with AEGL-3 area increase	1%	1%	0%	0%	0%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	15%	25%	37%	61%	63%
AEGL-2 Technique: average % reduction in AEGL-2 area	30%	36%	42%	55%	45%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	1%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	29%	35%	44%	55%	63%
AEGL-1 Technique: average % reduction in AEGL-1 area	25%	29%	34%	47%	35%
AEGL-1 Technique: % with AEGL-1 area increase	2%	2%	1%	0%	8%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%

I/O Conc. Technique: % reduction in area-weighted dosage sum	2%	3%	5%	6%	8%
I/O Conc. Technique: average % reduction in average dosage	21%	21%	23%	25%	27%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	4%

TABLE E-21 Results of the comparison of the two methods when considering various shelter ACH inputs and an actual 5.0 ACH shelter, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Various (as shown); Actual ACH = 5.0; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Input ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	38%	36%	34%	31%
AEGL-3 Technique: % with significant time difference	76%	78%	81%	83%	91%
AEGL-3 Technique: % reduction in total AEGL-3 area	6%	6%	7%	9%	23%
AEGL-3 Technique: average % reduction in AEGL-3 area	12%	14%	16%	19%	27%
AEGL-3 Technique: % with AEGL-3 area increase	5%	5%	7%	4%	0%
AEGL-2 Technique: % of total cases	14%	14%	13%	13%	12%
AEGL-2 Technique: % with significant time difference	76%	79%	80%	81%	90%
AEGL-2 Technique: % reduction in total AEGL-2 area	4%	7%	10%	18%	44%
AEGL-2 Technique: average % reduction in AEGL-2 area	16%	18%	20%	28%	41%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	0%
AEGL-1 Technique: % of total cases	27%	25%	22%	20%	18%
AEGL-1 Technique: % with significant time difference	89%	89%	91%	95%	99%
AEGL-1 Technique: % reduction in total AEGL-1 area	17%	20%	24%	28%	49%
AEGL-1 Technique: average % reduction in AEGL-1 area	14%	17%	19%	20%	37%
AEGL-1 Technique: % with AEGL-1 area increase	3%	3%	3%	3%	0%
I/O Conc. Technique: % of total cases	18%	23%	29%	34%	40%
I/O Conc. Technique: % with significant time difference	45%	53%	59%	64%	72%
I/O Conc. Technique: % reduction in area-weighted dosage sum	1%	1%	2%	2%	3%
I/O Conc. Technique: average % reduction in average dosage	12%	11%	11%	13%	15%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	0%

TABLE E-22 Results of the comparison of the two methods when considering a range of shelter ACH inputs (from approximately 0.2 ACH to 2.0 ACH) and various actual shelter ACH, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Input ACH: All Zones; All Cases; Input ACH = Max End Shelter Time from Input of Expedient 2.0 ACH; Actual ACH = Various (as shown); Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)

	Actual ACH				
	Expedient	**0.5**	**1.0**	**2.0**	**5.0**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	41%	41%	41%	41%
AEGL-3 Technique: % with significant time difference	75%	75%	75%	75%	75%
AEGL-3 Technique: % reduction in total AEGL-3 area	25%	18%	15%	14%	6%
AEGL-3 Technique: average % reduction in AEGL-3 area	37%	31%	28%	23%	12%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%	0%	2%
AEGL-2 Technique: % of total cases	14%	14%	14%	14%	14%
AEGL-2 Technique: % with significant time difference	75%	75%	75%	75%	75%
AEGL-2 Technique: % reduction in total AEGL-2 area	88%	59%	35%	16%	4%
AEGL-2 Technique: average % reduction in AEGL-2 area	37%	46%	38%	30%	16%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%	0%	0%
AEGL-1 Technique: % of total cases	27%	27%	27%	27%	27%
AEGL-1 Technique: % with significant time difference	88%	88%	88%	88%	88%
AEGL-1 Technique: % reduction in total AEGL-1 area	80%	59%	45%	35%	18%
AEGL-1 Technique: average % reduction in AEGL-1 area	49%	49%	45%	37%	16%
AEGL-1 Technique: % with AEGL-1 area increase	0%	0%	0%	0%	2%
I/O Conc. Technique: % of total cases	18%	18%	18%	18%	18%
I/O Conc. Technique: % with significant time difference	45%	45%	45%	45%	45%
I/O Conc. Technique: % reduction in area-weighted dosage sum	9%	7%	4%	2%	1%
I/O Conc. Technique: average % reduction in average dosage	39%	32%	27%	21%	12%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%	0%	0%

