WEB-BASED DATABASE-ENABLED EXECUTIVE INFORMATION SYSTEM FOR PRELIMINARY SITE ASSESSMENT UNDER CERCLA

by

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Abstract

This thesis summarizes the initial development of a Web-based database-enabled executive information system used to assist with the completion of federal environmental remediation projects. The executive information system presented here specifically addresses the preliminary site assessment phase of the Superfund program, which was created as a result of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) passed by Congress in 1980. This process involved filling out a set of scoresheets known as the Preliminary Site Assessment Scoresheets that ranks a site according to the threat it poses to ecological and human health.

CERCLA established broad authority for the government to respond to problems posed by the release, or threat of release, of hazardous substances, pollutants, or contaminants into the environment. The computerized executive information system described in this thesis was designed to assist the senior management of environmental engineering companies in the retrieval of information about particular sites under remedial investigation and in the monitoring of decisions by other staffs of the company. This information can then be used to determine the next step to be taken in the Superfund process. The system also contains data regarding the person responsible, the date investigation was completed, the confidence level of the data, the source, and any comment related to the information. This will increase accountability for answers to individual scoresheet sections, and to review the reliability of information that is used to complete the scoresheets.

The executive information system is part of a larger information system called Executive Information and Decision Support System (EIDSS). EIDSS will provide both "executive information" and "decision support". Besides providing varies functions mentioned above, EIDSS provides links to data sources on the Internet, local CD-ROM, and previously recorded preliminary site assessments. All together, the system not only helps executives, but also site investigators to gather information for filling out the scoresheets. EIDSS changes how preliminary site assessment is done and aligns the environmental engineering industry with the new Information Age.

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1.0 Introduction

1.1 Overview of Superfund (CERCLA) Process

1.1.1 History

In the past, there was little understanding of what effect certain wastes have on human health and the environment. Consequently, numerous abandoned hazardous waste sites contributed to the pollution of the earth's soil, water and air. Some common hazardous waste sites include abandoned warehouses, manufacturing facilities, processing plants and landfills. In 1980, Congress established the Superfund Program to clean up these sites in response to a growing concern over the health and environmental risks posed by hazardous wastes. The Superfund program was created as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which established broad authority for the government to respond to problems posed by the release, or threat of release, of hazardous substances, pollutants, or contaminants. In 1986, CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) and by the National Contingency Plan (NCP). At present the U.S. Environmental Protection Agency (EPA), in cooperation with individual states and tribal governments, administers the Superfund Program.

The Superfund Trust Fund was established to support the cost of cleanup of hazardous waste sites under the Superfund Program. The Trust Fund is supported from taxes on chemical and petroleum industries, and is used primarily when those companies or people responsible for contamination at Superfund sites cannot be found, cannot perform or pay for the cleanup work.

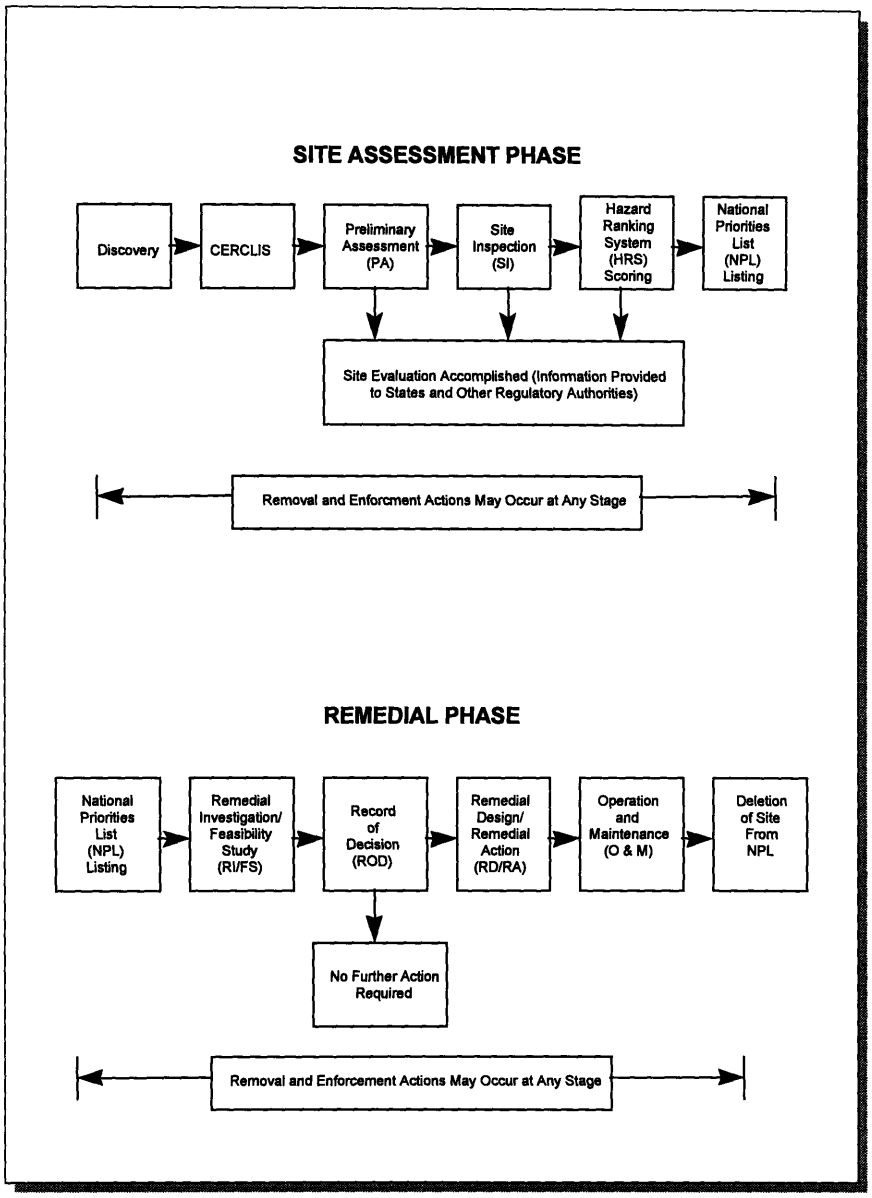

Figure 1.1.2a Superfund Process (See Appendix A for more details on Preliminary Site Assessment)

1.1.2 Current Superfund Process

The superfund process consists of two main phases: site assessment and remedial response action (Figure 1.1.2a). Site assessment is the evaluation of all sites to determine which one needs response action. If appropriate, the result of the site assessment process is the listing of a hazardous waste site on the National Priorities List (NPL). For sites that are placed on the NPL,

the second phase of the superfund process, the remedial response action, is performed. During this phase, the nature and extent of contamination is determined, followed by the selection and implementation of any necessary cleanups at the site. If threats to human health are imminent, immediate or short-term responses may be performed during either of these two main phases.

The site assessment phase begins with notification to the EPA of possible releases of hazardous substances. Sites are then entered into the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), which is the EPA's computerized inventory of potential hazardous substance release sites. The site assessment phase continues with the Preliminary Assessment and the Site Inspection stages. The Preliminary Assessment stage uses relatively limited data that is readily available to identify sites that may pose a threat to human health and the environment, and therefore require further investigation. If the Preliminary Assessment phase recommends further investigation, only then is the Site Inspection performed. The purpose of the Site Inspection is to determine which sites have a high probability of qualifying for the NPL. Once a site has been placed on the NPL, the site will undergo the remedial response action, as explained previously.

Recently, the EPA has developed the Superfund Accelerated Cleanup Model (SACM) to allow for immediate action combined with continuing study as necessary. The SACM improves upon the traditional Superfund process, which requires a prolonged initial phase of study and assessment. Under SACM, the EPA can institute actions to address threats to the health and safety of the surrounding population and environment as soon as those threats are identified. Listing sites on the NPL continues to be a prerequisite to using certain remedial action authorities to clean up sites.

1.2 Preliminary Assessment under CERCLA

1.2.1 Objective

Based on limited data, the Preliminary Assessment (PA) phase is designed to recommend whether or not a site should undergo further investigation.

1.2.2 Scope

The Environmental Protection Agency (EPA) maintains the CERCLIS, potentially hazardous sites that have been "discovered" by the EPA regional offices, state agencies or private citizens. Every site in CERCLIS must undergo the PA phase. The PA phase is performed using readily available information about it and its surrounding area. The report generated summarizes the information gathered, and based on this, suggests the site poses no threat to human health or the environment, there is a potential threat and the site needs further investigation, or emergency actions are necessary. If the site is determined to be potentially hazardous, the PA report will often be referred to throughout successive stages of the Superfund process.

The PA report consists of three parts: the data and site characteristic form, the narrative report and the PA Scoresheets. The data and site characteristics form, entitled "Potential Hazardous Waste Site Preliminary Assessment Form," is a four page summary of the PA scoresheets and the narrative report. The narrative report summarizes all of the information researched and presents it in a structure predetermined by the EPA. The last section of the narrative report should summarize the most important characteristics of the site and explain the major points of concern. The final section, comprising the PA scoresheet, is described in the following section.

The *Guidance for Performing Preliminary Assessments under CERCLA* (U.S. EPA 540/G-91/013, Sept. 1991) indicates that filling out the three sections of the PA report takes an average of 120 hours for each site. The guidance defines the scope of the Preliminary Assessment as sufficient to complete the following tasks:

- Review existing information about the site.
- Conduct a site and environs reconnaissance.
- Collect additional information about the site with an emphasis on target information.
- Evaluate all information and develop a site score.
- Prepare a brief site summary report and a site characteristic form.

1.2.3 The Preliminary Assessment Scoresheets

The PA scoresheets are distributed as a workbook made up of checklists, worksheets, factor value tables, and scoring forms, each with brief instructions and guidelines for scoring. Some regions may require additional scoresheets, but there is a set of standard scoresheets that must be filled out for all regions.

The scoresheets, see Appendix A for the entirety, are divided into six sections; General Site Information, Source and Waste Evaluation, and four more sections corresponding to the four hazardous substance exposure routes called pathways; Ground Water Pathway, Surface Water Pathway, Soil Exposure Pathway and Air Pathway. Each pathway section is loosely divided into three sections based on factor categories; likelihood of release (relative likelihood of a hazardous substance migrating from the site through the specific pathway), target (presence of people, physical resources or environmental resources that may be threatened by release of a hazardous

material from the site), and Waste Characteristics (an estimation of the type and quantity of the wastes at the site). The particular importance of each factor can vary with the pathway, but, for example, primary targets are weighed heavily in the score regardless of the pathway.

The scoresheets are set up so that the left-hand pages of the workbook are instructions for filling out the right-hand pages. It often explain the questions asked in greater detail, or provide help for the site investigator to transfer data obtained from tables and formulas into a numerical score for a particular section. There is also a review for internal consistency included in the workbook, which is designed to eliminate inconsistencies in the report, which may undermine the overall validity of the exercise. The EPA stresses, however, that the reviews and guidelines are merely to assist the environmental engineers in the scoring process, and much of the time the engineer will be expected to use his or her professional judgment in the actual scoring.

In this manner, many sections or pages are assigned a total score, which is combined at the end to determine the overall score of the site. Many pages, however, simply ask for an explanation of certain aspects of the site in paragraph form, rather than a numerical score. The total time to research the information and score a site averages about 100 hours, and writing the reports averages about 20 hours. Sites determined to be ineligible for CERCLA response (i.e. sites where there is no danger of hazardous waste leakage, not simply a lack of targets) may submit abbreviated PA reports. The scoresheets need not be submitted for CERCLIS analysis. However, first two pages of the Potential Hazardous Waste Site Preliminary Assessment Form and the narrative report remain a requirement.

Finally, the decision (i.e. further action or no action) made concerning the PA is usually based on the overall site score. In general, a score of 28.50 or higher receives a recommendation

for further investigation, while a score of less than 28.50 receives a "No Further Remedial Action Planned" recommendation.

1.3 The MMR Superfund Site

The Massachusetts Military Reservation (MMR) is selected as the primary focus of the information system because of its scale of operation and its availability of information. The system can be thoroughly tested using the existing information of the MMR in every aspect.

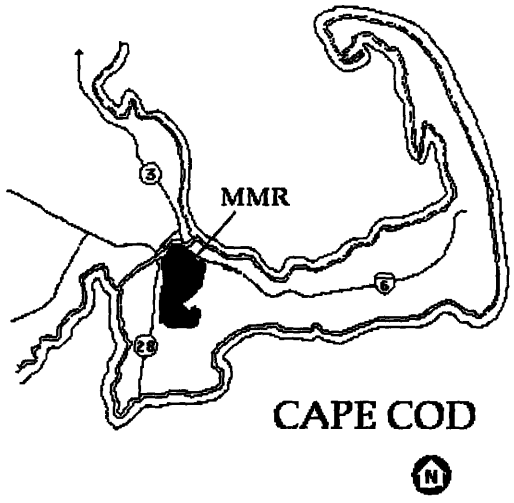

Figure 1.3.1a Massachusetts Military Reservation

1.3.1 Physical Characteristics

The MMR encompasses approximately 22,000 acres on western Cape Cod, Massachusetts (See Figure 1.3.1a). The reservation houses various facilities and related operations of many Department of Defense (DOD) branches. Additionally, the Veterans Administration National Cemetery, the U.S. Department of Agriculture, and the Commonwealth

of Massachusetts use portions of the base. Most facilities are located in the southern portion of the reservation. The northern portion consists of numerous firing ranges, which the Army National Guard uses for training with live ammunition.

1.3.2 Socio-Economic Characteristics

Western Cape Cod supports a population of approximately 150,000 to 524,000 permanent and seasonal residents, primarily in the townships surrounding the MMR. The permanent population of the MMR is approximately 2,000 people, located primarily in on-site housing maintained by the U.S. Coast Guard. Additionally, an estimated 800 non-residents are employed year-round within various operations at the reservation. Periodic activities associated with training military reserve personnel can increase the base population by several hundreds to several thousands. MMR land use is generally limited to supporting military training with some residential and recreational usage. Land uses adjacent to the MMR include residential, commercial, recreational, agricultural and wildlife management.

According to the Cape Cod Commission published in 1996, the Upper Cape economy was valued at $600 million in 1992; more than 60% of this revenue was derived from tourists, seasonal residents and retirement-based income. Hence, the economic base is believed to be highly sensitive to environmental contamination and associated perceived risk. The overall value of real and personal property increased by 3 times in the past 10 years to $8 billion in 1994.

1.3.3 History

The MMR has housed and served the U.S. military forces since 1911. The site was particularly active during WWII. Between 1955-1970, the MMR operated a number of

surveillance missions and aircraft operations through the Air National Guard. The use of petroleum products and other hazardous materials, as well as the generation of wastes, was at the highest during this period. Since 1970, the military activities have been scaled down.

Past releases of hazardous materials at the MMR have resulted in groundwater contamination in a number of areas. Documented sources of contamination include former motor pools, landfills, fire training areas and drainage structures such as dry wells. Figure 1.3.3a gives a map of nine major contaminant plumes that have been identified at the Reservation.

On November 21, 1989, the MMR was listed on the National Priorities List as a Superfund site. As a result, the National Guard Bureau and the U.S. Coast Guard entered into an Interagency Agreement with the EPA in July 1991. Consequently, all site investigations and remedial actions performed at the base are subject to the requirements and regulations of the Comprehensive Environmental Response and Emergency and Liability Act (CERCLA).

1.3.4 Present MMR Activities

At present, the majority of the preliminary site assessment at the MMR has been completed and most areas of contamination identified. In most cases, the source of contamination has also been controlled or eliminated. Currently, remediation alternatives are being pilot tested of most of the plume sites. In some cases, pilot tests have been performed and remediation alternatives are being expanded to full size. Remaining stages are planning and design of remedial facilities, as well as their construction, maintenance and operation. In all cases, close monitoring of progress of the site cleanup is crucial.

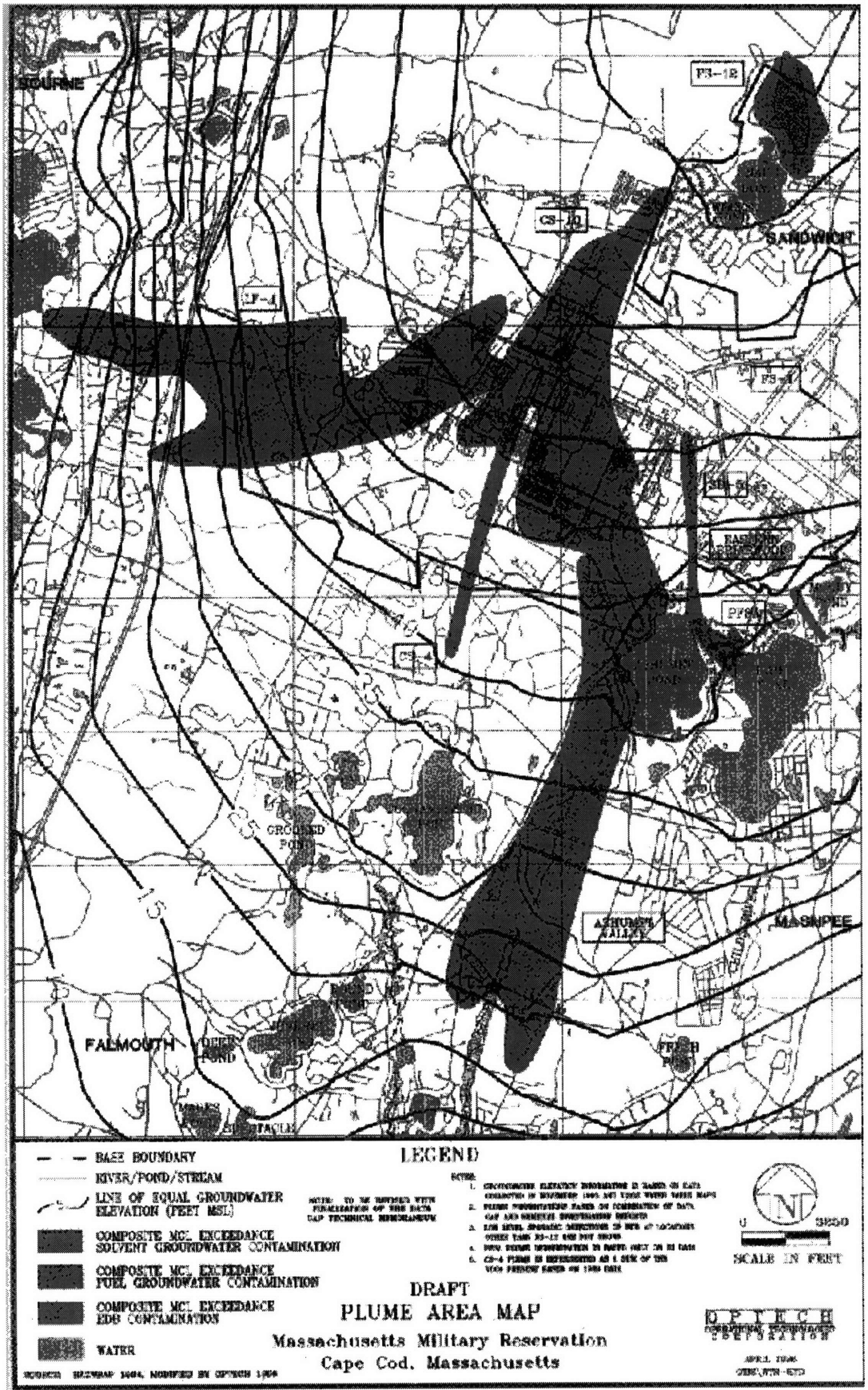

Figure 1.3.3a MMR Plumes Map

1.4 Preliminary Assessment under CERCLA at the MMR

1.4.1 History

The Installation Restoration Program (IRP) began at the Massachusetts Military Reservation in 1982. Under the direction of CERCLA guidelines, all potential areas of concern (AOC) were evaluated via the Preliminary Assessment (PA) Scoresheets. Any sites scoring 28.5 or higher were to be considered areas of concern and had to be further inspected prior to beginning the remediation process. By November 1989, 27 AOC's had been identified. Currently, there are a total of 78 AOC's which include 5 storm drainage ditches, 10 landfills of various sizes, 26 reported chemical spill locations, 29 reported fuel spill sites, 3 former firefighter training areas, 4 former coal yards and an AOC designated as the Drainage Structure Removal Program, consisting of over 170 sumps and drainage structures that need to be removed.

1.4.2 Present PA Activities

At the present time, there are two areas still in the preliminary assessment phase: John's Pond Dump - Off Base (LF-4) and Former Contractor Yard (CS-13) (Karson, 1997). The preliminary site assessment process at these areas will involve manual record searches of real estate and historical data, interviews with past and present employees and the inspection of aerial photographs.

1.4.3 Design of Future Approaches at the MMR and Elsewhere

To aid in the process of gathering data and storing decisions made during the preliminary assessment phase, data sources in electronic format may be used. There are many advantages

gained by converting the traditional paper PA Scoresheets to electronic forms on networked computers. Multiple engineers can work on the same scoresheet without the delay of paperwork transfer from one office to the other. Completed and partially completed scoresheets may be stored for the use of updating information or retrieving records of past decisions at any point in the future. Another advantage of placing the PA scoresheets on networked computers is that they can easily be linked to the Internet or databases where large amounts of relevant information may be found. Lastly, once the scoresheet is completed and stored in a database, an executive summary report may easily be generated.

2.0 Information Systems

To make the Preliminary Site Assessment (PA) process more efficient, an information system needs to be put in place. Before introducing the proposed information system that will aid the PA process, this section first looks at the definition of an information system, how it is being used in general, and how it is being used in the environmental engineering industry.

2.1 Definition of an Information System

An information system can simply be defined as a system for retrieving appropriate and relevant data from a source and transferring it to a designated target with a different format. A more advanced information system would also consist of a unit for processing the data and adding meaning to it.

Although extremely complex, the human body is the smallest information system. Our brains contain a large amount of information that we call knowledge. When we encounter a problem, part of our brain requires information from other known as memory. After the knowledge is processed, it can be expressed through speech, writing or body movement. A think tank—generally a group of people with similar skill-sets that get together to solve a problem—is an even more complex setup of an information system. Although a think-tank has a greater number and resources, it can introduce complex problems of conflict resolution and sharing among members.

A more diversified information system is demonstrated in a company. People with different interests and skill-sets are put together to help the company perform better as a whole. Information is stored not only in employees' brains, but also on paper and in other formats.

Processors of the information system can include engineers and scientists, office administrators, accountants and managers, depending on what type of organization the company is.

Other large-scale information systems are universities and governments. These information systems are extremely complicated. More importantly, however, is the fact that knowledge transfer in these complex systems comes from different sources. For example, when a student has a question, information and knowledge sources can be professors, teaching assistants or roommates. The reliability of this knowledge can vary according to the source. Because of the difficulty in ensuring reliability of information, computerized information systems were only implemented to alleviate the human work force from some rather routine processes such as automatic payroll systems and inventory tracking systems. These systems, like specialists, performed tasks within their knowledge boundaries.

As computer processing power and storage capabilities continuously grow, computerized information systems, referred to as information systems from now on, are becoming more sophisticated. People are beginning to require from information systems higher level of processing so that value is added to the information gathered. Systems are required to handle not only routine process, but also to support decision-making. In terms of improving communication, electronic-mailing and newsgroup systems are examples of some such improvements that have been recently introduced.

2.2 Use of Information Systems in Decision Making Process

Information systems can support the decision making process through two modules: the decision support system and the executive information system. They are being applied not only to help users make better decisions, but also to reduce the processing time.

A decision support system (DSS) is an information system designed to provide employees access to information crucial to their decision-making processes. The scope of a DSS is rather broad; any system providing its user with knowledge can be categorized as a DSS. For example, Tiger Creek, a paper manufacturer, introduced in 1983 an Expense Tracking System (ETS) to allow operators at their mill to make better technical adjustments by studying cost impact information provided by the system (Bronsema, 1984).

Frito-Lay Inc., a food distribution giant, developed a DSS through the use of Hand-Held Computers (HHC). HCC provides delivery and shelving employees better information on how to re-distribute and re-shelf a store. Thus, not only the employees can base their decisions on past experiences, but also obtain accurate and up-to-date account information for a particular store. Using this system, new employees can also learn quickly and become a productive part of the team (Applegate, 1989).

In addition to DSS, Frito-Lay also implemented an executive information system. In general, an executive information system (EIS) is an information system designed to provide senior managers access to information relevant to their management activities. This includes information concerning the company finance and accounting, the employee work-schedule, and the marketing and annual and quarterly reports. Because managers use the information to make fast and accurate decisions, companies using a well-designed EIS will gain competitive advantages over their competitors (Leidner, 1993).

The Frito-Lay EIS works in a similar manner to the HHC by assisting managers at Frito-Lay to better manage inventory distribution and to keep track of regional sales information. The EIS enables the design, creation, and storage of graphical information displays, and it provides a user-friendly interface for accessing information stored in predefined graphical displays. The

EIS also provides an excellent way for new managers to get up to speed quickly in the food-distribution business (Applegate, 1989).

During the late 80's, Phillips 66 Company, a major gasoline distributor, began using Phillip 66/EIS, an EIS containing over 1000 information displays for 45 managers and 35 secretaries and staff. The Phillip 66/EIS provided a tighter control of Phillip 66 inventories and a better monitoring of supply and pricing management. In 1988, the information system generated conservatively increased profits of $20 million (Applegate, 1988).

A more recent example of a DSS and EIS implementation comes from CIGNA Corporation. The CIGNA Property and Casualty (P&C) Division deployed an Underwriting Desktop System (UDS) and Strategic Feedback System (SFS). The UDS system was based on a suite of tools and applications that gives the underwriter access to everything needed to perform the job so that it was never necessary to leave the desktop. The suite of tools included an electronic form facility, electronic reference materials, access to Underwriting Guidelines, e-mail, and interactive business training modules (Nolan, 1995).

While the CIGNA UDS facilitated many of the tasks performed on a day to day basis, the SFS provided senior executives the capability to create, view and update a balanced scorecard throughout CIGNA P&C. The major point of the "Balanced Scorecard" (BSC) concept was to develop multiple performance measures to assess the achievement of a company's business vision. The automated BSC enhanced communication between business managers, both upward and among peers. It also simplified the presentation of information using simple graphics like the use of a red light for problems and a yellow light for caution (Nolan, 1995).

DSS and EIS provide a new way to do business. They have simplified information searches and presentation. As an information intensive and massive decision-based industry, the environmental engineering industry can benefit greatly from both systems.

2.3 Applications of Information Systems in the Environmental Engineering Field

Environmental engineering project management can be a very difficult task because so many factors must be taken into account. Environmental decision making involves understanding not only the immediate impact of human activity on the environment, but also issues like human health, economic costs, current and pending regulation and fairness. In principle, all of these interrelated factors have a bearing on any decision made relating to the environment.

To deal with these complex problems, the environmental engineering industry could greatly benefit by utilizing DSS. In general, there are three domains in which DSS can make a real difference. The first domain is in the modeling of complex environmental processes, such as air and water quality modeling and other calculation-intensive-aiding software. The second domain is in information management. Integrating information from diverse sources is necessary in order to make sound decisions. Important sources of information range from field-monitored data, to simulation results, to documents on regulatory policy. Finally, the last domain involves modeling the decision process itself and providing the structure and support to enable policy makers to make timely, balanced decisions that are consistent with what we know about the environment.

Satisfying the first criterion of modeling complex environmental processes, the analysis programs available in the market range from air quality modeling tools to groundwater migration modeling tools. In terms of information management, many United States government agencies

and private organizations are actively developing standardized information systems for storing geographic data called Geographic Information Systems (GIS). Using Global Positioning Systems (GPS), GIS databases store information about specific locations using their northings, eastings and elevations.

At present, most environmental engineering DSS tend to be hybrid systems of modeling and information management. For example, the International Institute for Applied Systems Analysis has developed a working beta of a DSS named the Decision Support System for Evaluation of River Basin Strategies (DESERT). Based upon the user-friendly environment of the Microsoft Windows interface, DESERT provides integration of important stages of decision support including data management, model calibration, simulation and optimization and presentation of results (Somlyódy, 1996).

The Colorado River Decision Support System (CRDSS) is another DSS under development. The principal goal of the CRDSS is to provide the capability to develop credible information on which to base informed decisions concerning the management of Colorado River water resources. It has same functions as DESERT in terms of its interface and data management (Johnson, 1996).

A simpler form of DSS is an environmental engineering specific Web search engine, which aid engineers find information in a specific area of interests. The Amazing Environmental Organization Web Directory lists commercial companies and academic institutes ranging from Animal Interest Groups to organizations concerned with Sustainable Development (Dickson, 1997). Other search engines include EnviroPhantom (Garvey, 1997), ECOLINKING (Rittner, 1997) and YAHOO (Filo, 1997).

Most DSS for environmental engineering that are under development tend to only combine modeling and information management, there is little work on developing EIS which combine all three functions of environmental project management. Those EIS that are being developed are only in the conceptual design phase. For example, the Environmental Programs Group at MCNC's North Carolina Supercomputing Center, working closely with the EPA, is developing the Environmental Decision Support System (EDSS) that includes all three aspects of environmental project management. However, EDSS only focuses on a "next-generation" air quality modeling system (Bilicki, 1996).

The following section proposed a system that integrates the three aspects of environmental project management on the more general area of preliminary site assessment of hazardous waste sites. This system uses a plug-in architecture where components are used for modeling, information management and decision process.

2.4 Proposed Information System for Preliminary Site Assessment under CERCLA

The global objective of 1997 Master of Engineering Information Technology Group project, Executive Information and Decision Support System (EIDSS), was to develop an information system that can support decision making during the complex process of hazardous waste site remediation. Within that process, EIDSS focuses on the preliminary site assessment under CERCLA (PA). Figure 2.4a shows a system diagram of EIDSS.

EIDSS is separated into two different sub-systems: DSS and EIS. DSS aims to aid investigators to research information faster and more accurate. It is more catered towards retrieving information from outside the company, with the exception of one system. EIS, on the

other hand, targets management level employees. It is catered towards extracting information from the company's internal database for project management purposes.

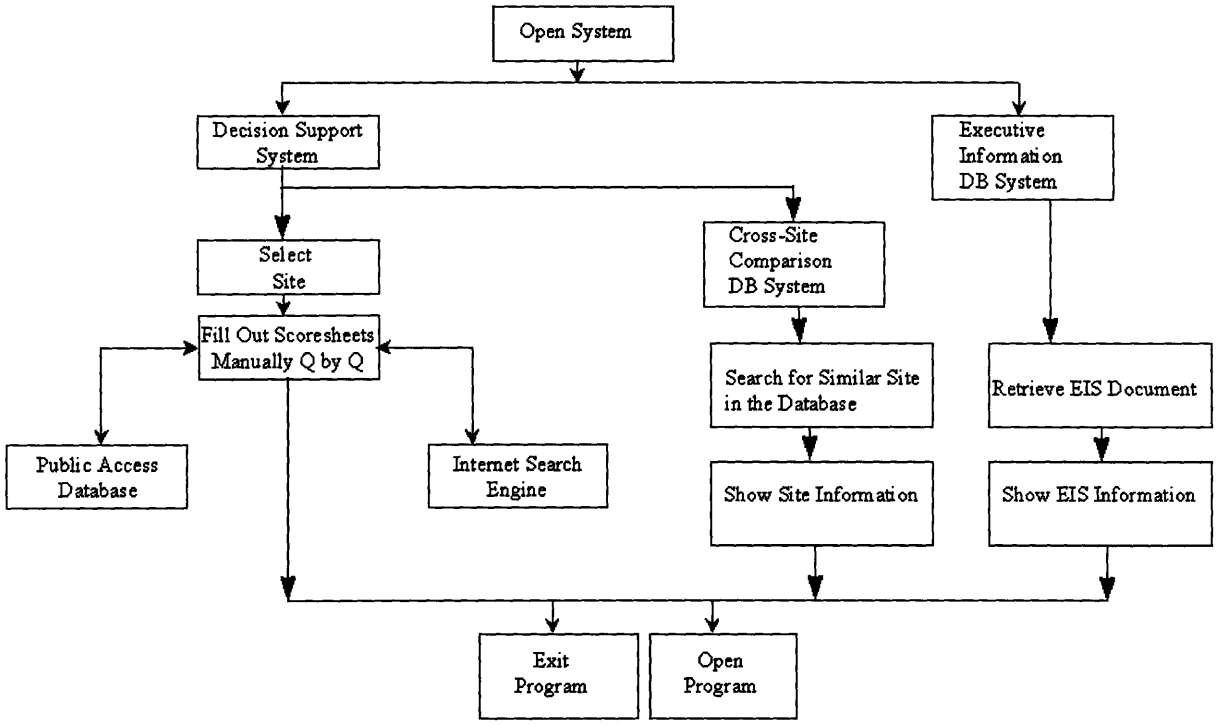

Figure 2.4a System Diagram of EIDSS

From the diagram, one can see that EIDSS is missing several components such as modeling, project management, etc. However, since these modules are not need for the PA process, they are components to be added when the system expands to cover other processes. Adding them will be similar to adding new branches to the diagram.

2.4.1 Information System Under current Preliminary Site Assessment Processes

The information system is designed to search data for engineers and scientists to fill out the PA Scoresheets. With a user friendly graphical user interface designed to look like individual pages of the PA Scoresheets, it will help users become familiar quickly to the new information

system. In addition, since this system is Web-enabled, the user can have the system search for data on the Internet or on any electronic formats. To do so, there are two different types of search engines developed: Internet Search Engine and Data Store Search Engine.

The Internet Search Engine uses the Excite search engine. By passing specific parameters into Excite, the search result will be more precise and concise. This will narrow down the information the user has to skim through before finding the right document on the Internet. For example, passing in MMR and water well will return a list of pages containing environmental related homepages with MMR and water well inside the documents, not millions of pages containing the word water and well. The Data Store Search Engine uses database query instead. This search engine targets specific database on the Internet, such as the USGS database, or in electronic form, such as on CD-ROM. Passing in specific query information consists of location, in the form of longitude and latitude or city name, and the requested parameter, such as rainfall or population, the database will return the specific result for the question. For example, passing in the coordinate of MMR and a requested parameter on rainfall, the database will return the average precipitation rate of the MMR area (see Appendices D, E and F).

This information system is not designed, however, to replace engineers and scientists. It will assist them to arrive to conclusion in a much shorter time frame. This system should be able to cut the 120 hours of PA process to at least half the time. This is based on the fact that investigators spend the majority of their time searching for information, and the fact that generating reports will be much easier using the system with electronically stored data. The information system will double, at the very least, the capability of the environmental engineering firm evaluating sites. This will allow the company to be more efficient on performing the PA.

2.4.2 Future Architecture of Preliminary Site Assessment Processes

While the information system described above will greatly improve the current PA process by making information more reliable and readily available, the potential exists for future enhancements to the information system. Reusing the completed site/facility assessments could enhance the information system. Once the proposed information system has been used to complete one or more PA's, a database of previous studies would be collected. This additional data source, from the Cross-Site Comparison Database System, could provide valuable comparisons for performing new studies. If a new site has characteristics that are similar to sites that have been studied previously, referring to these previous studies may facilitate the completion of the PA process. Some characteristics used to compare sites include geographic location, suspected release of hazardous wastes and type of facility or operations engaged on the site. Comparing new sites with completed studies would also provide an additional check for reliability and support for the current site under assessment (see Appendix I).

Having briefly described three separated systems, this concluded the introduction of the decision support system portion of the EIDSS. Although the decision support system is an important part of EIDSS, the focus of this thesis, however, is the documentation of the implementation of the executive information system potion instead. Therefore, the implementation of the decision support system by other members of the project group is included in the appendices.

2.5 Proposed Executive Information System

Expanding beyond the scope of aiding engineers and scientists, the system can incorporate the concept of an EIS to provide better information for senior management.

The development of an EIS, which can support decision making for senior management of an environmental engineering firm or a government agency during the complex process of hazardous waste site remediation, is the primary focus. The EIS, with project information stored electronically in a database, can provide better information for the senior management, or anyone looking for information regarding finished or on-going projects of the company. For example, a senior manager could use the system to manage the individual progress of site remediation projects of various sites that the individual oversees. An EIS also opens new opportunities in document tracking and decision management. These new functions allow senior managers, especially the Chief Executive Officer and the Chief Financial Officer, to better monitor and control the company performance and growth rate.

By examining the implementation of an EIS for the PA process, one can better understand the different processes and technical difficulties facing the development of such an information system. This prototype will also help developers and users better visualize the benefits of such a system and allow users of the system to define improvements and changes to better fit their needs. In addition, with a better understanding of the capability of an information system, senior management can also make any necessary adjustment within their organizational structure, workflow and other managerial domains to ensure the success of implementing the full system.

3.0 Executive Information System Design and Development

The need for a database-enabled information system is apparent in many applications, especially when large amounts of data are involved. However, because of the growing interest with respect to the usage of the Internet, simply developing a database-enabled system is often not sufficient. It is also important that the system is Web-based so that stored information can travel beyond local communication limitation, and support staffs, if applicable, all over the world.

This chapter will first talk about what kind of database management system is there in the market. Then it will explain how a database management system is designed. After that, it will layout the design process of the Preliminary Site Assessment Executive Information System. Before moving on to implementation, the chapter will examine the use of Web-based information system and the planning of implementation process.

3.1 Database Management System

Today, most of the database management systems used by commercial applications are based on one of four basic models: the hierarchical model, the network model, the relational model and the object-oriented model.

3.1.1 Hierarchical and Network Models

Although hierarchical and network models are the older generation of databases, they are still being used in many companies because the majority of mainframe computers from the late 60's and 70's use these models. Migrating from these legacy systems is costly and difficult.

