INFORMATION TECHNOLOGY TOOLS
FOR ESTIMATING COSTS OF SURFACE MINING RECLAMATION[1]

by

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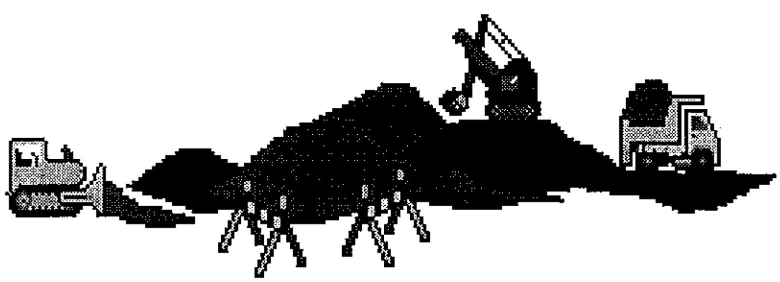
Abstract. There are thousands of operating and abandoned surface mining sites in the US. These sites, which include metal, industrial mineral, and coal mining operations, are in various stages of operation and closure. Abandoned mines, waste dumps and tailings piles, if left unreclaimed, can result in sediment runoff or acid mine drainage, which degrades stream and river water quality, hampers recreation, destroys fish and fisheries, and taints water supplies. Leachate from these mines can contaminate groundwater supplies with heavy metals, acidity or alkalinity, or radionuclides. Mine owners and operators, as well as regulatory agencies, need to be able to budget and schedule construction, operations and closure in order to avoid potential environmental damage. In addition, once impacts have occurred, a tool is needed to develop budgetary costs for reclamation and cleanup of those abandoned sites. Program and detailed budgets can be developed quickly and accurately using Parametric-based automated cost estimating software programs. PROSPECTOR™ (Pit Reclamation Engineering Cost Tool) is a tool that can be used to accurately forecast mine reclamation costs. In addition to quantitative computer-based cost estimating, mining operations can benefit from qualitative estimating tools by using decision support and uncertainty estimating software such as Expert Choice, DPL (Decision Programming Language), and Crystal Ball. These tools are beneficial in the decision-making process when life cycle cost estimates are similar and there is a fine line between alternatives. Issues such as uncertainty, environmental constraints, regulatory requirements, community acceptance, and safety requirements may tip the balance toward one option over another. This paper focuses on cost estimating tools and qualitative decision-support tools which can be used in hard rock and industrial mineral mine reclamation and cleanup. Discussion will be provided on tools that can be used to develop budgets and detailed estimates. Mining reclamation examples using these tools will also be discussed. A subset of the presentation will include a discussion on Parametric cost estimating and the PROSPECTOR™ model.

Additional Key Words: Information Technology, Costing, Parametrics, Decision-Support Tools, PROSPECTOR, Reclamation



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Environmental Requirements Background

In order to understand the socioeconomic and cultural implications of surface mining reclamation and the value of the tools that have evolved from other industries to support this field, one must have a general understanding of the current environmental regulations and an historical perspective of the events that led up to the current state-of-the-practice. Today's reclamation project is scrutinized more than ever by the public. This public awareness is an outgrowth of the disasters of our recent times, including: the 1977 Love Canal, New York, chemical disposal incident; the 1979 Three-Mile Island, Pennsylvania, nuclear incident; the 1984 Bhopal, India, Union Carbide toxic gas accident that killed 8,000 people and injured 500,000; and, most recently, the 1986 Chernobyl, Kiev (former USSR) nuclear meltdown that affected Eastern Europe. In a free society where the media reports on an incident within hours of its occurrence, the US citizenry is accustomed to and viscerally aware of the dangers, or at least the perceived dangers of environmental accidents and incidents. The NIMBY (not-in-my-backyard) syndrome which has evolved from our fears of potential environmental catastrophe, not only affects siting of new facilities, but equally affects the remedy of an existing environmental problem.

