Chapter 7
Achieving Quality Cleanups

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Achieving Quality Cleanups

INTRODUCTION

This chapter considers the challenge of assuring timely, environmentally sound, and cost-effective remedial work at Superfund sites. The chapter first identifies several major problems affecting the quality of work at Superfund sites. Second, it examines technical oversight of cleanups. Good *technical oversight is a key to a successful Superfund program*. Finally, because competent, trained technical specialists from many fields are critical to a successful national cleanup program, OTA looks at current and projected needs for technical specialists. Bottlenecks that might slow the program or reduce its effectiveness are discussed.

PERFORMANCE AT SITE CLEANUPS

Based on a broad examination of the Superfund program and on several engineering case studies at NPL sites, OTA has evaluated the performance at site cleanups. The analysis found problems with designing and building long-term, effective measures to control releases of hazardous substances, The three sites studied were: Stringfellow Acid Pits, Glen Avon, California; Seymour Recycling Corp., Seymour, Indiana; and the Sylvester Site, Nashua, New Hampshire, (See chapter 1 for summaries of the case studies.)

OTA looked at the history of remedial response, the extent and quality of the site assessments, and at the evaluation, selection, and construction of remedial measures.[1] These studies show significant problems in the implementation of the Superfund program and a pattern of incomplete and inadequate site assessments. Problems were identified in such key areas as:

- estimates of the amounts of wastes and contaminated materials on site;
- estimates of the costs of remedial alternatives;
- hydrogeological assessments;
- design, installation and operation of groundwater monitoring systems; and
- design and construction of onsite containment systems.

Insufficient coordination among some States, EPA regional offices, and EPA headquarters may have contributed to problems with contractor performance.

Some problems may result from the newness of the Superfund program, But there are indications that if the Superfund program expands, they may grow acute as less qualified and less experienced technical people are employed by

[1]Certain terms describing site cleanup have very specific meanings in the Superfund Program and the stages of remedial activity. **Immediate measures** (also referred to as removals, planned removals, or interim or initial remedial measures) stabilize site conditions and mitigate imminent danger to provide temporary or short-term protection. **Remedial Investigations** or RIs provide an assessment of site conditions and include onsite sampling and data collection. **Feasibility Studies** or FSs evaluate possible response actions for long-term site protection. Separate feasibility studies can be done for different phases of site cleanup. **Remedial Design** studies provide a detailed site remedial action plan and engineering specifications for construction of the selected remedy. **Remedial Construction**, sometimes also referred to as remedial action, includes all construction activities and an initial period of operations and maintenance. Remedial construction can include relocation of residents or provision of a permanent alternate water supply. A site may have more than one remedial construction phase. **Operations and Maintenance** or "O&M" are any onsite activities occurring after construction of the permanent remedy, such as operation of the onsite treatment plant, maintenance of the site cover, and monitoring.

the government and the private sector. Their frequency suggests that they may be endemic to the Superfund program as currently structured and managed. These problems are discussed below, not necessarily in order of importance. Cleanup progress at several Superfund sites is examined to identify areas where the program might be improved.

Nature of Surroundings and Contaminant Transportation

The interaction of wastes with soil, clay, gravel, sand, and bedrock greatly influences the effectiveness of a cleanup. If these interactions are misunderstood or ignored, the control measures selected may be ineffective. Chemicals, particularly complex chemical wastes, can change the properties of soils and clay. For example, clay, which is considered relatively impermeable at 10^{7} cm/see, can increase in permeability by several orders of magnitude in the presence of some contaminants.[2] Some chemicals can migrate faster than water alone through porous materials such as soil and clay.

When chemical wastes are placed into the ground they can migrate and eventually find their way into groundwater. No natural containment is impermeable to chemical transport. Bedrock, often wrongly assumed to be impermeable, may, for example, itself be an aquifer or contain fractures that can act as conduits for chemical transport. Chemicals can also attack and change the porosity and other properties of engineered containment structures such as slurry walls. Eventually, these structures become permeable to the chemical wastes they were designed to contain.

Once chemicals reach the groundwater, a contaminant plume forms. Even if the waste source is removed, a threat remains in the moving plume of contamination which may be 50 or 100 feet below the surface, The transport of chemicals in an aquifer by the contaminant plume is often incorrectly assumed to be similar to the flow of groundwater. The movement of the contaminant plume may in fact be very different from the general groundwater flow, Contaminants in a plume may change the properties of the medium, often adsorb and desorb from the surrounding medium and can interact chemically with each other. Thus, the rates of contaminant transport are complex and differ from that of water in the same medium. For these reasons, the common practice of using groundwater flow maps to describe plume migration can produce misleading results,

Some contaminant flow models exist, but they are not necessarily reliable in predicting the migration of contaminant groundwater plumes under complex hydrogeological conditions, The current practice of relying on homogeneous models, such as Darcy's Law, for predictions in nonhomogeneous, stratified subsurface conditions yields, at best, crude estimates of contaminant movement, Subsurface geology is often nonhomogeneous and contaminant plume behavior may be complex. For example, despite a predominant flow direction for groundwater, a contaminant plume may have multiple paths and directions,

[2] Waste l iqu ids and water carrying contaminants leached from hazardous wastes can percolate through the soil and subsurface and reach groundwater. Typically, contaminants pass through the unsaturate subsurface, the ''zone of aeration or vadose zone, and then to the saturated zone where voids between rock or soil particles are filled with groundwater; this zone that ca n store and transmit significant quantities of groundwater is called an aquifer. once contaminated, and depending on site condit ions, restoration of groundwater to its previous condition can be difficult, if not impossible. Many factors influence groundwater flow and the behavior of contaminants i n groundw a ter. Porosity and permeability control the ability of a material to store and transmit liquids, Porosity, expressed as a percent of the bulk volume of the material, is a measure of void space and how much fluid can be stored in it. See generally David W. Miller, cd., *Waste Disposal k; ffects on Groundwater: A Comprehensive Survey of the Occurrence and Control of Ground \ vater Contamination Resulting From Waste Disposal Practices (Berkeley,* CA: Premier Press, 1980), pp. 45-59. This publication is a reproduction of a 1977 publication, *The Report to Congress, Waste Disposal Practices and Their Effects on Groundwater,* U .S. Environmental Protection Agency, office of Water Supply and Office of Solid Waste Management. See also U.S. Congress, Office of Technology Assessment, *Protecting the Nation Ground\\ ater From Contamination, OTA-O-233* [Washington, DC: [J. S. Government Printing Office, October 1984) for a more detailed discussion of the nature of ground water contamination and methods for detecting and correcting contamination in the groundwater. in particular, see Volume I, p. 116, for a description of problems and information used i n assessing contaminat ion and hydrogeologic conditions. See Volume I 1, p. 396, app. D for k e y defin it ions.

Multiple Studies, Multiple Contractors

OTA's case studies and other analyses of remedial activities at Superfund sites show that frequently a single site will undergo multiple studies and have multiple contractors. Multiple studies at the same site create the potential for delay or inaction without guaranteeing thorough site assessment or effective cleanup plans, Often, these studies produce conflicting or inconsistent results and are of uneven quality. Studies of site conditions may be repeated needlessly; for example, earlier adequate site studies prepared for State or local agencies are sometimes ignored during the Superfund Remedial Investigation and Feasibility Study (RI/FS), In other cases, the scope and direction of later studies and remedial actions have been set by inaccurate or misleading initial studies.

Sometimes poor coordination in the same study can be a problem. OTA's case studies found examples of different sections of the same report using different data and assumptions. Contractors who may not have done quality work in an early phase maybe rehired at a later stage of the study or during the implementation phase.

Some multiple studies at Superfund sites are inevitable because of the highly specialized skills required for cleanups and the sometimes rapidly changing or uncertain site conditions. Because multiple site studies continue to be done, it is especially important that site supervisors: 1) are technically competent and experienced, and z) maintain adequate oversight of site contractors.

How do problems with multiple or repetitive studies arise? After a site begins to have problems or is known to have contaminated groundwater, local officials, perhaps under pressure from local citizens, may commission a study to examine the problem and recommend remedial action. Because ground or surface waters are at risk, the local water district or the health department may become involved and commission studies, in addition to investigations by the State hazardous waste agency. Water districts may have local civil-sanitary engineering consultants who have worked many years for the district. Consequently, in many cases they are awarded the initial study contract. However, even skilled sanitary engineers and hydrologists may not be familiar with the movement or treatment of hazardous wastes. This lack of experience can result in a flawed study despite hard work and good intentions. Common problems include: the effect of chemicals on soil properties usually is not considered; the fact that a contaminant plume can have multiple paths is not reflected in a pumping program if it is predicated solely on the direction of groundwater flow; natural basins and aquifers that are nonhomogeneous and stratified are modeled as constant property homogeneous bodies; the suggested remedies are not appropriate for the variable nature of the buried wastes; groundwater contaminant treatment plants are designed for a steady, predictable influx, which is unlikely; the option of treating the wastes is usually not considered. Other site-specific examples can be found in the case studies.

Early studies may underestimate the magnitude of the problems, yet they often set the tone and direction for future study and action. Opportunities for effective, timely responses to detect or control the spread of contamination may be lost. For example, programs to monitor surface waters, basins, and aquifers will not be implemented if the problem is thought to be localized.

When a site becomes a Superfund site, EPA and its consultants become involved. The National Contingency Plan (NCP) requires that an RI/FS be completed before remedial action begins, and thus, another study starts. In many cases, the RI/FS follows reviews, updates, and critical evaluations by the EPA's zone consultant, so that the RI/FS may represent the third or fourth study of the same site by EPA contractors. The RI/FS contractor maybe more experienced in hazardous waste management than the earlier contractors, but if inexperienced staff are assigned to the work, the final outcome may not be improved.

Two general problems have been encountered with multiple studies: 1) Mistakes or omissions in early site studies are not detected through timely and critical review and propagate through the RI/FS process, contributing to the adoption of ineffective remedies; and 2) good quality early work is ignored in a lockstep “start from scratch” RI/FS approach as studies are needlessly repeated, delaying remedial action. At first glance, the two results may appear contradictory, but they really are different possible consequences of the inherent risks in multiple studies. Minimizing these risks is an important goal for effective oversight of Superfund contractors.

Information and study results obtained by a consultant at a particular site generally are not shared with contractors working at other sites. Consequently, the study phase of the Superfund program suffers from the “reinventing the wheel” syndrome. This is especially true for Feasibility Studies where the same alternative technologies are described and discussed generically for different sites. Even though information is obtained with public funds, consultants tend to take a proprietary view of their work. As an example, the approach to treating contaminated groundwater varies with consultants and may not incorporate field experience gained at other Superfund sites.

Containment Rather Than Treatment

EPA shows a consistent bias toward containing wastes on the site rather than rendering them harmless through treatments such as detoxification, conversion, or destruction. Containment is popular because it is often seen as a cost-effective remedy, For a variety of reasons, confining mixtures of complex chemicals in the ground can, at best, only be temporary. Some of these reasons have already been mentioned. Engineered containment such as grout curtains and slurry cutoff walls can be affected by the chemicals they are designed to contain. A containment material that is highly impermeable to water can become several orders of magnitude more permeable when altered by leachate from chemical wastes. Furthermore, such structures can be difficult to key or seal to bedrock, which may itself be fractured and/or only slightly less permeable than the containment material. Containment structures can only temporarily reduce the inflow of water into the wastes or retard the migration of contaminants from the site.

