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Subsurface Contamination Focus Area Technical Requirements

Volume II

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ABSTRACT

Volume II contains supporting information, approach, definitions, and calculations pertaining to functions and requirements for remediation of source term and plume sites identified by the Subsurface Contamination Focus Area.

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Volume II

1. INTRODUCTION

1.1 Vision

Decisions will be made based on verifiable, quantitative (measurable) data that enable the decision-maker to support and defend his/her decision.

This is our vision, a vision that replaces the ad hoc or "delphi" method which is to get a group of "experts" together and make decisions based upon opinion. To fulfill our vision for the Subsurface Contaminants Focus Area (SCFA), it is necessary to generate technical requirements or performance measures which are quantitative or measurable. Decisions can be supported if they are based upon requirements or performance measures which can be traced to the origin (documented) and are verifiable, i.e., prove that requirements are satisfied by inspection (show me), demonstration, analysis, monitoring, or test. The data from which these requirements are derived must also reflect the characteristics of individual landfills or plumes so that technologies that meet these requirements will necessarily work at specific sites. Other subjective factors, such as stakeholder concerns, do influence decisions. Using the requirements as a basic approach, the SCFA can depend upon objective criteria to help influence the areas of subjectivity, like the stakeholders.

In the past, traceable requirements were not generated, probably because it seemed too difficult to do so. There are risks that the requirements approach will not be accepted because it is new and represents a departure from the historical paradigm. We are encouraged by remarks made by Under Secretary of Energy, Thomas Grumbly, at the Weapons Complex Monitor Decision-Makers' Forum, Jacksonville, Florida, September 27, 1996. "Somebody famous in the literature of public management said almost 500 years ago, 'There is nothing more difficult to execute, nor more dubious of success, nor more dangerous to administer than to introduce a new system of things: for he who introduces it has all those who profit from the old system as his enemies, and he has only lukewarm allies in all those who might profit from the new system.' Machiavelli knew what he was talking about. Changing the culture within which we operate is our most difficult task--."

1.2 Approach

1.2.1 Developing Requirements and Setting Priorities

Our approach is to define requirements for the SCFA complex that will be useful both to the decision-makers within the Subsurface Contaminants Focus Area (SCFA) and to the technology providers who are developing and demonstrating technologies and systems. It is relatively simple to define requirements for remediating one site where the site characteristics and contaminants are known; it is much more difficult to define requirements for the complex where each site has different characteristics and constraints. In order to develop complexwide requirements, one must understand the complexwide problem and break the problem down into requirements. Requirements for the complex take on a different look than requirements for a single site. For example, each site that has a preferred remediation alternative to retrieve waste has waste at a defined depth which requires a technology to retrieve at that depth. Some sites are less than five feet, some from 5 feet to 10 feet, some from 10 to 100 feet, and some are greater than 100 feet. A technology that can retrieve at 5 feet is useful and satisfies a fraction of the site requirements, but, all other things being equal, a technology that retrieves at 50 feet is more useful because it satisfies a greater fraction of the site requirements even though it does not satisfy requirements for all sites. These requirements are expressed most meaningfully as ranges of values embedded in a requirement rather than a specific site requirement. Similar rationale is used for the other requirements. When all of the site characteristics are taken into account, there exists a set of requirements that are based upon the complexwide site characteristics. Priorities for technology development can be established based upon the measured benefit to the SCFA complex. The benefit to the complex can be measured based upon the fraction of the requirement range satisfied. Satisfying requirements is one important technology selection criteria. Other selection criteria include regulatory constraints, cost, implementability, effectiveness, and risk which are also quantifiable. Subjective criteria include the weights given to the selection criteria by the decision-maker and the stakeholder constraints.

1.2.2 The Problem with Needs Statements

Currently needs statements generated by the Site Technology Coordination Group (STCG) are used as the basis for generating technology development priorities. There are at least three problems associated with this approach:

- Needs statements are typically general, all inclusive, and not normalized, i.e., one site may have numerous needs while another site with similar characteristics may have few needs.

- There are no common definitions for items such as problem, need, and site; for example, Hanford site 200 has 44 Operating Units and 191 distinct "sites" but Hanford site 200 is only 1 site in the database whereas other sites consisting of a French Drain or a fraction of an acre spill are listed as 1 site in the database.

- Operating Unit needs reflect the current phase of remediation. For example, an operating unit preparing a Feasibility Study needs information on technology alternatives ranging from containment and stabilization to retrieval and shipping.

1.2.3 Importance of the Preferred Solution

It is important that a site have a preferred solution even if that solution may later be discarded in favor of some other solution. Buildings, caps, barriers, in situ stabilization, bioremediation, soil washing, in situ vitrification, retrieval, selective retrieval, vapor extraction, and others are all possible solutions to the problems. Since each solution has its own specific requirements, once a solution or suite of solutions is "preferred," one can develop a set of lower level requirements specific to the solution and specific to the site. Without a "preferred solution" technology developers have many uncorrelated needs to consider and no way of prioritizing those needs.

1.2.4 Pulling It All Together

The approach to developing complexwide requirements took all of the above into consideration. A preferred configuration option was chosen or assumed; the problem was based upon site characteristics; and the site characteristics drove the requirements development.

1.3 General Information

The site manager must decide on a preferred remediation alternative for technology development investment. As a minimum, the preferred alternative shall be "contain" or "retrieve"; if possible, the minimum should be followed by the type of containment (cap, barriers, in situ treat, bioremediation, ...) or removal (excavation, vapor extraction, pump and treat, ...). Although a preferred alternative is chosen, it is not necessarily final. The preference may change and the technology investment decisions may change with it.

Requirements are go/no-go. They must be satisfied as one element driving technology development decisions. Cost, risk, implementability, and effectiveness also drive technology development decisions.

1.4 Technical Requirements, Desirables, Trade Studies (Cost, Benefits)

Volume I contains the technical requirements, desirables, and trade studies recommended to determine cost benefits and benefits to the SCFA.

Technical *requirements* are performance metrics that must be satisfied by a technology or system. Satisfying a requirement requires proof: proof by verification.

Specifications or performance metrics whose effect is cost savings, but are not otherwise necessary to meet site remediation objectives, are labeled as *desirables*. Desirables can be considered goals which, if satisfied, provide a better product; but goals may not be satisfied. Desirables do not require proof; they are nice to have.

Trade studies are accomplished via alternative analysis. An alternative analysis yields data provided to the decision-maker which helps the decision-maker defend and support a decision. Trade studies must show that the alternatives satisfy the technical requirements and meet schedule. Performance and schedule variances often disqualify an alternative. Given that performance and schedule requirements are met, life cycle cost influences the decision.

Several trade studies suggested in Volume I are often thought to be requirements. For example, removal of clean overburden during a retrieval remedial action is seen as a requirement. It may be advantageous to remove the overburden, set it aside, and put it back into the pit when all the contaminated material is removed because the overburden is not contaminated. However, it may be more expensive to remove it, assay it to ensure that it is not contaminated, separate it from contaminated soil, and return it to the pit than it would be to include it in the whole retrieval action and treat it along with the waste. This is the type of trade study suggested in Volume I.

Once a trade study is complete, specific requirements may be generated that are associated with the outcome of the trade study and the associated decision. In the above example, if the decision is to remove the overburden prior to remediating the contaminated waste, this is a requirement that must be satisfied and proven to be satisfied. This requirement becomes part of the remediation specification.

Benefits to the project can be measured by proving that the requirements have been satisfied. Benefits for the SCFA can be measured by assessing the degree to which technology development satisfies the complexwide requirements now written as a range of values. A hypothetical example follows: if depth of source terms ranges from 1 foot to 100 feet, a technology that is capable of retrieving at 40 feet depth can be used at 20 of 50 sites or satisfies 40 percent of the SCFA requirement. In addition, when that technology is used to remediate a site or several sites, the impact on the total volume, number of sites remaining to be cleaned up, and total area can be computed. That technology has a *quantifiable impact* on the total SCFA problem. When factors such as relative risk and life cycle costs are added, a total benefits determination is made available.

2. OBJECTIVES

The specific objectives are to provide quantitative, unbiased, and measurable criteria for technology development investments. This requirements document responds to and supports the more general SCFA management objectives of:

1. Accelerate development of technology solutions to meet the Office of Environmental Management's highest priority requirements.

2. Ensure applicable technologies are identified and/or developed and delivered ready for field application.

3. Facilitate programmatic decision-making, reduce uncertainty, and minimize/reduce net remediation costs through a better understanding of site problems.

4. Ensure that basic research necessary to develop landfill remediation technologies is addressed.

5. Develop and maintain a program that is under control managerially and financially.

There are three sources of requirements: 1. Regulatory drivers, 2. Site characteristics, 3. Other constraints. Technical functions and resulting requirements for waste site contaminate containment and retrieval options address the system level requirements stated as follows:

Prevent the formation or development of secondary sources of contamination due to migration of contaminants of concern to the groundwater and/or to the site boundary at a rate faster than the decomposition rate of the contaminate or dispersed to the water supply/cross the boundary in a quantity exceeding EPA standards.

Prevent human ingestion, inhalation, exposure or direct contact with contaminants of concern that would result in a total excess cancer risk of 1E-04 to 1E-06 or exposure to individuals, who inadvertently intrude, not to exceed 100 mrem/year for continuous exposure or 500 mrem for a single acute exposure.

3. TECHNOLOGY DEVELOPMENT INFLUENCES

3.1 Factors

3.1.1 Regulatory Drivers

1. Regulations such as Environmental Protection Agency, RCRA, CERCLA, Clean Air Act, Clean Water Act, Toxic Substance Control Act, NEPA, DOE, NRC.

2. Agreements such as the Federal Facility Compliance Agreement and Consent Order, Interagency Agreement, and State.

3. Health and safety risk assessments.

3.1.2 Site Characteristics

4. Site specific requirements based upon waste characteristics and site characteristics such as site geology (soil properties, hydrogeology, topography, climate, depth of waste).

5. Site physical constraints such as access to the waste site.

3.1.3 Other Constraints

6. Preferred remedial options (alternatives) including technology availability, implementability, effectiveness, cost, and solution specific requirements.

7. Stakeholders with technical, logical, or emotional arguments.

8. Program requirements including operations planning.

3.2 Assumptions

There are assumptions that have been made as part of the requirements development process. These are:

1. There is a problem that requires remediation at each site/operating unit within the SCFA data set.

2. All major sites requiring remediation have been identified. Continuing investigations may lead to the discovery of additional areas requiring remediation which may affect requirements.

3. Site characterization technology development is funded by and accomplished by a focus area separate from the SCFA. Process control and long-term monitoring necessary to accomplish the functions within a configuration option, e.g., characterization for site preparation or excavation, barriers installed properly, etc., are considered functions to be part of this requirements document.

4. There is no technology development necessary for the Walk Away and the Monitor configuration options.

5. A site is considered as "no impact" if the schedule for remediation precludes technology development, i.e., technology cannot be developed in time to meet the remediation schedule.

3.3 Configuration Options

Configuration options (alternatives) were developed to assist requirements development. They are shown in Appendix A. A configuration option contains the functions associated with a preferred remedial action. Each function in a configuration option has specific requirements associated with it. There are six configuration options relating to containment and five configuration options relating to retrieval. Characterization, to determine the site characteristics, is required for all options but site characterization technologies are covered by a separate focus area. Therefore, characterization requirements should be developed but they are not developed in this document. Some requirements apply to all configuration options; for example, meet schedules. Some requirements apply to a general class of configuration options such as contain/stabilize or retrieve; for example, maintain the water balance is a contain/stabilize requirement whereas retrieve objects of a specific size and weight is a retrieve requirement. Other requirements are specific to function within a configuration option such as the not to exceed temperature for in situ stabilization materials. By separating alternatives into configuration options, one can begin requirements development based upon the functions required for the remedial action. Note that the source of many requirements can be traced to the regulatory drivers.

3.4 Summary of Applicable Règulatory Requirements.

This summary of applicable regulatory requirements were extracted and/or paraphrased from two Hanford documents: DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*, Bechtel Hanford, Inc., Richland, Washington, May 1996, page 2-1ff and BHI-00007, *Prototype Hanford Surface Barrier: Design Basis Document*, Bechtel Hanford, Inc., Richland, Washington, November 1994, pages 3-1 ff. While these documents were intended to provide information relating to engineered barriers, much of the information here will also be useful when considering contaminant removal technologies.

Many of the regulatory requirements are an applicable or relevant and appropriate requirement (ARAR). ARAR is a promulgated federal or state statute or regulation that establishes requirements that would apply to or otherwise be relevant and appropriate for the implementation of a remedial action under CERCLA. Typically ARAR type criteria are applied by other government agencies responsible for remediation. The ARARs are typically grouped into contaminant-specific, location-specific, and action-specific categories. Since they are negotiated, they may differ from state to state and even from site to site.

