Further, both wind speed and direction may change during the course of the release. Because of this, it is suggested that planners use a circle for fixed sites or a corridor for transportation routes when estimating vulnerable zones.

2.2.4 Application of Estimated Vulnerable Zones to Hazards Analysis for Extremely Hazardous Substances

This section provides an overview of how vulnerable zones can be estimated as part of a hazards analysis. To estimate the zone, specific values must be assigned to each of the variables discussed in the previous sections. Values may be obtained from the reporting facilities, from techniques contained in this document, or other sources recommended in this guide. In several instances, this guide provides liquid factors which replace a series of calculations. These factors are intended to make the process of estimating the vulnerable zones much easier for local emergency planning committees (LEPCs).

The step-by-step hazards analysis described in Chapter 3 of this guidance is divided into two major phases. The first phase involves a screening of all reporting facilities to set priorities among facilities so that more detailed hazards analysis can be conducted for those facilities that pose the greatest risk should a release occur. The first phase employs assumptions for a credible worst case scenario. The second phase involves the reevaluation of the facilities by priority. During this phase the LEPCs have the opportunity to reevaluate the assumptions used in the screening phase on a case by case basis using data that may be unique to a particular site.

Estimating Vulnerable Zones for Initial Screening

Because of time and resource limitations, local planners may not be able to evaluate all reporting facilities at the same time or to the same extent. Thus planners should set an order of priority among potential hazards for all facilities that have reported the presence of one or more EHSs in excess of the TPQ. One way to do this is to estimate a vulnerable zone radius using assumptions for a credible worst case scenario. Values that reflect these assumptions are assigned to all the variables discussed in Section 2.2.2. In this way, all facilities and substances are similarly evaluated to establish a relative measure of potential hazard for purposes of prioritization.

The initial estimated screening zones are based on the following credible worst case assumptions.

- Quantity released: maximum quantity that could be released from largest vessel or interconnected vessels.
- Rate of release to air: total quantity of gas, solid as a powder, or solid in solution is assumed to be released in 10 minutes; for liquids and molten solids, the rate is based on the rate of evaporation (rate of voltization). As explained in Appendix G this guidance simplifies the calculation of the rate of evaporation with a liquid factor which approximates a series of calculations. This number is called liquid factor ambient (LFA), liquid factor boiling (LFB), or liquid factor molten (LFM) depending on the handling conditions of the EHS.
- Temperature: not applicable to gases or solids as powders or in solution; for liquids, dependent on whether they are used at ambient temperature or near their boiling points; for molten solids, at their melting point.
- Meteorological conditions: wind speed of 1.5 meters per second (3.4 miles per hour); F atmospheric stability.
- Topographic conditions: flat, level, unobstructed terrain; use of the dispersion model for rural areas.
- LOC: one-tenth of the (NIOSH) published (IDLH) value or one-tenth of its approximation.* (See Appendix D for a discussion of LOC.)

* Provided it is not exceeded by the ACGIH TLV. In this case, the TLV is used.

As a result, the only information necessary to estimate the vulnerable zone for initial screening is:

- Chemical identity;
- Maximum potential quantity in a single vessel or interconnected vessels (obtained from the facility);
- Location of vessel and facility (obtained from the facility);
- LOC (found in Appendix C); and
- In instances of confidentiality claims, the approximate LOC as defined in this guidance, physical state, and approximate vapor pressure of a liquid or molten solid (obtained from the facility).

Planners can use the estimated zone, together with an initial consideration of population and essential service facilities within this zone and any readily available information on the likelihood of a release to establish an order of priority among the facilities. The considerations of population and critical services are discussed in Section 2.3 of this chapter.

Reevaluation of the Estimated Zones

Once the prioritization of facilities is completed, the LEPCs should begin a systematic reevaluation of those facilities which initially appear to represent the greatest potential hazards. This will require careful review of the considerations presented in Chapters 2 and 3 and Appendices G and I in this document, consultation with facility officials, and perhaps the aid of experts in the appropriate technical areas. After careful evaluation of new data, planners may wish to alter certain values and assumptions such as:

- Quantity likely to be released (use information from facility);
- Likely rate of release to air (obtain information from facility or other sources);
- Meteorological conditions (obtain information from facility, local, State, or regional experts, or other sources);
- Topographical considerations (e.g., urban versus rural landscape); and
- Values used for the LOC.

Reevaluation of the screening zones based on "credible worst case" assumptions used for screening purposes should be performed with utmost care and prudence. Although some changes in estimated or assumed values may increase the size of the estimated vulnerable zone, in many instances the zone will be reduced by such changes. Exhibit 2-9 provides a summary table of how the principal variables affect the estimated zone. For example, discussions with a facility representative may indicate that in one particular operation, vessels are rarely filled to maximum capacity or that equipment is engineered or designed to minimize or contain accidental releases. Chemicals may be subjected to higher temperatures or pressures than was originally assumed. Meteorological data may show that the worst-case conditions prevail for only a small percentage of the time or that they prevail for a large percentage of the time. The use of one-tenth of the IDLH or an approximation of this value as the LOC may or may not be considered overly protective for local circumstances. Local planners may favor the use of another value as an appropriate guideline for an LOC.

