A COST MODEL FOR RECLAMATION OF CLAY SETTLING AREAS IN THE CENTRAL FLORIDA PHOSPHATE DISTRICT

by

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ABSTRACT

This thesis presents a cost model to assist in planning the reclamation of clay settling ponds characteristic of the central Florida phosphate district. A planning model must be able to recognize practical methods of reclamation, actual dimensions of the settling pond, reclamation standards, provide detailed specification of the work to be performed, and accurately estimate costs. However, no cost models currently exist with sufficient accuracy for planning reclamation of settling ponds, so planning has been performed by hand creating the need for an accurate and quick evaluation tool.

Clay wastes are a result of mining an unconsolidated sedimentary phosphate ore and represent roughly 25% of the material mined. Because clays consolidate poorly, the settling ponds will cover from 55% to 70% of the area mined.

A review of existing reclamation standards and technology was conducted to outline reclamation practices for clay settling ponds. Individual activities were then identified for these practices, and a model was developed to estimate reclamation requirements and costs. Once cost models had been developed for the various methods of reclamation, a computer program was written so as to speed the cumbersome calculative work.

Settling area reclamation is composed of three phases; development of a stable surface across the pond, reclamation of the settling pond features, and revegetation. There are two practical methods of reclamation: the Crust Development Method and the Sand Capping Method. These two methods are primarily different in how they stabilize the clay surface.

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I developed the original concept for the model and the logic for the dam earthmoving while under the employment of Zellars-Williams, Incorporated. I would like to thank Steve Neas for his programming assistance during this initial stage and Glenn Gruber who approved its use for this thesis. The model was then enlarged while I was employed by International Minerals and Chemical Corporation. I would like to thank my superiors, S. L. Cawley and G. F. McKereghan, who approved the use of company equipment for its development and free access to reclamation data. In addition, I would like to thank the Manager of Reclamation, G. F. Goodrich, and his staff for the information that they provided on reclamation practice.

CHAPTER 1

INTRODUCTION

The purpose of this study is to develop a model to be used as a planning tool for estimating the effort and cost of reclaiming clay settling ponds characteristic of the central Florida phosphate district.

Mining in Florida is exclusively surface mining with most of it in the central phosphate district. One major feature of these phosphate mining operations are large settling ponds for consolidating a suspension of clay particles. These clays are a waste rejected during concentration of the phosphate ore.

The State of Florida is trying to eliminate the use of settling ponds, known locally as "settling areas," because of their limited land use when mining is finished. A number of novel alternative methods for clay waste disposal have been proposed in the recent past along with proposals for various methods of reclamation of clay settling areas. Despite this, there are thousands of acres of unreclaimed settling areas, and new ones are being constructed on a regular basis.

Effective July 1, 1975, the State of Florida stipulated that lands disturbed by mining would have to be reclaimed in a reasonable amount of time. Reclamation, or restoration, must be conducted on lands excavated or directly affected by mining and beneficiation activities. The authority for promulgating regulations and enforcing them rests with the Department of Natural Resources (DNR), but counties have received the authority to write stricter regulations on mining activities in their jurisdiction. These regulations require that mining companies must operate under an approved mine plan and a master reclamation plan. Operating plans must be detailed in their scope and schedule, and mining activities are not allowed to deviate from the approved program without prior approval.

Settling ponds are difficult to reclaim because (a) they usually are quite large, (b) most mines have several of them, (c) reclamation experience and technology for the ponds is limited, and (d) the cost of this reclamation activity can be significant.

All currently operating phosphate mining companies and those that will be operating in the near future have the task of detail planning the reclamation of clay settling areas. Depending on which county they are operating in and the regulations in effect when their master reclamation plan was approved, the requirements for reclamation can vary significantly. It is quite likely that in the future, the DNR or individual counties will be even more stringent in their reclamation standards. This means that reclamation standards may change before the master reclamation plan is accepted requiring several reclamation proposals.

Currently, this evaluation work has been performed by hand. Hand evaluations are time consuming and mining companies do not have the resources to devote a lot of evaluation time for these reclamation plans. So, accuracy is often sacrificed to speed the work and there is little time for sensitivity analysis on the plans. A mining company could reap several financial benefits by modeling this reclamation activity on the computer. Not only would the number of evaluation hours be reduced significantly and the degree of accuracy improved, but a better reclamation program would be developed and changes could be implemented easily. Such well thought out programs would build better working relations between the mining company and regulatory personnel.

A cost model for evaluation of reclaiming clay setting areas will require the following features.

1. It must provide a detail specification of the work to be performed using practical methods of reclamation.
2. The model must account for the actual settling area dimensions, no matter how variable, to develop an accurate estimate of the earthmoving requirements.

3. The model must estimate the minimum earthmoving requirements to meet reclamation standards.
4. The model must recognize limitations to earthmoving created by adjacent features which cannot be disturbed.
5. It must utilize specific pieces of equipment for each reclamation activity.
6. It must estimate equipment hours by reclamation activity for purposes of scheduling.
7. Reclamation costs must be itemized by activity.
8. The model must be adaptable to changes in reclamation standards.
9. The model must provide a detailed estimate of the revegetation effort including two separate ecological systems.
10. The model must be easy to use.

The DNR has a computer model for estimating the cost for reclamation of abandoned settling areas, but this model was designed to assist in disbursement of state funds for reclamation of abandoned mined lands and lacks many of the requirements listed above.

The model in this thesis meets the above requirements for a planning tool. To create the model, it was necessary to investigate all proposed methods of settling area reclamation to determine which ones were practical and then to investigate previous modeling efforts on the subject. From these findings, a model and computer program was developed.

This study will be composed of seven sections: introduction, background information, literature search, methodology of the reclamation model, case study, summary, and recommendations for additional work to refine and expand the model. In addition, documentation and coding for the program will be provided in the appendixes.

CHAPTER 2

BACKGROUND INFORMATION

The Deposit

Phosphates are derived from a carbon flourapatite mineral which commonly is found in marine deposits. These carbon flourapatites, or for simplicity, phosphates, are found in the hard rock, soft rock, river pebble, and land pebble deposits of central and northern Florida. The only significant economic resource at present is the land pebble deposit known as the Bone Valley Formation.

The Bone Valley Formation is a flat lying, shallow, unconsolidated sedimentary bed that spreads over five counties. The ore is generally 10 to 25 feet thick with overburden ranging from 10 to 40 feet deep. The ore known as "matrix" consists of clay-sized particles, silica sand, and a phosphate rich gravel. Generally, the phosphate gravel and clays are in equal proportions, and the sand to phosphate ratio can range from 1:1 to 3:1.

