Identification and Selection of Remedial Action Alternatives

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CHAPTER 2

IDENTIFICATION AND SELECTION OF REMEDIAL ACTION/CORRECTIVE MEASURE ALTERNATIVES

Section I. Introduction

2-1. Three-Step Approach.

a. Responses to the uncontrolled release of hazardous substances are conducted under the statutory authority of either CERCLA or RCRA. Although the terminology used under each authority is different, in each case the identification and selection of the appropriate response to the release of hazardous substances is conducted in an orderly, phased approach. Figure 2-1 illustrates the similarities and differences between the response action process under each statute. Because of the similarities in the processes and the substantially larger experience base associated with response actions conducted under CERCLA, the remainder of this chapter focuses on the CERCLA process and uses CERCLA terminology. Where appropriate, the user of this manual should use Figure 2-1 and Table 2-1 to crosswalk between the CERCLA and RCRA response action processes.

b. Under CERCLA, the identification and selection of the appropriate response to the uncontrolled release of hazardous substances is conducted in an orderly, phased approach consisting of three steps: (1) the preliminary assessment (PA), (2) the site investigation (SI), and (3) the remedial investigation/feasibility study (RI/FS). The overall process is shown in Figure 2-2.

c. The PA is usually a review of historical records, including current and past land uses. The emphasis of the PA is the identification of activities that may have resulted in the improper handling of hazardous substances. Interviews with personnel familiar with site operations may be conducted during the PA. The PA is designed to identify the potential, not the extent, of a hazardous waste problem.

d. Should the PA reveal a potential problem, a SI may be conducted. The SI includes topographic setting, geological surveys, surface and groundwater flow, building and utility layouts, and the condition of structures located on site. The SI may include some field investigations to identify site characteristics such as soil contamination, liquid discharges, and abnormalities in vegetation.

e. Should the SI indicate the need for further study, a RI/FS may be conducted. The RI/FS is the methodology that the USEPA Superfund program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options. This approach should be tailored to specific circumstances of individual sites; it is not a rigid step-by-step approach that must be conducted identically at every site. The objective of the RI/FS is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site. The general RI/FS process is shown in Figure 2-3.

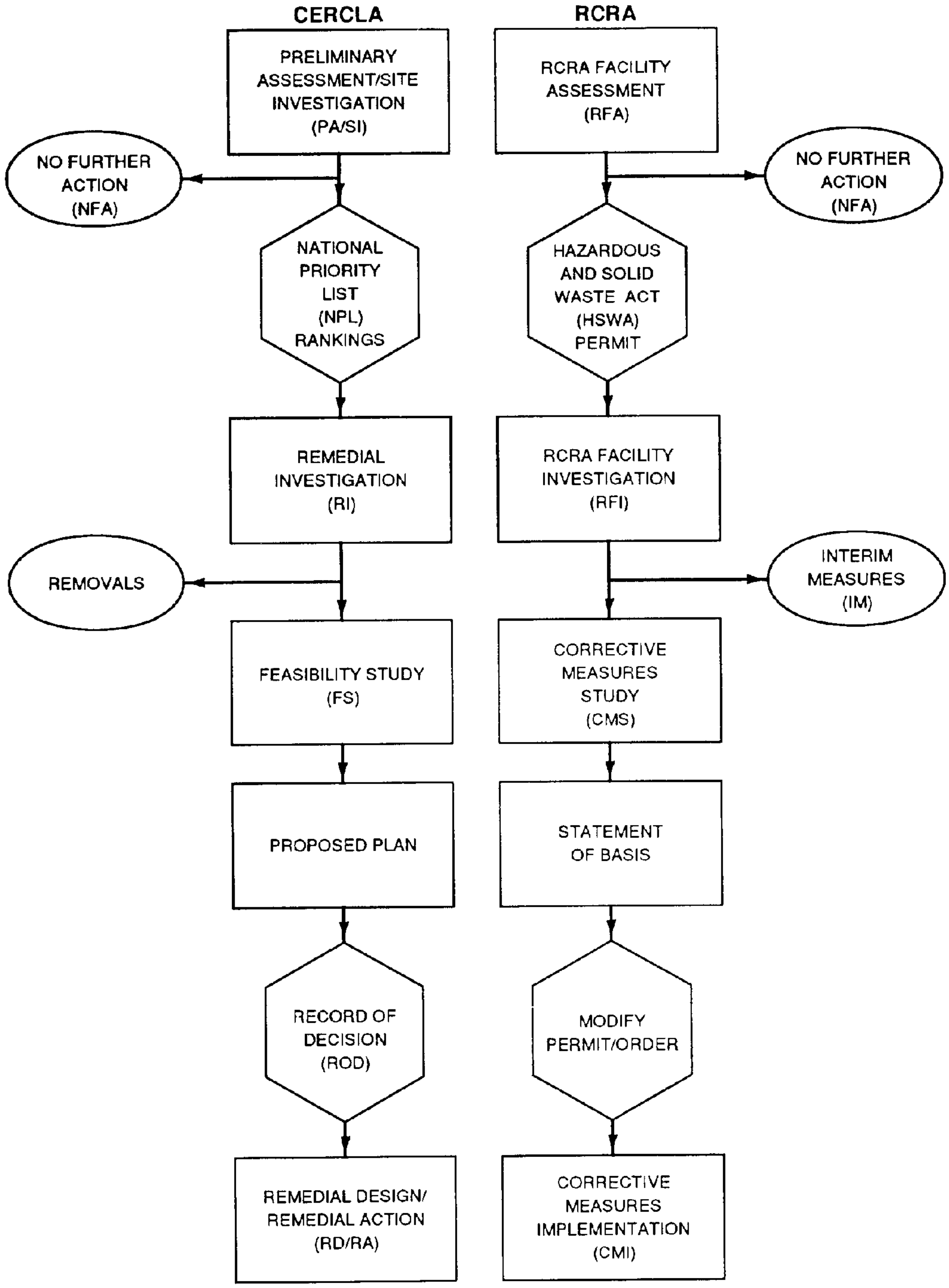


Figure 2-1. Comparison of RCRA/CERCLA Action Processes

Table 2-1. CERCLA\RCRA Terminology Crosswalk

CERCLA Process	RCRA Process	Objective
Preliminary Assessment (PA)	RCRA Facility Assessment (RFA)	Determine the potential for a present of past release, based primarily on historical records.
Site Investigation (SI)	See Note 1	Provide sufficient information to determine the need for a full remedial investigation, based on preliminary site data and field sampling for contamination.
Remedial Investigation (RI)	RCRA Facility Investigation (RFI) (RFI)	Characterize the nature, extent, direction, rate, movement and concentration of releases.
Feasibility Study (FS)	Corrective Measures Study (CMS)	Evaluate potential remedial actions and provide sufficient information to decision makers to allow an informed

[1] There is no direct RCRA equivalent for the SI. The RFA may have many of the field investigation aspects of the SI.

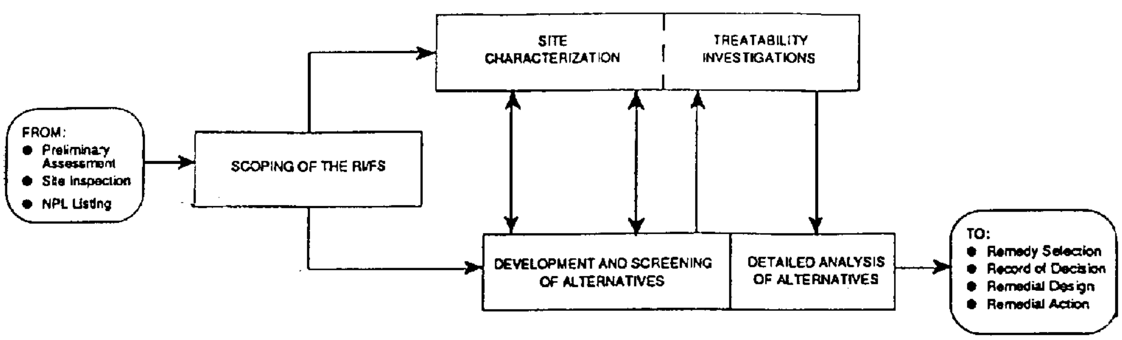


Figure 2-2. Remedial Action Evaluation Process

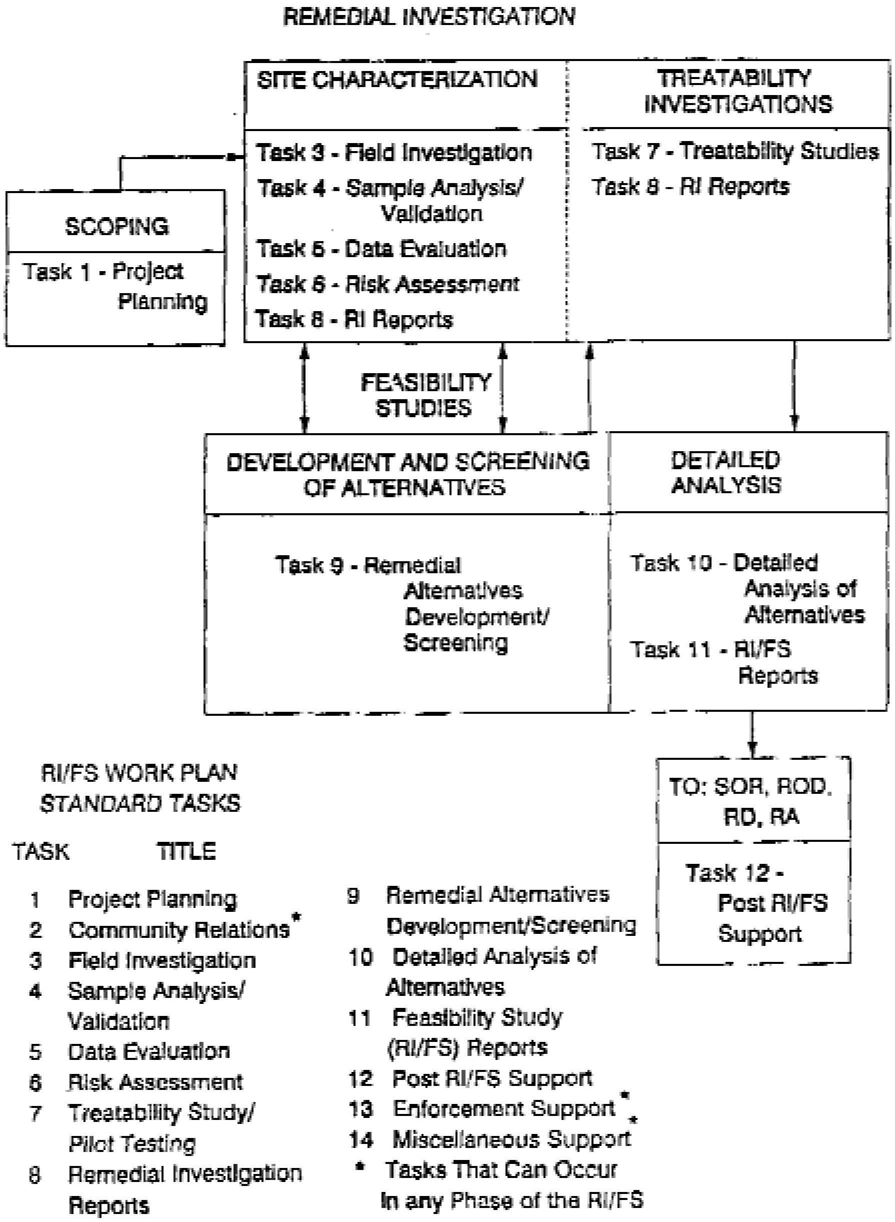


Figure 2-3. Overview of the RI/FS Process

2-2. Guidance.

a. For primary guidance on the formulation, evaluation, and selection of remedial action alternatives, the National Oil and Hazardous Substances Contingency Plan (NCP) found at 40 CFR 300 should be followed.

b. For detailed information on the conduct of remedial investigations and feasibility studies, EPA* s Guidance on Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final, October 1988) should be consulted. The revised guidance is designed to (1) reflect new emphasis and provisions of the Superfund Amendments and Reauthorization Act (SARA), (2) incorporate aspects of new or revised guidance related to aspects of remedial investigations and feasibility studies (RI/FSs), (3) incorporate management initiatives designed to streamline the RI/FS process, and (4) reflect experience gained from previous RI/FS projects.

2-3. RI/FS Procedure.

a. Scoping. Scoping is the initial planning phase of the RI/FS process, and many of the planning steps begun here are continued and refined in later phases of the RI/FS. Scoping activities typically begin with the collection of existing site data, including data from previous investigations such as the preliminary assessment and site investigation. On the basis of this information, site management planning is undertaken to preliminarily identify boundaries of the study area, identify likely remedial action objectives and whether interim actions may be necessary, and establish whether the site may best be remedied as one unit or several separate operable units. Once an overall management strategy is agreed upon, the RI/FS for a specific project or the site as a whole is planned. Typical scoping activities, shown in Figure 2-4, include:

(1) Initiating the identification of potential applicable or relevant and appropriate requirements (ARARs) and discussing them with the support agency.

(2) Determining the types of decisions to be made and identifying the data and other information needed to support those decisions.

(3) Assembling a technical advisory committee to serve as a review board for important deliverables and to monitor progress during the study.

(4) Preparing the work plan, the sampling and analysis plan (SAP) (which consists of the quality assurance project plan (QAPP) and the field sampling plan (FSP)), the health and safety plan, and the community relations plan.

b. Site Characterization.

(1) During site characterization, field sampling and laboratory analyses are initiated. Field sampling should be phased so that the results of the initial sampling efforts can be used to refine plans developed during scoping to better focus subsequent sampling efforts. Data quality objectives are revised based on an improved understanding of the site to facilitate a more efficient and accurate characterization of the site and, therefore, achieve reductions in time and cost.

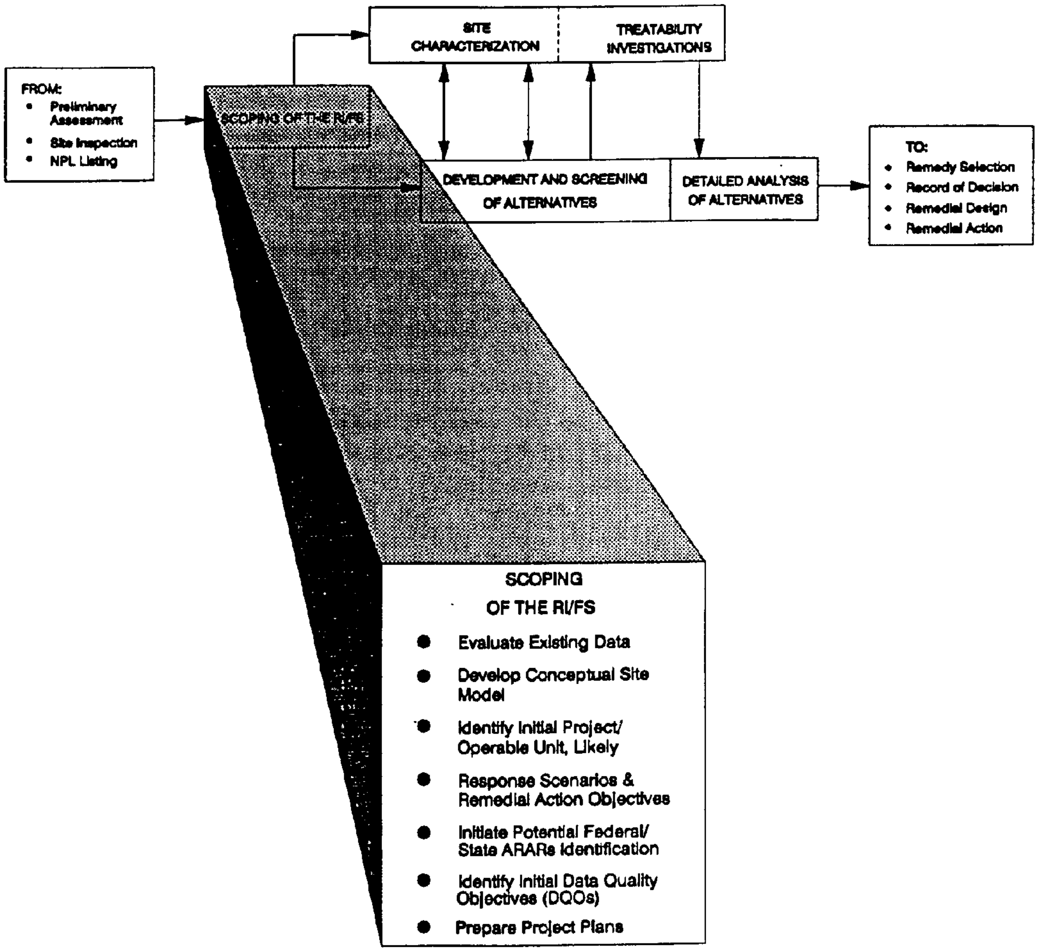


Figure 2-4. Scoping the RI/FS Process

(2) A preliminary site characterization summary is prepared to provide the lead agency with information on the site early in the process before preparation of the full RI report. This summary will be useful in determining the feasibility of potential technologies and in assisting both the lead and support agencies with the initial identification of ARARs. It can also be used to assist in performing their health assessment of the site.

(3) A baseline risk assessment is developed to identify the existing or potential risks that may be posed to human health and the environment by the site. This assessment also serves to support the evaluation of the no- action alternative by documenting the threats posed by the site based on expected exposure scenarios. Because this assessment identifies the primary health and environmental threats at the site, it also provides valuable input to the development and evaluation of alternatives during the FS. Site characterization activities are shown in Figure 2-5.

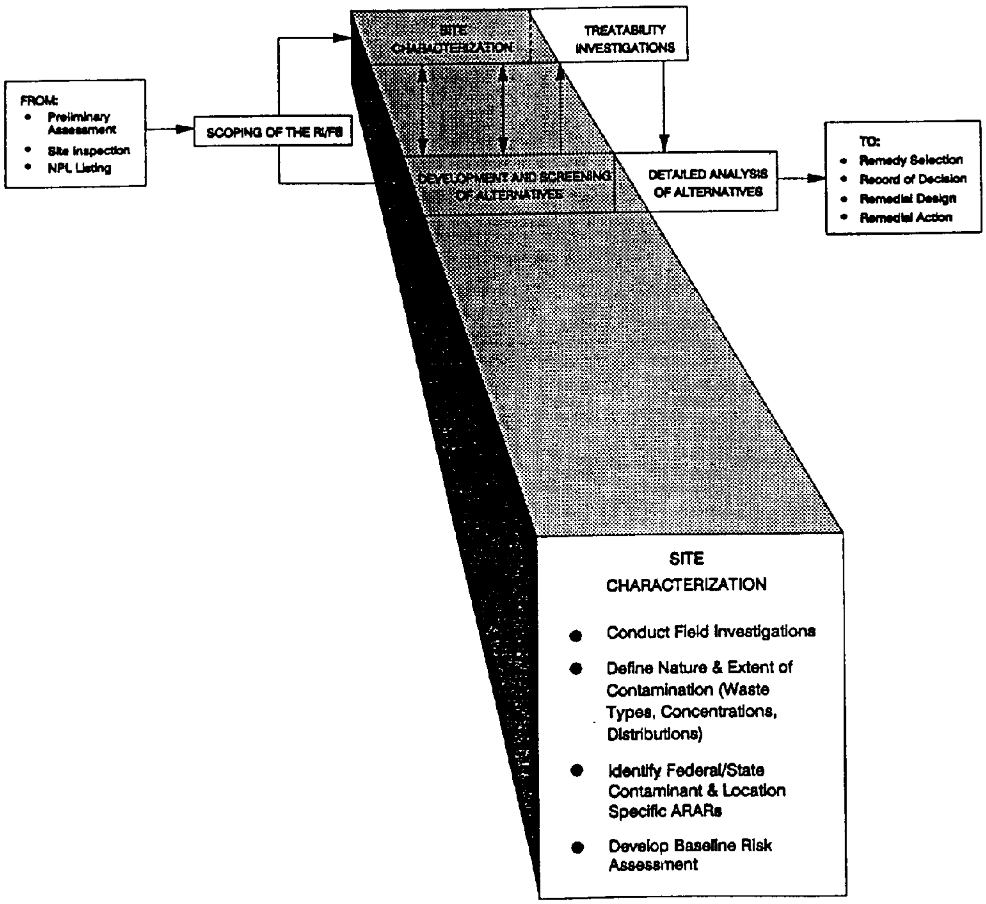


Figure 2-5. Overview of the Site Characterization Process

c. Development and Screening of Alternatives.

(1) The development of alternatives usually begins during or soon after scoping, when likely response scenarios may first be identified. The process for developing and screening of alternatives is shown in Figure 2-6. The development of alternatives requires (a) identifying remedial action objectives; (b) identifying potential treatment, resource recovery, and containment technologies that will satisfy these objectives; (c) screening the technologies based on their effectiveness, implementability, and cost; and (d) assembling technologies and their associated containment or disposal requirements into alternatives for the contaminated media at the site or for the operable unit.