Contaminant specific ARARs generally are used to establish acceptable limits for hazardous chemical and radiological constituents in various environmental media, based on human health and ecological risks and exposure pathways. The ARARs may influence the site-specific selection of remediation alternatives by setting objectives that the alternatives must meet to reduce risks to health and the environment. Thus, these ARARs relate more to the acceptability of a remedial alternative and not as much to the establishment of design or performance criteria for the designs. Thus, they are not addressed in this document.

Although several location-specific ARARs apply or may be relevant to the siting of land-disposal facilities and waste-containment units, it was determined that they only address where certain activities (e.g., waste disposal) may or may not be conducted. They do not dictate design criteria or performance requirements. Consequently, they are not addressed in this document.

Action-specific ARARs generally include design and performance considerations when implementing remedial alternatives. Action specific ARARs constitute the majority of the regulatory criteria for designs.

The CERCLA mandates that remedies must comply with any promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law that is more stringent than any federal standard, requirement, or limitation, if applicable or relevant and appropriate to the hazardous substance or release in question.

In general, 10 CFR includes regulations promulgated by the NRC and/or DOE. The 40 CFR regulations are promulgated by EPA. Regulations that pertain to land disposal of low level waste have been promulgated by the NRC. The EPA and the states promulgate regulations controlling air emissions of radionuclides and limiting public exposure to airborne radionuclides.

The regulatory documents that serve as a source for technology requirements are 10 CFR Part 61, 40 CFR Part 241 and 264, and DOE Order 5820.2A. Text for the applicable regulatory documents is summarized as follows:

10 CFR Part 61 - Licensing Requirements for Land Disposal of Radioactive Waste; Subpart C - Performance Objectives.

1O CFR Part 61.41 Protection of the general population from releases of radioactivity.

Concentrations of radioactive material that may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body or 75 mrem to any other organ of any member of the public. A reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable (ALARA).

10 CFR Part 61.42 Protection of individuals from inadvertent intrusion.

Design, operation, and closure of the land-disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.

10 CFR Part 61.44 Stability of the disposal site after closure.

The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.

10 CFR Part 61 Subpart D - Technical Requirements for Land Disposal Facilities

10 CFR Part 61.51 (a) Disposal site design for near-surface disposal. Paragraphs

(4) Covers must be designed to minimize, to the extent practicable, water infiltration, to redirect percolation or surface water away from the disposed waste, and to resist deterioration by surface geologic processes and biotic activity.

(5) Surface features must direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require ongoing active maintenance in the future.

(6) The disposal site must be designed to minimize to the extent practicable the contact of standing water with waste during disposal, and the contact of percolating or standing water after disposal.

10 CFR Part 61.52 Land disposal facility operations and disposal site closure.

Wastes designated as Class C must be disposed of so that the top of the waste is a minimum of 5 meters below the top surface of the cover or must be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years.

40 CFR Part 241, 209-1 Requirement

Cover material shall be applied as necessary to minimize fire hazards, infiltration of precipitation, odors, and blowing litter; control gas venting and vectors; discourage scavenging; and provide a pleasing appearance.

40 CFR Part 264 - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

40 CFR Part 264.310 Closure and post-closure care

(a) At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:

(1) Provide long-term minimization of migration of liquids through the closed landfill;

(2) Function with minimum maintenance;

(3) Promote drainage and minimize erosion or abrasion of the cover;

(4) Accommodate settling and subsidence so that the cover's integrity is maintained; and

(5) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

DOE Order 5820.2A Radioactive Waste Management

Chapter 3: Management of Solid Low-Level Waste, Paragraph 3 -Requirements, a - Performance Objectives, (4) Intruder Protection

"Disposal closure systems shall be designed to ensure that exposure to individuals who inadvertently intrude the closed facility after the active institutional control period shall not exceed 100 mrem/year for continuous exposure, or 500 mrem for a single acute exposure. For wastes that may remain hazardous to inadvertent intruders beyond 100 years, passive controls (e.g., appropriate markers and barrier systems) shall be incorporated to provide reasonable assurance that inadvertent intruders will be warned and deterred from disturbing the site for up to 500 years."

Figure 1 is a graphic depiction of the number of sites' classes of regulatory drivers for plumes. A similar graph will be added for landfills when data are available.

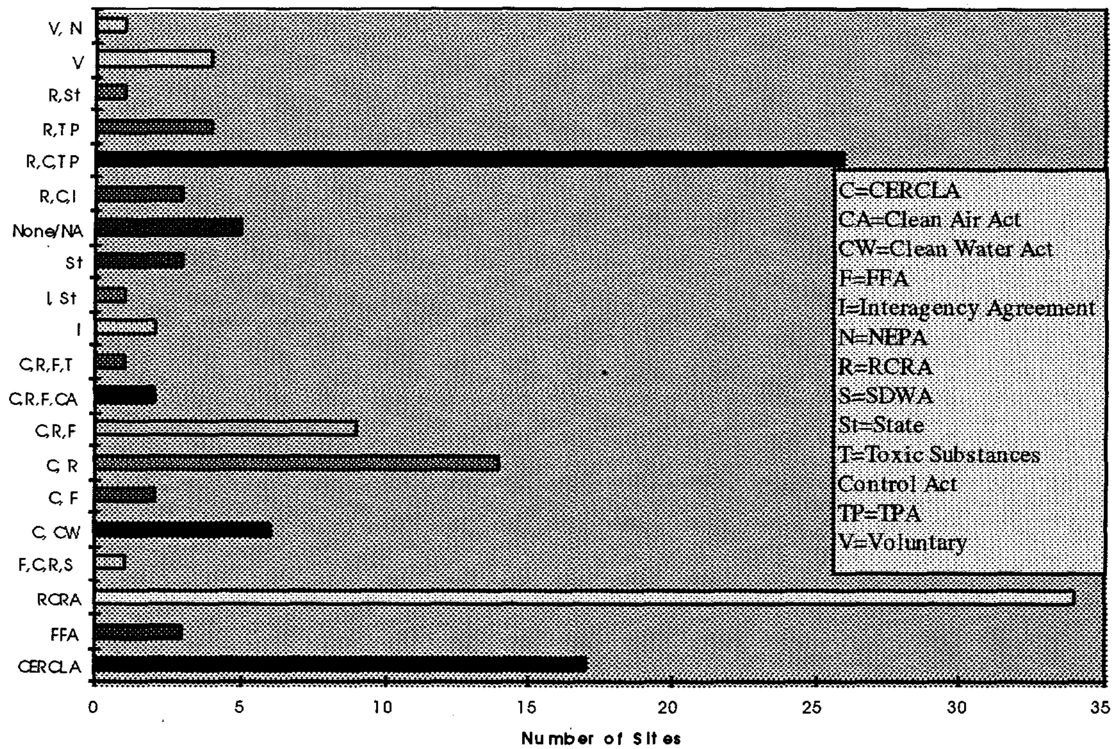


Figure 1. Summary of plumes sites' classes of regulatory drivers.

3.5 Stakeholder Constraints

The stakeholders impose constraints upon remedial actions. One of the constraints is the future land use which drives the level of remediation, i.e., "clean" or how clean is clean. The degree to which a site must be cleaned up is a negotiated issue between the site and the state. There is a hierarchy of future land use that can be used for planning purposes when developing a technology for remediating a site. Examples of the hierarchy is that unrestricted use probably requires a "cleaner" site than restricted use; recreation requires a "cleaner" site than industrial. Figure 2 depicts the anticipated land use associated with some plume sites. These are the reported land use plans but 191 sites have not yet reported on land use plans. Additional data on land use plans for plume sites and data for landfill land use will be added when available.

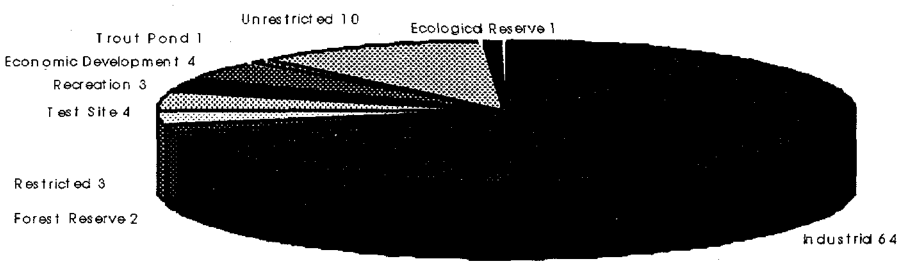


Figure 2. Summary of plume sites' land use plans.

3.6 Preferred Remedial Alternatives

The plume data baseline contains the site specific preferred alternatives for remediating plumes. This information is provided in Figure 3. The alternatives are in categories which show technology developers possibilities for focusing their efforts. This section is for information to help technology developers; these are not requirements. The landfill technical baseline does not currently have preferred alternatives other than retrieve, contain/stabilize, and vitrify.

3.7 Verification

A verification matrix is included in Volume I. The matrix summarizes all requirements and shows how each requirement will be verified by an X in a column under inspection, analysis, demonstration, monitor, or test. Some requirements can be verified in several ways and this is shown by multiple Xs in the columns. Verification is important because there is no requirement if the requirement cannot be verified as having been met. This means that there must be documented proof that the requirement was met.

Preferred Alternatives (plumes)

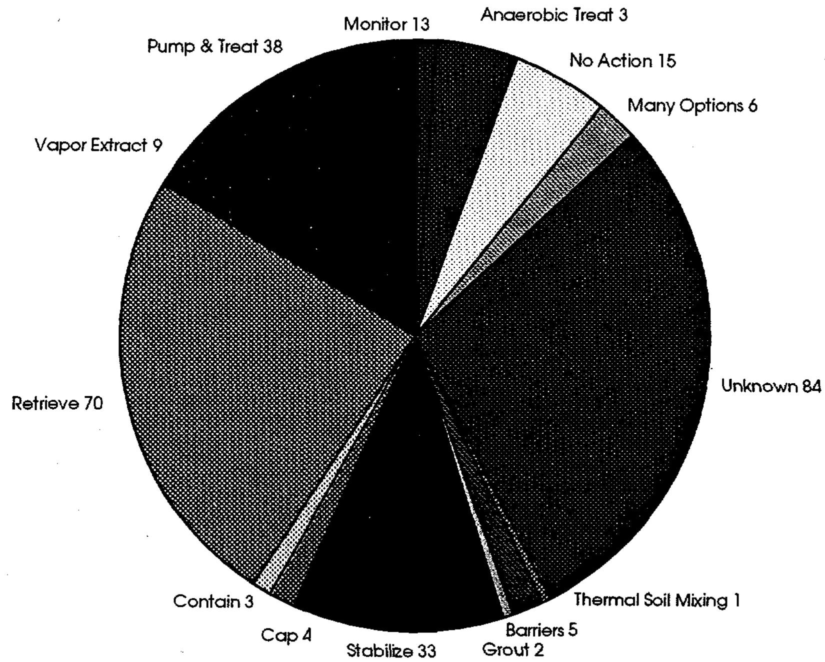


Figure 3. Summary of plume sites' preferred remedial alternatives (technologies).

4. REQUIREMENTS SUPPORT/CALCULATIONS

4.1 Site Data

Section 4 contains supporting data for developing the requirements presented in Volume I and data from references in Volume I for the reader to have access to the information without having to use library resources. The requirement number, in Volume I, that the data in Section 4 supports, will be listed in the paragraph with the supporting data.

Data collected during the site visits of 1995 and modified with additional site information in 1996 are contained in Excel spreadsheets. These spreadsheets are not included in this report because of the volume of paper they would generate. However, the spread sheets are available either on hard copy or disk to anyone who wants them. For copies or a disc, contact the authors of this requirements document at 208-526-9061d or E-mail request to dfn@inel.gov. A database is being developed to host the data and is expected to be available by January 1997. Additional data will be collected to verify existing data and/or to supplement existing data. The additional data will be added to the database, and charts and tables supporting requirements will be updated.

4.2 Volume I, Paragraph 2.1, Requirement 4

"Control advective and diffusive flow of contaminants, exceeding EPA guidelines, away from their place of disposal." EPA guideline references and content follow:

40 CFR - Protection of Environment, Section 261.21 Characteristic of ignitability.

(a) A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:
(1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60 degrees C (140 degrees.F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard
D-93-79 or D-93-80 (incorporated by reference, see Section 260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78 (incorporated by reference, see Section 260.11), or as determined by an equivalent test method approved by the Administrator under procedures set forth in Sections 260.20 and 260.21.
(2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.
(3) It is an ignitable compressed gas as defined in 49 CFR 173.300 and as determined by the test methods described in that regulation or equivalent test methods approved by the Administrator under Sections 260.20 and 260.21.
(4) It is an oxidizer as defined in 49 CFR 173.151.
(b) A solid waste that exhibits the characteristic of ignitability has the EPA Hazardous Waste Number of D001.

40 CFR - Protection of Environment, Section 261.22 Characteristic of corrosivity.

(a) A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste has either of the following properties:
(1) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter using Method 9040 in ``Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in Section 260.11 of this chapter.
(2) It is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55 degrees.C (130 degrees.F) as determined by the test method specified in NACE (National Association of Corrosion Engineers) Standard
TM-01-69 as standardized in ``Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in Section 260.11 of this chapter.
(b) A solid waste that exhibits the characteristic of corrosivity
has the EPA Hazardous Waste Number of D002.