In general, both the hierarchical model and the network model make use of permanent internal pointers to locate information. For example, record A will point to records B and C, and records B and C will then point to something else. Because of this specific routing feature, the process of changing and updating information in the database requires synchronization of all inter-related pointers. Due to the fact that a long and complicated application code, usually in COBOL, is required to run these models, maintenance of these systems is quite cumbersome and difficult.

Since the 1980's, following the commercial debut of the relational model software, hierarchical or network database systems have not been installed ever since. Companies use relational databases model to implement new information systems. For those existing legacy systems, companies try hard to migrate to new database models either by paying a lot or abolishing the old one (Swadley, pp. 4).

3.1.2 Object-Oriented Model

Before discussing the relational model, a quick introduction of the object-oriented model is needed. This is the next generation of database model. Borrowing form the object-oriented programming concept, object-oriented database models are databases that support objects and classes. Thus, they allow structured sub-objects. Each object has its own identity, or an object-id (as opposed to a purely value-oriented approach), and its own properties. The model supports methods and inheritance. It is also possible to provide relational operations on an object-oriented database.

The object-oriented model allows all the benefits of object-orientation, as well as the ability to have a strong equivalence with object-oriented programs – an equivalence that would be lost if an alternative were chosen, as with a purely relational database (Hathaway, 1996).

Although an extremely powerful model, there are still a few issues unresolved that slow and stop the migration of this model into general use. First of all, the object-oriented model is still undergoing a lot of development and improvement. Universities and research institutes are still exploring the different possibilities of this model.

Secondly, because the market is saturated with the relational database model, none of the object-oriented database software companies has been to appropriate a large segment of the market in order to create a snow ball effect. Last but not least, people in the industry are not familiar with the concept of object-orientation. Thus, before this model is accepted by the industry, a radical change in thinking about the world, and how the world operates is needed.

Because the commercial world is not ready for the object-oriented model, the relational model continues to dominate the world of database management system.

3.1.3 Relational Model

Information in the relational database model is stored in tables with columns and rows. Columns define attributes, or fields; rows define records, or tuples. All cells belonging to the same column must contain information of the same type ranging from integer, floating point number, text, memo to a yes/no selection (Stanczyk, pp. 12).

There are also three different kinds of relationship, or a named directed mapping between two tables: one-to-one, one-to-many and many-to-many relationship. The first one is the one-to-one relationship, which means that a set of records in a table is mapped to only one set of records

in another table. For example, the relationship between left and right hand is one-to-one, or at least in most cases. The second one is the one-to-many relationship, which means that a record can map to multiple records in another table. For example, parents with more that one child demonstrate this property. The last one is the many-to-many relationship. An employee-project relationship clearly demonstrates the type of mapping; each employee can be involved in multiple projects while each project has a team of employees performing different tasks (Stanczyk, pp. 19).

Another important feature of the relational model is the query. There are three major roles for the query. One of them is to filter information in a set of records, by setting criteria, for example, displaying only those sales that occurred in 1994. This allows users to narrow down the information displayed, which improves searching time. Queries can also be used to combine sets of records using one or several common fields. This is useful when the user wants to gain a better insight into the information stored in the database. For example, the user can not only see information about customers and sales people, but also about which sales person sold which item to which customer, drawing data from many tables. The last function allows users to filter a set of combined records (Stanczyk, pp. 109).

Different from other three models, because of the use of tabular structure and its natural ability to provide an easy-to-use user interface, the relational model was quick to be adapted by many different industries as the database standard. However, the most important feature of relational model is that it has a well-structured theory governing the design of database management system that object-oriented model does not have. The following section will go into the design theory of a relational database management system.

3.2 Relational Database Management System Design

Because most commercially available database systems use this model and the need to make the system easier to interface with other commercial systems, Preliminary Site Assessment Executive Information System (PAEIS) described here will be implemented using the relational model.

3.2.1 Relational Database Design Methodology

Although easier than designing with other models, designing a relational database is not exactly trivial. There are several rules for designing a good relational database that need to be followed. These rules are discussed below.

3.2.1.1 One Piece of Data per Cell

First of all, each cell needs to contain one piece of data, and the user will never want to use only part of that data. A good example is the Address field. An address is a piece of data. However, there will be instances where the user will want to group address information by city or by state. Therefore, the address is separated into street address, city, state, and zip code to accommodate this anticipated need (White, pp. 66).

3.2.1.2 Meaningful Tables

Secondly, tables need to be meaningful. The table title not only has to describe the content, but also set the limit on the contents. For example, the Employee table should not contain information about projects that each employee is working on; likewise the Project table should not have information about which employee is working on which project. Instead, the

interaction between these two tables should be another table labeled Task for describing this many-to-many relationship (White, pp. 70).

3.2.1.3 Primary Keys

Each table should have at least a key, which is a set of columns that picks out a unique row from the table. A good example of a key is a key to identify a person. Using the last name is not a good example of a key because of the possibility that many people might share the same last name. As a matter of fact, even using all last, first and middle names is not error proof. A specific personal ID is needed, and the social security number serves that purpose very effectively, or at least in the US (Hawryszkiewycz, pp. 29). In cases when there are several keys per table, the primary key should be the simplest one. For example, even if there will be no repeat of names, using the social security number as the primary key is superior because users can distinguish a record using only one field.

3.2.1.4 Tables Related with Foreign Keys

In general, using an extra table to build a relationship is specific for many-to-many relationship. To build one-to-one and one-to-many relationships, tables can be related using foreign keys. A foreign key is a column of key values in a table that will point to the primary key of another table. For example, in the Employee table, a column labeled department will consist of integer values between one and ten, while in the Department table, there will be nine records each with a different DepartmentID ranging from one to ten. Using this method, users can build very interesting and useful relationships (Hawryszkiewycz, pp. 33).

3.2.1.5 Eliminate Redundant Storage of Data and Empty Cells

In order to create efficient databases, redundant data storage and empty cells need to be eliminated. In order to reduce redundancy, users can simply redesign the tables and relationships (Hawryszkiewycz, pp. 14). Expanding on the employee-department example from 3.2.1.4, if both employee and department tables include the name of departments, one can just remove the column from the employee table and use query to get the department name.

Eliminating empty cells is more complicated. It may require the creation of several different tables in order to minimize the number of empty cells on one table. For example, not every employee has a mobile or secondary phone number. So, instead of assigning a mobile phone number field to the employee table, the database designer can create a mobile phone table with two columns: a column of foreign key containing the EmployeeID and a column giving the mobile phone number. Users can use query to link these two tables together (Hawryszkiewycz, pp. 20).

3.2.1.6 Normal Forms

The idea of normal forms revolves around relation keys and dependencies. There are five different levels of normal forms; each form indicates a set of conditions that a table must satisfy. A table achieves the first normal form when there is only one piece of data per cell. To reach the second normal form, each non-key field in the table must depend on the whole key and not part of the key. For example, in figure 3.2.1.6a, although Total Time depends on both PersonID and ProjNo, Project Budget depends only on ProjNo. Figure 3.2.1.6b shows two tables of the same information reaching the second normal form (Hawryszkiewycz, pp. 34).

PersonID	ProjNo	Project Budget	Total Time
1	1	20	20
3	1	20	16
2	2	17	35
2	3	84	42
3	2	17	17
2	1	20	83
4	3	84	41
	4	90	

Figure 3.2.1.6a Project Data Table: Non Second Normal Form

ProjNo	Project Budget
1	20
2	17
3	84
4	90

PersonID	ProjNo	Total Time
1	1	20
3	1	16
2	2	35
2	3	42
3	2	17
2	1	83
4	3	41

Figure 3.2.1.6b Projects and Works Tables: Second Normal Form

The third normal form is achieved when no column depends on anything but the primary key. In another words, none of the non-key field will depend on another non-key field. Figure 3.2.1.6c demonstrates the difference. The DOB of the Second Normal Form table can depends on ProjNo and Manager; in the Third Normal Form tables, DOB only depends on Manager, and then Manager only depends on ProjNo.

ProjNo	Manager	DOB
1	Joe	Jan-63
3	Vicki	Mar-57
2	Joe	Jan-63
4	Marilyn	Jul-58

Second Normal Form

ProjNo	Manager
1	Joe
2	Joe
3	Vicki
4	Marilyn

Manager	DOB
Joe	Jan-63
Vicki	Mar-57
Marilyn	Jul-58

Third Normal Forms

Figure 3.2.1.6c Comparison between Second and Third Normal Form

And finally, both fourth and fifth normal forms eliminate multi-value dependencies and are beyond the scope of this information system (Hawryszkiewycz, pp. 43).

3.2.2 Entity-Relationship Model

Having understood how to design a good database, one can then start to build one. The most commonly used design method for top-level analysis is the Entity-Relationship Model (ER Model). In general, the ER Model is a method of grouping and linking. Objects, or entities, with similar properties are grouped into entity sets. Relationships will then govern the interaction between these entity sets. Figure 3.2.2a shows an ER diagram (Hawryszkiewycz, pp. 85).

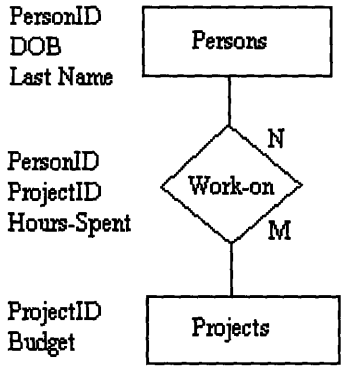

Figure 3.2.2a An ER Diagram: The rectangle indicates entity set and the diamond indicates relationship. N and M indicate the relationship type; if N and M are both 1, then the relationship is one-to-one; 1 and N means one-to-many; N and M means many-to-many.

Ideally, each set in the ER diagram becomes a relationship. The conversion must satisfy a few criteria. The most obvious one is achieving the highest normal form. Besides that, preserving integrity constraints, or specific rules between the creation and existence of data, and minimizing the number of relationships are also important.

3.3 Preliminary Site Assessment Executive Information System Database Design

The approach to designing the database system is to put aside the fact that this is an Executive Information System and focus first on the tabulated raw data. These base tables

contain information needed to fill out the PA Scoresheet. So, the initial step involves studying relationships within and between PA Scoresheets.

3.3.1 Base Tables Design

Most relationships between tables in the scoresheet are one-to-one. This is because every blank, every comment and every answer corresponds to one facility. This makes administrating information within one record easier because a common ID can be used for all tables. Relationships between scoresheets are more complicated. First of all, a site, defined as an area of operation, consists of many facilities, a one-to-many relationship. Data integrity needs to be enforced so that each facility belongs to a site. Furthermore, data integrity also needs to ensure that scoresheet data are linked to facilities. Figure 3.3.1a shows the ER for these base tables.

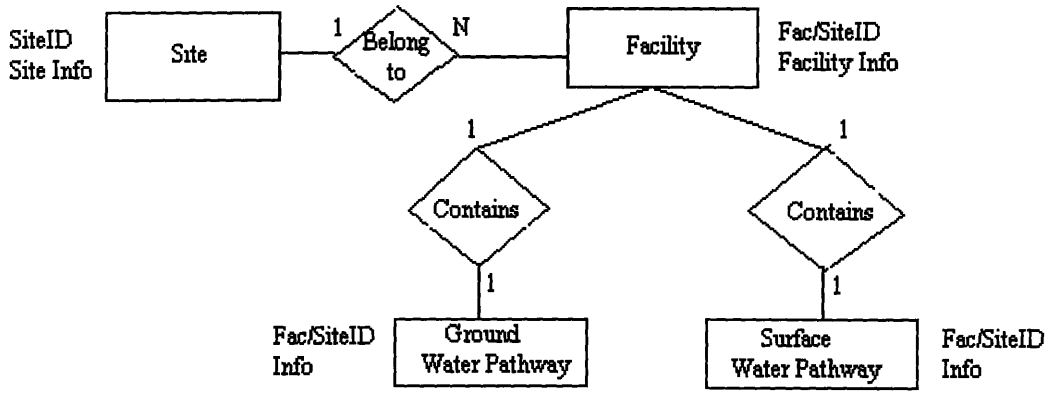

Figure 3.3.1a Preliminary ER Diagram: one-to-one relationship between Facility and Pathway information; one-to many between site and facility.

By further exploring the site information section of the scoresheet, it is clear that a site can contain more than one prior spill. To reach the third normal form, the site information is spilt into two. The same rationale can be applied to the facility information. A facility can have

more than one suspected hazardous substance and spill source. Therefore, the facility information is spilt into three. See Figure 3.3.1b for more details.

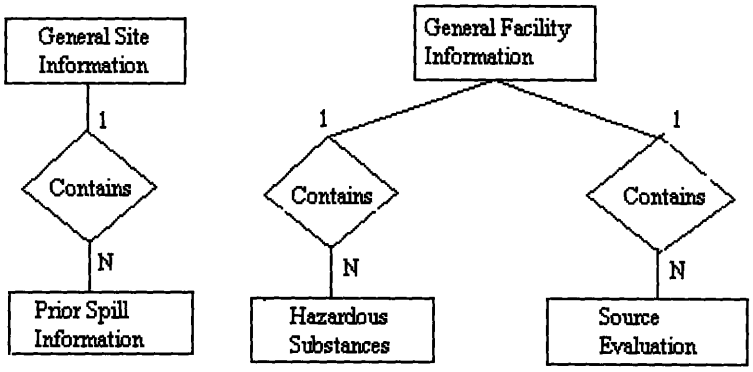

Figure 3.3.1b General Site and General Facility Information ER Diagram

The executive information system selected two different pathways to implement: the Ground Water Pathway (GWP) and the Surface Water Pathway (SWP). After carefully studying the prescription and data for each individual pathway, a few issues need to be addressed. First, it would take more than a hundred columns to map each pathway relationship, making data management difficult. Thus, instead, each pathway has been broken down into several individual sections according to the scoresheet. For example, the GWP is divided into General Information, Suspected Releases, Primary Target, Private Well and Scoresheets. For a diagram of relationships of the system, see Appendix B.

Second, there are a few one-to-many relationships embedded in these sections. For example, in the GWP, a facility have four different private well impact analysis allocated with it and one or more targets; in the SWP, a facility can not only have more than one Primary Target, but also Drinking Water Threat and Food Chain/Environment Threat. Figure 3.3.1c shows how all the relationships have been resolved. There is no indication of specific relationship type because it varies from one to another (1/1 for one-to-one and 1/N for one-to-many).

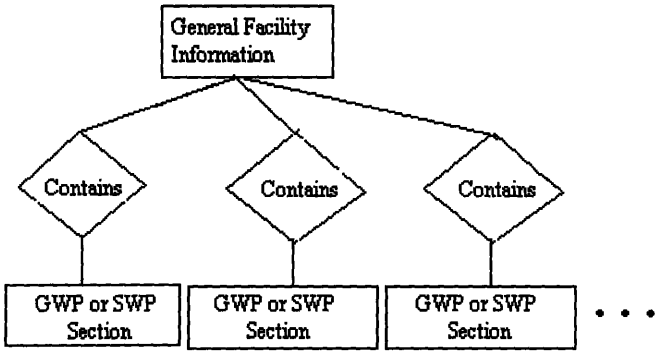

Figure 3.3.1c GWP and SWP Sections: GWP contains General Information (1/1), Primary Target (1/N), Private Wells (1/N), Suspected Releases (1/1), and Scoresheet (1/1); SWP contains General Information (1/1), Primary Target (1/N), Suspected Release (1/1), Drinking Water Threat (1/N), Food Chain/Environment Threat (1/N) and Scoresheets (1/1)

3.3.2 Executive Information System Table

In addition to these base tables, a series of EIS tables has been build to record information about the data in the base table. These EIS tables contain information such as the confidence level assigned to the data, the person who filled out the field, the date, the information source and any comment related to the field. Figure 3.3.2a shows how these data relate to the individual section. See also Appendix B for sample tables and data sets.

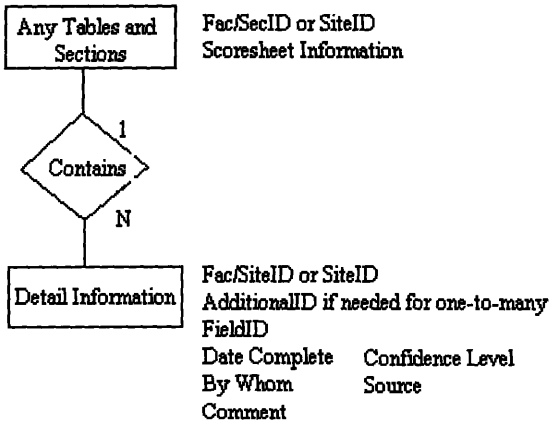

Figure 3.3.2a EIS Tables: All EIS Tables follows the ER diagram above. A few of them will be different: including an extra AdditionalID to combine with Fac/SiteID to serve as Primary Key. This is used whenever there is a one-to-many relationship between General Facilty Information and individual sections, such as Primary Target.

3.4 Web-Based Information Systems

Unknown to most people, the Internet has been in place since the late 1960's. Because this so called information highway was primarily designed for national defense against nuclear attacks and academic research purposes, and was funded by the federal government, only government agencies and selected universities initially had access to it. Although designed as an opened system, the information flow was still in a closed loop.

In 1990, having sensed and recognized the potential and the growing commercial interest of the Internet, Merit, IBM and MCI formed an organization called Advanced Network and Services (ANS) to commercialize the Internet by upgrading the then-existed infrastructure of the Internet to handle more commercial information traffic. This is the first sign that signaled the growth of the Internet (Weingarten, pp.2).

Today, the most important area of the Internet is the World Wide Web (WWW), which is a wide-area information retrieval initiative that aimed to give universal access to a large universe of documents (Hughes, 1993). Many will argue that Centre d'Etude et de Recherche Nucléaire, CERN, with its WWW invention and Mosaic at National Center for Supercomputing Applications, NCSA, kick-started the Internet. However, during the era of Mosaic, WWW is still utilized mostly by academic and research institute (Salomon, 1996). It is not until 1993, when Netscape, as a public company having had received lots of exposure at the time, introduced the Navigator to the WWW, that the Internet went super-nova. Its affect was similar to the impact that spreadsheet applications, such as Lotus 123, had on the personal computer industry; the distribution of Netscape Navigator is definitely the single most important event that led to the explosive growth of the Internet.

3.4.1 Infro-Structure of the World Wide Web

The information flow structure of the World Wide Web (WWW) is based on the popular client-server model. Information providers of the WWW deploy data by constantly running a Web server application. The Web server will wait for requests for information through the Internet from a Web client, which normally is a WWW browser tool such as Netscape Navigator or Microsoft Internet Explorer.

Web clients communicate with Web servers using the HyperText Transmission Protocol (HTTP). All Web clients and servers must be able to speak HTTP in order to send and receive information. Because of this reason, Web servers are sometimes called HTTP servers. The phrase "World-Wide Web" refers to the collective network of servers speaking HTTP as well as the information available that uses the protocol (Hughes, 1993).

Beside HTTP protocol, there are numerous other protocols available for the transferring of information. One of the more popular Internet protocols is File Transfer Protocol (FTP). This allows FTP clients to view files on FTP servers. This make transferring of the entire directory or a specific group of files easier.

3.4.2 Web Publishing with HTML

HyperText Markup Language (HTML) is the standard publishing language of the WWW. HTML files contain not only the information people see on screen, but also connections information to other documents. In addition, besides HTML files, these other documents can be pictures, audio clips, video clips and applications. This makes the multimedia representation of information possible, which is an attractive feature.

HTML also drove the Internet in the beginning because of its ease of coding. HTML is not a conventional computer programming language; rather, it is a scripting language, which uses codes to indicate the formatting of text and graphics. For example, putting text in between <B> and </B> means that the text will be bolded; putting text in between <I> and </I> means that the text will be italicized.

Since the expansion of the Internet, there have been many improvements added to the capability of HTML. These features include text alignment, bullet listing, table formatting and most recently, framing. Framing is a way to divide the Web browser's area to present information from different HTML files. The frame technology helps information to be organized better and easier to access. However, because HTML is a scripting language, HTML homepages present nothing more than simply information and formatting.

3.4.3 Web Programming with CGI Script, JAVA and Active X

Computer programmers first began tackling the programming limitation of HTML using Common Gateway Interface (CGI) programming. A CGI program is executed in real-time, so that it can output dynamic information. However, since a CGI program is executable, it is basically the equivalent of letting the world run a program on the server's system, which is not the safest thing to do. Therefore, there are some security-precautions that need to be implemented when it comes to using CGI programs. For example, allowing Web clients to access only a certain directories of information on the server is one security protocol that can be implemented.

As long as the system allows the program to be executed, a CGI program can be written in any programming languages such as C/C++, Fortran, PERL, TCL and Visual Basic. It only depends on the availability of these software packages on the server's system. Out of those

programming language mentioned, many people prefer to write CGI scripts using PERL or TCL, since they are easier to debug, modify and maintain than a typical compiled programming language such as C/C++ or Fortran.

However, since these CGI programs runs on the server's machine, they slow down the performance of the system in general. Around 1995, the JAVA language was introduced onto the Internet as a new way of Internet programming. As a matter of fact, JAVA has become the standard programming language on the Internet. This is mainly because JAVA supports advanced programming features such as object-orientated programming, multithread, network programming, and graphical user interface design.

In addition, since the structure of JAVA closely resembles that of C++, which has been the programming language of choice for the late 80's and 90's, JAVA was very quickly adopted by the programming community. The most important feature of JAVA, however, is the fact that JAVA programs are platform independent and run on Web clients.

Trying to gain market share and control over the growth of the Internet, Microsoft developed ActiveX Control for its Internet Explorer. ActiveX is a network-centric solution grounded in existing object linking and embedding (OLE) technology, which allows users to leverage their investment in Windows-based client/server computing and create engaging interactive applications for the Internet and intranets. In other words, ActiveX does pretty much the same thing JAVA does, but is catered towards only Microsoft operating systems and the Internet Explorer.

3.5 Planning Implementation Process

Having finished designing the database, it is necessary to implement the system using a database management system tool. There are many different tools available in the market ranging from high-end products such as SAP R/3, through mid-range products such as Oracle and Sybase, to low-end products such as Access.

High-end products are very expensive and difficult to implement. In addition, they normally cover the entire operation process of a company such as accounting, budgeting, workflow, employee management, etc. Therefore, they are beyond the scope of the information system being setup here. Mid-range products are the ideal choice of platform because these products are scaleable, expandable and relatively affordable. However, because this is a prototype to study the applicability of the model being developed, a low-end system is brought in to test quickly the design before the full implementation.

For the Preliminary Site Assessment Executive Information System, Microsoft Access 97 will be used to test the design to see if anything within the system needs to be changed and improved. Afterward, the information system will be implemented using Oracle7.

In addition to setting up the database, in order for the system be accessible through the Internet, a Web server needs to be run. To use the Publish to the Web Wizard for Access 97, the server must be running the Microsoft Information Internet Server 2.0 or better, and the Web pages must be viewed using Microsoft Internet Explorer 3.0 or better. Oracle also provides its own Web server: the Oracle WebServer which will be used for the implementation of the system on Oracle7.

4.0 System Implementation Using Access 97

As mentioned in section 3.5, the Preliminary Site Assessment Executive Information System (PAEIS) is first being tested using Access 97 before fuller implementation. The test information system takes advantage of the graphical user interface and the Publish to the Web Wizard of Access 97. This allows the system be implemented in a relatively short period of time and therefore demonstrates tangible results.

4.1 Introduction to the Microsoft Access 97 Database Application

Access 97 uses the relational database abstraction to store information. Data are stored in Access tables and are filtered and combined into Access queries. Access 97 provides two different ways to create queries: SQL View and Design View. SQL View allows users with Structured Query Language (SQL) experience to generate a query by typing query code in directly. Although restricting the degree of complexity of query output, Design View simplifies the query process by allowing the user to choose tables, to select specific fields, to set criteria and to perform sorting in a user-friendly graphical interface environment. Since the Design View automatically generates SQL codes, middle level users use the Design View for preliminary design and switch to SQL view to implement more complex queries. Figure 4.1a shows the two different Views for a query under the test EIS for Preliminary Assessment.

Before the development of database forms, information was presented in tabular format. The format is normally very hard to read and to understand. Therefore, to better present information, Access 97 uses the form function. Forms can be generated using data from tables or queries and presented in a user-defined format. Besides Text Box, List Box, Buttons, and

Background Images, one of the newest functions in Access 97 Form is Tab Control. Using the Tab Control function, the amount of information presented on a form is no longer limited to the surface area. The function allows users to set up pages of tab to display additional information within a form (Gates, 1996).

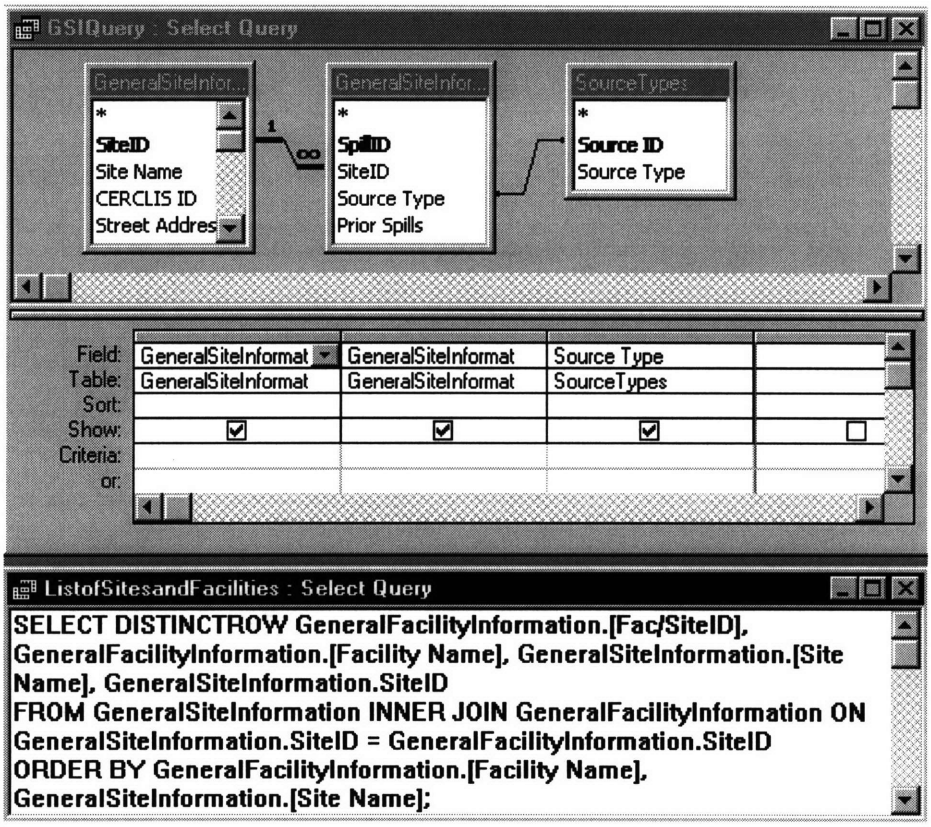

Figure 4.1a Design View (above) and SQL View (below)

Finally, the most attractive function of Access 97 is the Publish to the Web Wizard. Access 97 is capable of automatically generally 3 different kinds of Web exports: Hypertext Markup Languages Pages (HTML), Internet Database Connector Pages (IDC) and ActiveX Server Framework Pages (ASP). The HTML Pages option generates static HTML files. These pages contain only information in the database at the moment of creation, and remain static until the user exports another set of pages containing most recent information. The advantage of this

option is that it has no specific World Wide Web (WWW) browser and server requirement. On the other hand, both the IDC and ASP options generate dynamic pages, in that a connection to the Microsoft Access database is created and maintained so Web pages are continuously updated. The differences between the IDC and ASP systems are in software requirements and form exporting. Although both options create dynamic forms, IDC creates forms in a datasheet (tabular) view, while ASP creates an approximation of a form layout using ActiveX Layout Control. Also, because of ActiveX, ASP supports record navigation, editing, inserting and deleting (Gates, 1996). Figure 4.1b shows the Publish to the Web Wizard.

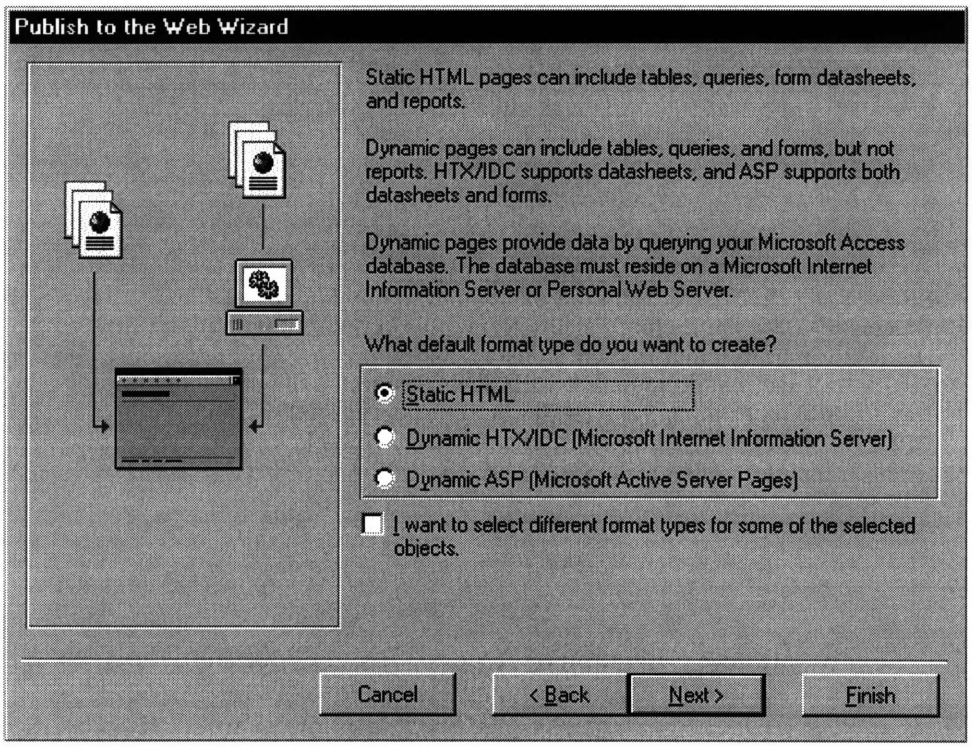

Figure 4.1b Publish to the Web Wizard

Although more powerful, software requirement makes both IDC and ASP options not feasible. Besides having to run Microsoft Internet Information Server as a Web server for both IDC and ASP, ASP specifically requires Microsoft Internet Explorer 3.0 as the browser tool.

This is not a welcome feature, especially when sixty to seventy percent of Web browsers use Netscape Navigator. Anyway, to generate dynamic and eye-pleasing output, ASP was chosen.

4.2 System Implementation Process and Result

Because of the easy access to information provided by Access 97, putting in the proposed EIS tables was relatively simple. Figure 4.2a shows all the tables created for the information system.

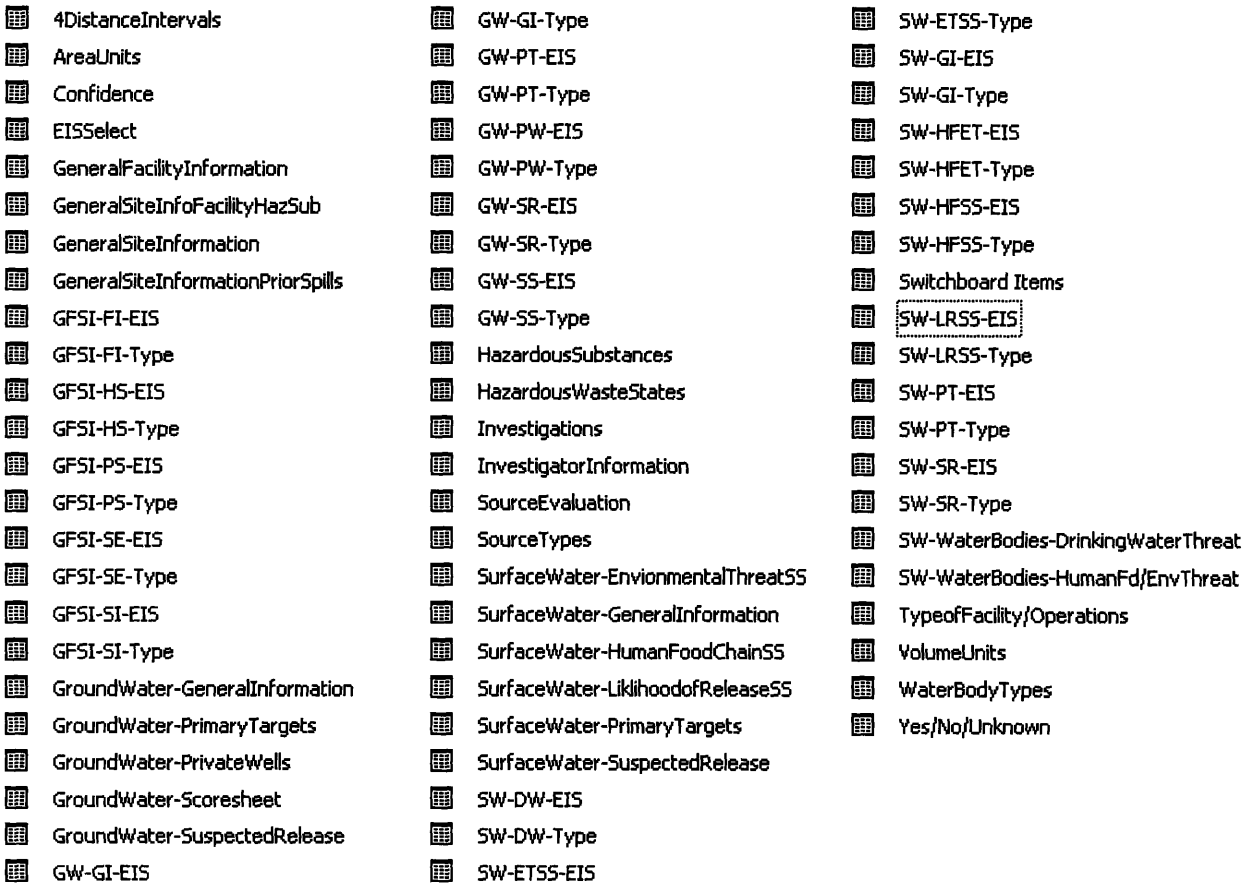

Figure 4.2a All Tables of Preliminary Site Assessment Executive Information System

There are also several functions in Access 97 that make record adding and editing easier. First of all, Access 97 supports Lookup Wizard; thus, instead of typing in a value, users can

select from a list. This list is created using an internal query. For example, in the EISSelect Table, both fields are using the lookup function: the Site Name is looking up the Site Name field in General Site Information, and the Facility Name is looking up the Facility Name field in General Facility Information. The advantage in using this format is to avoid users typing in an invalid name. See Figure 4.2b.

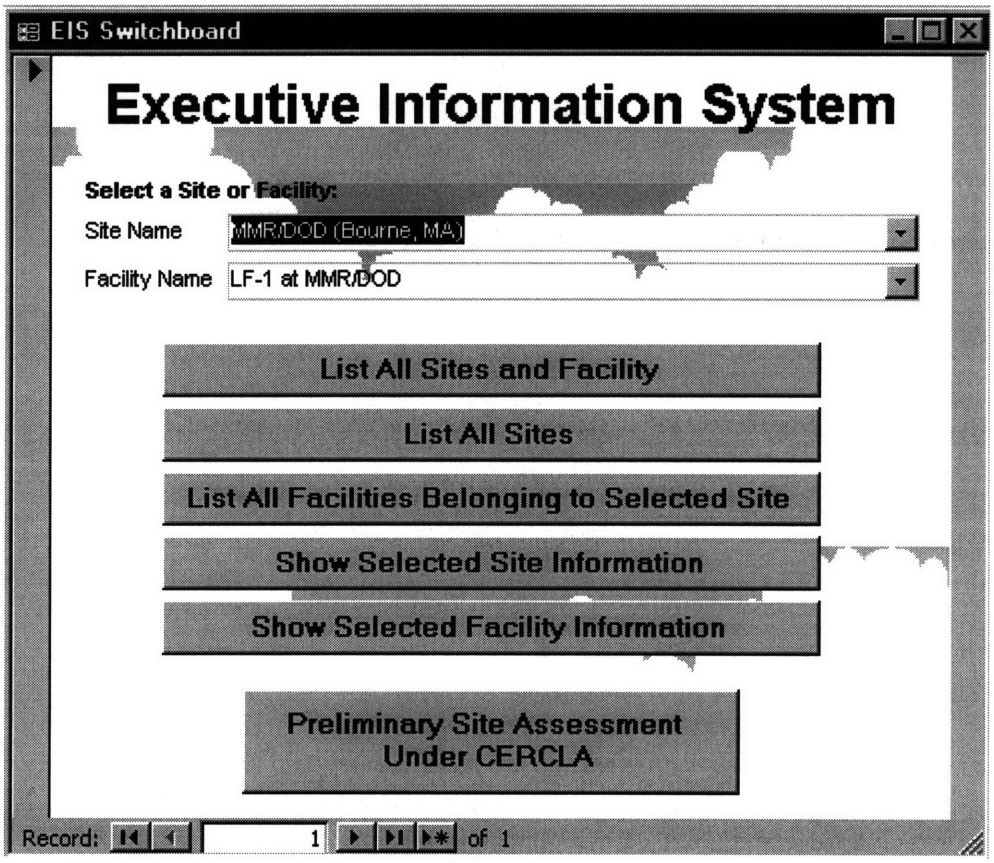

Figure 4.2b EISSelect Table to EIS Switchboard Form

In the EIS Switchboard, the user can select any site or facility that is already in the system, and further explore its properties. There are three List-All functions allowing users to find out which sites and facilities are in the system. Specifically, the List All Facilities Belonging to a Selected Site button will show all facilities in the site selected by the user in the Site Name field. Then, there are two Show-Detail buttons that will display information, in

forms, about the site or facility selected. Finally, the most important button of the system is used to call information from the PA Scoresheet of the selected facility.