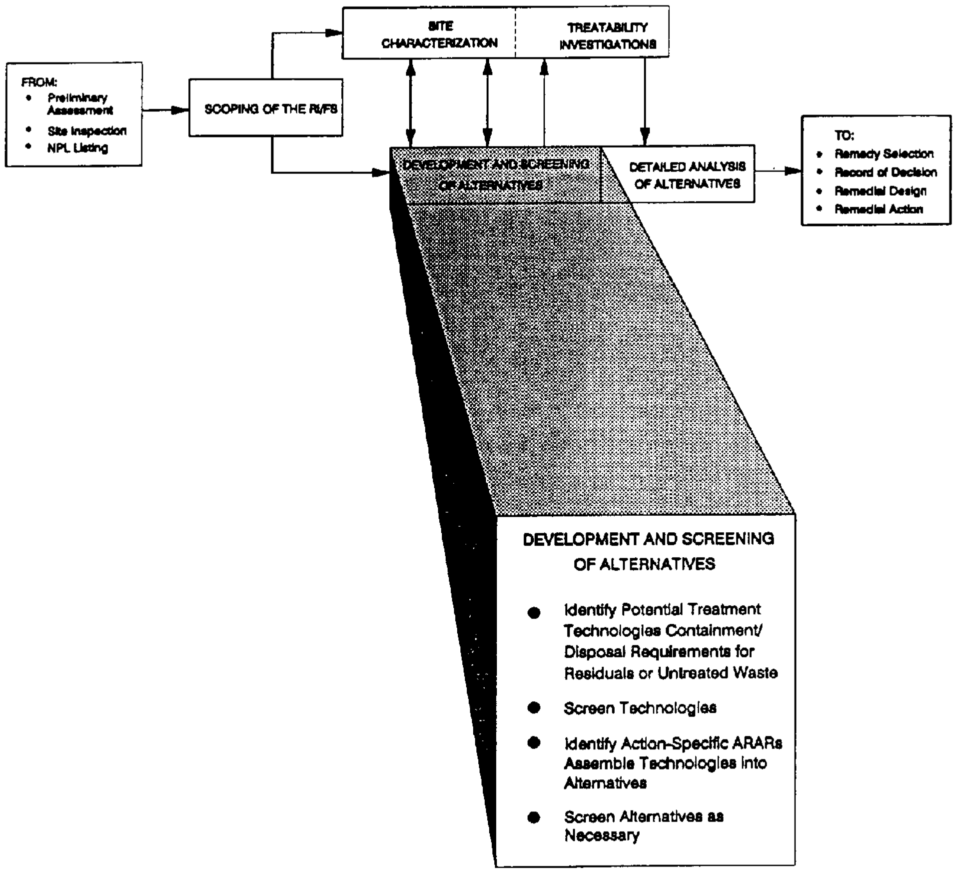


Figure 2-6. Overview of the Development and Screening of Alternatives Process

Alternatives can be developed to address contaminated medium (e.g., ground water), a specific area of the site (e.g., a waste lagoon or contaminated hot spots), or the entire site. Alternatives for specific media and site areas either can be carried through the FS process separately or combined into comprehensive alternatives for the entire site. The approach is flexible to allow alternatives to be combined at various points in the process.

(2) A range of treatment alternatives should be developed, varying primarily in the extent to which they rely on long-term management of residuals and untreated wastes. The upper bound of the range would be an alternative that would eliminate, to the extent feasible, the need for any long-term management (including monitoring) at the site. The lower bound would consist of an alternative that involves treatment as a principal element (i.e., treatment is used to address the principal threats at the site), but some long-term management of portions of the site that did not constitute "principal threats" would be required. Between the upper and lower bounds of the treatment range, alternatives varying in the type and degrees of treatment and associated containment/disposal requirements should be included. In addition, one or more containment options involving little or no treatment should be developed, and a no-action alternative should always be developed.

(3) Once potential alternatives have been developed, it may be necessary to screen out certain options to reduce the number of alternatives that will be analyzed in detail in order to minimize the resources dedicated to evaluating options that are less promising. The necessity of this screening effort will depend on the number of alternatives initially developed, which will depend partially on the complexity of the site and/or the number of available, suitable technologies. For situations in which it is necessary to reduce the initial number of alternatives before beginning the detailed analysis, a range of alternatives should be preserved so that the decisionmaker can be presented with a variety of distinct, viable options from which to choose. The screening process involves evaluating alternatives with respect to their effectiveness, implementability, and cost. It is usually done on a general basis and with limited effort (relative to the detailed analysis) because the information necessary to fully evaluate the alternatives may not be complete at this point in the process.

d. Treatability Investigations. Should existing site and/or treatment data be insufficient to adequately evaluate alternatives, treatability tests may be necessary to evaluate a particular technology on specific site wastes. Generally, treatability tests involve bench-scale testing to gather information to assess the feasibility of a technology. In a few situations, a pilot-scale study may be necessary to furnish performance data and develop better cost estimates so that a detailed analysis can be performed and a remedial action can be selected. To conduct a pilot-scale test and keep the RI/FS on schedule, it will usually be necessary to identify and initiate the test early in the process.

e. Detailed Analysis. Once sufficient data are available, alternatives are evaluated in detail with respect to nine evaluation criteria that the EPA has developed to address the statutory requirements and preferences of CERCLA. The alternatives are analyzed individually against each criterion and then compared to determine their respective strengths and weaknesses and to identify the key tradeoffs that must be balanced for that site. The results of the detailed analysis are summarized and presented to the decisionmaker so that an appropriate remedy consistent with CERCLA can be selected. The detailed analysis process is shown in Figure 2-7.

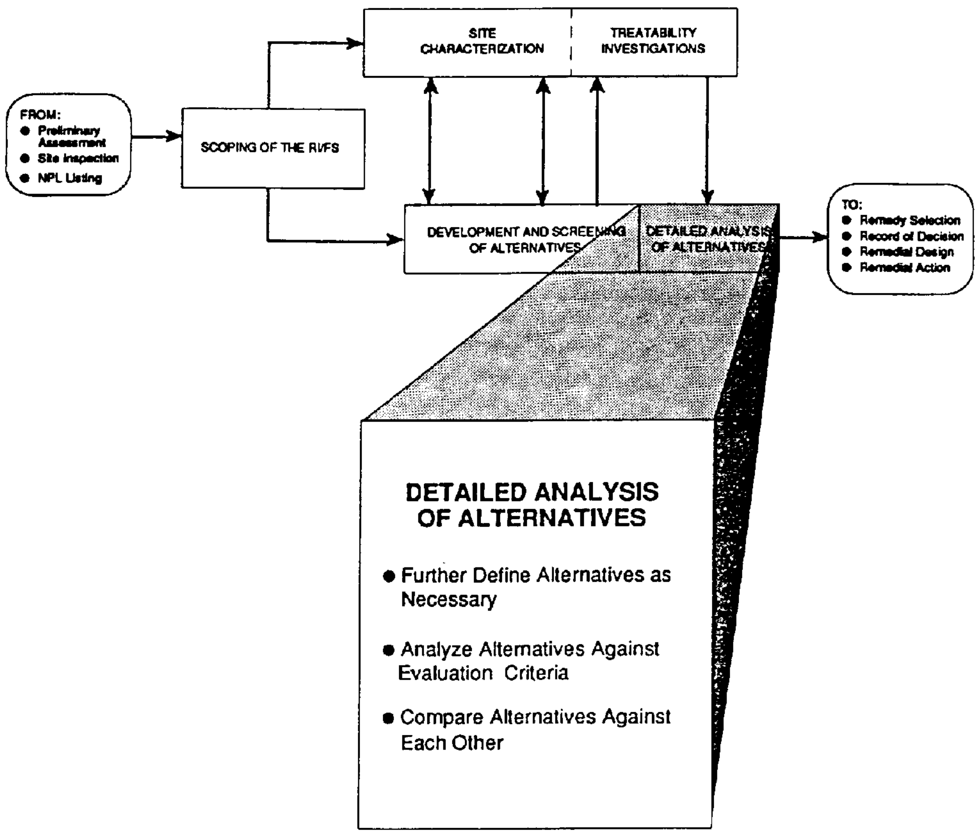


Figure 2-7. Overview of the Detailed Analysis of Alternatives Process

Section II. Determining the Nature and Extent of Contamination

2-4. Existing Site Conditions. The first step in the remediation process is to determine the nature and extent of contamination. The scope and complexity of the investigation and any subsequent studies are highly site specific.

2-5. Scoping. Scoping is the initial planning phase of site remediation and is begun, at least informally, by the lead agency* s responsible project manager as part of the funding allocation and planning process. The lead and support agencies should meet and, on the basis of available information, begin to identify (a) the types of actions that may be required to address site problems; (b) whether interim actions are necessary to mitigate potential threats, prevent further environmental degradation, or rapidly reduce risks significantly, and (c) the optimal sequence of site actions and investigative activities.

a. Objectives. Once the lead and support agencies initially agree on a general approach for managing the site, the next step is to scope the project and develop specific project plans. Project planning is done to:

(1) Determine the types of decisions to be made.

(2) Identify the type and quality of data quality objectives (DQOs) needed to support those decisions.

(3) Describe the methods by which the required data will be obtained and analyzed.

(4) Prepare project plans to document methods and procedures.

b. Project Planning. The specific activities conducted during project planning include:

(1) Meeting with lead agency, support agency, and contractor personnel to discuss site issues and assign responsibilities for RI/FS activities.

(2) Collecting and analyzing existing data to develop a conceptual site model that can be used to assess both the nature and the extent of contamination and to identify potential exposure pathways and potential human health and/or environmental receptors.

(3) Initiating limited field investigations if available data are inadequate to develop a conceptual site model and adequately scope the project.

(4) Identifying preliminary remedial action objectives and likely response actions for the specific project.

(5) Preliminarily identifying the ARARs expected to apply to site characterization and site remediation activities.

(6) Determining data needs and the level of analytical and sampling certainty required for additional data if currently available data are inadequate to conduct the FS.

(7) Identifying the need and the schedule for treatability studies to better evaluate potential remedial alternatives.

(8) Designing a data collection program to describe the selection of the sampling approaches and analytical options. (This selection is documented in the SAP, which consists of the FSP and QAPP elements.)

(9) Developing a work plan that documents the scoping process and presents anticipated future tasks.

(10) Identifying and documenting health and safety protocols required during field investigations and preparing a site health and safety plan.

(11) Conducting community interviews to obtain information that can be used to develop a site-specific community relations plan that documents the objectives and approaches of the community relations program.

(12) Submitting deliverables required for all RI/FSs in which field investigations are planned including a work plan, SAP, a health and safety plan (HSP), and a community relations plan (CRP). Although these plans usually are submitted together, each plan may be delivered separately.

2-6. Site Characterization.

a. Remedial action at any uncontrolled hazardous waste disposal site is preceded by an extensive site investigation. In most cases, the site investigation is conducted in sequenced phases. The initial site description is usually completed by the state or Federal agency that is screening the site to identify the associated hazards and to determine its ranking as a prospective candidate for cleanup activities. In this screening operation, information often is collected that is not directly applicable to engineering problems, and critical factors may be omitted that are necessary for selection of specific remedial measures. At various stages in the design of remedial measures, it becomes necessary to develop specific information for evaluation of particular processes; i.e., additional phases of data collection become necessary as the remedial program evolves.

b. During site characterization, the SAP, developed during project planning, is implemented and field data are collected and analyzed to determine to what extent a site poses a threat to human health or the environment. The major components of site characterization are presented in Figure 2-5 and include:

(1) Conducting field investigations.

(2) Analyzing field samples in the laboratory.

(3) Evaluating results of data analyses to characterize the site and develop a baseline risk assessment.

(4) Determining if data are sufficient for developing and evaluating potential remedial alternatives.

c. Because information on a site can be limited prior to conducting an RI, it may be desirable to conduct two or more iterative field investigations so that sampling efforts can be better focused. Therefore, rescoping may occur at several points in the RI/FS process. During site characterization, rescoping and additional sampling may occur if the results of field screening or laboratory analyses show that site conditions are significantly different than originally believed. In addition, once the analytical results of samples have been received (either from a laboratory or a mobile lab) and the data evaluated, it must be decided whether further sampling is needed to assess site risks and support the evaluation of potential remedial alternatives in the FS.

At this time, it is usually apparent whether the data needs identified during project planning were adequate and whether those needs were satisfied by the first round of field sampling.

d. Field investigation methods used in RIs are selected to meet the data needs established in the scoping process and outlined in the work plan and SAP. Specific information on the field investigation methods described below is contained in A Compendium of Superfund Field Operations Methods (EPA 1987)

e. The initial investigation for site screening purposes produces a body of data that, in most cases, provides the basis for planning all further data collection. At the beginning of any remedial program, it is vital that the screening data be examined critically and data gaps be identified. Any remedial investigation report generated by a site inspection team will include a description of the physical layout of the site and the activity at the site; i.e., treatment, storage, concentration, reclaiming of waste, etc., and a preliminary assessment of the nature and extent of the hazard posed by the site, e.g. , toxic release, fire, explosion, etc.

f. Table 2-2 provides a checklist of the major features to be included in any site description. In many cases, limitations of time and equipment may prevent the site visitation team from making complete assessments, and some features of the site that are critical to remedial action may be intentionally or unintentionally concealed by the personnel at the site. For example, where drummed wastes have been stored in an unprotected manner, it would not be surprising to discover that drums are also buried at the site. In some cases, the visible wastes may be less of a problem than the buried material. If bulk liquids were handled and the site investigation indicated the absence or inadequacy of controlled drainage loading and unloading areas, it may be assumed that spillage has contaminated the soils at waste transfer points. Inferences such as this are helpful in providing clues as to what additional investigations would be useful. Table 2-3 provides guidance on what features in the initial remedial concept report can be useful in indicating the course for further data collection.

g. In any review of preliminary hazard assessments and site inspection reports, all major pathways for movement of toxicants should be considered (Figure 2-8). The review should result in a ranking of potential or actual waste dispersal pathways as to potential damage to the site* s surroundings and an overall hazard assessment based on waste characteristics, pathways, receptors, and site management practices (Figure 2-9).

2-7. Health and Safety Considerations.

a. Due to the very nature of remedial investigation, necessary precautions to prevent loss of life, prevent injury, or minimize health hazards are paramount. Since exact rules cannot be developed for every contingency, an effective health and safety program should take into consideration:

(1) Established rules and adherence thereto.

(2) The application of common sense, judgment, and technical analysis.

Table 2-2. Checklist of Major Features Included in Site Description

I. Site Sketch

The following features should be included:

- Site boundaries
- Entrance and exit locations
- Access roads
- Disposal locations
- Storage areas
- Loading/unloading areas
- Office areas
- Water well locations
- Treatment facility locations
- Surface drainage II.

II. Chemical Storage Facilities Description

Storage tanks: number, volume, condition, content, etc.
Drums: number, condition, labeling, volume, content, etc.
Lagoons and surface pits: number, size, use of liner, content, etc.

III. Treatment Systems

The presence of any treatment systems should be noted. These can be difficult to evaluate visually. General appearance, maintenance, and integrity should be visually assessed; operators should be asked for any monitoring records; presence of odors should be noted; any effluents or residues should be visually characterized; and types of wastes and volumes treated should be described.

- Incinerators
- Flocculation/filtration
- Chemical/physical treatment
- Biological treatment
- Volume reduction
- Waste recycling
- Other

IV. Disposal Facilities

The presence and use of any of the following operations should be noted. A description of the size, use of liners, soil type, presence of leachate, and presence of dead vegetation or animals should be obtained. A description of management practices should be obtained. Site workers should be interviewed. Waste types should be described.

- Landfills
- Landforms
- Open dump
- Surface impoundment
- Underground injection
- Incineration

(Continued)

Table 2-2 (Concluded)

V. Hazardous Substance Characteristics

Manifests, inventories, or monitoring reports should be obtained. Markings on containers should be noted.

Chemical identities	Container markings
Quantities	Monitoring data, other analytical data
Hazard characteristics (toxic, explosive, flammable,	Physical state (liquid, solid, etc.) gas, sludge)

VI. Geohydrological Assessment

Situations that promote hazardous substance migration (i.e., porous soils, porous or fractured bedrock formations, shallow water tables, flowing streams or rivers nearby, etc.) should be included in the site report.

Soil geology or rock type	Water wells (use and water depth) Surface
water features	Erosion potential
Surface drainage pattern	Flooding potential
Ground-water conditions/depths/ movement	

VII. Identification of Sensitive Receptors

Number and location of homes	Other public use areas (roads, private parks, etc.)
Public buildings	Natural areas

b. ER 385-1-92 comprehensively establishes those safety and health documents and procedures required to be developed for hazardous and toxic waste (HTW) activities. 29 CFR 1910.120 addresses the safety and health of employees working at hazardous waste sites. It defines, at least in a regulatory sense, the components of an effective safety and health program, and should be considered the primary reference for all safety and health- related matters at hazardous waste operations.

c. Agencies involved in remedial investigations must clearly establish an effective organization with prescribed responsibilities. Detailed discussions of the various levels of responsibility of an organization are covered in applicable EPA guidance.

Table 2-3. Critical Areas in Evaluation of Site Data from Preliminary Assessment

I. Waste Volumes

Do the input, output, and storage records agree with observed activities?
Were wastes received and not logged in? Are designated wastes received and not logged in? Are designated waste burial sites of a size consistent with the volumes recorded? If drum storage is used, are the drums filled and do they contain solids or liquids? Would an inventory based on a drum count be reliable for this site?

II. Waste Characteristics

Do analyses of samples of wastes agree with recorded contents on logs and labels? Is there obvious evidence from drum corrosion or fuming that the labels are incorrect? Are wastes observed consistent with the stated waste sources?

III. Extent of Damage Observed

Do ground-water, surface-water, and soil samples show contaminants consistent with the types of wastes appearing on records, logs, manifests, and labels?
Are the wells sampled for water contamination suitable as monitoring wells in construction and location?

2-8. Data Base Requirements. A data base for each site will be developed as the site investigation proceeds. As the selection of remedial action is made, additional specific data requirements will appear. Typically, the preliminary site assessment will produce a compilation of data on types of material, receptors, and site management practices. As specific options are investigated and treatment or containment options are evaluated, more data on the type of material and on the position and concentration of specific pollutants in ground or surface water will be required.

a. Waste Identification and Quantification.

(1) In most field investigations for site assessment an attempt will be made to select samples from an enforcement viewpoint, i.e., to find high concentrations of toxicants that must be cleaned up. Samples collected in nonenforcement activities (normal site characterization) may have been taken using a random sampling technique to obtain average concentrations of potential toxicants. Care should be taken to distinguish between these two types of samples in evaluating site assessment data.

(2) Table 2-4 gives the typical numbers of samples taken for analysis from different types of waste containers or waste spill areas. Full use of these data should be made in planning additional sample collection and analysis activities. In data collected for detailed design of remedial actions, ranges of concentration of contaminants will be the critical criterion for design rather than the highest value obtained or the average value.