40 CFR - Protection of Environment, Section 261.23 Characteristic of reactivity.

(a) A solid waste exhibits the characteristic of reactivity if a representative sample of the waste has any of the following properties:
(1) It is normally unstable and readily undergoes violent change without detonating.
(2) It reacts violently with water.
(3) It forms potentially explosive mixtures with water.
(4) When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.
(5) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.
(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.
(7) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.
(8) It is a forbidden explosive as defined in 49 CFR 173.51, or a Class A explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.
(b) A solid waste that exhibits the characteristic of reactivity has the EPA Hazardous Waste Number of D003.

40 CFR - Protection of Environment, Section 261.24 Toxicity characteristic.
(a) A solid waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure, test Method 1311 in ``Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in Section 260.11 of this chapter, the extract from a representative sample of the waste contains any of the contaminants listed in Table 1 at the concentration equal to or greater than the respective value given in that table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering using the methodology outlined in Method 1311, is considered to be the extract for the purpose of this section.
(b) A solid waste that exhibits the characteristic of toxicity has the EPA Hazardous Waste Number specified in Table 1 which corresponds to the toxic contaminant causing it to be hazardous.
40 CFR - Protection of Environment, Section 261.24 Toxicity characteristic.
(a) A solid waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure, test Method 1311 in ``Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,"

Table 1. Maximum Concentration of Contaminants for the Toxicity Characteristic.

EPA HW No. {1}	Contaminant	CAS No. {2}	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	200.0 {4}
D024	m-Cresol	108-39-4	200.0 {4}
D025	p-Cresol	106-44-5	200.0 {4}
D026	Cresol		200.0 {4}
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	0.13 {3}
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	0.13 {3}
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychior	72-43-5	10.0
D035	Methy ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	5.0 {3}
D010	Selenium	7782-49-2	1.0
D011	Silver	7440-22-4	5.0
D039	Tetrachloroethylene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethylene	79-01-6	0.5
D041	2,4,5-Trichlorophenol	95-95-4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	2.0
D017	2,4,5-TP (Silvex)	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

{1} Hazardous waste number.

{2} Chemical abstracts service number.

{3} Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.
{4} If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

EPA Publication SW-846, as incorporated by reference in Section 260.11 of this chapter, the extract from a representative sample of the waste contains any of the contaminants listed in Table 1 at the concentration equal to or greater than the respective value given in that table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering using the methodology outlined in Method 1311, is considered to be the extract for the purpose of this section.
(b) A solid waste that exhibits the characteristic of toxicity has the EPA Hazardous Waste Number specified in Table 1 which corresponds to the toxic contaminant causing it to be hazardous.
40 CFR - Protection of Environment, APPENDIX VIII TO PART 261 - HAZARDOUS CONSTITUENTS is not repeated herein because it is such a long list. The table shows hazardous constituents but does not show quantifiable limits.

4.3 Volume I, Paragraph 3.1, Function 1, Requirement 1, Trade Study

Retrieval volume increases due to boundary measurement inaccuracies.

Retrieval volumes will increase as the uncertainty of linear boundaries of a landfill grow. This can be the result of measurement uncertainties during characterization for excavation planning. If the extent of excavation is based on pre-excavation measurements, the excavated volume must necessarily increase. Volume is first-order dependent on the cube of density. Therefore the change in volume in linear dimension will be proportional to the square of linear dimension. Similarly, area is first-order proportional to the square of density, and its derivative by linear dimension is proportional to linear dimension. Thus, the increase in volume due to linear dimensional measurement errors will vary as the square of the error, and the area will vary proportionately with the error.

4.4 Volume I, Paragraph 3.2, Function 1, Requirement 4

Matrix density and lift weight.

There were 25 matrices cited by the landfill retrieval sites in the site visit information. The densities vary from 48 pounds per cubic foot (hardware in soil) to 139 pounds per cubic foot (sludge). Retrieval weights were calculated by assuming a one cubic yard (27 cubic foot) bucket. Table 2 lists the matrix densities used for this report. They were derived or calculated using data from construction handbooks.

4.5 Volume I, Paragraph 3.2, Function 1, Requirements 3 and 4

Object dimension and weight.

Table 2. Matrix densities for the retrieve option in the requirements document.

Matrix	Density (pounds/cubic foot)
Calcified sludge	13
Concrete debris	78
Flyash	88
Hardware in soil	48
Mine tailings	93
Misc. debris in soil	100
Sand and gravel	110
Sand, silt, and gravel	90
Slag and debris	78
Slag and residue	100
Sludge	139
Sludge and wet residue	139
Soil	88
Soil with clay	88
Soil with 0.7% debris	88
Soil and debris	90
Soil and gravel	93
Soil and sludge	139
Soil with sediment	93
Soil, ash, and debris	88
Soil, gravel, and asphalt	93
Wet construction debris	90

Multiple objects are discussed in the site visit reports. Table 3 lists the dimensions and weights that form the basis for the associated requirements in Volume I of this report.

4.6 Volume I, Paragraph 3.2, Function 1, Requirement 1

Physical matrix summary. Known volumes of all physical matrices are listed in Table 4.

4.7 Volume I, Paragraph 3.2, Function 1, Requirement 6

Definition for "alpha" re: contamination control.

10 CFR Part 835 codifies requirements contained in various DOE directives referring to contamination control requirements. For alpha, assume any alpha emitter in contaminants will necessitate contamination control (this is common practice but is not in 835; and is based on the extremely high quality factor for alpha particles). 10 CFR 835 specifies allowable removable and total (fixed plus removable) surface radioactivity (disintegration per minute) values for mixed fission products and beta/gamma emitters at

Table 3. Dimensions and weights for materials and objects for retrieval option.

Material/Object	Dimension (feet)	Weight (pounds)
Small debris	2	20
Ammunition can	1	30
Degraded barrel	4	350
Battery	2	50
Rock/cobblestone	1	30
Culvert	8	100
Car body	16	4000
Lab equipment	3	100
Drain pipe	8	75
UST	16	12300
Caisson	10	no estimate
Structural steel	10	300
Glove box	6	150

Table 4. Volumes for physical waste streams associated with the retrieval option.

Matrix	Volume (cubic yards)
Soil and 1% debris	2680000
Miscellaneous debris in soil	447972
Soil	2281816
Soil and sludge	511200
Hardware in soil	10264
Soil with clay	467706
Sludge	18835
Soil with sediment	1775000
Sand and Gravel	20071
Soil, ash, and debris	103400
Slag and debris	72800
Flyash	71600
Soil and debris	26200
Slag and residue	9600
Sludge and wet residue	9000
Construction debris	6280
Calcified sludge	5000
Wet construction debris	4300
Sand, silt, and gravel	3000
Mine tailings	1850
Concrete debris	1532
Soil and gravel	1000
Soil, gravel, and asphalt	1000
Metal debris	unknown

allowable levels of 10 - 50 times the allowable activity of the transuranics, Ra-226,228, Th-230,228, Pa-231, Ac-227, and I-125,129. These levels are:

Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129:

20 disintegrations per minute (removable)
500 disintegrations per minute (total)

Natural Uranium, U-235, U-238, and associated decay products:

1000 disintegrations per minute (removable)
5000 disintegrations per minute (total)

Natural Thorium, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133:

200 disintegrations per minute (removable)
1000 disintegrations per minute (total)

Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90:

1000 disintegrations per minute (removable)
200 disintegrations per minute (total)

Disintegrations per minute assumes an area of 100 square centimeters. Refer to 10 CFR 1035 Appendix D for further information.

4.8 Volume I, Paragraph 3.2, Function 1, Requirement 7

Contaminant Classification

Contaminants are classified into ten different categories. As listed below, each category has certain elements or compounds associated with it. Note that many elements represent the isotope associated with the category. Examples are Cesium, which refers to Cs-137, or Strontium, which refers to Sr-90.

Volatile Organics

Thirteen contaminants were classified as volatile organics for this report. These are:

TCE
PCE
1,1,2 TCE
DCE
TCA
Dichloroethane
Dichloroethene

Carbon Tetrachloride
Toluene
Ethyl Benzene
Chloroform
Acetone
Xylene
Benzene
1,3 Dichlorobenzene
Freon
Naphthalene

Semivolatile Organics

Two semivolatile organics were included in the baseline data set. These are:

Vinyl Chloride
EDB

TSCA Organics

Polychlorinated Biphenols

Tritium

Uranium

High Explosives (HE)

EPA Toxic Metals

Ag
As
Ba
Be
Cd
Cr/Chromate
Cu
Hg
Pb
Se

Other Metals

Li
Mg
Ni

Zn
Fe
Mn

Nonmetallic Inorganics:

Four nonmetallic inorganics were reported:

Nitrate
Cyanide
Fluorine
NaCl (chloride)

Alpha

Classification for alpha and beta-gamma is based on surface count rate categories presented in 10 CFR Part 835:

Thorium
Iodine
Strontium
Americium
Curium
Europium
Plutonium
Radium

Beta-Gamma:

Barium
Technetium
Cobalt
Cesium
Potassium
Iodine
Carbon 14
Californium
Antimony

4.9 Volume I, Paragraph 3.2, Function 1, Requirement 7

Contaminant Class Distribution

There are various combinations among the contaminant categories that are observed at the landfill retrieval facilities. The known combinations are listed in Table 5.

Table 5. Combinations among the contaminant categories that are observed at the landfill facilities preferring a retrieve option.

Contaminant Classes	Number of Facilities
alpha	14
alpha, beta-gamma	2
alpha, beta-gamma, U	1
alpha, U	7
beta-gamma	3
beta-gamma, U	1
EPA toxic metal	3
EPA toxic metal, alpha	1
EPA toxic metal, alpha, U	2
EPA toxic metal, beta-gamma	1
nonmetallic inorganic	1
nonmetallic inorganic, alpha, beta-gamma, U	1
nonmetallic inorganic, alpha, U	1
other metals, U	1
TOSCA organics	1
TOSCA organics, alpha	1
TOSCA organics, alpha, EPA toxic metal, beta-gamma	1
Tritium	1
U	2
VOC	3
VOC, alpha	3
VOC, alpha, beta-gamma	1
VOC, alpha, U	2
VOC, EPA toxic metal, alpha	3
VOC, EPA toxic metal, alpha, beta-gamma	5
VOC, EPA toxic metal, nonmetallic inorganic	1
beta-gamma, Tritium., U	1
VOC, nonmetallic inorganic, alpha	1
VOC, other metal, alpha	1
VOC, SVOC, other metal, nonmetallic inorganic, alpha	1
VOC, TOSCA organics, EPA toxic metal	2
VOC, TOSCA organics, EPA toxic metal, beta-gamma	1

5. DEFINITIONS

Terms used in this requirements document and commonly used to describe a technology application or process are defined as follows:

Advection The process by which solutes are transported by the motion of flowing groundwater. Generally, the principal means for contamination transport in groundwater.

Barrier An engineered subsurface structure that surrounds the waste but is not in the waste; prevents movement of contaminants from the enclosed region by containment or redirection of subsurface water flow; provides chemical treatment or hydraulic barrier; functions for at least as long as the contaminant poses a risk; and remains functional in the waste and site environments for the long term.

Cover or Cap An engineered surface structure to control infiltration (water, plants, animals, humans) into underlying materials, to provide a physical separation of the underlying materials from the surface environment, to control release of gas to the surface, or to serve other site-specific objectives.

Cap Components Five components of a cap (all are not needed for all caps):

- Surface or erosion layer - separate the underlying components of the cap from the ground surface and to minimize temperature and precipitation extremes in underlying layers.
- Protection layer - store water that has infiltrated into the cap until removed, physically prevent intrusion by humans or animals, protect the underlying layer from the natural elements.
- Drainage layer - drain the overlying protection and surface layers.
- Barrier layer - most critical component of the final cap. Minimizes percolation of water through the cap by impeding infiltration through it. It also restricts upward movement of any gases or volatile constituents that might be emitted from the waste.
- Foundation - provides strength for the cap so that the cap will not collapse and provides a gas collection layer if required.

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act. The act imposes cleanup and reporting requirements for remediating hazardous waste sites. Under this act, the Department of Energy conducts Remedial Investigations and Feasibility Studies which are usually performed together. The Remedial Investigation characterizes conditions at the site to identify the sources and extent of contamination. The Feasibility Study evaluates specific alternatives for cleaning up the site. The selected remedial action is documented in a Record of Decision.

DNAPL Dense nonaqueous phase liquids (heavier than water) typically have low solubility in water and high interfacial surface tensions (move downward, ponding above low-permeability formations, trapped in the pore system by surface tension forces).

Formal Verification Process Proving that a requirement has been satisfied through inspection, analysis, demonstration, monitoring, or test.

Key A groove channeled into a subsurface formation that allows a vertical barrier to conform and adhere to the formation.