Wastes from Beneficiation

Florida phosphate mining began in 1888, and by 1982, the region was annually producing over 47 million tons of phosphate concentrate. This amounts to 80% of the United States production and 30% of world production (Lawver, 1982).

Concentration activities at the mine site produce three waste products: clean sand tailings, a minus 150-mesh clay waste, and +7/8" material which is sometimes scalped and discarded instead of being processed. The clays leave the plant in a slurry form at 3% solids (by weight) and are pumped into very large settling ponds known as settling areas. The clean sand tailings are pumped to their place of disposal, either in old mine cuts or inactive settling areas. The scalped +7/8" material is pumped into settling areas because it often contains large balls of clay which muddy the transport water thus requiring clarification.

Within the settling area, clays consolidate quite slowly, so that the area must be large enough to give the transport water sufficient clarification time before it is returned to the plant. These settling areas can range from 300- to 800-acres in size with impounding dike structures that range from 15- to 60-feet above the original ground elevations. The clays will consolidate to 15%-18% solids in the lower portion of the pond within three to six months, but to exceed 30% solids can take decades. As a result, several settling areas will be needed over the life of the mine for adequate storage capacity.

With the exception of the initial settling area at the mine, settling areas are built on mined land and will cover from 55% to 70% of the area mined. Figure 1 shows a typical settling area layout for a mine at extinction and Figure 2 shows the profile of a settling area built on mined land. To date, in central Florida there are more than 75,000 acres of active and inactive clay settling areas with 5000 acres of new ponds being constructed each year (Lawver, 1982).

Regulatory History

Since 1940, there have been 40 settling area dam failures in the phosphate industry. As a result of such a failure in 1971, the State of Florida under Chapter 17-9 of the Florida Administrative Code, developed regulations governing the design, construction, operation, maintenance, and abandonment for all settling areas. However, by this time, large acreages of elevated clay settling pond had become a common feature of the phosphate industry. In addition, this 1971 act placed a severance tax on solid minerals. The tax provided a source of revenue and an inducement to mining companies to reclaim disturbed lands through tax rebates for every acre reclaimed (Zellars and Williams, 1977).

Florida Statutes 211.32 and 370.021 were enacted on July 1, 1975 requiring that all lands mined after that date be reclaimed. Under these statutes, the State Department of Natural Resources (DNR) was given the power to promulgate

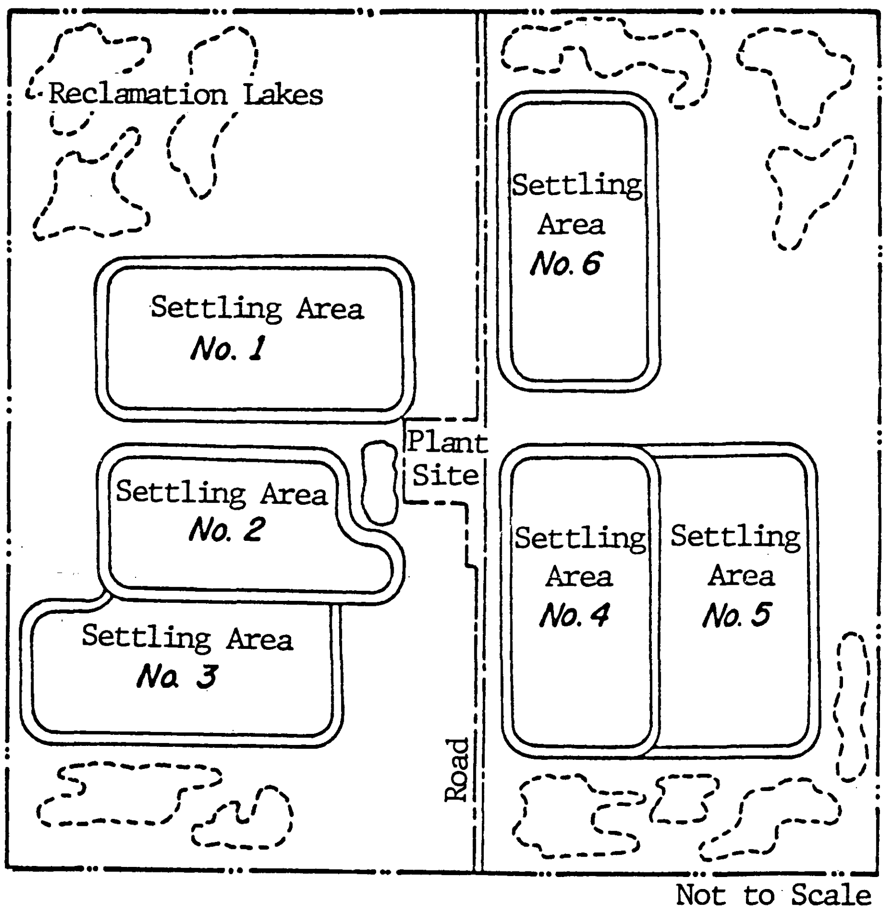


Figure 1. Conventional Settling Area Layout for a Mine at Extinction (Adapted from Bromwell, Oxford, and Greenwood, 1978)