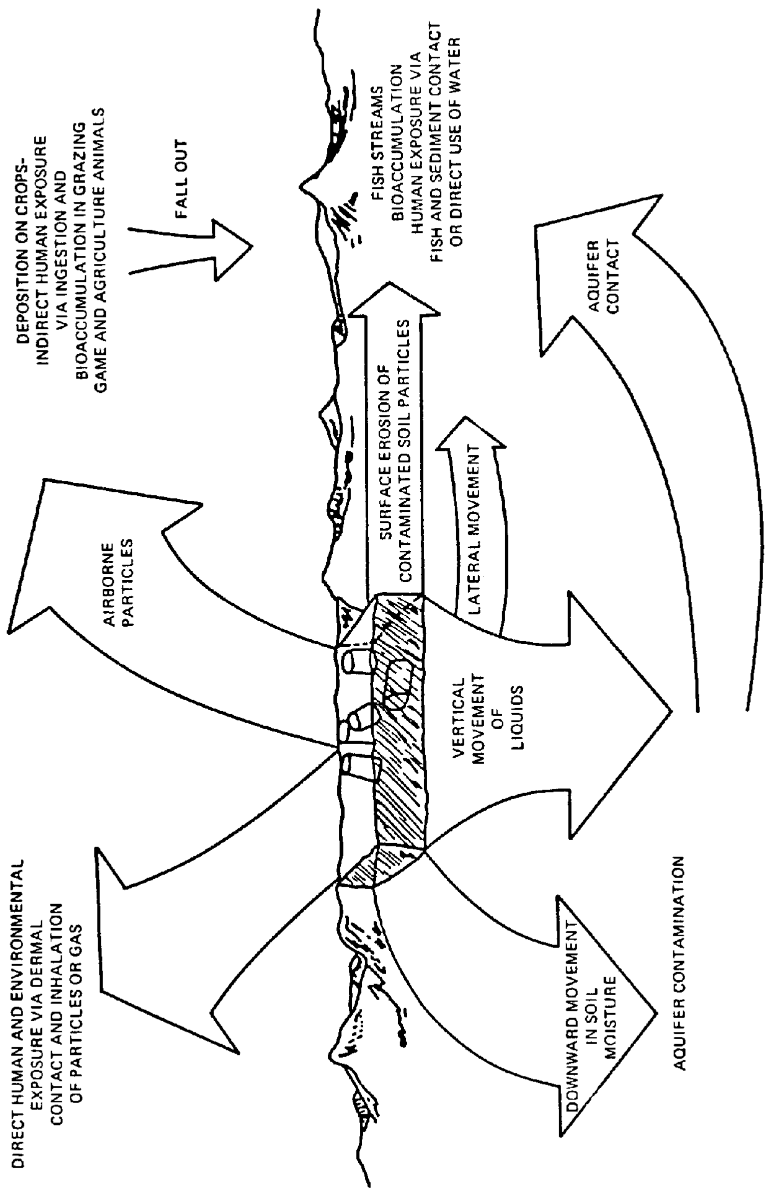


Figure 2-8. Dispersal Pathways for Contaminants

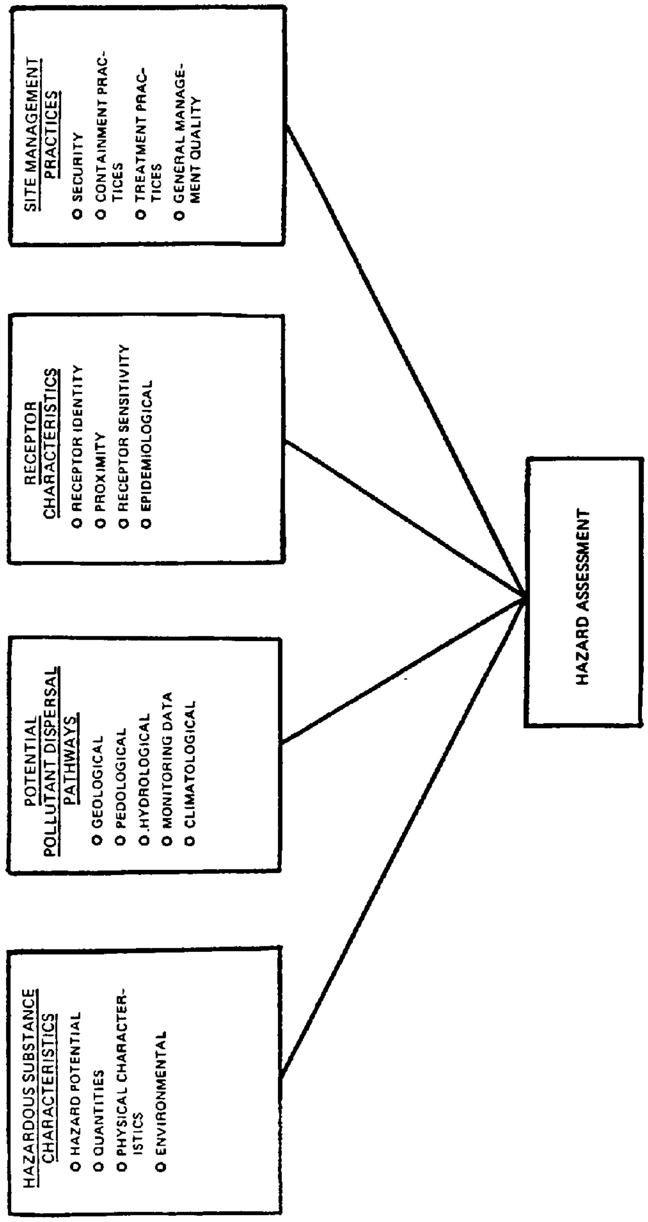


Figure 2-9. Topic Areas for the Hazardous Substance Site Assessment

Table 2-4. Typical Number of Samples to be Collected for Different Informational Requirements

Case No.	Information desired	Waste type	Container type	Number of samples to be collected
1	Average concentration	Liquid	Drum, vacuum truck, and similar containers	1
2	Average concentration	Liquid	Pond, pit, lagoon	1 combined sample of several samples collected at different points or levels
3	Average concentration	Solid (powder or granular)	Bag, drum, bin, sack	Same as case No. 2
4	Average concentration	Waste pile	- -	Same as case No. 2
5	Average concentration	Soil	- -	1 combined sample of several samples collected at different sampling areas
6	Concentration range	Liquid	Drum, vacuum truck, storage tank	3 to 10 samples, each from a different depth of the liquid
7	Concentration range	Liquid	Ponds, pit, lagoon	3 to 20 samples from different sampling points and depths
8	Concentration range	Solid (powder or granular)	Bag, drum, bin	3 to 5 samples from different sampling points
9	Concentration range	Waste pile	- -	Same as case No. 8
10	Concentration range	Soil	- -	3 to 20 samples from different sampling areas

(Continued)

Table 2-4. (Concluded)

Case No.	Information desired	Waste type	Container type	Number of samples to be collected
11	Average concentration for legal evidence	All types	All containers	3 identical samples or 1 combined sample divided into 3 identical samples if homogeneous
12	Average concentration	Liquid	Storage Tank	Same as case No. 6

(3) Waste quantification is performed in an approximate manner during preliminary site assessment through drum counts (often made from aerial photos) or volume estimates of lagoons, along with written records of waste burial. However, many of the approximate numbers may have to be refined for scaling treatment or containment strategies. For example, additional soil samples may be required if a major soil cleanup is contemplated. Drummed liquid wastes may have to be examined to determine if they still contain the waste originally placed in them. The life of a drum in a buried or exposed environment is dependent on many variables including the contents of the drum, the corrosivity of the soil, and the climatological factors the drum is exposed to. The life of a steel drum can range from 3 to 15 years. The life of fiber or plastic drums is expected to be longer than that of a steel drum; however, no data are available to support this and, as with any drum, the life expectancy will be site specific.

(4) Quantification of buried waste is extremely difficult and may require interviews with site employees, and even remote sensing techniques such as ground-penetrating radar or electromagnetic surveys to confirm locations. Normally, only a minimum of this type of work would be done during a preliminary assessment.

(5) Data that will be used as the basis for decision-making require that the analysis of samples in laboratories meets specific quality assurance/quality control (QA/QC) requirements. To meet these requirements, Federal- or state-lead site investigations have the option of using mobile laboratories; the certified laboratory procedure (CLP) laboratory, which is established by EPA; or a non-CLP laboratory that meets the data quality objectives (DQO) of the site investigation.

b. Site Parameters. During preliminary site assessment, data on site parameters will have been collected. Most of this information will have been collected with a goal of establishing the extent of hazard. More detailed information will be needed as remedial systems are evaluated. For example, while the initial assessment may have established that an aquifer is contaminated, later phases of the investigation will have to establish the position of the plume of contamination, the speed and direction of ground- water movement, and the interconnections present between aquifers.

Initial investigations may have established the average or maximum concentration of specific contaminants; follow-up investigations may be concerned with the retention of contaminants in the soil under specific conditions. Later phases of data collection will be specifically oriented toward evaluating the use of selected treatment options. Often, samples obtained in the preliminary sampling phase of site assessment can be used to obtain more data if they are maintained in an unchanged condition. For example, if phenol-contaminated soil is being examined for possible transport and incineration, it may be vital to establish levels of refractory toxic organics such as PCB or dioxin. Waste samples already collected along with new samples can be reanalyzed using techniques providing low limits on these specific contaminants.

2-9. Data Base Development.

a. General.

(1) The preliminary site assessment documentation usually covers the sources of information specific to the nature and extent of hazard posed by the site. Table 2-5 summarizes the sources of data for site assessment. A broader data base must be developed for remedial planning. While much of the data will be developed through field investigation at the site, many critical factors related to contaminant containment or treatment will be obtained from published literature and record searches.

(2) When detailed data collection is planned, care should be taken to see that the accuracy and the extent of the data suit the need. Many of the needs in remedial action planning will arise from input parameters required for models that relate to treatment or containment programs. For example, if a water balance model is to be employed in designing a cover for a hazardous waste model, rainfall and evapotranspiration rates become critical factors as input to the model. Daily rainfall records and hourly rainfall patterns through typical storm events would be important. Data with less than this detail would not be useful. Review of modeling approaches is often a useful method of determining what is needed in data and which parameters must be known with great accuracy and where estimates can be substituted for “hard data.” For example, Table 2-6 lists variables used in a hydrologic model for landfill cover design and indicates the critical or noncritical nature of each parameter. This type of model sensitivity analysis can be used where available to save time and expense in data collection.

b. Sources of Information. Preliminary data sources used in site assessment can often yield detailed information on other parameters useful in estimating the effectiveness of various treatment or containment strategies. Usually, however, much of the data must be obtained from laboratory analyses and field tests. As an example, Table 2-7 lists sources of information and systems for gathering information related to estimating vapor transfer through a soil landfill cover for a toxic organic waste.

Table 2-5. Sources of Data for Site Assessment

Substance characterization	Pollutant dispersal pathways	Receptor characterizations	Site management practices
Site records	Geology	U. S. Public Health Service	State and local regulatory offices
Inventories	Publications	Local planning agencies	Review of site management
Shipment manifests	Topographic maps	Federal/state fish and wildlife departments/agencies	Personal interviews
Permits	USGS state geological surveys, universities	Area universities	Aerial photo
Waste generator records	Hydrology	Local naturalists	OSHA/NIOSH
Personal interviews	USGS water resource divisions	Aerial imagery	Fire departments
Site personnel	State water resource divisions	Medical reports	
Public officials	Flood insurance rate maps from HUD	News sources	
Private citizens	Aerial imagery		
Monitoring/sampling/testing data (if available)	EPA sources		
	Other sources		
	NASA EROS		
	Local planning agencies		
	Private companies		
	National Weather Service		
	EPA site reports		
	Corps/USGS		

Note: USGS = U.S. Geological Survey, HUD = Housing and Urban Development, NASA EROS = National Aeronautical Space Adminstration Earth Resources Orbital Satellite, OSHA = Occupational Safety and Health Administration, NIOSH = National Institute for Occupational Safety and Health.

Table 2-6. Example of Data Quality Variation in a Selected Number of Parameters Used in Hydrologic Simulation Models

Parameter	Suggested source	Effect in model
Saturated hydraulic conductivity of soil	Field or laboratory measurement	Critical; model very sensitive
Soil evaporation parameter	Estimate from soils handbook	Moderate
Soil porosity	Estimate	Not sensitive
Leaf area of plant cover	Estimate from crop information handbook	Moderately sensitive
Rainfall	Climatological data from National Weather Service	Critical
Runoff	Estimate from drainage handbook	Critical

Table 2-7. Examples of Typical Data Required to Assess Vapor Movement through a Soil Cover

Parameter	Source of estimate	Measurement system
Vapor diffusion coefficient for volatile organic in air (cm^2/day)	Chemical handbook	Specialized laboratory measurement using gas chromatograph/ mass spectroscopy (GC/MS) analysis
Soil air-filled porosity	Estimated from porosity and water content	Measured by displace-ment of gas in pore spaces
Total soil porosity	Estimated from particle density and bulk density	Direct measurement by filling pore spaces
Concentration of volatiles at bottom of cover	Estimated from concen-tration of saturation	Measured by CC/MS techniques on soil gas
Depth of soil cover	Estimated from records	Measured in a boring

c. Data Measurement.

(1) Data collected for one phase of a remedial investigation can often be used in another phase either as an accurate measurement or as a rational estimate. It is important that site data be in an organized, transferable form, perhaps as a directory report, which should include discrete data sets relating the waste and the character of the surrounding environment.

(2) Where data are primarily numeric values (concentrations, permeabilities, inches of precipitation, etc.), computer-based data management is often the cheapest and best system for allowing rapid updating of files and multiple access. With data in a machine-readable form, implementing models for treatment or containment is rapid and inexpensive. In a similar manner, computer-based cost analysis systems can also be accessed.

(3) Analyses of the data collected should focus on the development or refinement of the conceptual site model by presenting and analyzing data on source characteristics, the nature and extent of contamination, the contaminated transport pathways and fate, and the effects on human health and the environment. Data collection and analysis for the site characterization are complete when the DQOs that were developed in scoping (including any revisions during the RI) are met, when the need (or lack thereof) for remedial actions is documented, and when the data necessary for the development and evaluation of remedial alternatives have been obtained. The results of the RI typically are presented as an analysis of site characteristics and the risk associated with such characteristics (i.e., the baseline risk assessment).

(4) An RI may generate an extensive amount of information, the quality and validity of which must be consistently well documented because this information will be used to support remedy selection decisions and any legal or cost recovery actions. Therefore, field sampling and analytical procedures for the acquisition and compilation of field and laboratory data are subject to data management procedures. The discussion on data management procedures is divided into three categories: field activities, sample management and tracking, and document control and inventory.

(5) A file structure suggested by EPA for the collected data is shown in Table 2-8. A file structure consistent with that of other agencies greatly facilitates communication.

2-10. Community Relations During Site Characterization. Two-way communication with interested members of the community should be maintained throughout the RI. The remedial project manager and community relations coordinator will keep local officials and concerned citizens apprised of site activities and of the schedule of events by implementing several community relation activities. These actions are usually delineated in the community relations plan and typically include, but are not limited to, public information meetings at the beginning and end of the RI; a series of fact sheets that will be distributed to the community during the investigation and will describe up-to-date progress and plans for remedial activities; telephone briefings for key members of the community, public officials, and representatives of concerned citizens; and periodic news releases that describe progress at the site.

Table 2-8. Outline of Suggested File Structure for Superfund Sites Congressional Inquiries and Hearings:

Correspondence
Transcripts
Testimony
Published hearing records

Remedial Response
Discovery
- Initial investigation reports
- Preliminary assessment report
- Site inspection report
- Hazard Ranking System data

Remedial Planning
- Correspondence
- Work plans for RI/FS
- RI/FS reports, treatability study results
- Health and safety plan
- QA/QC plan
- Record of decision/responsiveness summary

Remedial Implementation
- Remedial design reports
- Permits
- Contractor work plans and progress reports
- Corps of Engineers agreements, reports, and correspondence

State and Other Agency Coordination
- Correspondence
- Cooperative agreement/Superfund state contract
- State quarterly reports
- Status of state assurances
- Interagency agreements
- Memorandum of Understanding with the state

Community Relations
- Interviews
- Correspondence
- Community relations plan
- List of people to contact, e.g., local officials, environmental groups
- Meeting summaries
- Press releases
- News clippings
- Fact sheets
- Comments and responses

(Continued)

Table 2-8. (Concluded)

Community Relations (continued)

- Transcripts
- Summary of proposed plan
- Responsiveness summary

Imagery:
! Photographs
! Illustrations
! Other graphics

Enforcement:
! Status reports
! Gross-reference to any confidential enforcement files and the person to contact
! Correspondence
! Administrative orders

Contracts
! Site-specific contracts
! Procurement packages
! Contract status notifications
! List of contractors

Financial Transactions:
! Cross-reference to other financial files and the person to contact
! Contractor cost reports
! Audit reports

2-11. Extent of Hazard. A preliminary judgment of the extent of hazard has generally been made on any hazardous waste sites selected for remedial action. As additional data become available, the hazard assessment must be updated based on new field and laboratory data. Revised hazard estimates can be used to adjust safety planning and to refine designs for treatment and containment.

Section III. Establishment of Cleanup Criteria 2-12.

Limits of Allowable Contamination Onsite and Offsite.

a. The extent of site cleanup will depend on the hazard posed by the site as judged from four major factors:

(1) Nature of the waste.

(2) Dispersal pathways.

(3) Receptor characteristics.

(4) Site management.

b. In most cases restoration of a site to a state which is equivalent to its predisposal situation will not be practical. The relationship between cost and cleanup is an ever-steepening curve with the final steps to 100 percent restoration being the most expensive. Restoration will be balanced against costs at most sites at the point where immediate adverse effects to the surrounding environment are eliminated and long-term releases and dangers of bioaccumulation of toxicants are controlled at some low level. Many sites will never reach a state of restoration where the land can be designated for unlimited use. In some cases, onsite contamination may remain at levels that require access to the site be restricted indefinitely.

2-13. <u>Cleanup Standards</u>.

a. Section 121 (Cleanup Standards) of CERCLA (PL 96-510) states a strong statutory preference for remedies that are highly reliable and provide long-term protection. In addition to the requirement for remedies to be both protective of human health and the environment and cost-effective, additional remedy selection considerations in Section 121(b) include:

(1) A preference for remedial actions employing treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element.

(2) Offsite transport and disposal without treatment is the least favored alternative where practicable treatment technologies are available.

(3) The need to assess the use of permanent solutions and alternative treatment technologies or resource recovery technologies and use them to the maximum extent practicable.

b. Section 121(c) also requires a periodic review of remedial actions, at least every 5 years after initiation of such action, for as long as hazardous substances, pollutants, or contaminants that may pose a threat to human health or the environment remain at the site. If it is determined during a 5-year review that the action no longer protects human health and the environment, further remedial actions will need to be considered.

2-14. <u>Applicable or Relevant and Appropriate Requirements (ARARs)</u>.

a. <u>Statutes</u>. Section 121(d)(2)(A) of CERCLA incorporates into law the CERCLA compliance policy, which specifies that Superfund remedial actions meet any Federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). Also included is the new provision that state ARARs must be met if they are more stringent than Federal requirements. Federal statutes that are specifically cited in

CERCLA include the Solid Waste Disposal Act (SWDA), the Toxic Substances Control Act (TSCA), the Safe Drinking Water Act (SDWA), the Clean Air Act (CAA), the Clean Water Act (CWA), and the Marine Protection Research and Sanctuaries Act (MPRSA). Additional guidance on ARARs is provided in the "CERCLA Compliance with Other Statutes" manual (EPA, Draft, August 1988).

b. Waivers. Section 121(d) (4) of CERCLA identifies six circumstances under which ARARs may be waived:

(1) The remedial action selected is only a part of a total remedial action (interim remedy) and the final remedy will attain the ARAR upon its completion.

(2) Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.

(3) Compliance with the ARAR is technically impracticable from an engineering perspective.

(4) An alternative remedial action will attain an equivalent standard of performance through the use of another method or approach.

(5) The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.

(6) For Section 104 Superfund-financed actions, compliance with the AFAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

2-15. Risk Assessment.

a. Purpose. Risk assessments provide an evaluation of the potential threat to human health and the environment in the absence of any remedial action. They provide the basis for determining whether or not remedial action is necessary and the justification for performing remedial actions. The baseline risk assessment will also be used to support a finding of imminent and substantial endangerment if such a finding is required as part of an enforcement action. Detailed guidance on evaluating potential human health impacts as part of this baseline assessment is provided in the Superfund Public Health Evaluation Manual (EPA, October 1986). Guidance for evaluating ecological risks is currently under development within U.S. EPA, Office of Solid Waste and Emergency Response (OSWER).

b. Objectives. In general., the objectives of a risk assessment may be attained by identifying and characterizing the following:

(1) Toxicity and levels of hazardous substances present in relevant media (e.g., air, ground water, soil, surface water, sediment, and biota).

(2) Environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions.

(3) Potential human and environmental receptors.

(4) Potential exposure routes and extent of actual or expected exposure.

(5) Extent of expected impact or threat; and the likelihood of such impact or threat occurring (i.e., risk characterization).

(6) Level of uncertainty associated with the above items.

c. Effort Required. The level of effort required to conduct a risk assessment depends largely on the complexity of the site. The goal is to gather sufficient information to adequately and accurately characterize the potential risk from a site, while at the same time conduct this assessment as efficiently as possible. Use of the conceptual site model developed and refined previously will help focus investigation efforts and, therefore, streamline this effort. Factors that may affect the level of effort required include:

(1) The number, concentration, and types of chemicals present.

(2) Areal extent of contamination.

(3) The quality and quantity of available monitoring data.

(4) The number and complexity of exposure pathways (including the complexity of release sources and transport media)

(5) The required precision of sample analyses, which in turn depends on site conditions such as the extent of contaminant migration and the proximity, characteristics, and size of potentially exposed populations.

(6) The availability of appropriate standards and/or toxicity data.

d. Components. The risk assessment process can be divided into four components:

(1) Contaminant identification.

(2) Exposure assessment.

(3) Toxicity assessment.

(4) Risk characterization.

e. Overview. Figure 2-10 illustrates the risk assessment process and its four components. A brief overview of each component follows.

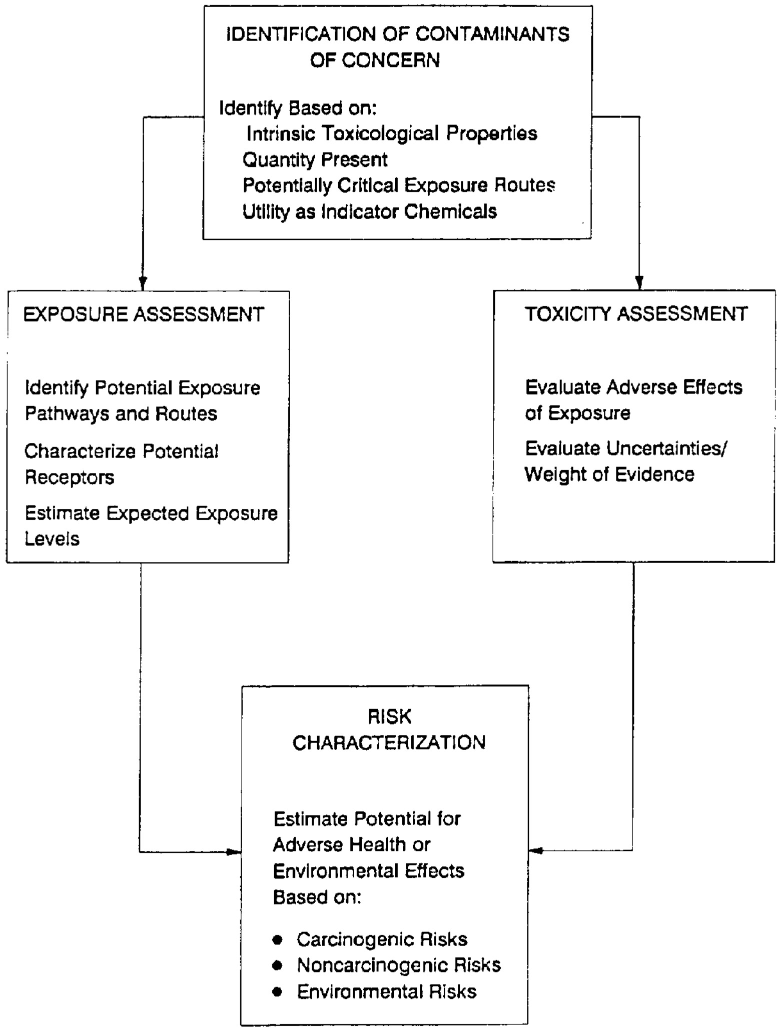


Figure 2-10. Overview of the Risk Assessment Process

(1) Contaminant identification.