TABLE E-23 Results of the comparison of the two methods when considering various options to end SIP, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Relocation Time: All Zones; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Various (Select TSIP Time Base Upon "Assumed Action Listed")			
	Action at TSIP End Shelter Time		
	Exit Shelter, Don't Relocate	**Exit Shelter, Relocate (15 min)**	**Exit Shelter, Relocate (20 min)**
Number of Cases	2898	2898	2898
AEGL-3 Technique: % of total cases	41%	46%	46%
AEGL-3 Technique: % with significant time difference	75%	86%	85%
AEGL-3 Technique: % reduction in total AEGL-3 area	15%	86%	82%
AEGL-3 Technique: average % reduction in AEGL-3 area	28%	63%	61%
AEGL-3 Technique: % with AEGL-3 area increase	0%	0%	0%
AEGL-2 Technique: % of total cases	14%	13%	13%
AEGL-2 Technique: % with significant time difference	75%	86%	86%
AEGL-2 Technique: % reduction in total AEGL-2 area	35%	97%	96%
AEGL-2 Technique: average % reduction in AEGL-2 area	38%	74%	73%
AEGL-2 Technique: % with AEGL-2 area increase	0%	0%	0%
AEGL-1 Technique: % of total cases	27%	28%	28%
AEGL-1 Technique: % with significant time difference	88%	91%	89%
AEGL-1 Technique: % reduction in total AEGL-1 area	45%	91%	89%
AEGL-1 Technique: average % reduction in AEGL-1 area	45%	76%	74%
AEGL-1 Technique: % with AEGL-1 area increase	0%	2%	2%
I/O Conc. Technique: % of total cases	18%	13%	14%
I/O Conc. Technique: % with significant time difference	45%	45%	43%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	57%	30%
I/O Conc. Technique: average % reduction in average dosage	27%	49%	47%
I/O Conc. Technique: % with average dosage increase	0%	0%	0%

TABLE E-24 Results of the comparison of the two methods when considering various times to enter shelter after the release, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Enter Shelter Time: All Zones; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Various (as shown); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Enter Shelter Time in Minutes				
	0	**8**	**16**	**21**	**30**
Number of Cases	2898	2898	2898	2898	2898
AEGL-3 Technique: % of total cases	46%	43%	41%	40%	39%
AEGL-3 Technique: % with significant time difference	70%	73%	75%	76%	76%
AEGL-3 Technique: % reduction in total AEGL-3 area	16%	16%	15%	15%	15%
AEGL-3 Technique: average % reduction in AEGL-3 area	36%	29%	28%	26%	24%
AEGL-2 Technique: % of total cases	14%	14%	14%	13%	13%
AEGL-2 Technique: % with significant time difference	72%	72%	75%	75%	77%
AEGL-2 Technique: % reduction in total AEGL-2 area	35%	35%	35%	34%	34%
AEGL-2 Technique: average % reduction in AEGL-2 area	36%	40%	38%	38%	37%
AEGL-1 Technique: % of total cases	28%	28%	27%	26%	25%
AEGL-1 Technique: % with significant time difference	86%	86%	88%	88%	90%
AEGL-1 Technique: % reduction in total AEGL-1 area	49%	48%	45%	43%	41%
AEGL-1 Technique: average % reduction in AEGL-1 area	47%	48%	45%	43%	42%
I/O Conc. Technique: % of total cases	11%	15%	18%	20%	23%
I/O Conc. Technique: % with significant time difference	48%	46%	45%	44%	42%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	4%	4%	4%	4%
I/O Conc. Technique: average % reduction in average dosage	18%	24%	27%	28%	28%