Monitoring Includes instrumentation, data interpretation, and prediction of contaminant movement to ensure proper design of stabilization structures and materials; verification of proper installation; identification of failed structures; effect of engineered solution on overall area; verification of properly functioning structures; and identification of chemical and physical property of waste, waste site, and stabilization structures.

Need Something desirable such as technology development to remediate a problem validated by a risk investigation or feasibility study.

Plume Chemical and/or radiological contaminants exceeding background concentrations in groundwater or in soil that have migrated or are migrating from a source term.

Plume Retrieval The physical removal of contaminants from a groundwater or contaminated soil plume.

Problem General statement of concern relating to a contaminate which lends itself to further investigation by way of a risk investigation or feasibility study.

RCRA Resource Conservation and Recovery Act. The act provides requirements for the management of hazardous waste. These guidelines regulate waste at all stages, from before it is generated until after its disposal. The act also establishes a permit program for hazardous waste storage, treatment, and disposal facilities. Permits identify the administrative and technical standards to which facilities must adhere.

Requirement A quantitative or qualitative measure relating to a need which must be satisfied and verified as being satisfied through a formal verification process. Requirements will establish specific objectives for the technology developers.

Risk Driver One or more contaminants that show increased risk, above a baseline number, when processed through a relative risk model that drives the remedy selection decision process.

Selective Retrieval The full or partial removal of selected contaminants of concern or the partial removal of site volumes from a source term or plume.

Site (Landfill or Plume) One or more pits, trenches, tanks, cribs, french drains, ponds, seepage basins, and/or plumes grouped for one remediation decision process such as risk investigation/feasibility study or record of decision.

Soil Water Balance The mass balance of water entering a soil profile (precipitation, run-on, capillary rise), removed from a soil profile (run-off, drainage, evapotranspiration), and stored in a soil profile.

Source Origin of a contaminant migration or of a potential contaminant migration, e.g., landfill, pond, well, ...
Source Term Retrieval The removal of contaminants by excavation from a designated source term such as a landfill.

Subsidence Settlement caused by compression of underlying material.

Treatment A process which reduces the volume of contaminants or reduces the volume of soil to be treated, or reduces, immobilizes, or eliminates contaminant concentration.

Waste Stream A term relating to the Mixed Waste Focus Area that marries a contaminant and waste matrix, e.g., fly ash, debris, ..., with a treatment process.