Because containment provide only temporary and partial control of the spread of contamination, they are sometimes used in combination with groundwater pumping and treatment, At the Sylvester site, a slurry wall and cap with pumping, treatment, and recirculation of contaminated groundwater through the site have been designed to reduce releases of hazardous substances to acceptable levels within a few years. The slurry wall and cap have not reduced water flow from the site as much as projected, An interim pumping program has been started to contain the plume. The water treatment system is not yet complete.

The experience at Sylvester thus far has been limited, and it is not yet possible to evaluate the effectiveness of the remedial containment/ treatment strategy there. Waste sites often contain tons of hazardous substances. Removing these contaminants through a water treatment system could take decades. There is also no guarantee that pumping and treating a particular plume are effective in stopping or controlling all of the material leaving the site. These types of remedial actions may not be found in the longer term to be permanent cleanups, except under certain conditions, such as where wastes have been limited to relatively small amounts dissolved in groundwater.

EPA’s preference for containment strategies rather than treatment has limited the consideration of other, more reliable alternatives. At many sites, waste treatment is only considered, if at all, as part of an excavation and removal for redisposal alternative. Although removing the wastes eliminates the source of the problem at one place, it almost always means that the problem has been shifted to another 1ocation. Onsite treatment plants for contaminated soil and wastes are rarely considered in detail in an RI/FS even though the proposals and contracted scope of work for these studies call for evaluation of all options. In some cases, technologies exist to detoxify and treat the wastes and materials that are contaminating the groundwater, but they are given little attention in the RI/FS. In other cases, innovative solutions would be required.

There is an important lesson to be learned from the experiences of the Superfund program. In designing and evaluating alternative strategies for cleanup, the cost of failure or impermanence is rarely included (see chapter 3). The selected remedy is often presumed to be totally effective. If, however, the cost of further actions to repair failure is calculated, then an option which is initially more expensive, but more reliable, may prove to be the most cost-effective solution in the long term.

Political Pressures

Political influences rather than technical considerations can control the speed and nature of studies and cleanups at Superfund sites. In many cases, publicity and persistent citizen complaints eventually can force public officials and agencies to take action. Sites located in areas where the residents are politically sophisticated and organized are sometimes given priority over other sites that may pose greater or more immediate threats to health or the environment. Political considerations have at times influenced the timing of resource allocations for cleanups.[3]

In addition to being sensitive to public pressure, officials are sensitive to the types of remedial actions that EPA prefers and is likely to fund. This has a direct bearing on the scope and results of contractor studies. The case studies document several examples of the correlation between the views of the funding agencies and the recommendations of the consultant. Approaches that differ from familiar containment and pumping alternative are given little attention in the RI/FS.

Citizens, individually or in groups, often rely on common sense rather than on technical expertise, yet they can sometimes provide an effective check and balance for the action being considered or implemented at a site. At several sites, citizen suggestions modified the preferred remedial approach (see chapter 8), However, opportunities for effective public involvement in and scrutiny of site assessments and evaluation of remedial alternatives are limited.

Studies Versus Timely Actions

Successful remedial action must be based on an accurate assessment of site conditions, risks to health and the environment, and the technical feasibility and cost effectiveness of alternative remedies. OTA's review disclosed a number of problems with the adequacy, completeness, cost effectiveness, and timeliness of site assessments.

Many of the sites on the NPL have been known for some time and have or are undergoing a series of Federal and State responses. At all three OTA case study sites, remedial investigations and emergency actions were initiated before passage of Superfund legislation. OTA has found that studies of site conditions often were repeated by different State and Federal agencies. In one instance, and perhaps in others, studies were repeated to meet requirements of various emergency and remedial response programs,

EPA has defended its current ad hoc approach by emphasizing that every site is unique. Many sites, however, share common characteristics and, with the experience the Superfund program has gained, it should become possible at many sites to limit extensive site assessments for initial responses and for high-priority remedial measures, Time and money could be saved. For example, 2- to 3-year site assessments may cost many hundreds of thousands of dollars, but result in the selection of a partial remedy costing only $1 million to $3 million or less. Experience to date suggests that there has been overdesign and overemphasis on extensive, high-cost, time-consuming site investigations and feasibility studies for impermanent partial remedies such

[3] See also *Hearings on EPA: Investigation of Superfund and Agency Abuses Before the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce*, 98th Cong., 1st sess., 1983 (3 vol.).

as temporary containment, removals, and alternate water supplies,

At Stringfellow, remedial action was delayed while several successive groundwater contamination studies and site assessments were performed by local, State, and Federal contractors. Contamination grew and site conditions changed. Over $15 million has been spent at the site so far. A permanent remedy is still under study and its cost could be very high, with the State now estimating **$65** million.

At Seymour, about $4 million has been spent so far in studies and emergency response to achieve a $7 million incomplete, limited surface cleanup by private parties. When further site assessment is completed, some of the "toxic hot spots" that were buried in the partial cleanup area may have to be reexcavated to remove a continuing source of groundwater contamination.

Adequacy of Site Assessments

OTA found a number of technical problems with contractor studies for the three Superfund sites. Poor quality work on groundwater conditions and site hydrology has been the most serious recurrent problem. This underscores the critical need for competent, trained technical specialists in hydrology and related fields to work on Superfund sites that have extensive or complex aquifer contamination.

The initial site investigation of the Seymour Recycling facility had several shortcomings, The extent of offsite contamination from incinerator operations was not investigated. Possible pathways of escape for contaminants offsite through surface runoff, groundwater, and city sewer lines were not adequately investigated, so that the suggested onsite containment and control options may not effectively prevent the spread of contaminants. There were allegations that preliminary groundwater monitoring wells were not installed properly. Some samples taken from these wells were reportedly not usable by EPA's contractors. One generator-funded contractor study attributed groundwater contamination to improper well installation. OTA was unable to determine whether the monitoring wells were improperly installed. Difficulties with inadequate design, installation, and operation of groundwater monitoring systems are not uncommon at Superfund sites and at interim status RCRA facilities (see chapter 5).

At Sylvester, initial estimates of the degree to which bedrock was fractured now appear to have been low, and the amount of waste deposited at the New Hampshire site might have been significantly underestimated.

The Stringfellow case study found a long history of problems with contractor work on site geology and hydrology, The complexity of the site geology was consistently underestimated with adverse consequences for the effectiveness of the control measures recommended. Until the late 1970s, it was generally assumed that the site lay on impermeable bedrock. Then it was discovered that the granitic and metamorphic bedrocks were highly fractured and jointed and hosted several underground springs that flowed into the site, In **1982** the permeability of the site and down-gradient areas was found to be much greater than originally thought. Earlier indications of the presence of an extensive, rapidly moving plume of contamination had been discounted and wrongly attributed to surface runoff. In 1980, interceptor wells were drilled to control the plume of contaminants. However, the wells were not pumped continuously as required and the plume moved beyond the zone of influence of the wells. Incorrect conclusions about site geology caused two interceptor wells to be misplaced, The wells were set west of the buried drainage channel in the alluvium underlying the canyon and drilling was abandoned when bedrock was not encountered at the projected 100-foot" depth,

Another Stringfellow contractor was unable to analyze depth-specific samples of the plume to determine its extent because its laboratory could not perform the appropriate analysis of total organics. As a result, information showing the three-dimensional extent of the plume and the areas with the highest concentration of contaminants is not available. The expense incurred in designing and executing an elaborate drilling procedure to obtain the data was wasted. This waste might have been avoided if EPA had verified the contractor's laboratory qualifications before awarding the contract and if EPA had required collection of two samples and the use of a backup laboratory.

Optimistic Assumptions

In all three case studies that OTA examined, a tendency towards optimistic assumptions about site conditions and remedial technologies was evident. At Stringfellow, for example, optimism about containment has prevailed despite mounting evidence that the site is fundamentally unsuited for this strategy. At Seymour, removal of a limited amount of soil was deemed adequate, without testing for residual contamination. (Contaminated surface water runoff indicates that significant amounts of contamination remain in the soil at the site.) At Sylvester, the figure adopted for the amount of waste deposited at the site might be a significant underestimate. Finally, the pervasive preference for containment as a key festure of remedial cleanups at Superfund sites is based on an optimistic assumption of doubtful validity about the long-term effectiveness of this technology.

Constraints on Superfund Contractors

Several Superfund contractors have expressed concern over the direction of the program and the structure of the remedial response under the NCP. These engineering firms complain of the lack of clear goals for cleanup design (see chapter 4). Lack of explicit cleanup standards or guidance from EPA makes it difficult for engineering firms to perform their assignments, such as comparing the relative cost effectiveness of remedial alternatives. According to one major Superfund contractor:

> [Engineering practice needs the law to require the use of engineering criteria and standards on which to base the extent and cost effectiveness of a remedial action.[4]

A representative of CH2M Hill, one of EPA's major Superfund contractors, testified that the lack of cleanup standards makes evaluating the suitability of alternative treatment and destruction technologies difficult:

> There are a wide variety of existing and promising technologies that might be employed to destroy hazardous contaminants . . . There are few design and performance criteria against which the technologies might be tested. In other words, we *do not have any reliable performance standards or risk assessment methodologies that we can use to determine whether or not a particular technology performs well enough to be applied to a specific site* [emphasis in the original]. It is very difficult to determine whether a particular technology will clean up a site if we have not defined what "clean" means. s

The cost-balancing test for remedial actions also poses difficulties for engineering contractors:

> The practice of "balancing" site-specific engineering issues, such as cleanup criteria, with external factors, such as availability of money and the remedial needs of other sites, hinders effective engineering efforts. We have found that this balancing requirement poses several problems for engineering firms trying to develop and implement an adequate cleanup plan. First, it is difficult to judge the cost-effectiveness of different plans without site-specific standards. Second, it is difficult to determine what a site can be used for after it is "cleaned up" if such standards do not exist. Third, the absence of standards can often delay a response action. Fourth, a remedial action lacking specific standards is not generally trusted by the public.[6]

Some consultants have noted that institutional tensions in the program favor the selection of impermanent remedial alternatives. A representative of the Hazardous Waste Treatment Council made the following observations about problems in the use of the cost-balancing test in the implementation of Superfund:

> The situation can best be described as one which results in the overdesign and evalua-

[4]Gary Dunbar, Camp Dresser & McKee, statement in *Hearings on the Implementation of the Superfund Program Before the Subcommittee on Commerce, Transportation and Tourism of the House Committee on Energy and Commerce*, 98th Cong., 1st and 2d sess., 1984. (Hereafter referred to as Hearings on Superfund Implementation.)

[5]William A. Wallace, statement during *Hearings on Superfund Implementation*.

[6]Dunbar, *Hearings on Superfund Implementation, op. cit.*

> tion of short-term cleanups; cleanups which will likely require additional future remedial action.[7]

The current process for assessing remedial alternatives seems to be producing a "least cost" preference for containment approaches using slurry walls and caps—despite the fact that containment is not a permanent solution. Nor are these techniques appropriate for some hydrogeological conditions, According to congressional testimony, construction of a slurry containment wall at $3 million was selected as the remedial alternative at one unnamed NPL site in New England. Further site analysis has determined that a more cost-effective approach would be to install an onsite system to treat, rather than contain, the wastes at an additional cost of $4 million, The treatment option would have initially cost $1 million more than containment, "but in the end would have saved approximately $3 million. "[8]

Another adverse impact of the balancing test, in some opinions, is the trend toward employing remedial options with high operation and maintenance (O&M) costs, e.g., dyking and counterpumping for long periods of time. These options may have low initial construction costs, but have high, and perhaps indeterminable, O&M costs. These are paid by the States rather than the Federal Superfund. In most cases these strategies are not a truly permanent remedy to the threat posed:

> The "balancing test" issue is fundamental in both nature and choice: the fund can either be used to temporarily contain many sites at a lower short-term cost or be used to permanently remove site hazards from posing future threats to health and the environment at a higher short-term cost. It is a most difficult issue, but perhaps the most critical one on which Congress must act.[9]

The artificial segmentation of projects into emergency actions, removal actions, and remedial actions, or into surface and subsurface remedial actions, also poses difficulties. A contractor is asked to look only at part of the problem and can expect to be responsible for that segment only. This limited focus may preclude consideration or design of more comprehensive and effective cleanups. Not taking a comprehensive environmental systems approach to releases has also limited the effectiveness of engineering consultants in designing a remedial alternative appropriate for site conditions. It is very unlikely that a single engineering contractor will work on a site from initial response through completion of remedial construction. This switching of firms for successive phases of one project and without clear cause differs remarkably from what generally occurs in other large engineering projects.

