

# **SOLVING CONTAMINATED SITE PROBLEMS COST-EFFECTIVELY: PLAN, USE GEOGRAPHICAL INFORMATION SYSTEMS (GIS) AND EXECUTE**

**Contaminated sites remediation, data analysis and planning, web-enabled GIS.**

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*(1) Ian Webster, I.W., is the author we refer to in the paper when mentioning "...the author's company".*

## **SUMMARY**

**This article describes a different and highly effective method for companies to solve complex environmental problems. These problems involve not just engineering and construction but, more importantly, negotiating with government agencies, communicating with the stakeholders (including local city governments and communities), and developing environmental solutions, all this while not compromising on strategic and financial objectives. But, environmental projects are quite often associated with vast amounts of data and a myriad of regulatory standards. Navigation through this information jungle requires planning.**

**We believe that the combination of a hypothesis-based solutions approach coupled with an extensive use of GIS data analysis achieves the above by:**

- **Maximal, cost-effective use of information**
- **Identification of data gaps**
- **Development of a detailed roadmap on how to comprehensively solve the environmental problem**

**This article describes the approach and demonstrates the methodology with project examples.**

## INTRODUCTION

In business consulting, techniques applied for identification of a solution to a business problem could be classified into two main categories: those that utilize a deductive approach and the few<sup>(2)</sup> that use a hypothesis-driven approach.

As the name implies, a deductive approach involves collecting data and facts related to the problem and/or facts and frameworks that were relevant to other, yet similar, problems. The aim is to gather as much information as feasible within the allocated budget, in order to facilitate the development of a solution.

In contrast the hypothesis driven approach involves dissecting a problem into its key components (with, for example, the use of a decision-tree analysis) and the leveraging of a minimal amount of data and facts to formulate a conceptual solution to the problem; this becomes the hypothesis against which all succeeding efforts are benchmarked. This approach has proven to be cost-effective for a project sponsor, especially when a project solution involves multiple stakeholders who are required to view the problem solving process from different perspectives, and provide input. The probability that the stakeholders will become aligned is enhanced if there is an evolving tangible vision of the project solution that the stakeholders can carry in their mind's eye. The project hypothesis becomes these "project handles" on which they will rely for decision making. This paper discusses techniques and tools that the author's company has used to generate project hypotheses.

In environmental engineering consulting, complex projects are typically plagued by the generation of a vast amount of data. Most engineering and construction projects involve multi-parties, with stakeholders often located in geographically distant areas, and a myriad of regulatory issues to be overcome. The individuals responsible for the review and understanding of the information may also have technical and non-technical backgrounds. It is also common for decisions to be made by a committee. Complex project concepts and technical information may need to be presented to lay audiences.

It is common practice for data to be presented in descriptive reports, tables of data or simplified graphs. This results in ineffective communication and disagreements in understanding, hence hindering the effective decision-making process, all of which costs the project sponsor, time and money.

With the use of state-of-the-art tools to store, analyze and visualize environmental information, the environmental project management consultant is now able to effectively communicate with project members of different backgrounds and expertise, such as geologists, hydrologists, engineers, computer programmers, regulatory entities and clients who may be less familiar with the technical, engineering and regulatory aspects of the project. *Visualization* can play a key role in effective communication, understanding and facilitating decision-making for

complex environmental projects. Software used for the storage, analysis and visualization of environmental data include Geographical Information System (GIS) software and an Environmental Visualization System (EVS).

In the following paper, we describe how the author's firm uses GIS techniques can be utilized to generate visual project solutions. The initial project visuals produce an early project hypothesis, which can be modified as new project information becomes available.

## **DISCUSSION**

### **THE TYPICAL SITUATION FACED BY AN ENVIRONMENTAL CONSULTANT**

Environmental problems are most often characterized by:

- Large quantities of data;
- Numerous stakeholders, with a range of expertise, involved in the review and decision-making process
- Extensive effort devoted to the analysis and modeling of the environmental conditions, and,
- Numerous regulatory negotiations with government authorities.

The output of detailed investigations and efforts are generally presented in the form of text, numerical tables or simplified graphs, which rather than simplifying the information transfer process, may actually complicate it. In worst-case scenarios with environmental projects, poor data communication between stakeholders can lead to distrust.