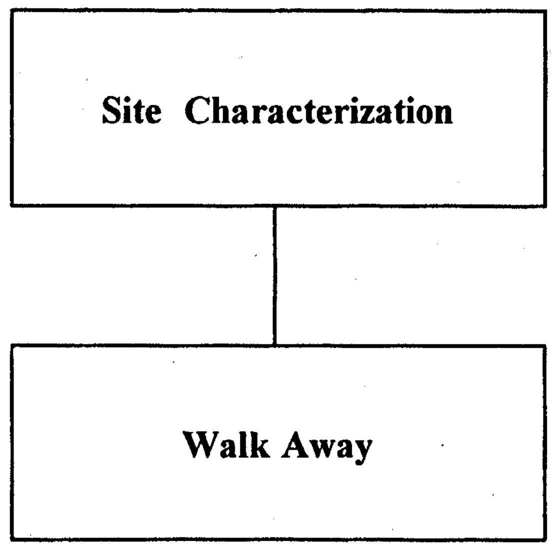
Appendix A

Configuration Options for Containment/Stabilization and Retrieval

Appendix A

Configuration Options for Containment/Stabilization and Retrieval

Walk Away Configuration Option
Risk < (10)^ -4
Uncertainty is Low

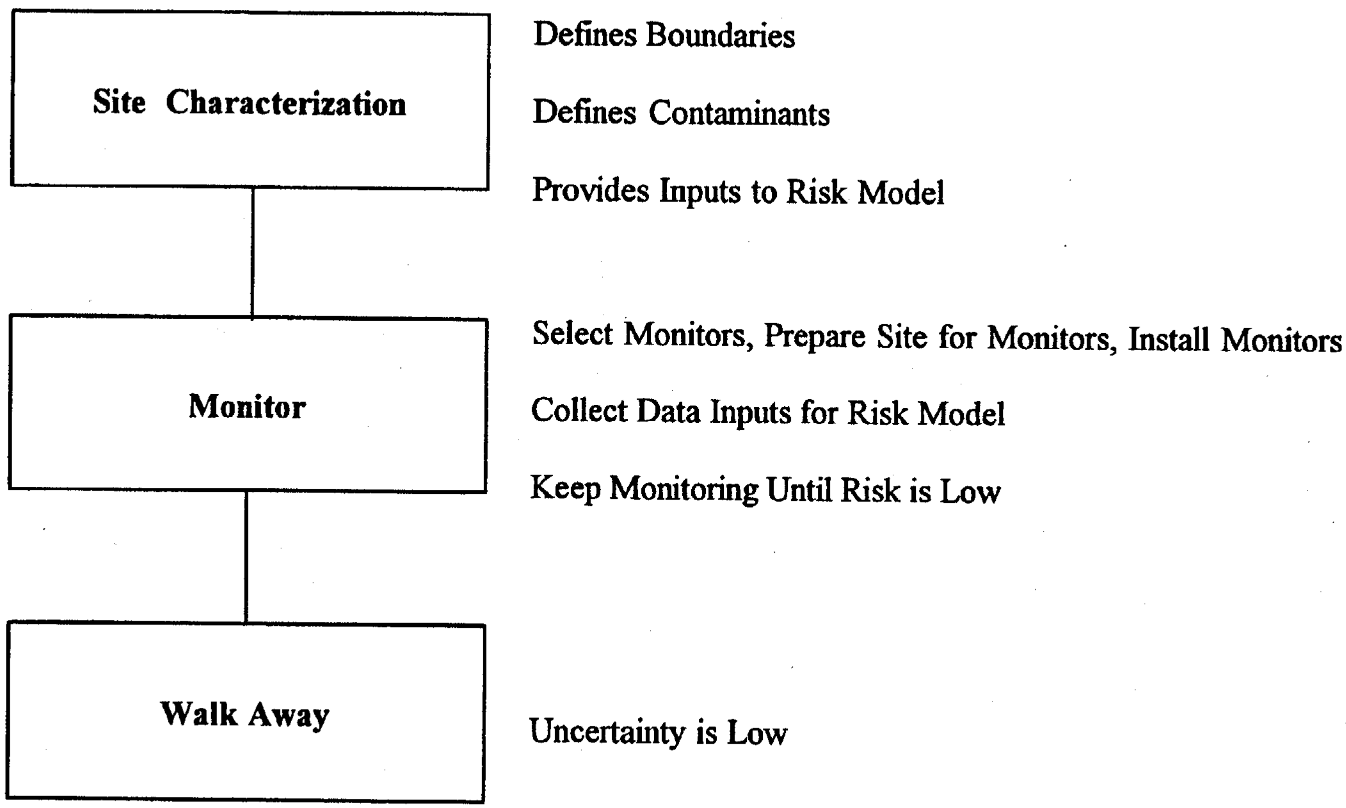


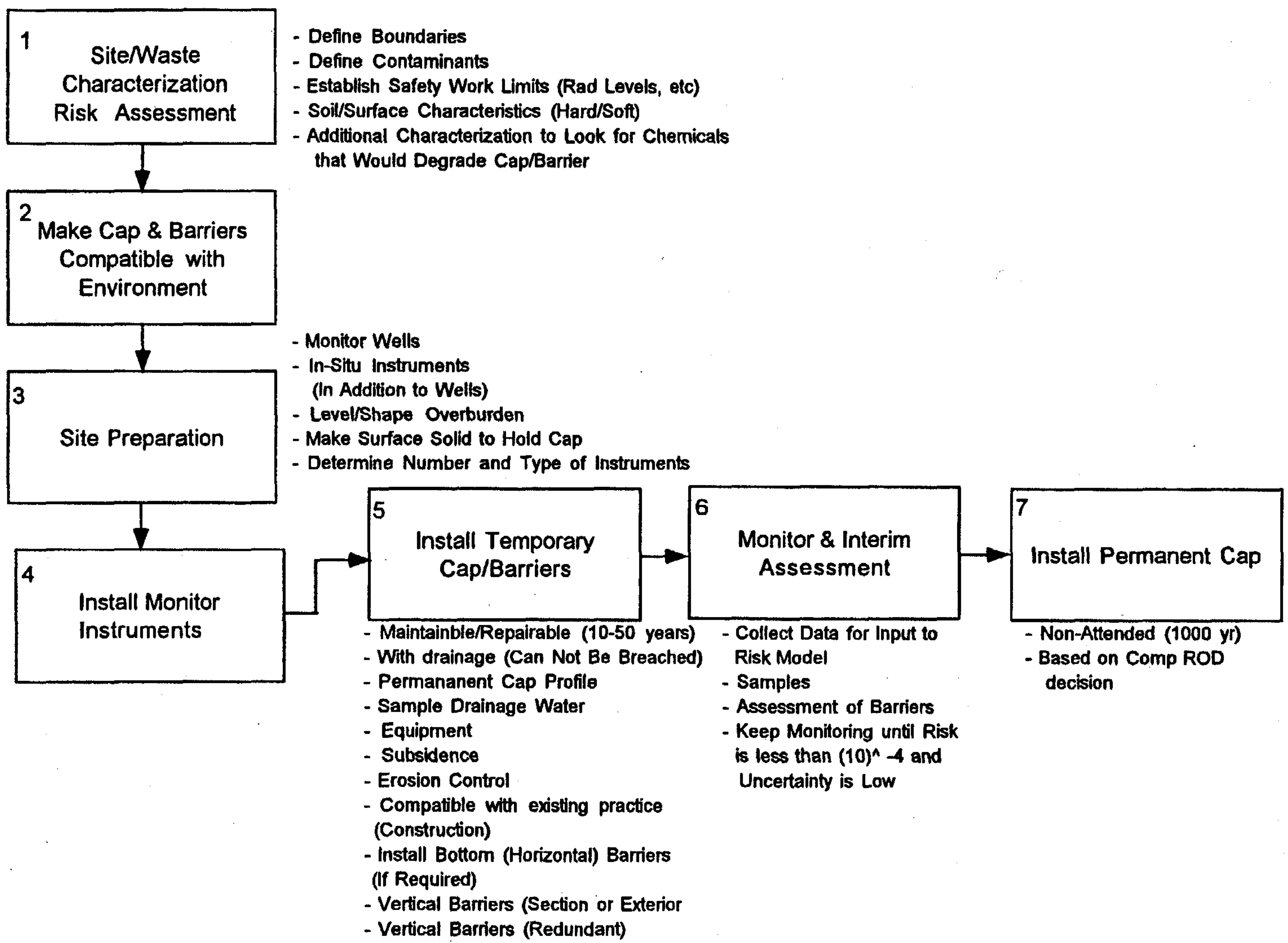
Defines Boundaries

Defines Contaminants

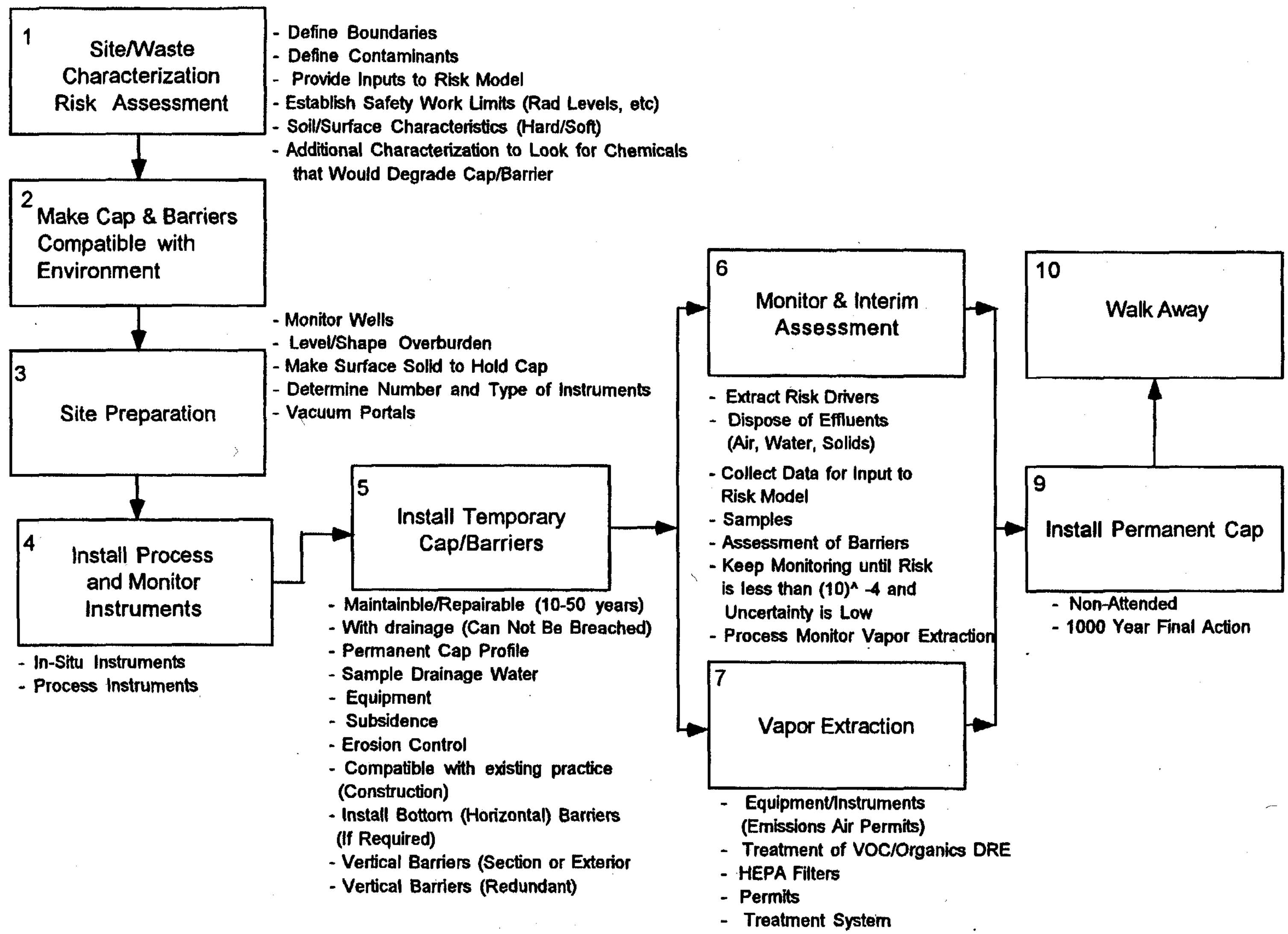
Provides Inputs to Risk Model

Monitor Configuration Option
Risk < (10)^ -4
Uncertainty High

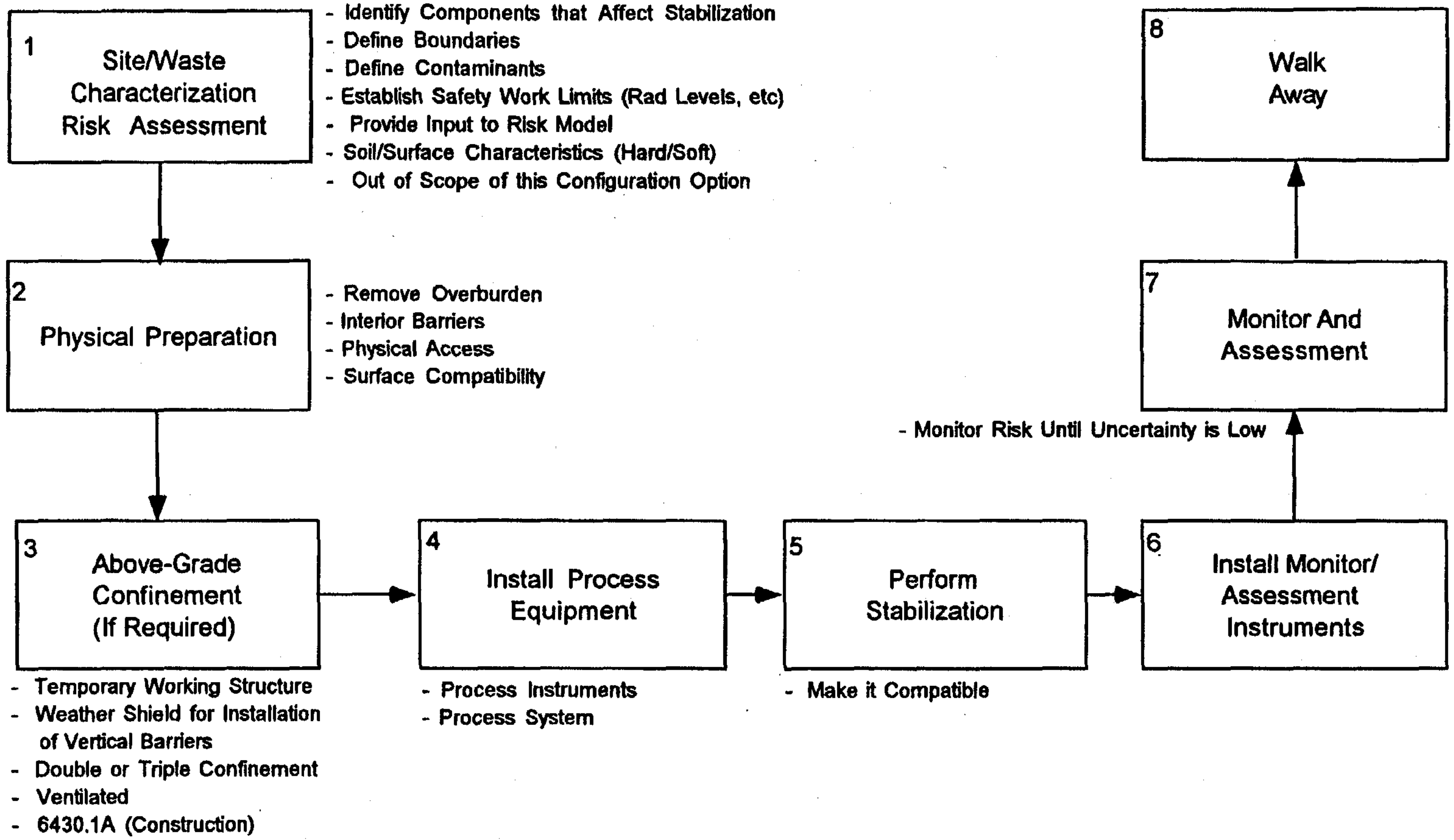




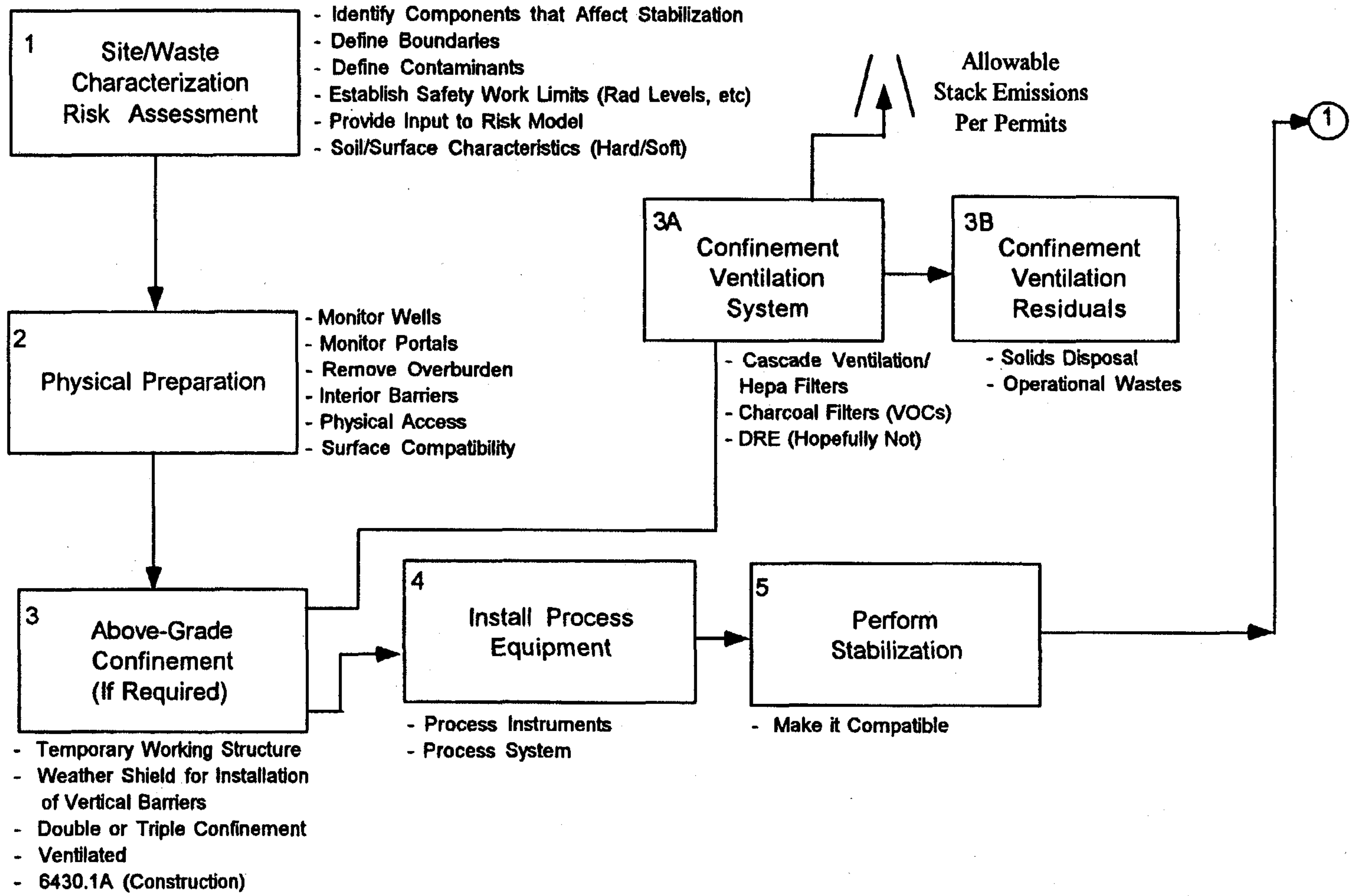
Cap and Barriers Configuration Option



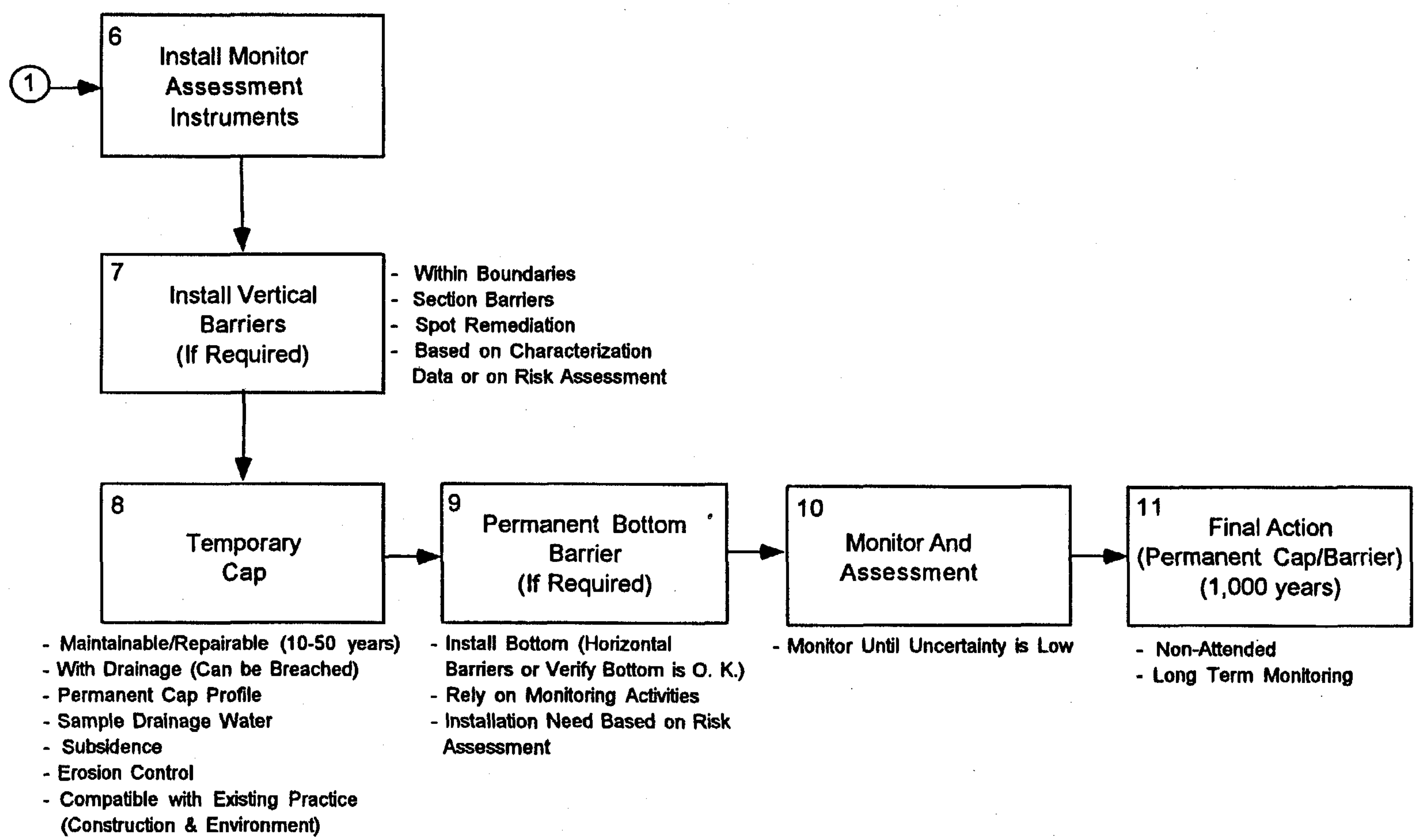
Cap and Barriers With Vapor Extraction Configuration Option