OTA found that contractor assessments of remedial alternatives were very limited in scope. Certain remedial alternatives were excluded from detailed feasibility analysis for cost or policy reasons. This may contribute to the ineffectiveness of some remedial actions. In all three case studies (Stringfellow, Seymour, and Sylvester) the cost effectiveness, long-term reliability, and risk equity of removing wastes from the site and redisposal elsewhere was given little or no analysis in EPA or contractors' documents.

OTA's Seymour case study concluded that government contractors at the site generally performed satisfactorily within the scope of what they were asked to do. However, the report found that limitations on the amount of money available and restrictions on its use (i.e., no offsite material disposal) may have hampered their effectiveness,

At the Stringfellow site, pressures from EPA regional and headquarters officials may have precluded serious consideration of site excavation and removal of the wastes, contaminated soil, and groundwater followed by onsite or offsite waste treatment and/or destruction, Yet, in this case, extremely complex and unfavorable hydrogeological conditions would make any successful containment option difficult if not impossible; removal of the materials from the site might be the only effective option.

[7] *Hearings on Superfund Implementation.*
[8] Ibid.
[9] Richard Fortuna, testimony during *Hearings on Superfund Implementation.*

The Stringfellow fast-track feasibility study completed in 1984 was the basis for selecting an interim remedial action to pretreat contaminated groundwater onsite. The contractor warned of possible problems with this option. Because of the lack of water sample testing, there exist "extremely significant" uncertainties in the quantity of water to be treated, its characteristics, and response to treatment. These uncertainties may cause major revisions to cost estimates and projections of the treatment's effectiveness. The contractor is now proceeding on bench-scale treatability studies that will shed some light on these uncertainties, but EPA appears to have no plans for a pilot facility on the site. Reliance on bench-scale work to adequately resolve uncertainties may be overly optimistic. This interim action appears to be an attempt to respond to public pressure rather than being a thorough engineering solution.

The full site investigation and feasibility study for Stringfellow is now underway and is scheduled to be completed in mid-1985. A review of the contractor's proposal, approved by EPA, indicates that the scope of remedial alternatives to be considered focuses on containment strategies and excludes several important permanent remedies. The feasibility of removal may not be examined and, hence, not considered as a permanent remedy. The option of building an onsite treatment facility for contaminated materials may also not be considered.

EPA's current preference in the Stringfellow RI/FS would leave the contaminated soil and water at the site and control the inflow of groundwater upgradient by hydrofracturing the bedrock, which is an untested and unproven technique for this application. It would also use conventional containment systems. An onsite, permanent water treatment facility would be built to control the hazardous constituents leached from the site into groundwater.

OTA's study found that the proposed RI/FS did not attack the source of the problem: the buried wastes and contaminated soil. Removing the source of contamination is not taken seriously in the proposal. Emphasis is on dealing with the effect rather than the cause of the problems, with consideration given only to containment methods similar to those that have been unsuccessful before at this site of complex geology,

EPA has issued guidance documents to its contractors to help them prepare site assessments that will be used *to* select remedial alternatives. The use of guidance manuals suggests the beginning of some degree of uniformity and consistency in work being done by EPA contractors. The manuals call for extensive policy-related technical judgments by the technical personnel on matters such as the seriousness of site contamination and the relative effectiveness of alternatives. But the technical judgment of contractors is limited in other areas such as the suitability and reliability of particular remedial technologies. The guidance documents do not yet include information to accommodate changes in setting a cleanup standard for remedial alternatives under the proposed NCP revisions. It is thus possible that a significant number of sites moving through the RI/FS and remedial design phases will not be consistent with the new policy. It is not known whether these site assessments will be required to be redone, or if remedial actions will proceed, perhaps with inconsistent and less stringent standards of protection.

Effects of Early Responses on Long-Term Remedies

OTA has found that most emergency responses have worked well where materials were *removed* from the site because of immediate threats. When immediate removal actions consist only of waste containment, which they often do, the site may get worse over time and require repeated removal actions. Actual removals, however, pose questions about the long-term adequacy of redisposal sites and the transfer of risks, The Superfund program management has put little emphasis on inter-site problems.

Onsite emergency responses to contain wastes temporarily and control contamination have not advanced permanent cleanups and in some cases have exacerbated conditions at the site. Often, "cleanup" is used to describe a limited action.

At Stringfellow and Seymour, initial actions have not been effective because contractors misinterpreted site conditions and applied inadequate control measures. Lack of quality supervision in building and designing these controls may also have contributed to their failure, Total cleanup involving removal of wastes, site decontamination, and groundwater treatment was advocated at an early stage, However, because of the cost involved, this prompt remedial action was rejected in favor of partial removal, temporary containment, and further study. Delays let the plume of contaminants spread substantially increasing the amount of contaminated soil and groundwater to be dealt with in later remedial actions at greater expense.

In *1982,* construction was completed on interim abatement measures for the Stringfellow site that were originally proposed in 1977 and approved in 1979. Some contaminated waste liquids and contaminated soils were removed. The site was excavated, bedrock fractures were grouted, kiln dust was mixed with the waste and soil to neutralize it, and the site was covered with a clay cap and regraded. A series of monitoring and interceptor wells were installed to deal with groundwater contamination. Contaminated groundwater is continuing to be pumped from the wells and shipped offsite to RCRA hazardous waste facilities for disposal. The emergency and interim cleanup actions taken to date at Stringfellow have alleviated immediate threats of floods and sudden catastrophic failure of the site impoundment, but they have been largely ineffective in protecting the water supply of the nearby community of Glen Avon from surface and subsurface contamination. Some of the interim control strategy measures exacerbated soil and groundwater contamination.

At the Seymour site the initial response in 1981-82 included: 1) security fencing, spill cleanup and removal, restaging about 45,000 drums, constructing a berm around the drum storage area to retard surface contamination (all typical immediate removal actions); and 2) building a rudimentary surface water pretreatment system consisting of an interception pond and two large concrete pipes filled with activated carbon to treat contaminated surface water runoff before it entered the municipal sanitary sewer system. Some actions prior to the actual surface cleanup were relatively ineffective and may have hindered the cleanup, since the structural integrity of the drums was reduced. At least one contractor study of one site found that the bermed area was a source of soil and water contamination. The impact of the initial response actions on the cost of the surface cleanup, however, was slight.

Design and Construction of Remedial Measures

The effectiveness of a cleanup depends on the remedial alternative selected. An ineffective remedy properly designed and built is still ineffective. However, effectiveness also depends on the quality of design and construction of the chosen alternative.

OTA's Stringfellow case study found several inadequacies in the design and construction of site control measures. Problems in construction of the Stringfellow interim abatement program were not corrected by State and Federal supervisors overseeing construction, For instance, during work at the site, underground springs were observed. The fact that these springs would cause leaching of materials left in the ground does not appear to have caused the site cleanup approach to be reevaluated. Kiln dust was mixed with soil to reduce the acidity of the waste, but its effectiveness could not be determined because no background testing was done on the soil before the addition of the kiln dust. The kiln dust may therefore only have added to the bulk of contaminated material onsite. The clay cap does not appear to have been installed as designed and consequently may be of limited value. Because the construction contractor used local materials instead of imported clay, it is not certain that the site does in fact have a clay cap. Surface water intrusion into the ground was exacerbated because the cover was built concave instead of convex because there was not enough material available to create the proper shape. Instead, drainage ditches were installed near the bottom of the cover. The site was not promptly seeded and rain has eroded the cover.

The Sylvester slurry wall and cap completed in 1982 have not contained the flow of water to the degree predicted. A hydrogeological study is underway to evaluate this problem. Building a slurry wall around the 20-acre site to a relatively unprecedented depth of 100 feet to retard the spread of contamination in unconsolidated glacial material over fractured bedrock was a bold engineering initiative. Because of the unprecedented construction involved, care was exercised in onsite supervision of slurry wall installation, but nonetheless the containment is less effective than predicted. State officials believe that most of the leakage is attributable to highly fractured bedrock. Another cause for leakage may have been construction problems in the installation of the wall, In addition, laboratory studies gave early indications that contaminants in the groundwater could degrade the slurry wall material, increasing its permeability, Based on hydrogeological modeling, State officials reject the possibility of leakage through the wall. The effectiveness of the slurry wall over time is highly dependent on the quality of initial construction and the length of time during which the wall must maintain its integrity. No containment system has been proven effective for long periods of time,

At Sylvester, the cap design and construction may be inadequate for the *long-term* maintenance of a surface seal over the site. Specifications for cap design, such as topsoil thickness, and drainage layer permeability, appear to be less stringent than that recommended for RCRA land disposal facilities.

Implications for Future Superfund Strategy

As seen in the case studies, the cleanup of uncontrolled hazardous waste sites poses many new technical and institutional challenges. The economic and environmental costs of inadequate assessment of site conditions, of delays, and of impermanent remedies can be substantial. Public expectations of progress in site cleanup have been high, but the rate and success of cleanups have been disappointing. Public confidence in a renewed and expanded cleanup program can be improved if lessons are learned from past experiences and incorporated into a long-term strategy for permanent cleanups that effectively protect public health and the environment.

Difficulties can be expected in the implementation of the Superfund remedial action program and in the assessment, design, and construction of remedial measures. There are many reasons why such difficulties will occur. Some circumstances are inherent in the program and cannot be avoided, but they can be anticipated and dealt with through effective contingency plans.

There are significant uncertainties and gaps in knowledge about site conditions, nature of hazards, environmental fate, interaction of substances, and hydrologic characteristics and behavior at sites. As more experience is gained and more research is done, some of these uncertainties will be reduced. But to a large degree, cleanup decisions, early or late, will always be based on incomplete information.

Complex situations at Superfund sites require specialized and sometimes novel or experimental approaches to achieve permanent cleanups. Because of this, the possibility or probability of failure must be given greater consideration in the design and selection of cleanup approaches. The concept of an "Impermanence Factor" used in chapter 3 could be further developed by EPA. Means to measure the performance and efficacy of remedial actions and assess the availability and feasibility of later corrective actions should be given greater attention. Where appropriate, cleanup goals and specifications might provide for an adequate margin of safety because of the risk of failure.

No proven technological solutions exist for many of the conditions present at uncontrolled hazardous waste sites. Despite this, construction projects at remedial sites have been treated as routine public works projects rather than as experimental or demonstration efforts. Technologies that may be proven for some applications are not necessarily proven for dealing with uncontrolled site problems.

For example, some containment strategies being applied to uncontrolled sites, such as slurry walls, were not originally designed to control mobile, highly reactive hazardous substances in soil and groundwater. The long-term effectiveness of these containment under Superfund conditions remains to be demonstrated. Methods must be established to monitor the performance effectiveness of such control measures. Moreover, reliance on groundwater monitoring alone also poses some problems, and so far, the success and effectiveness of this strategy has been poor at RCRA facilities.