Clients, who face an environmental problem affecting their business, typically seek the advice of an environmental consultant to help them devise a solution. The consulting work must be performed efficiently, both assessing and minimizing the risks involved. The consultant is expected to successfully manage the project, facilitate negotiations with regulatory bodies, navigate with familiarity through the myriad of constraints and formulate a satisfactory solution. When communicating the situation and the possible options available for remediation to the client and other stakeholders, the consultant must be clear, concise and compelling in providing solutions.

## THE HYPOTHESIS-DRIVEN VISUALIZATION APPROACH

The problem solving approach described in this article has been developed and used within the author's company in the USA. The method involves three elements that work synergistically.

The first element is the extensive use of the internet and a web-based project management tool. The second element involves the tools used to analyze the client's problem and generate a visually oriented solution. A third element is the problem-solving culture of the consultant, which can be either deductive or hypothesis-driven.

### 1) Web-enabled project management:

Along all stages of the consulting process and particularly at the level of project management, web-enabled management tools are extremely effective for improved communication, resulting in time and cost savings, which generate project momentum. Such a web-based tool was devised and is currently operated by the author's company to serve three major purposes: data storage, information management, and has information search functionalities. It is designed to assist clients, contractors and project managers and is accessible 24 hours a day, 7days a week, allowing the client to be constantly updated on the progress of the project, irrespective of their geographic location. The key features of the site are:

- The client can access and be updated on projects regularly
- All data, information is systematically stored
- Online project bidding and procurement can be conducted.

### 2) Information and project visualization techniques:

The techniques used by the author's company include a Geographical Information System (GIS) and visualization tools such as Environmental Visualization System (EVS). GIS is a powerful technique for environmental data storage and analysis. The results of data input are available in interactive 3D images and scenarios. A varied collection of numerical and other digital information (e.g. aerial photographs) can be viewed simultaneously on the same image. Three-dimensional (3D) modeling, and analysis via GIS help the consultant unlock technical visualization problems and identify spatial data trends quickly and efficiently. This can be imperative as the majority of environmental projects involve data collection at different geographical locations over various timeframes. Visualization of an environmental project's data and information, guides the development of the solution's hypothesis, and the formulation of a remedial solution. Such tools can also ease the calculation of cleanup costs (via the rapid computation of, for example, impacted masses of soils, and volumes). Transforming the normal presentation of extensive environmental data from tabular form into three-dimensional visuals can provide an effective means for communicating and promoting an understanding of complicated environmental projects to clients and regulatory bodies. Moreover, clear, concise graphical communication of proposed solutions maximises the effectiveness of regulatory negotiations, translating into time and cost savings.

In fact, whether the individual(s) who require(s) to understand the environmental information is an environmental engineer, a geologist, the public, a CEO, or a regulatory body, the use of GIS and visualization tools permit better decision-making and eventual project execution and provides an invaluable method to present environmental, spatially referenced data.

### 3) Hypothesis-driven problem solving culture

While providing strategic consulting services, the environmental consultant can use a hypothesis-driven approach to solve a challenging technical or regulatory problem. Figure 1 illustrates the concept. The approach involves breaking the site remediation situation (both technical and business issues) into six discrete elements. These elements include:

- Analysis of business drivers
- Technical analysis of the site remediation problem
- Presenting the solution to all stakeholders
- Managing all facets of the problem from concept to construction
- Implementation of the site remedy
- Providing leadership and project momentum on behalf of the client(s)

In this paper, we will only discuss the central triangle of the environmental consulting process.

**Analyzing** - once a business has identified an environmental problem that could produce regulatory or compliance concerns, it can seek a solution using the hypothesis driven approach. First, the problem is framed. Data gaps that hinder the clear formulation of a site hypothesis are identified; a field program is then planned and put into operation that would collect the missing critical data. The final stage involves the interpretation of the results, the formulation of the “site hypothesis (SH)” and, the necessary reporting. It is important to be more definitive about the form of the SH: In our company, we always attempt to condense the site raw data into 3D explanation schematics that will detail, for example, the vertical and lateral extent of contamination, groundwater flow directions and the locations of any potential receptors. Additionally, conceptual solutions to the environmental problem can be graphically developed and “electronically draped” over the SH. In one package, then, we have the environmental problem and a series of possible solutions.

**Presenting** – When a SH has been developed with conceptual solutions, they can now be presented to project stakeholders. As you will see further on in the text, electronic presentation is best, especially if the conceptual remedies are going to be placed over the SH.