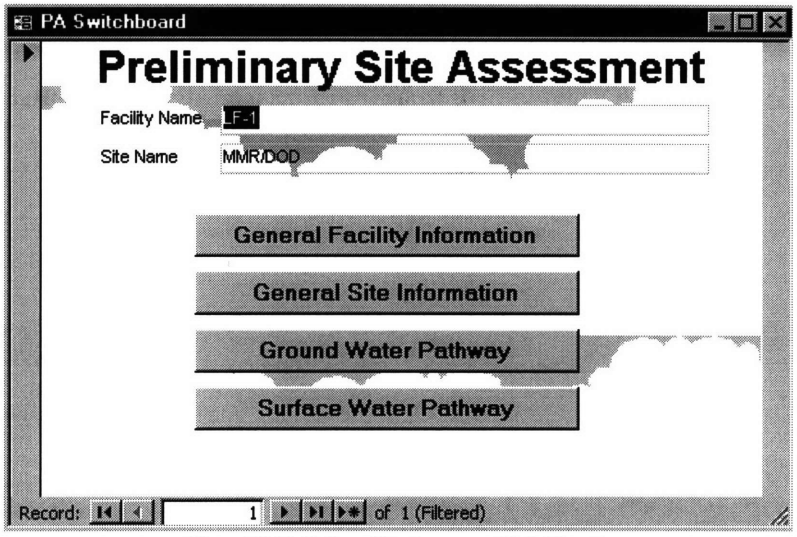

Figure 4.2c Preliminary Site Assessment Switchboard

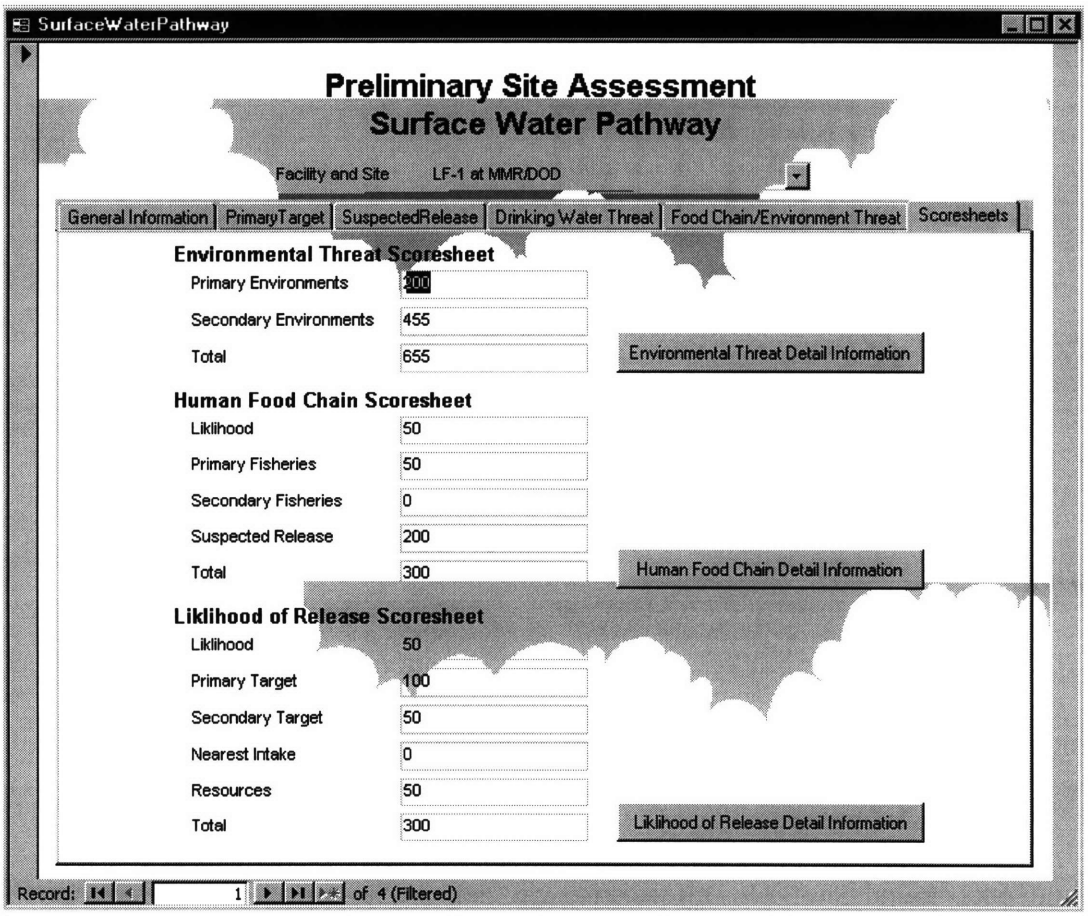

Figure 4.2d Surface Water Pathway

The PA Switchboard, shown in Figure 4.2c, has four different options: General Site Information, General Facility Information, Ground Water Pathway and Surface Water Pathway. Selecting either one of these will bring up a form displaying all the information stored about that section. These section forms use Tab Control to allow access to all the information instead of squeezing everything on a single form. Figure 4.2d shows the Surface Water Pathway form with its six tabs.

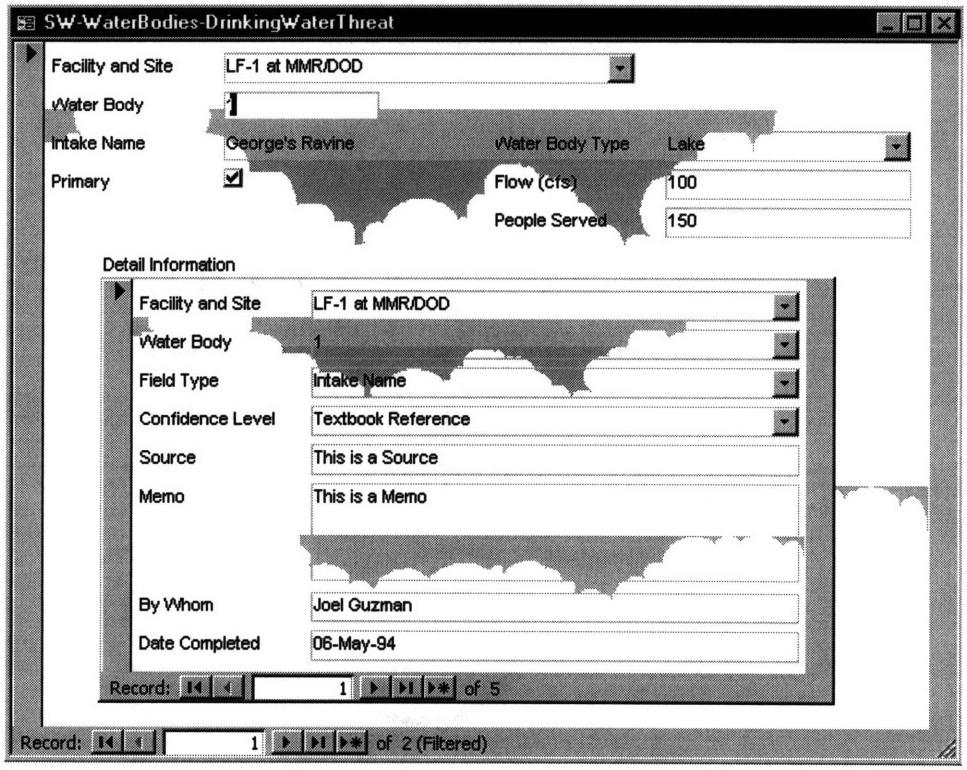

Figure 4.2e Executive Informatoin System sample table

Inside each tab, there is at least one Detail Information button. Clicking on this button will bring up another form showing the supporting information for data fields in the section. The EIS form, including information about Confidence Level, Data Completed, By Whom, Source and Comments is found here. This information will help whoever reviews the PA Scoresheet to understand why the decision was made in a specific manner, or where the person gets his or her

information form. Figure 4.2e shows the EIS information of the Surface Water-Water Bodies-Drinking Water Threat section of the PA.

Using Access 97 to test the EIS resulted in an easy and smooth implementation process. However, problems did occur when using the Publish to the Web Wizard. The Microsoft Information Internet Server and Active Page Server were installed on the Windows NT 4.0 operating system, and all sample-ASP files that came with these servers work correctly and entirely. However, ASP pages of the PAEIS are not working; although the Wizard correctly generates all forms in ASP format, many function used in Forms are not supported, for example, tab control and scrolling. The only reliable way to avoid this problem is to generate tables, which defeats the purpose of using a graphical user interface. As a result, the idea of deploying the database through the Web using Access 97 alone, although not as pleasant as expected, it is wholly feasible.

Appendix C contains screen shots of all forms of the PAEIS. They will demonstrate the capabilities of PAEIS using Land Fill-1 of the Massachusetts Military Reservations as an example.

4.3 Future System Development

Although the information system developed using Access 97 is limited to presentation of information, the implemented database structure paves the backbone for any future development. Here are four features that can be added easily: pop-up, project management, warning system and Web deployment.

First of all, Access 97 allows the user to build event activities. One event is the OnDblChick (on double chick). Using this event, the designer or administrator can set the

information system up so that when a user double chicks on a field in a form, the system automatically shows a table with the EIS information. Besides replacing the Detail Information Button, this will also replace all EIS forms with one standard EIS form. This will keep the database file smaller.

Secondly, since data in the database are dated in the EIS tables, adding project management and analysis tools is relatively easy. For example, users of the system, particularly senior managers can easily see how long it takes to complete a preliminary site assessment project, or more specifically, a pathway investigation. It is also possible to determine the average time needed to complete each field. With new information gathered by the computerized information system, performance analysis can be conducted to determine the efficiency of people filling out the forms and identify bottlenecks slowing the project down. This helps the company to formulate solutions, such as providing extra information for bottlenecks and changing the process to improve efficiency by grouping related questions together. In addition, using the fact that blank cells indicate incomplete tasks and information research, it will be a simple job to determine the progress of a project.

Thirdly, it is important to make use of the information that is already in the database. A warning system takes a little bit more effort to implement because it involves macro and Visual Basic coding. However, such a system would greatly benefit the EIS. The idea is that using confidence level data for each field and some standard criteria, the information system will warn and indicate likely trouble spots for users. For example, instead of going through the entire scoresheet to look for mistakes, the senior manager will only look at fields flagged with warnings either because the confidence level is low, or the value in the field is questionable.

Last but not least, although the first attempt of simply exporting the database as ASP files was not successful, there are other alternatives such as JAVA/JDBC, and CGI Script Programming that can be investigated. Web deployment is important because of the growing interest and its capability to expand and support beyond a local network. Besides, as long as those Forms in the database do not use the advance Access layout functions, a reasonable graphical user interface can still be developed for accessing the database over the Internet.

In general, this information system will assist upper management to better monitor decision made by lower level employees. Senior managers can then focus on what they need to be doing instead, which is managing, and not, for example, double-checking and approving. This information system also can help to empower lower level employees by giving them more responsibility and ownership of the process. In managerial terms, this is a positive thing for organizational development (Hammer, 83-101).

5.0 System Implementation Using Oracle

Today, Oracle owns more than 60% of the database market. Oracle7 Server, the flagship product of the company, offers many more functions and capacities than Microsoft Access 97 does, for example, it can handle more simultaneous users manipulating a database, and it can accommodate a much larger database. Therefore, Oracle7 Server is a mid-range to high-end database software.

5.1 Installation of Oracle7 Server 7.3.2.2.0 for Windows NT 4.0

Because of its scale, the installation of Oracle7 is not as trivial as the installation of other window products. However, since the Oracle7 Server that the executive information system (EIS) is using is designed specifically for Windows NT 4.0, its Windows installation is relatively easier than installing it on a mainframe computer.

Oracle Installer, the automated installation program, guides the user through the process of installation. After asking for which directory to install Oracle, the Installer displays all of the different installation options. For the system to work correctly, and in case of an expansion to other Oracle products, a full installation options was selected.

During the full installation, the first question asked was which SQL*Net Protocol Adapter is needed. SQL*Net is a messaging software that provides a way for the Oracle Server and the Client to communicate over the network (Swadley, 20). Because the computer that Oracle7 resides on is connected to the network using TCP/IP (Transfer Control Protocol/Internet Protocol) protocol, the TCP/IP Adapter was selected. Next, the Installer asked for the installation of SQL*Net V2.3, and again, in case of expansion, a full installation was selected

here. Finally, to ensure correct installation, all options of Oracle7 Client and Server were selected.

The Installer then asked whether the user wishes to install a Starter or a Replication database. A Starter database is a set of files that is configured and ready for use with Oracle7; a replication database is used for remote accessing. Since there will be no remote accessing at this stage, the Starter database was selected. After that, a series of questions relating to the security of the database, such as the supply of a password, was asked.

After th eabove steps came the installation of the Oracle WebServer. First, the connectivity information, such as Host Name (tiller.mit.edu) and Port Number (9999), was requested. Then needed security information, such as Username and Password, was requested. An Oracle WebListener needed to be installed as well, which was set up using the same Port Number (9999); the listener is similar to a door being opened to the outside world, waiting for a request. Thus, it is the part of Web Server, or another other servers, that actually "listens" for Internet requests.

Finally, before completing the installation, it was necessary to use SQL*Net to add a database alias. This steps allows the database to be connected to remote databases. In order to do this, the program needs to know the TCP/IP Host Name and the name of the database for the installation.

5.2 Installation of Oracle Designer/2000 1.3.2 for Windows 95/NT 4.0

Developing a database management system using conventional Oracle7 tools, which are generally text-based, is very difficult. Responding to this customer need, Oracle has developed a set of tool known as Designer/2000 for developing sophisticated application. Although the

system is normally used for client/server architecture application development and the current EIS is not designed for such a task, Designer/2000's graphical user interface and its connection to all other Oracle products makes it a great developing tool.

Fortunately, the installation process for Designer/2000 is similar to that for the Oracle7 Server. Therefore, with the use of the default installation options, the Oracle Installer does much of all the thinking for the user and installs all parts of the program in the correct directories with the right configuration. Figure 5.2a shows the Oracle Installer finishing the full installation option.

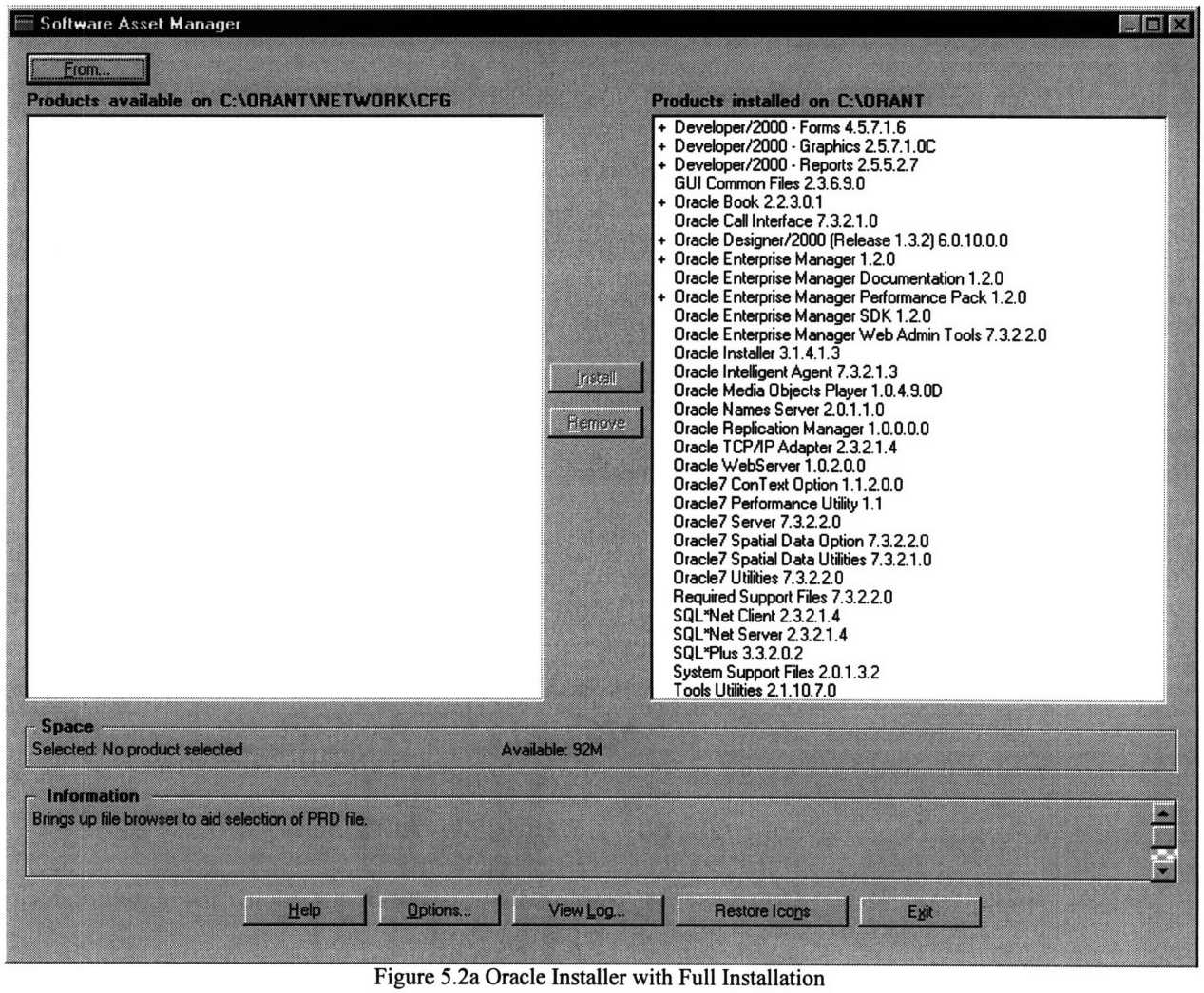

Figure 5.2a Oracle Installer with Full Installation

5.3 Starting Oracle7 Server and Desginer/2000

After starting the Designer/2000 for Windows NT, the computer will ask the user for the User Name, Password and a Connect String. Since the Connect String is only used when connecting to a remote database, the field is left blank. Having entered the username and password, the program asked for an Application System. The user can simply hit cancel for the first time running it.

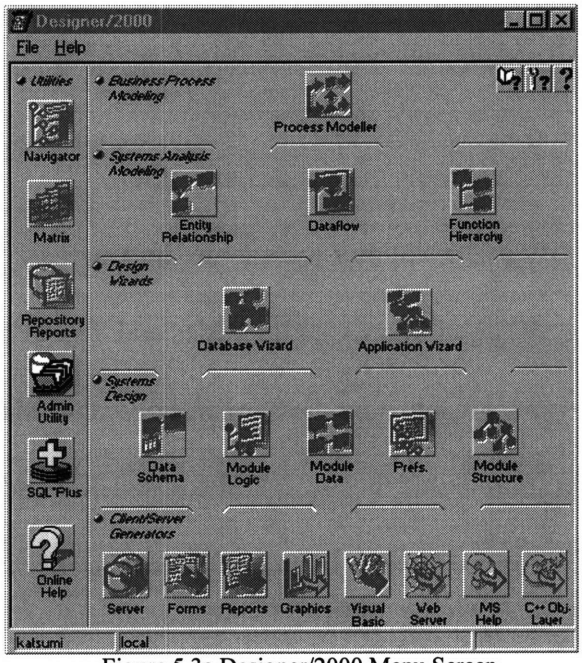

Figure 5.3a Designer/2000 Menu Screen

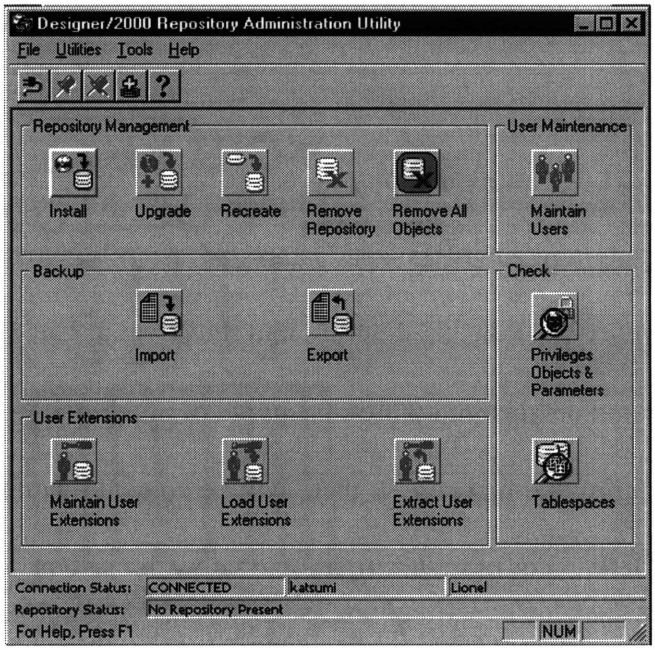

Figure 5.3b Repository Administration Utility

The Designer/2000 menu screen is displayed (see Figure 5.3a). The first step now is to install a database. By clicking on the Admin Utility button, the user can choose Install from the Repository Administration Utility (see Figure 5.3b). This will automatically install all necessary files for a database. After that, the user can make use of all the different functions of Oracle7.

5.4 Using Oracle7 and Future Development

The first time Oracle was being installed on the computer, it was working fine, and everything installed correctly. The author of this thesis managed to use Oracle 7 to generate the General Site Information and General Facility Information table using some Oracle7 Designer/2000 tools. However, as the author decided to retrace the procedure of installation by redoing the entire process – first uninstalled the current copy and then reinstalled the entire package again, the installation failed. Therefore, only the experience of creating tables can be recorded in this thesis.

Putting in tables is easy using exciting Designer/2000 tools: Entity Relationship Diagrammer (ERD) and Database Design Wizard (DDW). ERD allows the user to draw actual entity-relationship diagram into the computer, and the DDW will convert all entities and relationships into tables, primary keys and foreign keys. Unfortunately, no screen shot was made during the first run, so there will be no detail demonstration in this thesis on how to use ERD and DDW. For more information on how to use Oracle7, there are lots of Oracle7 reference books on the market; *Oracle7 Unleashed* is used as the reference of this thesis.

The implementation of Oracle7 took much longer than Access 97. The installation of Oracle7 alone took almost four weeks. Although the installation procedure mentioned earlier is short and concise, getting Windows NT and the computer system ready for installation was a lengthy process. Afterward, getting the actual installation to take place was also problematic. In general, there were many trails and errors throughout the entire installation process. A more structured technical installation plan could have helped.

However, learning how to work with Oracle7 takes a long time. Matter of fact, learning each component of Oracle from classes offered by the Oracle Corporation takes about one to two

weeks. These classes range from installation, database administration, database design, form, SQL*Plus, etc. Because of this, using Oracle requires a larger investment up front. Of course, once the user is a long way up on the learning curve, the possibilities offered by Oracle7 are more or less limitless. In addition, the Oracle Corporation is committed to its product, and upgrades with new functions are very frequently available.

5.5 Oracle7 versus Access 97

This section will not compare Oracle7 against Access 97. The scale of operation between these two systems presented is too big of a difference. However, installing the Preliminary Site Assessment Executive Information System (PAEIS), a part of Executive Information and Decision Support System (EIDSS), on Access 97 and Oracle7 illustrates that the information system is not limited to being installed onto any specific database management system. PAEIS, or EIDSS in general, is a concept, not a specific system requiring specific software. As long as the software package support the technical functional requirements of PAEIS, it can be used as the platform.

6.0 Managerial View of System Design and Development

This thesis, so far, has taken a rather technical approach towards the implementation of the EIDSS. However, there are always two sides to system design and development processes: technical and managerial. Without undermining the importance of technological issues or trivializing the significant of managerial issues, the managerial view is isolated and presented in this section.

6.1 Problem Statement Formulation

In the beginning of the design process, the project group met thesis supervisors and a MMR expert to determine which process of the site remediation process, see figure 6.1a, can be improved using information technology. The group was initially leaning towards processes involving modeling, geographical information system and environmental engineering system analysis. However, in the final analysis, the group selected the Preliminary Site Assessment (PA) process because it is more information intensive and had relatively few existing systems in the market. The PA also involves problem in many different areas ranging from information gathering to automatic scoring capabilities.

Having decided to computerize the PA process, the group began researching this process. Each individual was assigned a set of parameters to determine whether the information needed for computerization was available in an electronic form or not. The result was quiet discouraging because the majority of the information was not immediately available in electronic format. Although there are a few exceptions, most relevant data are normally in paragraph format, which is difficult for a data-based computer program to extract information from.

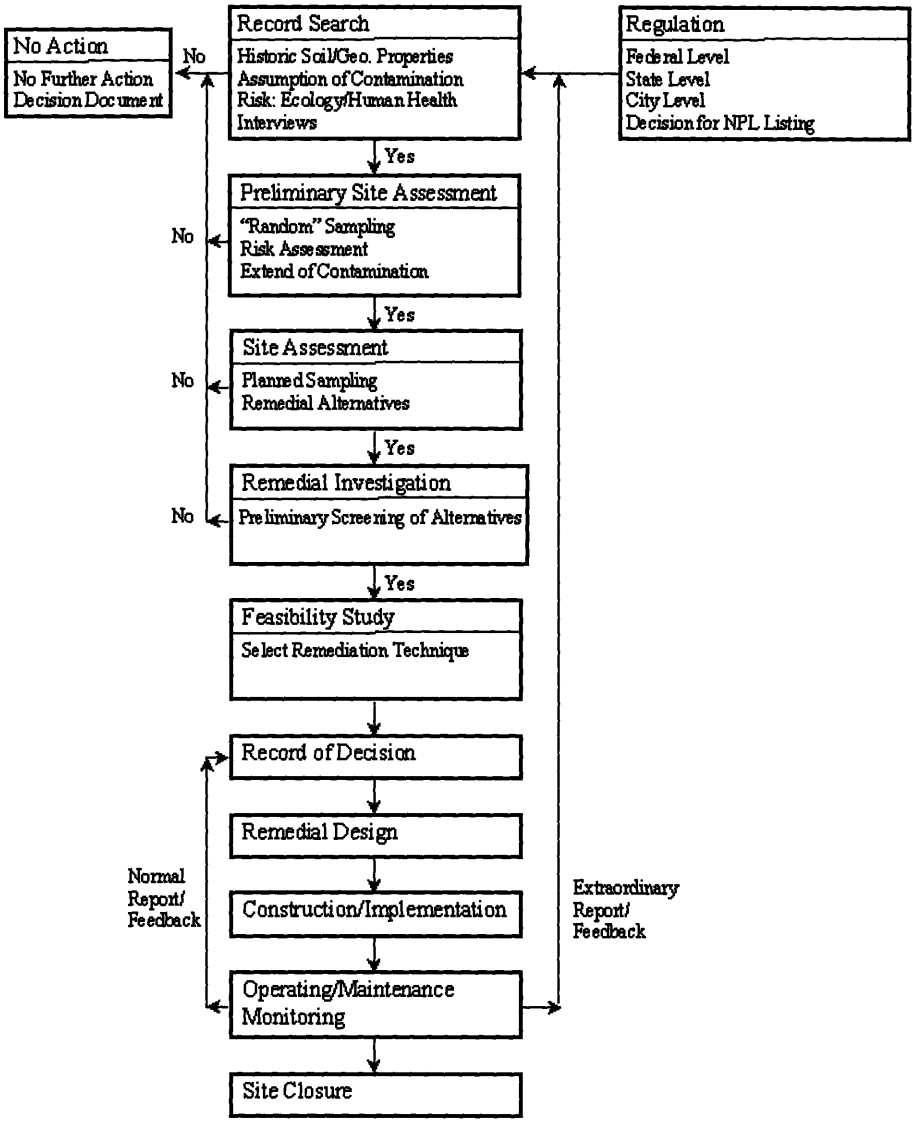

Figure 6.2a Site Remediation Process

6.2 Early System Design and Conceptualization

After a series of meeting, the group came up with a system that can make use of what is currently available and possible. The system consists of two major modules: one will access data that is known to be available in a standard form; another will require the user to select relevant data from sources that the system points out. The first part, known as the Standardized Public Access Database (SPAD), links to data that is available in a standard form on CD or on databases

that are already on the Web. Since this data is in standard form, the system will be able to run queries and actually retrieve particular figures from fields, wherever they are located.

The system will accommodate data in non-standard form in two ways. If the data is on the web, then the system will have an intelligent search engine, which will point to, and allow the user to, read the information. The user can then enter the information back into a local database, known as the Standardized Pre-Defined Database (SPDD), where it will remain for later queries. The user will also be able to enter information from books and articles into the database.

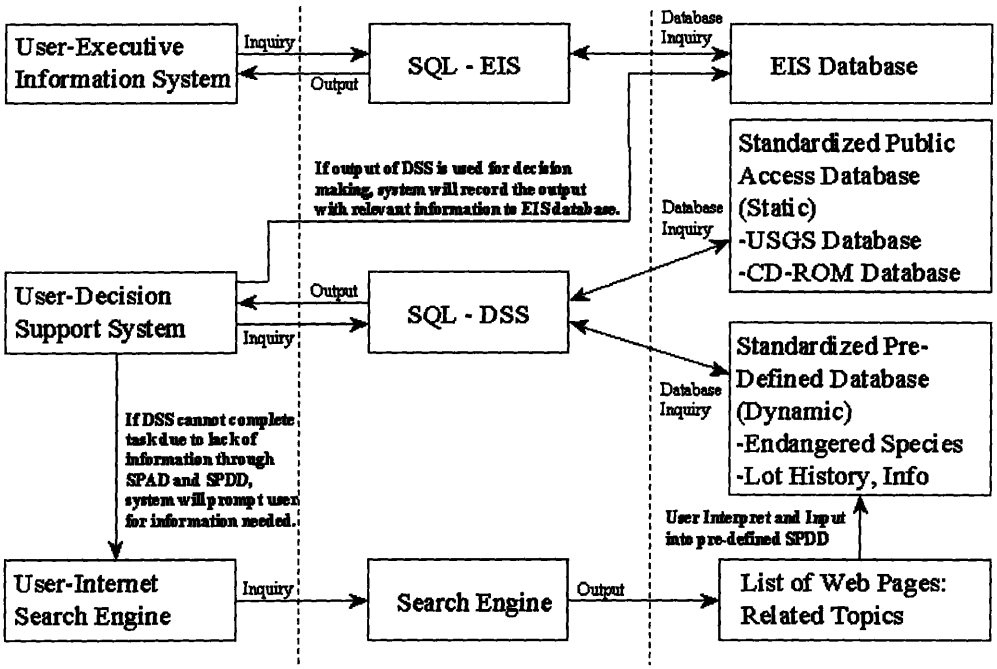

Figure 6.2b Early Stage System Diagram

With links to all of this information, the user will be able to run queries of many different types. When these queries are executed, the information obtained will be displayed for the user, and then the user will be asked whether this query was made simply for browsing, or for actual decision making. If the query was made for decision making, the information that was given to the user, where that information was taken from, when it was taken and what decision it was

taken to support will all be recorded in a separate local database, known as the Executive Information System Database. This database can be accessed independently to determine the origin of any information that was used for a particular decision.

Figure 6.1b shows modules and information flow of the system. The system then slowly evolves to become the current system, as shown in figure 2.4a. EIS remains an EIS in EIDSS. The SPAD becomes the Data Store Search Engine. The intelligent search engine becomes the Internet Search Engine. Finally, although not fully implemented, the Cross-Site Comparison Database System uses a localized database to help also provide in the decision making process.

6.3 Alternative Managerial Design Approach

From the technology point of view, EIDSS is a good system because it successfully implemented the PA process using information technology. However, from the managerial point of view, the design and development process is not ideal at all. The PA process was initially presented and interpreted as a technology problem, and because of this, the group quickly decided on an information system capable of solving associated technical problems such as data searching and manipulation. Obviously, the overall problem was trivialized; the computerized PA processes also presents a business problem for an environmental engineering company because the information system will eventually alter how business is conducted. Isolating it as a technology issue undermines the potential of the system.

6.3.1 Decentralized Design versus Centralized Design

The group decided to split up and explored different computer technologies. To maintain consistency, before splitting up, the group had already decided on a universal platform. The

information system will use JAVA as the graphical user interface for its client/server and Internet capabilities, Oracle as the underlying database system and JDBC as the interface between the user, the local database and databases on the Internet. As soon as each individual explored different options of implementation, however, the process became decentralized. In the end, JavaScript was used for the graphical user interface; JDBC and ODBC (Open Database Connection) were both used for the Data Store Search Engine; Access 95 was used to implement the Cross-Site Comparison Database System; Access 97 was used to implement the EIS.

The consolidation of all these different parts of the system would have taken probably another four months. Consolidating these systems would involve problems from not only the native system, but also problems between each system. Information systems need to be implemented in a centralized environment because system development is no longer as trivia as buying a monitor, a CPU and a keyboard and plugging them into each other. Modern day information systems involve networking, security, software compatibility, etc.

In addition, due to the complexity, the implementation process needs not only a system design plan, but also an integration plan if, in fact, different parts are using different products, or different developers are working on different modules of the system. A decentralized design will work as long these plans exist and are followed. However, the EIDSS group did not have a system design plan. Having decided that different parts would have been connected, the group should have studied immediately how they could be connected.

6.3.2 Technology Focus versus Business Focus

Immediately after having chosen the Preliminary Site Assessment as the primary focus of the project, the group made another mistake. The entire project was designed to last less than

four months. When the author of this thesis suggested the splitting, the period was not supposed to last for more than three weeks. This process was meant to give each member some time to become familiar with information and computer technology. However, because members of the group became attached to technology, whether it was fascination or confusion, this process went on for almost two months, and in case of two systems, almost three. This significantly reduced the time spent on actually developing business functions for the system.

Although after a month of splitting, the author of this thesis attempted to reconsolidate the design process and redirect the focus towards business functions, the rest of the group decided that it would be best that each individual worked on his or her module first and consolidate the software later. What the group failed to realize at that point was that not only the consolidation would be very difficult, the capability of functions of the system would be limited.

The group should have kept a more neutral approach. A good balance between technology and business would have helped the group to focus on the real problem and to find the right solution. The group would have discovered that there are a few business functional requirements that an environmental engineering company demands from an information system. In the end, instead of coming up with solution to present and display information, the group could have developed systems that would assist, for example, the workflow management, project control and scheduling, finance and accounting system, etc. during the Preliminary Site Assessment process.

6.3.3 Temporary Problem versus Actual Problem

Although the system design addressed the issue of data very effectively, the group put too much emphasis on data during the design process. Besides focusing initially on finding available

information, the group also focuses on data manipulation and related technology. These can be classified as temporary information system problems.

There are two types of temporary problems. One type arises when the installed information system fails to address a specific area of interest. The problem is temporary because it can be addressed by building a new module to the system. Another type arises when a whole new information system is put in place. When installing an information system, if the focus was to address, automate or computerize the existing process, then those problems addressed will most likely be temporary. This is because the scope of the information system normally involves more than one obvious process.

In the case of the EIDSS, obvious problems are computerized data presentation, electronic format storage, and some automated calculation tools. These functions involve relatively simple planning for implementation because all procedures and processes have been defined. However, this is only the beginning of solving a larger problem. The ultimate problem of an environmental engineering company could be managing site remediation progress and processes. If this actual problem were to be solved using an information system with a new reengineered process (Hammer, 83), temporary problems would be solved either because they are vital parts of the new system, or they become unnecessary.

Redundantly, EIDSS addressed both problems. The Internet Search Engine and Data Store Search Engine of the decision support portion used the Internet to find information. However, the implementation of both the Cross-Site Comparison Database System (CSCDS) and the Executive Information System (EIS) eliminated the need for those systems. Both CSCDS and EIS addressed the user interface problem by using the graphical user interface provided by the database software, solved the problem of storage, and provided means to view information.

In addition, the software package is capable of linking to remote databases using any kind of protocols such as TCP/IP, which addresses the linking problem. Web client software can also be connected to the database easily. And, on the issue of using the Web to deploy information, both Access 97 and Oracle have the capability of acting as a WebServer.

Therefore, it is more important to solve the actual problem, instead of prancing around the current process for immediate solution. Sometimes, an immediate solution will actually be the limiting fact for the company to grow.

6.3.4 Bleeding Edge Technology versus Leading Edge Technology

Some of the implementation problem is caused by the usage of bleeding edge technologies, which are technologies in beta testing or at the end of the development stage. The attempted implementation of JDBC is a good example.

JDBC classified the part of the JAVA language used for database connectivity and manipulation; it is an alternative to ODBC, a standardized database communication tool provided by Microsoft. At the time of studying its capabilities, JDBC sounded promising, offering all functions the system needed such as remote database access. However, it was introduced into the database and Internet community in December 1996. Many software companies, such as Oracle, talked about having JDBC drivers available in late February or early March, but that never happened. In addition, the developer of the JDBC part had problems not only with the interface between GUI, database and remote database, but also the JDBC language itself. In the end, the developer settled with a more conventional technology of ODBC, and coupled it with some JDBC.

Bleeding edge technologies might be wonderful on paper, however, the network of support for these technologies is not yet established, as is the case of JDBC. There will be limited support during the implementation process and might be a damaging factor. Another thing is that most of these technologies are developed by startup companies. There is no guarantee that they will still be in business after some time either because of fierce competitions in the industry, or because the startup is bought out by a major. Leading edge technologies are safer because they are proven technologies supported by well-established companies, and they are not, by any standard, obsolete. For example, using JAVA and JDBC to do electronic commerce on the Web is bleeding edge technology, but using HTML and CGI-BIN, although a two-year old technology, is still leading edge. Of course, using e-mail to transfer invoices is obsolete. Therefore, it is more important to select a doable technology and not to get too excited over new ones, especially when new technologies come out every week or day.