How can problems be avoided when there are no specific criteria against which to measure the cost or technical effectiveness of alternatives? The determination of relative effectiveness (more a cost-benefit analysis) is left to the subjective judgment of individual contractors preparing background studies. Nor has any mechanism been established to let us learn from mistakes, so they are not repeated, *An overemphasis on the uniqueness of each uncontrolled site has resulted in very little collection of information for the national program*. Information and technology transfer among contractors, EPA, and States appear minimal. Yet the guidance documents encourage an approach of selecting the alternatives to be analyzed from a list of approved technologies (for the most part containment and land disposal). The suitability of site conditions for alternative technologies is inadequately considered, This is, of course contradictory to the "each site is unique" perspective, but might be the result of attempts to speed program progress and compensate for inexperienced personnel.

The Superfund program as currently structured and administrated seems poorly prepared to assume greater responsibility as the number of NPL sites increases and as many sites progress from site assessment to remedial design and construction. The whole cleanup program seems to assume that sites move smoothly through the process from site investigation to remedial design and construction and that there is little possibility of failure or mistakes, The history of site remedial actions contradicts this assumption. Design and construction of remedial actions are not predictable, routine engineering or construction projects and should not be managed that way. Some aspects of remedial action will always pose great uncertainties, but experience shows that these can be anticipated, The challenge is to build a Superfund program that can accommodate both the controllable and the uncontrollable.

AN EXPANDING PROGRAM'S NEED FOR TECHNICAL OVERSIGHT

Effectiveness of Contractor Oversight

The quality of work at Superfund sites depends largely on effective management of contractors. For cleanups performed by responsible parties, technical oversight by EPA is also needed. Three aspects of cleanup supervision are important: technical direction, oversight, and continuity, Contractors must be given a technically adequate scope of work, performance must be monitored to assure compliance and to allow modification of scope or effort if conditions change, and there must be some continuity of oversight for long-term contracts and multiple contractors at a site. Technical supervisors must have an appreciation of the complex and often unprecedented work they are overseeing. OTA's Stringfellow case study found that the State and Federal people involved with the day-to-day operations were mostly young engineers with relatively little experience in hazardous waste management. Without technically competent and experienced site supervisors, contractors are relied on to assure the quality of their own work. Outside review can also be used, but, as discussed in chapter 8, opportunities for effective technical review of site studies and selected remedies by the public and by potentially responsible parties are limited. The short amount of time available for review and comment and the lack of independent technical assistance for community groups limit the utility of outside review as a quality control measure for Superfund contractor performance.

Assuring continuity in oversight of remedial work appears to be an emerging problem, and there is a very high turnover in agency staff responsible for onsite coordination of contractor activities. OTA has been told by several EPA on scene coordinators (OSC) that they do not expect to be at the site when the evaluation is complete because they expect a reassignment or promotion to a more responsible position in Government or an outside job offer, High turnover rates increase the possibility that work will be repeated needlessly because of the lack of institutional memory. Management of an expanding Superfund cleanup program should therefore anticipate high employee turnover and adopt measures to minimize its impact.

OTA found that multiple contractor studies at a single site frequently yielded conflicting conclusions. Examples from OTA's case studies are summarized in table 7-1. The record does not indicate specifically how government technical site supervisors responded to these inconsistencies or even if they were aware of them. However, at Stringfellow, failure of government or contract personnel to recognize the implications of conflicting conclusions and assumptions in a timely manner may have contributed to the selection or construction of ineffective remedial measures at considerable cost.

To be effective, the remedial response process (particularly at the design and construction stages) must have the capability to be more flexible and responsive to new information or better interpretations about actual site conditions, even if these contradict earlier assumptions. This requires vigilance on the part of the site contractors and the government cleanup supervisors,

A Larger Program

The number of remedial actions under the Superfund program will increase substantially. New sites are being added to the NPL and more and more sites already on the NPL *are moving* from the initial study phase toward remedial design and construction. Cleanup at many of these sites may take years, Responsible parties also are initiating more private cleanups. As the level of activity increases, so will the need for additional qualified and experienced staff at the State and Federal level to design and implement an expanded program, to make judgments on cleanup goals, to support enforcement efforts, and to supervise work by government contractors and responsible parties. To be successful, the program must have adequate, experienced staff to provide sound management and technical oversight.

EPA's current staffing levels appear to be too low to provide effective oversight of the rapidly expanding number of sites requiring remedial action. Moreover, EPA has identified several institutional constraints on its ability to expand its program quickly. EPA has projected that States may take over management of as many as half of the NPL site cleanups. However, many States lack the needed technical and administrative personnel to support Superfund cleanups. Where money is available, States report delays in obtaining qualified technical specialists,

There are several reasons to question whether the Superfund program can effectively man-

Table 7.1.—Four Examples of Inconsistencies in Reported Site Characteristics

Site/location	Factor	Values reported	Contractors	Type work performed	Date reported	Impact
Chem-Dyne, Hamilton, OH	Linear velocity of groundwater	1.71 ft/day	E&E	EPA field invest.	June 1982	Speed of movement of contaminated groundwater underestimated originally. Might have influenced decision on when action needed.
		2.8 ft/day	Weston	Preliminary feasibility investigation	June 1983	
Stringfellow, Glen Avon, CA	Linear velocity of groundwater	0.6 ft/day	Neste, Brudin &. Stone	Regional Water Board study	June 1973	Rapid movement of contamination by groundwater rather than surface water not realized until after failure of containment techniques. Effective remedial action delayed.
		3.5 ft/day	CH2MHill	EPA RI/FS study	April 1984	
	Nature of bedrock	Solid	Neste, Brudin & Stone	Regional Water Board study	June 1973	
		Fractured	James M. Montgomery		December 1979	
Seymour, Seymour, IN	Nature of site subsurface	Permeable	ES&E	Coast Guard study	February 1982	If subsurface is permeable, much contaminated soil left onsite and continued water intrusion causes further groundwater contamination.
		Impermeable	Canonie Environmental Services	Responsible parties study	July 1982	

SOURCE Office of Technology Assessment, based on data in various reports age and oversee even current NPL site cleanups, let alone an expanded number of cleanups,

First, progress to date has been slow. Certainly one reason for this has been the inherent delays in starting a new program, developing procedures, identifying sites, and conducting preliminary site assessments. The Superfund program has also changed policy direction over the relative priority of fund-financed cleanups and enforcement, However, there is reason to suspect that EPA may fall short of meeting its *currently* projected cleanup goals. At the end of fiscal year 1984, EPA reported some form of remedial activity was underway at about 30 percent of NPL sites, however, site remedial *construction* had started at only 50 sites, a relatively small number of the 552 NPL sites, The number of sites where cleanup is considered *complete* or where a permanent long-term remedy is under construction is relatively low, Many remedial actions announced so far are temporary or interim remedial measures that will need further work or nonremedial measures, such as supplying alternate drinking water, intended to remove an immediate threat of exposure to hazardous substance releases. Moreover, as discussed in chapter 1, the adequacy of remedial action at several of the "completed" cleanups is under question.[10]

Detailed information on EPA cleanup activities at Superfund sites is not easily obtained. One of few publicly available summaries tracking Superfund cleanup progress at individual sites is The National Campaign Against Toxic Hazard's recently published "Assessment of Cleanup Progress at Superfund Sites.''[11] This report documents the status of remedial activities at 343 NPL sites in 19 States as of mid-1984 based on EPA data and a phone survey of EPA site project officers. (According to the Campaign, detailed information on the remaining 209 sites was not available for study because of problems with EPA's computerized site tracking system.) Table 7-2 shows the *latest* stage of remedial activity for the 343 sites surveyed as of July 1984,

Remedial Investigations and Feasibility Studies were underway or complete at about 44 percent of the sites. These stages are the beginning of the Superfund "pipeline. " However, only 14 percent of the sites in the survey have advanced to remedial design (seven sites) or remedial construction (42 sites]. Responsible party cleanups, rather than fund-financed cleanups, account for about half of the 42 sites where a long-term remedy is being implemented. The report found that some form of

Table 7-2.—Status **of Cleanup Progress, July 1984**
(343 NPL **sites)**

Latest stage of remedial activity[a]	Number of sites at stage	Percent of sites at stage
No site activity[b]	96	28-
Immediate measures only[c]:		
Complete ., ...	27	8
Underway	19	5
Total	46	13%
Remedial Investigation (RI):		
RI complete ., ...	5	
RI underway. ., ...	77	23
Total	82	240/o
Feasibility study (FS):		
FS complete ., ., ...	25	7
FS underway	45	13
Total	70	20%
Remedial design (RD)[d]:		
RD complete ... ., .	2	1
RD underway	5	1
Total ., ...	7	2%
Remedial construction (RC)		
RC complete, delisted . . .,	2	1
RC complete	4	1
RC underway	36	10
Total	*42*	12“/0
Grand total	343 sites	100%

[a]Number of NPL sites at this stage of remedial activity in July 1984 This is not the *cumulative* number of sites at which this stage has been completed or initiated
[b]No activity means neither immediate measures nor studies have been started at these sites Studies or response activity *before* the site was listed on the NPL are not included Some no activity sites have had remedial action master plan (RAMP) studies completed; RAMPs are low cost (about $25,000) summaries of available information on the site RAMPs were recently discontinued
[c]Immediate measures include removals that were taken *after* the site was listed on the NPL Not all NPL sites require immediate measures
[d]Sites proceed to the remedial design stage after selection of an appropriate remedy based on the RI/FS Selection of an appropriate remedy is documented in a Record of Decision (ROD)

SOURCE Office of Technology Assessment from National Campaign Against Toxic Hazards, 'An Assessment of Cleanup Progress at Superfund Sites, " September 1984

[10]See also Richard C. Bird, Jr. and Michael Podhorzer, "Evaluation of the Six National Priorities List Sites Delisted by the Environmental Protection Agency', National Campaign Against Toxic Hazards, Oct. 24, 1984.
[11]Dana Tulis, Henry S. Cole, and Michael Podhorzer, "An Assessment of Cleanup Progress at Superfund Sites, " National Campaign Against Toxic Hazards, September 1984.

onsite cleanup work, either immediate measures and/or long-term remedial construction, had occurred at 147 of the 343 sites. (Immediate measures at 105 sites; remedial construction underway or complete at 34 sites; eight sites had both immediate measures and remedial construction.) Some sites with immediate measures have progressed to later stages of remedial activity as shown in table 7-2. No onsite cleanup had occurred at 196 of the 343 sites surveyed (57 percent). There were 100 sites with studies only and 96 sites with no remedial activity at all.

Based on EPA records, the Campaign was able to assess the cleanup progress through the end of fiscal year 1984 for all 552 NPL sites (including six delisted sites where cleanup is completed), The group found that there has been no onsite cleanup (either immediate measures or remedial construction) at 332 NPL sites. Some form of remedial action (RI/FS, design, or construction) had begun at 120 sites. There were immediate measures underway at 100 more sites.

The Campaign's study focused on the stage of remedial activity at NPL sites and did not examine what kinds of remedial activities were occurring and whether the remedies would provide effective long-term control of threats to human health and the environment. OTA's own review of EPA Records of Decision (RODS) for remedial actions at NPL sites and the site activities described in the Campaign's report suggests that both the EPA and Campaign figures overstate the progress made in cleaning up Superfund sites. Many of the remedial actions taken do not represent a final or permanent remedy providing for the removal, destruction, or treatment of the wastes and the decontamination and, where feasible, restoration of the site. Such remedial actions require more technical oversight than the early measures that now account for most program activity. (See table 7-3 and the discussion in chapter 2 of this report,) Of 24 RODS reviewed, 10 were for initial remedial measures to deal with immediate problems at the site. Of the 14 remedial actions, six involved complete or partial remedies with additional measures to effectively deal with site releases and contamination still under study. Three remedial actions provided for replacement or treatment of the threatened water supply; three others involved only partial or surface removals with source control measures. Only eight sites had a final or permanent remedial action underway (these eight are in addition to the six sites where EPA says cleanup has been completed). The RODS indicate that completion of remedial construction at many sites will not result in site cleanup or a final remedy, Additional remedial activities at these sites may continue for years or may be required at some later time.