**Managing** – To succeed in promoting a hypothesis-driven, fact based problem solving approach, the continual management of all stakeholders is required. It is important that the client delegates enough project responsibility

and negotiating latitude to the environmental consultant to permit this to happen. Excessively tight control by the client on a seasoned consulting team can actually be, in the long run, detrimental to the project.

## **THE COMBINED USE OF WEB-BASED PROJECT MANAGEMENT, AND DATA VISUALISATION TOOLS WITH A HYPOTHESIS-DRIVEN PROBLEM-SOLVING APPROACH.**

Figure 2 illustrates the foundations of using analysis and visualization tools combined with the hypothesis-driven approach to solve an environmental problem. The method involves a systematic approach to framing the problem, gathering data and facts required for the analysis and, proposing a *visual* solution. It is important that the early data gathering and interpretation is not excessive and does not become a major project event in itself...the goal is to generate a crude early version of the SH for project stakeholders to critique as quickly as possible.

The process followed by the environmental consultant is iterative, as illustrated in Figure 3.

The problem is reduced to its essential components. A decision tree analysis can be useful at this stage and accounts both for what is known, and conversely, unknown.

The data is visualized by converting it into a 3D schematized format, which permits the team to discuss and develop an initial solution.

Also at this stage, further analysis and data gathering may be required to prove or disprove the hypothesis. The key drivers are identified: that is to say, which data variables are driving project cost and schedule? For example, it may be the extent of benzene impacts in the subsurface soils, or the methane generation rates at a municipal landfill. If the project driver variable(s) can be controlled, then one has a potential remediation solution and a methodology of determining project costs.

In the event that a SH cannot be formulated, the use of GIS and visuals can still assist the project team to analyze the environmental problem. By assessing risks, defining engineering and construction constraints, considering the client's needs and the regulatory requirements, the consultant can prepare an initial set of solutions and a remediation side-by-side alternatives analysis can be conducted to assess the feasibility of each possible solution.

New data will only be collected after the first SH has been developed. The SH guides the identification of data gaps and where, how, and if it is necessary for these to be filled. After new data is collected, it is again tested against the original SH, thereby adjusting and improving the hypothesis. However, in the incorporation of new information into the SH, the 80/20 rule is employed<sup>(3)</sup>. Early in the task, absolute precision is not essential and this

rule is vital to making cost-effective decisions. Using storage, analysis and visualization tools, creation of images for the environmental process under scrutiny will facilitate interpretation of information, the approval or dismissal of an initial hypothesis and the subsequent postulation of a remedy that meets the client's business necessities and the expectations formulated by the regulatory authorities. The consultant's role is therefore to produce an initial SH and then via selective further data collection prove or disprove the initial hypothesis. With the use of visuals, the evolving SH can be communicated in an understandable way to the clients and project stakeholders.

By deriving the SH, using the 80/20 rule, at the outset of a remediation project, the project team has a visual technical benchmark against which to compare all future findings or proposed solutions. The SH is a great tool to use at project team meetings to facilitate dialogue between the different disciplines, which staff environmental projects (engineers, lawyers, biologists, public relations specialists).

The final stage in the problem solving process involves presenting the data findings and proposed remediation solutions to the client and, perhaps, regulatory bodies. The use of GIS techniques and visualization tools enables the audience to assimilate the information much faster and more efficiently, easing negotiations, promoting improved communication and decision-making. The clients' goals are typically attained more quickly, when project stakeholders understand through project visualization techniques, rather than being confused with mountains of data.

In addition to ease of understanding and better decision-making, the use of analysis and visualization techniques will promote project "buy-in" at those critical project stages where it is necessary to maximize the chances that the stakeholders will accept your recommendations<sup>(4)</sup>. Utilization of web-based project management tools can add value. Web sites can be used to securely store information for clients and to provide an open location where stakeholders can be updated on project progress. Additionally, the sites can be utilized by the client for bidding purposes in an attempt to procure project services at best-price. A web site is a prime location to place the aforementioned SH for review and input by project stakeholders. Stakeholders' input can be managed successfully via a web site, and the impersonality of the technique removed via selective communications.