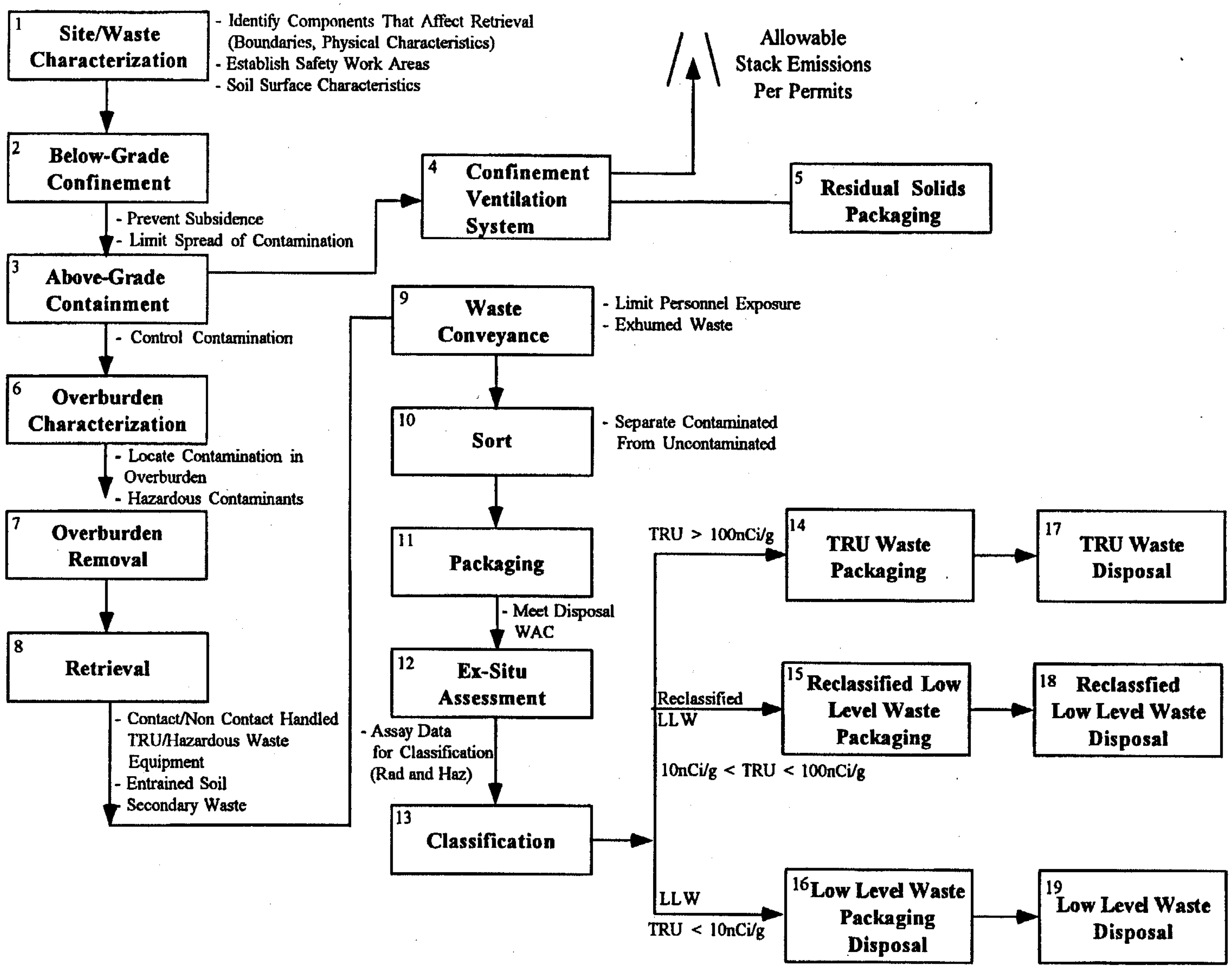
Stabilization Configuration Option



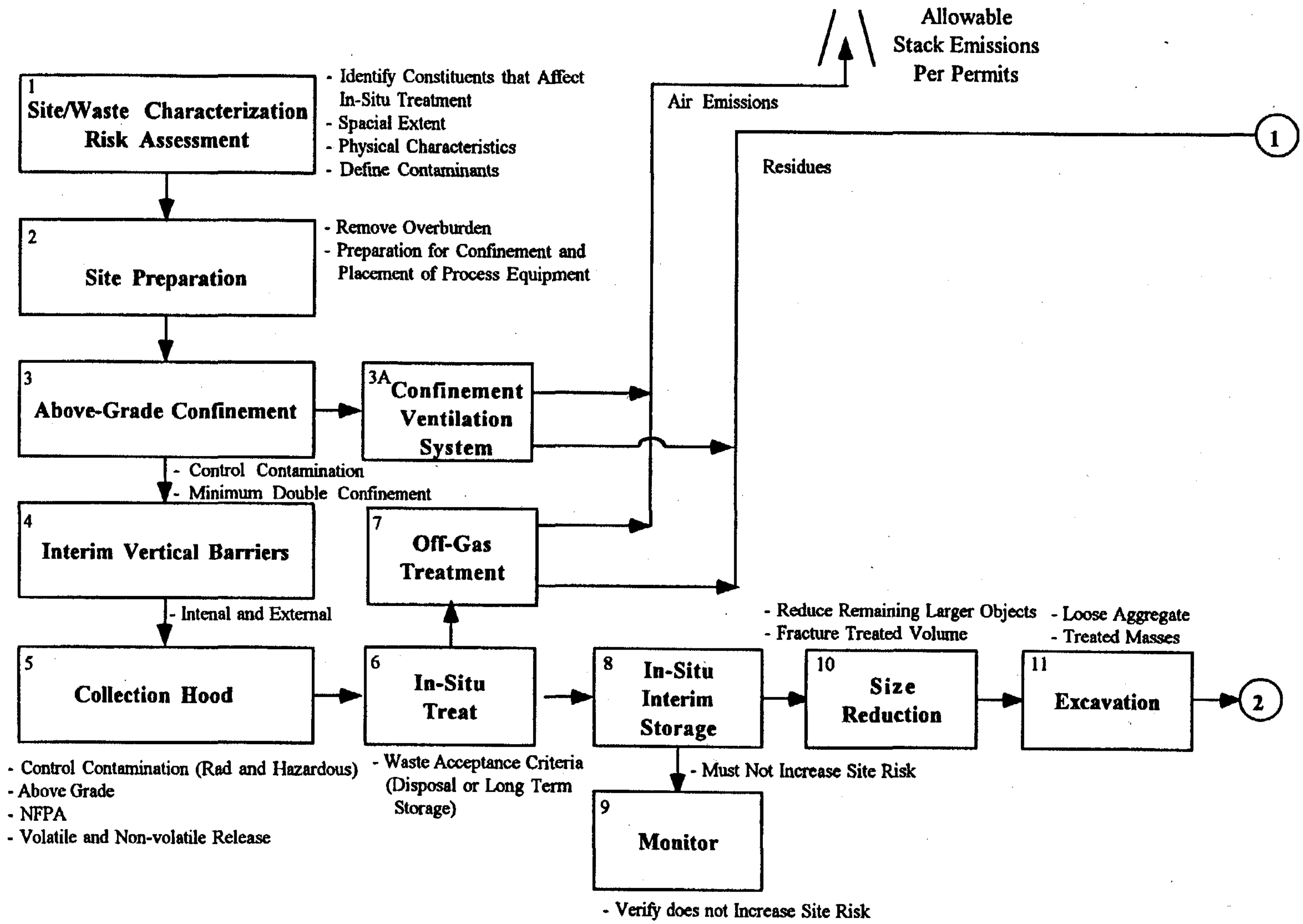
Containment & Stabilization with Barriers Configuration Option



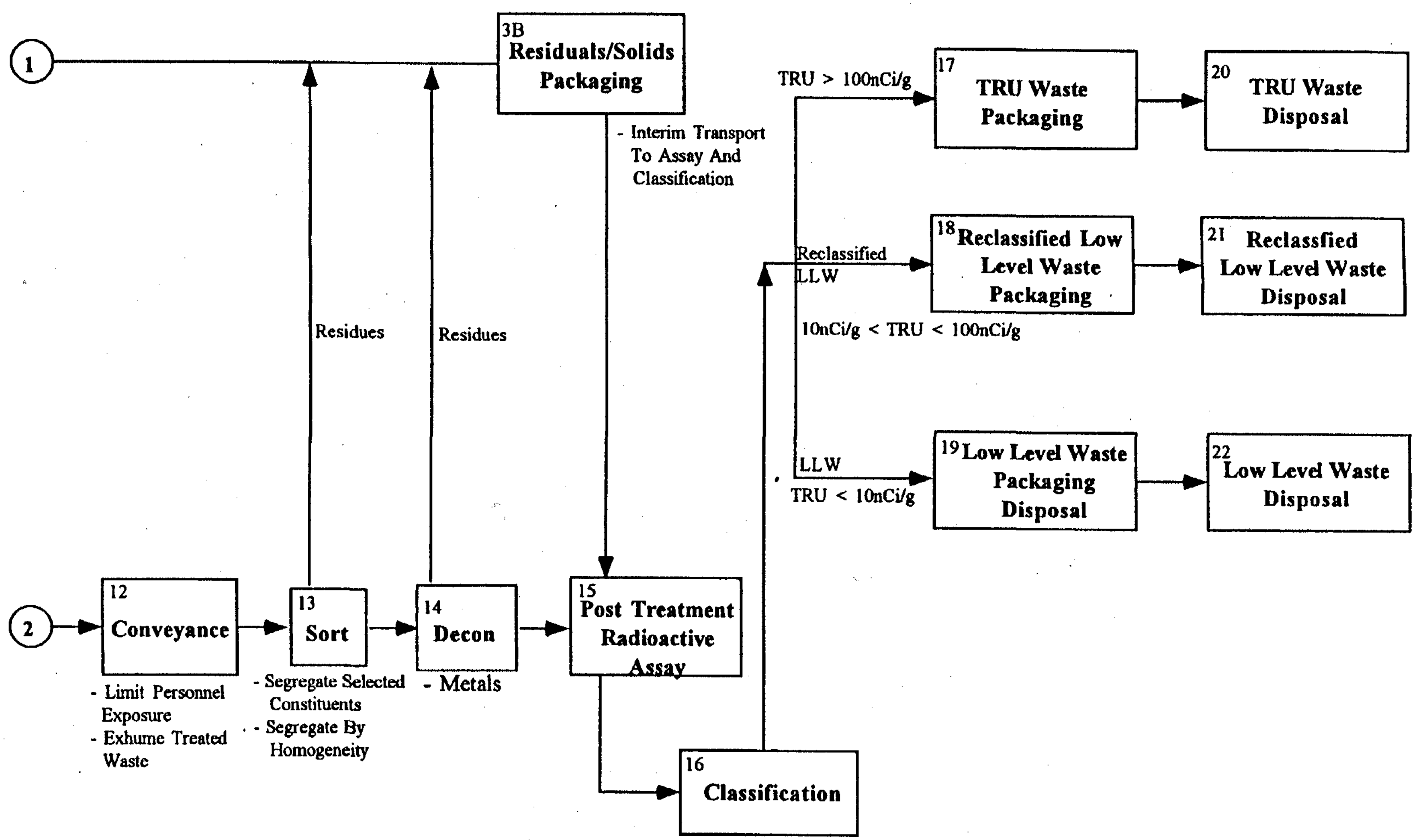
Containment & Stabilization with Barriers Configuration Option