Decisions to alter the values or assumptions that affect the size of the estimated vulnerable zone involve a consideration of acceptable risk and are a matter of judgement at the local level. There is no guidance available that can provide values that would ensure no risk or that can provide an acceptable balance between risk and the appropriate level of planning for each district. This decision rests with local officials.

It is possible that reevaluation of the screening zones may lead to the estimation of several vulnerable zones as shown in Exhibit 2-7. Planners must then carefully consider the populations and essential services at risk, both within and outside these zones and reach conclusions on the level and type of planning they believe is necessary. Section 2.3 provides information on analyzing the risk associated with releases of EHSs to populations and essential services facilities within the planning district.

2.2.5 Evacuation Considerations for Airborne Releases of Extremely Hazardous Substances

Decisions about whether or not to evacuate as well as about evacuation distances are incident-specific and must be made at the time of an ac-

EXHIBIT 2-9

FACTORS AFFECTING VULNERABLE ZONE ESTIMATIONS

IF	IT WILL CAUSE	RESULTING IN
the quantity on site that might be involved in an accident is reduced	a reduction in the total airborne quantity and the quantity released per minute	smaller estimated zones
the time period of release of a given quantity increases	a reduction in the airborne quantity released per minute	smaller estimated zones
the release source point is above ground level	an increase in dispersion (mixing and diluting of the chemical in air)	smaller estimated zones (possibly)
the terrain considered is rough (uneven and mountainous) instead of flat	an increase in dispersion (mixing and diluting of the chemical in the air)	smaller estimated zones
the area is urban, containing high buildings and other man-made structures	an increase in dispersion (mixing and diluting of the chemical in the air)	smaller estimated zones
a higher value for LOC is chosen	a reduction in the geographical area with airborne concentrations above the LOC	smaller estimated zones
a lower value for LOC is chosen	an increase in the geographical area with airborne concentrations above the LOC	larger estimated zones

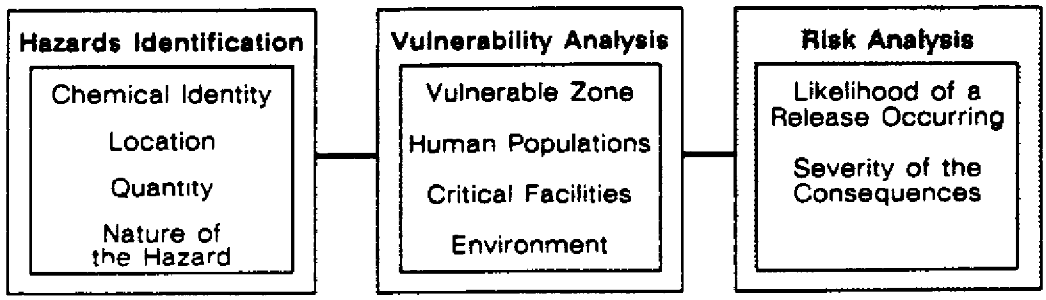
tual release. An estimated vulnerable zone should not automatically be used as the basis for evacuation during an incident response. For example, the following variable factors are always part of an evacuation decision: wind speed and direction, temperature, humidity, air dispersion conditions, and time of day. In addition, the vulnerable zone is described as a circle or a corridor surrounding the possible incident site and provides no information on the breadth of a potential plume. An evacuation zone is typically a pathway through which a plume might move from the point of release. The vulnerable zone is helpful because it identifies an area about which evacuation decisions might need to be made, but the evacuation zone will always depend on other factors.

Evacuation during incidents involving the airborne release of acutely toxic chemicals is sometimes, but by no means always, necessary. Release of airborne toxics can occur and move downwind so rapidly that there would be no time to evacuate residents. For short-term releases, the most prudent course of action for the protection of the nearby residents would often be to remain indoors with the doors and windows closed and the heating and air conditioning systems shut off. An airborne cloud will frequently move quickly past. Vulnerable populations, such as the elderly and sick, may suffer more injury by being evacuated than by staying inside and putting simple countermeasures into effect. If the releases occur over an hour or more, or if there is a fire that cannot be readily controlled within a short time, then evacuation may be a sensible alternative.

The disadvantages of evacuation in incidents involving airborne releases of EHSs are numerous. Two have already been alluded to, namely that events occur so rapidly that there may be no time to evacuate and that vulnerable populations would sustain fewer adverse effects by remaining inside until the toxic cloud has passed. Slight changes in wind velocity and direction could be very important if evacuation were begun during a release of airborne toxic chemicals; differences in temperature between air layers could also cause the toxic cloud to disperse in ways that would be hard to predict. It would be difficult to estimate how long a community would be exposed to a toxic cloud.

The estimated vulnerable zone for a potential airborne release of a specific quantity of EHS represents the area surrounding the potential release site within which vulnerable populations and facilities might be affected. It does not reflect the time frame of the impact of an accident. It also does not mean that just beyond the zone boundary residents are safe. The many assumptions made in the calculations for the vulnerable zones and the fact that no safe levels for any of the chemicals on the list of EHSs have been established for the general population, make it inappropriate to base evacuation solely on these estimates. If the estimated vulnerable zone is greater than planners can cope with, the community should work closely with the facility to discuss the possibility of reducing the risk of exposure. This could be achieved by reducing inventories, establishing controls or alarms to make sure no release occurs, and by installing early warning systems. A more detailed discussion of evacuation is given in Appendix H.