We now consider the third peak of the triangle, that of project management: here too the use of information and project visualization tools can be invaluable. The management of a multidisciplinary team working on an environmental project extends beyond the walls of the project manager's and environmental consultants' offices. Involved parties include engineering companies, commodity service providers (e.g. analytical laboratories or drilling contractors), government environmental agencies, and city and local governments. The environmental project manager can increase his/her efficiency by possessing the best possible tools to maintain the flow of information. The result is the creation of a project lifetime list of opportunities to save time and cost.

To further illustrate the above notes, two case studies, each of which employed visualization techniques and the derivation of an early SH, are described in the following section. The projects' early available data was converted into visuals using GIS and EVS tools; this initial stage then helped in the formulation of a SH to help understand the environmental problem. The case studies described below are projects the author's firm is managing in the USA. The two projects are Superfund Sites<sup>(5)</sup>, a classification that typically means that the remediation project is technically large and complex, and may be burdened with political obstacles.

## **CASE STUDY 1**

Figures 4 to 6 refer to the Ascon Site, in Huntington Beach (California, USA). The site was a waste disposal facility for oil field related waste from the 1930s to the 1980s. The consultant's involvement with the project began in 2001. At the initiation of the project, the previous data consisted of a 20,000 member database provided by the California Department of Toxic Substances Control. Previous data had been collected by a series of consultants throughout the mid 1980s, and was poorly structured and had not been spatially analysed. Our goal was to extract maximal value from the previous data (Figure 4), before considering any supplemental data collection efforts. The data was inserted into a GIS interactive electronic site database and the spatially referenced data was visualized three dimensionally.

As shown in Figure 5, the information logged from borings was transformed into an electronic format suitable for analysis and visualisation using tools such as ArcView GIS<sup>(6)</sup> and EVS. Such information included the thicknesses of waste, fill and impacted soils, and the concentrations of organics and inorganics in the different layers. By using EVS, volumes can be calculated. Using GIS, historical aerial photographs can be imported. Past images were layered over today's data findings, thereby helping to reconcile current activities with historical disposal practices on the property.

Information on the analysis of the soil at the site (Figure 6) consisted of 15,000 data points collected from 125 soil sampling locations. The data was reorganized to geographically delineate data gaps in two and three dimensions. In addition, all off-site data was imported into a GIS format for storage, easy retrieval and analysis, including air monitoring data and community odors complaints.

The visualisation of the above information accelerated the process of framing the problem for the client, and developing a SH. By using visualised data, rather than data tables or graphs, focus can be maintained on deriving solutions for not only an engineering, scientific and construction problem, but also, for what has become a regulatory and community issue.

## **CASE STUDY 2**

Figure 7 shows the Waste Disposal Inc. (WDI) Superfund site, located in Santa Fe Springs near Los Angeles (California, USA). Consistent with the Ascon site, the WDI site was also a former waste disposal facility. The information provided to this consultant was populated by more than 80,000 data points. In fact, from as early as 1988, the US Environmental Protection Agency (EPA) began collecting data related to the site in order to assess the site's health risks. In 1994, a group of oil company stakeholders involved with the site formed a "Potential Responsible Parties" (PRP) group and began collecting additional facts under an administrative order issued by the EPA. As a result, until 1998, two data-bases existed that resulted in disagreements on how the site should be characterized. These disagreements were impeding conceptual design discussions between EPA and the PRPs, in that a remedy could not be formulated that satisfied both data bases. (We previously discussed the need to identify project drivers and in this case the project's progress was being held hostage to the existence of competing data bases).

A solution to the EPA-PRP impasse occurred when all information was organized to identify valid data and data gaps. The information was assembled into an Access database, thereby permitting analysis via GIS. By depicting the information in three dimensional space, a SH was formulated. The SH provided both parties with a working model of site environmental conditions. At every meeting between the EPA and the PRPs, the GIS system was available so that data "what-ifs?" could be answered in real time and not stall progress towards an agreement. Presently, the project is rapidly progressing with a remedy poised to be constructed that can contain and solve the site's environmental problems, and simultaneously e permits development of the 40 acre parcel of valuable land.

## **CONCLUSION**

The management of complex environmental and regulatory issues requires that one deals with vast amounts of data and information. Creating solutions to environmental problems can also involve the affected public as stakeholders. The consultant must be skilled in providing a solution to the client's problem from not only a scientific, engineering and construction perspective, but must also be able to negotiate the solution with regulatory bodies and the public, so that the most cost-effective solution results.