TABLE E-25 Results of the comparison of the two methods when considering various wind speeds, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Wind Speed: All Zones; All Cases by Wind Speed; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Wind Speed in m/s				
	1	**2**	**5**	**10**	**15**
Number of Cases	940	882	396	363	317
AEGL-3 Technique: % of total cases	41%	41%	40%	42%	39%
AEGL-3 Technique: % with significant time difference	89%	78%	60%	60%	62%
AEGL-3 Technique: % reduction in total AEGL-3 area	14%	15%	20%	24%	22%
AEGL-3 Technique: average % reduction in AEGL-3 area	25%	34%	22%	29%	30%
AEGL-2 Technique: % of total cases	15%	18%	8%	7%	13%
AEGL-2 Technique: % with significant time difference	94%	81%	29%	41%	42%
AEGL-2 Technique: % reduction in total AEGL-2 area	33%	39%	15%	24%	16%
AEGL-2 Technique: average % reduction in AEGL-2 area	37%	44%	32%	26%	14%
AEGL-1 Technique: % of total cases	23%	27%	36%	34%	21%
AEGL-1 Technique: % with significant time difference	98%	94%	87%	76%	58%
AEGL-1 Technique: % reduction in total AEGL-1 area	22%	47%	59%	89%	57%
AEGL-1 Technique: average % reduction in AEGL-1 area	36%	43%	49%	61%	50%
I/O Conc. Technique: % of total cases	20%	14%	15%	17%	27%
I/O Conc. Technique: % with significant time difference	66%	32%	33%	28%	34%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	5%	45%	45%	45%
I/O Conc. Technique: average % reduction in average dosage	19%	24%	45%	45%	46%

TABLE E-26 Results of the comparison of the two methods when considering various stability classes, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Stability Class: All Zones; All Cases by Stability Class; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)			
	Stability Class		
	B	**D**	**F**
Number of Cases	661	1993	244
AEGL-3 Technique: % of total cases	48%	41%	24%
AEGL-3 Technique: % with significant time difference	80%	72%	98%
AEGL-3 Technique: % reduction in total AEGL-3 area	19%	15%	12%
AEGL-3 Technique: average % reduction in AEGL-3 area	35%	27%	13%
AEGL-2 Technique: % of total cases	13%	15%	9%
AEGL-2 Technique: % with significant time difference	79%	73%	91%
AEGL-2 Technique: % reduction in total AEGL-2 area	15%	42%	6%
AEGL-2 Technique: average % reduction in AEGL-2 area	29%	44%	5%
AEGL-1 Technique: % of total cases	35%	27%	3%
AEGL-1 Technique: % with significant time difference	98%	83%	100%
AEGL-1 Technique: % reduction in total AEGL-1 area	40%	50%	31%
AEGL-1 Technique: average % reduction in AEGL-1 area	42%	46%	46%
I/O Conc. Technique: % of total cases	3%	17%	64%
I/O Conc. Technique: % with significant time difference	43%	41%	54%
I/O Conc. Technique: % reduction in area-weighted dosage sum	16%	4%	4%
I/O Conc. Technique: average % reduction in average dosage	18%	34%	16%

TABLE E-27 Results of the comparison of the two methods when considering various agent types, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Agent Type: All Zones; All Cases by Agent Type; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)			
	Agent Type		
	GB	**VX**	**Mustard**
Number of Cases	1404	1424	70
AEGL-3 Technique: % of total cases	34%	50%	0%
AEGL-3 Technique: % with significant time difference	69%	80%	0%
AEGL-3 Technique: % reduction in total AEGL-3 area	15%	16%	0%
AEGL-3 Technique: average % reduction in AEGL-3 area	21%	33%	0%
AEGL-2 Technique: % of total cases	18%	7%	64%
AEGL-2 Technique: % with significant time difference	67%	86%	98%
AEGL-2 Technique: % reduction in total AEGL-2 area	13%	43%	84%
AEGL-2 Technique: average % reduction in AEGL-2 area	18%	57%	78%
AEGL-1 Technique: % of total cases	34%	20%	36%
AEGL-1 Technique: % with significant time difference	82%	98%	100%
AEGL-1 Technique: % reduction in total AEGL-1 area	13%	56%	93%
AEGL-1 Technique: average % reduction in AEGL-1 area	31%	61%	83%
I/O Conc. Technique: % of total cases	14%	23%	0%
I/O Conc. Technique: % with significant time difference	33%	52%	0%
I/O Conc. Technique: % reduction in area-weighted dosage sum	4%	4%	0%
I/O Conc. Technique: average % reduction in average dosage	13%	33%	0%