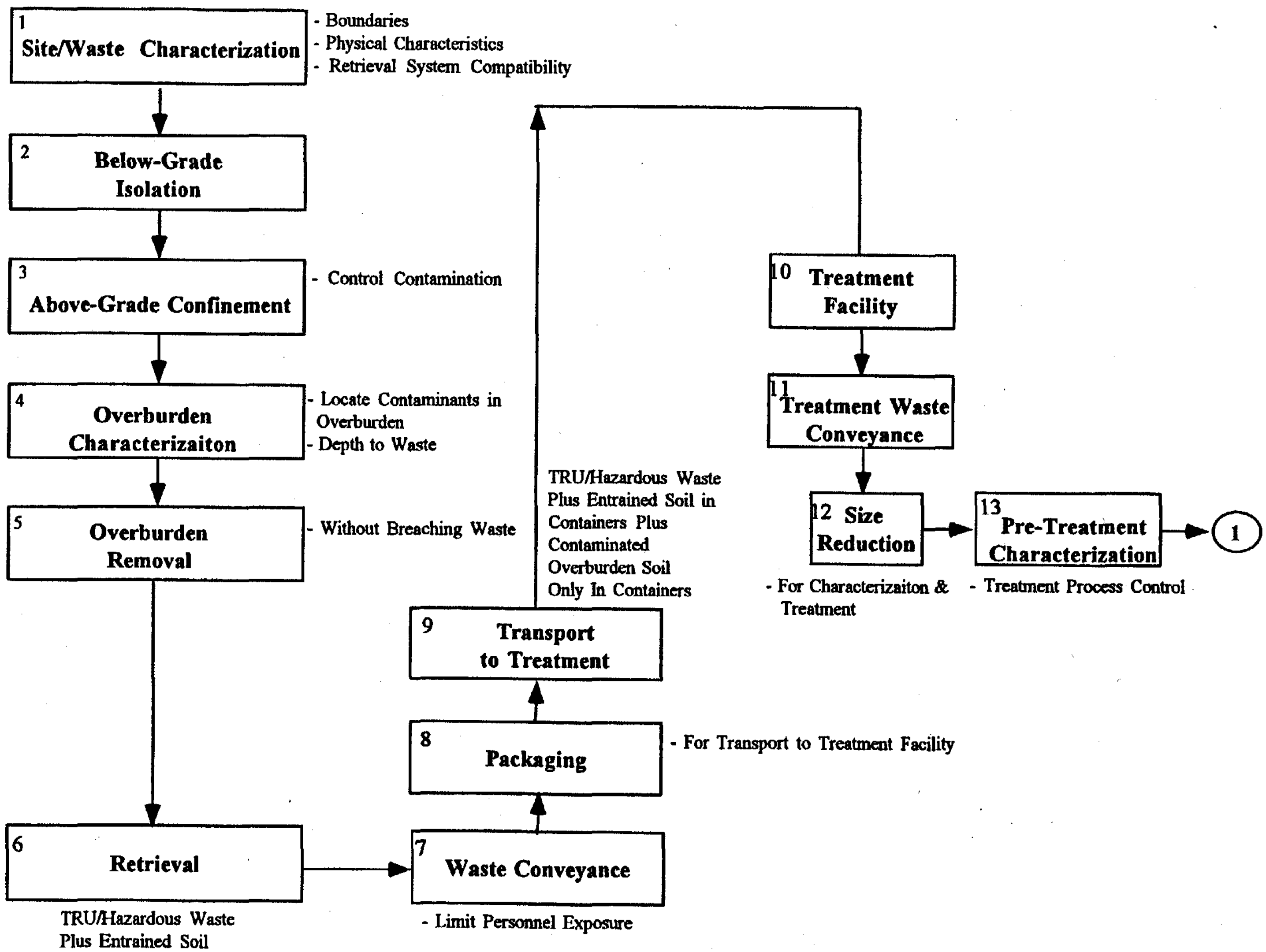
Retrieve and Dispose Configuration Option



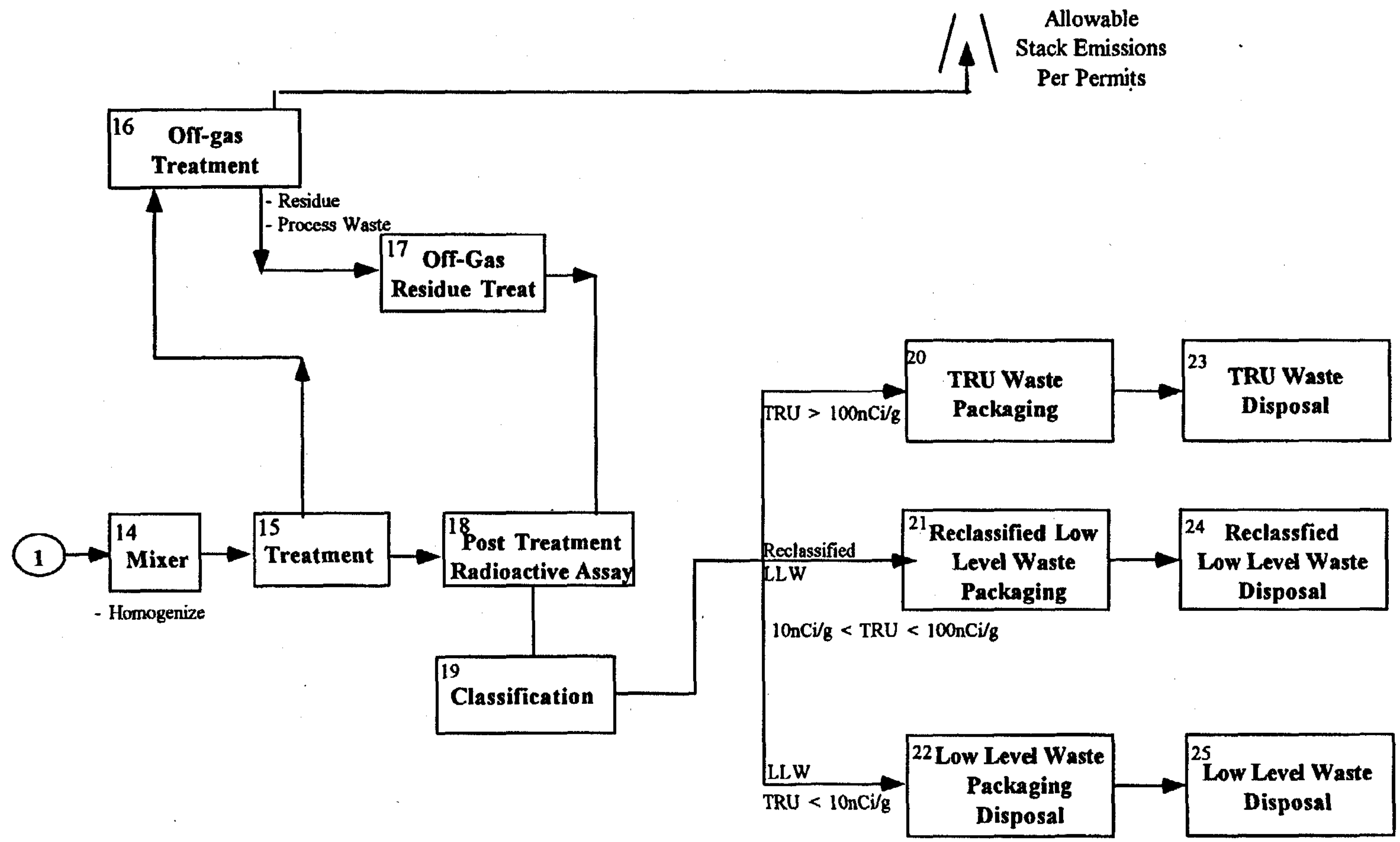
In-Situ Treatment/Retrieval Configuration Option



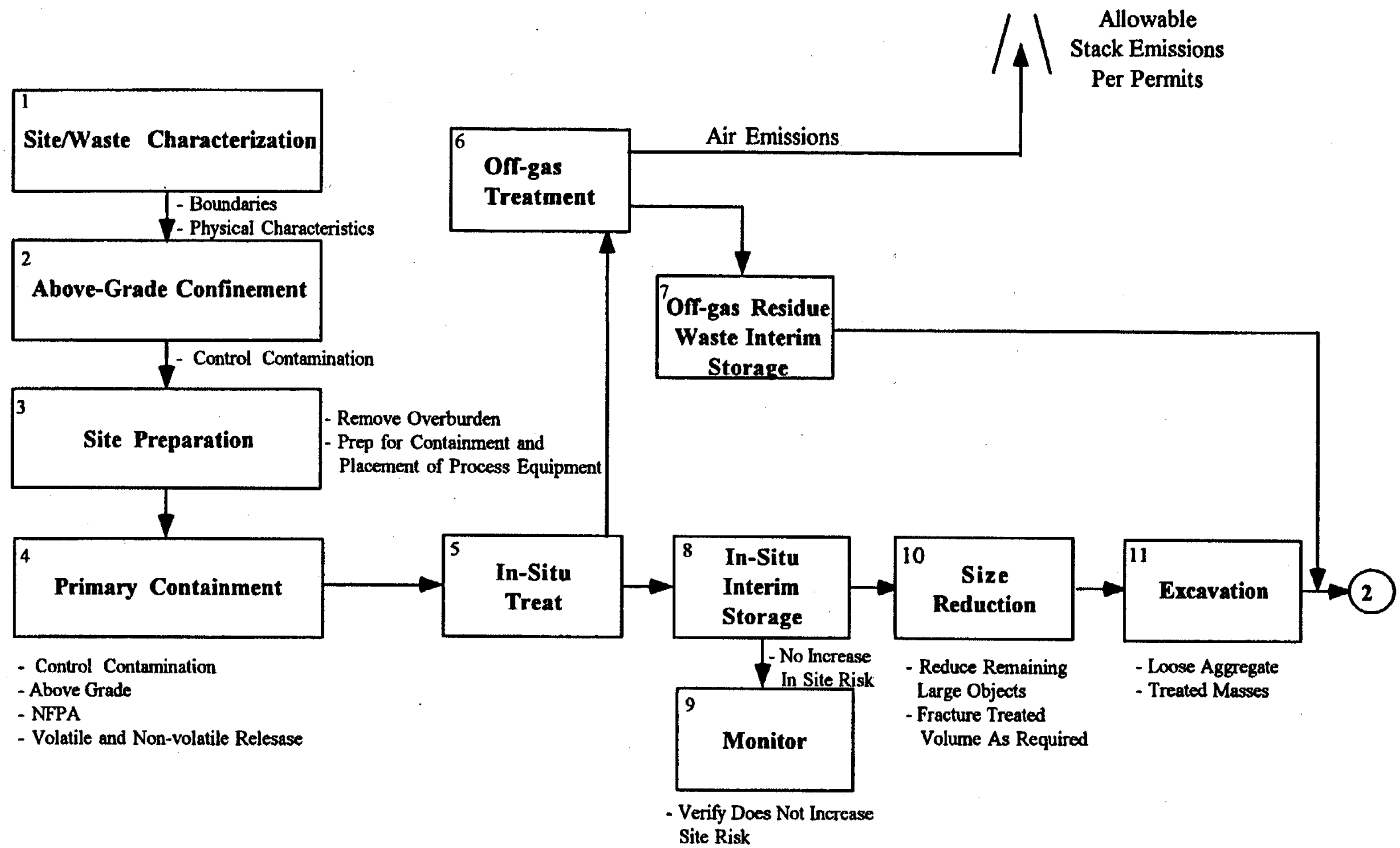
In-Situ Treatment/Retrieval Configuration Option