In the development of a remedial solution, an approach that involves extensive use of GIS and visualization tools combined with the use of a derived Site Hypothesis has proven to be successful at the author's organization. This is especially valid regarding complex projects with multiple stakeholders and millions of pounds at stake.

## **ABBREVIATIONS**

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (a.k.a Superfund)
DTSC	(California) Department of Toxic Substances Control
EVS	Environmental Visualization System

<b>GIS</b>	<b>Geographical Information System</b>
<b>NPL</b>	<b>National Priorities List</b>
<b>PRP</b>	<b>Potentially Responsible Parties</b>
<b>QA/QC</b>	<b>Quality Assurance/Quality Control</b>
<b>RI</b>	<b>Remedial Investigation</b>
<b>SH</b>	<b>Site Hypothesis</b>
<b>2D</b>	<b>Two dimensional</b>
<b>3D</b>	<b>Three dimensional</b>

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## **NOTES**

**(2) Including the approach used by the business strategy consulting firm McKinsey.**

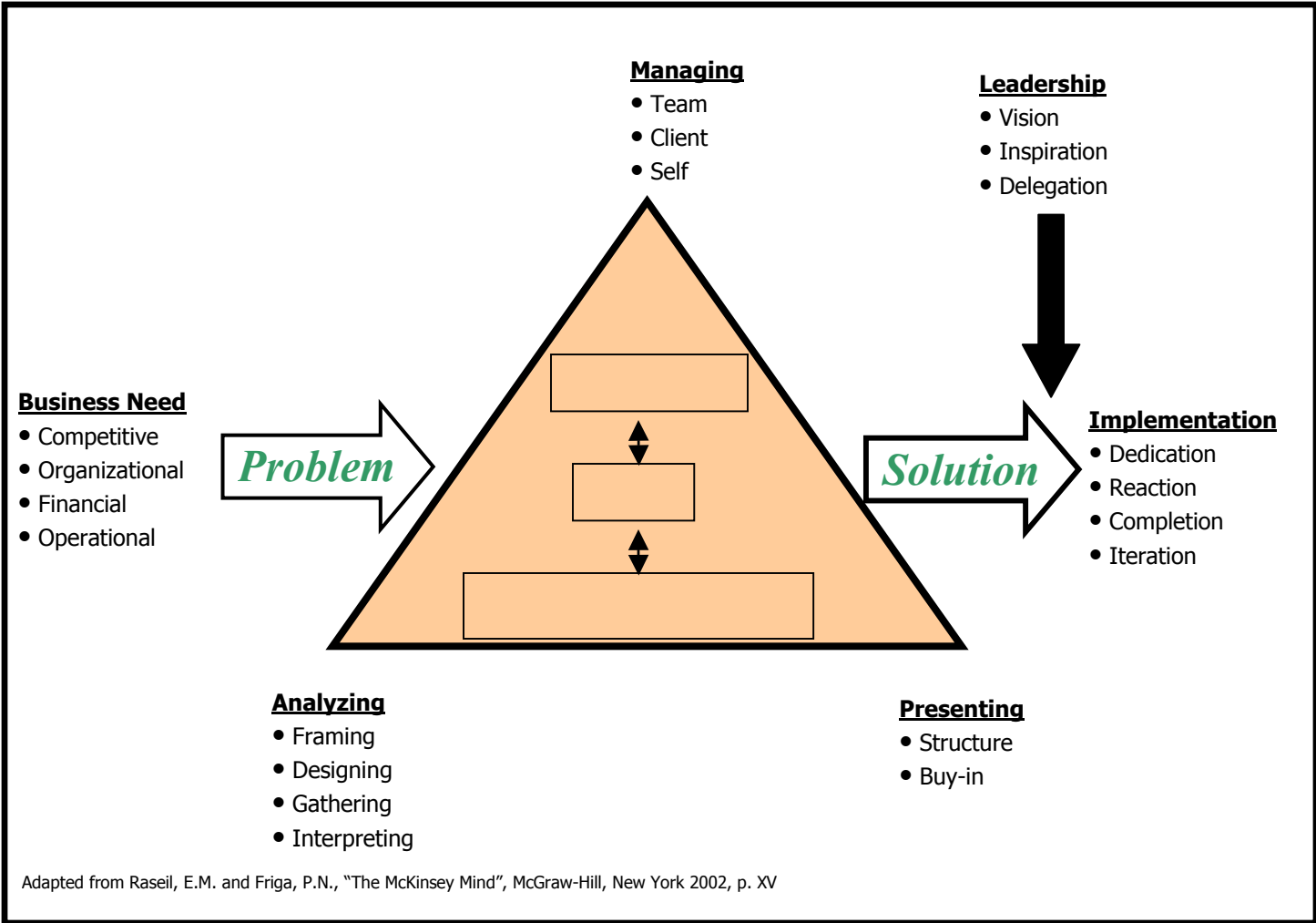
**(3) This rule is one of the great truths of the business world. Formulated by the economist Vilfredo Pareto, it is of a “rule of thumb”, which says that 80% of an effect under study is generated by 20% of the elements accounted for as being responsible.**