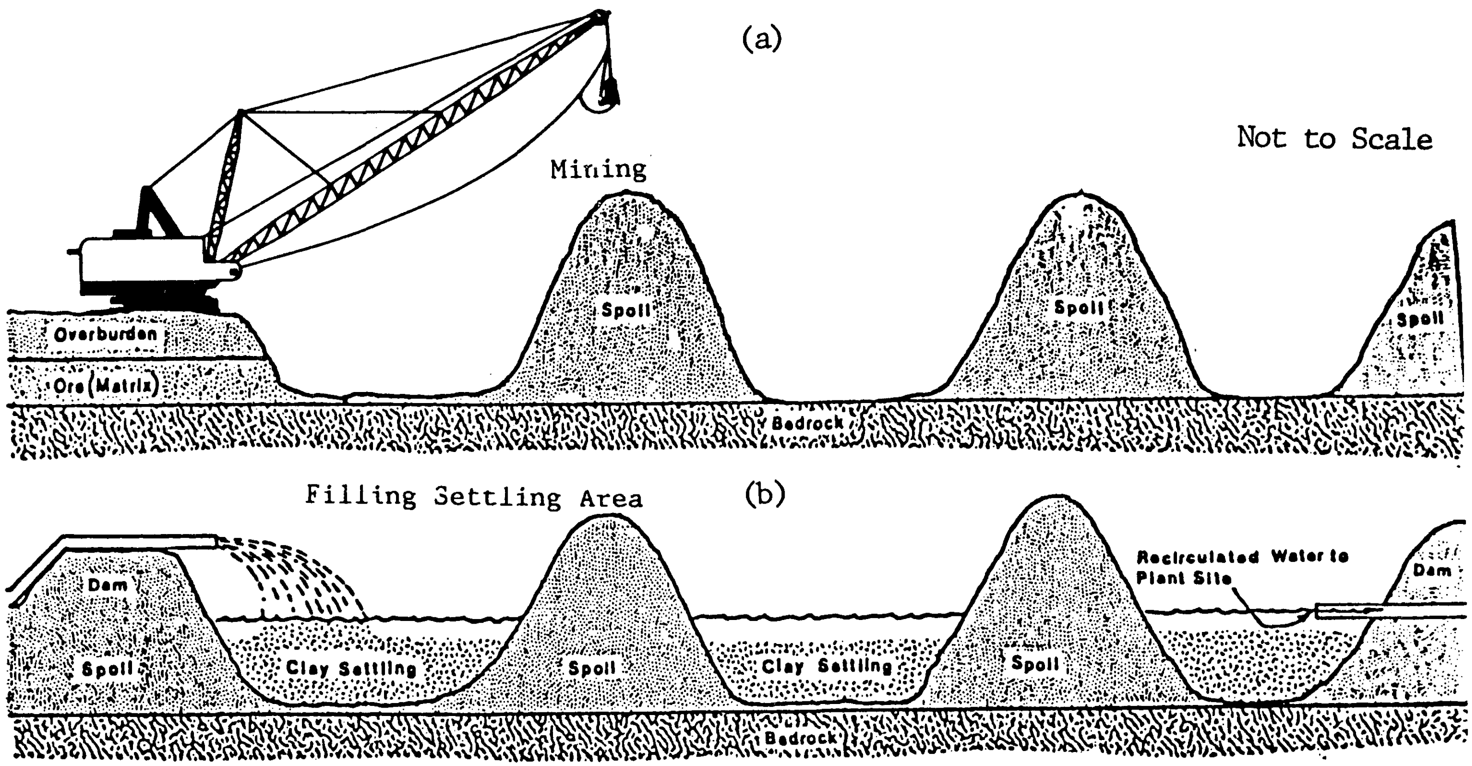


Figure 2. Settling Area Profile on Mined Land (a) Mining Created Landscape and (b) Active Settling Area (Adapted from Zellars-Williams, Inc., 1977)

regulations, inspect, and enforce reclamation requirements. These regulations were outlined in Chapter 16C-16 and its later revisions covering all mining disturbed lands including clay settling areas.

In 1977, the state legislature enacted amendments to Florida Statute 211.32 which increased the tax rate, reduced the tax refunds for reclaiming lands mined prior to July 1, 1975, and created the Phosphate Land Reclamation Study Commission to inventory all lands disturbed by mining phosphate and to estimate the cost for its reclamation. The studies initiated by the commission included reclamation for clay settling areas. To study the broader issue of developing technology for reclamation of phosphate mining disturbed lands, the state in 1978 created the Florida Institute for Phosphate Research. By 1982, a number of intensive studies had been conducted by these agencies to determine effective techniques for reclamation of clay settling areas.

The thrust of regulatory action to date has been to achieve two goals: one, to eliminate conventional above ground clay settling areas, or at least to increase the percentage of below ground disposal, and two, to reduce the turnaround time between mining and land reclamation.

Clay Settling Area Abandonment

Prior to 1975 and mandatory reclamation, clay settling areas had been abandoned after they were filled to capacity. Design capacities assumed an average solids content from 20% to 25% by weight. According to theory, the average density could reach 32% solids (by weight) after 20 years of consolidation.

Upon abandonment and removal of standing water, the top layers of clay will desiccate and a cover of vegetation will quickly develop. In essence, a crust will develop that will have sufficient strength to support light equipment. Due to the limited bearing capacity of the clay crust, these settling areas can be used only for light agricultural activities, such as pasture land. The clays are high in nutrients, but farming is difficult due to poor traction and continued settling of the clays over many years. Given enough time, consolidation of the clays will produce an undulating surface containing a combination of uplands, marsh land, and lake.

Reclamation Requirements

While the State Department of Natural Resources has promulgated a series of reclamation regulations, the intent of such regulations cannot always be met. Commonly, these regulations will have qualifying statements which say that reclamation shall proceed to the point that the requirements are met or to the point that reclamation is technically feasible and economically possible. As a result, there are few clear cut guidelines for reclamation of clay settling areas.

Generally, above ground storage of clays in settling areas is viewed by many state authorities as a distasteful alternative due to the limited land use afterwards. Since no effective techniques have been developed for disposal of all mining wastes below ground level, state authorities have been recommending that the amount of wastes stored above ground should be minimized.

Following is a review of the reclamation studies that have been conducted to outline those methods, most effective and currently practiced, for reclamation of settling areas.

CHAPTER 3

LITERATURE SEARCH

The purpose of this literature search is to evaluate the practicality of various published methods for settling area reclamation, determine the necessary activities for those methods considered acceptable, and investigate cost models that have been developed for these methods.

Reclamation of surface mining disturbed lands became mandatory in 1975. Until that time, the only incentive for reclaiming land was a state tax rebate originating in 1971. Despite the tax rebate, reclamation of settling areas had been limited owing to the large expense and limited technology on the subject. Besides, abandonment and slow consolidation of the clays seemed the most effective and inexpensive way of reclaiming settling areas.

In 1977, the State of Florida took an active role in developing reclamation technology. The Department of Natural Resources and the Florida Institute for Phosphate Research sponsored a series of studies on the subject. These reports represent the bulk of published information on reclamation of clay settling areas. The following is an overview of these reports.

Zellars-Williams, Inc. in 1977 conducted a study for the Department of Natural Resources titled, "A Model for

Determination of Reclamation Methods for Disturbed Lands in the Phosphate District." This model was intended to assist in specifying reclamation activities and to estimate the cost. Five methods of reclamation were outlined and activities were grouped into three major categories: earthmoving, revegetation, and holding costs for owning the land during reclamation and the associated change in land value due to reclamation.