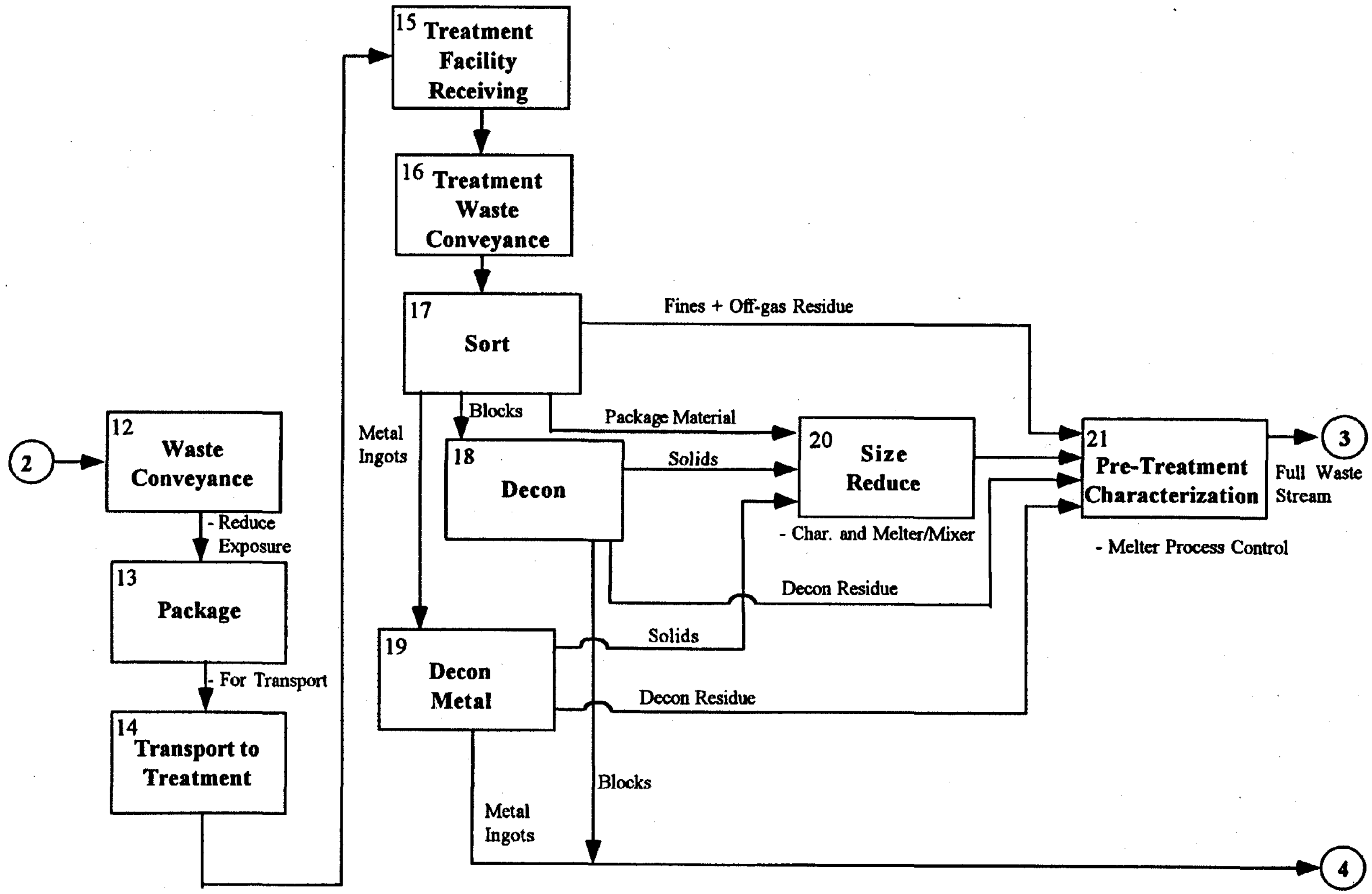
Retrieval/Ex-Situ Treatment



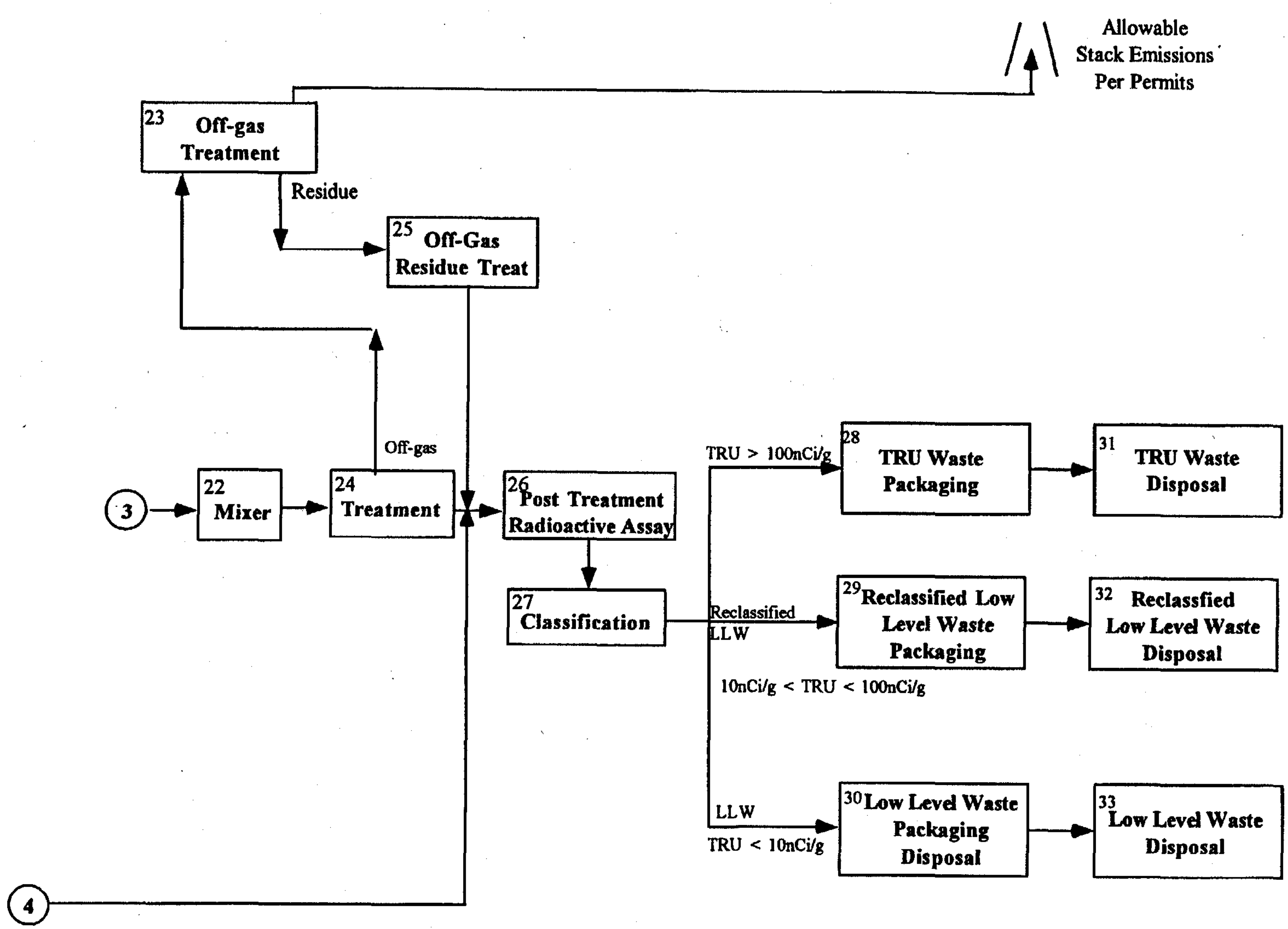
Retrieval/Ex-Situ Treatment



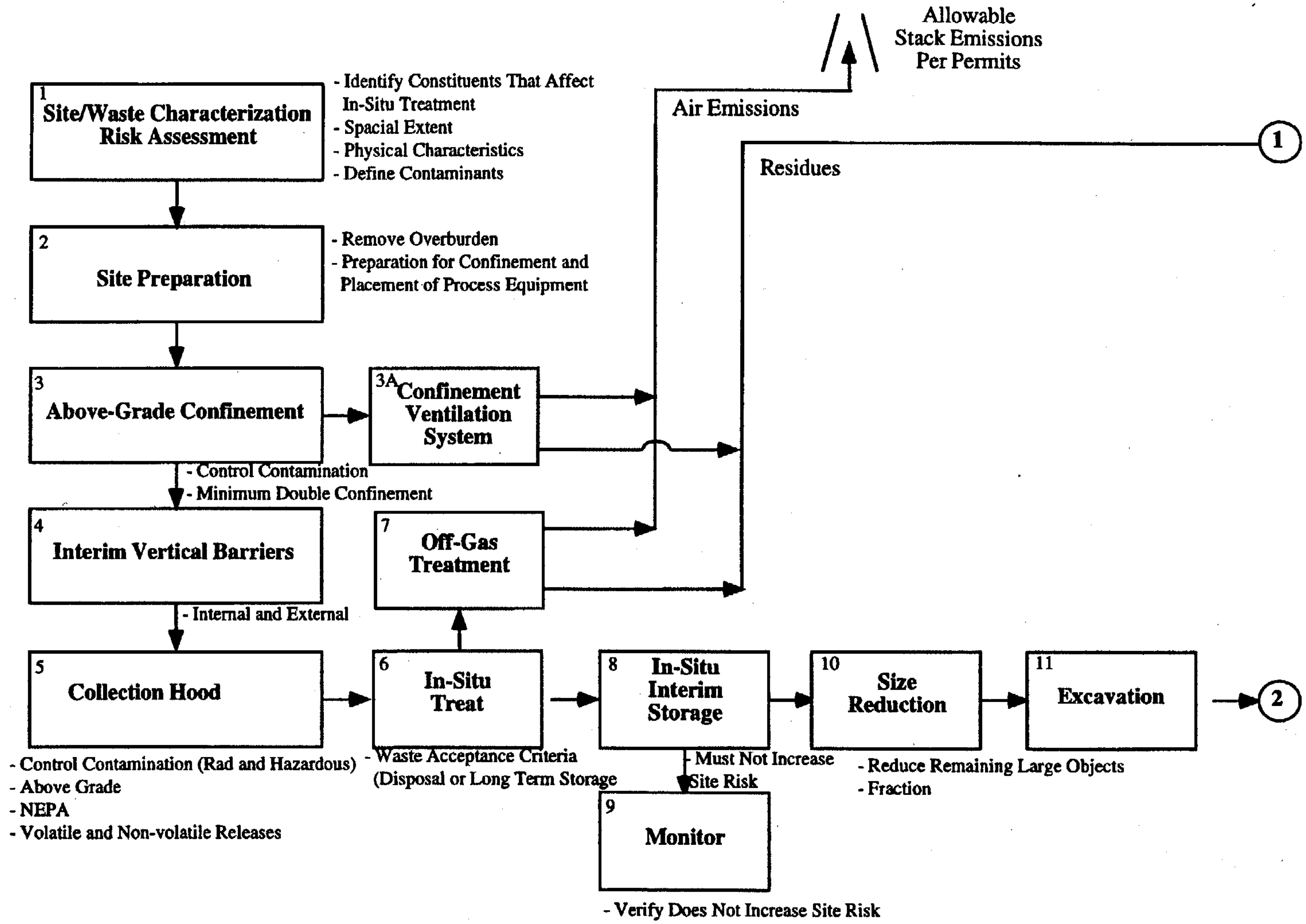
In-Situ Treatment/Retrieval/Ex-Situ Treatment



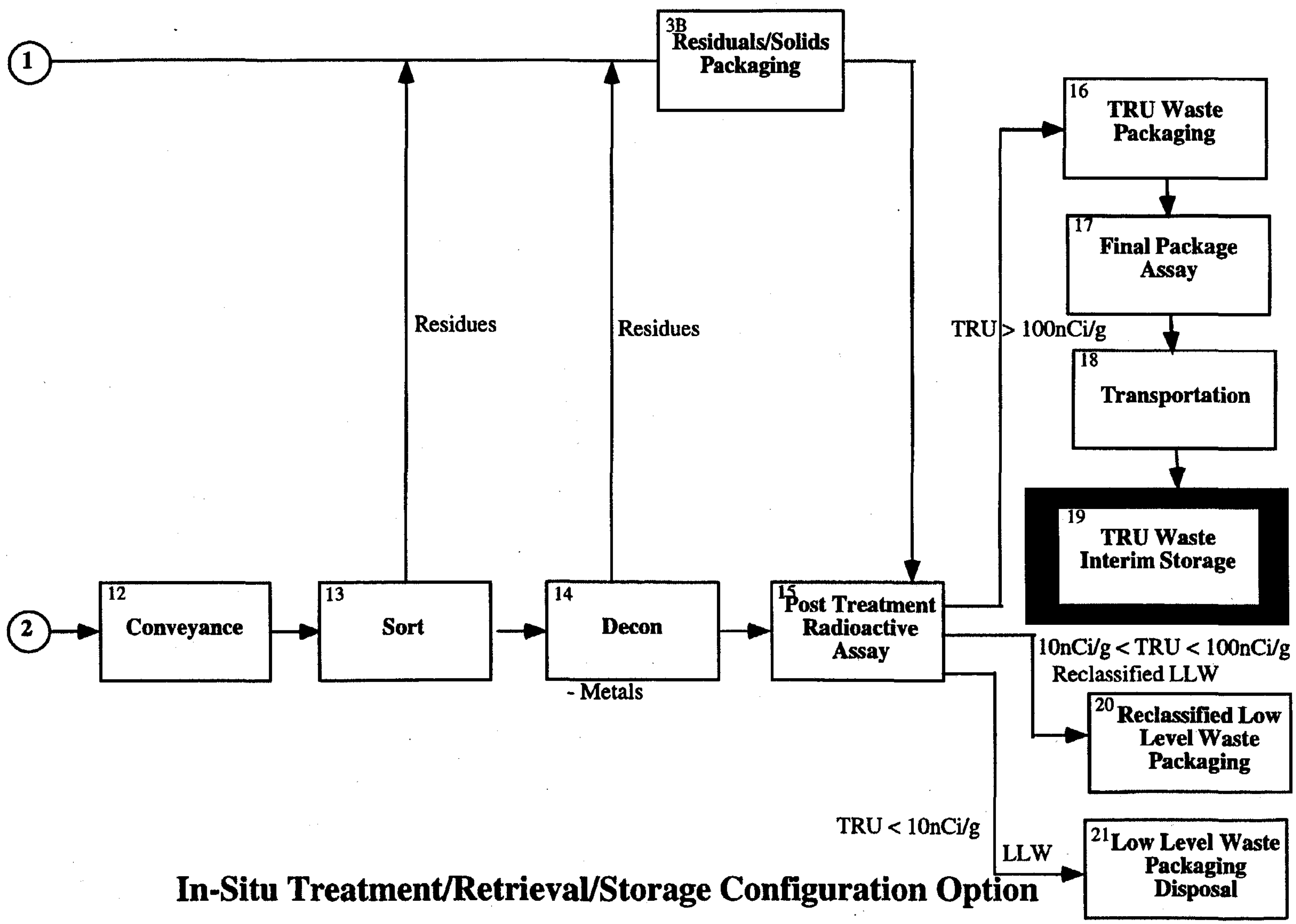
In-Situ Treatment/Retrieval/Ex-Situ Treatment



In-Situ Treatment/Retrieval/Ex-Situ Treatment



In-Situ Treatment/Retrieval/Storage Configuration Option



In-Situ Treatment/Retrieval/Storage Configuration Option