(a) The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants of concern to focus subsequent efforts in the risk assessment process. Contaminants of concern may be selected because of their intrinsic toxicological properties, because they are present in large quantities, or because they are presently in or potentially may move into critical exposure pathways (e.g., drinking water supply).

(b) At some sites it may be useful to select "indicator chemicals." Indicator chemicals are chosen to represent the most toxic, persistent, and/or mobile substances among those identified that are likely to significantly contribute to the overall risk posed by the site. In some instances, an indicator chemical may be selected for the purpose of representing a "class" of chemicals (e.g., TCE to represent all volatiles). Although the use of indicator chemicals serves to focus and streamline the assessment on those chemicals that are likely to be of greatest concern, a final check must be made during remedy selection and the remedial action phase to ensure that the waste management strategy being implemented addresses risks posed by the range of contaminants found at the site.

(2) Exposure assessment.

(a) The objectives of an exposure assessment are to identify actual or potential exposure pathways, to characterize the potentially exposed populations, and to determine the extent of the exposure. Detailed guidance on conducting exposure assessments is provided in the Superfund Exposure Assessment Manual (U.S. EPA, April 1988), and is briefly discussed below.

(b) Identifying potential exposure pathways helps to conceptualize how contaminants may migrate from a source to an existing or potential point of contact. An exposure pathway may be viewed as consisting of four elements:

- A source and mechanism of chemical release to the environment;
- An environmental transport medium (e.g., air, ground water) for the released chemical;
- A point of potential contact with the contaminated medium (referred to as the exposure point); and
- An exposure route (e.g., inhalation, ingestion) at the exposure point.

(c) The analysis of the contaminant source and how contaminants may be released involves characterizing the contaminants of concern at the site and determining the quantities and concentrations of contaminants released to environmental media. Figure 2-11 presents a conceptual example identifying actual and potential exposure pathways.

(d) Once the source and release mechanisms have been identified, an analysis of the environmental fate and transport of the contaminants is conducted. This analysis considers the potential environmental transport (e.g., ground-water migration, airborne transport); transformation (e.g., biodegradation, hydrolysis, and photolysis); and transfer mechanisms (e.g., sorption, volatilization) to provide information on the potential magnitude and extent of environmental contamination. The actual or potential exposure points for receptors are identified. The focus of this effort should be on those locations where actual contact with the contaminants of concern will occur or is likely to occur.

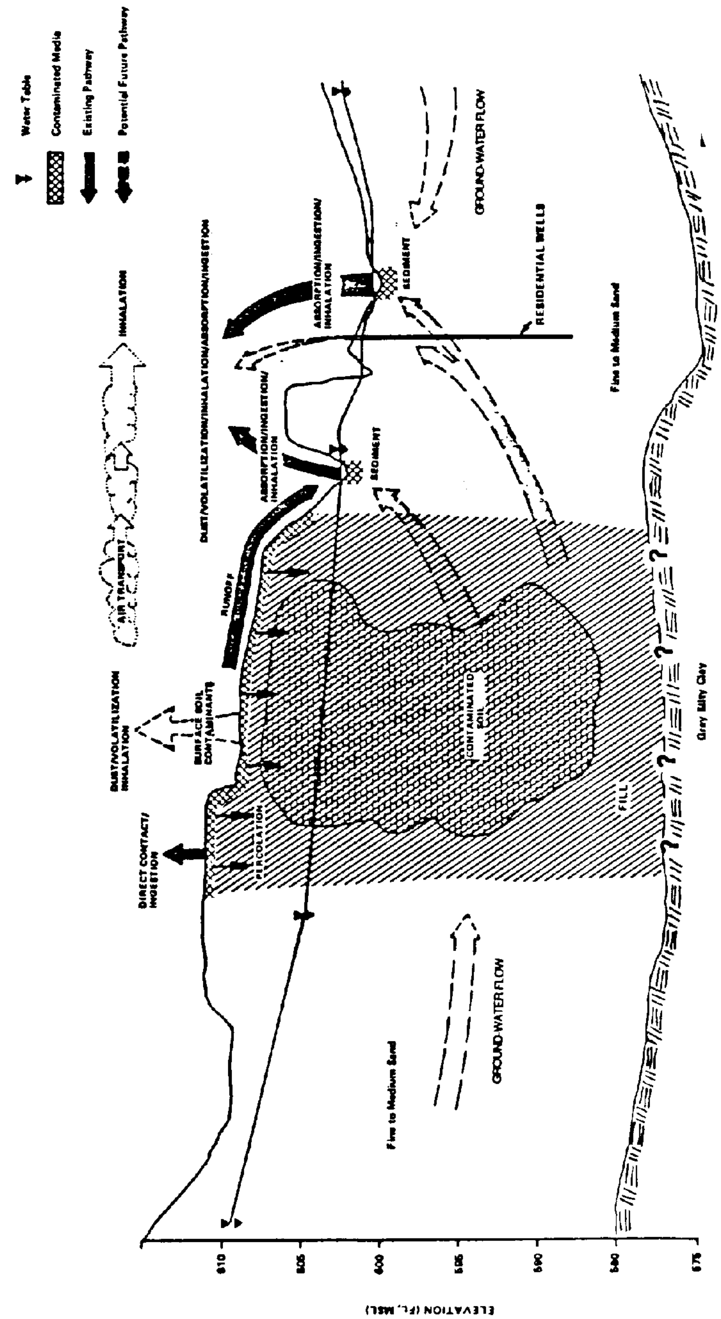


Figure 2-11. Identification of Exposure Pathways

Potential exposure routes that describe the potential uptake mechanism (e.g., ingestion, inhalation, etc.) once a receptor comes into contact with contaminants in a specific environmental medium are identified and described. Environmental media that may need to be considered include air, ground water, surface water, soil and sediment, and food sources. Detailed procedures for estimating and calculating rates of exposure are described in detail in the Superfund Exposure Assessment Manual.

(e) After the exposure pathway analysis is completed, the potential for exposure should be assessed. Information on the frequency, mode, and magnitude of exposure should be gathered. These data are then assessed to yield a value that represents the amount of contaminated media contacted per day. This analysis should include not only identification of current exposures but also exposures that may occur in the future if no action is taken at the site. Because the frequency mode and magnitude of human exposures will vary based on the primary use of the area (e.g., residential, industrial, or recreational), the expected use of the area in the future should be evaluated. The purpose of this analysis is to provide decisionmakers with an understanding of both the current risks and potential future risks if no action is taken. Therefore, as part of this evaluation, a reasonable maximum exposure scenario should be developed, which reflects the type and extent of exposures that could occur based on the likely or expected use of the site (or surrounding areas) in the future. The reasonable maximum exposure scenario is presented to the decisionmaker so that possible implications of decisions regarding how to best manage uncertainties can be factored into the risk management remedy selection.

(f) The final step in the exposure assessment is to integrate the information and develop a qualitative and/or quantitative estimate of the expected exposure level resulting from the actual or potential release of contaminants from the site.

(3) Toxicity assessment.

(a) Toxicity assessment, as part of the Superfund baseline risk assessment process, considers the types of adverse health or environmental effects associated with individual and multiple chemical exposures; the relationship between magnitude of exposures and adverse effects; and related uncertainties such as the weight of evidence for a chemical* s potential carcinogenicity in humans. Detailed guidance for conducting toxicity assessments is provided in the Superfund Public Health Evaluation Manual.

(b) Typically, the risk assessment process relies heavily on existing toxicity information and does not involve the development of new data on toxicity or dose-response relationships. Available information on many chemicals is already evaluated and summarized by various EPA program offices or cross-Agency work groups in health and environmental effects assessment documents. These documents or profiles will generally provide sufficient toxicity and dose-response information to allow both qualitative and quantitative estimates of risks associated with many chemicals found at Superfund sites. These documents often estimate carcinogen exposures associated with specific lifetime cancer risks (e.g., risk-specific doses or RSDs), and systemic toxicant exposures that are not likely to present appreciable risk of significant adverse effects to human populations over a lifetime (e.g., reference doses or Rfds).

(4) Risk characterization.

(a) In the final component of the risk assessment process, a characterization of the potential risks of adverse health or environmental effects for each of the exposure scenarios derived in the exposure assessment, is developed and summarized. Estimates of risks are obtained by integrating information developed during the exposure and toxicity assessments to characterize the potential or actual risk, including carcinogenic risks, noncarcinogenic risks, and environmental risks. The final analysis should include a summary of the risks associated with a site.

(b) Characterization of the environmental risks involves identifying the potential exposures to the surrounding ecological receptors and evaluating the potential effects associated with such exposure. Important factors to consider include disruptive effects to populations (both plant and animal) and the extent of perturbations to the ecological community.

(c) The results of the baseline risk assessment may indicate that the site poses little or no threat to human health or the environment. In such situations, the FS should be either scaled down to that site and its potential hazard, or eliminated altogether. The results of the RI and the baseline risk assessment will therefore serve as the primary means of documenting a no- action decision. If it is decided that the scope of the FS will be less than what is presented in this guidance or eliminated altogether, the lead agency should document this decision and receive the concurrence of the support agency.

2-16. Technological Limitations on Cleanup. In some cases, the technology to handle the total cleanup of a site may not exist. For example, where contamination of a subsurface aquifer has occurred, it may be impossible to flush all contaminants out of the porous geologic units simply because of the limited access any flushing agent has to pore space in the units. In other instances, the reactions (adsorption, precipitation, etc.) used to remove a contaminant from surface water may not be efficient enough to restore the water to its precontamination condition.

Section IV. Alternative Development and Screening

2-17. Developing Options.

a. The primary objective of alternative development and screening is to develop a range of waste management options that will be analyzed more fully in the detailed analysis phase. Waste management options that ensure the protection of human health and the environment may involve, depending on site- specific circumstances, complete elimination or destruction of hazardous substances at the site, reduction of concentrations of hazardous substances to acceptable health-based levels, and prevention of exposure to hazardous substances via engineering or institutional controls, or some combination of the above.

b. Alternatives are typically developed concurrently with the RI site characterization, with the results of one influencing the other in an iterative fashion. RI site characterization data are used to develop alternatives and screen technologies, whereas the range of alternatives developed guides subsequent site characterization and/or treatability studies. Table 2-9 summarizes important site characteristics affecting selection of remedial measures.

2-18. Alternative Development Process.

a. Analytical Steps. The alternative development process may be viewed as a series of six analytical steps that involve making successively more specific definitions of potential remedial activities. Alternatives for remediation are developed by assembling combinations of technologies, and the media to which they would be applied, into alternatives that address contamination on a sitewide basis or for an identified operable unit. These steps are shown in Figure 2-12 and discussed below.

(1) Develop remedial action objectives specifying the contaminants and media of interest, exposure pathways, and preliminary remediation goals that permit a range of treatment and containment alternatives to be developed. The preliminary remediation goals are developed on the basis of chemical-specific ARARs, other available information (e.g., Rfds), and site-specific risk-related factors. These preliminary remediation goals are reevaluated as site characterization data and information from the baseline risk assessment become available.

(2) Develop general response actions for each medium of interest defining containment, treatment, excavation, pumping, or other actions, singly or in combination, that may be taken to satisfy the remedial action objectives for the site.

(3) Identify volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the remedial action objectives and the chemical and physical characterization of the site.

(4) Identify and screen the technologies applicable to each general response action to eliminate those that cannot be implemented technically at the site. It is important to distinguish between this medium-specific technology screening step during development of alternatives and the alternative screening that may be conducted subsequently to reduce the number of alternatives prior to the detailed analysis. The general response actions are further defined to specify remedial technology types (e.g., the general response action of treatment can be further defined to include chemical or biological technology types).

(5) Identify and evaluate technology process options to select a representative process for each technology type retained for consideration. Although specific processes are selected for alternative development and evaluation, these processes are intended to represent the broader range of process options within a general technology type.

(6) Assemble the selected representative technologies into alternatives representing a range of treatment and containment combinations.

b. Develop Remedial Action Objectives.

(1) Remedial action objectives consist of medium-specific or operable unit-specific goals for protecting human health and the environment. The objectives should be as specific as possible but not so specific that the range of alternatives that can be developed is unduly limited. Column two of Table 2-10 provides examples of remedial action objectives for various media. Remedial action objectives aimed at protecting human health and the environment should specify the following.

(a) The contaminant of concern.

(b) Exposure route and receptor.

(c) An acceptable contaminant level or range of levels for each exposure route (i.e., a preliminary remediation goal).

(2) Remedial action objectives for protecting human receptors should express both a contaminant level and an exposure route, rather than contaminant levels alone, because protectiveness may be achieved by reducing exposure (such as capping an area, limiting access, or providing an alternate water supply) as well as by reducing contaminant levels. Because remedial action objectives for protecting environmental receptors typically seek to preserve or restore a resource (e.g., as ground water), environmental objectives should be expressed in terms of the medium of interest and target cleanup levels, whenever possible.

(3) Although the preliminary remediation goals are established on readily available information [e.g. , reference doses (Rfds) and risk-specific doses (RSDs)] or frequently used standards (e.g., ARARs), the final acceptable exposure levels should be determined on the basis of the results of the baseline risk assessment and the evaluation of the expected exposures and associated risks for each alternative. Contaminant levels in each media should be compared with these acceptable levels and include an evaluation of the following factors:

(a) Whether the remediation goals for all carcinogens of concern, including those with goals set at the chemical-specific ARAR level, provide protection within the risk range of 10^{-4} to 10^{-7}.

Table 2-9. Important Site Characteristics and Considerations Affecting Selection of Remedial Measures

Site characteristics	Considerations
Waste characteristics	
Quantity	Determines volume and size of area, affects costs
Chemical makeup	Determines transport paths, materials of construction
Toxicity	High toxicity calls for immediate action, worker safety
Persistence/ biodegradability	Resists decomposition/can be treated by biodegradation
Radioactive	Requires special materials of construction, worker safety, site security
Reactivity/ corrosiveness	Requires special materials of construction potential explosion
Infectiousness	Calls for immediate action, worker safety
Solubility	Affects hydrology migration
Volatility	Affects migration in gaseous state
Climate	
Precipitation	Humid areas - abundant surface water, shallow ground-water table
	Arid areas - high wind and water erosion potential, deep groundwater table
Temperature	Affects physical processes such as rates of reaction, volatilization, sealed container pressure as well as microbial degradation and transformation processes

(Continued)

Table 2-9. (Continued)

Site characteristics	Considerations
Surface characteristics	
Soil texture and permeability	Coarse-textured (sandy) soils have greater permeability and transmit liquid and gases faster than fine- textured (clay) soils
Soil moisture content	Wet soils are less permeable to gases than dry soils
Slope	Steeper slopes have greater runoff, less infiltration
	Very steep or unbroken slopes have high erosion potential
Vegetation	Increases infiltration, decreases erosion
Subsurface characteristics	
Depths of ground water	Deep - higher pumping costs
	Shallow - may require lowering water table
Permeability	Permeable soils readily transmit water and gases
	Low permeability causes difficulty in pumping; drainage
Depths to bedrock	Shallow impermeable bedrock may cause leachate surface seepage; shallow or deep permeable bedrock may cause rapid and extensive contaminant migration
	Deep - limit on trench excavation depth
Direction of ground-flow and points of discharge	Direction of flow toward point of water use presents a significantly adverse impact; point of discharge must be known to assess areal extent of contamination and degree of impact

(Continued)

Table 2-9. (Concluded)

Site characteristics	Considerations
Receptors	Nearby working and residential populations, farms, orchards, grazing lands, natural areas, critical habitats may require immediate relief
Existing land use	Maintenance of site security, protection of equipment, and soil cover from accidental abuse; vandalism

(b) Whether the remediation goals set for all noncarcinogens of concern, including those with goals set at the chemical-specific ARAR. level, are sufficiently protective at the site.

(c) Whether environmental effects (in addition to human health effects) are adequately addressed.

(d) Whether the exposure analysis conducted as part of the risk assessment adequately addresses each significant pathway of human exposure identified in the baseline risk assessment. For example, if the exposures from the ingestion of fish and drinking water are both significant pathways of exposure, goals set by considering only one of these exposure pathways may not be adequately protective. The Superfund Public Health Evaluation Manual (SPHEM) provides additional details on establishing acceptable exposure levels.

c. Develop General Response Actions.

(1) General response actions describe those actions that will satisfy the remedial action objectives. General response actions may include treatment, containment, excavation, extraction, disposal, institutional actions, or a combination of these. Like remedial action objectives, general response actions are medium specific.

(2) General response actions that might be used at a site are initially defined during scoping and are refined throughout the RI/FS as a better understanding of site conditions is gained and action-specific ARARs are identified. In developing alternatives, combinations of general response actions may be identified, particularly when disposal methods primarily depend on whether the medium has been previously treated. Examples of potential general response actions are included in column three of Table 2-10.

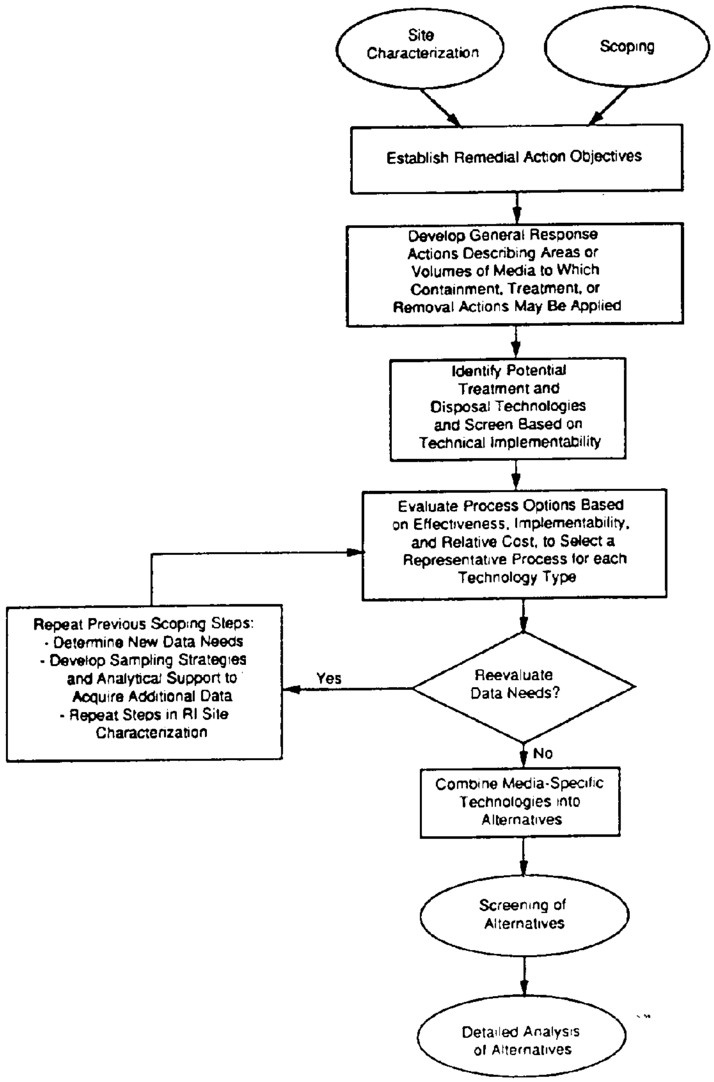


Figure 2-12. Alternative Development and Screening

Table 2-10. Example of Remedial Action Objectives, General Response Actions, Technology Types, and Example Process Options for the Development and Screening of Technologies

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Ground Water	For Human Health:			
	Prevent ingestion of water having [carcinogen(s)] in excess of [MCL(s)] and a total excess cancer risk (for all contaminants) of greater than 10^{-4} to 10^{-7}.	No Action/Institutional Actions: No Action Alternative residential water supply Monitoring	No Action/Institutional options: Fencing Deed restrictions	
		Containment Actions: Containment	Containment Technologies: Capping Vertical barriers Horizontal barriers	Clay cap, synthetic membrane, multi-layer slurry wall, sheet piling liners, grout injection
	Prevent ingestion of water having [noncarcinogen(s)] in excess of [MCL(s)] or [reference dose(s)].	Collection/Treatment Actions: Collection/treatment discharge/ in situ ground-water treatment Individual home treatment units	Extraction Technologies: Ground-water collection/ pumping Enhanced removal	Wells, subsurface or leachate collection. Solution mining, vapor extraction, enhanced oil recovery
	For Environmental Protection:		Treatment Technologies:	
	Restore ground-water aquifer to [concentration(s)] for [contaminant(s)].		Physical treatment	Coagulation/ flocculation, oil-water separation, air stripping, adsorption.
			Chemical treatment	Neutralization, pre-cipitation, ion exchange oxidation/ reduction.
			In situ treatment	Subsurface bioreclamation
			Disposal Technologies: Discharge to POTW (after treatment) Discharge to surface water (after treatment)	