One method of reclamation pertained to clay settling areas and is known as the Crust Development Method. This method depends on the development of a clay crust through accelerated desiccation of the surface. Then the remaining settling area structures are removed, the dam profiles are reduced, and the settling area is revegetated. Listed below are the activities specified in this report for this method.

1. Perimeter Ditch. Dig a perimeter ditch around the inside of the settling area.
2. Spillway Drainage. Clean around spillways so that drainage will flow readily into them.
3. Interior Ditching. Dig a pattern of ditches across the settling area once a crust has started to develop to further promote drainage of the upper clay layers.
4. Dam Earthwork. Reduce dam profiles and level slopes to an acceptable maximum grade.

5. Revegetation. Remove the naturally occurring vegetation growth from the crust surface and establish the planned ecological system.

To estimate earthmoving costs, the model used a simple settling area cross section, dimensions were kept constant around the pond, and average costs for the industry were used. Thus, the earthmoving volumes could be estimated with a single calculation.

Nine revegetation ecological systems were outlined based on the disturbed land form, soil type, and intended land use. For each system, revegetation activities and plant types were specified. Two ecological systems applied to clay settling areas and were differentiated by soil type: consolidated clays and clays capped with overburden. For consolidated clays, vegetation was specified for two forms of land use, pasture, and wetlands. For clays capped with overburden, vegetation was specified for four forms of land use, pasture, forest, cropland, and wetland.

The purpose of this study was to develop magnitude order estimates for various forms of reclamation so that the different methods could be compared. As a result, it was not desirable to develop a model which was too intricate, especially since few settling areas had been reclaimed and there was little information on all of the necessary reclamation activities or the effectiveness of proposed techniques.

In April 1978, L. G. Bromwell, T. P. Oxford, and N. R. Greenwood wrote a report entitled, "Economic Evaluation of Waste Clay Disposal Processes" which was later presented at the Second International Tailings Symposium in Denver under the title, "Tailings Disposal Costs of Florida Phosphate Mining." The purpose of this report was to evaluate the economics of three alternative clay waste disposal techniques that had shown merit in small scale testing. These techniques are:

1. Flocculating. To flocculate clays to 15% solids (by weight), mix them with sand tailings and dispose of the mixture in mined cuts.
2. Sand Spray. Pump clays from the plant at 3% solids into mined cuts, let them consolidate to 12% solids, and then spray sand tailings on top.
3. Dredge-Mix. Fill a settling area with clays. Once they have thickened sufficiently, pump the thickened clays out, mix them with sand tailings, and pump the mixture into mined cuts.

These techniques were compared to a conventional elevated clay settling area. The study concluded that sand spray and dredge-mix clay disposal systems were better than the conventional settling area. It should be pointed out that this evaluation used an idealized mine, did not specify much detail, and promoted two techniques that were unproven in the field. All three clay waste disposal alternatives employed a mixture of sand and clay waste which would later be known as Sand-Clay Mix Techniques.

From June 1977 to June 1978, Zellars-Williams, Inc. conducted a study for the U.S. Bureau of Mines entitled, "Evaluation of the Phosphate Deposits of Florida Using the Minerals Availability System." The purpose of this study was to evaluate the Florida phosphate resources so that it could be entered into the Minerals Availability System (MAS). The MAS is an inventory of mineral resources and their value. The size and quality of these reserves were estimated by reviewing published information, their value was estimated by using market prices, and capital and operating costs were based on six case study mines representing various sizes, age, and quality of ore. For the study, Zellars-Williams wrote a computer program to project costs for the identified deposits in central Florida. As in their previous 1977 report to the Department of Natural Resources, they outlined reclamation activities for a variety of mining disturbed landforms. The cost model was capable of evaluating reclamation costs for clay settling areas using the Crust Development Method, Sand-Clay Mix Methods, and the Sand Capping Method.

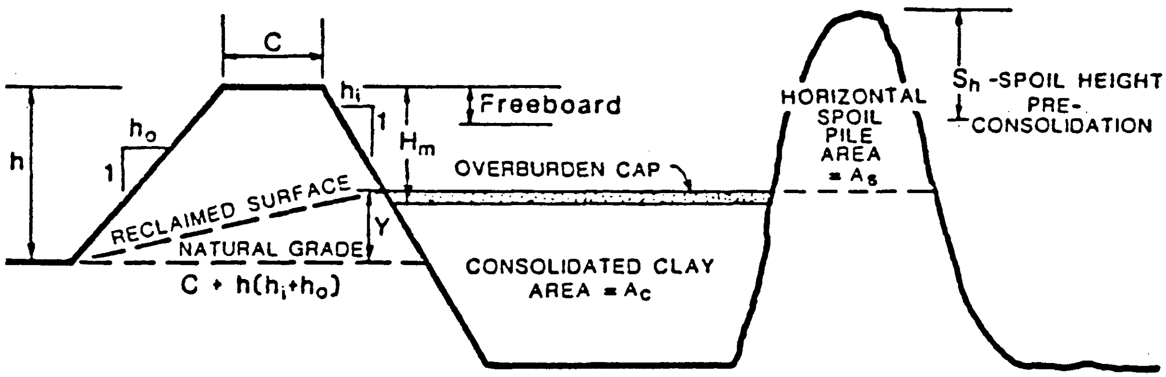
The Sand Capping Method reclaims a filled settling area by creating a cap of sand tailings over the clays. This will compress the clays, speed their consolidation, get more clays below ground level, and provide a stable surface. The model assumed that the cap was placed using a slurry pipeline.

While this reclamation model was capable of evaluating more methods of reclamation than their 1977 model, it still used a simplified settling area cross section for estimation of earthmoving volumes.

In August 1980, Zellars-Williams submitted a report to the Department of Natural Resources entitled, "Evaluation of Pre-July 1, 1975 Disturbed Phosphate Lands." The purpose of this study was to evaluate all lands in the state mined prior to July 1, 1975 and to develop a cost model so that the state could disburse reclamation funds where it was most needed. Thus, this report inventoried phosphate mining disturbed lands categorizing them by size, type of disturbance, condition, and desirability for reclamation. Then a computer program was written which utilized the data gathered for the disturbed land inventory to estimate reclamation costs for each parcel.