In addition to public awareness, Congress has strengthened federal environmental regulations and the authority of the US Environmental Protection Agency (USEPA) over the last twenty years. As the nation as a whole becomes more aware of environmental issues, owners of facilities requiring corrective actions are relying more heavily on multi-disciplined teams of experts to develop defensible cleanup remedies and to inform the local community on proposed alternatives in terms that residents can understand.

Surface mining reclamation and cleanup, like other types of remediation, is a field that requires the input of a diverse, and well educated, experience-based project team. Teams of experts representing toxicology, hydrogeology, chemistry, remediation technology evaluation, mining engineering, cost engineering, and the legal profession are now more commonplace than they were in the 1970s and 1980s. This type of compact, yet talented, group can provide detailed recommendations for sites that can then be evaluated by the USEPA and other state and federal regulators. Depending upon the site's operational permits, ownership status, and magnitude of the problem, the cleanup of the site will typically be either regulated under Resource Conservation and Recovery Act (RCRA) of 1976, amended in 1984 or Comprehensive Environmental Response Compensation Liability Act (CERCLA) of 1980, amended in 1986. Other federal acts may also apply depending upon the form of the waste and toxicity. If the site is not deemed contaminated, but requires filling and regrading, then state, county and local requirements prevail. However, if the site is deemed to have imminent and immediate health and safety effects on the community, then the owner can begin a response action to limit the effects. Otherwise, the owner must investigate the site, develop a report, and work with the USEPA, and State Regulators to develop a remedy for the site for which the owner is bound by law to initiate and complete. Regardless of the Regulatory Act, the steps taken to develop a Record of Decision (CERCLA-ROD) or Decision Document (RCRA-DD) are similar. Under the CERCLA statute, the Remedial Investigation/Feasibility Study (RI/FS) team conducts the investigation and under the RCRA statute the RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) team conducts the investigation. These two groups are staffed with similar personnel.

The owner and his investigation team must develop a list of treatment options that will be effective in addressing the environmental contamination. Once the list is developed, it must then be technically screened for a number of criteria. The National Contingency Plan (NCP) sets forth nine criteria to be evaluated for each potential remedy on the list. The nine criteria are subdivided into three major categories: Threshold Criteria, Primary Balancing Criteria, and Modifying Criteria. Each technology option must be evaluated against these criteria. The technology option must meet the Threshold Criteria before it is evaluated further. If it does not meet the Threshold Criteria, that technology is removed from consideration as a viable option for the site. The categories and criteria are listed below in their order of evaluation (Sullivan 1995).

1. Threshold Criteria
   - Overall Protection of Human Health and the Environment
   - Compliance with Applicable or Relevant and Appropriate Requirements (ARAR's)

2. Primary Balancing Criteria
   - Long-Term Effectiveness and Permanence
   - Reduction of Toxicity, Mobility, or Volume Through Treatment
   - Short-Term Effectiveness

- Impementability, and
- Cost

3. Modifying Criteria.
    - State Acceptance
    - Community Acceptance

CERCLA Section 121 states that the following are ARAR's for the hazardous substance, pollutant, or contaminant concerned:

1. Any standard requirement, criteria, or limitation under any federal environmental law; and
2. Any promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law that is more stringent than any federal standard (42 USC).

Software Tools for Reclamation Support

Now that a cursory background of environmental law and environmental history has been provided, the software tools that can assist in the screening process will be discussed.