2.3 Risk Analysis



Risk analysis is the third part of the hazards analysis process. Risk analysis can provide a relative measure of the likelihood and severity of various possible hazardous events and enable the emergency plan to focus on the greatest potential risks. Risk analysis requires certain information collected during the first two steps of the hazards analysis (hazards identification and vulnerability analysis), as well as other information specific to the facility or the local area. The appropriate level of detail and scope of the risk analysis must be determined based on the local situation and the resources available. This guide is meant primarily to assist local emergency planning committees (LEPCs) in carrying out a relatively quick and inexpensive risk analysis. LEPCs with access to the necessary resources may wish to conduct a detailed quantitative risk analysis. However, a risk analysis of this type is beyond the scope of the guidance presented here and it is recommended that committees seek other guidance and expert advice for conducting quantitative risk assessments. A quantitative risk assessment is not deemed essential to performing a hazards analysis suitable for emergency response planning in most cases. The real value of risk analysis derives from the fact that it gives planners an ability to put each potential situation into perspective (in terms of the probability that it will occur and the resulting effects it will have) and results in emergency plans that will address the most likely and most severe potential hazards.

2.3.1 Overall Approach to Risk Analysis: Ranking of Hazards

Because available safeguards such as containment, controlled flow, and proper venting may greatly reduce the opportunity for, or extent of, exposure, the mere presence of a hazardous chemical is insufficient to identify the level of risk involved. Whenever a hazard exists, however, there is always some risk, however small it might be.

Risk analysis includes an estimate of the probability or likelihood that an event will occur. Risk can be characterized in qualitative terms as high, medium, or low, or in quantitative terms using numerical estimates and statistical calculations. For practical purposes, a risk analysis may be based on a subjective, common-sense evaluation. Few people live in daily fear of being struck by a meteorite. They know that, although the risk exists, it is very small because the probability is low. A busy street corner, known to be the site of frequent auto accidents, could be considered to present a high risk of accidents. Citizens know that the likelihood of being struck by an automobile is much greater and requires safeguards (e.g., looking both ways before crossing a street). In both of these situations, the evaluation of the probability of a future incident is based on knowledge of the frequency with which that incident has occurred in the past. Historical records of past events can, therefore, be put into practical use in risk analysis.

Both probability and consequences are extremely important in evaluating risk. A high risk situation can be the result of a high probability with severe consequences (e.g., irreversible health effects or death due to an airborne toxic chemical, a fire or explosion with injuries or fatalities), whereas moderate risk situations can be a result of either high probability with mild consequences or low probability with more severe consequences. Diminishing the likelihood of an accident or minimizing the consequences will reduce risk overall.

A relative ranking of hazards for the purposes of community emergency planning does not require extensive mathematical evaluations, application of statistics, or extensive support from experts. Application of readily available information and common sense, when combined with site-specific evaluations such as the vulnerability analysis, will complete much of the risk analysis process. Because it is based on the knowledge, experience, local considerations, and the priorities of the people in the planning district or community involved, there is no universal right answer in risk analysis.

2.3.2 Types of Information Required for Risk Analysis

Much of the information concerning sources of hazard, populations, and essential services subject to damage should have been assembled during the screening portion of the hazards identification and vulnerability analysis. Risk analysis will also require information on facility and community plans and safeguards, existing local response capabilities in place, and an historical record of past incidents and their outcomes.

Planners who have used the screening methodology to estimate vulnerable zones as described in Section 2.2 of this chapter and in Chapter 3 will then need additional information about priority facilities for which they will develop plans first. The process described in this section is iterative: (1) Planners gather additional information about high priority facilities first; (2) Planners then reevaluate and rank the risks associated with highest priority sites (and make emergency plans accordingly); (3) Planners then return to the original list of facilities that were assigned a lower priority during the screening and repeat the process until all reporting facilities have been reevaluated. Following the reevaluation of all facilities, appropriate emergency plans should be developed.

Facility Information

Facilities are an important source of information about risk. They are required under Title III of SARA to provide both chemical inventory and release information to LEPCs. Information required under Section 304 about spills or releases that have occurred will be useful for this phase of hazards analysis. Certain State and local governments have additional community-right-to-know regulations and spill reporting requirements with which facilities must also comply. Thus industries can and should be approached with questions regarding the hazards and safeguards present at their facilities. Interaction with facilities should be based on cooperation, respect for trade secrets and other confidential business information, and recognition of the industry as a member of the community. Facilities should be aware of the importance of certain information (e.g., the results of a facility risk assessment) and should cooperate in providing as much pertinent information as possible. Specific types of information concerning extremely hazardous substances (EHSs) that LEPCs may want to request from facilities include:

- Anticipated adverse health effects of a substance and their degree of severity;
- Safeguards in place on-site;
- Recommendations made by facilities for community safeguards;
- Prevention approaches used for past events in which adverse health effects were prevented, and details of the events;
- Lessons learned from past events in which adverse health effects occurred, and details of the events;
- Hazards evaluations conducted by the facility (e.g., HAZOP; see Appendix J).