The model estimated reclamation efforts and cost for the following mining disturbed land forms: dams without clay, settling areas reclaimed without sand (See Figure 3), settling areas reclaimed with sand (See Figure 4), interior windrows reclaimed without sand, interior windrows reclaimed with sand, piles and depressions. For each land form, reclamation activities were identified and a mathematical model was developed so that machine-hours and cost could be estimated for each activity. However, as in previous efforts by Zellars-Williams, the model was able to specify only a few reclamation requirements.

Since the reclamation cost evaluation had to rely on data gathered from a short field investigation, the model would have to utilize average dimensions and a simplified cross section. This simplicity in the two settling area models required the use of several assumptions which were erroneous or seldom found in practice. They assumed that settling areas were built on level ground, that the dam was a single straight structure with constant dimensions for its full length, did not border with any other settling area, and that there was a single spoil ridge enclosed within the pond which was the same length as the dam and exhibited constant dimensions throughout its full length. In addition, the models assumed that a maximum amount of



P - Length of Dam

A_c - Acres of Clay Settling Area - Spoil Acres

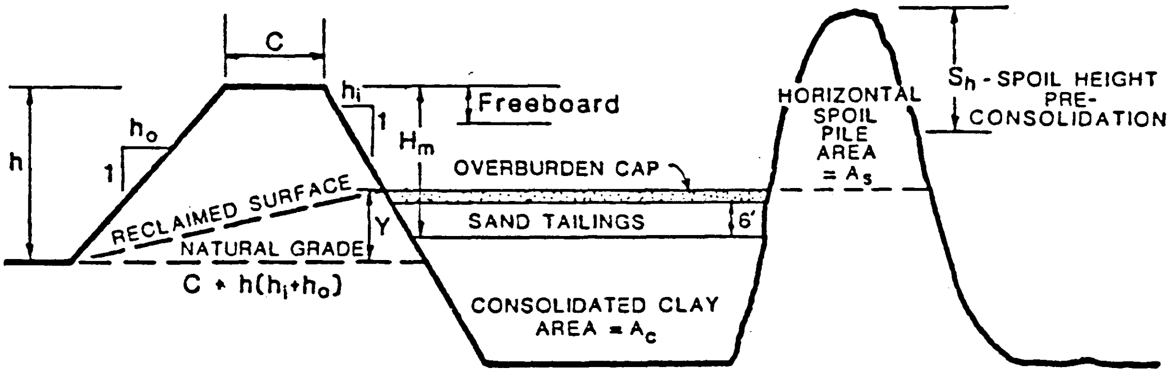
SOLVE FOR "Y"

CAP VOLUME = DAM VOLUME ABOVE RECLAIMED SURFACE + PROTRUDING SPOILS VOLUME

$$\left[43560\,A_c\,(H_m-(h-Y))\right] = \left[\frac{2C + h(h_i+h_o)}{2}(h) - \frac{C + h(h_i+h_o)}{2}(Y)\right]P + \left[\frac{(Sh-Frbd+(h-Y))(A_s)43560}{3}\right]$$

$$Y = \frac{2Ch + h^2(h_i+h_o) + \dfrac{87120(A_s)}{3p}(Sh - Frbd + h) + \dfrac{87120\,(A_c)}{p}(-H_m+h)}{\dfrac{87120(A_s)}{3p} - h(h_i+h_o) + C + \dfrac{87120(A_c)}{p}}$$

Figure 3. DNR Cost Model: Settling Areas Reclaimed Without Sand (Zellars-Williams, Inc., 1983)



P - Length of Dam
Ac - Acres of Clay Settling Area - Spoil Acres

SOLVE FOR "Y"

CAP VOLUME = DAM VOLUME ABOVE RECLAIMED SURFACE + PROTRUDING SPOILS VOLUME

$$43560Ac[Hm-(h-Y)-Tails] = \frac{P[2C+h(hi+ho)]h}{2} - \frac{P[C+h(hi+ho)]Y}{2} + \frac{[Sh-Frbd+(h-Y)](As)43560}{3}$$

$$Y = \frac{2Ch+h^{2}(hi+ho)+[87120(As)(Sh-Frbd+h)]/3p+[87120(Ac)(-Hm+h-Tails)]/p}{[87120(As)]/3p - h(hi+ho) + C + [87120(Ac)]/p}$$

Figure 4. DNR Cost Model: Settling Areas Reclaimed With Sand (Zellars-Williams, Inc., 1983)

material was removed from the dam structure and that all material removed from the dam and spoil ridge were spread on the clays as a uniform cap by bulldozers or scrapers. Reclamation standards do not require all earth moved to be placed on the clays, no contractor would move the maximum amount of material, and scrapers cannot operate on clays.

The data gathered from the field investigation for the disturbed land inventory represented current conditions. This required the investigator to estimate average dimensions which were of limited accuracy. In addition, the model utilized the acreage of clay surface based on current consolidation. Over the long term, the clay acreage changes depending upon the amount of consolidation, inside slope of the dam, and the dimensions of enclosed spoil piles, so that it would be time consuming to estimate the clay acreage for several years later.

As a result, the accuracy of these models was extremely limited due to flawed logic, simplistic equations, and the use of input data which was time consuming to calculate and whose accuracy had been compromised. Since the purpose of the program was to assist in scheduling reclamation expenditures, it was not necessary for the model to develop a high degree of accuracy or to minimize costs.

In March 1981, the Department of Natural Resources enacted the current set of reclamation regulations known as Chapter 16C-16. Those regulations pertaining to reclamation of clay settling areas were outlined in 16C-16.051 Reclamation Criteria and Standards and are listed in the following excerpt.

> 1) a) Site Cleanup - All lands reclaimed shall be completed in a neat, clean manner by removing or adequately burying all visible debris, litter, junk, . . . and covered to a minimum depth of four feet.
> 2) a) Backfilling and Grading - Slopes of any reclaimed land area shall be no steeper than four (4) feet horizontal to one (1) foot vertical.
> 3) a) Overburden and Soil Zone - The use of good quality topsoils is encouraged.
> 9) a) 1) Waste Storage-Clays - To the greatest extent practical, all waste clays shall be disposed of below grade, in a manner that avoids the long term existence of elevated clay disposal areas.
> 9) b) 2) Waste Storage-Sand Tailings - The operator shall give the highest priority to the use of sand tailings for . . . accelerating the thickening of waste clays, or as a soil enhancement by mixing the sand with the surface clays on clay storage areas.
> 10) b) Revegetation - All land areas must have established ground cover through the approved growing season over 80% of the reclaimed land area. . . . Bare areas shall not exceed one-quarter acre.
> 10) c) Revegetation - At a minimum, 10% of the upland area will be revegetated as upland forested areas . . . . An area will be considered to be reforested if a stand density of 200 trees/acre is achieved at the end of one growing season.