It may take many years for cleanups at current NPL sites to be completed and varying degrees of oversight and activity will be required for the duration of each cleanup. At the same time, more and more sites can be expected to

Table 7.3.—Summary of Remedial Cleanup Approved, 1981 to mid-1984

Cleanup actions approved	Number of decisions a/	Initial remedial actions b/	Remedial actions	Final remedies c/
Removal/offsite disposal with/without source control	14	6	8 d/	5
Off site removal with incineration	1	0	1	1
Alternate water supply provided	3	1	2	0
Alternate water supply and treatment e/	2	1	1	0
Treatment f/	2	1	1	1
Source control and onsite treatment	2	1	1	1
Totals	**24**	10	14	8

a/ Total includes two sites and two RODS each which are combined in the above table
b/ Includes planned removals
c/ Final remedies are remedial actions that are intended as the last action at the site and that, If successful, wi II effectively control releases from the site
d/ Includes three partial remedial actions, e g , surface cleanup, additional remedial measures are still under review
e/ Includes treatment of contaminated drinking water
f/ Includes treatment of contaminated groundwater

SOURCE Of fice of Technology Assessment

enter the system. The RI/FS process can take up to 18 months to complete, remedial designs take 9 to 12 months. The whole pre-construction process can take 3 years once activity has begun and without any other delays. A range of from 2 to 5 years from site investigation to completion of construction. Complex sites, particularly those with extensive groundwater contamination, will require more time to assess, and to design and construct a remedy. Operations, maintenance, and monitoring could continue for 20 to 30 years or more at sites with significant groundwater contamination and cleanup. There will be a continuing long-term need for technical oversight and monitoring at a large number of sites.

The rate at which EPA has been able to obligate and spend Superfund appropriations gives some indication of the agency's ability to handle a greatly expanded program. Only a small percentage of funds obligated for remedial action actually has been spent on construction of long-term remedies. *With two-thirds of Super fund's $1.6 billion obligated, the resources of EPA and State agencies may not be adequate to manage an accelerating rate of cleanup activities, even if only for a 2,000 site NPL.* There appear to be significant delays in moving sites from the study stage to construction. A major portion of the $1.6 billion Superfund appears to have been obligated for initial contractor assessments and administrative expenses, creating the probability that the program will need very large amounts for remedial construction and, hence, oversight in the future.

The Campaign found that for 343 sites surveyed, over $100 million had been obligated for remedial actions out of a total of over $236 million in Superfund obligations in those 19 States. Less than half of the remediaI action obligations were for construction. Of the total monies obligated, $44 million had been paid out (see table 7-4).

The slow rate of cleanup and the small portion of obligated funds spent on remedial construction suggests that EPA and State agencies may not have sufficient resources or personnel to carry out the process efficiently. EPA officials have admitted that the frequent switching of project officers has been a problem in maintaining the momentum of cleanup activities. Retention of experienced, qualified cleanup supervisors was also identified as a problem in OTA's case studies.

Table 7-4.—Superfund Obligations and Expenditures, 19 States, July 1984

State	Number of sites	Remedial" act ions funds obligated	Total fund obligated	Total funds expended
California	19	$25,478,390	$37,867,020	$1,010,047
Connecticut	6		1,369,000	49,965
Florida	29		6,390,828	1,766,279
Illinois	11	0	4,069,291	678,855
Indiana	17	0	3,911,401	307,519
Iowa	3	0	2,187,014	1,075,276
Maine	5	0	1,639,932	90,306
Massachusetts	15	8,121,800	17,415,68	2,241,413
Minnesota	23	0	5,903,543	908,517
New Hampshire	10	10,007,018	13,605,340	4,719,449
New Jersey	85	17,885,809	55,004,130	7,049,176
New York	29	11,702,800	31,173,799	8,373,695
North Carolina	3	2,374,176	2,364,176	2,364,176
Ohio	23	3,191,125	9,787,656	5,394,571
Oregon	3	0	139,000	2,266
Pennsylvania	40	11,440,400	23,575,534	4,110,486
Rhode Island	6	5,043,570	5,766,831	2,373,831
Vermont	2	0	360,000	0
Washington	14	5,000,00	13,820,269	2,346,767
19 State total	343	$100,235,088	$236,350,445	$44,862,594

SOURCE : Natinal Campaign Against Toxic Hazards, An Assessment of Cleanup Progress at Superfund Sites, September 1984 at 14

EPA Staffing Needs

The pace at which Superfund remedial actions are moving through the system suggests that *current* staffing levels are not sufficient to support *current* Superfund activities. This is shown by the lag between the number of sites with RI/FSs and the number of sites where construction is underway and by the percent of obligated remedial action funds that have been spent (see tables 7-2 and 7-4). The problems with effective technical oversight of EPA contractor work revealed in OTA's case studies is another indication that EPA staffing may not be adequate either in the number of technical staff assigned to a site or in the qualifications and experience of those employees.

EPA has greatly expanded the number of employees allocated to the Superfund program. Administrator Ruckelshaus testified that the hiring rate for Superfund is now at the highest level that EPA has ever experienced.[12] EPA's authorized Superfund employment has been increased from 774 workyears in fiscal year 1983 to 1,357 in fiscal year 1985, This staffing level is needed to support currently planned activities for only a moderately increased program, With this staff, EPA estimates that it could support about 115 sites in the RI/FS stage per year, EPA expects that a total of about 200 sites will reach the remedial design and construction stage at the end of fiscal year 1985 (including 68 new designs and 46 new remedial cleanups). About 150 immediate removals are also projected for fiscal year 1985. By the end of fiscal year 1986, some kind of remedial response would have been started at about 400 existing NPL sites. After that, the number of sites in various phases of response would remain fairly constant. EPA has said that there may be an upper limit of about 600 NPL sites that EPA can effectively deal with at any one time. This includes overseeing removals, RI/FSs, and remedial design and construction.[13]

EPA officials are concerned that the agency may not be able to quickly absorb a significantly expanded number of cleanups even if additional funds were made available for more staff. They have identified the following limitations on the agency's capacity to expand:

1. Superfund staff and resources are already expanding at an exceptional rate to manage projects already in the pipeline,
2. The Federal Government's competitive hiring regulations would delay the hiring and housing of additional new employees 6 to 8 months at a minimum;
3, Intensive training would be required before the newly hired staff would be fully effective—at least 2 to 3 months on-the-job training for nontechnical personnel and considerably longer for technical personnel.
4, The private sector support industry for Superfund would not 'be able to expand rapidly enough to allow effective use of a larger work force for several reasons. The analytical laboratory industry, already operating near capacity, is unlikely to increase its capacity for organic sample analysis and high hazard sample analysis at a correspondingly rapid rate. Lead time for procuring additional, highly specialized equipment is up to 6 months. It could take years to find, hire, and train competent technical staff.

Administrator Ruckelshaus argued that too rapid an expansion risked increased potential for fraud, waste, and abuse:

> Too large a program pushed at too rapid a pace could create excessive public expectations that even with the best of management and will could not be met. The result could be—could be—one more case of disillusionment with the ability of Government to protect and serve the public responsibly.[14]

EPA's claimed inability to expand maybe a consequence of its own policies: Moreover, the constraints cited by Mr. Ruckelshaus are pri-

[12] *Hearings on HUD-Independent Agencies Appropriations, 1985-Part 1, Before the Senate Committee on Appropriations,* 98th Cong., 2d sess., 1984, pp. 302.

[13] Lee Thomas, statement before the Environmental Law Institute-American Bar Association Superfund Conference, NOV. 29, 1984.

[14] *Hearings on Superfund Reauthorize tion Before the Subcommittee on Commerce, Transportation and Tourism of' the House Committee on Energy and Commerce,* 98th Cong., 2d sess., 1984, pp. 725-26.

marily short-term constraints of perhaps a year or two, Some of EPA's statements seem to assume that Superfund staffing will not increase much over currently projected levels. This assumption may reflect budget policies more than actual experience or actual need. EPA has been able to accommodate the significant spending and hiring increases in the Superfund program of the last 3 years, albeit with some inefficiencies, The capacity—and, more importantly, the quality—of the private analytical laboratories to accommodate increased need for chemical analysis for cleanups is a matter that merits further investigation.

Another assumption in EPA's projections for only modest additional Superfund expansion seems to be that sites are dealt with expeditiously and will not require further attention after the 2 to 5 years needed to complete remedial construction. This view does not reflect the impermanent nature of many remediaI actions or recent experience with cleanups. Perhaps EPA is assuming that the States will be able to take over all oversight of sites with completed remedial construction. If this is so, then State staffing needs will continue to grow, and probably will be largely unmet. Without increases in staffing and resources for Superfund cleanups, it could take decades to dispose of the large number of known sites that are anticipated to require remedial action, The 10,000 site NPL seen possible by OTA (see chapter 5) would clearly require decades under almost any conceivable program,

OTA does not have information on specific EPA personnel needs for an expanded number of remedial actions under Superfund, The long-term nature of cleanup actions suggests that long-range planning for hiring, training, and retaining qualified technical personnel to oversee cleanups is warranted, Existing information provides some indication of the magnitude of future staff needs. EPA estimates that it requires 2,8 staff workyears to complete a Superfund remedial action, ” Given the complexity and long-term nature of many site cleanups, this estimate may be low for both the duration of site activity and the level of management required. One State Superfund agency representative has advised OTA that most sites require a team of several technical specialists from various disciplines over the 2 to 5 years required to oversee site activities from initial investigation to completion of all construction. (This would suggest a modest estimate of from 4 to 10 staff workyears per site.) More complex site cleanups would require a larger team and probably more time. Post-construction operations, maintenance, and monitoring of the site will present a continuing need for oversight.

OTA's review of technical personnel availability later in this chapter estimates that there are about 3,750 technical specialists currently working on Superfund cleanups both inside and outside of government. There were an estimated 1,000 Federal and 700 State staff positions (including administrative and technical jobs) for Superfund and other remedial activities in 1984. Not all of these people are directly involved in site activities and so total Superfund program employment may not have to increase in direct proportion to the growth in cleanup expenditures. Assuming that site personnel currently represent one-half of government positions at most, this ratio would suggest that government employment would have to increase significantly to accommodate an expanding number of cleanups. OTA has estimated that overall demand for technical personnel could grow to about 22,750 specialists in 1990-95 under a moderately expanded level of funding for cleanups.

New State and Federal positions for technical specialists to supervise site cleanups will likely represent a significant share of this increased demand. Even with a significant expansion in State and Federal technical personnel to direct and oversee site cleanups, the Superfund program will still depend to a great degree on private contractors for site assessments, design, and construction of remedial actions for decades.

[15] Donald Lazarchick, ASTSWMO, testimony at *Hearings on Superfund Reauthorization Before the Subcommittee on Commerce, Transportation and Tourism of the House Committee on Energy and Commerce*, 98th Cong., 2d sess., 1984, pp 536.