In addition to the information and recommendations which they will provide, facilities may be willing to contribute resources to assist in emergency response management including:

- Assistance in planning and response by facility technical experts;

- Copies of facility emergency response plans and spill prevention control and countermeasures (SPCC) plans (see Appendix I);
- Assistance in cleanup and recycling of spilled materials; and
- Training and safe handling instructions.

Community Plan and Safeguard Information

Many communities will already have in place one or more emergency response plans developed to address a variety of hazards. Such plans may require revision to include recent new regulations and perhaps may be incomplete in addressing acutely toxic airborne releases, but will provide a valuable starting point for additional planning. Specific types of plans which may already exist include:

- Local multi-hazard emergency operations plans (EOPs) (developed under Federal Emergency Management Agency (FEMA) guidance);
- Emergency plans for transportation-related hazards (developed under Department of Transportation (DOT) guidance);
- Community Awareness and Emergency Response (CAER) plans (developed by the Chemical Manufacturers Association (CMA)); and
- The SPCC plans of individual facilities.

Historical Accident Records

There are two benefits to the review of historical records of hazardous materials incidents in risk analysis. First, an analysis of the sites and materials involved in prior accidents will indicate hazards that may represent significant risks. Although no two accidents will be identical, certain situations, if unaltered, can precipitate other more severe incidents. A second benefit is the development of an ability to recognize and assess potential risks which would not be apparent to an untrained evaluator. The development of an appreciation for what could happen can be achieved through a review of what has happened in the past. To assist in increasing the overall awareness of the nature and complexity of hazardous incidents, Exhibit 2-10 includes brief summaries of some accidents that occurred during 1980 and 1981 throughout the world. The Acute Hazardous Events Data Base prepared for the EPA Office of Toxic Substances (December 1985) has information on the chemicals involved in accidents that posed high risks to human health. The historical record of local hazardous incidents may be more valuable in identifying possible hazards in each district. Facility compliance with Section 304 of Title III of SARA will provide this type of information in the future.

An historical record of local hazardous materials incidents should include information from the following organizations:

- Fire department and rescue squad;
- Police department;
- Public health department;
- Local hospitals and physicians;
- Local chemical cleanup and spill response companies;
- Universities (chemistry, chemical engineering, and science laboratory safety personnel);
- Local industry; and
- News media (print and broadcast).

When accumulating records of past incidents, information concerning the responsible parties will not be essential to the risk analysis process. Many of the information sources listed above may be more willing to provide the needed data (e.g., date, time, location, material, extent of incident, injuries sustained, remedial actions taken, safeguards implemented) if they are assured that blame will not be assigned in the process.

Changing Factors Affecting Future Incidents

The historical record of incidents will contain valuable information. However, to properly apply such data to the risk analysis process requires that any changes which have occurred be taken into account. For example, the assembled historical record may contain several accidents involving the release of hazardous materials at a particular site. If the engineering controls, containment facilities or processes used are altered over time, the results of the risk analysis may be substantially different from what the historical record might predict. Any evaluation of past accidents must take into account any changes in the following:

Exhibit 2-10

SUMMARIES OF SOME ACCIDENTS THAT OCCURRED IN 1980-81

Location	Date	Incident	Consequences
1. Mexico	1980	Line rupture caused spill of liquid ammonia being pumped from a rail tank car to tank trucks at a loading rack.	3 bus passengers, 4 motorists and 2 pedestrians killed by vapor cloud.
2. California	1981	Pallets in a department store were tipped over and chlorine and ammonia became mixed.	10 persons attempting to clean up showed respiratory distress. 30 employees were evacuated, 6 required treatment.
3. Kentucky	1980	Fire in 6 of 10 derailed tank cars. The cars contained vinyl chloride, chlorine, acrylonitrile, and toluene. 3000 foot column of toxic smoke resulted.	Evacuation of 7500 residents.
4. Florida	1981	Vandalism at a swimming pool company resulted in a leak of chlorine and of muriatic acid.	Area was evacuated. 45 persons required hospital treatment.
5. Idaho	1980	Fire at a chemical plant resulted in airborne toxic fumes from pesticides and herbicides.	700 residents evacuated. 30 firefighters treated for fume inhalation.
6. Washington	1980	Nitric acid vapor released during transfer from a holding tank to a tank truck at an aircraft plant. Fumes drawn through plant via ventilation system.	800 employees evacuated.
7. Michigan	1981	Valve on vat of hot phenol formaldehyde/carbolic acid ruptured. An acid cloud covered one square mile of Detroit.	19 people treated for burns, eye and respiratory problems. Dead animals. Paint stripped from buildings and vehicles.

(Source: FEMA Interim SM-110. Analysis of Hazardous Materials Emergencies for Emergency Program Managers: Student Manual. January 1985.)

- Surrounding populations and critical facilities;
- Transportation routes; and
- Engineering control methods.