The regulations are limited with few standards on final land use, contours, ecological, or hydrological schemes, giving wide latitude in their interpretation. To meet regulation 9)a)1), which calls for minimizing elevated disposal of clay wastes, the DNR has interpreted this statement to mean that reclaimed settling area profiles shall be reduced as much as possible. As a result, the dam and any exposed spoil ridges must be struck off at the level of consolidated clays or sand cap. The struck dam, sand cap, and spoil ridges are stable ground and are often reclaimed as uplands and must meet the criterion for minimum forested uplands.

In June 1983, Zellars-Williams produced an addendum to their 1980 report, entitled "1983 Addendum: Cost Model and Program, Pre-July 1, 1975, Disturbed Phosphate Lands." The addendum was necessary due to the 1981 rule changes in reclamation standards. The program was modified to recognize inflation, and the project was used as a training session for DNR personnel in the use of the program. The changes did not significantly impact the degree of accuracy for the reclamation estimates.

In February 1982, J. E. Lawver, Technical Manager for the Minerals Division of International Minerals and Chemical Corporation (IMC), published a report summarizing the results of a four-year intercompany research project titled, "Progress Report Six: IMC-Agrico-Mobil Slime Consolidation and Land Reclamation Study." The purpose of this joint project was to prove a workable technique for disposing of mine wastes below ground. Through laboratory and field work, they tested all technically feasible methods of dewatering and disposing of clay wastes. This included self-consolidation (traditional method), sand-clay mix techniques, and compaction of clays through capping. Their conclusions follow.

1. Self-Consolidation (Traditional Method). The traditional method of consolidating clays in elevated settling areas is the only technically feasible and economically viable method for disposal of clays. This means that settling areas will continue to be used in the phosphate industry, and that the Crust Development Method will be the predominant method for reclamation.
2. Sand-Clay Mix Techniques. These techniques were not effective for the following reasons: 1) they required more sand tailings than were available, 2) they did not produce a stable surface, and 3) they failed to get all wastes below ground level.
3. Compaction Through Capping. This method proved technically feasible in getting most clay wastes below ground level. It required placing a 6- to 8-foot cap of sand tailings on top of a settling area filled with

clays. To achieve this, the sand tailings had to be placed in 2-foot lifts using low ground pressure bulldozers and a topsoil layer spread as a growing medium. Lawver concluded that this method was prohibitively expensive.

At a January 1983 symposium conducted by the Florida Institute for Phosphate Research, two papers were presented dealing with reclamation of clay settling areas. The paper by J. E. Garlander and N. F. Fuleihan outlined the physical properties and engineering requirements for reclaiming settling areas using four different methods.

1. Desiccation (Mother Nature). Clays consolidate in a settling area though natural processes.
2. Trenching/Dewatering (Crust Development). The traditional Crust Development Method.
3. Sand-Capping. The idealized sand-cap method where a uniform 9-foot cap of sand tailings is pumped on top of the clays. Lawver had previously proved that a uniform sand cap could not be created by pumping.
4. Sand-Clay Cap. A variation of the capping technique where a mixture of sand and clay is used to cap a settling area. Again, Lawver had already proved that sand-clay mixtures did little to compress the clays and proved to be a poor foundation for heavy equipment.

This paper is a presentation of old wishful thinking and some engineering properties that had been developed in the laboratory.

The paper presented by R. F. Goodrich, IMC manager of reclamation, outlined current IMC reclamation practices based on what they found both feasible and economically sound. This included two methods, the Crust Development Method and a realistic version of the Sand Capping Method. Lawver had determined that sand tailings would displace the clays unless they were spread in thin layers by bulldozers, a technique which was prohibitively expensive. The modified sand-cap method does not attempt to place a uniformly thick cap. Once the settling area is filled to capacity with clay wastes, clean sand tailings are introduced around the inside perimeter of the settling area leaving a drainage path to a spillway. The sand sinks displacing the clays, but agitation of the clays cause them to give up some of their water, increasing their density and strength. Thus, as the tailings pipeline is advanced, the clays are able to support increasing amounts of sand tailings. Eventually the sand tailings will stop sinking into the clays and begin capping them. A sand cap is extended in the following sequence of steps: a pile of sand will build up at the discharge of the pipe, a bulldozer will push it down, and another joint of pipe will be added. The sand cap will be extended around the settling area in this fashion, a row at a time. Because of initial displacement of the clays, the sand cap can range anywhere between 15- and 30-feet thick. After most of the settling area has been capped, a ridge of clays will squeeze up in the uncovered area, thus preventing any further capping with sand. This uncapped area will eventually subside because of consolidation, and a swale will have to be extended to this area for long term drainage.

Once the cap is in place, a suitable growing medium will have to be placed on top since the clean sands don't contain nutrients. This topsoil can be created by robbing overburden from the dam structure or exposed spoil ridges to create 8 to 12 inches of topsoil. It may be tilled into the sand if the topsoil is in short supply. The topsoil can also be created by borrowing the squeezed-up clays, spreading a 2-inch layer on the sand cap, and tilling them in.

A later conversation with R. F. Goodrich in 1985 provided the following information.

Sand Capping has advantages over the Crust Development Method; it reduces the reclamation turnaround time, puts more wastes below ground level, builds a more stable surface, and is preferred by the state. Its application is generally limited by the availability of sand tailings and proximity to the plant, the source of the tailings.

Overburden is robbed from the dam structure and exposed spoil ridges using scrapers and bulldozers. For short distances, the overburden is pushed with bulldozers and for longer hauls, scrapers are used. To create a growing medium using clays, the clay is loaded into pans with backhoes, and then spread in a thin layer over the sand. This layer is then tilled into the sand, producing a growing medium as effective as topsoil.

A reclaimed settling area will have two distinct soil types and growing environments. As the dam and spoil ridges are composed of overburden cast by the dragline, it will be planted with upland grasses and trees. The clay surface, on the other hand, is high in nutrients and is commonly planted in pasture grasses if above the original ground level, or as a wetlands if below original elevations. As such, the work effort for each is significantly different.

To achieve this vegetation growth on the dam and spoil ridges, the land may have to be tilled, limed to reduce the soil acidity, and more than one application of seed and fertilizer may be necessary. Revegetation of the clay surface is much easier, usually requiring a single application of seed, no fertilizer or lime, but volunteer vegetation may have to be removed and the surface tilled if the settling area has been inactive for any length of time.