6.4 Non System-Related Potential Improvements in Development Process

To summarize the previous section, information systems need to be design according to the perfect world scenario. Assuming that there are no technological limitations, business people will first come up with what they want to see happening on the screen. After that, the list of business functional requirements is then brought to technologists for implementation. Since the development of the system will be based on a set of requirements, when the information system is completed, it will not be missing some critical functions, or something the business people want. From the point of view of technologists, instead of immediately passing judgement on whether the system is possible or not, they will try to solve it. And in most case, a solution can be found, and the information system can be implemented.

This approach relies on two groups of very important people: technologists and the business people, and business technologists. All these groups need to be involved in the development process to ensure the development of a successful information system.

6.4.1 Technical Knowledges from Technologists

Technologists are important because of their technical knowledge. There are roughly three kinds of them: the pioneer, the specialist and the generalist. Pioneers are those technology gurus who constantly check out new products and get really excited over program specifications. They are the people who bring bleeding edge technology to the company. Specialists, on the other hand, are those who understand only a set of specific software or hardware and believe that they can solve all problems with those tools. Both of these groups should be avoided because the solutions they provide are often not reliable.

Pioneer's solutions, involving bleeding edge technologies, are unstable as described earlier. Although specialist's solutions, generally leading edge technologies, might seem more reliable because of established support system, there are personal hidden agenda to these solutions. Since specialists only work with a few specific products, they have developed tight bonds with them. For example, Oracle database developers will constantly push a company to migrate to use Oracle not necessarily because it is the best, but because that is what they know. There is also a danger that a specialist will bring obsolete technologies into the company.

However, pioneers and specialists are good sources of technical information. They can provide useful information for the development team to consider. The leader of the technology development team should be a generalist. Generalists are technologists who have broad understanding of existing technologies, but have no special tie to any specific one, while still

open to news bleeding edge technology. These people can provide an objective view of implementation that focuses on the system, and not on choosing brands; they focus on the implementation of the system, but not the implementation of an individual, specific tool.

EIDSS would have benefited greatly from some inputs of generalist because selections of technology by the group were based on what was hot, and what each member wanted to learn. The group should have picked technologies that addressed the problem instead.

6.4.2 Business Functional Requirements from Business People

Inputs of business people are important because they are people who ultimately use the system. Using the old design and development process, technologists often imposed functions they think the business people should need. The truth is that no one knows better about what functions are needed but business people themselves.

Although EIDSS was designed to solve problems for an environmental engineering company, there was virtually no involvement of any kind from the industry. Supervised by environmental engineering experts, the procedures of the PA process was implemented correctly. However, the system failed to address business problems, or explore potential functions. Even the current EIS was limited to just the presentation of information and the storage of executive information. Had there be more conversations with company executives, the future development portions described in section 4.3 might actually be a reality already.

6.4.3 Project Leadership from Business Technologists

The problem is that technologists and business people talk in different languages during meetings in order to impress each other. Bringing these people together will be the job of a

business technologist, who is responsible for overseeing the implementation. This person, in most cases a Chief Information Officer or a technology director, will make sure that the system is installed correctly and is given proper maintenance and upgraded, and employees are adequately trained to use the system. This person needs to also study the impact the system has on the company and formulate appropriate action, such as compensation adjustment and organizational restructuring. Business technologists can come from two backgrounds: managers with an interest in information technology or computer scientists with a business sense.

These people are difficult to find. This is true, particularly when neither business schools nor engineering schools are producing them. Engineering schools are busy graduating computer science students who probably spend the rest of their life programming, and business schools are busy graduating business management students who probably retire when they reach 40. Unless one of these technical people becomes enlightened and goes to a business school for training in business management, or vice versa, finding good business technologists will continue to be difficult.

Fortunately, new programs, such as Management Information System and Information Technology, continue to grow in higher education institutions. Both business schools and engineering schools are beginning to understand the importance of both business and technical skills in this Information Age.

6.5 Business and Information Technology Strategies

Another important issue during the design and development process is the issue of strategies. Besides successfully implementing the system, it is also important that the investment is not wasted. There must be a business strategy that coexists with the information technology

strategy, which includes everything mentioned in section 6.0, because this will give the company a clear direction and objective.

6.5.1 Introduction to Strategy

It was a very simple question every company needs to ask itself: what is the company's business and information technology strategy in order for the company to stay competitive? There used to very easy answers. For example, companies in the financial service industry need to become more customers oriented and services driven. Companies around the world are taking full advantage of new advances in computer technology and incorporating information system to deliver information faster and more accurately to their customers and employees.

There are different definitions of the term strategy. Conventional ones are, for example, how the company positions itself to target different segments of the industry, or how the company was information systems to enhance company performance. However, according to what Michael Porter, Harvard Business School professor, pointed out in his "What is Strategy?" article in the Harvard Business Review, Nov/Dec 1996, and his lecture on April 14, 1997 at Massachusetts Institute of Technology, none mentioned above is strategy. Every one of them is operational effectiveness, which is simply a way for the company to catch up to the best practice. Although unconventional and controversial, there are some truths to his argument, and it is especially true in the process of developing and implementing an information system.

6.5.1 Definition of Strategy

As suggested by Professor Porter, it is not a strategy if it is something that each company needs to do. Using an information system is needed in today's fast pace of information intensive

commerce. Such changes are essential for a company to stay competitive or to achieve the best practice. He suggested that strategy is something that a company deliberately does so that it can achieve a different outcome than others in the industry. For example, deliberately avoiding a specific class of customer to cut spending, or deliberately choosing a business model or process that is not at all efficient, but targeting a specific set of customers. Strategy is about making a choice. However, strategy, more importantly, involves tradeoff (Porter, 1996).

Porter explained that when a company is able to improve performance, quality, etc. without tradeoff, the company is still catching up, trying to achieve the best they can be and pushing to reach the outer limit. Illustrated by a production possibility frontier diagram used frequently by economists, this phenomenon is natural. When a company is inside the frontier, there is still room to improve by moving upward and rightward towards the frontier. This is the same as improving performance of both categories without tradeoff. However, when a company is on the frontier, moving alone the frontier requires tradeoff. Only when the company decides to move from a point on the frontier to another can this be considered a strategy (Porter 1996).

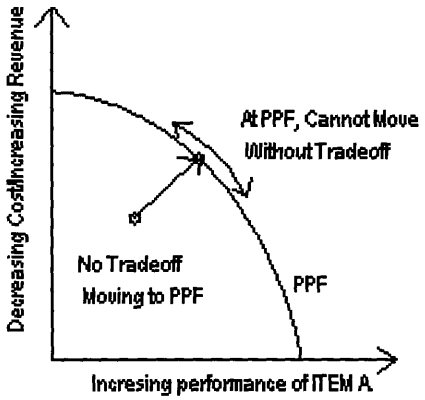

Figure 6.5.2a Illustration of Production Possibility Frontier

A strategy is not only measured by its output performance or revenue generation, but most importantly, by its sustainability. Strategy needs to be designed so that it is not easily

copied. In another word, if a company first did something that is then copied by a competitor, chances are that is not strategy; that is probably another move toward best practice. For a strategy to be sustainable, the change a competitor goes through during its implementation must not only be dramatic, but in most cases, unbearable. For example, when a small overnight shipping company does only deliveries among large cities such as New York, San Francisco and Chicago, this company can charge a lower price since it has less overhead and much less operating cost. A large shipping company, such as Federal Express and United Parcel Services, will not copy this procedure not because the business is not profitable, but because they cannot bear giving up hundreds of millions of revenue stream from shipping deliveries all over the world. This natural barrier of entry is what keeps the strategy sustainable (Porter 1996).

6.5.3 EIDSS Business Strategy

Besides all of the strategic items mentioned earlier for the design and development process, there is a more ambitious goal for developing the EIDSS. Since there is a serious lack of information systems in the environmental engineering industry, the strategy for EIDSS as a software package to capture the market is by setting an architectural standard. Although there are some standards such as USGS database and chemical substance tables, they are not being used as data sources for information systems, but by naked eyes. Because people read through a table to find the information they need instead, the table structure is nowhere new optimal form for conversion to database. Therefore, it is much easier to create a standard in this case.

Many will question, however, the decision of introducing a new architecture; the idea is probably too bold and too far a stretch. However, since there is no better way and no competing standard, there is no reason not to. Similarly, during the dawn of the Microsoft's empire of

operating system, Bill Gates created the MS-DOS disk operating system instead of going to Apple Computer and asking to use its system (Carroll, 92). Also, to put things into perspective, Gates actually had to compete against a standard, but the EIDSS will not. So, why should the strategy be less than setting the standard?

The EIDSS will target all level of environmental engineering practices, from large government agencies or private corporations to small regional companies. In addition, besides selling the tools, EIDSS will also sell data. With an established system and data architecture, compiling and distributing data is very important because a good system without good data is just an ordinary system. It is like a sport's car; no matter how good it looks outside, it is the engine that counts. Besides, providing data also locks in customers to the product and makes switching cost unbearable. For example, imagine all computers in an office will need to be changed to Intel-based Microsoft-driven platform from Macintosh. This will require changes to hardware, software, support staff and many other factors.

Therefore, the EIDSS can be packaged as a software tool. Owning both the architecture and data standards and the data, the EIDSS will be able to provide the tools and the information for an environmental engineering firm to compete; keeping them on the system will increase the profit margin of the product.

7.0 Conclusions and Future Recommendations

This thesis presented the development of an executive information system to support senior management in making better and faster decisions during the Preliminary Assessment (PA) phase of the Superfund process. Technically, there are four aspects of the Executive Information System (EIS) and the overall Executive Information and Decision Support System (EIDSS) requiring further resolution: the availability of information, the technology used, its expandability, and the potential impacts of this system on the Superfund process.

Managerially, companies implementing EIDSS or other similar information system need to focus on these following three areas to ensure successful implementation: complementary business and information technology strategy, understanding business functional requirements and organizational impact statements and structure changes.

7.1 Availability of Information

Information is the most important part of this system. Although information exists in the environmental engineering industry, these data are not standardized, which make using the information impossible. First of all, not all data are in electronic forms. Paper remains to be the primary storage of information in the industry. This make the implementation of the two search engines very difficult because the capability of computer, using artificial intelligence, understanding text documents is not readily available yet. This means that all these data need to be stored in database format, or table or spreadsheet format.

Even if these data are readable electronically, most environmental engineering related databases on the Internet are developed by individual company, state or city. These databases are

developed to fit the specific purpose of running efficiently and correctly on the one platform that the individual organization uses. This is a mess when the EIDSS need to access databases from different organization. For example, water well information is stored for most cities in the United States. However, like the case of MMR, when the scope of the project covers more than one city, this requires all water well databases of these cities to have the same format so that EIDSS can send the same query to them. Because of this, the current EIDSS is limited greatly by region and by database similarity. Having offices and projects all over the United States, an environmental engineering company will not benefit from the system at all unless the databases are in standard format, or the system can handle different data formats.

Another concern of information comes from inside the organization. Studies previously done for preliminary site assessment or all other processes are generally stored in paper format. This makes the initial implementation of the Cross-Site Comparison Database System and the EIS very difficult. Either the company has to start with a blank database, or has to hire someone to enter all the paper information into the new information system. Starting with blank database will cut the initial performance of the system, but re-entering information will take a long time. However, the system will benefit in the long run of the input of PA scoresheets since it will be able to use for following projects.

7.2 Technology Issues

A number of technology-related issues arose during the system's development. These issues restricted some aspects of the current system, but advancements in the tools used are anticipated, so future systems should not face such restrictions.

7.2.1 Data Source

For the EIDSS as a whole, there were many obstacles encountered in trying to connect the scoresheet pages on the Web to the data source itself. A large part of this was because the development of the Data Store Search Engine uses primarily Open Database Connectivity (ODBC). The system currently requires that the program executing the query on the data source and the data source itself to be located on the same server. So, when more sources are gathered, either a program must be installed at the location of each data source, or all of the data sources must be brought on to a single server. This significantly reduces the portability of data sources, and requires a large local database storage capacity.

Using Java Database Connectivity (JDBC) for the Data Store Search Engine, however, would eliminate this requirement. There could be one query program located on a server that is easily accessed by system administrators, and the data could be stored anywhere, as long as they are in the correct format and their owners give the system access permission. Although JDBC is still in early release stage, it will definitely be more reliable within a year, so the possibility of using a more robust system is conceivable in the near future.

7.2.2 Linking the EIS with the DSS

Currently, the EIDSS consists of two separated entities: Executive Information System (EIS) and Decision Support System (DSS). The EIS is the information system discussed in section 3, 4, and 5. The DSS consists of information systems described in section 2.4, including Web-enabled graphical user interface, Internet Search Engine, Data Store Search Engine and Cross Site Comparison Database System. Because all these systems are developed on different platform, the integration of these parts was also restricted by the available technology. However,

again, these restrictions will likely disappear in the near future, as the technology matures, and the development is based on the same platform.

The basis of the EIS is a local database, which resides on the same machine as the Web pages that the user accesses. Each user's decisions from the DSS are recorded on this database for later examination. The DSS links data sources in three different forms: an Internet Search Engine locating possible relevant data locations in non-standard form, a Data Store Search Engine retrieving data that is known to exist from standardized data sources, and a Cross-Site Comparison Database System allowing retrieval of data from previously filled out scoresheets. More database types, however, are becoming easier to connect to through the use of tools that easily display query results or table values on a Web page. This facility makes the inclusion of EIS access from a DSS link very easy to implement. The versatility and reliability of these Web connections, however, is not yet established, though is also expected to be so in the near future.

7.3 Expandability beyond the Preliminary Site Assessment Phase

Due to the scope of the project, the Executive Information System is currently limited to the Preliminary Assessment phase. Using the same principle of combining a document-like user-interface and a database management system, however, a similar executive information system could be designed and used in other steps of the Superfund process. This expanded system would then allow users to easily refer to, and use, information from various Superfund process steps throughout their work on a particular site.

In addition, expanding beyond the scope of just focusing on senior executive, the information system can also be designed to link to other company's functions such as finance and accounting, project management and learning or knowledge transfer. It can also be linked to

GroupWare software such as Lotus Notes to provide mailing list capability, discussion group and other workflow related functions. This can greatly increased the communication between employees of the company.

7.4 Impact of the System on the Preliminary Assessment Process

This EIS provides numerous advantages to its users at the level of a senior executive, and the EIDSS provides the same for the entire company. First of all, the supporting documentation needed to monitor and keep track of the Superfund PA process will be greatly reduced. All information related to site remediation can be stored electronically along with the bibliographical information. In addition, if there is more than one person scoring a certain site, much of the confusion accompanying trading the papers and other documentation will be eliminated by the accessibility of the forms over the Internet. Anyone with permission who needs to access the information can do so from any office using a desktop computer, or from the field using a laptop. It is also much faster to answer managerial related questions using the system, than to manually search out documentation stored in many different locations and forms.

Also, on a management level, this system provides many advantages to executives by having greater accountability both to the people filling out the scoresheets and the sources being used for the information entered into these scoresheets. Recording the source, date and time of a particular decision can greatly simplify the assessment process if particular decisions or sources need to be questioned. Indeed, the system can even be used to identify the engineers most efficient at filling out the scoresheets, have them share their insight and knowledge and reward or promote them accordingly.

7.5 Complementary Business and Information Technology Strategy

First, the company needs to have a vision. Whether it is achieving economics of scale, becoming low cost provider, developing strategic alliances, becoming service innovator or positioning for greater risk assumption, a well-defined vision will give the company a much easier time to define its strategy. It also provides company employee a target to work towards.

Then, from the vision, it is important that a company has both business and information technology strategy that are driven by the business and technology environment. This gives the entire company a common vision of what needs to be done, and how to do it. However, it is not enough just to have strategies. It is important that a company has strategies that complement each other because if they are not, they will be taking the company towards two different directions, damaging the effectiveness of the company as a whole. The complementation is achieved by the information technology strategy becoming the strategic alignment of business strategy, receiving business needs and providing business enablers. This way, since the communication channel between two functions is established, a more coherent solution is formulated.

In addition, a good information technology should challenge business strategy since the information technology environment changes more rapidly than the business environment. This will keep the company's business strategy always on the leading edge.

7.6 Understanding of Business Functional Requirements

A new computer technology comes out to the market almost every week. Many companies jumped on to these new technologies and made huge mistakes. Therefore, to better

understand a good information technology implementation, a better understanding of reasons of migration, or business functional requirements, is needed.

Migration from one information system to the other is an effort for companies to re-balance three fundamental criteria for choosing a platform: convenience, cost and speed. These migrations are often driven, however, not by changes of functional requirements. It is all too often that a sales team's power of persuasion and the technology division's eagerness to try new things and gadgets determine the direction of information technology strategy.

For example, in the database software technology, companies such as Oracle and Sybase have provided reasonably reliable services. However, over the past few years, System Application Product Data Processing (SAP) has actively promoted its new product SAP R/3 system, and has become the fastest growing database application posting more than 100% growth annually. Yet, implementation of SAP has been proved costly and difficult, and in most cases, the improved performance did not make up for the difference. Of course, these migrations will not be the last. In a year or two, these hardware and software systems will be obsolete and a new group of sales teams and technical people will convince companies and users to change again.

Because of all these smoke screens, chief executive officers (CEO's) and chief information officers (CIO's) need to have the ability to protect the company in this environment. The most important one is the ability to focus on system design and development, and not choosing brands. A good system design and information technology strategy will work with any software packages. Designs of systems could not be determined by the pre-defined procedure of any software package, but according to functional requirements layout by operation units. Since the computer industry reshapes itself to accommodate new interests and new demands, there will always be new products targeting those specific needs. Companies should focus on defining or

redefining of their business objective and functional requirements instead of having technologists of vendor telling then how to run a business.

7.7 Organizational Impact Statements and Organizational Structure Changes

Before implementation, information system and business personnel will have to perform Organizational Impact Statements. This will give the CEO and senior management a better understanding of consequences of the information system resulted not only from the technology, but also the company culture. Doing so will help the company to better define the scope and goal of the information system and to better manage human resources.

For example, since the role of site investigator changed, there must be some reflections in the compensation system. With increased responsibilities, employees need to be compensated for additional stress and extra effort going into their new contribution. Otherwise, there will be no incentive for them to change. Of course, the company also has to invest in employees' training or re-training programs so that they know how to use the system.

Another area is the company structure. There needs to be a clear definition of scope of work between investigators and managers since decision responsibilities belonged originally to management have now shifted to investigators. Their scopes of work need to be re-defined on paper to avoid ambiguity and conflict.

People are extremely important while designing and developing the information system, and senior management needs to keep that in mind. Inputs needs to be drawn from all level of personnel for the organizational impact statements because it is very difficult to predict how deep and wide the information system will penetrate.

7.8 Final Thoughts

Although this information system is currently limited by certain constraints, it has great overall potential to assist in the Superfund process and companies' project management process. Information system will no longer be limited to analysis and design. It will change how information is being used in the Preliminary Site Assessment process, and also many other aspects of operations in a company. Information will become a vital part of a successful environmental engineering firm, which will transform how the entire industry does business.

Therefore, the further development and implementation of the Executive Information System and the Executive Information and Decision Support System will help the environmental engineering industry to catch up to other industries such as financial services and manufacturing in the use of information technology for mission critical and value added operations.

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Appendices

Appendix A: Preliminary Site Assessment Scoresheets under CERCLA

OMB Approval Number: 2050-0095
Approved for Use Through: 1/92

PA Scoresheets

Site Name: _____
CERCLIS ID No.: _____
Street Address: _____
City/State/Zip: _____

Investigator: _____
Agency Organization: _____
Street Address: _____
City/State/Zip: _____
Date: _____

INSTRUCTIONS FOR SCORESHEETS

Introduction

This scoresheets package functions as a self-contained workbook providing all of the basic tools to apply collected data and calculate a PA score. Note that a computerized scoring tool, "PA-Score," is also available from EPA (Office of Solid Waste and Emergency Response, Directive 9345.1-11). The scoresheets provide space to:

- Record information collected during the PA
- Indicate references to support information
- Select and assign values ("scores") for factors
- Calculate pathway scores
- Calculate the site score

Do not enter values or scores in shaded areas of the scoresheets. You are encouraged to write notes on the scoresheets and especially on the Criteria Lists. On scoresheets with a reference column, indicate a number corresponding to attached sources of information or pages containing rationale for hypotheses; attach to the scoresheets a numbered list of these references. Evaluate all four pathways. Complete all Criteria Lists, scoresheets, and tables. Show calculations, as appropriate. If scoresheets are photocopy reproduced, copy and submit the numbered pages (right-side pages) only.

GENERAL INFORMATION

Site Description and Operational History: Briefly describe the site and its operating history. Provide the site name, owner/operator, type of facility and operations, size of property, active or inactive status, and years of waste generation. Summarize waste treatment, storage, or disposal activities that have or may have occurred at the site; note also if these activities are documented or alleged. Identify probable source types and prior spills. Summarize highlights of previous investigations.

Probable Substances of Concern: List hazardous substances that have or may have been stored, handled, or disposed at the site, based on your knowledge of site operations. Identify the sources to which the substances may be related. Summarize any existing analytical data concerning hazardous substances detected onsite, in releases from the site, or at targets.

GENERAL INFORMATION

Site Description and Operational History:

Probable Substances of Concern:
(Previous investigations, analytical data)

GENERAL INFORMATION (continued)

Site Sketch: Prepare a sketch of the site (freehand is acceptable). Indicate all pertinent features of the site and nearby environs, including: waste sources, buildings, residences, access roads, parking areas, drainage patterns, water bodies, vegetation, wells, sensitive environments, etc.

GENERAL INFORMATION (continued)

Site Sketch:
(Show all pertinent features, indicate sources and closest targets, indicate north)

SOURCE EVALUATION

- Number and name each source (e.g., 1. East Drum Storage Area, 2. Sludge Lagoon, 3. Battery Pile).
- Identify source type according to the list below.
- Describe the physical character of each source (e.g., dimensions, contents, waste types, containment, operating history).
- Show waste quantity (WQ) calculations for each source for appropriate tiers. Refer to instructions opposite page 5 and PA Tables 1a and 1b. Identify waste quantity tier and waste characteristics (WC) factor category score (for a site with a single source, according to PA Table 1a). Determine WC from PA Table 1b for the sum of source WQs for a multiple-source site.
- Attach additional sheets if necessary.
- Determine the site WC factor category score and record at the bottom of the page.

Source Type Descriptions

Landfill: an engineered (by excavation or construction) or natural hole in the ground into which wastes have been disposed by backfilling, or by contemporaneous soil deposition with waste disposal, covering wastes from view.

Surface Impoundment: a topographic depression, excavation, or diked area, primarily formed from earthen materials (lined or unlined) and designed to hold accumulated liquid wastes, wastes containing free liquids, or sludges that were not backfilled or otherwise covered during periods of deposition; depression may be dry if deposited liquid has evaporated, volatilized or leached, or wet with exposed liquid; structures that may be more specifically described as lagoon pond, aeration pit, settling pond, tailings pond, sludge pit, etc.; also a surface impoundment that has been covered with soil after the final deposition of waste materials (i.e., buried or backfilled).

Drums: portable containers designed to hold a standard 55-gallon volume of wastes.

Tanks and Non-Drum Containers: any stationary device, designed to contain accumulated wastes, constructed primarily of fabricated materials (such as wood, concrete, steel, or plastic) that provide structural support; any portable or mobile device in which waste is stored or otherwise handled.

Contaminated Soil: soil onto which available evidence indicates that a hazardous substance was spilled, spread, disposed, or deposited.

Pile: any non-containerized accumulation above the ground surface of solid, non-flowing wastes; includes open dumps. Some types of piles are: Chemical Waste Pile -- consists primarily of discarded chemical products, by-products, radioactive wastes, or used or unused feedstocks; Scrap Metal or Junk Pile -- consists primarily of scrap metal or discarded durable goods such as appliances, automobiles, auto parts, or batteries, composed of materials suspected to contain or have contained a hazardous substance; Tailings Pile -- consists primarily of any combination of overburden from a mining operation and tailings from a mineral mining, beneficiation, or processing operation; Trash Pile -- consists primarily of paper, garbage, or discarded non-durable goods which are suspected to contain or have contained a hazardous substance.

Land Treatment: landfarming or other land treatment method of waste management in which liquid wastes or sludges are spread over land and tilled, or liquids are injected at shallow depths into soils.

Other: a source that does not fit any of the descriptions above; examples include contaminated building, ground water plume with no identifiable source, storm drain, dry well, and injection well.

SOURCE EVALUATION

Source No.:	Source Name:	Source Waste Quantity (WQ) Calculations:
Source Description:		

Source No.:	Source Name:	Source Waste Quantity (WQ) Calculations:
Source Description:		

Source No.:	Source Name:	Source Waste Quantity (WQ) Calculations:
Source Description:		

Site WC:

WASTE CHARACTERISTICS (WC) SCORES

WC, based on waste quantity, may be determined by one or all of four measures called "tiers": constituent quantity, wastestream quantity, source volume, and source area. PA Table 1a (page 5) is divided into these four tiers. The amount and detail of information available determine which tier(s) to use for each source. For each source, evaluate waste quantity by as many of the tiers as you have information to support, and select the result that gives you the highest WC score. If minimal, incomplete, or no information is available regarding waste quantity, assign a WC score of 18 (minimum).

PA Table 1a has 6 columns: column 1 indicates the quantity tier; column 2 lists source types for the four tiers; columns 3, 4, and 5 provide ranges of waste amount for sites with only one source, which correspond to WC scores at the top of the columns (18, 32, or 100); column 6 provides formulas to obtain source waste quantity (WQ) values at sites with multiple sources.

To determine WC for sites with only one source:

1. *Identify source type (see descriptions opposite page 4).*
2. *Examine all waste quantity data available.*
3. *Estimate the mass and/or dimensions of the source.*
4. *Determine which quantity tiers to use based on available source information.*
5. *Convert source measurements to appropriate units for each tier you can evaluate for the source.*
6. *Identify the range into which the total quantity falls for each tier evaluated (PA Table 1a).*
7. *Determine the highest WC score obtained for any tier (18, 32, or 100, at top of PA Table 1a columns 3, 4, and 5, respectively).*
8. *Use this WC score for all pathways.**

To determine WC for sites with multiple sources:

1. *Identify each source type (see descriptions opposite page 4).*
2. *Examine all waste quantity data available for each source.*
3. *Estimate the mass and/or dimensions of each source.*
4. *Determine which quantity tiers to use for each source based on the available information.*
5. *Convert source measurements to appropriate units for each tier you can evaluate for each source.*
6. *For each source, use the formulas in column 6 of PA Table 1a to determine the WQ value for each tier that can be evaluated. The highest WQ value obtained for any tier is the WQ value for the source.*
7. *Sum the WQ values for all sources to get the site WQ total.*
8. *Use the site WQ total from step 7 to assign the WC score from PA Table 1b.*
9. *Use this WC score for all pathways.**

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* The WC score is considered in all four pathways. However, if a primary target is identified for the groundwater, surface water, or air migration pathway, assign the determined WC or a score of 32, whichever is greater, as the WC score for that pathway.

PA TABLE 1: WASTE CHARACTERISTICS (WC) SCORES

PA Table 1a: WC Scores for Single Source Sites and Formulas for Multiple Source Sites

TIER	SOURCE TYPE	SINGLE SOURCE SITES (assigned WC scores)			MULTIPLE SOURCE SITES
		WC = 18	WC = 32	WC = 100	Formula for Assigning Source WQ Values
Hazardous Constituent	N/A	≤100 lb	>100 to 10,000 lb	>10,000 lb	lb ÷ 1
Waste Quantity	N/A	≤500,000 lb	>500,000 to 50 million lb	>50 million lb	lb ÷ 5,000
VOLUME	Landfill	≤6.75 million ft³ ≤250,000 yd³	>6.75 million to 675 million ft³ >250,000 to 25 million yd³	>675 million ft³ >25 million yd³	ft³ ÷ 67,500 yd³ ÷ 2,500
	Surface impoundment	≤6,750 ft² ≤250 yd²	>6,750 to 675,000 ft² >250 to 25,000 yd²	>675,000 ft² >25,000 yd²	ft² ÷ 67.5 yd² ÷ 2.5
	Drums	≤1,000 drums	>1,000 to 100,000 drums	>100,000 drums	drums ÷ 10
	Tanks and non-drum containers	≤50,000 gallons	>50,000 to 5 million gallons	>5 million gallons	gallons ÷ 500
	Contaminated soil	≤6.75 million ft² ≤250,000 yd³	>6.75 million to 675 million ft² >250,000 to 25 million yd³	>675 million ft² >25 million yd³	ft² ÷ 67,500 yd³ ÷ 2,500
	Pile	≤6,750 ft² ≤250 yd²	>6,750 to 675,000 ft² >250 to 25,000 yd²	>675,000 ft² >25,000 yd²	ft² ÷ 67.5 yd² ÷ 2.5
	Other	≤6,750 ft² ≤250 yd²	>6,750 to 675,000 ft² >250 to 25,000 yd²	>675,000 ft² >25,000 yd²	ft² ÷ 67.5 yd² ÷ 2.5
AREA	Landfill	≤340,000 ft² ≤7.8 acres	>340,000 to 34 million ft² >7.8 to 780 acres	>34 million ft² >780 acres	ft² ÷ 3,400 acres ÷ 0.078
	Surface impoundment	≤1,300 ft² ≤0.028 acres	>1,300 to 130,000 ft² >0.028 to 2.9 acres	>130,000 ft² >2.9 acres	ft² ÷ 13 acres ÷ 0.00029
	Contaminated soil	≤3.4 million ft² ≤78 acres	>3.4 million to 340 million ft² >78 to 7,800 acres	>340 million ft² >7,800 acres	ft² ÷ 34,000 acres ÷ 0.78
	Pile*	≤1,300 ft² ≤0.028 acres	>1,300 to 130,000 ft² >0.028 to 2.9 acres	>130,000 ft² >2.9 acres	ft² ÷ 13 acres ÷ 0.00029
	Land treatment	≤27,000 ft² ≤0.62 acres	>27,000 to 2.7 million ft² >0.62 to 62 acres	>2.7 million ft² >62 acres	ft² ÷ 270 acres ÷ 0.0062

1 ton = 2,000 lb = 1 yd³ = 4 drums = 200 gallons

* Use area of land surface under pile, not surface area of pile.

PA Table 1b: WC Scores for Multiple Source Sites

WQ Total	WC Score
>0 to 100	18
>100 to 10,000	32
>10,000	100

GROUND WATER PATHWAY

Ground Water Use Description: Provide information on ground water use in the vicinity. Present the general stratigraphy, aquifers used, and distribution of private and municipal wells.

Calculations for Drinking Water Populations Served by Ground Water: Provide populations from private wells and municipal supply systems in each distance category. Show apportionment calculations for blended supply systems.

GROUND WATER PATHWAY
GROUND WATER USE DESCRIPTION

Describe Ground Water Use Within 4-miles of the Site:
(Describe stratigraphy, information on aquifers, municipal and/or private wells)

Calculations for Drinking Water Populations Served by Ground Water:

GROUND WATER PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing hypotheses concerning the occurrence of a suspected release and the exposure of specific targets to a hazardous substance. The check-boxes record your professional judgment in evaluating these factors. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypotheses, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several site, source, and pathway conditions that could provide insight as to whether a release from the site is likely to have occurred. If a release is suspected, use the "Primary Targets" section to evaluate conditions that may help identify targets likely to be exposed to a hazardous substance. Record responses for the well that you feel has the highest probability of being exposed to a hazardous substance. You may use this section of the chart more than once, depending on the number of targets you feel may be considered "primary."

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

GROUND WATER PATHWAY CRITERIA LIST

SUSPECTED RELEASE

Yes	No	Unk	
☐	☐	☐	Are sources poorly contained?
☐	☐	☐	Is the source a type likely to contribute to ground water contamination (e.g., wet lagoon)?
☐	☐	☐	Is waste quantity particularly large?
☐	☐	☐	Is precipitation heavy?
☐	☐	☐	Is the infiltration rate high?
☐	☐		Is the site located in an area of karst terrain?
☐	☐	☐	Is the subsurface highly permeable or conductive?
☐	☐	☐	Is drinking water drawn from a shallow aquifer?
☐	☐	☐	Are suspected contaminants highly mobile in ground water?
☐	☐	☐	Does analytical or circumstantial evidence suggest ground water contamination?
☐	☐		Other criteria?_____
☐	☐		**SUSPECTED RELEASE?**

PRIMARY TARGETS

Yes	No	Unk	
☐	☐	☐	Is any drinking water well nearby?
☐	☐	☐	Has any nearby drinking water well been closed?
☐	☐	☐	Has any nearby drinking water user reported foul-tasting or foul-smelling water?
☐	☐	☐	Does any nearby well have a large drawdown or high production rate?
☐	☐	☐	Is any drinking water well located between the site and other wells that are suspected to be exposed to a hazardous substance?
☐	☐	☐	Does analytical or circumstantial evidence suggest contamination at a drinking water well?
☐	☐	☐	Does any drinking water well warrant sampling?
☐	☐		Other criteria?_____
☐	☐		**PRIMARY TARGET(S) IDENTIFIED?**

Summarize the rationale for Suspected Release (attach an additional page if necessary):

Summarize the rationale for Primary Targets (attach an additional page if necessary):

GROUND WATER PATHWAY SCORESHEET

Pathway Characteristics

Answer the questions at the top of the page. Refer to the Ground Water Pathway Criteria List (page 7) to hypothesize whether you suspect that a hazardous substance associated with the site has been released to ground water. Record depth to aquifer (in feet): the difference between the deepest occurrence of a hazardous substance and the depth of the top of the shallowest aquifer at (or as near as possible) to the site. Note whether the site is in karst terrain (characterized by abrupt ridges, sink holes, caverns, springs, disappearing streams). Record the distance (in feet) from any source to the nearest well used for drinking water.

Likelihood of Release (LR)

1. **Suspected Release:** Hypothesize based on professional judgment guided by the Ground Water Pathway Criteria List (page 7). If you suspect a release to ground water, use only Column A for this pathway and do not evaluate factor 2.

2. **No Suspected Release:** If you do not suspect a release, determine score based on depth to aquifer or whether the site is in an area of karst terrain. If you do not suspect a release to ground water, use only Column B to score this pathway.

Targets (T)

This factor category evaluates the threat to populations obtaining drinking water from ground water. To apportion populations served by blended drinking water supply systems, determine the percentage of population served by each well based on its production.

3. **Primary Target Population:** Evaluate populations served by all drinking water wells that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Ground Water Pathway Criteria List (page 7) to make this determination. In the space provided, enter the population served by any wells you suspect have been exposed to a hazardous substance from the site. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) determine population served. Multiply the population by 10 to determine the Primary Target Population scor Note that if you do not suspect a release, there can be no primary target population.

4. **Secondary Target Population:** Evaluate populations served by all drinking water wells within 4 miles that you do not suspect have been exposed to a hazardous substance. Use PA Table 2a or 2b (for wells drawing from non-karst and karst aquifers, respectfully) (page 9). If only the number of residences is known, use the average county residents per household (rounded to the nearest integer) to determine population served. Circle the assigned value for the population in each distance category and enter it in the column on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

5. **Nearest Well** represents the threat posed to the drinking water well that is most likely to be exposed to a hazardous substance. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 2a or 2b for the closest distance category with a drinking water well population.

6. **Wellhead Protection Area (WHPA):** WHPAs are special areas designated by States for protection under Section 1428 of the Safe Drinking Water Act. Local/State and EPA Regional water officials can provide information regarding the location of WHPAs.

7. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if ground water within 4 miles has no resource use.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

Waste Characteristics (WC)

8. **Waste Characteristics:** Score is assigned from page 4. However, if you have identified any primary target for ground water, assign either the score calculated on page 4 or a score of 32, whichever is greater.