Remedial Option Selection Software

Early in the RI/FS (RFI/CMS) process, the owner must develop technologies that will clean up the site or contain the waste in order to minimize risk to the public. There are several software tools that can be used to select appropriate remedies based on contaminant, risk to the public and migration pathways. One of these tools is the REOPT software developed by Battelle Pacific Northwest Laboratories (PNL). This software provides a library of technologies and their associated effectiveness versus various chemical contaminants. Other software tools and aids provided by the USEPA include VISITTv6.0 (Vendor Information System for Innovative Treatment Technologies) which provides on-line information about various technologies. The software can be downloaded from the CLU-IN (Hazardous Waste Clean-Up Information) homepage (see literature cited). Another USEPA tool is the Remediation Technology Screening Matrix (contain in the CLU-IN homepage) that provides a screening matrix comparing the technologies to sixteen criteria (nine of which are in the National Contingency Plan). Another USEPA source of information is the REACH IT (Remediation and Characterization Innovative Technologies) Database. This is a source of information on the availability, performance, and cost associated with the application of various remediation technologies. EPA REACH IT is intended to inform Federal, state, and private-sector remediation professionals about their treatment, characterization, and monitoring options and the capabilities of the firms listed in the system's database to provide remediation services. REACH IT is intended to replace the VISITT Database and can be downloaded from the CLU-IN homepage (see literature cited). Another location for finding remediation technology information is the Remedial Information Management System 2000 (RIMS2000) database developed by Remedial Technologies Network, L.L.C., which can be purchased for a fee (Remedialtech 2000).

In summary, the following software tools may prove useful when selecting remedial technologies:

- Remedial Options (REOPT)
- Vendor Information System for Innovative Treatment Technologies (VISITT)
- Remediation and Characterization Innovative Technologies (REACH IT)
- Remediation Technologies Screening Matrix
- Remedial Information Management System (RIMS) 2000

Cost Estimating Tools

Once a selection of the remedial technologies has been selected and pass the CERCLA "Threshold Criteria" screening phase, the next step is to evaluate those technologies versus the five criteria in the CERCLA "Primary Balancing Criteria." The tools listed in the Remedial Option Selection above can be used at this stage of the CERCLA screening process as well. However, there are more sophisticated tools that have been developed specifically for cost estimating purposes. Those options will be discussed herein.

Parametric Cost Estimating.

The cost of a treatment technology can be determined at various stages. Early in the process, an "order of magnitude" estimate is appropriate. This is also called a "100% Concept Estimate" or "Preliminary Estimate" since there may not be any plans or specifications available at this early stage of the project design. This is typically the case for the RI/FS or RFI/CMS stage. Parametric models are ideally tailored to develop these types of cost estimates.

Parametric cost engineering is a computerized, accurate method of developing the "real world" remediation budget for facilities, infrastructure, and materials. The system is based on current materials pricing database and pre-defined engineering relationships that link various parameters to detailed quantities. The predetermined quantities and relationships to size and function are based on actual, detailed materials "take-offs" from prior projects. Nothing is omitted down to the valves, fittings, and bolts. The underlying facts provide the confidence that errors and omissions, common to budget estimating, are avoided during the early design and budgeting process.

By utilizing these pre-developed engineering models, users can actually cost out the remediation of a site by utilizing a computer before design is started. Once the computer solution is generated, a detailed cost budget can then be established based on the specific quantities identified.

In 1991, Delta Research Corporation (Delta) of Niceville, Florida was awarded a contract with the U.S. Air Force to develop a parametric cost estimating tool called the Remedial Action Cost Engineering and Requirements (RACER) system for environmental remediation cost estimating. In the process of developing this system, a multi-agency federal task force was commissioned to review the system as it was developed. Membership consisted of representation from the U.S. Army, U.S. Air Force, U.S. Navy, U.S. Department of the Interior, and U.S. Department of Energy. The Department of the Interior recognized the potential of parametrics and contracted Delta to develop two parametric models specifically tailored for mining reclamation. These models were the Passive Water Treatment and Air Sparged Hydrocyclone (see discussions below). These models along with additional models developed by Delta are currently being incorporated into a package in MS Excel called PROSPECTOR™ shown below in Figure 1.

The MS Excel format is used throughout the U.S. and does not require any special compilers or licenses and can be used universally. BTG Inc., (Delta Research Division) is currently developing additional Excel models (e.g., the Environmental Remediation and Decontamination and Decommissioning of Nuclear Facilities) for the Department of Energy. BTG has also developed ordnance explosive remediation models for the US Army Corps of Engineers (Thurston 1995).