A 1985 conversation with Jesse Perez, Jr., an IMC reclamation engineer, provided the following details on reclamation technique. When the settling area is first made inactive, the upper clays have very little bearing strength and there is little natural growth on top. Thus, only those activities that can be done without crossing the clay surface are performed. This includes installing temporary spillways and digging a perimeter ditch around the inside of the dam structure.

Temporary spillways are installed as early as possible around the perimeter of the settling area to help drain standing water as the clays consolidate. A temporary spillway is created by pushing a small coffer dam into the pond, installing the spillway through the upper portion of the dam, and then removing the coffer dam. The installation costs for these spillways are relatively independent of the location and they are used for both the Crust Development and Sand Capping Methods.

A perimeter ditch is dug around the inside of the settling area dam by either a small dragline or a backhoe to promote drainage to the temporary spillways. Clays will slough into the ditch, so that they will have to be cleaned out on a regular basis.

As the clays consolidate and water released from the upper layers is drained off, the clay surface will subside, and a dense, stiff crust will develop on top. This subsidence will leave the perimeter ditch and temporary spillways high and dry, so that periodically they will have to be relocated further downslope on the inside of the dam.

Once the clays develop sufficient bearing strength, low ground pressure bulldozers or ditching equipment will dig a pattern of drainage ditches across the clay surface, further accelerating the drying out process. Originally, this was performed by a low ground pressure bulldozer pulling a plow, but recently a full flotation machine has been employed which uses a rotary ditcher. As with the perimeter ditch, sloughing of clays will require that the interior ditches are cleaned out on a regular basis. Estimation of equipment hours is based on the length of ditch.

The whole crust development procedure can take up to five years. Consolidation will continue for many years after reclamation, lowering the clay surface, but the rate of subsidence will be slow. If the crust had been allowed to develop on its own for many years, a heavy growth of vegetation would have developed, including small trees. Therefore, reclamation of old abandoned settling areas will include a cost for removal of this volunteer growth so that the planned ecological system can be established.

The ecological systems chosen will determine the cost of revegetation. Inside a clay settling area, the ecological systems may grade from uplands to wetlands, or may be entirely pasture land. However for most systems, the same kinds of activities usually are conducted. These activities are removal of naturally occurring vegetation (chopping), tilling the topsoil, applying lime to reduce the soil acidity (not necessary for clays), seeding, fertilizing, and tree planting.

Chopping and tilling are one-time activities and are usually contracted by the acre. The cost for chopping is dependent upon the degree of volunteer growth, but this is only important when dealing with a settling area that has been inactive for a long time. Lime, seed, and fertilizer applications are contracted by the pound per acre. The number of applications and the intensity of each application are based on the condition of the topsoil.

The state requires that at least 10% of reclaimed uplands have a concentration of 200 trees/acre after one growing season. Therefore, trees are planted at a concentration of 400 trees/acre so that 200 trees/acre will be guaranteed to survive.

In summary, the most comprehensive reclamation cost model for settling areas was developed for the State Department of Natural Resources. This model was designed as a budgeting tool for disbursement of funds to reclaim abandoned mine lands. As a result, it does not provide many design details for a reclamation program, is limited in its ability to recognize site specific features, is fatally flawed in its logic, and requires an estimation of average dimensions at the time of reclamation. To be useful to an active mining operation, the above mentioned shortcomings would have to be overcome and the model would have to exhibit the following features.

1. Utilize practical reclamation methods. The model should be able to evaluate reclamation requirements for the Crust Development and Sand Capping Methods.
2. Minimize the required work. The model should be able to choose the operating conditions which will minimize the work needed to meet reclamation standards.
3. Account for variability in settling area configuration. The model should be able to account for variability in the settling area dimensions so that accurate earthmoving volumes and haulage distances can be estimated.
4. Estimate required equipment hours. The model should calculate the required equipment hours for each

reclamation activity to be used in the cost estimate and reclamation scheduling.

5. Itemize reclamation costs. An itemized breakdown of reclamation costs is needed by activity.
6. Adaptable to changes in reclamation standards. The model should be able to recognize reclamation standards and be adaptable to some changes.
7. Recognize boundary limits. The model should recognize the limitations to reclamation activities created by adjacent features that cannot be disturbed.
8. Incorporate two ecological systems for revegetation. The model should be able to evaluate costs for more than one ecological system.
9. Easy to use. The model should be easy to use, able to create and edit input files, and provide sufficient information in the printed output.

From the above observations, a more complex cost model and computer program would be needed if it were to be useful to an active mining operation. The next chapter will outline a cost model which will overcome the limitations of previous models and attempt to meet the requirements mentioned above.

CHAPTER 4

METHODOLOGY OF MODEL

The literature search provided two methods of reclamation practical for settling areas which have been incorporated in this cost model, the Crust Development and the Sand Capping Methods. Both methods contain activities that are unique to the method and activities common to both methods. Listed below are the reclamation activities used in the model and which are outlined in the literature search.

Activities Unique to Crust Development

- A Diversion Ditch Outside of the Settling Area
- A Perimeter Ditch Around the Inside of the Dam
- A Pattern of Ditches Across the Clay Surface

Activities Unique to Sand Capping

- Placement of a Sand Cap
- Leveling the Sand Cap
- Placement of Topsoil on the Cap

Activities Common to Both Methods

- Temporary Spillway Installation
- Spillway Removal
- Reducing Dam to Reclamation Standards
- Reducing Exposed Spoil Ridges

Revegetation on the Crusted Clays

Chopping

Tilling

Seeding

Fertilizing

Revegetation on the Dam/Spoil Ridges/Cap

Tilling

Seeding

Fertilizing

Tree Planting

Using a geometric description of the settling area, specifications for the reclamation activities, equipment performance parameters, and cost data, the model estimates the work required (feet of ditch dug, volume of earth moved, acres planted), the number of machine hours required for specific pieces of equipment, and a cost for each activity.

A computer program named SETREC was written based on the model. SETREC estimates the reclamation requirements and costs, and prints the results in a tabular form with the option of printing a more detailed listing of earthmoving requirements. The reclamation estimate is based on data provided by two input files, the settling area input file and equipment input file. The settling area input file provides information required for evaluation of the specific settling area. This includes a geometric description of the settling area and specifications for reclamation activities. The equipment file provides information that is independent of the individual settling area. This includes the equipment performance parameters and cost data. The program will be used as a guide for presenting the model.