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Soil	<u>For Human Health:</u>			
	Prevent ingestion/direct contact with soil having [noncarcinogen(s)] in excess of [reference dose(s)].	No Action/Institutional Actions:	No Action/Institutional options:	
		No action	Fencing	
		Access restrictions	Deed restrictions	
		Containment Actions:	Containment Technologies:	
		Containment	Capping	Clay cap, synthetic membrane, multilayer slurry wall, sheet piling liners, grout injection diversion/ collection, grading, soil stabilization
	Prevent direct contact/ ingestion with soil having 10^{-4} to 10^{-7} excess cancer risk from [carcinogen(s)].		Vertical barriers	
			Horizontal barriers	
			Surface controls	
			Sediment control barriers	Coffer dams, curtain barriers
			Dust controls	Revegetation, capping
	Prevent inhalation of [carcinogen(s)] posing excess cancer risk levels of 10^{-4} to 10^{-7}.	Excavation/Treatment Actions:		
		Excavation/treatment/disposal	Removal Technologies:	
		In situ treatment	Excavation	Solids excavation
		Disposal excavation		
			Treatment Technologies:	
			Solidification, fixation stabilization, immobilization	Sorption, pozzolanic agents, encapsulation
	<u>For Environmental Protection:</u>		Dewatering	Belt filter press, dewatering, and drying beds
	Prevent migration of contaminants that would result in ground-water contamination in excess of [concentration(s)] for [contaminant(s)].		Physical treatment	Water/solvent leaching (with subsequent liquids treatment)
			Chemical treatment	Lime neutralization
			Biological treatment	Cultured micro-organisms
			In situ treatment	Surface bioreclamation
			Thermal treatment	Incineration, pyrolysis

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Surface Water	For Human Health:	No Action/Institutional Actions: No action Access restrictions Monitoring	No Action/Institutional Options: Fencing Deed restrictions	
	Prevent ingestion of water having [carcinogen(s)] in excess of [MCLs] and a total excess cancer risk of greater than 10^{-4} to 10^{-7}.	Collection/Treatment Actions: Surface water runoff interception/ treatment/discharge	Collection Technologies: Surface controls	Grading, diversion, and collection
	Prevent ingestion of water having [noncarcinogen(s)] in excess of [MCLs] or [reference dose(s)].		Treatment Technologies: Physical treatment	Coagulation/ flocculation, oil-water separation, filtration, adsorption
			Chemical treatment	Precipitation, ion exchange, neutralization, freeze crystallization biological treatment,
	For Environmental Protection:		Biological treatment (organics)	Aerobic and anaerobic spray irrigation
	Restore surface water to [ambient water quality criteria] for [contaminant(s)]		In situ treatment	In situ precipitation, in situ bioreclamation
			Disposal Technologies: Disposal Technologies: Discharge to POTW (after treatment)	
	For Human Health:	No Action/Institutional Action: No action Access restrictions to Monitoring	No Action/Institutional options: Fencing Deed restrictions	
	Prevent inhalation of [carcinogen(s)] in excess of 10^{-4} to 10^{-7} excess cancer risk.	Collection Actions: Gas collection	Removal Technologies: Landfill gas collection	Passive vents, active gas collection systems

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Sediment	For Human Health:	No Action/Institutional Action:	No Action/Institutional Options:	
		No action	Fencing	
	Prevent direct contact with sediment having [carcinogen(s)] in excess of 10^{-4} to 10^{-7} excess cancer risk.	Access restrictions to	Deed restrictions	
		Monitoring		
		Excavation Actions:		
		Excavation	Removal Technologies:	
			Excavation	Sediments excavation
	For Environmental Protection:		Containment Technologies:	
			Capping	Removal with clay cap, multilayer, asphalt
	Prevent releases of [contaminant(s)] from sediments that would result in surface water levels in excess of [ambient water quality criteria].		Vertical barriers	
			Horizontal barriers	
			Sediment control barriers	Slurry wall, sheet piling liners, grout injection
		Excavation/Treatment Actions:		
		Removal/disposal		
		Removal/treatment/disposal		Coffer dams, curtain barriers, capping barriers
			Treatment Technologies	
			Solidification, fixation, stabilization	Sorption, pozzolanic agents, encapsulation
			Dewatering	Sedimentation, dewatering and drying beds
			Physical treatment	
			Chemical treatment	Water/solids leaching with subsequent treatment)
			Biological treatment	Neutralization, oxidation, electrochemical reduction
			In situ treatment	Landfarming
			Thermal treatment	Surface bioreclamation
				Incineration, pyrolysis

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Structures	For Human Health:	No Action/Institutional Action: No action Access restrictions Demolition/Treatment Actions: Demolition/disposal Decontamination	No Action/Institutional Options: Fencing Deed restrictions	
	Prevent direct contact with [carcinogen(s)] in excess of 10^{-4} to 10^{-7} excess cancer risk.		Removal Technologies: Demolition Excavation	Demolition Excavation, debris removal
	Prevent migration of [carcinogen(s)] which would result in ground-water concentrations in excess of [MCLs] or 10^{-4} to 10^{-7} total excess cancer risk level.		Treatment Technologies: Solids processing Solids treatment	Magnetic processes, crushing and grinding, screening Water leaching, solvent leaching, steam cleaning
	Prevent migration of [carcinogen(s)] which would result in soil concentration in excess of [reference dose(s)]			
	For Environmental Protection			
	Prevent migration of [contaminants] that would result in ground-water concentrations in excess of [concentration(s)].			

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Solid Wastes	For Human Health:	No Action/Institutional Actions: No action Access restrictions to [location]	No Action/Institutional Options: Fencing Deed restrictions	
	Prevent ingestion/direct contact with wastes having [non-carcinogen(s)] in excess of [reference dose(s)].	Containment Actions: Containment	Containment Technologies: Capping Vertical barriers Horizontal barriers	Clay cap, synthetic membranes, multi-layer slurry wall, sheet piling Liners, grout injection Dust controls
	Prevent ingestion/direct contact with wastes having 10^{-4} to 10^{-7} excess cancer risk from [carcinogen(s)].	Excavation/Treatment Actions: Removal/disposal Removal/treatment/disposal	Removal Technologies: Excavation Drum removal	Solids excavation Drum and debris removal
	Prevent inhalation of [carcinogen(s)] posing excess cancer risk levels of 10^{-4} to 10^{-7}		Treatment Technologies: Physical treatment Chemical treatment Biological treatment Thermal treatment	Water/solvent leaching (with subsequent liquids treatment) Neutralization Cultured micro-organisms Incineration, pyrolysis, gaseous incineration
	Prevent migration of [carcinogen(s)] which would result in ground-water concentrations in excess of [MCLs] or 10^{-4} to 10^{-7} total excess cancer risk levels.		Solids processing	Crushing and grinding, screening, classification
	For Environmental Protection:			
	Prevent migration of contaminants which would result in ground water contamination in excess of [concentration(s)] for [contaminant(s)].			

(Continued)

Table 2-10. (Continued)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Liquid Wastes	For Human Health:	No Action/Institutional Actions:	No Action/Institutional Options:	
		No action	Fencing	
	Prevent ingestion/direct contact with wastes having [noncarcinogen(s)] in excess of [reference does(s)].	Access restrictions to [location]	Deed restrictions	
		Containment Actions:	Containment Technologies:	
		Containment	Vertical barriers	Slurry wall
			Horizontal barriers	Liners
	Prevent ingestion/direct contact with wastes having 10^{-4} to 10^{-7} excess cancer risk from [carcinogen(s)].	Removal/Treatment Actions:	Removal Technologies:	
		Removal/disposal	Bulk liquid removal	Bulk liquid removal
		Removal/treatment/disposal	Drum removal	Drum removal
	Prevent inhalation of [carcinogen(s)] posing excess cancer risk levels of 10^{-4} to 10^{-7}.		Treatment Technologies:	
			Physical treatment	Coagulation/ flocculation, adsorption, evaporation, distillation
			Chemical treatment	Neutralization, oxidation, reduction, photolysis
	Prevent migration of [carcinogen(s)] which would result in ground-water concentrations in excess of [MCLs] or 10^{-4} to 10^{-7} total excess cancer risk levels.		Biological treatment	Aerobic/anaerobic biological treatment, 'biotechnologies
			Thermal treatment (organics)	Incineration, pyrolysis, co-disposal
			Disposal Technologies:	
			Product reuse	
			Discharge to POTW (after) treatment)	
	For Environmental Protection:			
	Prevent migration of contaminants that would result in ground-water contamination in excess of [contamination(s)] for [contaminant(s)].			

(Continued)

Table 2-10. (Concluded)

Environmental media	Remedial action objectives (from site characterization)	General response actions (for all remedial action objectives)	Remedial technology types (for general response actions)	Process options
Sludges	For Human Health:	No Action/Institutional Actions: No action Access restrictions to [location]	No Action/Institutional Options: Fencing Deed restrictions	
	Prevent direct contact with sludge having [carcinogen(s)] in excess of 10^{-4} to 10^{-7} excess cancer risk.	Containment Actions: Containment	Containment Technologies: Vertical barriers Horizontal barriers	Slurry wall, sheet piling liners
	Prevent ingestion/contact with sludge having [noncarcinogen(s)] in excess of (reference dose(s)].	Removal/Treatment Actions: Removal/disposal	Removal Technologies: Bulk sludge removal Drum removal Treatment Technologies: Solidification, fixation	Semisolid excavation, pumping Drum removal Sorption, pozzolanic agents, encapsulation
	Prevent migration of [carcinogen(s)] which would result in ground-water concentrations in excess of 10^{-4} to 10^{-7} excess cancer risk.	Removal/treatment/disposal	Physical Treatment Chemical treatment Biological treatment Thermal treatment (organics) Dewatering	freeze crystallization, neutralization, oxidation, electrochemical reduction Oxidation, reduction, photolysis Aerobic/anaerobic treatment, land treatment new biotechnologies Incineration, pyrolysis, co-disposal Gravity thickening, belt filter press, vacuum filtration
	For Environmental Protection:		Disposal Technologies: Product reuse Landfilling (after treatment)	
	Prevent releases of [contaminant(s)] from sludge that would result in surface water levels in excess of [ambient water quality criteria].			
	Prevent releases of [contaminant(s)] from sludge that would result in ground-water levels of [contaminant(s)] in excess of [concentration(s)].			

d. Identify Volumes or Areas of Media.

(1) During the development of alternatives, an initial determination is made of areas or volumes of media to which general response actions might be applied. This initial determination is made for each medium of interest at a site. To take interactions between media into account, response actions for areas or volumes of media are often refined after sitewide alternatives have been assembled.

(2) Defining the areas or volumes of media requires careful judgment and should include a consideration of not only acceptable exposure levels and potential exposure routes, but also site conditions and the nature and extent of contamination. For example, in an area in which contamination is homogeneously distributed in a medium, discrete risk levels (e.g., 10^{-5}, 10^{-6}) or corresponding contaminant levels may provide the most rational basis for defining areas or volumes of media to which treatment, containment, or excavation actions may be applied. For sites with discrete hot spots or areas of more concentrated contamination, however, it may be more useful to define areas and volumes for remediation on the basis of the site-specific relationship of volume (or area) to contaminant level. Therefore, when areas or volumes of media are defined on the basis of site-specific considerations such as volume versus concentration relationships, the volume or area addressed by the alternative should be reviewed with respect to the remedial action objectives to ensure that alternatives can be assembled to reduce exposure to protective levels.

e. Identify and Screen Remedial Technologies and Process Options.

(1) In this step, the universe of potentially applicable technology types and process options is reduced by evaluating the options with respect to technical implementability. The term "technology types" refers to general categories of technologies, such as chemical treatment, thermal destruction, immobilization, capping, or dewatering. The term "technology process options" refers to specific processes within each technology type. For example, the chemical treatment technology type would include such process options as precipitation, ion exchange, and oxidation/reduction. As shown in columns four and five of Table 2-10, several broad technology types may be identified for each general response action, and numerous technology process options may exist within each technology type.

(2) Technology types and process options may be identified by drawing on a variety of sources including references developed for application to Superfund sites and more standard engineering texts not specifically directed toward hazardous waste sites.

(3) During this screening step, process options and entire technology types are eliminated from further consideration on the basis of technical implementability. This is accomplished by using readily available information from the RI site characterization on contaminant types and concentrations and onsite characteristics to screen out technologies and process options that cannot be effectively implemented at the site.

(4) Two factors that commonly influence technology screening are the presence of inorganic contaminants, which limit the applicability of many types of treatment processes, and the subsurface conditions, such as depth to impervious formations or the degree of fracture in bedrock, which can limit many types of containment and ground-water collection technologies. This screening step is site specific, however, and other factors may need to be considered.

f. Evaluate Technology Options.

(1) Representative processes. The technology processes considered to be implementable are evaluated in greater detail before selecting one process to represent each technology type. One representative process is selected, if possible, for each technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. The representative process provides a basis for developing performance specifications during preliminary design; however, the specific process actually used to implement the remedial action at a site may not be selected until the remedial design phase. More than one process option may be selected for a technology type if two or more processes are sufficiently different in their performance that one would not adequately represent the other.

(2) Option criteria. Process options are evaluated using the same criteria, effectiveness, implementability, and cost, that are used to screen alternatives prior to the detailed analysis. These criteria are applied only to technologies and the general response actions they are intended to satisfy and not to the site as a whole. Furthermore, the evaluation should typically focus on effectiveness factors at this stage with less effort directed at the implementability and cost evaluation.

(3) Innovative and demonstrated technologies. Because of the limited data on innovative technologies, it may not be possible to evaluate these process options on the same basis as other demonstrated technologies. Typically, if innovative technologies are judged to be implementable they are retained for evaluation either as a "selected" process option (if available information indicates that they will provide better treatment, fewer or less adverse effects, or lower costs than other options), or they will be represented" by another process option of the same technology type. Tables 2-11 through 2-16 summarize available remedial action technologies for various contaminant migration pathways.

(4) Technology effectiveness evaluation.

(a) Specific technology processes that have been identified should be evaluated further on their effectiveness relative to other processes within the same technology type. This evaluation should focus on: the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the remedial action objectives; the potential impacts to human health and the environment during the construction and implementation phase; and how proven and reliable the process is with respect to the contaminants and conditions at the site.

(b) Information needed to evaluate the effectiveness of technology types for the different media includes contaminant type and concentration, the area or volume of contaminated media, and rates of collection of liquid or gaseous media. It may be necessary to conduct preliminary analyses or collect additional site data to adequately evaluate effectiveness for processes in which the rates of removal or collection and treatment are needed for evaluation, such as for ground-water extraction, surface-water collection and treatment, or subsurface gas collection. In such cases, a limited conceptual design of the process may be developed, and modeling of the potential environmental transport mechanisms associated with their operation may be undertaken. Such analyses are conducted during the later phases of the FS when alternatives are being refined and evaluated on a sitewide basis.

(c) If modeling of transport processes is undertaken during the alternative development and screening phases of the FS to evaluate removal or collection technologies, and if many contaminants are present at the site indicator chemicals should be identified, as is often done for the baseline risk assessments, to simplify the analysis. Indicator chemicals are selected on the basis of their usefulness in evaluating potential effects on human health and the environment. Commonly selected indicator chemicals include those that are highly mobile and highly toxic.

(5) Technology implementability evaluation. Implementability encompasses both the technical and administrative feasibility of implementing a technology process. Technical implementability is used as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site. Therefore, this subsequent, more detailed evaluation of process options places greater emphasis on the institutional aspects of implementability, such as the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology.

(6) Technology cost evaluation. Cost plays a limited role in the screening of process options. Relative capital and operation and maintenance (O&N) costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type. The greatest cost consequences in site remediation are usually associated with the degree to which different general technology types (i.e., containment, treatment, excavation, etc.) are used. Using different process options within a technology type usually has a less significant effect on cost than does the use of different technology types.

g. Assemble Alternatives.

(1) General response actions and the process options chosen to represent the various technology types for each medium or operable unit are combined to form alternatives for the site as a whole. Appropriate treatment and containment options should be developed. To assemble alternatives, general response actions should be combined using different technology types and different volumes of media and/or areas of the site.

Table 2-11. Summary of Available Remedial Action Techniques for Contaminated Surface Flows

Technique	Functions	Applications/restrictions
Surface sealing/capping	Isolates waste from contact with surface runoff and infiltration; stabilizes surface of site, controls offsite transport of contaminated sediments and debris; prevents surface leaks of leachate; supports revegetation	All land disposal sites; most effective when combined with grading and revegetation; requires suitable capping and cover materials
Grading	Shapes surface topography to provide for nonerosive runoff and minimize infiltration; supports revegetation	All land disposal sites; most effective when combined with surface sealing with revegetation; may require special landfill equipment
Revegetation	Stabilizes site surface; controls erosion by wind and water; controls off-site transport of contaminated debris; enhances surface sealing; may prepare site for future re-use	All land disposal sites; only recommended for properly sealed sites; may require irrigation in arid climates; most effective when combined with grading; may require special construction techniques and long-term maintenance
Surface water diversion and collection structures Dikes and berms Ditches, diversions, and waterways Terraces and benches Chutes and downpipes Levees	Upslope or at perimeter of site, channels runoff around critical areas; downslope or onsite, controls off-site erosive transport of contaminated sediments; collects/channels contaminated runoff to basins/traps	All land disposal sites in sloping areas, surface impoundments; most suited for wet climates; often provides only short-term control for small drainage areas; associated maintenance costs; most effective when combined with grading and revegetation

(Continued)

Table 2-11. (Concluded)

Technique	Functions	Applications/restrictions
Seepage basins	Collects surface runoff from diversion structures and provides for recharge to ground water	Wherever diversion structures have been implemented and where soil permeability is not too low to allow for recharge
Sedimentation basins/traps Check dams Sedimentation basins/ponds	Collects and detains contaminated sediments eroded from disposal site surface; sediment-laden surface run-off intercepted and channeled to these structures; prevents contamination of local watercourses by disposal site	All land disposal sites with sediment erosion problems; must be located in fairly remote areas for large sediment pond construction; smaller sediment traps for basins only effective for small drainage areas
Leachate control Collection Recirculation Treatment	Controls offsite migration of surface leachate seeps (e.g., at base of fill) by collecting and treating or recirculating leachate	All disposal sites with surface seepage of leachate; particularly applicable to sites located on bedrock, where shallow ground water exists, or with impermeable sublayer
Treatment of contaminated surface waters	Removes contaminants by physical, chemical, and/or biological treatment methods	For contaminated surface runoff or natural watercourses that must be treated

Table 2-12. Summary of Available Remedial Action Techniques for Contaminated Ground Water

Technique	Functions	Applications/restrictions
Surface sealing	Indirectly controls ground-water contamination by reducing surface water infiltration (provides impermeable barrier), thereby minimizing leachate generation	All land disposal sites; most effective when combined with grading and revegetation; requires suitable capping and cover materials
Grading	Indirectly controls ground-water contamination by promoting surface runoff and reducing infiltration, thereby minimizing leachate generation	All land disposal sites; most effective when combined with surface sealing and revegetation; may require special landfill equipment
Revegetation	May be used to dry surface layers of filled refuse through root uptake/evapotranspiration, reducing volume of leachate generated, and thereby indirectly controlling ground-water contamination	This function of revegetation may be offset by enhanced detention and infiltration of surface runoff; site-tolerant species will be effective; may be effective at landfill sites with poorly drained surface layers and nonphytotoxic wastes near the surface
Surface water diversion and collection structures Dikes and berms Ditches, diversions, and waterways Terraces and benches Chutes and downpipes	Upslope of sites may indirectly control ground-water contamination by intercepting and diverting surface runoff around site, reducing opportunity for runoff infiltration, and minimizing leachate generation	Structures must be upslope or at perimeter of disposal site to isolate site surface from contact with storm runoff; most suited for wet climates; often provide only short-term control for small drainage areas; associated maintenance costs; most effective when combined with grading and revegetation

(Continued)

Table 2-12. (Continued)

Technique	Functions	Applications/restrictions
Impermeable barriers Grout curtain Slurry wall Sheet piling	Upgradient from or around sites, diverts uncontaminated ground-water flow away from wastes; downslope or around sites contains/collects contaminated ground water to limit extent of aquifer pollution or protect offsite wells	All land disposal sites and surface impoundments with ground-water contamination; requires expensive preconstruction geotechnical evaluation, limited bedrock depths of less than 80 feet. Compatibility of wastes with grouts and, to a lesser extent, slurry walls has not been fully tested. Grouts not suitable for soils with low permeability
Permeable treatment beds	Adsorption, precipitation, or neutralization of certain ground-water contaminants downgradient of polluting disposal sites	Applicable to any land disposal site or surface impoundment with contaminated ground water flowing downgradient of site; carbon adsorption very costly; not a proven technique
Ground-water pumping	Lowers water table to prevent ground-water contact with buried or impounded wastes; lowers water table to prevent surface discharge of contaminated ground water; contains or collects a leachate plume for delivery to treatment system	Land disposal sites and surface impoundments that are contaminating local aquifers; particularly useful when dealing with permeable bedrock, where impermeable barriers connot contain vertical migration

(Continued)

Table 2-12. (Concluded)

Technique	Functions	Applications/restrictions
Bioreclamation	Bacterial degradation/removal of petrochemical contaminants and other organics as ground water is recycled between pump stations	Not effective for ground-water contaminated by heavy metals, certain chlorinated organics, or other non-biodegradables; short-term treatment only; may be very costly; possibility of producing treatment residue more difficult to treat than original contaminant
Leachate control Collection Recirculation Treatment	Intercepts subsurface leachate before it migrates to ground water; collects and transports leachate to retreatment system or for recirculation	All disposal sites (landfills, surface impoundments) with subsurface leachate generation; limited applicability where soils are of low permeability; may not intercept all leachate if site is very large

Table 2-13. Summary of Available Remedial Action Techniques for Contaminated Air/Soil Pore Spaces