TABLE E-28 Results of the comparison of the two methods when considering various zone sizes, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Zone Size: All Zones by Size; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Zone Size (km)				
	1	**3**	**5**	**15**	**25**
Number of Cases	728	630	630	524	386
AEGL-3 Technique: % of total cases	22%	37%	41%	54%	66%
AEGL-3 Technique: % with significant time difference	48%	63%	69%	86%	98%
AEGL-3 Technique: % reduction in total AEGL-3 area	26%	15%	16%	15%	15%
AEGL-3 Technique: average % reduction in AEGL-3 area	31%	27%	28%	28%	29%
AEGL-2 Technique: % of total cases	14%	14%	15%	14%	12%
AEGL-2 Technique: % with significant time difference	50%	71%	76%	97%	100%
AEGL-2 Technique: % reduction in total AEGL-2 area	36%	35%	32%	37%	34%
AEGL-2 Technique: average % reduction in AEGL-2 area	43%	37%	36%	35%	42%
AEGL-1 Technique: % of total cases	29%	28%	30%	27%	19%
AEGL-1 Technique: % with significant time difference	78%	83%	89%	100%	100%
AEGL-1 Technique: % reduction in total AEGL-1 area	52%	49%	44%	44%	45%
AEGL-1 Technique: average % reduction in AEGL-1 area	43%	43%	42%	47%	53%
I/O Conc. Technique: % of total cases	36%	21%	14%	6%	4%
I/O Conc. Technique: % with significant time difference	45%	39%	31%	73%	100%
I/O Conc. Technique: % reduction in area-weighted dosage sum	22%	16%	12%	4%	2%
I/O Conc. Technique: average % reduction in average dosage	36%	30%	16%	4%	3%

TABLE E-29 Results of the comparison of the two methods when considering various zones distances from the release, using IEM release scenarios

Comparison of TSIP Routine Relative to Plume Tail-Time for IEM Release Scenarios: Sensitivity to Zone Location: All Zones by Location; All Cases; Input ACH = Baseline; Actual ACH = Baseline; Enter Shelter Time = Baseline (16 minutes); End Shelter Action = Baseline (Exit Shelter But Do Not Relocate)					
	Zone Location from Release (km)				
	1	**2**	**10**	**20**	**25**
Number of Cases	1035	895	552	318	98
AEGL-3 Technique: % of total cases	51%	52%	21%	18%	15%
AEGL-3 Technique: % with significant time difference	80%	80%	51%	51%	60%
AEGL-3 Technique: % reduction in total AEGL-3 area	17%	17%	9%	7%	29%
AEGL-3 Technique: average % reduction in AEGL-3 area	29%	32%	11%	7%	22%
AEGL-2 Technique: % of total cases	12%	12%	20%	17%	14%
AEGL-2 Technique: % with significant time difference	81%	77%	76%	57%	71%
AEGL-2 Technique: % reduction in total AEGL-2 area	45%	34%	42%	26%	15%
AEGL-2 Technique: average % reduction in AEGL-2 area	48%	31%	37%	33%	30%
AEGL-1 Technique: % of total cases	18%	18%	43%	47%	49%
AEGL-1 Technique: % with significant time difference	81%	87%	92%	92%	83%
AEGL-1 Technique: % reduction in total AEGL-1 area	33%	41%	43%	50%	49%
AEGL-1 Technique: average % reduction in AEGL-1 area	44%	44%	40%	54%	42%
I/O Conc. Technique: % of total cases	19%	18%	16%	18%	21%
I/O Conc. Technique: % with significant time difference	33%	28%	57%	93%	100%
I/O Conc. Technique: % reduction in area-weighted dosage sum	3%	3%	7%	15%	21%
I/O Conc. Technique: average % reduction in average dosage	36%	30%	22%	20%	24%