Ground Water Pathway Score: Multiply the scores for LR, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

GROUND WATER PATHWAY SCORESHEET

Pathway Characteristics	
Do you suspect a release (see Ground Water Pathway Criteria List, page 71)?	Yes ___ No ___
Is the site located in karst terrain?	Yes ___ No ___
Depth to aquifer:	_____ ft
Distance to the nearest drinking water well:	_____ ft

	A Suspected Release	B No Suspected Release	References
LIKELIHOOD OF RELEASE			
1. SUSPECTED RELEASE: If you suspect a release to ground water (see page 71), assign a score of 550. Use only column A for this pathway.	550		
2. NO SUSPECTED RELEASE: If you do not suspect a release to ground water, and the site is in karst terrain or the depth to aquifer is 70 feet or less, assign a score of 500; otherwise, assign a score of 340. Use only column B for this pathway.		500 or 340	
LR =			
TARGETS			
3. PRIMARY TARGET POPULATION: Determine the number of people served by drinking water wells that you suspect have been exposed to a hazardous substance from the site (see Ground Water Pathway Criteria List, page 71). _____ people x 10 =			
4. SECONDARY TARGET POPULATION: Determine the number of people served by drinking water wells that you do NOT suspect have been exposed to a hazardous substance from the site, and assign the total population score from PA Table 2. Are any wells part of a blended system? Yes ___ No ___ If yes, attach a page to show apportionment calculations.			
5. NEAREST WELL: If you have identified a primary target population for ground water, assign a score of 50; otherwise, assign the Nearest Well score from PA Table 2. If no drinking water wells exist within 4 miles, assign a score of zero.			
6. WELLHEAD PROTECTION AREA (WHPA): If any source lies within or above a WHPA, or if you have identified any primary target well within a WHPA, assign a score of 20; assign 5 if neither condition holds but a WHPA is present within 4 miles; otherwise assign zero.			
7. RESOURCES			
T =			
WASTE CHARACTERISTICS			
8. A. If you have identified any primary target for ground water, assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.			
B. If you have NOT identified any primary target for ground water, assign the waste characteristics score calculated on page 4.			
WC =			
GROUND WATER PATHWAY SCORE: $\frac{LR \times T \times WC}{82,500}$		(subject to a maximum of 100)	

PA TABLE 2: VALUES FOR SECONDARY GROUND WATER TARGET POPULATIONS

PA Table 2a: Non-Karst Aquifers

Distance from Site	Population	Nearest Well (choose highest)	Population Served by Wells Within Distance Category: 1 to 10	11 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	Greater than 100,000	Population Value
0 to ¼ mile	_____	20	1	2	5	16	52	163	521	1,633	5,214	16,325	_____
> ¼ to ½ mile	_____	18	1	1	3	10	32	101	323	1,012	3,233	10,121	_____
> ½ to 1 mile	_____	9	1	1	2	5	17	52	167	522	1,668	5,224	_____
> 1 to 2 miles	_____	5	1	1	1	3	9	28	94	294	939	2,938	_____
> 2 to 3 miles	_____	3	1	1	1	2	7	21	68	212	678	2,122	_____
> 3 to 4 miles	_____	2	1	1	1	1	4	13	42	131	417	1,308	_____
Nearest Well =												Score =	

PA Table 2b: Karst Aquifers

Distance from Site	Population	Nearest Well (use 20 for karst)	Population Served by Wells Within Distance Category: 1 to 10	11 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	Greater than 100,000	Population Value
0 to ¼ mile	_____	20	1	2	5	16	52	163	521	1,633	5,214	16,325	_____
> ¼ to ½ mile	_____	20	1	1	3	10	32	101	323	1,012	3,233	10,121	_____
> ½ to 1 mile	_____	20	1	1	2	5	16	52	167	522	1,668	5,224	_____
> 1 to 2 miles	_____	20	1	1	1	3	9	28	94	294	939	2,938	_____
> 2 to 3 miles	_____	20	1	1	1	2	7	21	68	212	678	2,122	_____
> 3 to 4 miles	_____	20	1	1	1	1	4	13	42	131	417	1,308	_____
Nearest Well =												Score =	

SURFACE WATER PATHWAY

Migration Route Sketch: Sketch the surface water migration pathway (freehand is acceptable) illustrating the drainage route and identifying water bodies, probable point of entry, flows, and targets.

SURFACE WATER PATHWAY
MIGRATION ROUTE SKETCH

Suface Water Migration Route Sketch:
(include runoff route, probable point of entry, 15-mile target distance limit, intakes, fisheries, and sensitive environments)

SURFACE WATER PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing hypotheses concerning the occurrence of suspected release and the exposure of specific targets to a hazardous substance. The check-boxes record your professional judgment in evaluating these factors. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypotheses, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several site, source, and pathway conditions that could provide insight as to whether a release from the site is likely to have occurred. If a release is suspected, use the "Primary Targets" section to guide you through evaluation of some conditions that may help identify targets likely to be exposed to a hazardous substance. Record responses for the target that you feel has the highest probability of being exposed to a hazardous substance. You may use this section of the chart more than once, depending on the number of targets you feel may be considered "primary."

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

If the distance to surface water is greater than 2 miles, do not evaluate the surface water migration pathway. Document the source of information in the text boxes below the surface water criteria list.

SURFACE WATER PATHWAY CRITERIA LIST

SUSPECTED RELEASE

Yes	No	Unk	
☐	☐	☐	Is surface water nearby?
☐	☐	☐	Is waste quantity particularly large?
☐	☐	☐	Is the drainage area large?
☐	☐	☐	Is rainfall heavy?
☐	☐	☐	Is the infiltration rate low?
☐	☐	☐	Are sources poorly contained or prone to runoff or flooding?
☐	☐	☐	Is a runoff route well defined (e.g., ditch or channel leading to surface water)?
☐	☐	☐	Is vegetation stressed along the probable run-off route?
☐	☐	☐	Are sediments or water unnaturally discolored?
☐	☐	☐	Is wildlife unnaturally absent?
☐	☐	☐	Has deposition of waste into surface water been observed?
☐	☐	☐	Is ground water discharge to surface water likely?
☐	☐	☐	Does analytical or circumstantial evidence suggest surface water contamination?
☐	☐		Other criteria?_____
☐	☐		**SUSPECTED RELEASE?**

PRIMARY TARGETS

Yes	No	Unk	
☐	☐	☐	Is any target nearby? If yes:
			☐ Drinking water intake ☐ Fishery ☐ Sensitive environment
☐	☐	☐	Has any intake, fishery, or recreational area been closed?
☐	☐	☐	Does analytical or circumstantial evidence suggest surface water contamination at or downstream of a target?
☐	☐	☐	Does any target warrant sampling? If yes:
			☐ Drinking water intake ☐ Fishery ☐ Sensitive environment
☐	☐		Other criteria?_____
☐	☐		**PRIMARY INTAKE(S) IDENTIFIED?**
☐	☐		**PRIMARY FISHERY(IES) IDENTIFIED?**
☐	☐		**PRIMARY SENSITIVE ENVIRONMENT(S) IDENTIFIED?**

Summarize the rationale for Suspected Release (attach an additional page if necessary):

Summarize the rationale for Primary Targets (attach an additional page if necessary):

SURFACE WATER PATHWAY LIKELIHOOD OF RELEASE AND DRINKING WATER THREAT SCORESHEET

Pathway Characteristics

The surface water pathway includes three threats: Drinking Water Threat, Human Food Chain Threat, and Environmental Threat. Answer the questions at the top of the page. Refer to the Surface Water Pathway Criteria List (page 11) to hypothesize whether you suspect that a hazardous substance associated with the site has been released to surface water. Record the distance to surface water (the shortest overland drainage distance from a source to a surface water body). Record the flood frequency at the site (e.g., 100-yr, 200-yr). If the site is located in more than one floodplain, use the most frequent flooding event. Identify surface water use(s) along the surface water migration path and their distance(s) from the site.

Likelihood of Release (LR)

1. **Suspected Release:** Hypothesize based on professional judgment guided by the Surface Water Pathway Criteria List (page 11). If you suspect a release to surface water, use only Column A for this pathway and do not evaluate factor 2.

2. **No Suspected Release:** If you do not suspect a release, determine score based on the shortest overland drainage distance from a source to a surface water body. If distance to surface water is 2,500 feet or less, assign a score of 500. If distance to surface water is greater than 2,500 feet, determine score based on flood frequency. If you do not suspect a release to surface water, use only Column B to score this pathway.

Drinking Water Threat Targets (T)

3. List all drinking water intakes on downstream surface water bodies along the surface water migration path. Record the intake name, the type of water body on which the intake is located, the flow of the water body, and the number of people served by the intake (apportion the population if part of a blended system).

4. **Primary Target Population:** Evaluate populations served by all drinking water intakes that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. In the space provided, enter the population served by all intakes you suspect have been exposed to a hazardous substance from the site. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) to determine population served. Multiply by 10 to determine the Primary Target Population score. Remember, if you do not suspect a release, there can be no primary target population.

5. **Secondary Target Population:** Evaluate populations served by all drinking water intakes within the target distance limit that you do not suspect have been exposed to a hazardous substance. Use PA Table 3 (page 13) and enter the population served by intakes for each flow category. If only the number of residences is known, use the average county residents per household (rounded to the nearest integer) to determine population served. Circle the assigned value for the population in each flow category and enter it in the column on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

Gauging station data for many surface water bodies are available from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that the flow category "mixing zone of quiet flowing rivers" is limited to 3 miles from the probable point of entry.

6. **Nearest Intake** represents the threat posed to the drinking water intake that is most likely to be exposed to a hazardous substance. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 3 (page 13) for the lowest-flowing water body on which there is an intake.

7. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if surface water within the target distance limit has no resource use.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

SURFACE WATER PATHWAY
LIKELIHOOD OF RELEASE AND DRINKING WATER THREAT SCORESHEET

Pathway Characteristics

Do you suspect a release (see Surface Water Pathway Criteria List, page 111)? Yes ___ No ___
Distance to surface water: _____ ft
Flood frequency: _____ yrs
What is the downstream distance to the nearest drinking water intake? _____ miles
Nearest fishery? _____ miles Nearest sensitive environment? _____ miles

	A Suspected Release	B No Suspected Release	References
LIKELIHOOD OF RELEASE			
1 SUSPECTED RELEASE: If you suspect a release to surface water (see page 11), assign a score of 550. Use only column A for this pathway.			
2. NO SUSPECTED RELEASE: If you do not suspect a release to surface water, use the table below to assign a score based on distance to surface water and flood frequency. Use only column B for this pathway.			
Distance to surface water ≤ 2,500 feet	500		
Distance to surface water > 2,500 feet, and			
Site in annual or 10-year floodplain	500		
Site in 100-year floodplain	400		
Site in 500-year floodplain	300		
Site outside 500-year floodplain	100		
LR =			
DRINKING WATER THREAT TARGETS			
3. Record the water body type, flow (if applicable), and number of people served by each drinking water intake within the target distance limit. If there is no drinking water intake within the target distance limit, factors 4, 5, and 6 each receive zero scores			
Intake Name / Water Body Type / Flow / People Served			
_____ _____ _____ cfs _____			
_____ _____ _____ cfs _____			
_____ _____ _____ cfs _____			
4. PRIMARY TARGET POPULATION: If you suspect any drinking water intake listed above has been exposed to a hazardous substance from the site (see Surface Water Pathway Criteria List, page 11), list the intake name(s) and calculate the factor score based on the total population served. _____, _____ _____ people x 10 =			
5. SECONDARY TARGET POPULATION: Determine the number of people served by drinking water intakes that you do NOT suspect have been exposed to a hazardous substance from the site, and assign the total population score from PA Table 3. Are any intakes part of a blended system? Yes ___ No ___ If yes, attach a page to show apportionment calculations.			
6. NEAREST INTAKE: If you have identified a primary target population for the drinking water threat (factor 4), assign a score of 50; otherwise, assign the Nearest Intake score from PA Table 3. If no drinking water intake exists within the target distance limit, assign a score of zero.			
7 RESOURCES			
T =			

PA TABLE 3: VALUES FOR SECONDARY SURFACE WATER TARGET POPULATIONS

Surface Water Body Flow (see PA Table 4)	Population	Nearest Intake (choose highest)	Population Served by Intakes Within Flow Category: 7 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	100,001 to 300,000	300,001 to 1,000,000	Greater than 1,000,000	Population Value
< 10 cfs	_____	20	2	5	16	52	163	521	1,633	5,214	16,325	52,138	163,246	_____
10 to 100 cfs	_____	2	1	1	2	5	16	52	163	521	1,633	5,214	16,325	_____
> 100 to 1,000 cfs	_____	1	0	0	1	1	2	5	16	52	163	521	1,633	_____
> 1,000 to 10,000 cfs	_____	0	0	0	0	0	1	1	2	5	16	52	163	_____
> 10,000 cfs or Great Lakes	_____	0	0	0	0	0	0	0	1	1	2	5	16	_____
3-mile Mixing Zone	_____	10	1	3	8	26	82	261	816	2,607	8,162	26,068	81,683	_____
Nearest Intake =													Score =	

PA TABLE 4: SURFACE WATER TYPE / FLOW CHARACTERISTICS WITH DILUTION WEIGHTS FOR SECONDARY SURFACE WATER SENSITIVE ENVIRONMENTS

Type of Surface Water Body: Water Body Type	OR Flow	Dilution Weight
minimal stream	< 10 cfs	1
small to moderate stream	10 to 100 cfs	0.1
moderate to large stream	> 100 to 1,000 cfs	N/A
large stream to river	> 1,000 to 10,000 cfs	N/A
large river	> 10,000 cfs	N/A
3-mile mixing zone of quiet flowing streams or rivers	10 cfs or greater	N/A
coastal tidal water (harbors, sounds, bays, etc.), ocean, or Great Lakes	N/A	N/A

SURFACE WATER PATHWAY HUMAN FOOD CHAIN THREAT SCORESHEET

Likelihood of Release (LR)

LR is the same for all surface water pathway threats. Enter LR score from page 12.

Human Food Chain Threat Targets (T)

8. The only human food chain targets are fisheries. A fishery is an area of a surface water body from which food chain organisms are taken or could be taken for human consumption on a subsistence, sporting, or commercial basis. Food chain organisms include fish, shellfish, crustaceans, amphibians, and amphibious reptiles. Fisheries are delineated by changes in surface water body type (i.e., streams and rivers, lakes, coastal tidal waters, and oceans/Great Lakes) and whenever the flow characteristics of a stream or river change.

In the space provided, identify all fisheries within the target distance limit. Indicate the surface water body type and flow for each fishery. Gauging station flow data are available for many surface water bodies from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that, if there are no fisheries within the target distance limit, the Human Food Chain Threat Targets score is zero.

9. Primary fisheries are any fisheries within the target distance limit that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. If you identify any primary fisheries, list them in the space provided, enter 300 as the Primary Fisheries factor score, and do not evaluate Secondary Fisheries. Note that if you do not suspect a release, there can be no primary fisheries.

10. Secondary fisheries are fisheries that you do not suspect have been exposed to a hazardous substance. Evaluate this factor only if fisheries are present within the target distance limit, but none is considered a primary fishery.

A. If you suspect a release to surface water and have identified a secondary fishery but no primary fishery, assign a score of 210.

B. If you do not suspect a release, evaluate this factor based on flow. In the absence of gauging station flow data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). Assign a Secondary Fisheries score from the table on the scoresheet using the lowest flow at any fishery within the target distance limit. (Dilution weight multiplier does not apply to PA evaluation of this factor.)

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

SURFACE WATER PATHWAY (continued)
HUMAN FOOD CHAIN THREAT SCORESHEET

LIKELIHOOD OF RELEASE		A Suspected Release	B No Suspected Release	Reference
Enter Surface Water Likelihood of Release score from page 12.	LR =			

HUMAN FOOD CHAIN THREAT TARGETS

8. Record the water body type and flow (if applicable) for each fishery within the target distance limit. If there is no fishery within the target distance limit, assign a Targets score of 0 at the bottom of the page.

Fishery Name	Water Body Type	Flow
		_____cfs
		_____cfs
		_____cfs
		_____cfs
		_____cfs

9. PRIMARY FISHERIES: If you suspect any fishery listed above has been exposed to a hazardous substance from the site (see Surface Water Criteria List, page 11), assign a score of 300 and do not evaluate Factor 10. List the primary fisheries:

_____, _____.
_____, _____.

10. SECONDARY FISHERIES

A. If you suspect a release to surface water and have identified a secondary fishery but no primary fishery, assign a score of 210.

B. If you do not suspect a release, assign a Secondary Fisheries score from the table below using the lowest flow at any fishery within the target distance limit.

Lowest Flow	Secondary Fisheries Score
< 10 cfs	210
10 to 100 cfs	30
> 100 cfs, coastal tidal waters, oceans, or Great Lakes	12

T =

SURFACE WATER PATHWAY ENVIRONMENTAL THREAT SCORESHEET

Likelihood of Release (LR)

LR is the same for all surface water pathway threats. Enter LR score from page 12.

Environmental Threat Targets (T)

11. PA Table 5 (page 16) lists sensitive environments for the Surface Water Pathway Environmental Threat. In the space provided, identify all sensitive environments located within the target distance limit. Indicate the surface water body type and flow at each sensitive environment. Gauging station flow data for many surface water bodies are available from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that if there are no sensitive environments within the target distance limit, the Environmental Threat Targets score is zero.

12. Primary sensitive environments are surface water sensitive environments within the target distance limit that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. If you identify any primary sensitive environments, list them in the space provided, enter 300 as the Primary Sensitive Environments factor score, and do not evaluate Secondary Sensitive Environments. Note that if you do not suspect a release, there can be no primary sensitive environments.

13. Secondary sensitive environments are surface water sensitive environments that you do not suspect have been exposed to a hazardous substance. Evaluate this factor only if surface water sensitive environments are present within the target distance limit, but none is considered a primary sensitive environment. Evaluate secondary sensitive environments based on flow.

- In the table provided, list all secondary sensitive environments on surface water bodies with flow of 100 cfs or less.

  1) Use PA Table 4 (page 13) to determine the appropriate dilution weight for each.

  2) Use PA Tables 5 and 6 (page 16) to determine the appropriate value for each sensitive environment type and for wetlands frontage.

  3) For a sensitive environment that falls into more than one of the categories in PA Table 5, sum the values for each type to determine the environment value (e.g., a wetland with 1.5 miles frontage (value of 50) that is also a critical habitat for a Federally designated endangered species (value of 100) would receive a total value of 150).

  4) For each sensitive environment, multiply the dilution weight by the environment type (or length of wetlands) value and record the product in the far-right column.

  5) Sum the values in the far-right column and enter the total as the Secondary Sensitive Environments score. Do not evaluate part B of this factor.

- If all secondary sensitive environments are on surface water bodies with flows greater than 100 cfs, assign 10 as the Secondary Sensitive Environments score.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

SURFACE WATER PATHWAY (continued)
ENVIRONMENTAL THREAT SCORESHEET

LIKELIHOOD OF RELEASE		A Suspected Release	B No Suspected Release	References
Enter Surface Water Likelihood of Release score from page 12.	LR =			

ENVIRONMENTAL THREAT TARGETS

11. Record the water body type and flow (if applicable) for each surface water sensitive environment within the target distance limit (see PA Tables 4 and 5). If there is no sensitive environment within the target distance limit, assign a Targets score of 0 at the bottom of the page.

Environment Name	Water Body Type	Flow
		cfs
		cfs
		cfs
		cfs
		cfs

12. PRIMARY SENSITIVE ENVIRONMENTS: If you suspect any sensitive environment listed above has been exposed to a hazardous substance from the site (see Surface Water Criteria List, page 11), assign a score of 300 and do not evaluate factor 13. List the primary sensitive environments:

_____, _____.

_____, _____.

13. SECONDARY SENSITIVE ENVIRONMENTS: If sensitive environments are present, but none is a primary sensitive environment, evaluate Secondary Sensitive Environments based on flow.

A. For secondary sensitive environments on surface water bodies with flows of 100 cfs or less, assign scores as follows, and do not evaluate part B of this factor:

Flow	Dilution Weight (PA Table 6)	Environment Type and Value (PA Tables 5 and 6)	Total
cfs	x	=	
cfs	x	=	
cfs	x	=	
cfs	x	=	
cfs	x	=	
		Subtotal =	

B. If all secondary sensitive environments are located on surface water bodies with flows > 100 cfs, assign a score of 10.

		T =	

PA TABLE 5: SURFACE WATER AND AIR PATHWAY SENSITIVE ENVIRONMENTS VALUES

Sensitive Environment	*Assigned Value*
Critical habitat for Federally designated endangered or threatened species Marine Sanctuary National Park Designated Federal Wilderness Area Ecologically important areas identified under the Coastal Zone Wilderness Act Sensitive Areas identified under the National Estuary Program or Near Coastal Water Program of the Clean Water Act Critical Areas identified under the Clean Lakes Program of the Clean Water Act (subareas in lakes or entire small lakes) National Monument (air pathway only) National Seashore Recreation Area National Lakeshore Recreation Area	100
Habitat known to be used by Federally designated or proposed endangered or threatened species National Preserve National or State Wildlife Refuge Unit of Coastal Barrier Resources System Federal land designated for the protection of natural ecosystems Administratively Proposed Federal Wilderness Area Spawning areas critical for the maintenance of fish/shellfish species within a river system, bay, or estuary Migratory pathways and feeding areas critical for the maintenance of anadromous fish species in a river system Terrestrial areas utilized for breeding by large or dense aggregations of vertebrate animals (air pathway) or semi-aquatic foragers (surface water pathway) National river reach designated as Recreational	75
Habitat known to be used by State designated endangered or threatened species Habitat known to be used by a species under review as to its Federal endangered or threatened status Coastal Barrier (partially developed) Federally designated Scenic or Wild River	50
State land designated for wildlife or game management State designated Scenic or Wild River State designated Natural Area Particular areas, relatively small in size, important to maintenance of unique biotic communities	25
State designated areas for protection/maintenance of aquatic life under the Clean Water Act	5
Wetlands	See PA Table 5 (Surface Water Pathway) or PA Table 7 (Air Pathway)

PA TABLE 6: SURFACE WATER PATHWAY WETLANDS FRONTAGE VALUES

Total Length of Wetlands	*Assigned Value*
Less than 0.1 mile	0
0.1 to 1 mile	25
Greater than 1 to 2 miles	50
Greater than 2 to 3 miles	75
Greater than 3 to 4 miles	100
Greater than 4 to 8 miles	150
Greater than 8 to 12 miles	250
Greater than 12 to 16 miles	350
Greater than 16 to 20 miles	450
Greater than 20 miles	500

SURFACE WATER PATHWAY WASTE CHARACTERISTICS, THREAT, AND PATHWAY SCORES

Waste Characteristics (WC)

14. Waste Characteristics: Score is assigned from page 4. However, if a primary target has been identified for any surface water threat, assign either the score calculated on page 4 or a score of 32, whichever is greater.

Surface Water Pathway Threat Scores

Fill in the matrix with the appropriate scores from the previous pages. To calculate the score for each threat: multiply the scores for LR, T, and WC; divide the product by 82,500; and round the result to the nearest integer. The Drinking Water Threat and Human Food Chain Threat are each subject to a maximum of 100. The Environmental Threat is subject to a maximum of 60. Enter the rounded threat scores in the far-right column.

Surface Water Pathway Score

Sum the individual threat scores to determine the Surface Water Pathway Score. If the sum is greater than 100, assign 100.

SURFACE WATER PATHWAY (concluded)
WASTE CHARACTERISTICS, THREAT, AND PATHWAY SCORE SUMMARY

WASTE CHARACTERISTICS	A *Suspected Release*	B *No Suspected Release*
14. A. If you have identified any primary target for surface water (pages 12, 14, or 15), assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.		
B. If you have NOT identified any primary target for surface water, assign the waste characteristics score calculated on page 4.		
WC =		

SURFACE WATER PATHWAY THREAT SCORES

Threat	*Likelihood of Release (LR) Score (from page 12)*	*Targets (T) Score (pages 12, 14, 15)*	*Pathway Waste Characteristics (WC) Score (determined above)*	*Threat Score LR x T x WC / 82,500*
Drinking Water				
Human Food Chain				
Environmental				

SURFACE WATER PATHWAY SCORE
(Drinking Water Threat + Human Food Chain Threat + Environmental Threat)

SOIL EXPOSURE PATHWAY CRITERIA LIST

Areas of surficial contamination can generally be assumed. This "Criteria List" helps guide the process of developing a hypothesis concerning the exposure of specific targets to a hazardous substance at the site. Use the "Resident Population" section to evaluate site and source conditions that may help identify targets likely to be exposed to a hazardous substance. The check-boxes record your professional judgment. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypothesis, list them at the bottom of the page or attach an additional page.

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question.

SOIL EXPOSURE PATHWAY CRITERIA LIST

SUSPECTED CONTAMINATION	*RESIDENT POPULATION*
Surficial contamination can generally be assumed.	Yes ☐ No ☐ Unk ☐ Is any residence, school, or daycare facility on or within 200 feet of an area of suspected contamination? ☐ ☐ ☐ Is any residence, school, or daycare facility located on adjacent land previously owned or leased by the site owner/operator? ☐ ☐ ☐ Is there a migration route that might spread hazardous substances near residences, schools, or daycare facilities? ☐ ☐ ☐ Have onsite or adjacent residents or students reported adverse health effects, exclusive of apparent drinking water or air contamination problems? ☐ ☐ ☐ Does any neighboring property warrant sampling? ☐ ☐ Other criteria?_____ ☐ ☐ RESIDENT POPULATION IDENTIFIED?

Summarize the rationale for Resident Population (attach an additional page if necessary):

SOIL EXPOSURE PATHWAY SCORESHEET

Pathway Characteristics

Answer the questions at the top of the page. Identify people who may be exposed to a hazardous substance because they work at the facility, or reside or attend school or daycare on or within 200 feet of an area of suspected contamination. If the site is active, estimate the number of full and part-time workers. Note that evaluation of targets is based on current site conditions.

Likelihood of Exposure (LE)

1. **Suspected Contamination:** Areas of surficial contamination are present at most sites, and a score of 550 can generally be assigned as a default measure. Assign zero, which effectively eliminates the pathway from further consideration, only if there is no surficial contamination; reliable analytical data are generally necessary to make this determination.

Resident Population Threat Targets (T)

2. **Resident Population** corresponds to "primary targets" for the migration pathways. Use professional judgment guided by the Soil Exposure Pathway Criteria List (page 18) to determine if there are people living or attending school or daycare on or within 200 feet of areas of suspected contamination. Record the number of people identified as resident population and multiply by 10 to determine the Resident Population factor score.

3. **Resident Individual:** Assign 50 if you have identified a resident population; otherwise, assign zero.

4. **Workers:** Estimate the number of full and part-time workers at this facility and adjacent facilities where contamination is also suspected. Assign a score for the Workers factor from the table.

5. **Terrestrial Sensitive Environments:** In the table provided, list each terrestrial sensitive environment located on an area of suspected contamination. Use PA Table 7 (page 20) to assign a value for each. Sum the values and assign the total as the factor score.

6. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if there is no land resource use on an area of suspected contamination.

Sum the target scores.

Waste Characteristics (WC)

7. Enter the WC score determined on page 4.

Resident Population Threat Score: Multiply the scores for LE, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

Nearby Population Threat Score: Do not evaluate this threat if you gave a zero score to Likelihood of Exposure. Otherwise, assign a score based on the population within a 1-mile radius (use the same 1-mile radius population you evaluate for air pathway population targets):

Population Within One Mile	Nearby Population Threat Score
< 10,000	1
10,000 to 50,000	2
> 50,000	4

Soil Exposure Pathway Score: Sum the Resident Population Threat score and the Nearby Population Threat score, subject to a maximum of 100.

SOIL EXPOSURE PATHWAY SCORESHEET

Pathway Characteristics	
Do any people live on or within 200 ft of areas of suspected contamination?	Yes ___ No ___
Do any people attend school or daycare on or within 200 ft of areas of suspected contamination?	Yes ___ No ___
Is the facility active? Yes ___ No ___ If yes, estimate the number of workers: ___	

LIKELIHOOD OF EXPOSURE	Suspected Contamination	References
1. SUSPECTED CONTAMINATION: Surficial contamination can generally be assumed, and a score of 550 assigned. Assign zero only if the absence of surficial contamination can be confidently demonstrated. LE =		

RESIDENT POPULATION THREAT TARGETS

2. RESIDENT POPULATION: Determine the number of people occupying residences or attending school or daycare on or within 200 feet of areas of suspected contamination (see Soil Exposure Pathway Criteria List, page 18).
___ people x 10 =

3. RESIDENT INDIVIDUAL: If you have identified a resident population (factor 2), assign a score of 50; otherwise, assign a score of 0.

4. WORKERS: Use the following table to assign a score based on the total number of workers at the facility and nearby facilities with suspected contamination:

Number of Workers	Score
0	0
1 to 100	5
101 to 1,000	10
> 1,000	15

5. TERRESTRIAL SENSITIVE ENVIRONMENTS: Use PA Table 7 to assign a value for each terrestrial sensitive environment on an area of suspected contamination:

Terrestrial Sensitive Environment Type	Value

Sum =

6. RESOURCES

T =

WASTE CHARACTERISTICS

7. Assign the waste characteristics score calculated on page 4. WC =

RESIDENT POPULATION THREAT SCORE: $\frac{LE \times T \times WC}{82,500.}$

NEARBY POPULATION THREAT SCORE:

SOIL EXPOSURE PATHWAY SCORE:
Resident Population Threat + Nearby Population Threat

PA TABLE 7: SOIL EXPOSURE PATHWAY
TERRESTRIAL SENSITIVE ENVIRONMENT VALUES

Terrestrial Sensitive Environment	*Assigned Value*
Terrestrial critical habitat for Federally designated endangered or threatened species National Park Designated Federal Wilderness Area National Monument	100
Terrestrial habitat known to be used by Federally designated or proposed threatened or endangered species National Preserve (terrestrial) National or State terrestrial Wildlife Refuge Federal land designated for protection of natural ecosystems Administratively proposed Federal Wilderness Area Terrestrial areas utilized by large or dense aggregations of animals (vertebrate species) for breeding	75
Terrestrial habitat used by State designated endangered or threatened species Terrestrial habitat used by species under review for Federal designated endangered or threatened status	50
State lands designated for wildlife or game management State designated Natural Areas Particular areas, relatively small in size, important to maintenance of unique biotic communities	25

AIR PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing a hypothesis as to whether a release to the air is likely to be detected. The check-boxes record your professional judgment. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypothesis, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several conditions that could provide insight as to whether a release from the site is likely to be detected. If a release is suspected, primary targets are any residents, workers, students, and sensitive environments on or within ¼ mile of the site.

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

AIR PATHWAY CRITERIA LIST

SUSPECTED RELEASE				PRIMARY TARGETS
Yes	No	Unk		
☐	☐	☐	Are odors currently reported?	If you suspect a release to air, evaluate all populations and sensitive environments within 1/4 mile (including those onsite) as primary targets.
☐	☐	☐	Has release of a hazardous substance to the air been directly observed?	
☐	☐	☐	Are there reports of adverse health effects (e.g., headaches, nausea, dizziness) potentially resulting from migration of hazardous substances through the air?	
☐	☐	☐	Does analytical or circumstantial evidence suggest a release to the air?	
☐	☐		Other criteria?_____	
☐	☐		SUSPECTED RELEASE?	

Summarize the rationale for Suspected Release (attach an additional page if necessary):

AIR PATHWAY SCORESHEET

Pathway Characterization

Answer the questions at the top of the page. Refer to the Air Pathway Criteria List (page 21) to hypothesize whether you suspect that a hazardous substance release to the air could be detected. Due to dispersion, releases to air are not as persistent as releases to water migration pathways and are much more difficult to detect. Develop your hypothesis concerning the release of hazardous substances to air based on "real time" considerations. Record the distance (in feet) from any source to the nearest regularly occupied building.

Likelihood of Release (LR)

1. **Suspected Release:** Hypothesize based on professional judgment guided by the Air Pathway Criteria List (page 21). If you suspect a release to air, use only Column A for this pathway and do not evaluate factor 2.

2. **No Suspected Release:** If you do not suspect a release, enter 500 and use only Column B for this pathway.

Targets (T)

3. **Primary Target Population:** Evaluate populations subject to exposure from release of a hazardous substance from the site. If you suspect a release, the resident, student, and worker populations on and within ¼ mile of the site are considered primary target population. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) to determine the population. In the space provided, enter this population. Multiply the population by 10 to determine the Primary Target Population score. Note that if you do not suspect a release, there can be no primary target population.

4. **Secondary Target Population:** Evaluate populations in distance categories not suspected to be subject to exposure from release of a hazardous substance from the site. If you suspect a release, residents, students, and workers in the ¼- to 4-mile distance categories are secondary target population. If you do not suspect a release, all residents, students, and workers onsite and within 4 miles are considered secondary target population.

Use PA Table 8 (page 23). Enter the population in each secondary target population distance category, circle the assigned value, and record it on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

5. **Nearest Individual** represents the threat posed to the person most likely to be exposed to a hazardous substance release from the site. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 8 (page 23) for the closest distance category in which you have identified a secondary target population.

6. **Primary Sensitive Environments:** If a release is suspected, all sensitive environments on or within ¼ mile of the site are considered primary targets. List them and assign values for sensitive environment type (from PA Table 5, page 16) and/or wetland acreage (from PA Table 9, page 23). Sum the values and enter the total as the factor score.

7. **Secondary Sensitive Environments:** If a release is suspected, sensitive environments in the ¼- to ½-mile distance category are secondary targets; greater distances need not be evaluated because distance weighting greatly diminishes the impact on site score. If you do not suspect a release, all sensitive environments on and within ½ mile of the site are considered secondary targets. List each secondary sensitive environment on PA Table 10 (page 23) and assign a value to each using PA Tables 5 and 9. Multiply each value by the indicated distance weight and record the product in the far-right column. Sum the products and enter the total as the factor score.

8. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if there is no land resource use within ½ mile.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

Waste Characteristics (WC)

9. **Waste Characteristics:** Score is assigned from page 4. However, if you have identified any primary target for the air pathway, assign either the score calculated on page 4 or a score of 32, whichever is greater.

Air Pathway Score: Multiply the scores for LR, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

AIR PATHWAY SCORESHEET

Pathway Characteristics	
Do you suspect a release (see Air Pathway Criteria List, page 21)?	Yes ___ No ___
Distance to the nearest individual:	_____ ft

	A Suspected Release	B No Suspected Release	References
LIKELIHOOD OF RELEASE			
1. SUSPECTED RELEASE: If you suspect a release to air (see page 21), assign a score of 550. Use only column A for this pathway.			
2. NO SUSPECTED RELEASE: If you do not suspect a release to air, assign a score of 500. Use only column B for this pathway.			
LR =			
TARGETS			
3. PRIMARY TARGET POPULATION: Determine the number of people subject to exposure from a suspected release of hazardous substances to the air. _____ people x 10 =			
4. SECONDARY TARGET POPULATION: Determine the number of people not suspected to be exposed to a release to air, and assign the total population score using PA Table 8.			
5. NEAREST INDIVIDUAL: If you have identified any Primary Target Population for the air pathway, assign a score of 80; otherwise, assign the Nearest Individual score from PA Table 8.			
6. PRIMARY SENSITIVE ENVIRONMENTS: Sum the sensitive environment values (PA Table 5) and wetland acreage values (PA Table 9) for environments subject to exposure from a suspected release to the air.			
Sensitive Environment Type / Value _____ / _____ _____ / _____ Sum =			
7. SECONDARY SENSITIVE ENVIRONMENTS: Use PA Table 10 to determine the score for secondary sensitive environments.			
8. RESOURCES			
T =			
WASTE CHARACTERISTICS			
9. A. If you have identified any Primary Target for the air pathway, assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.			
B. If you have NOT identified any Primary Target for the air pathway, assign the waste characteristics score calculated on page 4.			
WC =			

AIR PATHWAY SCORE: $\frac{LR \times T \times WC}{82,500}$

PA TABLE 8: VALUES FOR SECONDARY AIR TARGET POPULATIONS

Distance from Site	Population	Nearest Individual (choose highest)	Population Within Distance Category											Population Value
			1 to 10	11 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	100,001 to 300,000	300,001 to 1,000,000	Greater than 1,000,000	
Onsite	_____	20	1	2	6	19	62	183	621	1,833	6,214	18,325	62,136	183,246	_____
>0 to ¼ mile	_____	20	1	1	1	4	12	41	130	408	1,303	4,081	13,034	40,811	_____
> ¼ to ½ mile	_____	2	0	0	1	1	3	9	28	88	282	882	2,815	8,816	_____
> ½ to 1 mile	_____	1	0	0	0	1	1	3	8	28	93	281	934	2,812	_____
> 1 to 2 miles	_____	0	0	0	0	0	1	1	3	8	27	83	269	833	_____
> 2 to 3 miles	_____	0	0	0	0	0	1	1	1	4	13	38	120	376	_____
> 3 to 4 miles	_____	0	0	0	0	0	0	1	1	2	7	23	73	229	_____
Nearest Individual =													Score =		

PA TABLE 9: AIR PATHWAY VALUES FOR WETLAND AREA

Wetland Area	Assigned Value
Less than 1 acre	0
1 to 50 acres	25
Greater than 50 to 100 acres	75
Greater than 100 to 150 acres	125
Greater than 150 to 200 acres	175
Greater than 200 to 300 acres	250
Greater than 300 to 400 acres	350
Greater than 400 to 500 acres	450
Greater than 500 acres	500

PA TABLE 10: DISTANCE WEIGHTS AND CALCULATIONS FOR AIR PATHWAY SECONDARY SENSITIVE ENVIRONMENTS

Distance	Distance Weight	Sensitive Environment Type and Value (from PA Table 6 or 9)	Product
Onsite	0.10	a	
		b	
0-1/4 mi	0.025	a	
		b	
		c	
1/4-1/2mi	0.0054	a	
		b	
		c	
		d	
Total Environments Score =			

SITE SCORE CALCULATION

In the column labeled S, record the Ground Water Pathway score, the Surface Water Pathway score, the Soil Exposure Pathway score, and the Air Pathway score. Square each pathway score and record the result in the S^2 column. Sum the squared pathway scores. Divide the sum by 4, and take the square root of the result to obtain the Site Score.

SUMMARY

Answer the summary questions, which ask for a qualitative evaluation of the relative risk of targets being exposed to a hazardous substance from the site. You may find your responses to these questions a good cross-check against the way you scored the individual pathways. For example, if you scored the ground water pathway on the basis of no suspected release and secondary targets only, yet your response to question #1 is "yes," this presents apparently conflicting conclusions that you need to reconsider and resolve. Your answers to the questions on page 24 should be consistent with your evaluations elsewhere in the PA scoresheets package.