**(4) Project buy-in, attained using project visualization techniques can be especially important in projects where there are formal public comment periods, or there are threats of litigation. Environmental Impact Studies are especially prone to delay. Case in point, is the long sought approval by Arsenal F.C. to build a new football stadium in the Highbury area of London. The EIS process, which involved considerable public input, could have been facilitated by “project visualization.”**

**(5) See [www.epa.gov/superfund](http://www.epa.gov/superfund)**

**(6) Commercially available software was used; see [www.esri.com](http://www.esri.com)**

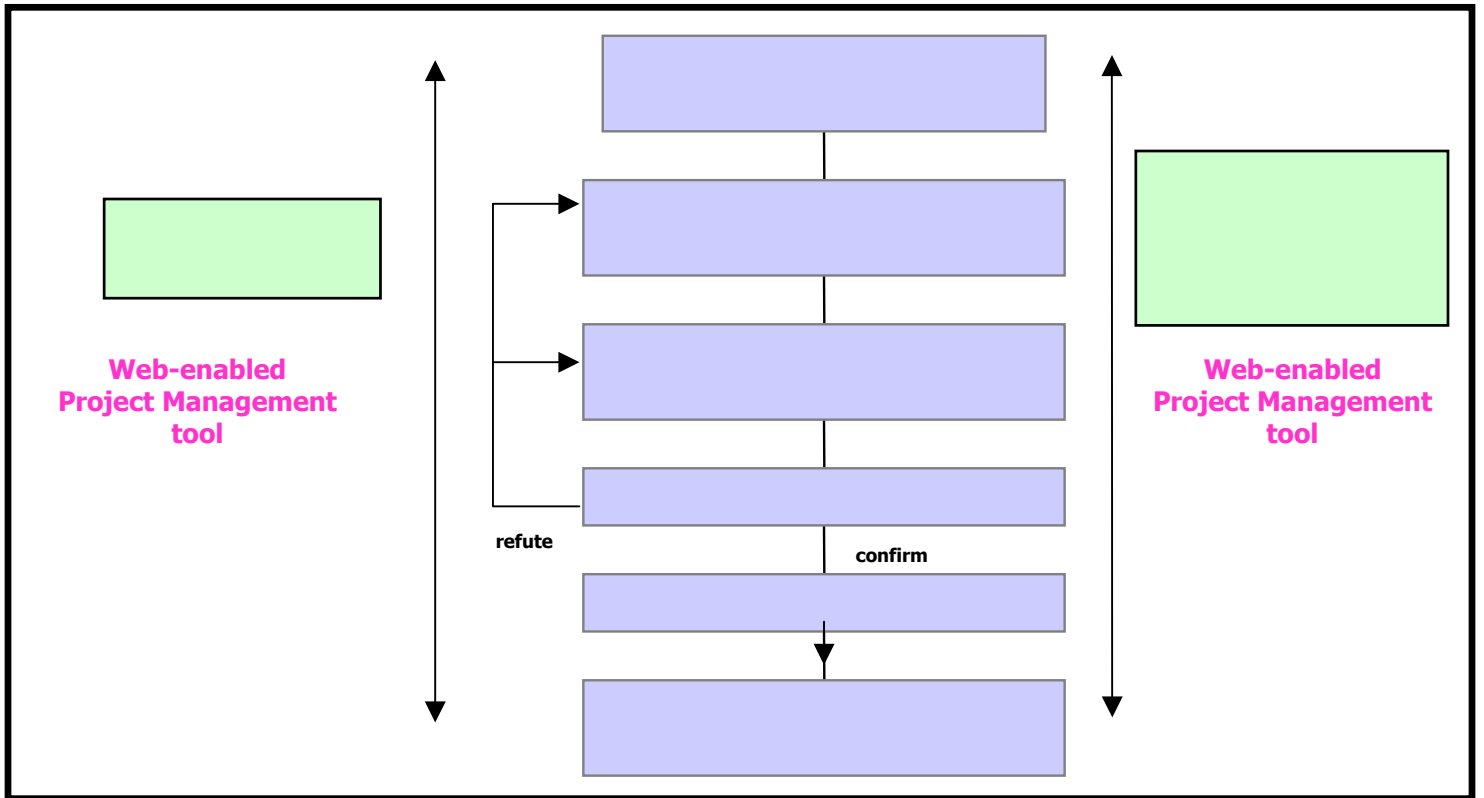
**Figure 1: Hypothesis-Driven Problem Solving Approach**