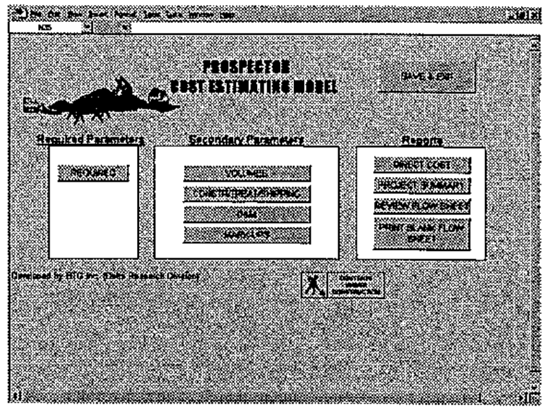

FIGURE 1
PROSPECTOR - MAIN SCREEN

Passive Water Treatment - Model.

Passive water treatment has applications in the remediation of storm water runoff containing organic constituents, metallic ions, and also acidic mine drainage contaminated with heavy metals. Compared to active water treatment methods such as chemical precipitation and neutralization, passive treatment methods generally have lower operations and maintenance (O&M) costs, but require more land area. The Passive Water Treatment model contains five technologies for treating contaminated surface water and the criteria for selecting one of them: storm water filtration, runoff detention ponds, anoxic limestone drains, anaerobic compost wetlands, and aerobic wetlands (RACER 1997).

Air Sparged Hydrocyclone - Model.

An air sparged hydrocyclone (ASH) is a physical separation device which has applications in the recovery of metals/minerals from mine tailings, the removal of fine contaminant particles from soils, and the removal of oil and volatile organic carbon (VOC) compounds from water. ASH technology is patented by the University of Utah and is licensed to several suppliers in the U.S.

The ASH technology is a flotation process. Flotation processes in the mining industry will become more common due to environmental legislation such as the Clean Water Act (CWA), 33 U.S.C. 1251, which serves to limit the amount of contaminants that may be discharged to surface waters in the U.S. In addition, flotation will allow beneficiation of waste mine tailing piles for the recovery of valuable minerals and hazardous components. On federal, state, and private lands, runoff from active and abandoned mines pollutes both groundwater and surface waters with acid mine drainage and heavy metal contamination.

In order to effectively manage contaminated mine water, remediation equipment such as ASH devices will be required by both mine operators and governmental agencies charged with maintaining environmental quality (RACER 1997).

Detailed Cost Estimating.

In addition to parametrics, which is a preliminary and high-level type estimating system, there is a need for more definitive estimates once the ROD or DD is signed and Remedial Design (RD) begins. There are typically four design submittals made by Remedial Design Contractors: conceptual, 30% design, 60% design, and 100% design. The level of accuracy of each estimate should increase as the design documents approach 100%. Parametrics is used for the conceptual design and up to the 30% design, with some editing required. The 60%, and 100% design are typically completed with detailed estimating packages like MCACES (Micro-Computer Aided Cost Estimating System), COSTLINK, or SUCCESS. These are design-based estimating systems with extensive regional and/or national line item databases that can be translated to a specific site using area cost factors (local pricing conversion factors). Quantity take-offs are the primary method of detailed estimating, and are actually an extension on estimated quantities of materials and labor.

MCACES is the US Army supported detailed cost estimating system. It has a supporting database of over 25,000 line items. The line items are updated on an annual to semi-annual basis by the US Army and its subcontractors. COSTLINK is the commercial version of the MCACES system. The SUCCESS system is a detailed line item estimating program supported by the US Navy and commercial industry. It is similar in capabilities to the COSTLINK system.