SITE SCORE CALCULATION

	S	S^2
GROUND WATER PATHWAY SCORE (S_{gw}):		
SURFACE WATER PATHWAY SCORE (S_{sw}):		
SOIL EXPOSURE PATHWAY SCORE (S_s):		
AIR PATHWAY SCORE (S_a):		
SITE SCORE: $\sqrt{\frac{S_{gw}^2+S_{sw}^2+S_s^2+S_a^2}{4}}$		

SUMMARY

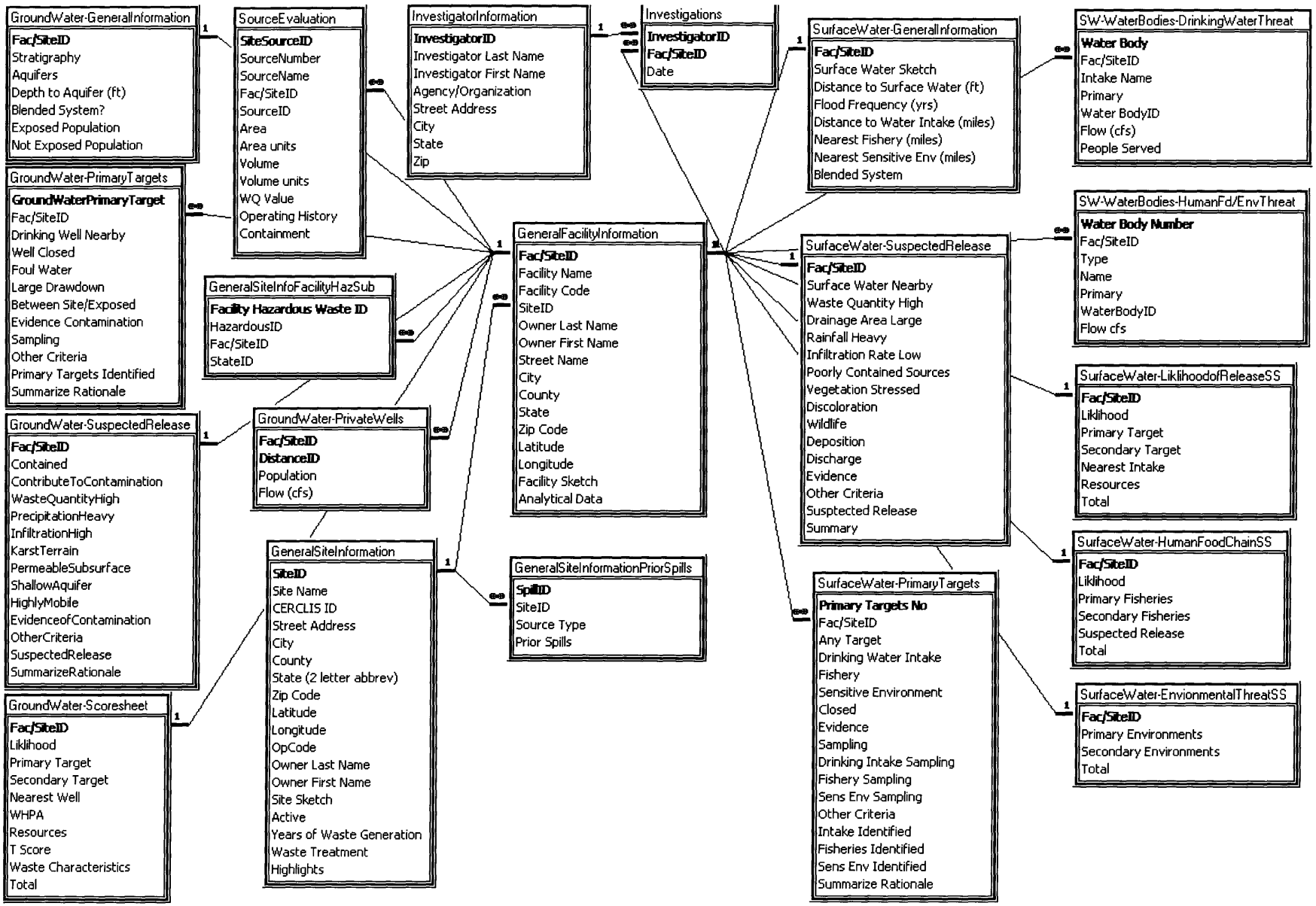
	YES	NO
1. Is there a high possibility of a threat to any nearby drinking water well(s) by migration of a hazardous substance in ground water?	☐	☐
A. If yes, identify the well(s). _____		
B. If yes, how many people are served by the threatened well(s)? _____		
2. Is there a high possibility of a threat to any of the following by hazardous substance migration in surface water?		
A. Drinking water intake	☐	☐
B. Fishery	☐	☐
C. Sensitive environment (wetland, critical habitat, other)	☐	☐
D. If yes, identify the target(s). _____		
3. Is there a high possibility of an area of surficial contamination within 200 feet of any residence, school, or daycare facility?	☐	☐
If yes, identify the property(ies) and estimate the associated population(s). _____		
4. Are there public health concerns at this site that are not addressed by PA scoring considerations? If yes, explain: _____	☐	☐

Appendix B: Access Tables of Executive Information System

This appendix demonstrates the design of the base-table system used in Access 97 and provides also an example of how Executive Information System information is stored.

The entire system is centered on the General Facility Information table as shown in the middle of the diagram. Using Fac/SiteID, the General Facility Information table is able to connect to all of the Source Evaluation table, the Ground Water Pathway tables and the Surface Water Pathway tables. The General Site Information table is connected to Facility by using a SiteID, which is used to then link to General Site Information Prior Spills table. Although most relationships are one-to-one (demonstrated as 1-1) or one-to-many (demonstrated as 1-∞), a many-to-many relationships is used in the database. The Investigations table is used to connect the General Facility Information table and the Investigators Information table and provide the many-to many relationships, which means that more than one investigator can be assigned to a facility, and an investigator can be inspecting multiple facilities.

Each table of the General Facility Information, the General Site Information, the Source Evaluation, the Ground Water Pathway and the Surface Water Pathway is connected to two other tables not shown in the base-table system diagram. They are the supporting Executive Information System tables as shown in the second diagram. These two tables, located near the top of the diagram, show how these EIS tables are designed, and located below that is an example of both tables containing EIS information for the Ground Water Pathway – Suspected Releases table.


GroundWater-GeneralInformation
Fac/SiteID
Stratigraphy
Aquifers
Depth to Aquifer (ft)
Blended System?
Exposed Population
Not Exposed Population
SourceEvaluation
SiteSourceID
SourceNumber
SourceName
Fac/SiteID
SourceID
Area
Area units
Volume
Volume units
WQ Value
Operating History
Containment
InvestigatorInformation
InvestigatorID
Investigator Last Name
Investigator First Name
Agency/Organization
Street Address
City
State
Zip
Investigations
InvestigatorID
Fac/SiteID
Date
SurfaceWater-GeneralInformation
Fac/SiteID
Surface Water Sketch
Distance to Surface Water (ft)
Flood Frequency (yrs)
Distance to Water Intake (miles)
Nearest Fishery (miles)
Nearest Sensitive Env (miles)
Blended System
SW-WaterBodies-DrinkingWaterThreat
Water Body
Fac/SiteID
Intake Name
Primary
Water BodyID
Flow (cfs)
People Served
GroundWater-PrimaryTargets
GroundWaterPrimaryTarget
Fac/SiteID
Drinking Well Nearby
Well Closed
Foul Water
Large Drawdown
Between Site/Exposed
Evidence Contamination
Sampling
Other Criteria
Primary Targets Identified
Summarize Rationale
GeneralFacilityInformation
Fac/SiteID
Facility Name
Facility Code
SiteID
Owner Last Name
Owner First Name
Street Name
City
County
State
Zip Code
Latitude
Longitude
Facility Sketch
Analytical Data
SurfaceWater-SuspectedRelease
Fac/SiteID
Surface Water Nearby
Waste Quantity High
Drainage Area Large
Rainfall Heavy
Infiltration Rate Low
Poorly Contained Sources
Vegetation Stressed
Discoloration
Wildlife
Deposition
Discharge
Evidence
Other Criteria
Susptected Release
Summary
SW-WaterBodies-HumanFd/EnvThreat
Water Body Number
Fac/SiteID
Type
Name
Primary
WaterBodyID
Flow cfs
GeneralSiteInfoFacilityHazSub
Facility Hazardous Waste ID
HazardousID
Fac/SiteID
StateID
SurfaceWater-LiklihoodofReleaseSS
Fac/SiteID
Liklihood
Primary Target
Secondary Target
Nearest Intake
Resources
Total
GroundWater-SuspectedRelease
Fac/SiteID
Contained
ContributeToContamination
WasteQuantityHigh
PrecipitationHeavy
InfiltrationHigh
KarstTerrain
PermeableSubsurface
ShallowAquifer
HighlyMobile
EvidenceofContamination
OtherCriteria
SuspectedRelease
SummarizeRationale
GroundWater-PrivateWells
Fac/SiteID
DistanceID
Population
Flow (cfs)
SurfaceWater-HumanFoodChainSS
Fac/SiteID
Liklihood
Primary Fisheries
Secondary Fisheries
Suspected Release
Total
GeneralSiteInformation
SiteID
Site Name
CERCLIS ID
Street Address
City
County
State (2 letter abbrev)
Zip Code
Latitude
Longitude
OpCode
Owner Last Name
Owner First Name
Site Sketch
Active
Years of Waste Generation
Waste Treatment
Highlights
GeneralSiteInformationPriorSpills
SpillID
SiteID
Source Type
Prior Spills
SurfaceWater-PrimaryTargets
Primary Targets No
Fac/SiteID
Any Target
Drinking Water Intake
Fishery
Sensitive Environment
Closed
Evidence
Sampling
Drinking Intake Sampling
Fishery Sampling
Sens Env Sampling
Other Criteria
Intake Identified
Fisheries Identified
Sens Env Identified
Summarize Rationale
SurfaceWater-EnvionmentalThreatSS
Fac/SiteID
Primary Environments
Secondary Environments
Total
GroundWater-Scoresheet
Fac/SiteID
Liklihood
Primary Target
Secondary Target
Nearest Well
WHPA
Resources
T Score
Waste Characteristics
Total

GW-SR-EIS : Table

Field Name	Data Type	
Fac/SiteID	Number	
GWSRFieldID	Number	
Confidence Level	Number	Confidence Level
Source	Text	Source
Memo	Memo	Memo or Comment
By Whom	Text	By Whom
Date Completed	Date/Time	Date Completed

GW-SR-Type : Table

Field Name	Data Type
GWSRFieldID	AutoNumber
Field Type	Text

GW-SR-EIS : Table

Facility and Site	Field Type	Confidence Level	Source	Memo	By Whom	Date Complete
Ashumet Valley at MMR/DOD	1	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	2	Magazine Article Ref	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	10	Supervisor Suggestic	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	9	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	5	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	6	Personal Calculation	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	11	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	7	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	4	Supervisor Suggestic	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	8	Magazine Article Ref	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	13	Personal Calculation	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	12	Personal Calculation	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
Ashumet Valley at MMR/DOD	3	Textbook Reference	This is a Source	This is a Memo	Kai Kuo	02-Jan-95
LF-1 at MMR/DOD	1	Textbook Reference	This is a Source	This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	2			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	10			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	9			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	5			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	6			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	11			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	7			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	4			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	8			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	13			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	12			This is a Memo	Joel Guzman	06-May-94
LF-1 at MMR/DOD	3			This is a Memo	Joel Guzman	06-May-94
SD-5 at MMR/DOD	1			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	2			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	10			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	9			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	5			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	6			This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	11	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	7	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	4	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	8	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	13	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	12	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
SD-5 at MMR/DOD	3	Textbook Reference	This is a Source	This is a Memo	Ken Till	24-Jul-93
	0					

Record: 40 of 40

GW-SR-Type : Table

GWSRFieldID	Field Type
1	Contained
2	ContributeToContamination
3	WasteQuantityHigh
4	PrecipitationHeavy
5	InfiltrationHigh
6	KarstTerrain
7	PermeableSubsurface
8	ShallowAquifer
9	HighlyMobile
10	EvidenceofContamination
11	OtherCriteria
12	SuspectedRelease
13	SummarizeRationale
(AutoNumber)	

Record: 14 of 14

Appendix C: Access Forms of Executive Information System

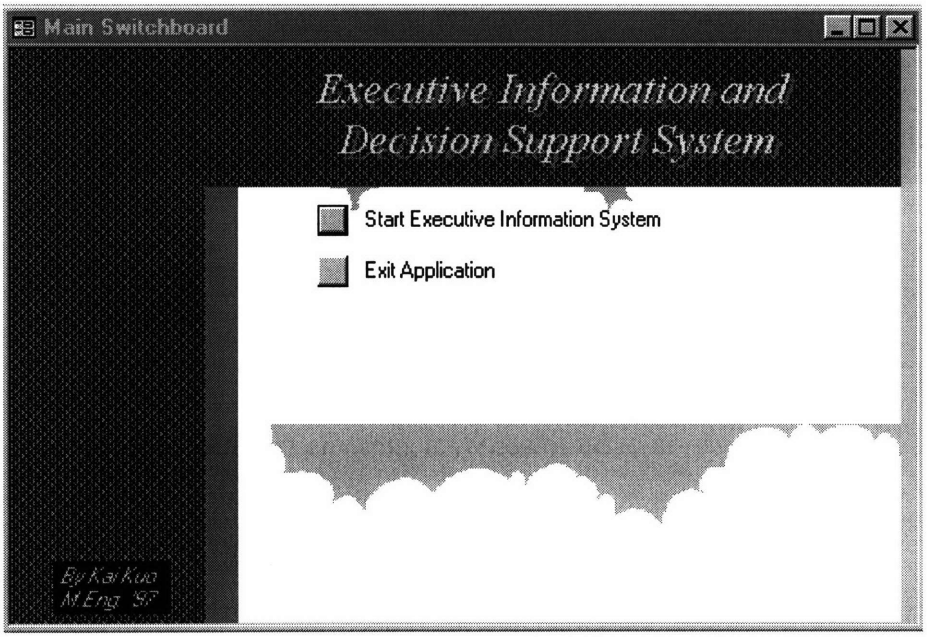
This appendix shows every form used in Access 97, demonstrating virtually every function of the database. This specific example uses LF-1 at the MMR to show what kinds of information are stored in the Executive Information System.

Starting with the EIDSS Main Switchboard, the user can go to the Executive Information System Switchboard and then go to the Preliminary Site Assessment Switchboard, which is the heart of the system. However, in order to see what sites and facilities are stored on the database, the EIS Switchboard provides three different types of listing capabilities: List All Sites and Facilities, List All Sites, and after selecting a site, List All Facilities Belonging to Selected Site.

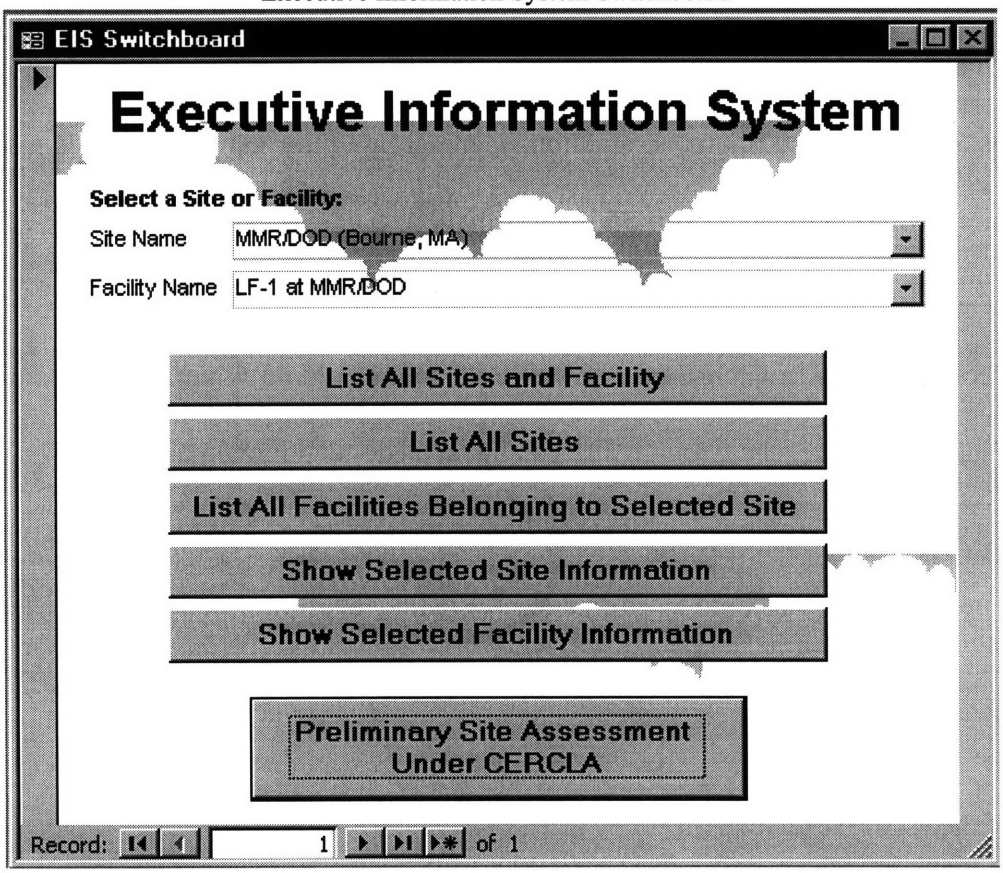
From both EIS and PA Switchboards, the user can request to see the General Facility and Site Information. General Facility Information is divided into three parts: General Information, Hazardous Substances and Source Evaluation. General Site Information is divided into two parts: General Information and Prior Spills Information.

Having selected a site and a facility, the user can go to the PA Switchboard. Beside general information, PA Switchboard provides links to the Ground Water Pathway and the Surface Water Pathway. The Ground Water Pathway is divided into 5 parts; the Surface Water Pathway is divided into 6 parts. Each part will have at least one Detail Information button inside the tab to connect to the Executive Information System –Detail Information form. These forms are linked individually to each of the supporting EIS tables mentioned in appendix B.

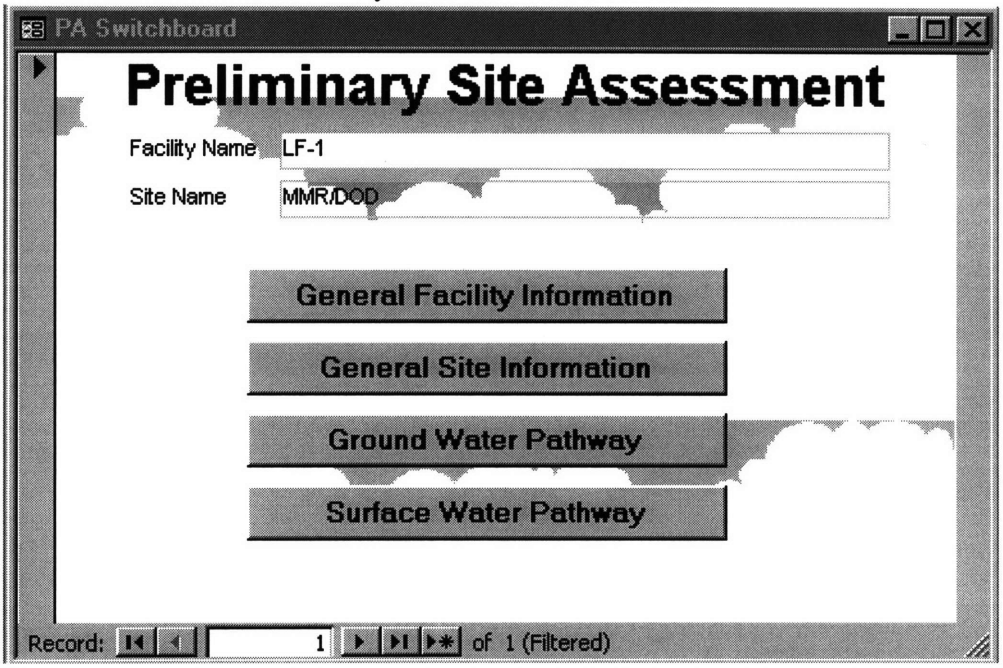
Main Switchboard



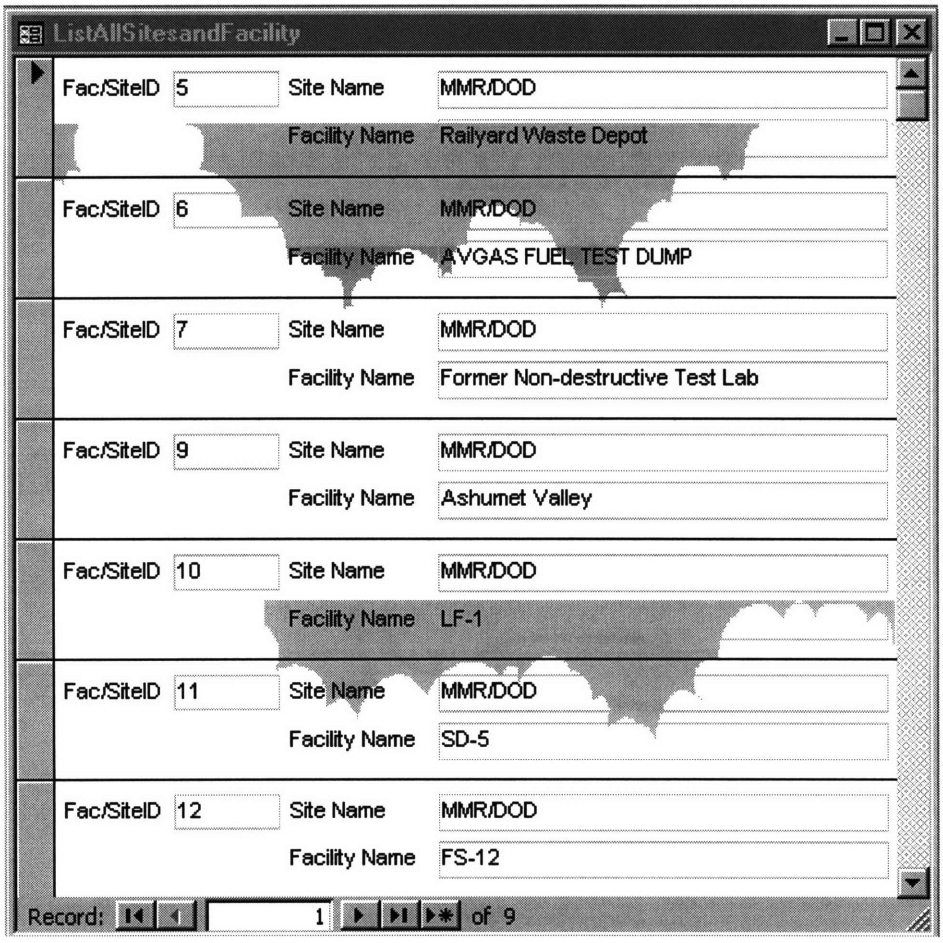
Executive Information System Switchboard



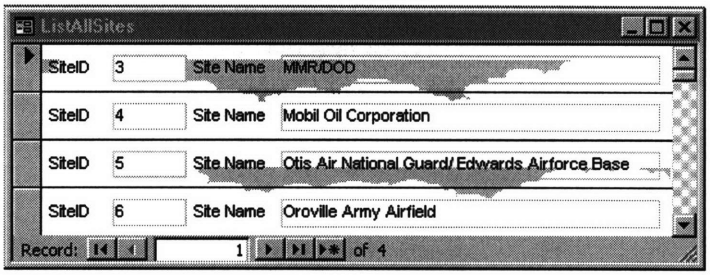
Preliminary Site Assessment Switchboard



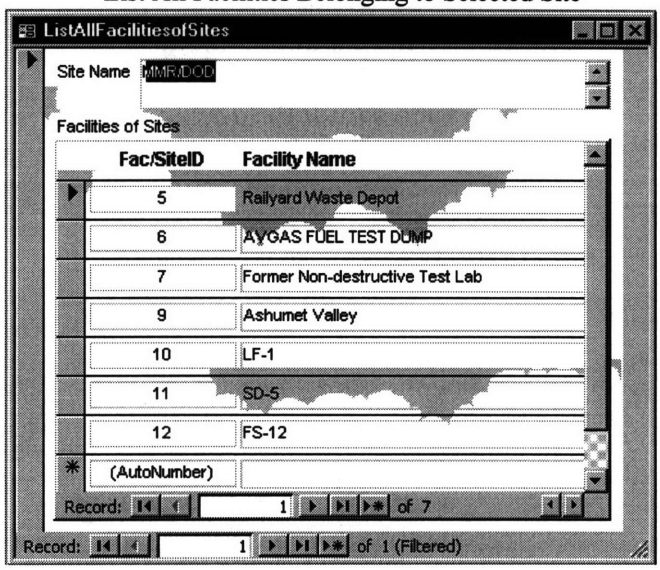
List All Sites and Facilities



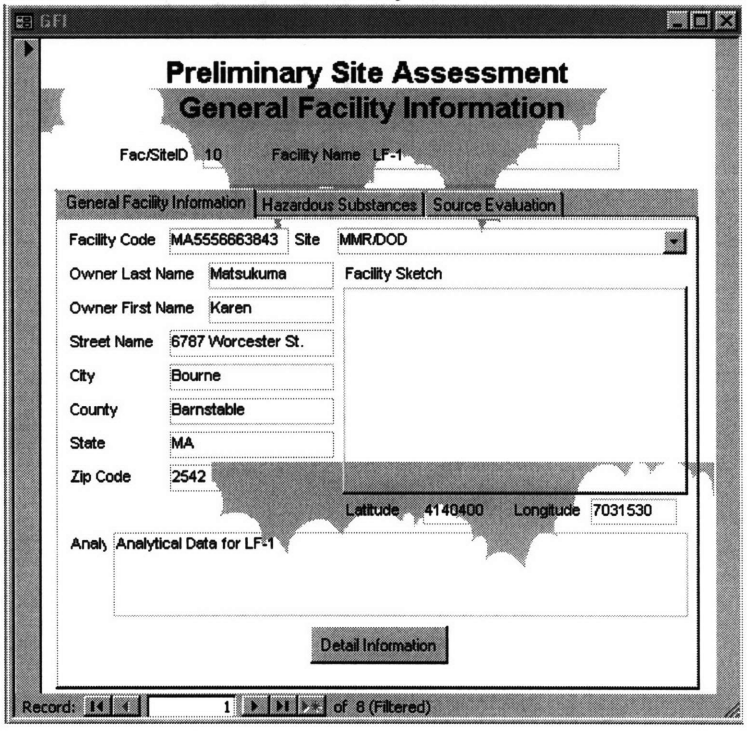
List All Sites



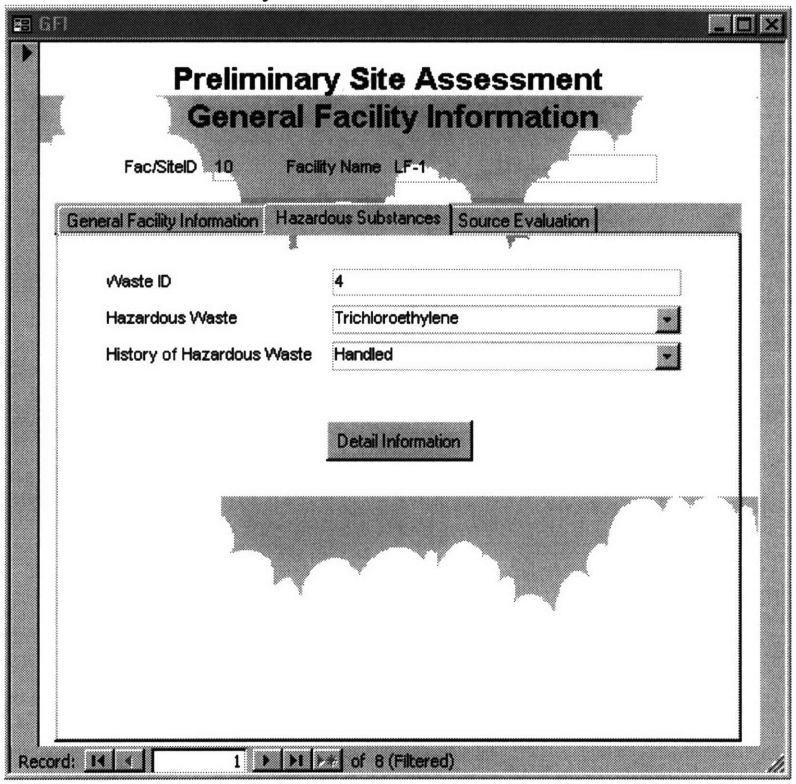
List All Facilities Belonging to Selected Site



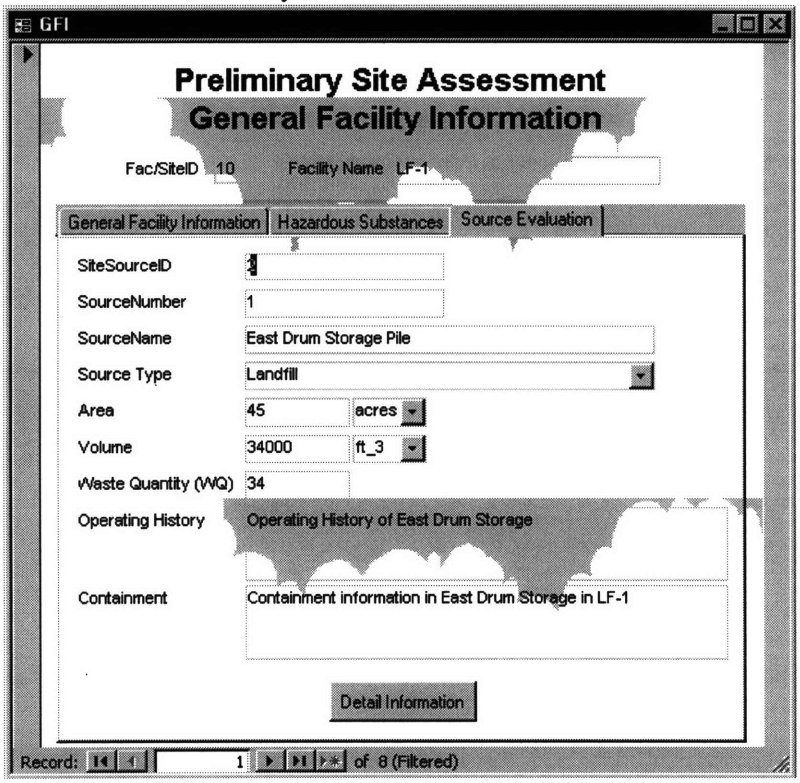
General Facility Information



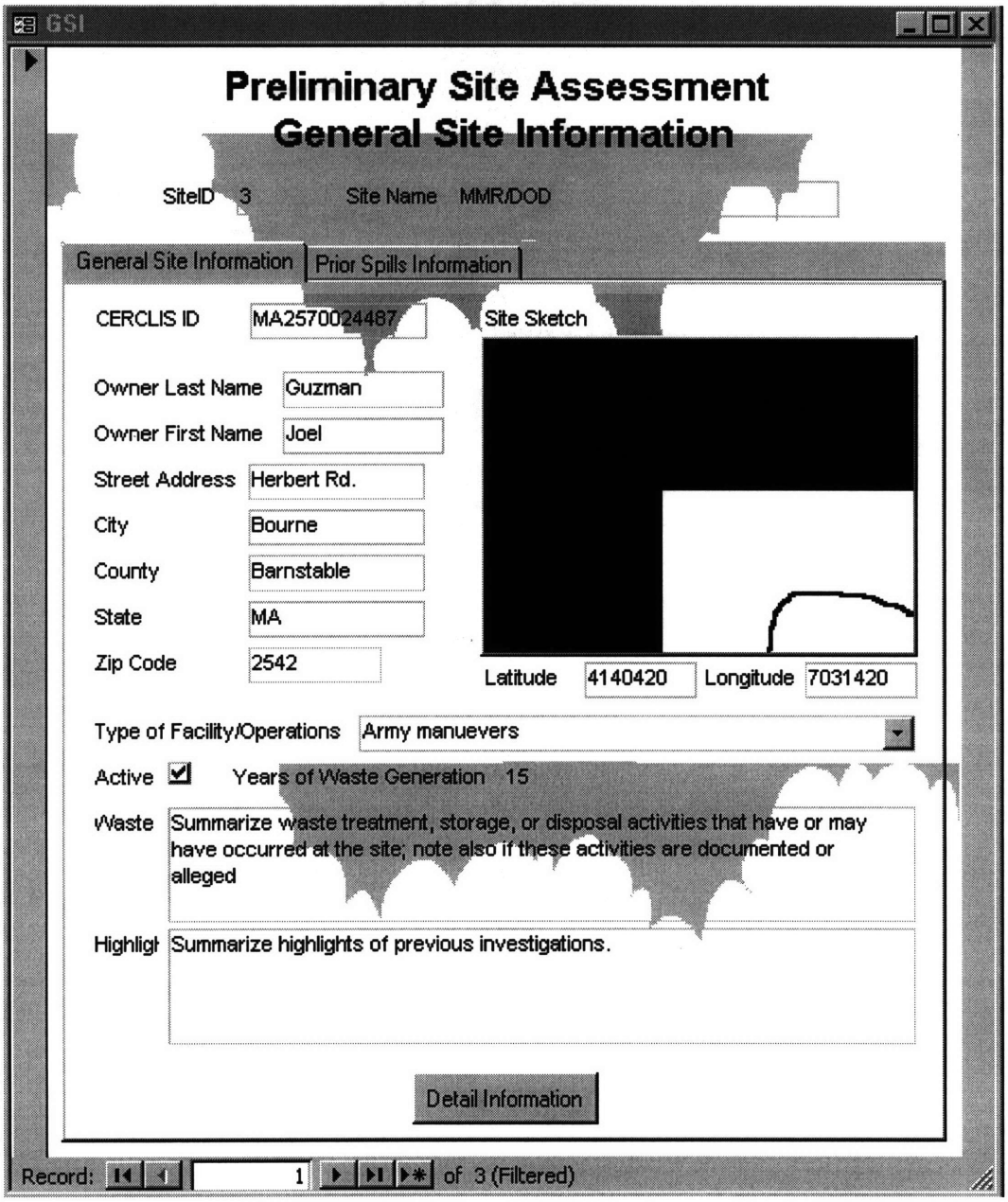
General Facility Information – Hazardous Substances



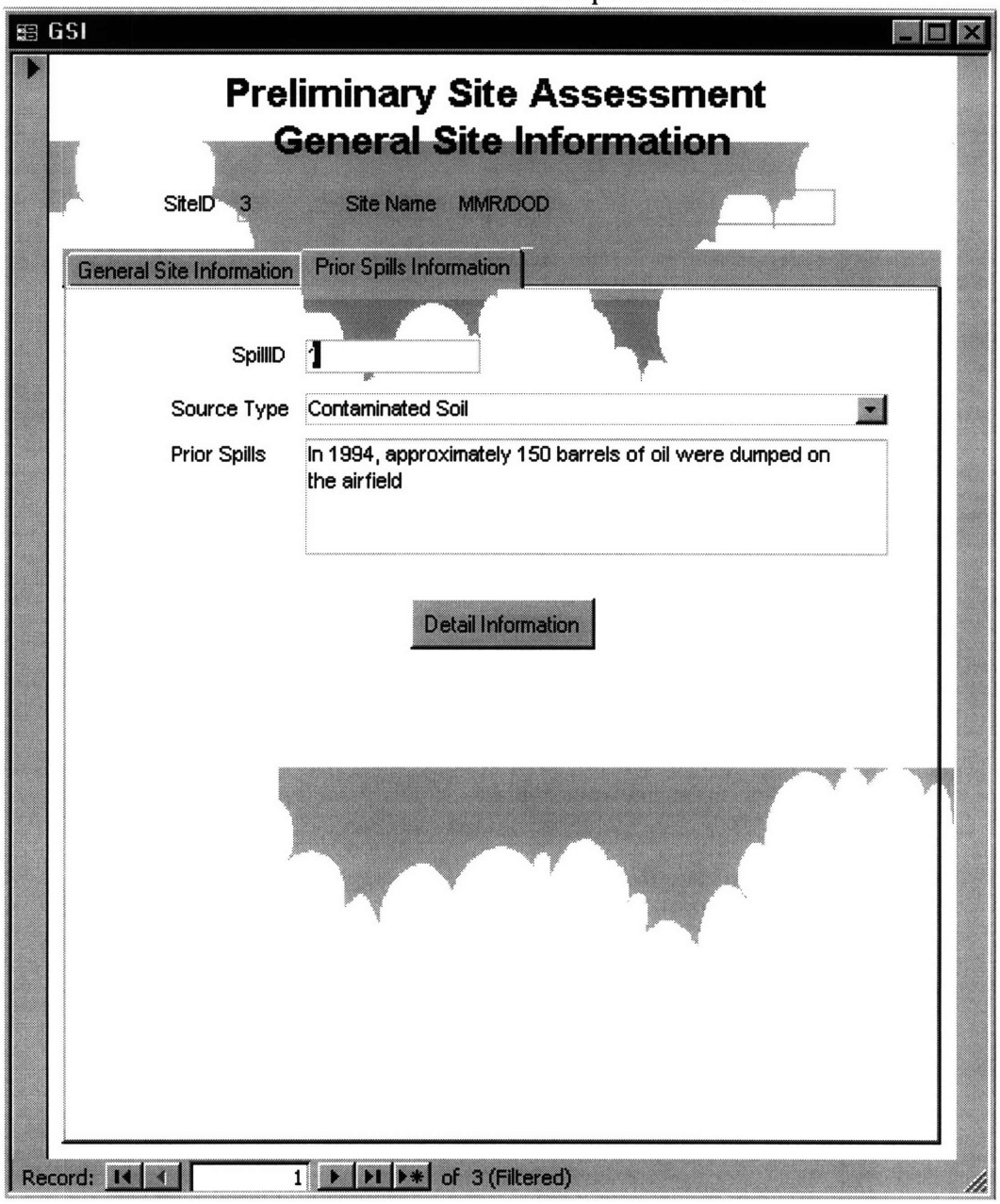
General Facility Information – Source Evaluation