State Staffing Needs

State agencies have repeatedly testified that they do not have enough qualified and experienced staff available to meet their responsibilities under the *current* program for identifying and ranking sites, consulting with EPA on site activities and enforcement, and in participating as the lead agency at some sites. Although some Federal funds are available to the States, they are limited and almost entirely site specific. States vary in their ability and willingness to provide funding for these activities. Remedial staff and funding are concentrated in a small number of States. Massachusetts, Michigan, California, New York, New Jersey, and Tennessee accounted for over 60 percent of positions in 1983 and 70 percent in 1984. These States have a total of 201 sites. On a national average, nearly 75 percent of the positions are paid for by State monies and about 25 percent are funded by Superfund or other Federal sources. The percentage of Federal funding, however, varies greatly by State.

Reliance on State funding for their own staffs leaves 20 States being able to devote less than 2.5 person years annually to Superfund program work. " EPA is currently projecting that State lead sites will account for about half of Superfund site cleanups. Cleanups may fall short of projections if States do not have enough technical people to provide direction and effective oversight,

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) has testified that States should receive Federal funding for a number of activities under Superfund including site identification, assessment, and investigation and the development and implementation of State contingency plans. Funds are needed to support enforcement, health studies, equipment, and staff training, These funds are in addition to funds that States might receive as part of a site-specific cooperative agreement.

A survey done by ASTSWMO in December 1983 for EPA's study of State participation in the Superfund program required by Section 301(a)(l)(E) of CERCLA concluded that States would have to increase their total fiscal year 1983 technical staffing levels by 84 percent to reach optimal levels to support the *current* Superfund program (table 7-5). The greatest need is for staff to oversee site cleanups, State technical staff allocated to remedial activities was expected to increase by 65 percent from 1983 to 1984 (from a total of 259 to 428 person years). These aggregate figures do not reflect the differences in individual State staffing levels nor do they differentiate between State-funded cleanups and Superfund actions.

The ASTSWMO survey also identified the types of technical specialists needed by the States. The most critical technical staffing needs were engineers, hydrologists, and chemists (table 7-5).

Among the constraints identified by the States in quickly obtaining additional technical personnel to support remedial activities were limitations on hiring under State civil service regulations, problems with the institutional stability of the programs such as hiring freezes and noncompetitive salaries, Another constraint on expanding State activities are delays in obtaining private contractors for site studies, remedial design, and construction due to competitive bidding and contract review procedures under State procurement regulations.

[16]Lazarchick, op. cit., pp. 530.

Table 7-5.—Current and Optimal Technical Staffing Levels (Annual totals for respondent states in person years) (41 States)

	Number of current staff	Number of optimal staff	Number of additional staff needed (optimal – current)	Percentage increase needed
Civil engineer	15.9	29.0	13.1	82
Sanitary engineer	86.6	165.1	78.5	91
Environmental engineer	35.7	96.6	60.9	171
Chemist	42.0	108.0	66.0	157
Biologist	46.7	55.7	9.0	19
Public health specialist	46.3	63.6	15,3	33
Geologist/hydrologist	47,0	119.5	72,5	154
Soil scientist	14,6	31.1	16.5	113
Other				
Agricultural engineer	0.5	0.3	–0.2	–40
Chemical engineer	3.1	4,3	1.2	39
Environmental field officer/scientist technician	27.2	42.9	15.7	58
Field inspectors	5.0	5.0	0.0	0.0
Investigator	0	1.0	1.0	—
Industrial hygienist	0.8	1.5	0.7	88
Pharmacist	1,0	1.0	0.0	0.0
Specialists (radiation solid waste, environmental enforcement, environmental, pollution control, resource control, emergency response, water quality)	119,2	177.0	57.8	48
Toxicologist	0.0	0.5	0.5	—
Zoologist	1.0	5.0	4.0	400
Totals	492.7	907.1	414,5	88 [a]

[a]Percentage Increase of total current technical staff needed to achieve total optimal technical staff

SOURCE ASTSWMO survey US Environmental Protection Agency State Participation in the Superfund Program CERCLA Section 301(a)(1)(E) Study final report December 1984

AVAILABILITY OF QUALIFIED TECHNICAL PERSONNEL FOR SUPERFUND CLEANUPS

An Overview of Findings

Cleanup of uncontrolled hazardous waste sites requires a concerted multidisciplinary approach. The situations often involve great uncertainty over the amounts, types, and behavior of the wastes and the appropriateness, feasibility, and effectiveness of various technical remedial options. Because of the relatively short history of a large-scale commitment to cleaning up hazardous waste sites, there is not yet a large cadre of experienced professionals in this area. As the number and complexity of public and private cleanup efforts continue to increase, demand for qualified technical personnel will grow. Because the availability of technical specialists could become a short- and long-term constraint on a greatly expanded cleanup effort, OTA conducted a study of the expected demand and supply of professionals in the required technical specialties.

Little work has been done in this area. Statistics on current and future personnel needs and on the pool of potentially available trained technical professionals for waste cleanup are not readily available. Thus, OTA had to assemble information on the available pool of technical specialists, on the enrollment and training capabilities of educational institutions, and on expected levels of future demand for technical specialists under significantly expanded public and private cleanups. Estimates of future demand were based on current Superfund staffing needs, contractor surveys and assumptions about future funding levels, and extrapolations for demand in 5 to 15 years. Several technical specialties that appear to be critical at various stages of Superfund cleanups were identified.

For a significantly expanded Superfund program, OTA's analysis concludes:

- It is probable that substantial increases in technical personnel needs will accompany expansion of Superfund. These jobs will be in Federal and State governments, in private sector consulting firms, and in the internal environmental management groups of private corporations active in cleanups. The overall number of new positions to be created is somewhat small when compared to employment in the national economy as a whole. However, this increase is several times more than the nuber of new graduates in some fields currently produced by institutions of higher education,
- Significant personnel bottlenecks could develop in the Superfund program. By bottleneck OTA means a condition where employees would not have the optimum training, background, or experience for the work required, and consequently the quality of responses and cleanups could suffer, Even moderate increases in the numbers of Superfund cleanups during the next decade and a shift to more permanent cleanups could lead to shortages of qualified technical specialists.
- With few exceptions, the present educational programs and manpower pools can supply adequate numbers of basically *qualified* scientists and engineers.
- There will be difficulty in developing adequate numbers of *experienced* professionals for the next decade at least, and yet the development of such a cadre of qualified supervisory professionals appears to be the key to the successful implementation of Superfund.
- There could be some shortages of technical specialists particularly in the critical fields of hydrology, ” geological engineering, and toxicology. The increase could strain the capabilities of existing institutions over the short term. Over a longer period it appears that an adequate supply of technically trained people would become available as more students are attracted to these specialties and new graduates enter the job market, Technical specialists in related fields can also be expected to shift to remedial work at uncontrolled sites. In some instances these professionals may require some retraining assistance.

Based on OTA's conclusions that a large Superfund program will be needed for several decades to come, serious consideration could be given to Federal support of training programs in critical technical specialties such as geology, hydrology, risk assessment, and toxicology to meet expected sharp increases in demand.

A range of options is available to promote technical training for hazardous waste cleanups. Among these options are:

- expanding graduate research and training in fields relevant to hazardous waste cleanups;
- encouraging development of specialized short courses to assist current hazardous

[17] The terms ground water hydrologist and **hydrogeologist** are often used synonymously in this report. Many geologists and professionals in the field of ground water hydrology refer to themselves simply as hydrologists. Some may associate hydrology with surface waters only. Hydrology as a science deals with both surface and subsurface waters. In this chapter hydrologist refers to both surface water and ground water h~'orologists. **Hydrogeologist** refers to a technical specialist in the field of hydrogeology, a subspecialty of hydrology dealing with subsurface? waters and related geologic conditions. Assessment of complex subsurface conditions at uncontrolled waste sites with extensive groundwater contamination will frequently require the special skills of a hydrogeologist.

waste profess ionals and those entering the field; and
- promoting the establishment of regional technical centers or "centers of excellence" to provide research, professional training, and graduate education.

Technical Specialists for Cleanup of Uncontrolled Sites

Estimates of the size of the effort required to clean up many of the known uncontrolled hazardous waste sites span a wide range (see chapters 3 and 5). There is general agreement among State and Federal authorities, however, that the cleanup could eventually involve many thousands of sites, will extend over many decades, and that contamination of surface and groundwater is a common problem.

Proposals to expand the cleanup effort raise the possibility of creating shortages of qualified technical professionals, Without such trained specialists, cleanups are unlikely to be performed well or cost effectively. Since little information was available, a personnel needs survey was conducted of practicing professionals in government agencies, Superfund contractors, and engineering firms to estimate the numbers of people required, their specialties, and the desired levels of training and experience.

The survey requested information on the importance and levels of skills for 30 specialties for four phases of cleanup actions—site investigation, emergency response, surface cleanups, and subsurface cleanups. (Note that site investigation and emergency response include all short-term investigations and site stabilization; surface and subsurface cleanups include all longer term "permanent solutions.") The specialties were identified from previous studies and a review of skills needed at 28 sites undergoing EPA remedial response. The respondents were asked to indicate their optimal staff training and experience requirements for cleanup work, rather than the training and experience levels of current employees. The optimal staff requirements were used because many contractor and government personnel now working on Superfund cleanups were not trained for these jobs and had little previous experience in dealing with uncontrolled waste sites. Analysis of survey results showed 18 specialties were deemed very important or important for at least one of these cleanup phases. A strong demand for experienced professionals in these fields is evident now. (See table 7-6 for a list of specialties.) The majority of respondents indicated that a master's degree and 3 to 5 years training were the desired qualifications for almost all technical specialties (figure 7-I). The second choice is for entry level people with a bachelor's degree and limited experience. A doctorate was not deemed necessary for most cases and specialties, except for toxicology,

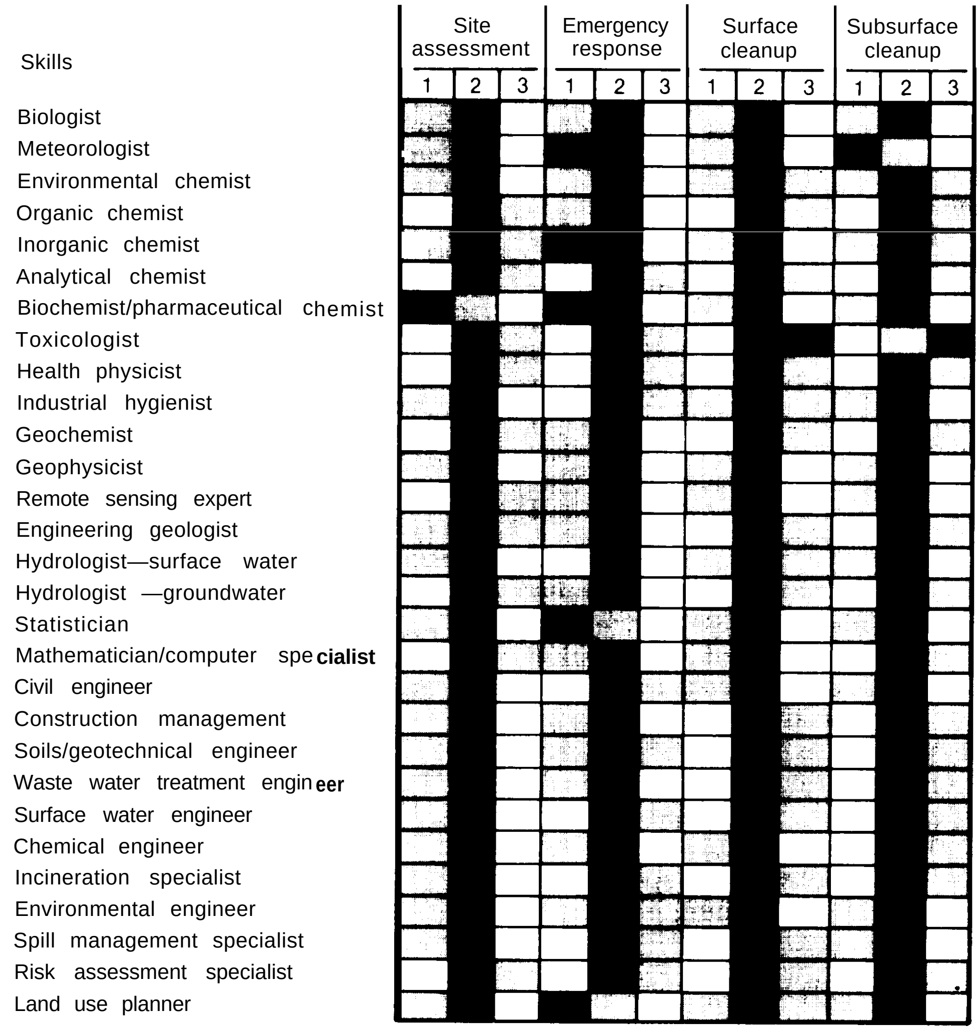
The survey confirmed general trends shown in earlier surveys and the case studies. Several disciplines were found to be most important