In summary some of the cost estimating tools available for reclamation include:

- Remedial Action Cost Engineering and Requirements (RACER)
- Pit Reclamation Estimating Tool (PROSPECTOR)
- Micro-Compuer Aided Cost Estimating System (MCACES)
- COSTLINK
- SUCCESS

Decision Support Tools

Decision support tools are important to the RI/FS team because of the final CERCLA screening category, "Modifying Criteria." Once the technologies pass the screening process for effectiveness, cost, and the other "Primary Balancing Criteria" then they must be screened for regulatory and community acceptance. One way to accomplish this prior to presenting the results to the regulators and community is to run through a decision-support logic evaluation. There are three standard, commercial-off-the-shelf (COTS) software packages that can be used for this purpose. Each package has its benefits and drawbacks. A contractor who can use all three effectively, is extremely valuable in strengthening an owner's negotiating ability. The three COTS decision support software tools that are most frequently used are:

- EXPERT CHOICE
- DPL (Decision Programming Language), and
- CRYSTAL BALL.

Examples of output from each product are provided in this section.

Expert Choice.

EXPERT CHOICE is a multiple-criteria decision support software tool that is based on the Analytical Hierarchy Process (AHP) (Expert Choice 1996). The Expert Choice format, an Evaluation and Choice hierarchical model, is comprised of a goal, criteria, and the alternatives identified by the user. Once the decision model is created, Evaluation and Choice guides the user in judging by means of: paired-wise comparisons (comparing each technology against another technology), the relative importance of the criteria, and the preference for the alternatives. The incorporation of paired comparisons of criteria, enables the user to derive quantitative values (or weights) for the criteria and alternatives.

Expert Choice enables decision-makers to efficiently sort out complexity, and assists with reducing the subjectivity that is inherent in many decisions. Evaluation and Choice develops priorities based on the user's experience and intuition (intangibles), and more discrete information such as data (tangibles). By incorporating both subjective judgments and discrete data into the decision-making process, the user is much more likely to arrive at a solution that is satisfactory to the RI/FS team, regulators and public. The input required by the software such as problem structuring, setting priorities, improving evaluations, performing "what-if" sensitivity analyses, and justifying decisions are straightforward processes.

Expert Choice has been used successfully by the U.S. Navy in selecting appropriate off-gas treatment systems for varying site criteria. An example of using Expert Choice to select the appropriate technology for a tailings pile restoration project is provided in Figures 2 and 3. Although the data and relationships provided in the screen captures are not the actual data used on the project, they are good facsimiles of how the tool could be used. The technologies to be screened for this sample site include:

- Capping
- Stabilization in-place
- Dewatering
- Excavation/Transport/Disposal
- Soil Washing, and
- Institutional Controls

The criteria that is used to screen these technologies is listed as follows:

- Effect on Endangered Species
- Length of Time to Cleanup Site
- Time for Environment to Recover
- Present Worth Cost of Each Alternative
- Regulatory Acceptance
- Community Acceptance
- Toxicity of Contaminant of Concern, and
- Risk Assessment Result

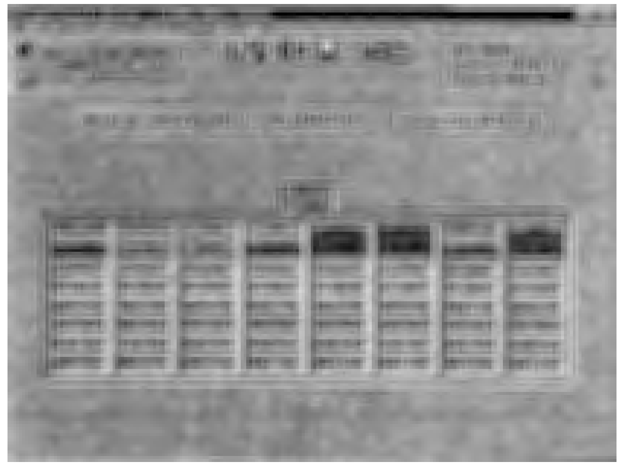

FIGURE 2
EXPERT CHOICE – MAIN SCREEN

Figure 3 shows that, given the weighting of the criteria (Regulatory Acceptance 20%, Community Acceptance 20%, and Risk to the Community 20%), the Excavate/Transport option would be the best choice. Notice that each criterion on the left was assigned a relative importance (percentage). The software then evaluates the rankings of each criterion and then applies the percentage in order to rank the technologies. The user can vary the importance of the criteria and leave the paired evaluation the same. By doing so, the user can develop a variety of data to support his final selection. Excavation is very expensive, so if the cost criterion is given a higher weighting, then one of the other options will most likely be the highest rated technology.