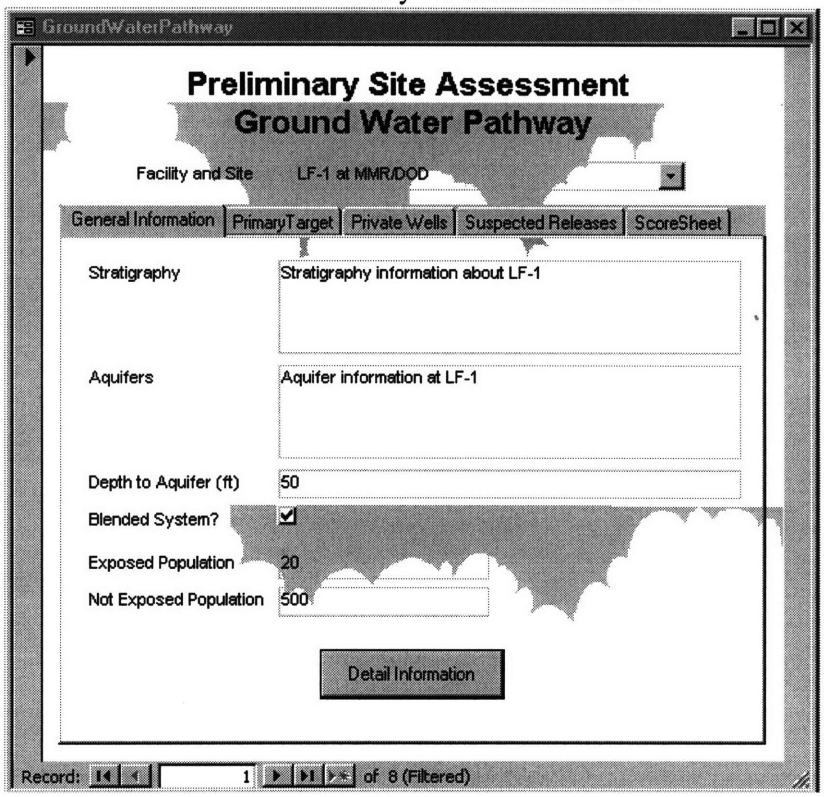
General Site Information



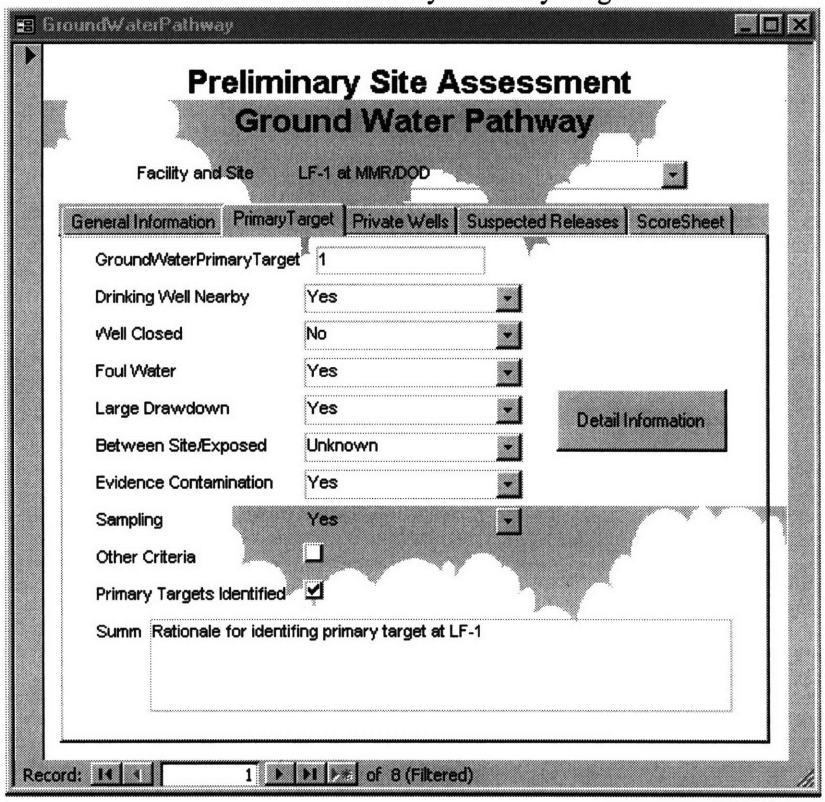
General Site Information – Prior Spills Information



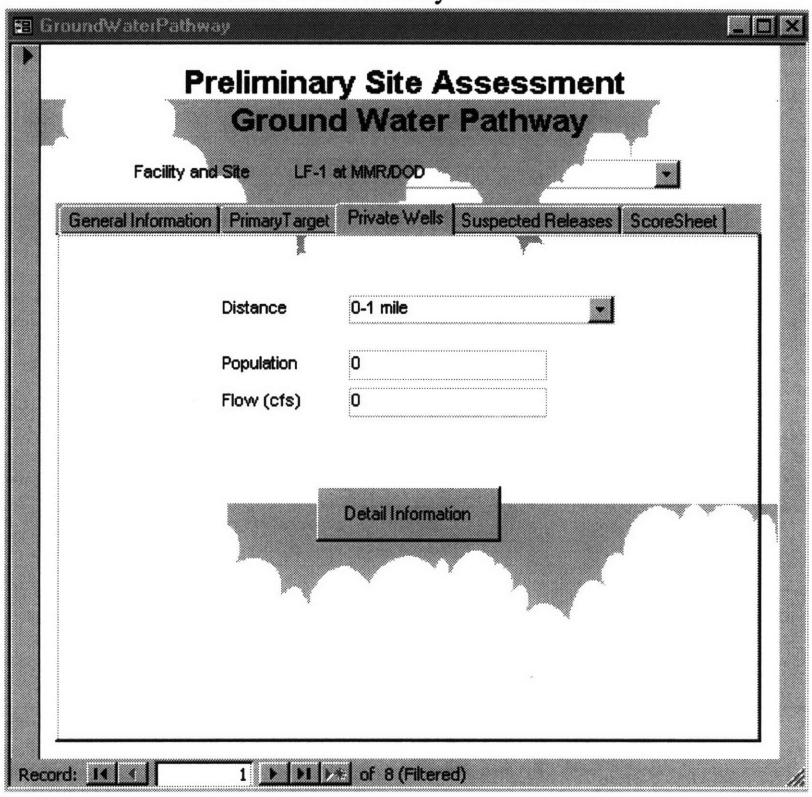
Ground Water Pathway – General Information



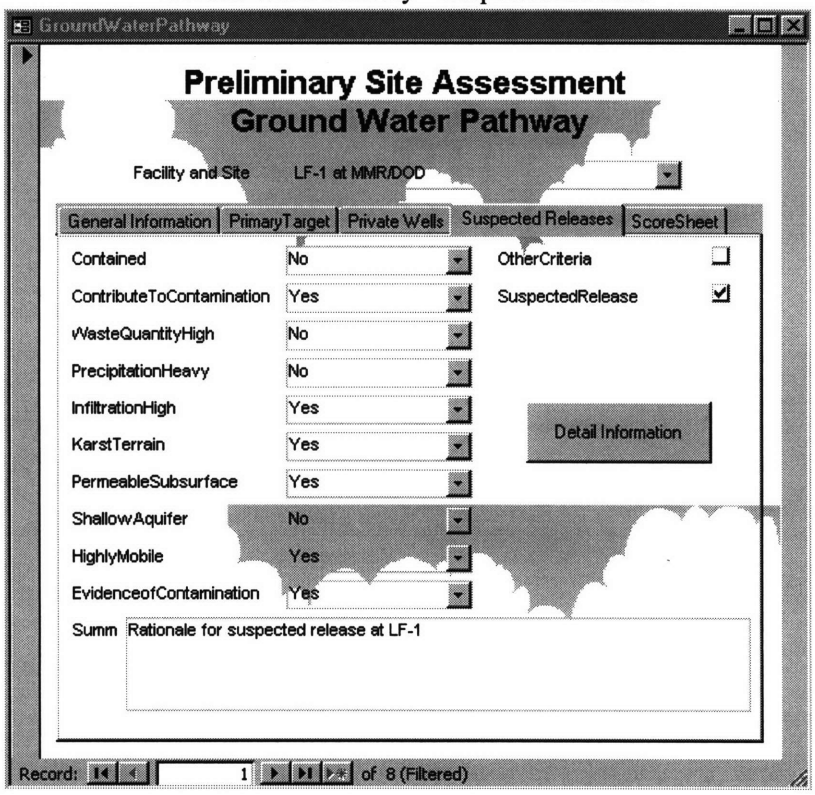
Ground Water Pathway – Primary Target



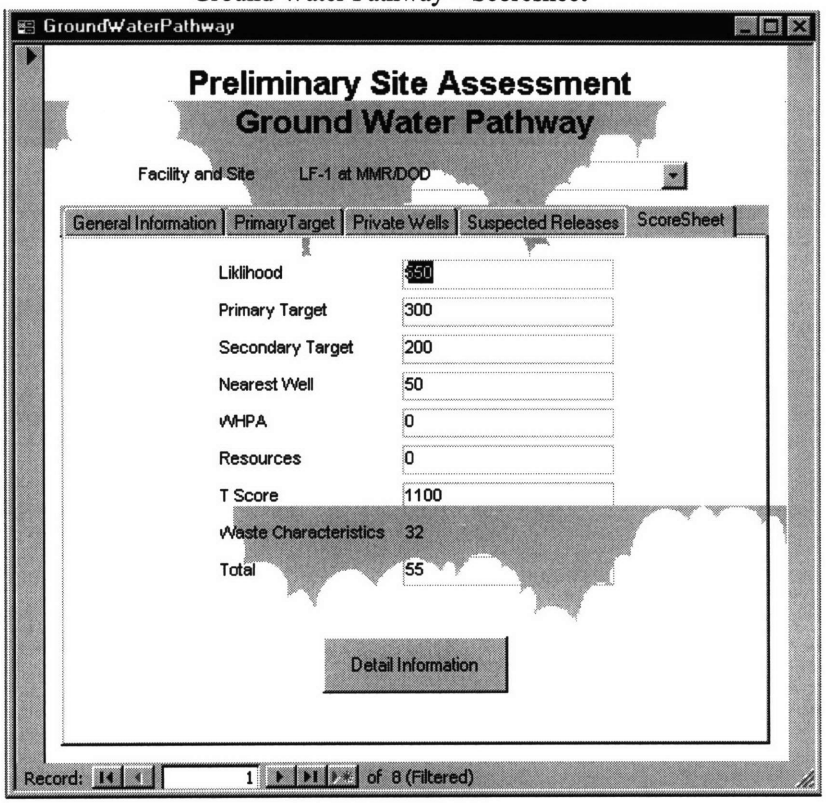
Ground Water Pathway – Private Wells



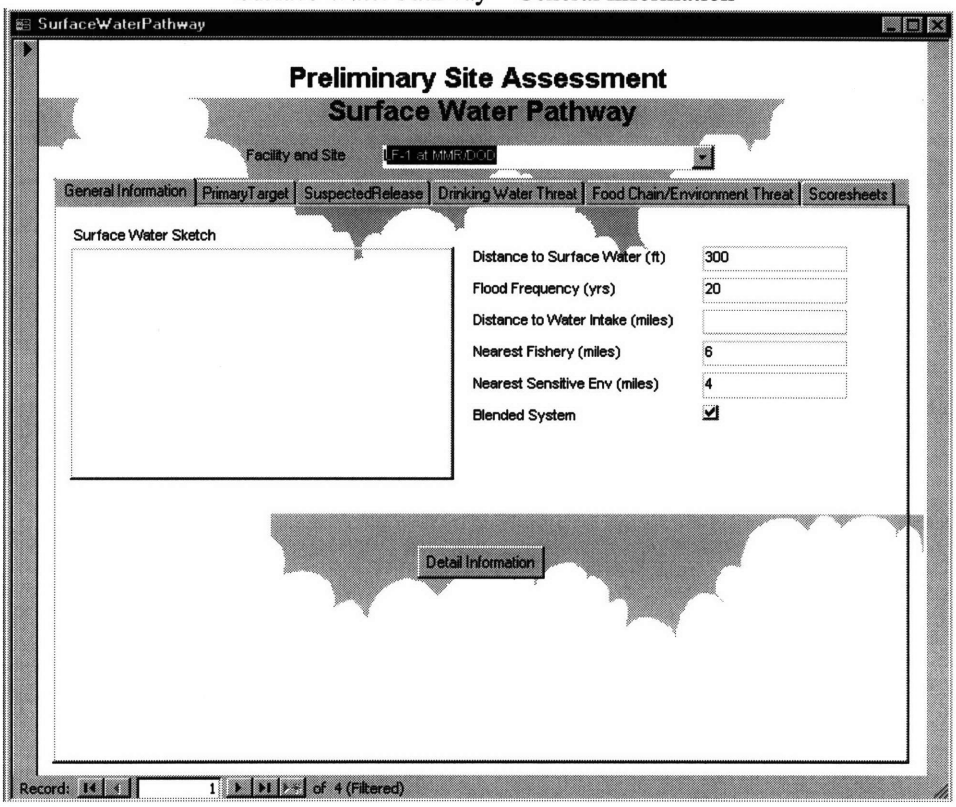
Ground Water Pathway – Suspected Releases



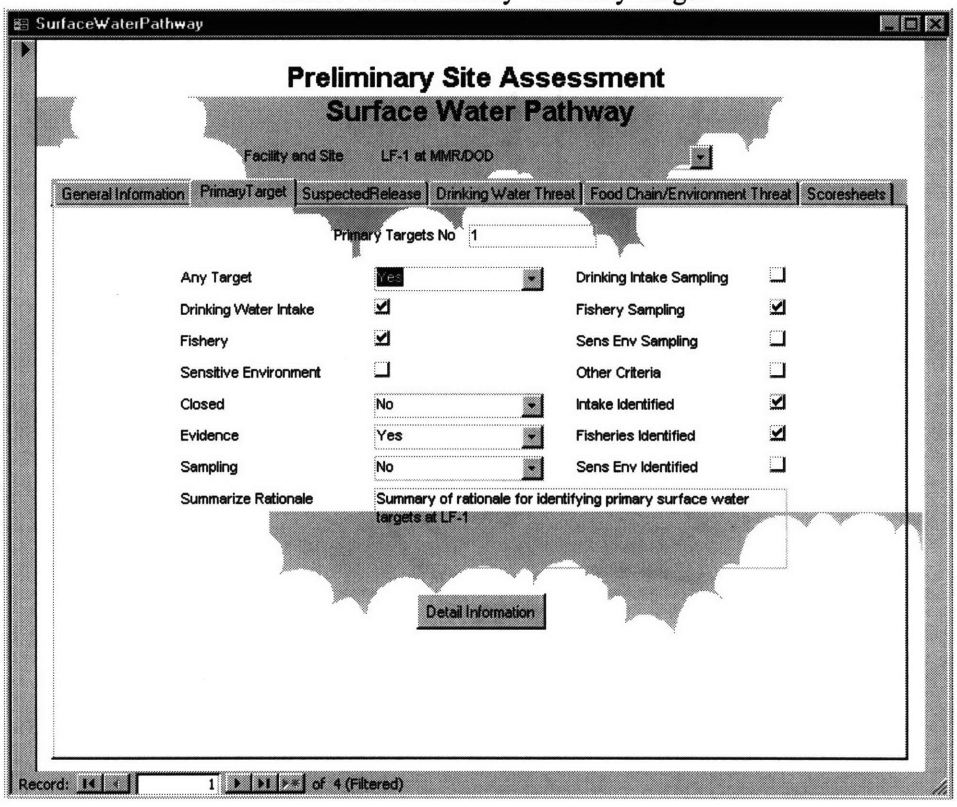
Ground Water Pathway – Scoresheet



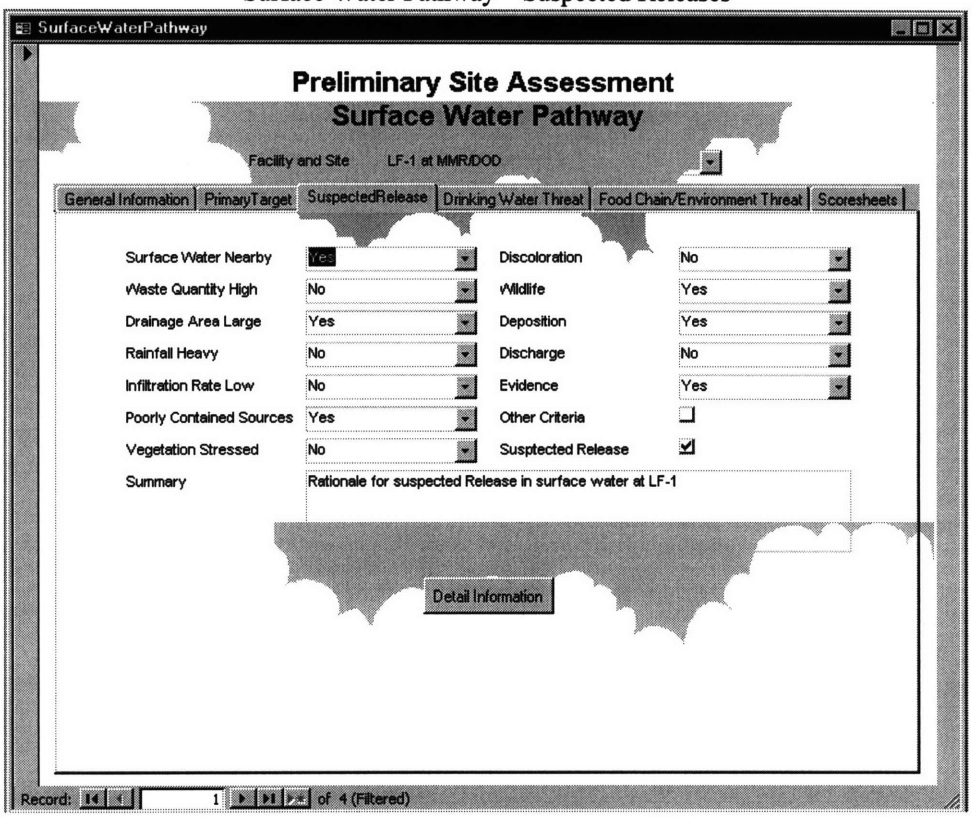
Surface Water Pathway – General Information



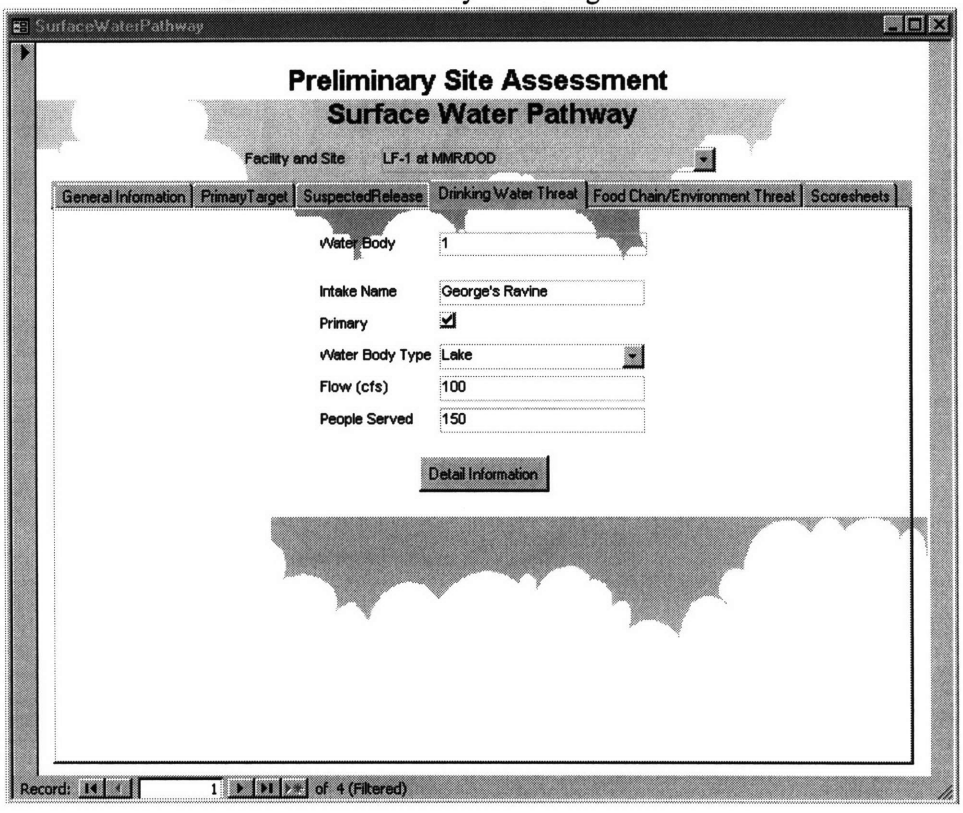
Surface Water Pathway – Primary Target



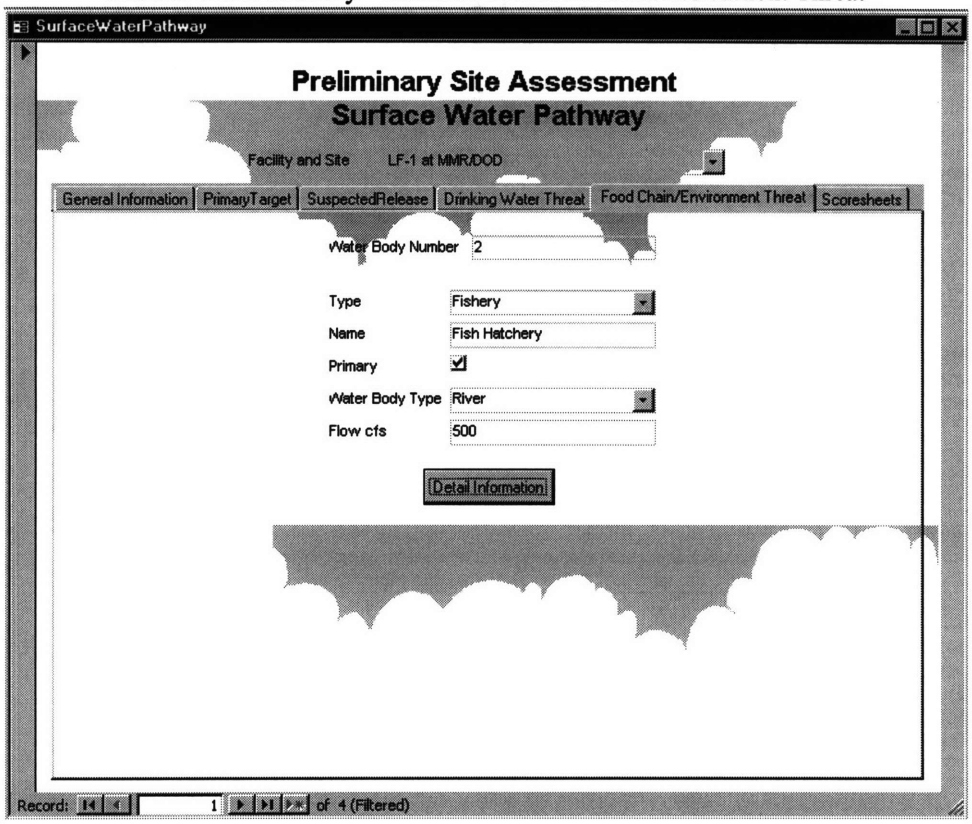
Surface Water Pathway – Suspected Releases



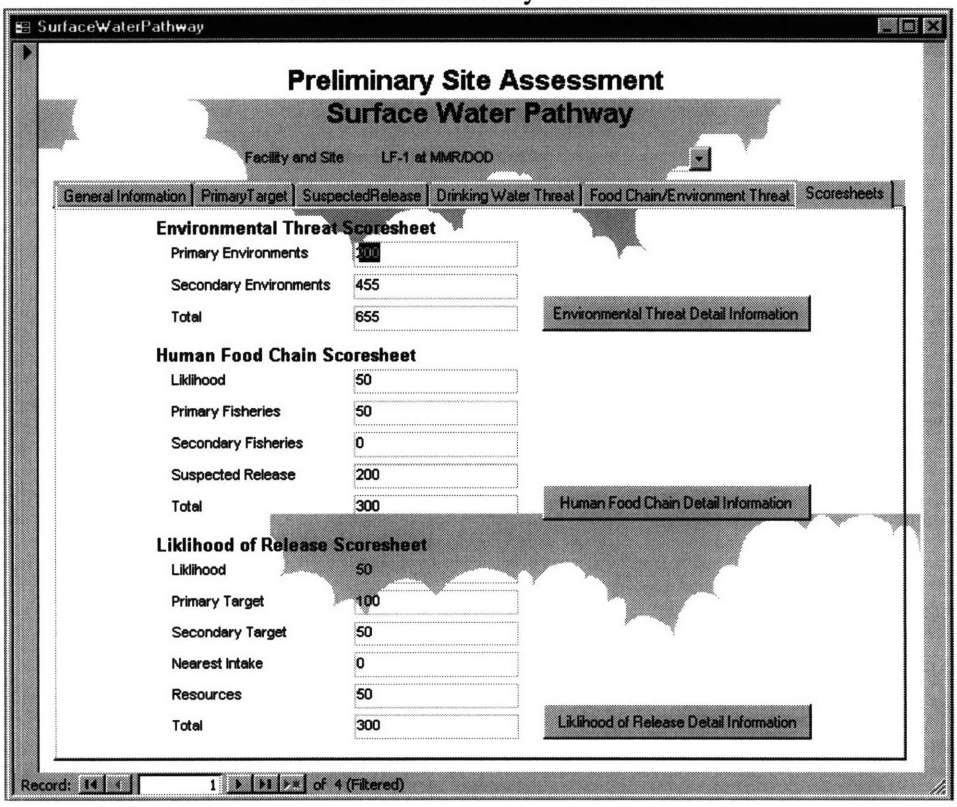
Surface Water Pathway – Drinking Water Threat



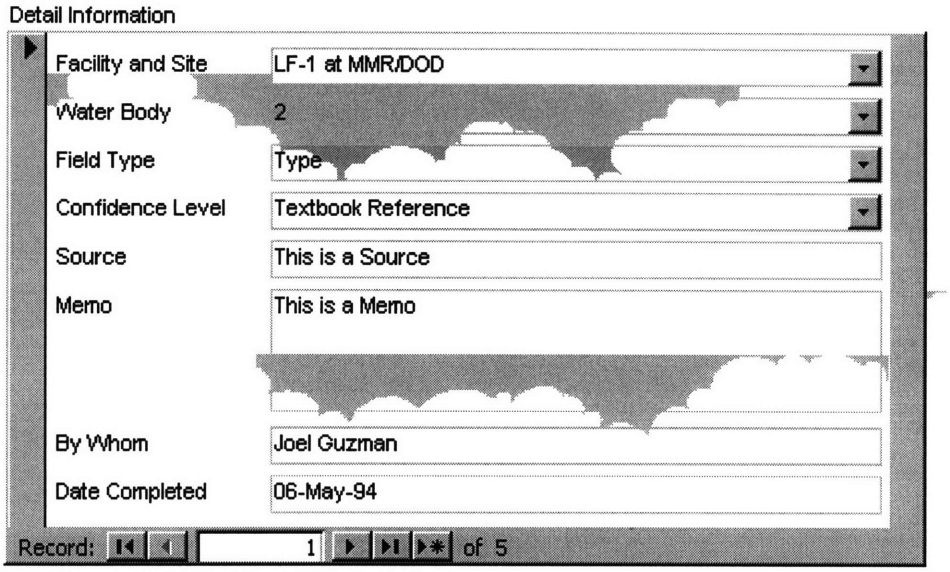
Surface Water Pathway – Human Food Chain and Environment Threat



Surface Water Pathway - Scoresheets



Executive Information System – Detail Information



Appendix D: Graphical User Interface for Existing PA Scoresheet

Source: Lukasiak, 1997

D.1 Overview of the Graphical User Interface of the Electronic Scoresheet

The Graphical User Interface for the electronic scoresheet presents information filtered out from the system that is determined to be useful to the user. The interface for the electronic scoresheet provides better definition of fields to make it easier for the user to fill out clearly stated questions, integration between the parts of the system that provide supporting information, and automation capabilities for calculating the score of the site.

First, the electronic scoresheet has better defined fields than the original paper PA Scoresheet. Many of the long and vaguely posed questions are rewritten in shorter form. New fields are created to simplify answering of the questions. In many instances, a list of possible answers is provided. The user has an option of selecting one of the choices from the list or entering a new value that is not on the list. Although much reformatting was done to simplify and clarify the electronic scoresheet, at no instance information was omitted. The electronic scoresheet reduces the complexity of filling out the document. Second, the Graphical User Interface provides integration of many parts of the system. It displays results of query for supporting information from both external databases and other Web-based sources. When answering each question, the user has an option of looking up additional information related to that particular question. In the future, the electronic scoresheet will be filled out almost entirely and automatically using information filtered out from other parts of the system. Finally, the electronic scoresheet has capabilities of automatically calculating the score and selecting values

from tables based on the user input. This eliminates tedious calculations by hand and an understanding of the layout of tables.

D.2 Structure of the Electronic Scoresheet

Since the current procedure for preliminary site assessment undergoes constant change, the format of the scoresheet is subjected to change. When implementing the current format of the scoresheet document, flexibility was a critical factor in determining the structure and technology used.

Currently, the scoresheet is broken into parts corresponding to physical aspects of the environment. Each part of the electronic scoresheet corresponds to one section of the existing scoresheet document. The first part asks for the name and address of the site and the investigator. Based on this information, both external and internal databases are searched for relevant information that could be used to fill out subsequent parts of the scoresheet.

Next two pages contain more detailed general information about the site and possible sources of contamination. These pages will be partially filled out by the system and partially by investigators. Based on the information, an internal database is created to fill out next four parts of the scoresheet, which will provide scores for individual aspects of the environment, including the ground water pathway, the surface water pathway, the soil pathway and the air pathway. The user will be asked to complete questions that are not filled out automatically by the system. Based on answered questions, each page's score is automated calculated. The last part of scoresheet will integrate all these information and will calculate automatically the final score.

D.3 Implementation of the Electronic Scoresheet

D.3.1 Implementation of Graphical User Interface

Providing flexibility to users and developers, the electronic scoresheet is a Web-based application. This grants platform independence and allows data to be stored on distributed sites. Different pages are created dynamically using CGI Perl script to allow filling out of default values relevant to the site that are results of initial and sequential searches and to provide connectivity between pages.

At its present state, the user is allowed to fill out the scoresheet only sequentially page by page. Values from the previous section are carried over to the next. The system can be updated to allow the user to browse back and forth between these pages in any order. HTML frames can be used to implement this feature; a frame containing indexes of all pages allows users to select any page at any instance, while the other frame contains the actual data and scoresheets page.

Fields in each form are part of the HTML <FORM>. Text fields, check boxes, radio buttons, text areas and lists are used to present information. The formatting of pages is done through usage of <TABLE> and <LIST> tags.

Upon pressing the "Next Page" button, values of fields are sent to CGI bin, where the data is written into temporary files, and a new page is created. Writing information into temporary files is necessary because an HTML page has no capability of storing any information. Upon exiting a page, all the information is lost and cannot be recovered. Perl script was used for storing and reading back information to and from these temporary files; this also allows the creation of dynamic pages with information from previous pages using default values provided by the system.

D.3.2 Calculations and Automation of Tables

Java Applets are used to perform calculations on data from fields that are located on the same Web page. Parameters are sent from the HTML page to the Java Applet, which performs the operation and displays results in Java Applet fields called "Score". Besides calculation, tables are automated as well. Based on the user input, appropriate values from tables are selected and displayed in result fields.

D.3.3 Temporary Storage of Information

A temporary file is created via CGI Perl script to store temporary information since the Web browser has no way of storing information. To recreate the page again, the CGI Perl script uses information from these temporary files. This will allow the user to go back and forth between pages.

D.3.4 Session Registration and Garbage Collection upon Exit

Using CGI scripts to store temporarily information and to create Web pages dynamically to provide connectivity between the pages has a serious drawback, as this does not register sessions of particular users. If at any time the user decides to exit the application before the completion of the scoresheet, there is no way to destroy temporary files automatically.

D.4 Alternative Implementation Scheme

An alternative implementation scheme is to use one Java Applet for the entire scoresheet. Passing variables between parts of the scoresheet is very easy since all variables are stored within one application. Since no temporary file is necessary, the problem of garbage collection upon

unexpected exit could be eliminated, as all traces of the Java Applet are destroyed when the application is suddenly terminated.

However, there is a serious drawback: lack of flexibility. Changing parts of the application becomes more complicated, involving adding functions to handle events, and recompiling the source code. Development of such a large size Java Applet is hard to debug. In addition, creating the user interface is complicated because the variety of layout options is still limited in Java.

D.5 Future Recommendation

In its final form, provided that the information is available, the entire scoresheet can be filled out automatically, and then it can be viewed and verified by a site investigator. Upon submission of the first page, a search for data will return necessary information that would assist with filling out the entire scoresheet. The user will then be given a chance to request additional information regarding the confidence level of sources. This last function is already partially implemented in the current version of the application for limited number of questions.

Finally, creating a Web-based application has many advantages. For example, the user is no longer restricted to a particular platform and does not have to worry about installation of the software. Therefore, the system should continue it development using Web-based technology.

Appendix E: Development of Internet Search Engine

Through the use of modern Internet search engine utilities, the system can sort through millions of documents, in many locations around the globe, with a single mouse click. There are increasing numbers of commercial Web sites now available to the public, free of charge, for the purpose of finding documents on the Internet. Using these search engines in a decision support system gives users the opportunity to view documentation relating to the current decision at hand, which they may possibly not have had access to in the past.

E.1 Availability of Information on the Internet for Decision Support of PA Scoresheets

For the purpose of completing a PA Scoresheet for an environmental clean up, there are many sites available to aid in the decision-making process. They are general sites, which contain information that can be applied to virtually any clean-up site, and specific sites, which contain information pertaining to only a particular clean-up location. It is important to note that in both cases, since these Web documents are maintained by different parties, the reliability of information found is often indeterminate.

An example of general sites is the US Environmental Protection Agency (EPA) Web site (http://www.epa.gov/). Because the EPA is a well-credited source, the information found here could be assumed accurate and reliable. However, the final decision of reliability is up to the engineer completing the PA Scoresheet. It may be useful to contact the Web server administrator to verify the status of the information found.

In the case of environmental clean up at the Massachusetts Military Reservation (MMR), there is a site (http://www.mmr.org) devoted to maintaining up-to-date information about the clean-up process at this site. Wide varieties of information can be found here to aid in the

decision process of evaluating any site at the MMR. In addition, an engineer in the process of evaluating a site not located at the MMR may find information here useful in comparing what was determined at the MMR, with what might be determined at their particular site. Again, it should be noted that it is up to the individual engineer to determine the reliability and confidence level of information found on this Web site.

E.2 Accessing Internet Search Tools Through the Use of Common Gateway Interface

As mentioned earlier, there are many Internet search utilities available free to the public. Some examples include Excite (http://www.excite.com), Yahoo! (http://www.yahoo.com), and Alta Vista (http://www.altavista.com). Each of these companies have developed programs that search their extensive databases of Universal Resource Locators (URL's) to return a series of Web pages that contain the search string queries entered by users. In each case, returned pages may vary due to differences in the database maintained and the search program created by different companies. For this reason, it may be desirable to use multiple search engines in order to increase chances of finding exactly the information requested by the user. This is known as "meta-searching". (An example of this can be found at "http://metasearch.com/".)

The Common Gateway Interface (CGI) is a method for dynamically retrieving information on the Internet. Search engines, such as those listed above, use CGI protocol to allow anonymous users to access and run programs located on their Web server and send the information back to the user's Web browser. Furthermore, the use of CGI allows variables to be passed to these programs, as in the case of search strings or user names, etc. The usual method for accessing these search programs is through HTML forms where values for each of the variables may be entered and the program may be run with a mouse or key click. Alternatively,

one may run the program directly by entering the variable name with their values following the URL of the CGI program at the "Go to:" line of your Web browser, or through the Open URL dialog box. For example, "http://search.yahoo.com/bin/search?p=common+gateway+interface".

Knowing how to access these search engines directly, the system can use a CGI script that can dynamically generate an HTML document containing links to specific search results, not just search engine home pages. Using this one CGI program, the user can pass just one search string and have direct access to results from a variety of commercial search engines. This puts a wide variety of Internet documentation relating to their search in one convenient location.

E.3 Multi-Keyword Searching

Anyone who has used an Internet search engine most likely will know that search results returned are sometimes not exactly desired results. Often, the user will have to wade through a variety of unrelated Web pages to find exactly what it is they were interested in finding. This usually happens because one or all of the search words used may also be found in documents pertaining to a completely different subject matter. In order to limit the amount of pages returned to only those pertaining to the exact topic you are looking for; it is useful to "parameterize" the search.

Parametric searching involves adding a series of search words to search string variable that will help to better describe the information that users are looking for. It is helpful if these words used are likely not to be found on any site pertaining to a different subject matter. An example of this would be to add the word "groundwater" to a search for the word "environment". Sites pertaining to topics such as "political environment" or "social environment" will most likely not contain the word "groundwater". Therefore, these unrelated sites will not appear at the

top of search results window, and the user need not bother wading through countless sites about President Clinton or the newest hip craze. Following are two examples from the Ground Water Pathway sheet of the PA Scoresheet showing the question asked, the call made to run the search and the list of keywords used.

Question 1: Are sources poorly contained?