Technique	Functions	Applications/restrictions
Surface sealing	Horizontal sealing provides impermeable barrier to upward migration/surface escape of decomposition gases and volatiles	All land disposal sites; layered systems most effective for control of gas migration
Gas barriers	Vertical sealing prevents lateral movement; layered sealing systems may channel gases to vents and treatment structures	Vertical barriers should not be used alone for control of lateral migration; clay may crack in arid regions
Gas ventilation systems Pipe vents Trench vents	Prevents lateral subsurface migration of gases; safely vents hazardous gases to the atmosphere or to treatment structures	Applicable as a remedial technique for control of volatile toxics or methane and decomposition gases at land disposal sites
Gas collection and treatment	For control of volatile toxics, and malodorous decomposition gases, removal or destruction of pollutants by thermal oxidation or adsorption	All land disposal sites; generally cost-effective

Table 2-14. Summary of Available Remedial Action Techniques for Contaminated Soil and Sediments

Technique	Functions	Applications/restrictions
Surface sealing	Controls offsite transport of contaminated surface soil by capping waste site and stabilizing cover soil; prevents leachate seeps and subsequent contamination	All land disposal sites; most applicable to wet climates
Grading and revegetation	Controls offsite erosion of cover soil; binds soil particles, protects from wind and rain	All land disposal sites; most effective when combined with surface sealing; may be costly in arid climates
Surface water diversion and collection Diversions Benches/terraces Sediment traps/basins	Upslope of sites; diverts eroding runoff; downslope or on site surface, slows runoff, controls soil erosion, channels sediment-laden runoff to collection structures (traps/basins) or stabilization outlets; traps and collects sediments	All land disposal sites; structures often temporary in nature; for small drainage areas; usually combined with revegetation and grading for long-term erosion control
Leachate control	Indirectly functions to prevent soil contamination by collecting and treating leachate that might otherwise migrate offsite	All land disposal sites and surface impoundments; effectiveness limited in poorly permeable soils
Disposal of dredged sediments	Safe disposal of contaminated sediments in secure landfill or by incineration	Only cost-effective for large volumes of dredged/excavated sediments

(Continued)

Table 2-14 (Concluded)

Technique	Functions	Applications/restrictions
Wet excavation techniques Stream diversion Mechanical excavation Hydraulic dredging Dewatering	Removes contaminated sediments from streams, rivers, and wetlands that may be ecologically fragile or important as public water sources	For contaminated sediments that have been eroded from the site and deposited in streambeds or wetlands; only cost-effective for removing large volumes of sediments; mechanical excavation is most cost-effective for small, low flow streams; may not be feasible for very remote, inaccessible sites

Table 2-15. Summary of Available Remedial Action Techniques for Hazardous Wastes

Technique	Functions	Applications/restrictions
Mechanical excavation	Removes waste materials from site for treatment or secured disposal by power shovel, clamshell, etc.	Landfills, small surface impoundments with high-solids waste material
Hydraulic dredging	Pumps waste materials to treatment, or for transportation to secured disposal	Surface impoundments with pumpable solids
Land disposal	Disposes of waste materials in impoundments, landfills, and landforms	Most widely used method for waste disposal; improper disposal can result in air pollution, ground-water and surface-water contamination; RCRA requirements will markedly increase the cost but will provide for more sound disposal methods
Incineration	Thermally oxidizes waste material in controlled environment	Most effective for all organic wastes, especially those with low flash points containing relatively low ash contents. Applicable to wastes that are oxidizable at temperatures below 2500°F
Wet-air oxidation	Oxidizes waste material by low-temperature thermal air	Most economical for wastes with high COD; may be used in conjunction with biological treatment
Solidification	Incorporates waste material into immobile matrix such as cement or resin	Most economical for small quantities of waste. Waste material must be compatible with solidification agent. Not well demonstrated for nonradioactive wastes; may leach from some matrices over time

(Continued)

Table 2-15. (Concluded)

Technique	Functions	Applications/restrictions
Encapsulation	Surrounds waste material with impermeable coating	Most applicable to containerized waste materials or dewatered sludges; not fully demonstrated; costly
Solution mining technical	Treats the waste in-place by mobilizing contaminants or flushing them through to ground water, and collecting	Most applicable to surface impoundments; may eliminate need for hazardous excavation; best suited for flushing heavy metals and basic organics; difficult to determine extent to which solution makes contact with wastes; generally used with ground-water pumping or leachate collection; not well demonstrated
In-situ solidification	Injects waste solidification agents directly into waste site	Applicable to liquid wastes from surface impoundments, well-defined landfill sections. Not applicable to containerized wastes
In-situ neutralization/ detoxification	Neutralizes or immobilizes wastes by application of a neutralization agent such as lime to the waste material	Most applicable to surface impoundments, disposal sites with permeable surfaces; metal-bearing wastes. Degree of effectiveness difficult to determine
Microbial seeding	Biodegrades organic wastes	Most effective for landforms and surface impoundments; can degrade a wide range of organics when acclimated; degradation process can be slow depending on acclimation and adequate aeration

Table 2-16. Summary of Available Remedial Action Techniques for Contaminated Water and Sewer Lines

Technique	Functions	Applications/restrictions
In-situ cleaning Scouring Flushing Dredging Suction cleaning	Cleans interiors of municipal sewer and water pipelines infiltrated by contaminated sediments or ground water; removes infiltrated contaminants	Most applicable to contaminated gravity sewer lines; most techniques well established and cost-effective
Leak detection and repair Pipeline inspection Grouting Relining	Allows discovery and repair of leaks, cracks, etc. (points of infiltration/exfiltration)	Most applicable to contaminated sewer lines; techniques well established and generally cost-effective
Pipeline removal and replacement	Replaces badly damaged sewer lines or contaminated water mains	May be only option feasible for contaminated public water mains; very costly for deep pipelines

Often more than one general response action is applied to each medium. For example, alternatives for remediating soil contamination will depend on the type and distribution of contaminants and may include incineration of soil from some portions of the site and capping of others.

(2) Alternatives should be developed that will provide decisionmakers with an appropriate range of options and sufficient information to adequately compare alternatives. In developing alternatives, the range of options will vary depending on site-specific conditions. Ranges for source control and ground-water response actions that should be developed are described below.

(3) For source control actions, the following types of alternatives should be developed to the extent practicable:

(a) A number of treatment alternatives, ranging from one that would eliminate or minimize to the extent feasible the need for long-term management (including monitoring) at a site to one that would use treatment as a primary component of an alternative to address the principal threats at the site. Alternatives for which treatment is a principal element could include containment elements for untreated waste or treatment residuals as well. Alternatives within this range typically will differ in the type and extent of treatment used and the management requirements of treatment residuals or untreated wastes.

(b) One or more alternatives that involve containment of waste with little or no treatment but protect human health and the environment by preventing potential exposure and/or reducing the mobility of contaminants.

(c) No-action alternatives. (Although a no-action alternative may include some type of environmental monitoring, actions taken to reduce the potential for exposure (e.g., site fencing, deed restrictions) should not be included as a component of the no-action alternatives. Such minimal actions should constitute a separate "limited" action alternative.)

(4) For ground-water response actions, alternatives should address not only cleanup levels but also the timeframe within which the alternatives might be achieved. Depending on specific site conditions and the aquifer characteristics, alternatives should be developed that achieve ARARs or other health-based levels determined to be protective within varying timeframes using different methodologies. For aquifers currently being used as a drinking water source, alternatives should be configured that would achieve ARARs or risk-based levels as rapidly as possible. More detailed information on developing remedial alternatives for ground-water response actions may be found in "Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites" (EPA, August 1988).

(5) Development of a complete range of treatment alternatives will not be practical in some situations. For example, for sites with large volumes of low contamination wastes such as some municipal landfills and mining sites, an alternative that eliminates the need for long-term management may not be reasonable given site conditions, the limitations of technologies, and extreme costs that may be involved.

If a full range of alternatives is not developed, the specific reasons for doing so should be briefly discussed in the FS report to serve as documentation that treatment alternatives were assessed as required by CERCLA.

2-19. Alternative Screening Evaluation.

a. General Concept.

(1) For those situations in which numerous waste management options are appropriate and developed, the assembled alternatives may need to be refined and screened to reduce the number of alternatives that will be analyzed in detail. This screening aids in streamlining the FS process while ensuring that the most promising alternatives are being considered.

(2) In other situations, the number of viable or appropriate alternatives for addressing site problems may be limited; thus, the screening effort may be minimized or eliminated if unnecessary. The scope of this screening effort can vary substantially, depending on the number and type of alternatives developed and the extent of information necessary for conducting the detailed analysis. The scope and emphasis can also vary depending on either the degree to which the assembled alternatives address the combined threats posed by the entire site or on the individual threats posed by separate site areas or contaminated media. Whatever the scope, the range of treatment and containment alternatives initially developed should be preserved through the alternative screening process to the extent that it makes sense to do so.

(3) As part of the screening process, alternatives are analyzed to investigate interactions among media in terms of both the evaluation of technologies (i.e., the extent to which source control influences the degree of ground-water or air-quality control) and sitewide protectiveness (i.e. whether the alternative provides sufficient reduction of risk from each media and/or pathway of concern for the site or that part of the site being addressed by an operable unit). Also, at this stage, the areas and quantities of contaminated media initially specified in the general response actions may also be reevaluated with respect to the effects of interactions between media. Often, source control actions influence the degree to which ground—water remediation can be accomplished or the timeframe in which it can be achieved. In such instances, further analyses may be conducted to modify either the source control or ground-water response actions to achieve greater effectiveness in sitewide alternatives. Using these refined alternative configurations, more detailed information about the technology process options may be developed. This information might include data on the size and capacities of treatment systems, the quantity of materials required for construction, and the configuration and design requirements for ground-water collection systems.

(4) Information available at the time of screening should be used primarily to identify and distinguish any differences among the various alternatives and to evaluate each alternative with respect to its effectiveness, implementability, and cost. Only the alternatives judged as the best or most promising on the basis of these evaluation factors should be retained for further consideration and analysis. As with the use of representative technologies, alternatives may be selected to represent sufficiently similar management strategies; thus, in effect, a separate analysis for each alternative is not always warranted.

Typically, those alternatives that are screened out will receive no further consideration unless additional information becomes available that indicates further evaluation is warranted. For sites at which interactions among media are not significant, the process of screening alternatives, described here, may be applied to medium-specific options to reduce the number of options that will either be combined into sitewide alternatives at the conclusion of screening or will await further evaluation in the detailed analyses.

b. <u>Alternative Screening Criteria</u>.

(1) Defined alternatives are evaluated against the short- and long- term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo a more thorough and extensive analysis, alternatives will be evaluated more generally in this phase than during the detailed analysis. However, evaluations at this time should be sufficiently detailed to distinguish among alternatives. In addition, the alternatives must be compared on an equivalent basis (i.e., definitions of alternatives are approximately at the same level of detail to allow preparation of comparable cost estimates).

(2) Initially, specific technologies or process options were evaluated primarily on the basis of whether or not they could meet a particular remedial action objective. During alternative screening, the entire alternative is evaluated as to its effectiveness, implementability, and cost.

(3) During the detailed analysis, the alternatives will be evaluated against nine specific criteria and their individual factors rather than the general criteria used in screening. Therefore, individuals conducting the FS should be familiar with the nine criteria at the time of screening to better understand the direction that the analysis will be taking. The relationship between the screening criteria and the nine evaluation criteria is conceptually illustrated in Figure 2-13.

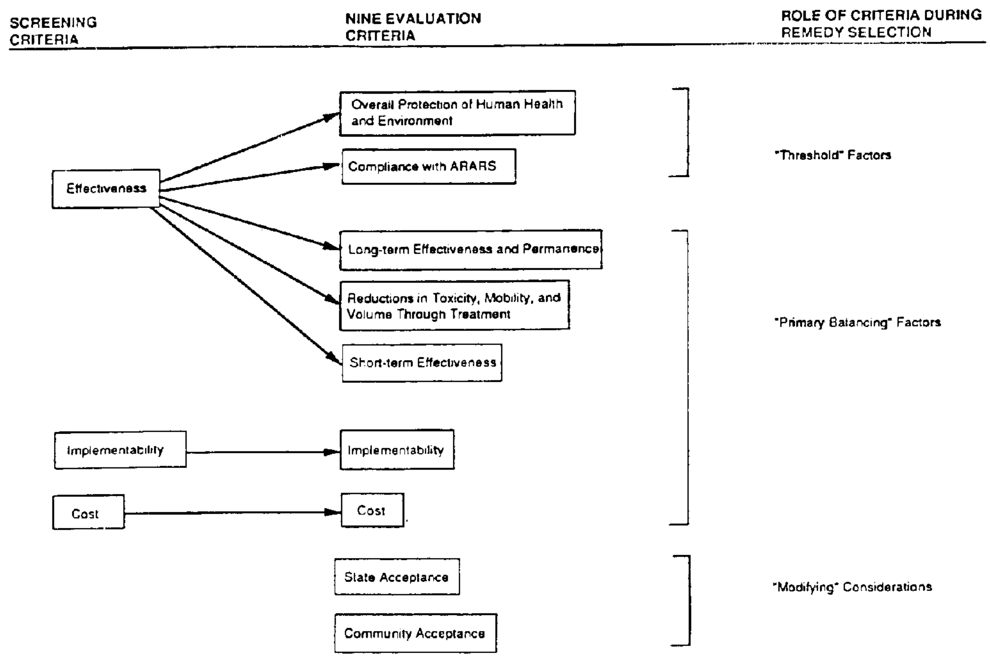


Figure 2-13. Relationship Between Screening Criteria and Detailed Evaluation

(4) It is also important to note that comparisons during screening are usually made between similar alternatives (the most promising of which is carried forward for further analysis); whereas, comparisons during the detailed analysis will differentiate across the entire range of alternatives.

c. Effectiveness Evaluation. A key aspect of the screening evaluation is the effectiveness of each alternative in protecting human health and the environment. Each alternative should be evaluated as to its effectiveness in providing protection and the reductions in toxicity, mobility, or volume that it will achieve. Both short- and long-term components of effectiveness should be evaluated; short-term referring to the construction and implementation period, and long-term referring to the period after the remedial action is complete. Reduction of toxicity, mobility, or volume refers to changes in one or more characteristics of the hazardous substances or contaminated media by the use of treatment that decreases the inherent threats or risks associated with the hazardous material.

d. Alternative Implementability Evaluation.

(1) Implementability, as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative, will be used during screening to evaluate the combinations of process options with respect to conditions at a specific site.

Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for process options until a remedial action is complete; it also includes operation, maintenance, replacement, and monitoring of technical components of an alternative, if required, into the future after the remedial action is complete. Administrative feasibility refers to the ability to obtain approvals from other offices and agencies, the availability of treatment, storage, and disposal services and capacity, and the requirements for, and availability of, specific equipment and technical specialists.

(2) The determination that an alternative is not technically feasible and is not available will usually preclude it from further consideration unless steps can be taken to change the conditions responsible for the determination. Typically, this type of "fatal flaw" would have been identified during technology screening, and the infeasible alternative would not have been assembled. Negative factors affecting administrative feasibility will normally involve coordination steps to lessen the negative aspects of the alternative but will not necessarily eliminate an alternative from consideration.

e. Alternative Cost Evaluation.

(1) Typically, alternatives will have been defined well enough before screening that some estimates of cost are available for comparisons among alternatives. However, because uncertainties associated with the definition of alternatives often remain, it may not be practicable to define the costs of alternatives with the accuracy desired for the detailed analysis (i.e., +50 percent to -30 percent).

(2) Absolute accuracy of cost estimates during screening is not essential. The focus should be to make comparative estimates for alternatives with relative accuracy so that cost decisions among alternatives will be sustained as the accuracy of cost estimates improves beyond the screening process. The procedures used to develop cost estimates for alternative screening are similar to those used for the detailed analysis; the only differences would be in the degree of alternative refinement and in the degree to which cost components are developed.

(3) Cost estimates for screening alternatives typically will be based on a variety of cost-estimating data. Bases for screening cost estimates may include cost curves, generic unit costs, vendor information, conventional cost-estimating guides, and prior similar estimates as modified by site-specific information.

(4) Prior estimates, site-cost experience, and good engineering judgments are needed to identify those unique items in each alternative that will control these comparative estimates. Cost estimates for items common to all alternatives or indirect costs (engineering, financial, supervision, outside contractor support, contingencies) do not normally warrant substantial effort during the alternative screening phase.

(5) Both capital and O&M costs should be considered during the screening of alternatives. The evaluation should include those 0&M costs that will be incurred for as long as necessary, even after the initial remedial action is complete. In addition, potential future remedial action costs should be considered during alternative screening to the extent they can be defined. Present worth analyses should be used during alternative screening to evaluate expenditures that occur over different time periods. By discounting all costs to a common base year, the costs for different remedial action alternatives can be compared on the basis of a single figure for each alternative.

f. Innovative Technologies.

(1) Technologies are classified as innovative if they are developed fully but lack sufficient cost or performance data for routine use at Superfund sites. In many cases, it will not be possible to evaluate alternatives incorporating innovative technologies on the same basis as available technologies, because insufficient data exist on innovative technologies. If treatability testing is being considered to better evaluate an innovative technology, the decision to conduct a test should be made as early in the process as possible to avoid delays in the RI/FS schedule.

(2) Innovative technologies would normally be carried through the screening phase if there were reason to believe that the innovative technology would offer significant advantages. These advantages may be in the form of better treatment performance or implementability, fewer adverse impacts than other available approaches, or lower costs for similar levels of performance. A "reasonable belief" exists if indications from other full-scale applications under similar circumstances or from bench-scale or pilot-scale treatability testing support the expected advantages.

2-20. Alternative Screening.

a. Guidelines for Screening.

(1) Alternatives with the most favorable composite evaluation of all factors should be retained for further consideration during the detailed analysis. Alternatives selected for further evaluation should, where practicable, preserve the range of treatment and containment technologies initially developed. It is not a requirement that the entire range of alternatives originally developed be preserved if all alternatives in a portion of the range do not represent distinct viable options.

(2) The target number of alternatives to be carried through screening should be set by the project manager and the lead agency on a site-specific basis. It is expected that the typical target number of alternatives carried through screening (including containment and no-action alternatives) usually should not exceed 10. Fewer alternatives should be carried through screening, if possible, while adequately preserving the range of remedies. If the alternatives being screened are still medium-specific and do not address the entire site or operable unit, the number of alternatives retained for each specific medium should be considerably less than 10.

b. Selection of Alternatives for Detailed Analysis.

(1) Once the evaluation has been conducted for each of the alternatives, the lead agency and its contractor should meet with the support agency to discuss each of the alternatives being considered. This meeting does not correspond to a formal quality control review stage but provides the lead agency and its contractor with input from the support agency and serves as a forum for updating the support agency with the current direction of the FS.

(2) The alternatives recommended for further consideration should be agreed upon at this meeting so that documentation of the results of alternative screening is complete; any additional investigations that may be necessary are identified; and the detailed analysis can commence.

(3) Unselected alternatives may be reconsidered at a later step in the detailed analysis if similar retained alternatives continue to be evaluated favorably or if information is developed that identifies an additional advantage not previously apparent. This provides the flexibility to double check a previous decision or to review variations of alternatives being considered (e.g., consideration of other similar process options). However, it is expected that under most circumstances once an alternative is screened out it will not be reconsidered for selection.

c. Postscreening Tasks. The completion of the screening process leads directly into the detailed analysis and may serve to identify additional investigations that may be needed to adequately evaluate alternatives. To ensure a smooth transition from the screening of alternatives to the detailed analysis, it will be necessary to identify and begin verifying action-specific ARARs and initiate treatability testing (if not done previously) and additional site characterization.

2-21. Treatability Investigations. As site information is collected during the RI and alternatives are being developed, additional data needs necessary to adequately evaluate alternatives during the detailed analysis are often identified. These additional data needs may involve the collection of site characterization data or treatability studies to better evaluate technology performance.

a. Objectives. Treatability studies are conducted primarily to achieve the following:

(1) Provide sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis and to support the remedial design of a selected alternative.

(2) Reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected.

b. Bench Versus Pilot Testing.

(1) Alternatives involving treatment or destruction technologies may require some form of treatability testing, if their use represents first-of- its-kind applications on unique or heterogeneous wastes.

(2) Once a decision is made to perform treatability studies, the RI/FS contractor and lead agency remedial project manager will decide on the type of treatability testing to use. This decision must always be made taking into account the technologies under consideration, performance goals, and site characteristics.

(3) The choice of bench versus pilot testing is affected by the level of development of the technology. For a technology that is well developed and tested, bench studies are often sufficient to evaluate performance on new wastes. For innovative technologies, however, pilot tests may be required since information necessary to conduct full-scale tests is either limited or nonexistent. A comparison of bench- and pilot-scale studies appears in Table 2-17.

Table 2-17. Bench and Pilot Study Parameters

Parameter	Bench	Pilot
Purpose	Define process kinetics, material compatibility, impact of environmental factors, types of doses of chemicals, active mechanisms, etc.	Define design and operation criteria, materials of construction, ease of material handling and construction, etc.
Size	Laboratory or bench top	1-100% of full scale
Quantity of waste and materials required	Small to moderate amounts	Relatively large amounts
Number of variables that can be considered	Many	Few (greater site-specificity)
Time requirements	Days to weeks	Weeks to months
Typical cost range	0.5-2% of capital costs of remedial action	2-5% of capital costs of remedial action[1]
Most frequent location	Laboratory	Onsite
Limiting considerations	Wall, boundary, and mixing effects; volume effects; solids processing difficult to simulate; transportation of sufficient waste volume	Limited number of variables; large waste volume required; safety, health, and other risks; disposal of process waste material

[1] Actual percentage cost of pilot testing will depend significantly on the total cost of the remedial action.

b. Treatability Test Work Plan. Laboratory testing can be expensive and time consuming. A well-written work plan is necessary if a treatability testing program is to be completed on time, within budget, and with accurate results. Preparation of a work plan provides an opportunity to run the test mentally and review comments before starting the test. It also reduces the ambiguity of communication between the lead agency* s remedial project manager (RPM), the contractor* s project manager, the technician performing the test, and the laboratory technician performing the analyses on test samples. The treatability test work plan may be an amendment to the original work plan if the need for the treatability tests was not identified until later in the process or may be a separate plan specifically for this phase. Regardless, the work plan should be reviewed and approved by the lead agency* s RPM. The RPM and RI/FS contractor should determine the appropriate level of detail for the work plan since a detailed plan is not always needed and will require time to prepare and approve. In some situations, the original work plan may adequately describe the treatability tests and a separate plan is not required (e.g., the need for treatability testing can be identified during the scoping phase if existing information is sufficient).