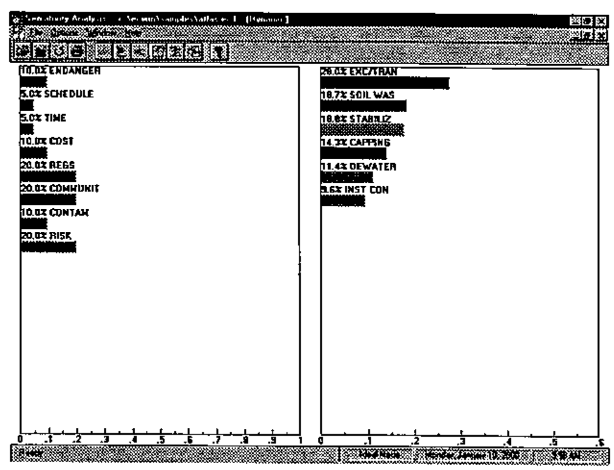

FIGURE 3
EXPERT CHOICE – DYNAMIC
DECISION DIAGRAM

DPL (Decision Programming Language).

This program employs a probabilistic approach using decision programming language (DPL) software (DPL 1997). The system uses both influence diagrams and "decision-trees" to provide the user with the capability to provide multiple analyses. The influence diagram allows the user to change the relationships by redirecting arrows on the screen in order to develop another probabalistic estimate (see Figure 4). Potential cleanup alternatives can be entered with specific dependencies assigned. The decision-tree is based on the relationships in the influence diagram. Work Packets (Technology Contracts) on decision-trees can be costed using a parametric cost estimating tool. Once costed, the cost and probability of occurrence are entered onto the decision-tree. Figure 4 is a sample influence (bubble) diagram.

The arrows in Figure 4 show the decision logic used in the sample. In this particular example the three options are: groundwater pump and treat, constructed wetlands, and installation of reactive zones technology. In some cases these are technologies that can be used concurrently and not exclusively.

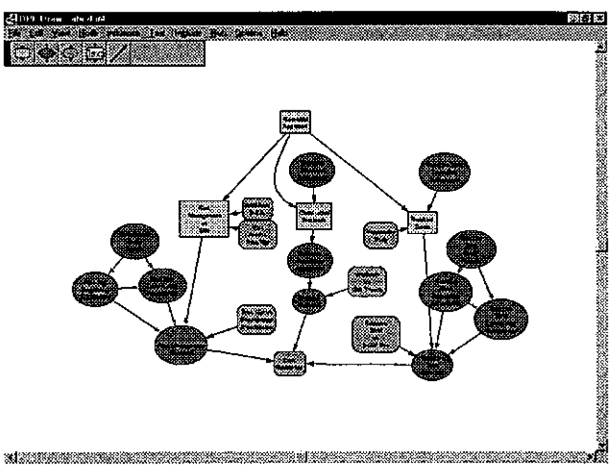

FIGURE 4
DPL – INFLUENCE DIAGRAM

Figure 5 is a sample of the corresponding decision-tree for the sample project. Each decision has a probabilistic factor associated with the action taken. For instance, there may be a 50% chance that the regulators will accept the alternative, but only a 25% chance that the community will accept the solution. Remember the NIMBY syndrome mentioned at the beginning of the paper.