**Fig 2: Hypothesis-Driven Problem Solving Approach Used in Conjunction with GIS**

- 1. Frame problem, and manage both knowns and unknowns combining intuition, experience and available facts**
- 2. Make maximum use of minimal data and available facts**
- 3. Use 3D GIS data visualization techniques to present information**
- 4. Identify key project drivers and look at the big picture**
- 5. Establish an early Site Hypothesis**
- 6. Define data gaps and carefully collect data to fill gaps**
- 7 Resist getting lost in the data ... that costs time and money**
- 8. Employ 80/20 rule, and make decisions**
- 9. Do not seek absolute precision, early in the task**
- 10. Rank findings against Site Hypothesis and modify, as required**
- 11. Use clear visuals to promote project understanding, and facilitate decision-making**

**Fig 3: The Site Hypothesis (SH) Problem Solving Method**

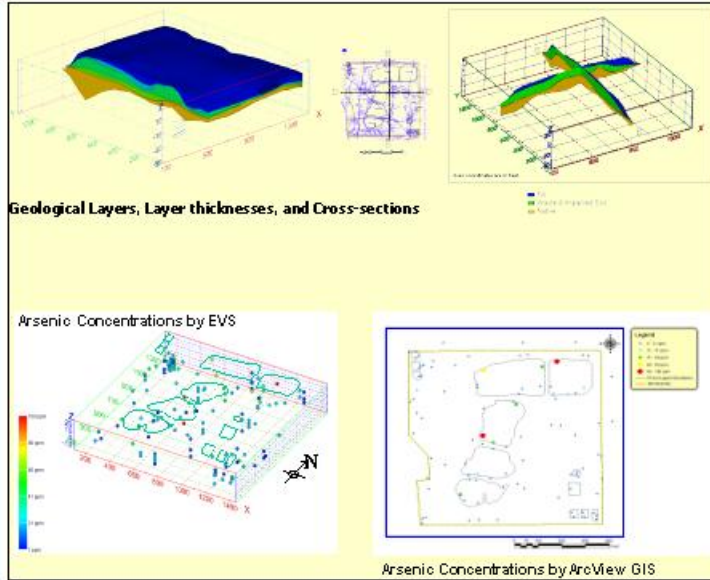


**Fig 4: Ascon Site, Huntington Beach, CA  
Site Visualization Outputs**

**Input Data Condition**

- 20,000 member database from DTSC
- Electronic database
- Poorly designed database structure
- No geospatial information was available
- Poorly QA/QC'd