Table 7.6.—Technical Specialties for Cleanup of Uncontrolled Hazardous Waste Sites: Personnel Skill s Survey-Importance of Technical Skills For All Site Activities

Rank	Speciality
1	Hydrologist —groundwater
2	Toxicologist
3	Environmental chemist
4	Analytical chemist
5	Hydrologist—surface water
6	Civil engineer
7	Soils/geotechnical engineer
8	Environmental engineer
9	Engineering geologist
10	Organic chemist
11	Risk assessment specialist
12	Chemical engineer
13	Construction management
14	Industrial hygienist
15	Geochemist
16	Inorganic chemist
17	Spill management specialist
18	Waste water treatment engineer
19	Health physicist
20	Mathematician/computer specialist
21	Surface water engineer
22	Remote sensing expert
23	Geophysicist
24	Biologist
25	Incineration specialist
26	Statistician
27	Meterorologist
28	Biochemist/pharmaceutical chemist
29	Land use planner

SOURCE A Keith Turner, Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Figure 7-1 .— Desired Levels of Experience or Education for Technical Specialists



– High
– Middle
– Low

1. Entry level
   Bachelors or O-2 years experience
2. Intermediate level
   Masters degree and 1-2 years or, 3-5 years experience
3. Advanced Level
   PhD or 5 + years experience

SOURCE A Keith Turner, "Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste sites, " final report, Nov. 30, 1984

for Superfund activities and are likely to see an increase in job opportunities. These are: 1) hydrologists, both groundwater and surface water; 2) geologists; 3) civil engineers, especially in the disciplines of soils/geotechnical engineering, construction management, and wastewater engineering; 4) certain classes of chemists and chemical engineers; 5) toxicologists; 6) industrial hygienists (and to a lesser extent health physicists); and 7) specialists in risk assessment and spill management. (See table 7-7, table 7-8, and figure 7-2.) Other specialties do not appear to be affected to the same degree.

Table 7-7.—Technical Personnel Needs for Uncontrolled Hazardous Waste Sites: Personnel Skills Survey—Importance of Technical Skills by Cleanup Category

Skill	Site assessment	Emergency response	Surface cleanup	Subsurface cleanup	Total
	Cleanup category				
Biologist	283	155	204	108	750
Meterologist	166	170	174	71	581
Environmental chemist	381	276	344	331	1332
Organic chemist	331	274	297	297	1199
Inorganic chemist	301	235	269	266	1071
Analytical chemist	365	298	336	332	1331
Piochemist/pharmaceutical chemist	145	105	119	107	476
Toxicologist	387	354	316	313	1370
Health physicist	233	230	213	195	871
Industrial hygienist	271	337	293	240	1141
Geochemist	366	157	205	359	1077
Geophysicist	277	108	139	248	772
Remote sensing expert	255	162	186	171	774
Engineering geologist	378	219	283	357	1237
Hydrologist—surface water	392	269	398	238	1297
Hydrologist—groundwater	452	265	261	500	1478
Statistician	189	92	166	172	619
Mathematician/computer specialist	241	124	196	310	871
Civil engineer	311	260	377	348	1296
Construction management	167	210	400	371	1148
Soils/Geotechnical engineer	324	199	369	379	1271
Waste water treatment engineer	182	162	280	314	938
Surface water engineer	191	156	285	188	820
Chemical engineer	280	266	313	331	1190
Incineration specialist	124	101	234	155	624
Environmental engineer	331	280	339	316	1266
Spill management specialist	185	447	227	162	1021
Risk assessment specialist	299	333	277	290	1199
Land use planner	122	49	96	96	363

NOTE This table based on 60 responses
The maximum possible score for each category IS 600
The maximum possible total score IS 2400

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Table 7-8.—The Top Skills by Cleanup Category

Skill category	Site assessment	Emergency response cleanup	Surface and subsurface
Very Important skill (rank ordered)	1) Hydrologist—groundwater 2) Toxicologist 3) Hydrologist—surface water 4) Environmental chemist 5) Engineering geologist	l) Spill manager 2) Toxicologist 3) Industrial hygienist	1) Hydrologist—groundwater 2) Construction manager 3) Civil engineer 4) Soils engineer 5) Engineering geologist 6) Hydrologist—surface water
Important skills (not ranked)	a) Biologist b) Organic chemist c) Analytical chemist d) Geochemist e) Civil engineer f) Soils engineer g) Environmental engineer h) Risk assessment specialist	a) Organic chemist b) Analytical chemist c) Hydrologist d) Civil engineer e) Chemical engineer f) Environmental engineer g) Risk assessment specialist	a) Environmental chemist b) Analytical chemist c) Toxicologist d) Waste water treatment engineer e) Chemical engineer f) Environmental engineer

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30 1984

Figure 7-2.—Classification of Importance of the Various Technical Specialties for Hazardous Waste Cleanup Actions

Skills	Site assessment	Emergency response	Surface cleanup	Subsurface cleanup
Biologist				
Meteorologist				
Environmental chemist	■			
Organic chemist				
Inorganic chemist				
Analytical chemist				
Biochemist/pharmaceutical chemist				
Toxicologist	■	■		
Health physicist				
Industrial hygienist		■		
Geochemist				■
Geophysicist				
Remote sensing expert				
Engineering geologist	■			■
Hydrologist—surface water	■		■	
Hydrologist —groundwater	■			■
Statistician				
Mathematician/computer specialist				
Civil engineer		■	■	■
Construction management			■	■
Soils/geotechnical engineer			■	■
Waste water treatment engineer				
Surface water engineer				
Chemical engineer				
Incineration specialist				
Environmental engineer				
Spill management specialist		■		
Risk assessment specialist				
Land use planner				

■ Very important skill
□ Important skill
□ Optional skill

SOURCE A Keith Turner, 'Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report, Nov. 30, 1984

Overall, *hydrology seems to be the most critical specialty*. This is because of the frequency of water contamination problems encountered at sites, For instance, the EPA reports that 75 percent of the NPL sites showed groundwater contamination and about 50 percent showed surface water contamination, With increasing attention being given to protecting groundwater resources, the demand for hydrologists will increase not only for waste site cleanups, but for design and monitoring of RCRA facilities and for groundwater protection programs.

The importance of qualified specialists for monitoring systems to determine the effectiveness of Superfund cleanups and to prevent future groundwater contamination at active hazardous waste facilities cannot be overstated. Groundwater consultant David W. Miller pointed this out in congressional testimony in 1982:

> The process of obtaining the data for predicting groundwater conditions, interpreting the information and making accurate decisions to implement compliance monitoring is a scientific endeavor. It can only be carried out in a confident manner by well trained groundwater technicians. There is presently a severe shortage of trained groundwater scientists in the public and private sector, and it is doubtful that there is sufficient talent available to work on more than a relatively small percentage of the existing sites that would fall under the compliance monitoring aspects of the new hazardous waste regulations.[18]

A report of the House Committee on Government Operations reviewing the development of a national groundwater protection strategy also noted the possibility of shortages of competent technical personnel:

> The Committee concludes that as the Groundwater Protection Strategy moves from the planning and strategy development phase into the implementation phase, there will be a significant increase in the need for well-trained professional groundwater specialists if the strategy is to succeed. The Committee, therefore, recommends that EPA and the Department of the Interior act in concert to assess the future and take such steps as are necessary to prevent any shortfall.[19]

Estimating the Pool of Available Professionals

Estimates of the current number of technical specialists in the work force and their probable future numbers were developed from data on enrollment trends, the awarding of technical degrees, and from membership in professional and scientific societies. Enrollment and degree figures tend to overstate the potential availability of trained graduates because not all students find work in their academic fields. Membership data, however, would tend to yield conservative estimates of available manpower because not all practitioners are members.

Performance issues aside, current staffing needs are being met for the most part. This is partly attributable to the slowdown in the minerals, petroleum, and construction industries which has reduced the demand for geologists, hydrologists, and civil engineers. Future staffing problems are likely to depend on general economic conditions as well as Federal funding for cleanup programs. The future levels of Federal funding for cleanup activities will greatly affect the overall levels of effort, even though not all activities will be funded from Federal sources. EPA Superfund monies currently fund about half of all cleanup activity. Other cleanup actions are being funded by other Federal agencies, such as the Departments of Defense and Energy, and by the States. Responsible parties in the private sector also pay for a substantial share of cleanups. It seems likely that cleanups paid for with non-Superfund money will continue to play a significant role in the demand for trained technical personnel. The perception of the importance of cleanup actions in the Nation's priorities will affect the future funding levels by these other sources; this perception will be largely shaped by the levels of funding authorized under Superfund.

Estimates of Future Demand

Using a range of what are believed to be reasonable projections of future funding needs, (see tables 7-9, 7-10, and 7-11), the demand for cleanup professionals was estimated using historically observed ratios of funds to technical personnel (table 7-12). About 3,750 professionals are estimated to be involved in current cleanup activities nationwide. It will undoubtedly take many decades to complete the clean-

[18] David W. Miller, *Hearings Before the House Subcommittee on Natural Resources, Agricultural Research and Environment of the House Committee on Science and Technology*, 97th Cong., 1 St sess. Nov. 30, 1982.

[19] U.S. Congress, *Groundwater Protection: The Quest for a National Policy*, Report of the House Committee on Government Operations, 98th Cong., 2nd sess., October 1984, p. 17,

Table 7-9.—Current and Projected Funding Levels Allocated to Type of Cleanup Activity (billions of dollars)

	Funding Levels[a]					
	1980-85		1985-90		1990-95	
Type of activity	Five-year total	Average annual expenditure	Five-year total	Average annual expenditure	Five-year total	Average annual expenditure
Long-term cleanups	$0.75	$0,15	$5.0	$1.0	$10.0	$2.0
Short-term cleanups	$1.0	$0.2	$2,75	$0.55	$5.5	$1,1
Emergency responses	$0.25	$0.05	$0.25	$0.05	$0.25	$0.05
Site investigations	$1.0	$0.2	$2.5	$0.5	$5.0	$1.0
Totals	$3.0	$0.6	$10.5	$2.1	$21.0	$4,2

[a]All dollar values are in billions and reflect midrange estimates Dollar values are constant 1984 dollars

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov 30, 1984

Table 7-10.—Current and Projected Funding Levels for the Cleanup of Uncontrolled Hazardous Waste Sites (billions of dollars)

Funding levels[a]	1980-85	1985-90	1990-95
Current	$3.0	—	—
Projected:			
Low		$7.6	$19.0
Midrange		$10.5	$21.0
High		$14.4	$25.6

[a]Includes Superfund, other Federal (e g., DOD, DOE). State-funded programs, and private industry

SOURCE A Keith Turner, "Potential for Future Shortages of Technical Personnet for a National Cleanup of Hazardous Waste Sites, " contractor report prepared for the Off Ice of Technology Assessment, Nov. 30, 1984

up of uncontrolled hazardous waste sites. The projections cover two 5-year increments 1985-1990 and 1990-1995. In making these projections it was assumed likely that after an initial steep increase in funding levels, the number of cleanups, and the number of required technical specialists, the program would reach a plateau or steady state and activity would continue at a similar level for several more decades.