HTML call: href="../../../scripts/gwp_test.pl?searchstring=MMR%2bgroundwater%2bGround%2bWater%2b Groundwater%2bPlume%2bplume%2bcontamination%2bsource%2bcontained%2bMassachusetts%2bMilitary%2bReservation %2bwww.mmr.org" target=search

Keywords: MMR groundwater Ground Water Groundwater Plume plume contamination source contained Massachusetts Military Reservation www.mmr.org

Question 2: Is waste quantity particularly large?

HTML call: href="../../../scripts/gwp_test.pl?searchstring=MMR%2bgroundwater%2bGround%2bWater%2b Groundwater%2bPlume%2bplume%2bwaste%2bquantity%2bMassachusetts%2bMilitary%2bReservation%2bwww.mmr.org" target=search

Keywords: MMR groundwater Ground Water Groundwater Plume plume waste quantity Massachusetts Military Reservation www.mmr.org

E.4 Displaying Results

As mentioned above, links to search results will be displayed in a Web browser window in HTML format. Due to the fact that users will need to run the program many times (perhaps for each question answered), and will then need to return to the PA Scoresheet document window to record their decisions, it is inconvenient to use the same browser window for both scoresheet and search results. For this reason, when the search program is run, a new browser window will

be opened. This allows the engineer to follow long search paths without the hassle of going back to the original PA Scoresheet document.

Show below are screen captures of a theoretical user session, with just the scoresheet browser window open, or with both scoresheet and search windows open.

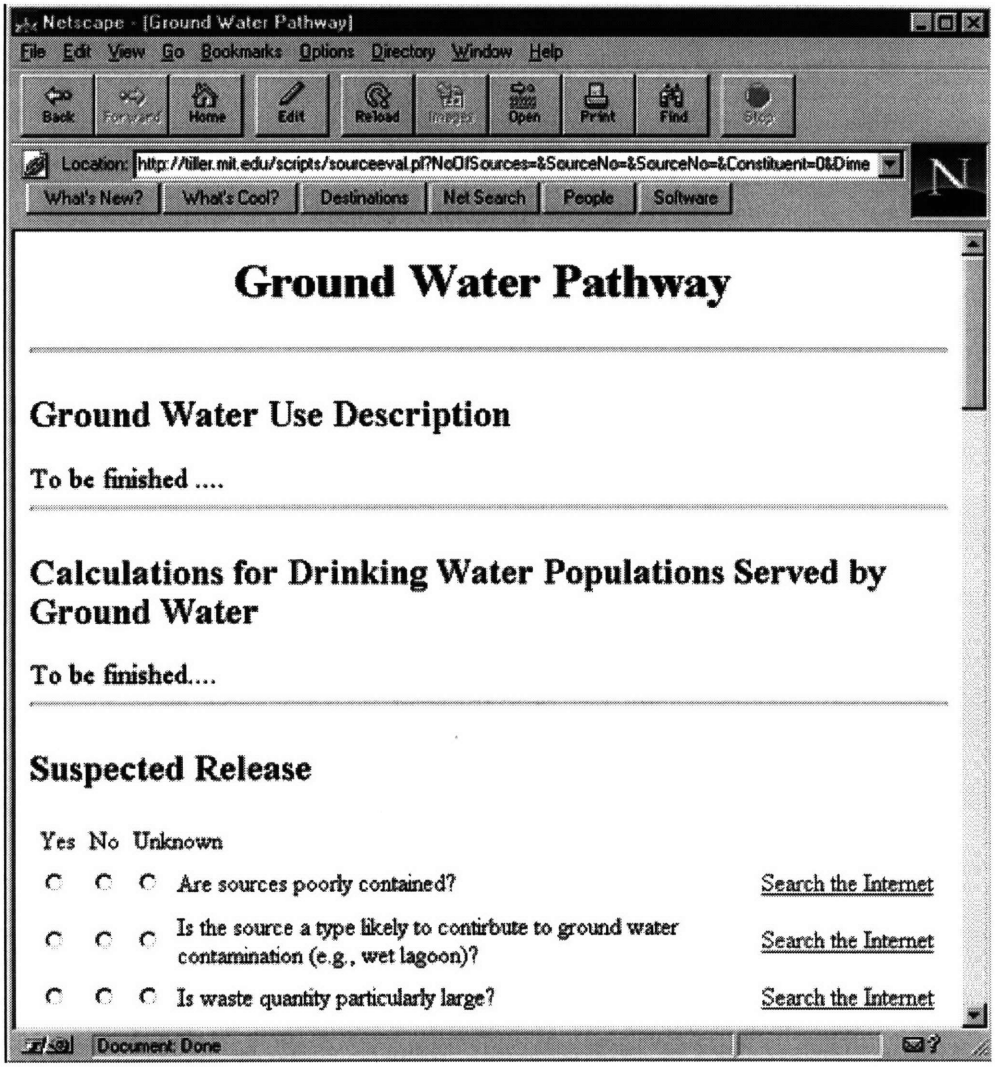


Figure E.4a Ground Water Pathway Section of Electronic PA Scoresheet

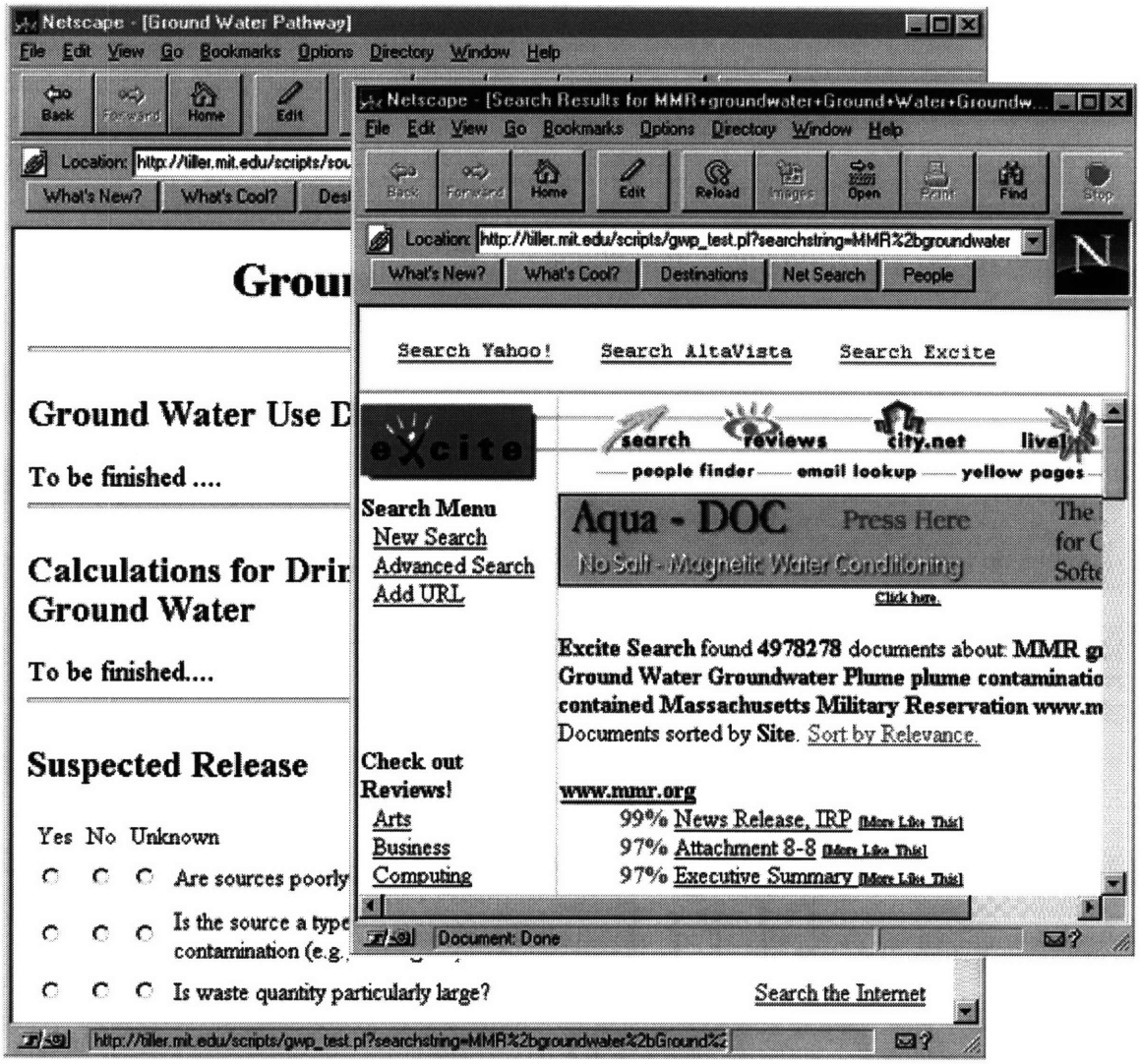


Figure E.4b Ground Water Pathway Section of Electronic PA Scoresheet with Search Results Window

Appendix F: Development of Data Store Search Engine

Source: Mukhopadhyay, 1997

F.1 The Data Store Search Engine's Role in the System

The data store search engine contains static links to data sources that are in a known, standard format. This section of the system is diagrammed in Figure F.1a. PA Scoresheet questions that can be answered by these data sources are marked with a "Query" button placed next to them on the electronic scoresheets. This button initiates the search of appropriate data sources. These include data sources that are in a parable standard format on the World Wide Web, on a connectable CD-ROM, or any other source where the information is in a format that allows the computer to extract specific information from the database without the user's help. Generally, this means that the data is held in a spreadsheet or database format, as opposed to a written document, or a less formatted information list.

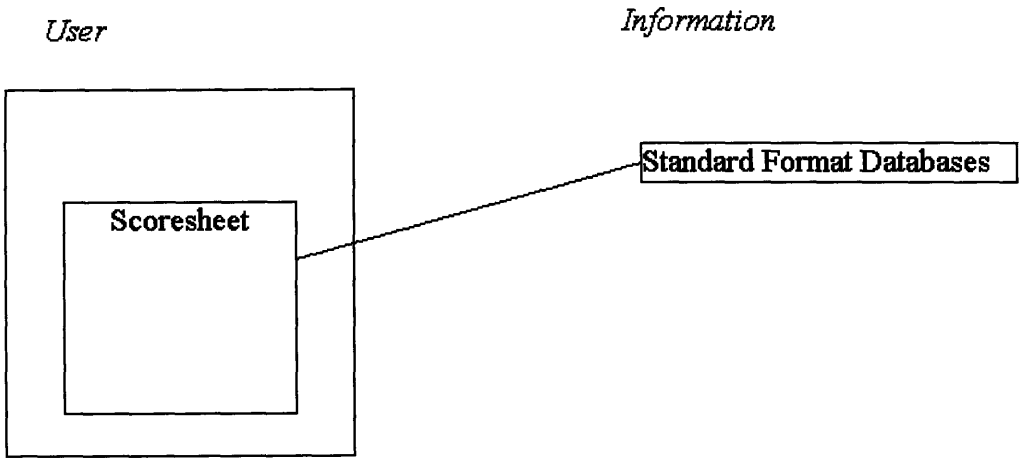


Figure F.1a Data Store Search Engine System Diagram

The extent of the implementation of the data store search engine described here was limited by the current availability of documents containing PA Scoresheet information in a standard format. Only a data source was located; a United States Geological Survey (USGS) Web site that provides water-use information for fifty states in the US. For this project, the USGS data source file for the state of Massachusetts was connected to the PA Scoresheets for the MMR.

F.2 Description of USGS Data Source

Each of the available USGS data source files contains information for a particular state in the United States. The data were gathered in 1990 and placed in standard text files written in spreadsheet format, with each row corresponding to a county in that state. Although the file currently connected to the PA Scoresheet is for the state of Massachusetts, combining the different state files into one countrywide file for conducting more generic queries would be an easy task, if this system were to be used for different Superfund sites in the future.

The column headings of the data file are codes for the water-use data elements present. A brief description of the file format is in Appendix G and a complete list of the water-use data elements along with their codes and descriptions is given in Appendix H. The elements used in the current system, together with the PA Scoresheet questions that they have been used to answer are as follows:

- ps-popgw (total population served by the ground water in the area), used to answer questions 3 and 4 on page 8 of the PA scoresheet

- to-totsw (total surface water used in millions of gallons per day), used to answer the first question in the "Suspected Release" column of page 11 of the scoresheets
- do-sstot (total domestic water withdrawals), used to answer the first question in the "Primary Targets" column of page 11 of the scoresheets
- ps-popsw (total population served by the surface water in the area), used to answer questions 4 and 5 on page 12 of the scoresheets

F.3 Matching Existing Data Source Information with Scoresheet Questions

Many of the questions on the scoresheet are currently unanswerable from existing data sources. However, much of the information required is such that it could one day be compiled into spreadsheet or database format.

For the system developed here, the scoresheet questions which have been liked to the existing data stores will be distinguishable by a "Query" button placed next to them. Pushing the button will open a new browser window that will display the results of the query. The results of any queries run from that point forwards will also appear in the same browser window.

When the answer is received from the data source, some of the PA Scoresheet questions require interpolation on the part of the user in order to translate the answer into relevant scoresheet information. For example, with the question "Is surface water nearby," (question 1, column 1, page 11 of PA), the system currently returns the amount of surface water used in the area. If this number is greater than zero, than the user will answer, "Yes," and if not, "No." Obvious answers such as this are not automatically filled in by the system to ensure that the user takes an active role in answering any question or making any recorded decision.

When the user pushes this "Query" button, they are actually executing a program that is on the same server as the web page they are viewing. As mentioned in Section F.2, the system currently accesses a USGS file containing Massachusetts's water-use information. It is envisioned that when the system is complete, the user will log on to a particular account and select the Superfund site that they wish to assess. This selection will automatically tell the system which data files to access. The particular button pushed will tell the system which question is being asked, and the program will determines how to run the query for that particular piece of information. The query will be run on the data source (also located at the site). The information will be parsed into HTML so the web browser can read it, and post it for the user.

It is important to note that for a particular scoresheet question, the program to execute the query and the data source components of the system must be on the same server. However, this server does not need to be the same server used for the main system user interface. This means that if there is an organization that maintains a standard format data source, the program to access their data will need to be on their server, otherwise their data files will need to be downloaded to another server. If the source is public, there should not be a problem bringing data into a server controlled by EIDSS administrators. If it is a private data source, permission must be obtained to access it. Once the permission is obtained, the relative locations of the data source and the program can be easily placed as required.

F.4 Conclusion

In general, the nature of the information requested on the scoresheets is not conducive to being placed in a database. It is far more likely that if data sources are created in the future, whether they are text files on the web, or CD-ROMs, they will be in spreadsheet format, as the

one currently used to demonstrate the development of a data source search engine here. The demonstration system that has been implemented in this project could be expanded to access other text data sources very easily, with the addition of approximately ten lines of code. This expansion will be simple, because the entire framework required to make this type of connection has been completed. If data sources of other types are found, it is estimated that the amount of code required to incorporate them will be similar. However, there will be some additional configuring that the system administrator would need to perform. The difficulty of this process will vary with the type of data source to be included in the search engine.

Appendix G: USGS Data Files

Source: http://h2o.usgs.gov/public/watuse/data/wudict.txt

All of the fields in the USGS data files were reformatted in May 1996. They are now in a 'spreadsheet' format, in which all fields are separated by a TAB character. This method should allow the data to be easily imported into a spreadsheet program on your computer.

The first line in each data file contains the 'headers', which is an 8 (or so) letter code describing each data element. For example, the code for 'Commercial withdrawals, ground-water, fresh' is 'co-wgwfr'. Each line (record) in the data files begins with some descriptive information, such as the state, year, and county or water-resources region code. There are headers for these items at the beginning of the first line (the header line). These first few header codes vary by file type.

NOTE: The initial header information (first 4 or 5 items in each line) varies by file. The actual code headers for the data elements are described in Appendix H.

The data elements with a "Entered by user" under the "HOW ELEMENT IS COMPUTED" heading indicate data that has been compiled and entered manually into the files. A data element that is not "Entered by user" was calculated by using other data values. For example, 'ps-popgw' (index #3) and 'ps-popsw' (index #4) are summed to create 'ps-popto'. So, total public supply population served is computed by summing the population served by ground water and the population served by surface water.

A table of data elements, element codes and method of computation is in Appendix H.

Appendix H: Complete List of Water-Use Data Elements

Source: http://h2o.usgs.gov/public/watuse/data/wudict.txt

WATER-USE DATA ELEMENT		CODE	INDEX	HOW ELEMENT IS COMPUTED
TOTAL POPULATION (in AREA, in thousands)		po-total	2	Entered by user
PUBLIC SUPPLY:				
Population served (thousands):	Ground Water	ps-popgw	3	Entered by user
" "	Surface Water	ps-popsw	4	Entered by user
" "	Total	ps-popto	5	3+4
Water withdrawals, fresh	Ground Water	ps-wgwfr	6	Entered by user
" " "	Surface Water	ps-wswfr	7	Entered by user
" " "	Total, Fresh	ps-wtofr	8	6+7
Water withdrawals, saline	Ground Water	ps-wgwsa	9	Entered by user
" " "	Surface Water	ps-wswsa	10	Entered by user
" " "	Total Saline	ps-wsato	11	9+10
Water withdrawals, total	Total Total	ps-total	12	6+7+9+10
Water deliveries:	Public Use and Losses	ps-loss	13	12-21-30-44-71-93
" "	Total Deliveries	ps-deliv	14	13+21+30+44+71+93
Per capita use:	Total, Gal/d	ps-prcap	15	12*1000/5
Number of facilities:	In Area	ps-facil	16	Entered by user
" " "	Water-Use Database	ps-facdb	17	Entered by user
COMMERCIAL:				
Self-supplied withdrawals:	Ground Water	co-wgwfr	18	Entered by user
" "	Surface Water	co-wswfr	19	Entered by user
" "	Total	co-wtotl	20	18+19
Deliveries from water supply:	Fresh	co-psdel	21	Entered by user
Total:	Withdr. + Deliveries	co-total	22	18+19+21
Consumptive use:		co-cuse	23	Entered by user
DOMESTIC:				
SELF SUPPLIED:				
Population:	Thousands	do-sspop	24	2-5
Water withdrawals:	Ground Water	do-ssgwf	25	Entered by user
"	Surface Water	do-ssswf	26	Entered by user
"	Total	do-sstot	27	25+26
Per capita use:	Gal/d	do-sspcp	28	(25+26)*1000/24
PUBLIC SUPPLIED:				
Population:	Thousands	do-pspop	29	5
Deliveries from water supply	Fresh	do-psdel	30	Entered by user
Per capita use:	Gal/d	do-pspcp	31	30*1000/29
TOTAL:				
Withdrawals + deliveries:		do-total	32	25+26+30

Consumptive use:		do-cuse	33	Entered by user
INDUSTRIAL:				
Self-supplied withdrawals:	Ground Water, fresh	in-wgwfr	34	Entered by user
" "	Ground Water, saline	in-wgwsa	35	Entered by user
" "	Ground Water, total	in-wgwto	36	34+35
" "	Surface Water, fresh	in-wswfr	37	Entered by user
" "	Surface Water, saline	in-wswsa	38	Entered by user
" "	Surface Water, total	in-wswto	39	37+38
" "	Total, Fresh	in-wtofr	40	34+37
" "	Total, Saline	in-wtosa	41	35+38
" "	Total, Total	in-wtotl	42	34+35+37+38
" "	Reclaimed Sewage	in-recww	43	Entered by user
Deliveries from water supply	Fresh	in-psdel	44	Entered by user
Total, withdrawal+deliveries	Fresh	in-total	45	34+37+44
Consumptive use	Fresh	in-cufr	46	Entered by user
" "	Saline	in-cusal	47	Entered by user
" "	Total	in-cuse	48	46+47
Number of facilities:	In Area	in-facil	49	Entered by user
" " "	In Water-Use Database	in-facdb	50	Entered by user
THERMOELECTRIC POWER (ELECTRIC):				
All thermoelectric water use:	Ground Water, fresh	pt-wgwfr	51	65+79+87
" " " "	Surface Water, fresh	pt-wswfr	52	66+88
" " " "	Surface Water, saline	pt-wswsa	53	67+89
" " " "	Surface Water, total	pt-wswto	54	66+67+88+89
" " " "	Total, Fresh	pt-frtot	55	65+66+79+87+88
" " " "	Total, Total	pt-wtotl	56	65+66+67+79+80+87+88+89
Deliveries from water supply	Fresh	pt-psdel	57	71+93
Total: Withdrawal + deliv	Fresh	pt-total	58	65+66+71+79+87+88+93
Consumptive use	Fresh	pt-cufr	59	73+82+95
" "	Saline	pt-cusal	60	74+83+96
" "	Total	pt-cuse	61	73+74+82+83+95+96
Total power generated:	Gigawatthours/year	pt-power	62	76+84+98
Number of facilities:	In Area	pt-facil	63	77+85+99
" " "	In Water-Use Database	pt-facdb	64	78+86+100
THERMOELECTRIC POWER (ELECTRIC), FOSSIL FUEL				
Fossil fuel: Withdrawals	Ground Water, fresh	pf-wgwfr	65	Entered by user
" " "	Surface Water, fresh	pf-wswfr	66	Entered by user
" " "	Surface Water, saline	pf-wswsa	67	Entered by user
" " "	Surface Water, total	pf-wswto	68	66+67
" " "	Total, Fresh	pf-frtot	69	65+66
" " "	Total, Total	pf-wtotl	70	65+66+67
Deliveries from water supply	Fresh	pf-psdel	71	Entered by user
Total: Withdrawal + deliver	Fresh	pf-total	72	65+66+71
Consumptive use	Fresh	pf-cufr	73	Entered by user
" "	Saline	pf-cusal	74	Entered by user
" "	Total	pf-cuse	75	73+74

Power generation	Gigawatthours/year	pf-power	76	Entered by user
Number of facilities:	In Area	pf-facil	77	Entered by user
" " "	In Water-Use Database	pf-facdb	78	Entered by user
THERMOELECTRIC POWER (ELECTRIC), GEOTHERMAL				
Geothermal: Withdrawals	Ground Water, fresh	pg-wgwfr	79	Entered by user
" "	Ground Water, saline	pg-wgwsa	80	Entered by user
" "	Total	pg-wtotl	81	79+80
Consumptive use	Fresh	pg-cufr	82	Entered by user
" "	Saline	pg-cusal	83	Entered by user
Power generation	Gigawatthours/year	pg-power	84	Entered by user
Number of facilities:	In Area	pg-facil	85	Entered by user
" " "	In Water-Use Database	pg-facdb	86	Entered by user
THERMOELECTRIC POWER (ELECTRIC), NUCLEAR:				
Nuclear: Withdrawals	Ground Water, fresh	pn-wgwfr	87	Entered by user
" "	Surface Water, fresh	pn-wswfr	88	Entered by user
" "	Surface Water, saline	pn-wswsa	89	Entered by user
" "	Surface Water, total	pn-wswto	90	88+89
" "	Total, Fresh	pn-frtot	91	87+88
" "	Total, Total	pn-wtotl	92	87+88+89
Deliveries from water supply	Fresh	pn-psdel	93	Entered by user
Total: Withdrawal + deliveries	Fresh	pn-total	94	87+88+93
Consumptive use	Fresh	pn-cufr	95	Entered by user
" "	Saline	pn-cusal	96	Entered by user
" "	Total	pn-cuse	97	95+96
Power generation	Gigawatthours/year	pn-power	98	Entered by user
Number of facilities:	In Area	pn-facil	99	Entered by user
" " "	In Water-Use Database	pn-facdb	100	Entered by user
MINING:				
Withdrawals:	Ground Water, fresh	mi-wgwfr	101	Entered by user
"	Ground Water, saline	mi-wgwsa	102	Entered by user
"	Ground Water, total	mi-gwtot	103	101+102
"	Surface Water, fresh	mi-wswfr	104	Entered by user
"	Surface Water, saline	mi-wswsa	105	Entered by user
"	Surface Water, total	mi-swtot	106	104+105
Withdrawals, total:	Total, Fresh	mi-frtot	107	101+104
" "	Total, Saline	mi-satot	108	102+105
" "	Total, Total	mi-total	109	101+102+104+105
Consumptive Use:	Fresh	mi-cufr	110	Entered by user
" "	Saline	mi-cusal	111	Entered by user
" "	Total	mi-cuse	112	110+111
LIVESTOCK:				
Stock: Withdrawals:	Ground Water	ls-gwtot	113	Entered by user
" "	Surface Water	ls-swtot	114	Entered by user
" "	Total	ls-total	115	113+114
Stock, consumptive use:		ls-cuse	116	Entered by user

Animal specialties, withdrawals:	Ground Water	la-gwtot	117	Entered by user
" " "	Surface Water	la-swtot	118	Entered by user
" " "	Total	la-total	119	117+118
Animal specialties, consumptive use:		la-cuse	120	Entered by user
Total livestock: Withdrawals:	Ground Water	lv-gwtot	121	113+117
" " "	Surface Water	lv-swtot	122	114+118
" " "	Total	lv-total	123	113+114+117+118
Total livestock, consumptive use:		lv-cuse	124	116+120
IRRIGATION				
Withdrawals, fresh	Ground Water	ir-wgwfr	125	Entered by user
" "	Surface Water	ir-wswfr	126	Entered by user
"	Reclaimed Sewage	ir-recww	127	Entered by user
" "	Total, Fresh	ir-frtot	128	125+126
Irrigated land, in 1000 acres:	Sprayed	ir-spray	129	Entered by user
" " " "	Flooded	ir-flood	130	Entered by user
" " " "	Total	ir-irrig	131	129+130
Conveyance losses:	Total	ir-convy	132	Entered by user
Consumptive use:		ir-cuse	133	Entered by user
HYDROELECTRIC POWER:				
Water use:	Total	hy-total	134	Entered by user
Power generation:	Gigawatthours/year	hy-power	135	Entered by user
Number of facilities:	In Area	hy-facil	136	Entered by user
" " "	In Water-Use Database	hy-facdb	137	Entered by user
SEWAGE TREATMENT:				
Number of facilities:	Public	ww-facpu	138	Entered by user
" " "	Industrial + Other	ww-facot	139	Entered by user
" " "	Total Number	ww-facil	140	138+139
Municipal system returns:		ww-retrn	141	Entered by user
Number of facilities:	In Water-Use Database	ww-facdb	142	Entered by user
Reclaimed waste water (WW) from pub.	WW facilities	ww-recww	143	Entered by user
RESERVOIR EVAPORATION				
Amt evaporated, (1000 acre ft):	Fresh	re-evap	144	Entered by user
Surface area, in 1000 acres:		re-area	145	Entered by user
TOTAL WATER USE:				
	Ground water, fresh	to-gwfr	146	6+18+25+34+65+79+87+101+113+117+125
	Ground water, saline	to-gwsal	147	9+35+80+102
	Ground water, total	to-totgw	148	6+9+18+25+34+35+65+79+80+87+101+ 102+113+117+125
	Surface water, fresh	to-swfr	149	7+19+26+37+66+88+104+114+118+126
	Surface water, saline	to-swsal	150	10+38+67+89+105
	Surface water, total	to-totsw	151	7+10+19+26+37+38+66+67+88+89+104+ 105+114+118+126
	Total, fresh	to-totfr	152	6+7+18+19+25+26+34+37+65+66+79+87+
	Total, saline	to-totsa	153	9+10+35+38+67+80+89+102+105

Total, total	to-total	154	6+7+9+10+18+19+25+26+34+35+37+38+65+66+67+79+80+87+88+89+101+102+104+105+113+114+117+118+125+126
Reclaimed sewage	to-recww	155	43+127
Consumptive use, fresh	to-cufr	156	23+33+46+73+82+95+110+116+120+133
Consumptive use, saline	to-cusal	157	47+74+83+96+111
Consumptive use, total	to-cuse	158	23+33+46+47+73+74+82+83+95+96+110+111+116+120+133
Conveyance losses	to-convy	159	132

Appendix I: Cross-site Comparison Database System

Source: Guzmán, 1997

I.1 Introduction

The feasibility of using databases located on the Internet and from local CD-ROM to complete preliminary site assessment scoresheets is limited by the actual availability of information from these data sources. One of the most useful sources of data may be previously completed PA scoresheets. Once the proposed information system discussed in this project has been used to complete one or more PA's, a database of previous scoresheets will be available for site comparisons. If a new site under investigation has characteristics that are in some way similar to sites that have been studied previously, completion of the new PA may be facilitated by referring to the database of these previous studies. Comparing new sites with completed studies will provide an additional check for reliability and support for the current site under assessment. This section summarizes the proposed architecture for an interactive database of PA scoresheets for cross-site comparison. This architecture will enhance the utility of the currently proposed decision support system. The database of scoresheets will additionally be used for implementation of the executive information system as well.

I.2 Design and Population of Data Storage

In order to take full advantage of the completed PA scoresheets, some data storage must be developed to keep track of the completed studies. A relational database, which is a set of data tables linked by common data fields, is well suited for this purpose. Figure I.2a shows an example of parts of two of the many data tables that will make up the PA database.

The table on the right in Figure I.2a shows a sample data associated with information classified as "General Site Information". The "General Site Prior Spills" table is separated from the "General Site Information" table because it contains data that is relevant to site spills only. The separation of tables linked by a common field, SiteID, also allows for the storage of information about multiple site spills corresponding to a single site.

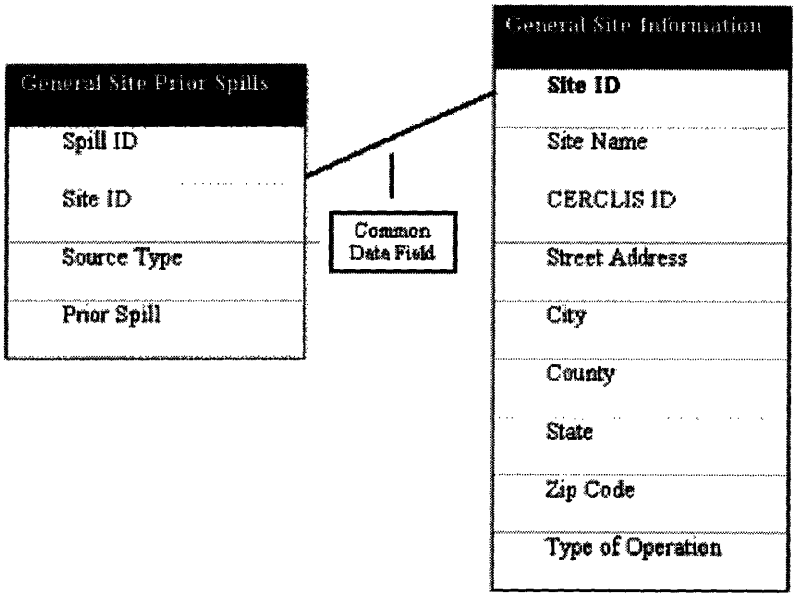


Figure I.2a Sample Tables of Relational Database of PA Scoresheet

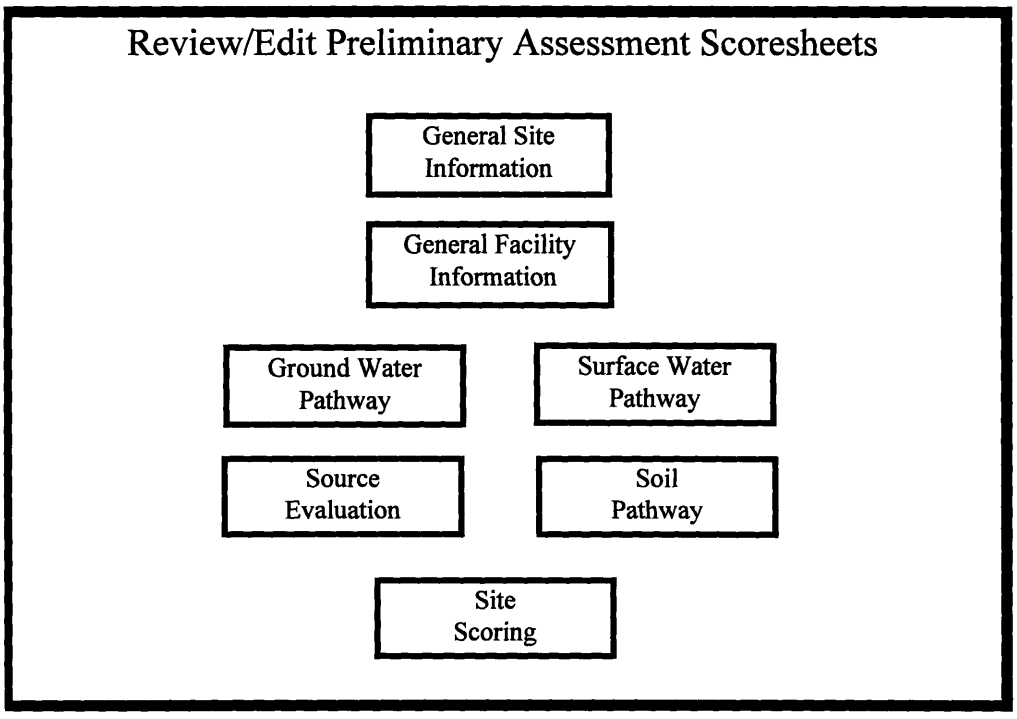
Any number of commercially available relational databases can be used to develop the tables that store the completed PA scoresheets. As more PA scoresheets are completed and entered into the database, the more information will be available for site comparisons and support of completion of other PA scoresheets. The best way to populate the database is to provide a direct connection between the proposed information system that will allow storage of user input provided over the Internet The ease of accomplishing this task will depend on development of current and new technologies. For example, both Microsoft Access '97 and

Oracle provide interfaces to allow connection to their databases through the Internet, but they are limited by how flexible they allow manipulation of the databases and are difficult to set up.

I.3 Database Queries and Comparison Criteria

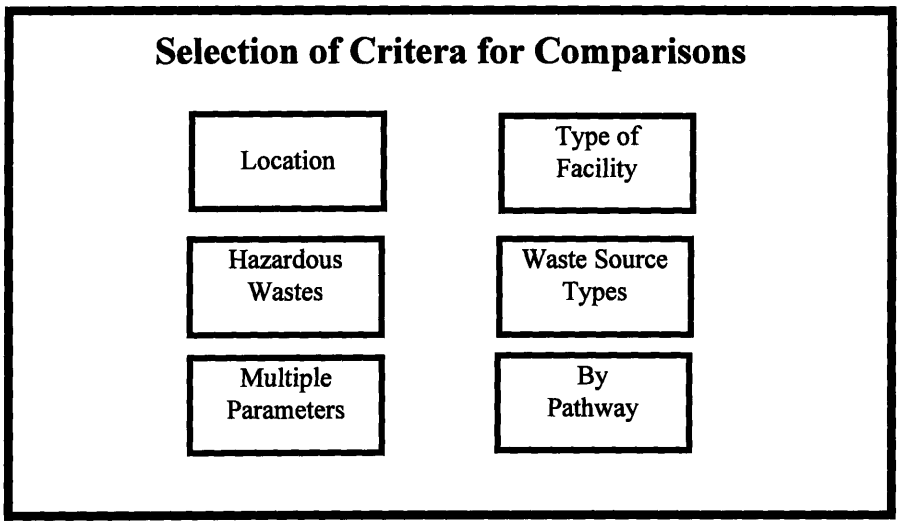
The database should be designed with particular queries or retrieval of information from the interactive database. At a minimum, the database should allow easy viewing of the various sections of the PA sections. These include General Site Information, General Facility Information, Source Evaluation, Ground Water Pathway, Surface Water Pathway, Air Pathway, Soil Pathway, and Scoring. The user should be able to select a facility and site and then be able to view any of the mentioned sections. Figure I.3a shows a sample screen of buttons showing the choices available for viewing the various sections of the PA scoresheet.

Figure I.3a Preliminary Assessment Scoresheet Sections



The real benefit of the database will be derived from the ability to perform comparisons between sites based on specific criteria such as geographic location, types of hazardous wastes, type of facility or operations, and types of waste sources. Figure I.3b shows a sample of choices available for making site comparisons.

Figure I.3b Criteria for Comparisons



The most flexible option will be the selection of any type and number of parameters for performing site comparisons. For example, sites could be ranked by both geographic location and the type or number of similar hazardous wastes. An additional option of comparing sites by individual sections (ground water, surface water, air, and soil pathways) will allow ranking of sites based on answers within these sections of the PA.

I.4 Using the System

To illustrate how the interactive database would be utilized, consider the case where the geographic location is used as a parameter for comparison of sites. A geographic location specified by latitude and longitude coordinates would first be entered. A query would then be run

outputting a listing of sites ranked by proximity to the specified geographic location. Alternatively, the user could select to first choose the geographical location of a particular site. The resulting query would return a specific number of sites ranked by proximity to the chosen site. The use of the type of facility or operations, types and sources of wastes will be used in similar fashion. The user explicitly inputs a value, which the sites are ranked or the user selects a site in which to compare. In the case where comparisons are based on individual sections of the PA scoresheet such as the ground water pathway or surface water pathway, a completed or partially completed PA will have to be selected first as the basis for the comparison. The result of all of these queries will be a listing the most similar PA scoresheets. The user will then be able to select any of the sites returned by the query and view the contents of the completed PA.

I.5 Making Use of the Results

If a facility is located very near some other site or has been contaminated by the same hazardous substances or is similar in some other way to other sites, then the user may find it useful to peruse the information that was used to fill out the completed scoresheets of previous sites. The most useful information may be found in the "memo" sections found in each of the major sections of the PA scoresheet. These sections which give further explanation as to the rationale behind answering some of the questions may cause whomever is responsible for completing the current PA scoresheet to think of some factors that are not explicitly covered by the PA scoresheet questions. Additionally, where sites share particular characteristics, the scoresheets can be compared to see if the data is reasonable. For example, if two sites were located very near each other, it would be expected that the population distribution recorded in both scoresheets would be similar as well.