2.3.3 Limiting the Collection of Information

The preceding section contains some general guidance concerning the types of information required for a risk analysis and where to obtain such data. Appendix I contains suggestions for more detailed questions and concerns which may be raised during discussions to collect the needed information. These are all tools for use in determining what information to collect; none of them, however, will be wholly adequate for emergency planning needs. Community-specific checklists will have to be developed for use in collecting information since each locality and community has different needs, requirements, and points of emphasis.

The suggested approach for using the tools in this guide to aid in the development of such a community-specific checklist is to:

1) Review Appendix I for the types of information that appear to be needed.
2) Highlight and amend the suggestions in Appendix I to reflect the specific needs of your local community or planning district.
3) Develop a detailed checklist of information needed based on the amended (tailored) version of Appendix I and the types of information outlined in the prior section of this guidance.
4) Set a priority for each item of information based on perceived need, effort involved, and available resources.
5) Request the needed information and assemble it. (This process will be described in the next section.)

It is very important to recognize when enough information has been collected. A cursory review of Appendix I, which is by no means a complete set of discussion points, will demonstrate the volume of information that can be collected for the risk analysis. Collection of data on all possible interactions of elements would be extremely time consuming. The complexity of the analysis and the effort required to perform it will depend directly on the volume of data collected. The focus of the information collection should be on developing a relative measure of the likelihood and severity of possible hazardous events. This goal does not demand an exhaustive collection of data. Reviewing data as they are collected will greatly assist in identifying information that is essential as opposed to that which is peripheral to the risk analysis process. If in doubt, base decisions on whether the information:

- Has the potential for altering the relative ranking of the hazard to the community; and
- Directly involves identification of a hazard, determination of likelihood of an incident, assessment of outcome of an accident, or identification of the safeguards needed or available to reduce the magnitude of the damage.

Anything outside these categories can be considered of secondary importance and should be collected only if resources allow. Such limitations, when properly applied to the entire information collection process (i.e., prioritization of the checklist before data is collected) can benefit the risk analysis by eliminating unnecessary types of information (e.g., details concerning damage from the least likely events) before effort is expended on its collection and analysis.

2.3.4 Assembly of the Information Obtained from the Hazards Analysis

Data that are systematically assembled as they become available during the three major steps of the hazards analysis can be easily evaluated as the risk analysis progresses and can be used to identify missing data as well as information that is complete. As has been discussed earlier in this chapter, a hazards analysis is first performed during the screening of reporting facilities using "credible worst case assumptions" for establishing priorities among facilities. The hazards analysis of each facility is then reevaluated according to priority based on a careful reassessment of the assumptions used in the screening process. A list of these steps is shown in Exhibit 2-11.

Information obtained during both the screening process and the reevaluation process can be stored in a hazards analysis matrix. The hazards

EXHIBIT 2-11

STEPS IN HAZARDS ANALYSIS

INITIAL SCREENING

1. HAZARDS IDENTIFICATION

A. List facilities that have reported EHSs in the community in excess of the threshold planning quantity TPQ

B. Contact each facility on the list for information on the EHSs present

i. Chemical identities

ii. Quantities and location of chemicals present

iii. Properties of the chemicals if identity is trade secret

iv. Conditions under which chemicals are used, produced, processed, or stored

C. Obtain information on transportation routes of EHSs, if possible

D. Obtain information on hazardous materials, facilities, and transportation routes (other than for those with EHSs above the TPQ) listed by SERCs (optional)

2. VULNERABILITY ANALYSIS

A. Estimate vulnerable zone for screening using credible worst case assumptions

i. Determine rate of release to air using information from the facility concerning quantity likely to be released from a vessel or interconnected vessels and fixed assumptions about time of release

ii. Use LOC from Appendix C

iii. Determine zone using Exhibit 3-1 and fixed conditions

B. Identify characteristics of human population (e.g., number, concentration, general health) within estimated vulnerable zone

C. Identify critical facilities within estimated vulnerable zone

3. RISK ANALYSIS

A. Collect information obtained in hazards identification and vulnerability analysis

B. Make rough estimate of risks posed by each based on readily available information on the likelihood of a release and severity of consequences

C. Identify those facilities with higher priority due to the estimated risks they pose

REEVALUATION OF FACILITIES BY PRIORITY

4. HAZARDS IDENTIFICATION

A. Contact each facility on the list and other expert sources for additional information on the EHSs present and what conditions might be present during a release

i. Reevaluate estimate of quantity likely to be present

ii. Reevaluate estimate of rate of release

iii. Consider typical weather and wind conditions

B. Obtain additional information on typical transportation conditions, if possible

5. VULNERABILITY ANALYSIS

A. Reestimate vulnerable zone using reevaluated assumptions gathered from conversations with the facility and other expert sources

B. Identify characteristics of human population within estimated vulnerable zone

C. Identify critical facilities within estimated vulnerable zone

6. RISK ANALYSIS

A. Collect all information obtained in hazards identification and vulnerability analysis into a table

B. Obtain additional information on community and facility safeguards, response capabilities, and accident records

C. Make judgment of probability of release and severity of consequences

D. Organize all information (from A, B, and C) in a matrix format

E. Rank risks

F. Develop, or revise emergency plans for higher priority facilities

INTEGRATING HAZARDS ANALYSIS INTO THE PLAN.