Section V. Detailed Analysis of Alternatives

2-22. Background.

a. The detailed analysis of alternatives consists of the analysis and presentation of the relevant information needed to allow decisionmakers to select a site remedy, not the decision-making process itself. During the detailed analysis, each alternative will be assessed against the evaluation criteria described in this chapter. The results of this assessment should be arrayed to compare the alternatives and identify the key tradeoffs among them. This approach to analyzing alternatives is designed to provide decisionmakers with sufficient information to adequately compare the alternatives, select an appropriate remedy for a site, and demonstrate satisfaction of the CERCLA remedy selection requirements in the record of decision (ROD). A detailed analysis of alternatives consists of the following components:

(1) Further definition of each alternative, if necessary, with respect to the volumes or areas of contaminated media to be addressed, the technologies to be used, and any performance requirements associated with those technologies.

(2) An assessment and a summary profile of each alternative against the evaluation criteria.

(3) A comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion.

b. The specific statutory requirements for remedial actions that must be addressed in the ROD and supported by the FS report are:

(1) They are protective of human health and the environment,

(2) They attain ARARs (or provide grounds for invoking a waiver),

(3) They are cost-effective,

(4) They utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable, and

(5) They satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element or provide an explanation in the ROD as to why the alternative does not.

c. In addition, CERCLA places an emphasis on evaluating long-term effectiveness and related considerations for each of the alternative remedial actions (Section 121(b)(l)(A)). These statutory considerations include:

(1) The long-term uncertainties associated with land disposal;

(2) The goals, objectives, and requirements of the Solid Waste Disposal Act (PL 96-463);

(3) The persistence, toxicity, and mobility of hazardous substances and their constituents, and their propensity to bioaccumulate;

(4) Short- and long-term potential for adverse health effects from human exposure;

(5) Long-term maintenance costs;

(6) The potential for future remedial action costs if the alternative remedial action in question were to fail; and

(7) The potential threat to human health and the environment associated with excavation, transportation, and re-disposal, or containment.

2-23. <u>Overview of Evaluation Criteria</u>.

a. Nine evaluation criteria have been developed to address the CERCLA requirements and considerations listed above, and to address the additional technical and policy considerations that have proven to be important for selecting among remedial alternatives. These evaluation criteria serve as the basis for conducting the detailed analyses during the FS and for subsequently selecting an appropriate remedial action. The evaluation criteria with the associated CERCLA statutory considerations are:

(1) Overall protection of human health and the environment.

(2) Compliance with ARARs (B).

(3) Long-term effectiveness and permanence (A, B, C, D, F, G).

(4) Reduction of toxicity, mobility, or volume (B, C).

(5) Short-term effectiveness (D, G).

(6) Implementability.

(7) Cost (E, F).

(8) State acceptance (relates to Section 121(f)).

(9) Community acceptance (relates to Sections 113 and 117).

b. The detailed analysis provides the means by which facts are assembled and evaluated to develop the rationale for a remedy selection. Therefore, it is necessary to understand the requirements of the remedy selection process to ensure that the FS analysis provides the sufficient quantity and quality of information to simplify the transition between the FS report and the actual selection of a remedy. The analytical process described here has been developed on the basis of statutory requirements of CERCLA Section 121. The nine evaluation criteria encompass statutory requirements and technical, cost, and institutional considerations the program has determined appropriate for a thorough evaluation.

c. Assessments against two of the criteria relate directly to statutory findings that must ultimately be made in the ROD. Therefore, these are categorized as threshold criteria in that each alternative must meet them. These two criteria are:

(1) Overall protection of human health and the environment - The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment.

(2) Compliance with ARARs - The assessment against this criterion describes how the alternative complies with ARARs, or if a waiver is required and how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the lead and support agencies have agreed is “to be considered.”

d. The five criteria listed below are grouped because they represent the primary criteria upon which the analysis is based. The level of detail required to analyze each alternative against these evaluation criteria will depend on the type and complexity of the site, the type of technologies and alternatives being considered, and other project-specific considerations. The analysis should be conducted in sufficient detail so that decisionmakers understand the significant aspects of each alternative and any uncertainties associated with the evaluation (e.g., a cost estimate developed on the basis of a volume of media that could not be defined precisely).

(1) Long-term effectiveness and permanence - The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met.

(2) Reduction of toxicity, mobility, and volume through treatment - The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ.

(3) Short-term effectiveness - The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met.

(4) Implementability - This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.

(5) Cost - This assessment evaluates the capital and O&M costs of each alternative.

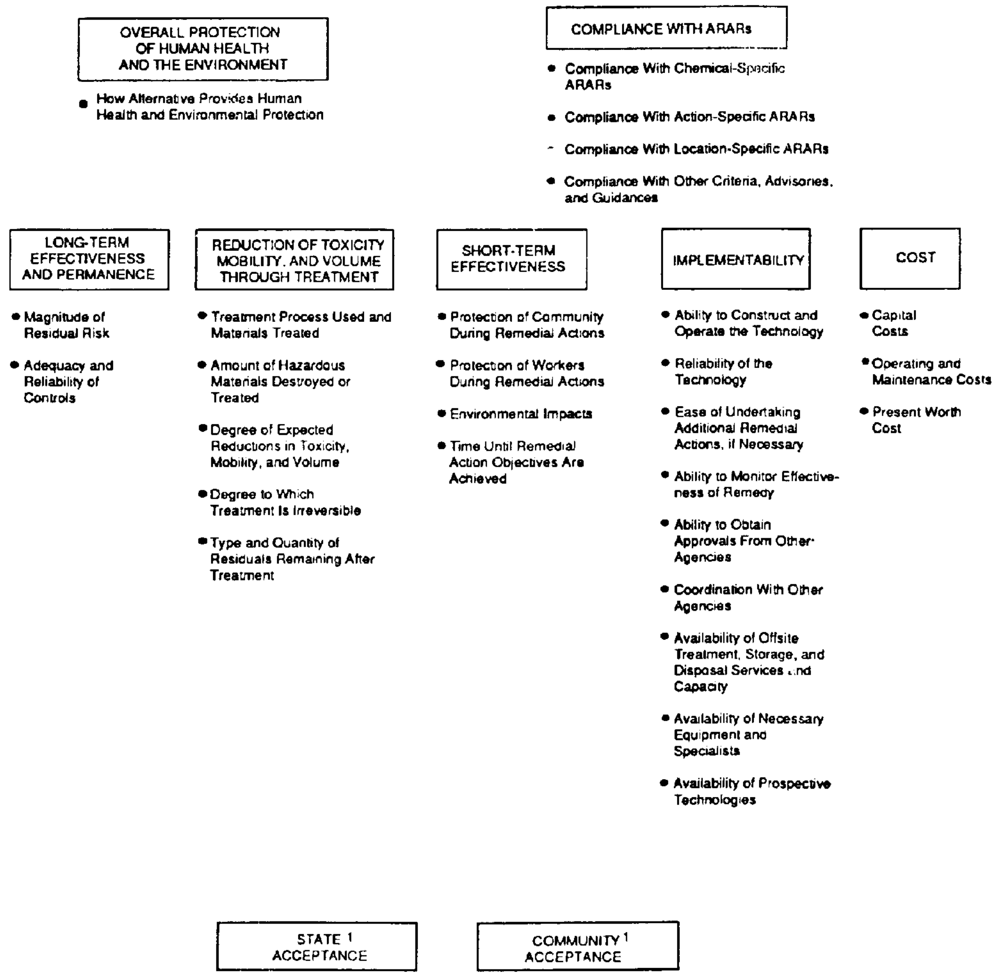
e. The final two criteria, state or support agency acceptance and community acceptance, will be evaluated following comment on the RI/FS report and the proposed plan and will be addressed once a final decision is being made and the ROD is being prepared. The criteria are as follows:

(1) State (support agency) acceptance - This assessment reflects the state* s (or support agency* s) apparent preferences among or concerns about alternatives.

(2) Community acceptance - This assessment reflects the community* s apparent preferences among or concerns about alternatives.

2-24. Discussion of Evaluation Factors. Each of the nine evaluation criteria has been further divided into specific factors to allow a thorough analysis of the alternatives. These factors are shown in Figure 2-14 and discussed below:

a. Overall Protection of Human Health and the Environment. This evaluation criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short- term effectiveness, and compliance with ARARs. Evaluation of the overall protectiveness of an alternative during the RI/FS should focus on whether a specific alternative achieves adequate protection and should describe how site risks posed through each pathway being addressed by the FS are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This evaluation also allows for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts.



[1] These criteria are assessed following comment on the RI/FS report and the proposed plan.

Figure 2-14. Detailed Analysis of Alternatives

b. Compliance with ARARs. This evaluation criterion is used to determine whether each alternative will meet all of its Federal and state ARARs (as defined in CERCLA Section 121) that have been identified in previous stages of the RI/FS process. The detailed analysis should summarize which requirements are applicable or relevant and appropriate to an alternative and describe how the alternative meets these requirements. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA should be discussed. The actual determination of which requirements are applicable or relevant and appropriate is made by the lead agency in consultation with the support agency. A summary of these ARARs and whether they will be attained by a specific alternative should be presented in an appendix to the RI/FS report. Detailed guidance on determining whether requirements are applicable or relevant and appropriate is provided in the "CERCLA Compliance with Other Laws Manual" (U.S. EPA, Draft, May 1988). The following should be addressed for each alternative during the detailed analysis of ARARs:

(1) Compliance with chemical-specific ARARs (e.g., maximum contaminant levels) - This factor addresses whether the ARARs can be met, and if not, whether a waiver is appropriate.

(2) Compliance with location-specific ARARs (e.g., preservation of historic sites) - As with other ARAR-related factors, this involves a consideration of whether the ARARs can be met or whether a waiver is appropriate.

(3) Compliance with action-specific ARARs (e.g., RCRA minimum technology standards) - It must be determined whether ARARs can be met or will be waived.

(4) Other available information that is not an ARAR (e.g., advisories, criteria, and guidance) may be considered in the analysis if it helps to ensure protectiveness or is otherwise appropriate for use in a specific alternative. These materials should be included in the detailed analysis if the lead and support agencies agree that their inclusion is appropriate.

c. Long-term Effectiveness and Permanence. The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of the risk remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. Table 2-18 lists appropriate questions that may need to be addressed during the analysis of long-term effectiveness. The following components of the criterion should be addressed for each alternative:

(1) Magnitude of residual risk - This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities (e.g., after source/soil containment and/or treatment are complete, or after ground-water plume management activities are concluded).

Table 2-18. Long-Term Effectiveness and Permanence

Analysis factor	Specific factor considerations
Magnitude of residual risks	– What is the magnitude of the remaining risks? – What remaining sources of risk can be identified? – How much is due to treatment residuals, and how much is due to untreated residual contamination? Will a 5-year review be required?
Adequacy and reliability of controls	– What is the likelihood that the technologies will meet required process efficiencies or performance specifications? – What type and degree of long-term management is required? – What are the requirements for long-term monitoring? – What operation and maintenance functions must be performed? – What difficulties and uncertainties may be associated with long-term operation and maintenance? – What is the potential need for replacement of technical components? – What is the magnitude of the threats or risks should the remedial action need replacement? – What is the degree of confidence that controls can adequately handle potential problems? – What are the uncertainties associated with land disposal of residuals and untreated wastes?

The potential for this risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of contaminants in waste, media, or treatment residuals remaining on the site. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

(2) Adequacy and reliability of controls - This factor assesses the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. It may include an assessment of containment systems and institutional controls to determine if they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals. It includes the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system, and the potential exposure pathway and the risks posed should the remedial action need replacement.

d. Reduction of Toxicity. Mobility, or Volume through Treatment. This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. In evaluating this criterion, an assessment should be made as to whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volume are reduced either alone or in combination. Table 2-19 lists typical questions that may need to be addressed during the analysis of toxicity, mobility, or volume reduction.

Table 2-19. Reduction of Toxicity, Mobility, or Volume through Treatment

Analysis factor	Specific factor considerations
Treatment process and remedy	- Does the treatment process employed address the principal threats? - Are there any special requirements for the treatment process?
Amount of hazardous material destroyed or treated	- What portion (mass, volume) of contaminated material is destroyed? - What portion (mass, volume) of contaminated material material is treated?
Reduction in toxicity, mobility, or volume	- To what extent is the total mass of toxic contaminants reduced? - To what extent is the mobility of toxic contaminants reduced? - To what extent is the volume of toxic contaminants
Irreversibility of the treatment	- To what extent are the effects of treatment irreversible?
Type and quantity of treatment residual	- What residuals remain? - What are their quantities and characteristics? - What risks do treatment residuals pose?
Statutory preference treatment as a principal element	- Are principal threats within the scope of the for action? - Is treatment used to reduce inherent hazards posed by principal threats at the site?

e. Short-term Effectiveness. This criterion addresses the effects of the alternative during the construction and implementation phase until remedial response objectives are met (e.g., a cleanup target has been met). Under this criterion, alternatives should be evaluated with respect to their effects on human health and the environment during implementation of the remedial action.

The following factors should be addressed as appropriate for each alternative:

(1) Protection of the community during remedial actions - This aspect of short-term effectiveness addresses any risk that results from implementation of the proposed remedial action, such as dust from excavation, transportation of hazardous materials, or air-quality impacts from a stripping tower operation that may affect human health.

(2) Protection of workers during remedial actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken.

(3) Environmental impacts - This factor addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts.

(4) Time until remedial response objectives are achieved - This factor includes an estimate of the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats.

(5) Table 2-20 lists appropriate questions that may need to be addressed during the analysis of short-term effectiveness.

f. Implementability. This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Table 2-
21 lists typical questions that may need to be addressed during the analysis of implementability. This criterion involves analysis of the following factors:

(1) Technical feasibility.

(a) Construction and operation - This relates to the technical difficulties and unknowns associated with a technology. This was initially identified for specific technologies during the development and screening of alternatives and is addressed again in the detailed analysis for the alternative as a whole.

(b) Reliability of technology - This focuses on the likelihood that technical problems associated with implementation will lead to schedule delays.

(c) Ease of undertaking additional remedial action - This includes a discussion of what, if any, future remedial actions may need to be undertaken and how difficult it would be to implement such additional actions. This is particularly applicable for an FS addressing an interim action at a site where additional operable units may be analyzed at a later time.

Table 2-20. Short-Term Effectiveness

Analysis factor	Basis for evaluation during detailed analysis
Protection of community during remedial actions	- What are the risks to the community during remedial actions that must be addressed? - How will the risks to the community be addressed and mitigated? - What risks remain to the community that cannot be readily controlled?
Protection of workers during remedial actions	- What are the risks to the workers that must be addressed? - What risks remain to the workers that cannot be readily controlled? - How will the risks to the workers be addressed and mitigated?
Environmental impacts	- What environmental impacts are expected with the construction and implementation of the alternative? - What are the available mitigation measures to be used and what is their reliability to minimize potential impacts? - What are the impacts that cannot be avoided should the alternative be implemented?
Time until remedial response being objectives are achieved	- How long until protection against the threat's addressed by the specific action is achieved? - How long until any remaining site threats will be addressed? - How long until remedial response objectives are achieved?

(d) Monitoring consideration - This addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.

(2) Administrative feasibility.

(a) Activities needed to coordinate with other offices and agencies (e.g., obtaining permits for offsite activities or rights-of-way for construction).

(b) Availability of services and materials.

(c) Availability of adequate offsite treatment, storage capacity, and disposal services.

Table 2-21. Implementability

Analysis factor	Specific factor considerations
	Technical Feasibility
Ability to construct and operate technology	- What difficulties may be associated with construction? - What uncertainties are related to construction?
Reliability of technology	- What is the likelihood that technical problems will lead to schedule delays?
Ease of undertaking additional remedial action, if necessary	- What likely future remedial actions may be anticipated? - How difficult would it be to implement the additional remedial actions, if required?
Monitoring considerations	- Do migration or exposure pathways exist that cannot be monitored adequately? - What risks of exposure exist should monitoring be insufficient to detect failure?
	Administrative Feasibility
Coordination with other agencies	- What steps are required to coordinate with other agencies? - What steps are required to set up long-term or future coordination among agencies? - Can permits for offsite activities be obtained if required?
	Availability of Services and Materials
Availability of treatment, storage capacity, and disposal services	- Are adequate treatment, storage capacity, and disposal services available? - How much additional capacity is necessary? - Does the lack of capacity prevent implementation? - What additional provisions are required to ensure the needed additional capacity?
Availability of necessary equipment and specialists	- Are the necessary equipment and specialists available? - What additional equipment and specialists are required? - Does the lack of equipment and specialists prevent implementation? - What additional provisions are required to ensure the needed equipment and specialists?

(Continued)

Table 2-21. (Concluded)

Analysis factor	Specific factor considerations
Availability of prospective technologies	- Are technologies under consideration generally available and sufficiently demonstrated for the specific application? - Will technologies require further development before they can be applied full-scale to the type of waste at the site? - When should the technology be available for full-scale use? - Will more than one vendor be available to provide a competitive bid?

(d) Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources.

(e) Availability of services and materials, plus the potential for obtaining competitive bids, which may be particularly important for innovative technologies.

(f) Availability of prospective technologies.

g. Cost. A comprehensive discussion of costing procedures for CERCLA sites is contained in the Remedial Action costing Procedures Manual EPA/600 8- 87/049 (U.S. EPA, October 1987). The application of cost estimates to the detailed analysis is discussed in the following paragraphs.

(1) Capital costs. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. (Sales taxes normally do not apply to Superfund actions.) Costs that must be incurred in the future as part of the remedial action alternative should be identified and noted for the year in which they will occur. The distribution of costs over time will be a critical factor in making tradeoffs between capital-intensive technologies (including alternative treatment and distribution technologies) and less capital-intensive technologies (such as pump and treatment systems).

(a) Direct capital costs may include construction costs such as the costs of materials, labor and equipment required to install a remedial action, equipment costs such as the costs of remedial action and service equipment necessary to enact the remedy (these materials remain until the site remedy is complete), land and site-development costs such as expenses associated with the purchase of land and the site preparation costs of existing property, buildings and services costs such as the costs of process and non-process buildings, utility connections, purchased services, and disposal costs, relocation expenses such as the costs of temporary or permanent accommodations for affected nearby residents, and disposal costs such as the costs of transporting and disposing of waste material such as drums and contaminated soils.

(b) Indirect capital costs may include engineering expenses such as the costs of administration, design, construction supervision, drafting, and treatability testing, license or permit costs such as administrative and technical costs necessary to obtain licenses and permits for installation and operation of offsite activities, startup and shakedown costs such as costs incurred to ensure system is operational and functional, and contingency allowances such as funds to cover costs resulting from unforeseen circumstances, such as adverse weather conditions, strikes, or contaminants not detected during site characterization.

(2) Annual/O&M costs. Annual 0&M costs are postconstruction costs necessary to ensure the continued effectiveness of a remedial action. The following annual O&M cost components should be considered:

(a) Operating labor costs - Wages, salaries, training, overhead, and fringe benefits associated with the labor needed for postconstruction operations.

(b) Maintenance materials and labor costs - Costs for labor, parts, and other resources required for routine maintenance of facilities and equipment.

(c) Auxiliary materials and energy - Costs of such items as chemicals and electricity for treatment plant operations, water and sewer services, and fuel.

(d) Disposal of residues - Costs to treat or dispose of residuals such as sludges from treatment processes or spent activated carbon.

(e) Purchased services - Sampling costs, laboratory fees, and professional fees for which the need can be predicted.

(f) Administrative costs - Costs associated with the administration of remedial O&M not included under other categories.

(g) Insurance, taxes, and licensing costs - Costs of such items as liability and sudden accidental insurance; real estate taxes on purchased land or rights-of-way; licensing fees for certain technologies; and permit renewal and reporting costs.

(h) Maintenance reserve and contingency funds - Annual payments into escrow funds to cover costs of anticipated replacement or rebuilding of equipment and any large unanticipated O&M costs.

(i) Rehabilitation costs - cost for maintaining equipment of structures that wear out over time.

(j) Costs of periodic site reviews - Costs for site reviews that are conducted at least every 5 years if wastes above health-based levels remain at the site.

(3) Future costs. The costs of potential future remedial actions should be addressed and should be included when there is a reasonable expectation that a major component of the alternative will fail and require replacement to prevent significant exposure to contaminants. Analyses of "long-term effectiveness and permanence" should be used to determine which alternatives may result in future costs. It is not expected that a detailed statistical analysis will be required to identify probable future costs. Rather, qualitative engineering judgment should be used and the rationale documented in the FS report.

(4) Accuracy of cost estimates. Site characterization and treatability investigation information should permit the user to refine cost estimates for remedial action alternatives in the FS. Typically, these "study estimate" costs made during the FS are expected to provide an accuracy of +50 percent to -30 percent and are prepared using data available from the RI. It should be indicated when it is not realistic to achieve this level of accuracy.

(5) Present worth analysis.