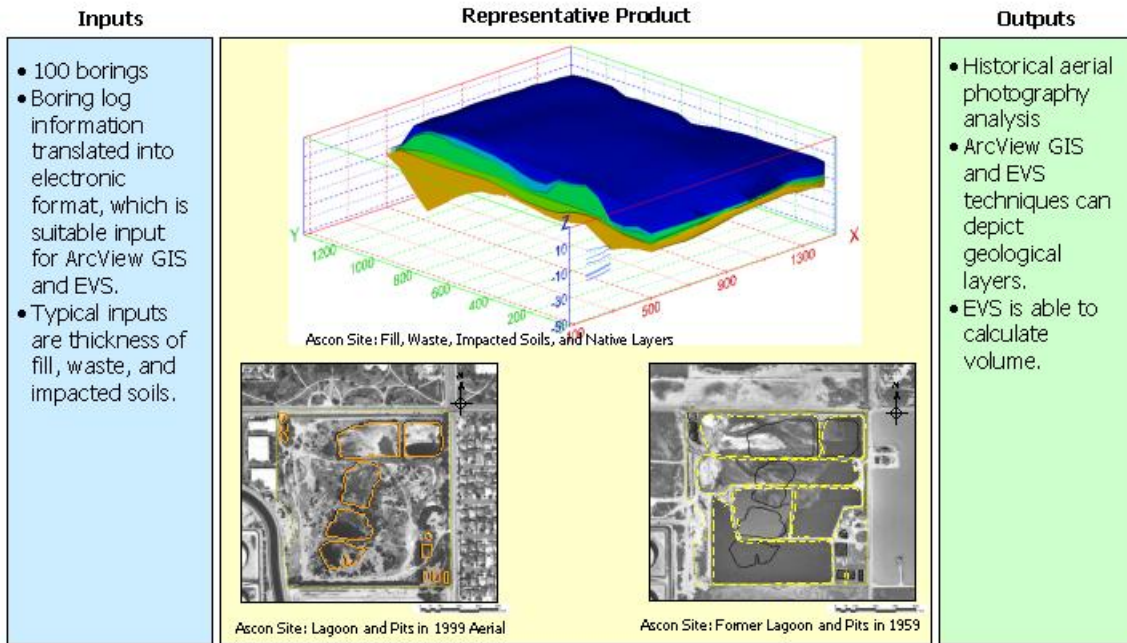
**Representative Product**



**Output**

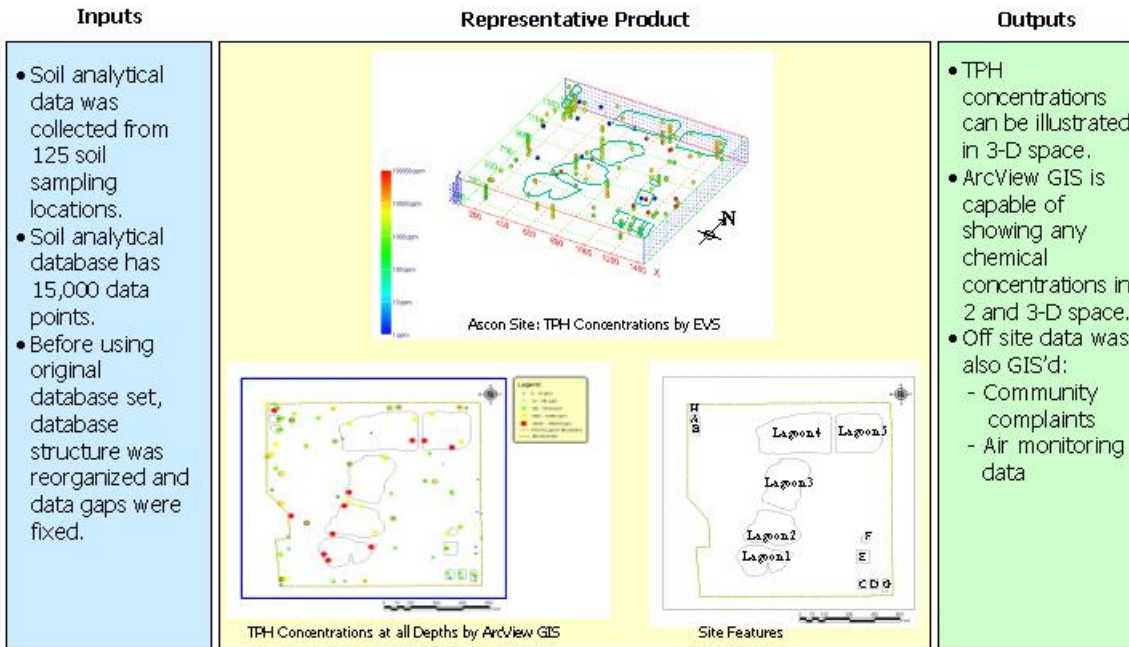
- 2 data entry technicians
- 1 GIS professional
- One month of work
- Product
  - Interactive electronic site database
  - 3D visual data depiction

**Fig 5: Ascon Site, Huntington Beach, CA  
Site Visualization Outputs**



**Figure 5: Ascon Site, Huntington Beach, CA; Representative Output from Data Mining and Analysis**

**Fig 6: Ascon Site, Huntington Beach, CA  
Site Visualization Outputs**



**Figure 7: Waste Disposal, Inc. Superfund Site, Santa Fe Springs, CA;  
Visualization Outputs**