See Exhibit 4-1 Emergency Planning Information Section.

analysis matrix is a technique for assembling all of the information that was collected during the risk analysis process, along with information from the hazards identification and vulnerability analysis steps. Each hazard occupies one column of the matrix, as shown in the example in Exhibit 2-12. This matrix also documents the safeguards that are in place to mitigate the hazard and the available historical record of similar accidents. (Note that the examples given in Exhibit 2-12 utilize data specific to a given locality. The ranking of hazards in a different community might result in a different perception of risk). By placing all of the information in a relatively abbreviated format, the hazards analysis matrix provides a direct way to identify missing information (i.e., blanks in the matrix) and compare hazards with one another. The hazards analysis matrix includes the probability or likelihood of an event occurring, as well as the resulting consequences or damage to people and property. The relative ranking of hazards will be discussed in some detail in the next section.

The hazards analysis matrix provides one format for recording available information and comparing obvious hazards. Other more sophisticated techniques for evaluating hazards are described in Appendix J. They require technical personnel and empirical data or good models. They include: hazard and operability study (HAZOP); event tree analysis; fault tree analysis; and failure modes, effects, and criticality analysis (FMECA). Each of these techniques has advantages which the community may find appropriate for the analysis of particular types of hazards. The hazards analysis matrix is recommended for structuring and analyzing the information collected during the hazards analysis process. The use of event tree analysis is most appropriate where visualization of the possible outcome is not readily apparent or where there are many possible outcomes of the event. Fault tree analysis also relates a chain of events, but works backwards from the expected outcome to determine only those events which could result in the situation under analysis. Fault tree analysis is a systematic approach focusing on a chain of events or occurrences. Fault trees will be most appropriate in situations where there are many factors interacting to produce an outcome. The HAZOP can be very time demanding; however, in situations where little or no knowledge of the potential hazard exists (e.g., a new process or manufacturing facility), this method can provide invaluable insight into the potential for hazardous events. As noted above, planners might request facilities to provide the results of these more detailed and complex risk analyses.

2.3.5 Relative Ranking of Risk

Once the information that appears most essential to the risk assessment has been assembled, the likelihood of the events has been determined, and the potential consequences have been identified, an evaluation can be made of the relative overall risk that is presented to the community. There are no rules for determining the relative risk that events present because, although one type of hazard may have the potential for extensive damage, the likelihood of its occurrence may be much less than another event which would be substantially less damaging. Subjective and qualitative judgments must be made based on the information available. This guidance provides a set of criteria upon which these judgments may be based; however, if a community feels that different types of criteria are more applicable to their needs, they should develop them accordingly.

The following steps will help you estimate overall risk during reevaluations:

- Each event can be assigned a ranking of likelihood in a relative sense of high, medium, or low. (See Exhibit 2-13 for suggested definitions. See Exhibit 2-12, Section 3a of "Further Evaluation" for an application to the example hazards analysis matrix.)
- Next, the severity of the potential consequences to people can also be ranked as high, medium, or low. (See Exhibit 2-13 for suggested definitions. See Exhibit 2-12, Section 3b of "Further Evaluation" for an application to the example hazards analysis matrix.)
- The results of the first two steps can be combined into a risk analysis matrix. There are nine possible ranking combinations, as indicated by the boxes in Exhibit 2-14.

Exhibit 2-12

EXAMPLE HAZARDS ANALYSIS MATRIX FOR A HYPOTHETICAL COMMUNITY

	Hazard A	*Hazard B*	*Hazard C*
INITIAL SCREENING			
1. HAZARDS IDENTIFICATION (Major Hazards)			
a. Chemical	Chlorine	Ammonia	Liquid methyl isocyanate (MIC)
b. Location	Water treatment plant	Tank truck on local interstate highway	Pesticide manufacturing plant in nearby semi-rural area
c. Quantity	800 lbs.	3000 lbs.	1000 lbs.
d. Properties	Poisonous; may be fatal if inhaled. Respiratory conditions aggravated by exposure. Contact may cause burns to skin and eyes. Corrosive. Effects may be delayed.	Poisonous; may be fatal if inhaled. Vapors cause irritation of eyes and respiratory tract. Liquid will burn skin and eyes. Contact with liquid may cause frostbite. Effects may be delayed. Although not flammable, will burn within certain vapor concentration limits and increase fire hazard in the presence of oil or combustible materials.	Causes death by respiratory distress after inhalation. Other effects would include permanent eye damage, respiratory distress, and disorientation. Explosive. Extremely flammable.
2. VULNERABILITY ANALYSIS			
a. Vulnerable zone*	A spill of 800 lbs. of chlorine from a storage tank could result in an area of radius greater than 10 miles where chlorine gas may exceed the level of concern (LOC). This would be a credible worst case scenario.	A spill of 3000 lbs. of ammonia resulting from a collision of a tank truck could result in an area of radius 7.6 miles where ammonia exceeds its LOC. This would be a credible worst case scenario.	A spill of 1000 lbs. of methyl isocyanate could affect an area of radius 7.6 miles with MIC vapors exceeding the LOC (assuming that the liquid is hot when spilled, the tank is not diked, and the MIC is at 100% concentration). This would be a credible worst case scenario.
b. Population within vulnerable zone	Approximately 600 residents of a nursing home; workers at a small factory; 29 workers at the water-treatment plant; urban area-400 persons/sq. mile; total population in vulnerable zone is more than125,000.	Up to 700 persons in residences, commercial establishments or vehicles near highway interchange; seasonal influx of visitors to forest preserve in the fall; rural area-75 persons/sq. mile; total population in vulnerable zone is 13,600.	Up to 200 workers at the plant and 1000 children in a school; rural area-85 persons/sq. mile; total population in vulnerable zone is 15,400.
c. Essential services within zone	2 fire stations and 1 hospital	1 volunteer fire station	None
3. RISK ANALYSIS (Initial Evaluation of Reporting Facilities--Relative Hazards)	Relative to potential hazards of other reporting facilities--high	Medium	High