(a) A present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year, usually the current year. This allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life.

(b) In conducting the present worth analysis, assumptions must be made regarding the discount rate and the period of performance. The Superfund program recommends that a discount rate of 5 percent before taxes and after inflation be assumed. Estimates of costs in each of the planning years are made in constant dollars, representing the general purchasing power at the time of construction. In general, the period of performance of costing purposes should not exceed 30 years for the purpose of the detailed analysis.

(6) Cost sensitivity analysis.

After the present worth of each remedial action alternative is calculated, individual costs may be evaluated through a sensitivity analysis if there is sufficient uncertainty concerning specific assumptions. A sensitivity analysis assesses the effect that variations in specific assumptions associated with the design, implementation, operation, discount rate, and effective life of an alternative can have on the estimated cost of the alternative. These assumptions depend on the accuracy of the data developed during the site characterization and treatability investigation and on predictions of the future behavior of the technology. Therefore, these assumptions are subject to varying degrees of uncertainty from site to site. The potential effect on the cost of an alternative because of these uncertainties can be observed by varying the assumptions and noting the effects on estimated costs. Sensitivity analyses can also be used to optimize the design of a remedial action alternative, particularly when design parameters are interdependent (e.g., treatment plant capacity for contaminated ground water and the length of the period of performance).

(a) Use of sensitivity analyses should be considered for the factors that can significantly change overall costs of an alternative with only small changes in their values, especially if the factors have a high degree of uncertainty associated with them. Other factors chosen for analysis may include those factors for which the expected (or estimated) value is highly uncertain. The results of such an analysis can be used to identify worst-case scenarios and to revise estimates of contingency or reserve funds.

(b) The following factors are potential candidates for consideration in conducting a sensitivity analysis: the effective life of a remedial action, the operation and maintenance costs, the duration of cleanup, the volume of contaminated material, given the uncertainty about site conditions, and other design parameters (e.g., the size of the treatment system).

(c) The 5 percent discount rate should be used to compare alternative costs; however, a range of 3 to 10 percent can be used to investigate uncertainties.

(d) The results of a sensitivity analysis should be discussed during the comparison of alternatives. Areas of uncertainty that may have a significant effect on the cost of an alternative should be highlighted, and a rational should be presented for selection of the most probable value of the parameter.

h. State (Support Agency) Acceptance. This assessment evaluates the technical and administrative issues and concerns the state (or support agency in the case of state-lead sites) may have regarding each of the alternatives. As discussed earlier, this criterion will be addressed in the ROD once comments on the RI/FS report and proposed plan have been received.

i. Community Acceptance. This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion will be addressed in the ROD once comments on the RI/FS report and proposed plan have been received.

2-25. Presentation of Individual Analyses.

a. The analysis of individual alternatives with respect to the specified criteria should be presented in the FS report as a narrative discussion accompanied by a summary table. This information will be used to compare the alternatives and support a subsequent analysis of the alternatives made by the decisionmaker in the remedy selection process. The narrative discussion should, for each alternative, provide a description of the alternative and a discussion of the individual criteria assessment.

b. The alternative description should provide data on technology components (use of innovative technologies should be identified), quantities of hazardous materials handled, time required for implementation, process sizing, implementation requirements, and assumptions. These descriptions, by clearly articulating the various waste management strategies for each alternative, will also serve as the basis for documenting the rationale of the applicability or relevance and appropriateness of potential Federal and state requirements. Therefore, the significant ARARs for each alternative should be identified and integrated into these discussions.

c. The narrative discussion of the analysis should, for each alternative, present the assessment of the alternative against each of the criteria. This discussion should focus on how, and to what extent, the various factors within each of the criteria are to be addressed.

d. As noted previously, state and community acceptance will be addressed in the ROD once concerns have been received on the RI/FS report and proposed plan. The uncertainties associated with specific alternatives should be included when changes in assumptions or unknown conditions could affect the analysis (e.g., the time to attain ground-water cleanup targets may be twice as long as estimated if assumptions made about aquifer characteristics for a specific ground-water extraction alternative are incorrect).

e. The FS also should include a summary table highlighting the assessment of each alternative with respect to each of the nine criteria.

2-26. Comparative Analysis of Alternatives.

a. Once the alternatives have been described and individually assessed against the criteria, a comparative analysis should be conducted to evaluate the relative performance of each alternative in relation to each specific evaluation criterion. This is in contrast to the preceding analysis in which each alternative was analyzed independently without a consideration of other alternatives. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another so that the key tradeoffs the decisionmaker must balance can be identified.

b. Overall protection of human health and the environment and compliance with ARARs will generally serve as threshold determinations in that they must be met by any alternative in order for it to be eligible for selection. The next five criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost) will generally require the most discussion because the major tradeoffs among alternatives will most frequently relate to one or more of these five.

c. State and community acceptance will be addressed in the ROD once formal comments on the RI/FS report and the proposed plan have been received and a final remedy selection decision is being made.

2-27. Presentation of Comparative Analysis.

a. The comparative analysis should include a narrative discussion describing the strengths and weaknesses of the alternatives relative to one another with respect to each criterion, and how reasonable variations of each alternative may be addressed.

b. The factors presented in Tables 2-18 through 2-21 have been included to illustrate typical concerns that may need to be addressed during the detailed analysis. It will not be necessary or appropriate in all situations to address every factor in these tables for each alternative being evaluated. Under some circumstances, it may be useful to address other factors not presented in these tables to ensure a better understanding of how an alternative performs with respect to a particular criterion.

c. Key uncertainties could change the expectations of their relative performance. An effective way of organizing this presentation is, under each individual criterion, to discuss the alternative that performs the best overall in that category, with other alternatives discussed in the relative order in which they perform. If innovative technologies are being considered, their potential advantages in cost or performance and the degree of uncertainty in their expected performance (as compared with more demonstrated technologies) should also be discussed.

d. The presentation of differences among alternatives can be measured either qualitatively or quantitatively, as appropriate, and should identify substantive differences (e.g., greater short-term effectiveness concerns, greater cost, etc.). Quantitative information that was used to assess the alternatives (e.g., specific cost estimates, time until response objectives would be obtained, and levels of residual contamination) should be included in these discussions.

2-28. Post-RI/FS Selection of the Preferred Alternative. Following completion of the RI/FS, the results of the detailed analyses, when combined with the risk management judgments made by the decisionmaker, become the rationale for selecting a preferred alternative and preparing the proposed plan. Therefore, the results of the detailed analysis, or more specifically the comparative analysis, should serve to highlight the relative advantages and disadvantages of each alternative so that the key tradeoffs can be identified. It will be these key tradeoffs coupled with risk management decisions that will serve as the basis for the rationale and provide a transition between the RI/FS report and the development of a proposed plan (and ultimately a ROD).

2-29. Community Relations During Detailed Analysis.

a. Site-specific community relations activities should be identified in the community relations plan prepared previously. While appropriate modifications of activities may be made to the community relations plan as the project progresses, the plan should generally be implemented as written to ensure that the community is informed of the alternatives being evaluated and is provided a reasonable opportunity to provide input to the decision-making process.

b. A fact sheet may be prepared that summarizes the feasible alternatives being evaluated. Small group consultations or public meetings may be held to discuss community concerns and explain alternatives under consideration. Public officials should be briefed and press releases prepared describing the alternatives. Other activities identified in the community relations plan should be implemented.

c. The objective of community relations during the detailed analysis is to assist the community in understanding the alternatives and the specific considerations the lead agency must take into account in selecting an alternative. In this way, the community is prepared to provide meaningful input during the upcoming public comment period.

2-30. Removal Activities.

a. Removals are the other type of response action that may be undertaken. Removals are expedited response actions as opposed to long-term action undertaken during remedial activities. There are two types of removal actions: time critical and non-time critical.

b. Removals may be implemented any time during the remedial action process. Most time-critical removals will be implemented within a short period following the discovery of a site. However, some imminent threats may not be revealed until construction during remedial action. Typical time-critical/non- time critical removals are shown in the flow chart in Figure 2-15.

c. RCRA has a parallel authority for implementing short-term responses to a release prior to full implementation of the corrective measure. The RCRA procedure is called an Interim Measure. RCRA Interim Measures must meet the requirements of all Federal, state, and local laws and regulations. Currently, there is no ARAR process equivalent under RCRA.

d. Under the FUDS program, removal actions also include building demolition/debris removal and abandoned ordnance-explosive waste removal.

2-31. Time-Critical Removal Actions

a. Time-critical removal actions are actions initiated in response to a release or threat of a release that poses a risk to public health or the environment, such that cleanup or stabilization actions must be initiated within 6 months following approval of the Action Memorandum. The typical flow of events for a time-critical action is shown in Figure 2-16. The two key items are the Action Memorandum and the Administrative Record. The Action Memorandum serves as the decision document that must accompany any CERCLA action. It corresponds to the ROD for a full remedial response. Because of the immediate nature of a time-critical removal action, the regulations do not require that the Administrative Record be available prior to the implementation of the action. However, all CERCLA actions must have an Administrative Record and it must be open to the public for review and inspection.

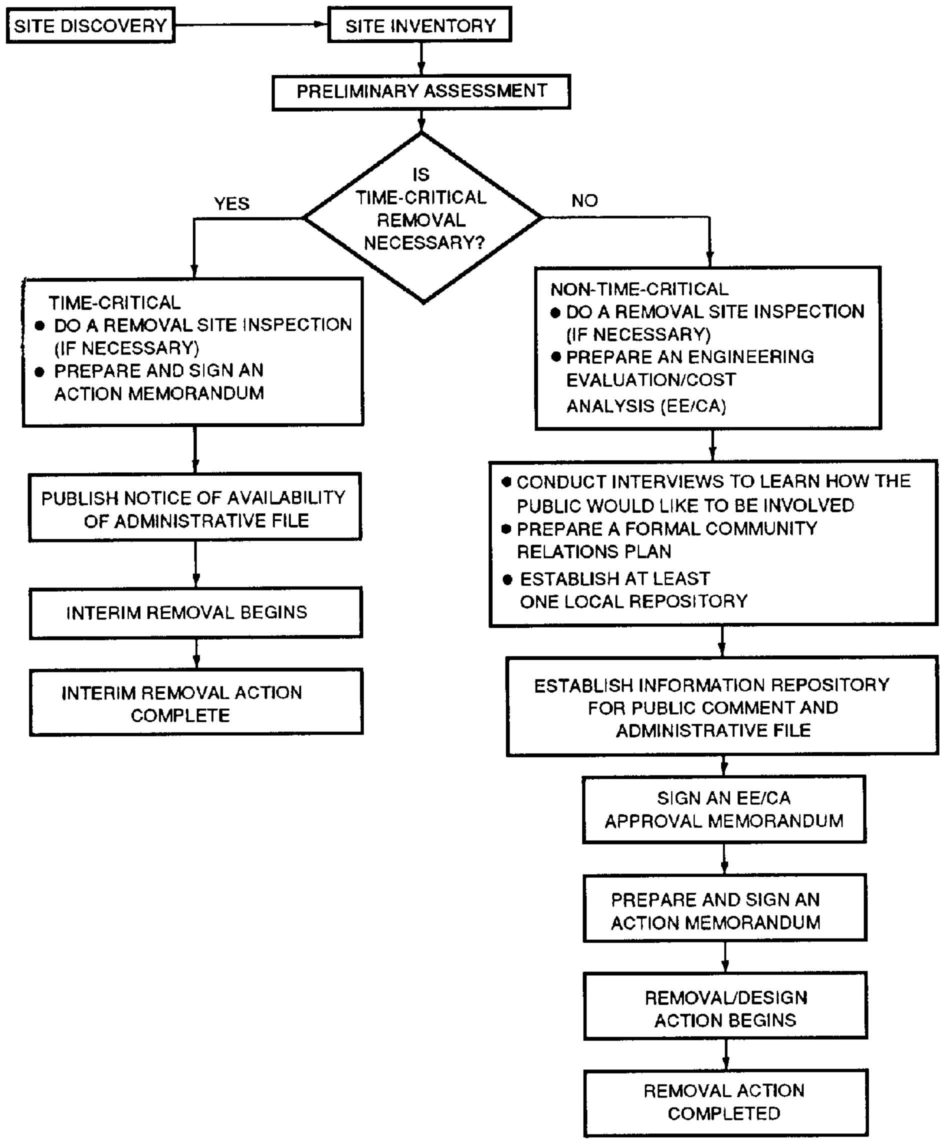


Figure 2-15. Typical Flow Chart for Time-Critical/Non-Time-Critical Removals

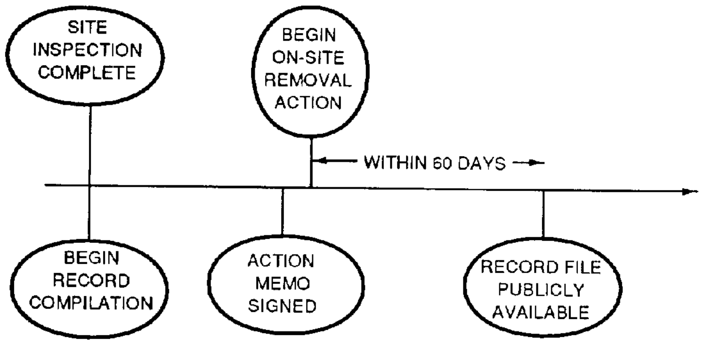


Figure 2-16. General Elements of a Typical Time-Critical Removal Action

b. Typical time-critical removal actions include:

(1) Fences to limit access to the site.

(2) Drainage control to limit the off-site migration of contaminants.

(3) Capping or containment of the contaminants on the site.

(4) Removal of containers of waste remaining on the site.

(5) Provision of alternative water supplies to citizens impacted by contaminated water.

(6) Stabilization of berms, dikes, or impoundments or the drainage or closing of lagoons.

(7) Using chemicals or other materials to retard the spread of contaminants or mitigate their effects.

(8) Excavation, consolidation, or removal of ordnance and explosive waste (OEW) or soils having an imminent safety threat contaminated by OEW or HTRW where such action will reduce the spread of or contact with these wastes and reduce the threat of fire or explosion.

(9) Containment, treatment, disposal, or incineration of hazardous substances to reduce the likelihood of human, animal, or food chain exposure.

c. Depending on the urgency of the situation, time-critical removals implemented in response to an imminent threat need not be compatible with future non-time-critical removals or remedial actions, need not be shown to be cost effective, and need not achieve applicable or relevant and appropriate requirements (ARARs).

However, time and other conditions permitting, these objectives should be considered. When making this determination, the urgency for a time-critical removal action should be documented and maintained in the project file along with the Action Memorandum.

2-32. Non-Time-Critical Removal Actions.

Non-time-critical removal actions are actions initiated in response to a release or threat of a release that poses a risk to human health, its welfare, or the environment such that initiation of removal cleanup or stabilization actions may be delayed for 6 months or more following approval of the Action Memorandum. The typical flow of events is shown in Figure 2-17. In the non- time-critical case, a 30-day comment period must be provided prior to the implementation of the action, and the Administrative Record must be available for review during that time. An Action Memorandum (taking the place of the ROD or the decision document) is also prepared and signed. One additional document is prepared in the case of a non-time-critical action--the Engineering Evaluation/Cost Analysis (EE/CA). This document takes the place of the RI/FS that is prepared for full remedial action.

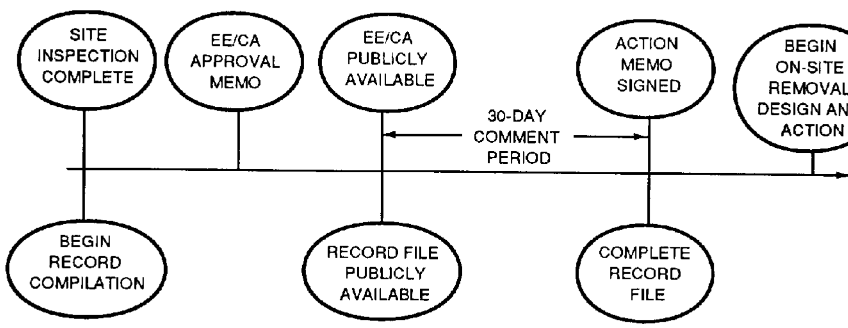


Figure 2-17. General Elements of a Typical Non-Time-Critical Removal Action

2-33. Removal Action Process.

a. Removal Site Inspection (RSI) (if necessary). The site inspection is an on-site inspection to determine the nature of the release or potential release and the nature of the associated threats. The purpose is to augment the data collected in the preliminary assessment and to generate, if necessary, sampling and other field data to determine if an EE/CA is appropriate. RSIs are typically performed for non-time-critical removal actions in accordance with 40 CFR 300.410.

b. EE/CA. For non-time-critical removal actions, CERCLA allows an EE/CA to be performed in lieu of an RI/FS. If the removal action is undertaken to partially fulfill a signed ROD (for a National Priority List (NFL) site), an EE/CA and public comment are not required. Under those circumstances, the RI/FS and associated public participation procedures fulfill the EE/CA requirements. The EE/CA process applies only to those actions determined at the outset to be non-time-critical. The principal steps in the EE/CA process are summarized in Table 2-22. The format for the EE/CA is summarized in Table 2-23. The EE/CA must meet the following requirements.

(1) Satisfy environmental review requirements applicable to removal action (including National Environmental Policy Act (NEPA) review equivalency).

(2) Satisfy administrative record requirements (documentation of removal action selection, public comment, and responsiveness summary).

(3) Provide a framework for evaluating and selecting alternative technologies (permanent solutions and alternative treatment technologies are to be stressed).

c. Decision Document. After completion of an EE/CA, a decision document, called an Action Memorandum, is prepared to identify the removal action chosen for implementation at a FUDS. The decision document is based on information contained in the EE/CA and consideration of public comments and community concerns.

d. Removal Design. The purpose of the removal design is to develop detailed designs, plans, specifications, and bid documents for conducting the removal action. The development of the removal design must ensure that Federal and state requirements, including any conditions or waivers to ARARs, have been identified and incorporated into the design.

e. Removal Action. After the removal design package is completed and approved, the removal action is implemented. The removal action starts with the solicitation and awarding of a contract, continues through completion of interim and final inspections, certification, and culminates with acceptance of the final project.

f. Site Closeout. A closed-out site is one in which the removal action is considered complete. The primary criterion for site closeout is a determination that the site is no longer a potential or significant threat to the public health or the environment. A site closeout document is prepared for each site or group of sites for which the site closeout decision is made. The site closeout document should clearly identify the site; reference the data, studies, and other evidence on which the decision is based; and describe the rationale for the decision.

Table 2-22. Key Steps in the EE/CA Process

EE/CA Steps	Activities
Site Inspection (SI)	Review of removal preliminary assessment/site investigation (PA/SI) indicates that a removal action is appropriate, but that the threat is non-time-critical.
Potentially Responsible Party (PRP) Notice	Issuance of a general notice (required) or a special notice (discretionary).
Approval and Initiation of EE/CA Study	Approval memorandum prepared which documents that the site meets criteria for a removal action and secures management approval to conduct EE/CA also, designate site spokesman, open Administration Record, initiate community interviews, and prepare Community Relations Plan.
Complete EE/CA Study and Report	Complete any additional on-site data collection activities necessary to better characterize the waste and define site conditions (see CERCLA Section 104(b)). Compile all appropriate removal/remedial action alternatives and analyze each for effectiveness, cost, and ability to implement. Conclude with recommended removal/remedial action(s). Cleanup measures are not permitted.
Release EE/CA Report	Place EE/CA report in Administrative Record; publish notice of availability and summary; complete Community Relations Plan.
Public Comment	Provide for 30-day public comment period on the EE/CA and other documents in the Administrative Record.
Action Memorandum	Prepare Action Memorandum describing the proposed removal action and soliciting management approval to implement the action. Attach a Responsiveness Summary (including a summary of significant public comments and responses to these comments). Close the Administrative Record when Action Memorandum is signed.
Implement Removal Action	Observe conditions of the EE/CA, on the implementation of the removal action, but not including any previous Section 104(b) activities.

Table 2-23 Outline and Contents of the EE/CA

Topic	Description of Contents
Site Characterization	Site description - location, surrounding land uses, nature and extent of contamination. Site background - prior site uses, site history, regulatory involvement. Analytical data - summarize analytical results Site conditions that justify a removal.
Removal Action Objectives	Removal action scope - describe scope of the project and identify any threats that will not be addressed. Removal action schedule. Applicable or relevant and appropriate requirements.
Removal Action Alternatives	A description of appropriate alternative actions for the site (Note: a no-action alternative is not required). Innovative technologies should be considered and evaluated.

Analysis of Alternatives	Each alternative should be individually evaluated based on the criteria below:
	
	- Effectiveness
	  – Protectiveness
	    Protection of the community during removal
	    Protection of workers during removal Threat reduction
	    Time until protection is achieved Compliance with chemical and location
	  – Specific ARARs
	    Environmental impacts
	    Potential exposure to remaining risks Long-term reliability
	  – Use of alternatives to land disposal
	
	- Ability to implement
	  – Technical feasibility
	    Ability to construct and operate
	  – Compliance with action-specific ARARs
	  – Ability to meet performance goals
	    Demonstrated performance
	    Compliance with long-term clean-up goals

(Continued)

Table 2-23. (Concluded)

Topic	Description of Contents
Analysis of Alternatives (con* t)	- Availability - Equipment, materials, and personnel – Off-site capacity (if needed) – Post-removal site control - Administrative feasibility – Public acceptance – Coordination with other agencies – Required permits of approvals (off-site only) - Cost – Total cost (present worth) – Statutory limits
Comparative Analysis of Alternatives	
Proposed Removal Design and Removal Action	