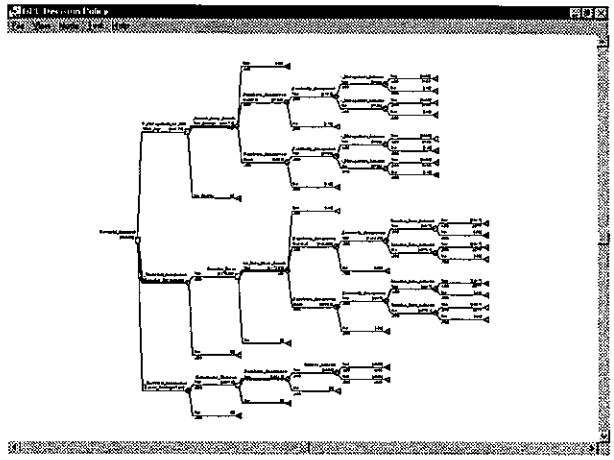

FIGURE 5
DPL - DECISION TREE DIAGRAM

The outcome is a probabilistic estimate. Based on the data entered the most likely cost can be obtained. This is an effective tool to evaluate decisions where regulator and community acceptance is important.

Crystal Ball.

Crystal Ball is a graphically-oriented forecasting and risk analysis program. It is a statistical package that can be used to forecast the most probable event, given a data set. Through the power of simulation, Crystal Ball provides the user an effective decision-making tool. Crystal Ball runs in MS Excel and uses spreadsheet data to develop forecasts using a Monte Carlo statistical simulation. It also provides confidence levels, so that the user can determine the likelihood of a specific event taking place (Crystal Ball 1996). Figure 6 provides a view of the Crystal Ball Probability Diagram. The diagram shows the most likely cost and the level of confidence that a certain value exceeds some threshold percentage specified by the user (e.g., 90%, 95%, etc.). Typically the user must run the Crystal Ball software through 1,000 iterations in order to develop a competent probability curve. This only takes a minute or so using a Pentium-based computer.

An example specific to the surface reclamation industry is the cost of excavation, treatment and disposal of mine tailings. A point estimate can be developed based on a single volume, type of treatment, location of disposal, and disposal fee. However, if the user wants to vary the volume to be excavated, select different treatment options and vary ultimate disposal locations, it becomes a time-consuming proposition on a detailed basis. The solution is to use parametric estimates in coordination with Crystal Ball. A range of costs can be developed along with the probability of the cost falling within a certain range.

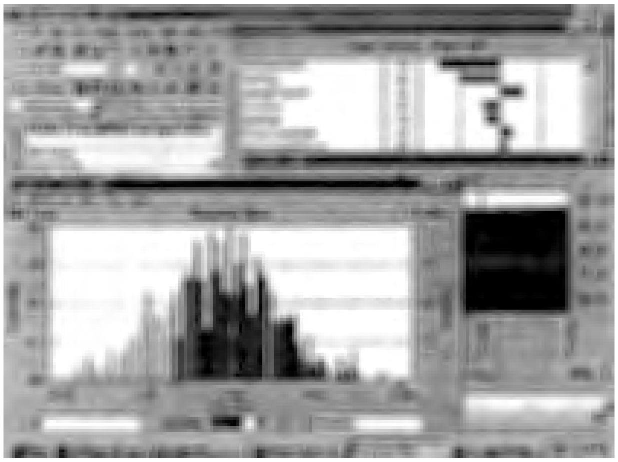

FIGURE 6
CRYSTAL BALL - PROBABILITY
DIAGRAM

Summary

The typical owner can't afford to develop multiple analyses in the conventional quantity take-off manner. However, the computer tools discussed in this paper, when used by a cost professional, can provide results invaluable to site restoration owners bargaining at the USEPA negotiating table.

In summary, there are three commonly used decision-support tools that can assist the reclamation team in developing analysis of reclamation alternatives and rating criteria. Expert Choice is best used to provide a documented, subjective evaluation of alternatives versus criteria to make a decision on issues other than cost alone. DPL is used to develop a probabilistic cost estimate factoring in community acceptance, regulatory acceptance and other pertinent issues. Crystal Ball allows the user to develop a cost range and a "most-likely" cost given a diverse set of assumptions and options.

Results from each of these decision-support tools can assist the owner in negotiations with federal and state regulators and provide the tools necessary for a consulting team to present the results to the community in a variety of formats. Some formats are more acceptable and more easily understood by the public and hence stand a better chance of acceptance.

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