*The distances here may not correspond with those in NRT-1 as the assumptions used in the calculation are different.

	Hazard A	*Hazard B*	*Hazard C*
REEVALUATION	(Select facilities by priority based on initial screening)		
1. HAZARDS IDENTIFICATION			
a. Chemical	Chlorine	Ammonia	Liquid methyl isocyanate (MIC)
b. Location	No change	No change	No change
c. Maximum quantity that could be released	500 lbs. (decrease)	No change	1500 lbs. (increase) due to increased production
d. Properties	No change	No change	No change
2. VULNERABILITY ANALYSIS			
a. Vulnerable Zone	Zone decreases (new radius-1.0 miles) due to smaller quantity released and use of urban dispersion model.	No change	Zone increases (new radius-greater than 10 miles) due to larger quantity released.
b. Population within vulnerable zone	Decreases; total population in vulnerable zone is 1250.	No change	Increases; total population in vulnerable zone is 26,700 including 200 workers at the plant and 1000 children in school.
c. Essential services	None	No change	1 fire station and 1 police station
3. RISK ANALYSIS			
a. Likelihood of hazard occurrence	Low-because chlorine is stored in an area with leak detection equipment in 24 hour service with alarms. Protective equipment is kept outside storage room.	High-highway interchange has a history of accidents due to poor visibility of exits and entrances.	Low-facility has up to date containment facilities with leak detection equipment and an emergency plan for its employees. There are good security arrangements that would deter tampering or accidents resulting from civil uprisings.
b. Consequences if people are exposed	High levels of chlorine gas in the nursing home and factory could cause death and respiratory distress. Bed-ridden nursing home patients are especially susceptible. High severity of consequences. However, gas is unlikely to reach a nursing home under reevaluated release conditions.	Motorists' reactions to release vapors may cause traffic accidents. Injured and trapped motorists are subject to lethal vapors and possible incineration. Windblown vapors can cause respiratory distress for nearby residents and business patrons. High severity of consequences.	If accident occurs while school is in session, children could be killed, blinded and/or suffer chronic debilitating respiratory problems. Plant workers would be subject to similar effects at any time. High severity in school hours, medium severity at all other times.
c. Consequences for property	Possible superficial damage to facility equipment and structures from corrosive fumes (repairable).	Repairable damage to highway. Potential destruction of nearby vehicles due to fire or explosions.	Vapors may explode in a confined space causing property damage (repairable). Damage could result from fires (repairable).
d. Consequences of environmental exposure	Possible destruction of surrounding fauna and flora.	Potential for fire damage to adjacent forest preserve due to combustible material (recoverable in the long term).	Farm animals and other fauna could be killed or develop health effects necessitating their destruction or indirectly causing death.
e. Summary: likelihood/ severity of consequences	Low/High. The community would assess this on site and incident specific basis.	High/High. The community would assess this on site and incident specific basis.	Low/High to medium. The community would assess this on site and incident specific basis.