With national spending to clean up uncontrolled hazardous waste sites at approximately $4 billion annually, the demand *for cleanup professionals* will *rise to about six times current levels, to about 22,750 professionals in 1995, and remain stable at this higher level for several decades as the cleanup actions are continued.* This growth will not affect all specialties equally. As discussed in the following section, for most specialties, such growth can be accommodated by the present work force and the educational system, *but additional emphasis on training in toxicology, hydrology, and engineering geology will be necessary to prevent shortages* in these areas, *There will be an unavoidable shortage of experienced technical*

Table 7-11 .—Current and Projected Manpower Levels Allocated to Type of Cleanup Activity

		Funding levels[a]					
		1980-85		1984-90		1990-95	
Type of activity	Ratio[b]	Average annual funding	Number of FTEs	Average annual funding	Number of FTEs	Average annual funding	Number of FTEs
Long-term cleanups	1:300,000	$0.15	500	$1.0	3,500	$2.0	7,000
Short-term cleanups	1:200,000	0.2	1,000	0.55	2,750	1.1	5,500
Emergency response	1:200,000	0.05	250	0.05	250	0.05	250
Site investigation	1:100,000	0.2	2,000	0.5	5,000	1.0	10,000
Totals		$0.6		$2.1	11.500	4.2	22.750
Average ratios[b]		1:160,000		1:182,600		1 : 184,600	

[a]All funding levels are in billions and reflect midrange estimate
[b]Ratios are in 1FTE/funding dollars (FTE - full time equivalent)

SOURCE. A Keith Turner, "Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites, " cent ractor report prepared for the Off Ice of Technology Assessment, Nov 30, 1984

Table 7-12.—Current and Projected Manpower Demand for 18 Critical Skills[a]

Skills	Numbers of people (FTEs) 1980-85	1985-90	1990-95
1. Hydrologist —groundwater	363	1,138	2,263
2. Hydrologist—surface water	333	1,013	2,013
3. Toxicologist	330	963	1,900
4. Civil engineer	283	938	1,863
5. Soils/geotechnical engineer	270	925	1,850
6. Environmental engineer	208	626	1,238
7. Construction manager	150	625	1,250
8. Engineering geologist	280	900	1,800
9. Geochemist	140	350	700
10. Environmental chemist	278	851	1,688
11. Analytical chemist	263	806	1,593
12. Organic chemist	135	315	615
13. Chemical engineer	88	326	638
14. Industrial hygienist	25	25	25
15. Risk assessment specialist	120	270	520
16. Waste water engineer	75	313	625
17, Biologist	100	250	500
18 Spill manager	38	38	38
Total	3,479	10,672	21,119

[a]Includes the top 18 of 29 technical specialists accounting for over 90 percent of total demand for cleanup specialists

SOURCE A Keith Turner Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov 30 1984

specialists in all disciplines due to the rapid growth projected for these activities. Additional shortages of personnel may occur if the economy improves and causes increased demands and competition for trained personnel in science and engineering.

Analysis of Demand Projections

The numbers of professionals needed for each 5-year time period are estimated in table 7-12. In the periods following 1995, employment levels in each of these categories is expected to stabilize as the hazardous waste cleanup activities at various uncontrolled sites are expected to continue at a steady level. The number of professionals projected in table 7-12 are comparable to previous estimates by the National Water Well Association (NWWA) and ASTSWMO for the demands for hydrologists and State employees. NWWA estimated the demand for hydrologists would double, to about 10,000 by 1990, but hydrologists work in many fields in addition to hazardous waste cleanups. The ASTSWMO estimated State employment related to hazardous waste activities should rise to 1,000 fairly quickly, and this seems in line with these projections. In general, *these different projections show that the employment rate over the next decade will rise to about six times current levels.* While such an increase sounds very dramatic, the numbers must be looked at in comparison with the total numbers of people in these specialties. It then becomes apparent that these demands will affect the various specialties unevenly.

Toxicologists, hydrologists, engineering geologists, and geotechnical engineers are going to be affected by the demands placed on them by hazardous waste cleanup activities. Current trends suggest that about half the present toxicologists could be involved in cleanup actions, and that over 2%-times the current number of practicing toxicologists could be needed by 1995. Obviously there is room for growth in this specialty. Similarly, over 10 percent of current hydrologists and engineering geologists are now involved in cleanup actions, and this could rise to over two-thirds of the current total number of such professionals by 1995, if growth does not occur.

The civil engineering profession as a whole will not be affected because a large number of civil engineers graduate annually. Within some disciplines, such as geotechnical engineering, construction management, and wastewater engineering, however, some changes will be required.

Increased opportunities for environmental chemists are evident. This is also true, to a lesser extent, for analytical chemists, and to an even smaller extent for organic chemists. There appears to be increased demand for risk assessment specialists, although the total demand is small and will remain relatively small (perhaps 500 people).

By contrast, the changes in demand for geochemists, industrial hygienists, biologists, chemical engineers, and the other remaining critical skills do not seem likely to pose undue strains on the present populations in these fields.

Of equal or greater concern to the number of technical specialists available is their *quality* and experience. The personnel needs survey indicated a strong preference for experienced middle managers, people with masters degrees and/or 3 to 5 years of experience. The demand for experience is going to be a major problem. The projected rate of growth over the decade, coupled with the relatively small base of experienced persons on which to build, will cause a continuing shortage of fully qualified, experienced specialists in almost all the critical skills. The impact of this shortage can be mitigated, at least in part, with specialized training courses, and in part, by careful personnel management policies, but the shortages cannot be fully overcome by these measures, Nevertheless, suggestions for increased training opportunities are made later in this chapter as one of the most effective methods for dealing with this problem.

Other Factors

Other factors affecting the future availability of technical specialists for hazardous waste cleanups should also be noted. Survey respondents noted problems already with employee burnout due to job stress and heavy workloads. This appears true both in the administrative agencies and in technical and administrative jobs with contractors and consultants.

EPA's system of awarding major contracts for the Superfund program may create some problems in providing a stable technical work force. Because it cannot be guaranteed that contracts will be renewed, large consulting firms are hesitant to invest in developing skills of employees who may have to be let go. Long-term employment commitments for technical specialists may be limited. In submitting contract proposals, many firms rely on the qualifications of persons not yet employed or under contract to them. Once the contract is awarded, the team will be assembled. Some professionals may be offered as staff by several different firms competing for the same contract. If a major contract is not renewed, experienced site assessment and remedial design teams may break up and disperse.

Shortages at State or Federal agencies caused by hiring freezes or noncompetitive pay-scales could greatly hamper the cleanup programs. A recent ASTSWMO study (1983) explored these issues at the State agencies and found them to be important.[20]

Increased use of technicians and less qualified professionals in field and site investigators hinges on the availability of experienced professionals to manage these teams. This underscores the importance of augmenting the supply of experienced professionals,

The survey also found that training in health and safety procedures for all current and future onsite employees will be required. Although the market is likely to respond to the demand for expansion of such courses and training facilities without government help, there may be some need for government assistance in quality control and monitoring.

Encouraging Technical Training for Hazardous Waste Cleanups

OTA's analysis concluded that the greatest need is for *experienced* scientists and engineers. There do not appear to be major problems in providing basic technical training to enough people, Methods for gaining practical experience rapidly are essential. Although nothing can fully substitute for years of on-the-job experience in the field, several alternatives can help.

The personnel needs survey asked questions about ways to gain experience. The results are shown in table 7-13. There were differences in preferences among respondents, The EPA, Superfund contractors, and industry respondents favored intensive retraining/refresher courses, while State agencies and other consulting firms favored masters level graduate training.

[20] The ASTSWMO report is published as: U.S. Environmental Protection Agency, "State Participation in the Superfund Program, CERCLA Section 301(a)(l)(E) Study" (Washington, DC: Office of Solid Waste and Emergency Response, December 1984).

Table 7-1 3.—Preferences for Training

Respondent/training method	Choice ranking 1st	2d	3d	4th
EPA:				
0 Undergraduate training .,	**0**	**4**	9	. .
Graduate (MS) Training	2	5	5	1
Retraining/refresher courses	9	3	1	0
On job training	2	5	3	3
State Superfund agencies:				
Undergraduate training	2	2	2	6
Graduate (MS) training	4	3	4	1
Retraining/refresher courses	3	5	3	1
On job training	3	2	3	4
Superfund contractors:				
Undergraduate training	1	0	2	7
Graduate (MS) training	2	2	4	2
Retraining/refresher courses	4	3	2	1
On job training	3	5	2	0
Private consultants:				
Undergraduate training	0	1	0	7
Graduate (MS) training	4	2	2	0
Retraining/refresher courses	2	2	2	2
On job training	1	3	4	0
Industry:				
Undergraduate training	0	0	0	5
Graduate (MS) training	1	3	1	0
Retraining/refresher courses	3	2	0	0
On job training	1	1	3	0
Academic:				
Undergraduate training	0	0	0	2
Graduate (MS) training	1	1	0	0
Retraining/refresher courses	1	1	0	0
On job training	0	0	2	0

SOURCE A Keith Turner, Potential for Future Shortages of Technical Personnel for a National Cleanup of Hazardous Waste Sites final report Nov. 30, 1984

Each method has advantages and disadvantages. The intensive courses, if properly prepared, can significantly upgrade skills in a short time. Graduate training is slower, usually more expensive, but offers a greater depth and breadth of study. It also allows for the continued development of improved methods through research programs.

Accordingly, a strategy combining the two methods appears beneficial:

1. develop additional intensive short course programs for training and retraining and for maintaining skills; and
2. expand graduate research and training programs.

A number of short courses and programs are currently offered by universities, professional societies, and private firms. Their quality is not uniform. In addition, there are limited sources of public information available, beyond that offered by the EPA.

A selected number of regional technical centers might be established to assist in the following:

- offer short courses on topics of interest to hazardous waste professionals, including health and safety training;
- develop graduate programs for hazardous waste cleanup skills within existing academic disciplines;
- conduct research on technical problems at cleanups;
- enhance the current EPA technical guidelines literature with other guidelines, technical memoranda, and reports aimed at the public, local and regional planning officials, and others; and
- serve as regional public information clearinghouses to assist the public, businesses, and State and local governments on hazardous waste issues, much as the existing State Water Resource Research Centers and Agricultural Extension Stations have assisted their clients in the past.

Such regional centers should be explicitly identified and funded for these activities. The cost would be a small fraction of the total cleanup budget and could be a solid investment in the overall program efficiency.

Sources. The following OTA working papers were used in the preparation of this chapter:

1. George J. Trezak, “A Case Study of the Sylvester Superfund Site, ” February 1985;
2. ERM-Midwest, Inc., “Case Study: Seymour Recycling Corporation, Seymour, Indiana,” March 1984;
3. George J. Trezak, “Engineering Case Study of the Stringfellow Superfund Site, ” August 1984; and
4. A. Keith Turner, “Potential for Future Shortages of Technical Personnel for National Cleanup of uncontrolled Hazardous Waste Sites,” NOV. 30, 1984.

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