Exhibit 2-13

EXAMPLE QUALITATIVE DEFINITIONS OF PROBABILITY OF OCCURRENCE

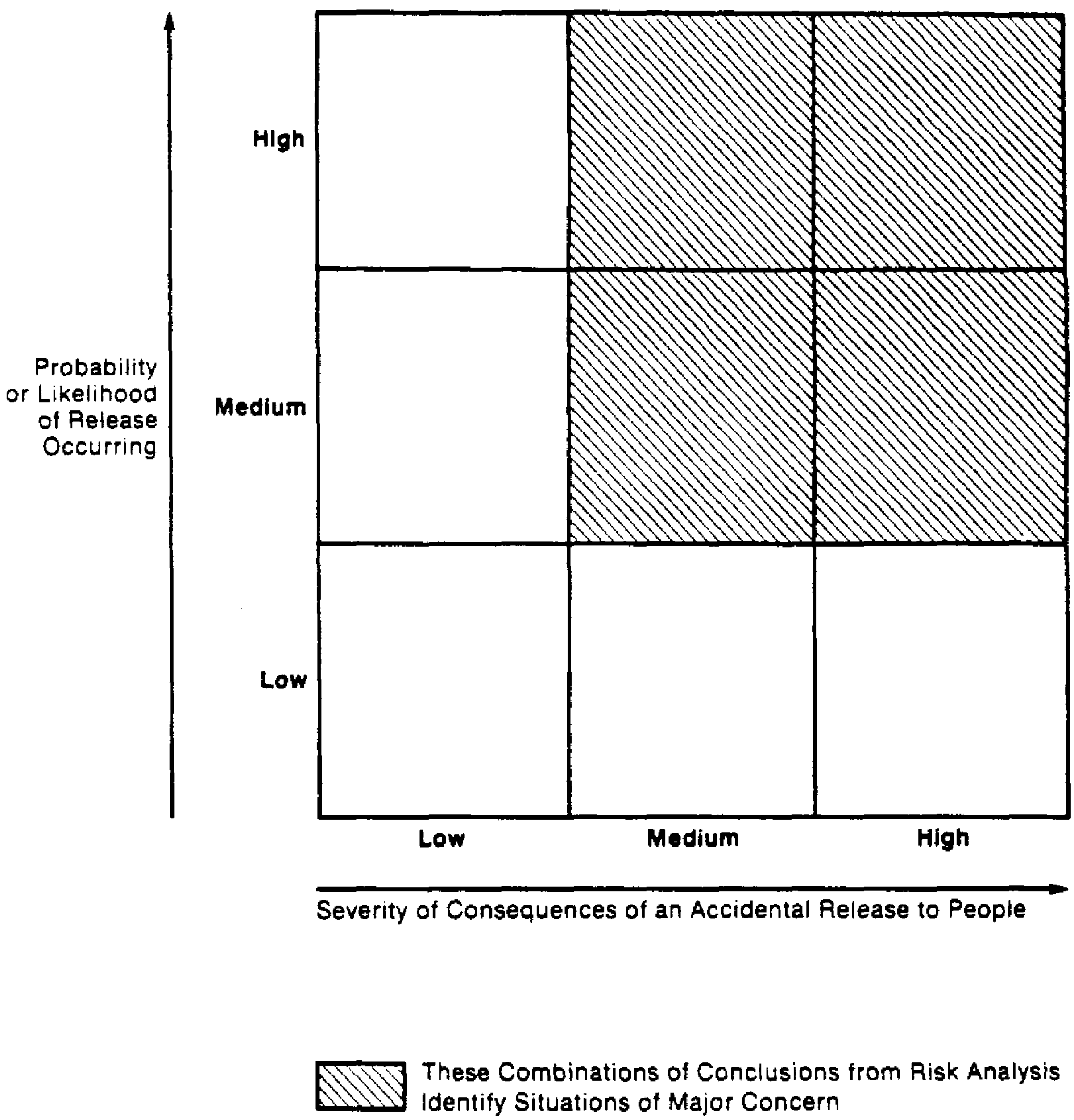
I. Low:	Probability of occurrence considered **unlikely** during the expected lifetime of the facility assuming normal operation and maintenance.
II. Medium:	Probability of occurrence considered **possible** during the expected lifetime of the facility.
III. High:	Probability of occurrence considered sufficiently high to assume event **will occur** at least once during the expected lifetime of the facility.

EXAMPLE DEFINITIONS OF SEVERITY OF CONSEQUENCES TO PEOPLE

I. Low:	Chemical is expected to move into the surrounding environment in negligible concentrations. Injuries expected only for exposure over extended periods or when individual personal health conditions create complications.
II. Medium:	Chemical is expected to move into the surrounding environment in concentrations sufficient to cause serious injuries and/or deaths unless prompt and effective corrective action is taken. Death and/or injuries expected only for exposure over extended periods or when individual personal health conditions create complications.
III. High:	Chemical is expected to move into the surrounding environment in concentrations sufficient to cause serious injuries and/or deaths upon exposure. Large numbers of people expected to be affected.

Exhibit 2-14

Risk Analysis Matrix



In general, the events with likelihood-consequence rankings of high-high, high-medium, medium-high, and medium-medium will require some additional attention and possible mitigating measures. However, other less likely scenarios may also have serious consequences and be of high concern to a particular community and would warrant the focus of emergency planning. This initial approach to ranking hazards can enable the best use of the available planning resources.

The planning and decision-making situations in which risk analysis information may prove valuable include:

- Development of a comprehensive local emergency plan;
- Updating of facility emergency response plans;
- Planning major transportation routes for hazardous chemicals (it should be emphasized that the Federal Highway Administration publication FHWA-IP-80-15, Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials, should be used. This document summarizes routing requirements at the Federal, State, and local levels consistent with the Hazardous Materials Transportation Act (HMTA) of 1975);
- Zoning;
- Providing a basis for requesting additional emergency response resources (e.g., fire department vehicles equipped for hazardous materials incidents); and
- Developing new training materials or selecting available materials.

The application of the results of a risk analysis to the emergency planning process will be described in detail in Chapter 4.

The summary description of the components of hazards analysis presented in this chapter and Appendices I and J will provide a sound basis for understanding the next chapter of this guidance. Chapter 3 leads planners step by step through a hazards analysis, beginning with the initial screening of reporting facilities to establish priorities, and followed by a subsequent reevaluation of the estimated vulnerable zones and hazards analysis by priority of potential hazard.