To understand how the model calculates the results, input for the specific settling area found in the settling area input file must be discussed. Then the model logic and equations can be presented.

Settling Area Input for Model

To evaluate the reclamation effort, SETREC requires a physical description of the settling area and a specification of reclamation requirements. Tables 1 and 2 are examples from the Chapter 5 case study showing the settling area input files for the two methods of reclamation.

Reclamation Requirements

To adequately specify the reclamation requirements, one must have performed a preliminary evaluation to determine what the reclaimed structure should be and what activities that are needed to achieve this goal. When reclaiming with the Crust Development Method, those requirements unique to

Table 1. Case Study Settling Area Input File: Crust Development

SETTLING AREA INPUT FILE

Settling Area Name: TEST CASE SETTLING AREA
Settling Area Location: FLORIDA
Number of Spillways: 3 Crest Road Elev: 150
Pond Acreage: 508 Operating Level Elev: 145

DAM SEGMENT DESCRIPTION

STARTING COORDINATES NORTH	EAST	STARTING ELEV	DAM SLOPES OUTSIDE	INSIDE	CREST WIDTH	BOUNDARY DISTANCE
11320.0	25855.0	150.0	2.5	3.0	12.0	150.0
11500.0	25745.0	150.0	2.5	3.0	18.0	255.0
12100.0	25885.0	150.0	2.5	3.0	16.0	115.0
14160.0	25765.0	150.0	2.5	3.0	16.0	145.0
14850.0	25550.0	150.0	2.5	3.0	16.0	185.0
16280.0	25510.0	145.0	2.5	3.0	24.0	150.0
16320.0	21400.0	145.0	2.5	3.0	24.0	900.0
16210.0	21310.0	95.0	2.5	2.3	24.0	200.0
12720.0	21250.0	100.0	2.5	2.3	24.0	200.0
12238.0	21447.0	100.0	2.5	2.3	24.0	200.0
11573.0	21480.0	100.0	2.5	2.3	24.0	200.0
11575.0	21600.0	126.0	2.3	2.5	24.0	900.0
11600.0	23260.0	126.0	2.3	2.5	20.0	900.0
11070.0	23860.0	126.0	2.3	2.5	20.0	900.0
10041.0	23719.0	128.0	2.3	2.5	20.0	280.0
10060.0	24322.0	128.0	3.0	3.0	24.0	900.0
10190.0	24480.0	89.0	3.0	3.0	24.0	900.0
10850.0	25450.0	89.0	3.0	3.0	24.0	900.0

SPOIL RIDGE DESCRIPTION

CREST ELEV	CREST WIDTH	RIDGE LENGTH	SPOIL SLOPES
150.0	15.0	950.0	1.5
145.0	18.0	620.0	1.5
140.0	20.0	870.0	1.5
135.0	25.0	870.0	1.5
130.0	30.0	950.0	1.6

RECLAMATION REQUIREMENTS

Method of Reclamation: Crust Development
Diversion Ditch Length (Ft): 5200.0 Int. Ditch Length (Ft/Ac):400.0
Temporary Spillways (No.): 8 Spillways Removed (No.): 3
Max. Reclaimed Slopes(H:V): 4.0 Est. Consolidation (Ft): 18.0

REVEGETATION

	DAM/CAP	CLAYS
Chop Vegetation(1-Yes/0-No):		0
Tilling (1-Yes/0-No):	1	1
Liming (No. Applications):	1	0
Seeding (No. Applications):	1	1
Fertilizer (No. Appl.):	2	0
Tree Planting (% of Area):	15	

Table 2. Case Study Settling Area Input File: Sand Capping

SETTLING AREA INPUT FILE

Settling Area Name: TEST CASE SETTLING AREA
Settling Area Location: FLORIDA
Number of Spillways: 3 Crest Road Elev: 150
Pond Acreage: 508 Operating Level Elev: 145

DAM SEGMENT DESCRIPTION

STARTING COORDINATES NORTH	EAST	STARTING ELEV	DAM SLOPES OUTSIDE	INSIDE	CREST WIDTH	BOUNDARY DISTANCE
11320.0	25855.0	150.0	2.5	3.0	12.0	150.0
11500.0	25745.0	150.0	2.5	3.0	18.0	255.0
12100.0	25885.0	150.0	2.5	3.0	16.0	115.0
14160.0	25765.0	150.0	2.5	3.0	16.0	145.0
14850.0	25550.0	150.0	2.5	3.0	16.0	185.0
16280.0	25510.0	145.0	2.5	3.0	24.0	150.0
16320.0	21400.0	145.0	2.5	3.0	24.0	900.0
16210.0	21310.0	95.0	2.5	2.3	24.0	200.0
12720.0	21250.0	100.0	2.5	2.3	24.0	200.0
12238.0	21447.0	100.0	2.5	2.3	24.0	200.0
11573.0	21480.0	100.0	2.5	2.3	24.0	200.0
11575.0	21600.0	126.0	2.3	2.5	24.0	900.0
11600.0	23260.0	126.0	2.3	2.5	20.0	900.0
11070.0	23860.0	126.0	2.3	2.5	20.0	900.0
10041.0	23719.0	128.0	2.3	2.5	20.0	280.0
10060.0	24322.0	128.0	3.0	3.0	24.0	900.0
10190.0	24480.0	89.0	3.0	3.0	24.0	900.0
10850.0	25450.0	89.0	3.0	3.0	24.0	900.0

SPOIL RIDGE DESCRIPTION

CREST ELEV	CREST WIDTH	RIDGE LENGTH	SPOIL SLOPES
150.0	15.0	950.0	1.5
145.0	18.0	620.0	1.5
140.0	20.0	870.0	1.5
135.0	25.0	870.0	1.5
130.0	30.0	950.0	1.6

RECLAMATION REQUIREMENTS

Method of Reclamation: Tailings Cap

Tailings Cap Thickness (Ft) :	10.0	Topsoil Thickness (Ft) :	0.7
Temporary Spillways (No.):	6	Spillways Removed (No.):	3
Max. Reclaimed Slopes(H:V):	4.0	Estimated Compaction (Ft):	20.0
Dist. Tails Pumped (Miles) :	1.8	Area Covered by Cap (%) :	60.0

REVEGETATION

	DAM/CAP	CLAYS
Chop Vegetation(1-Yes/0-No):		0
Tilling (1-Yes/0-No):	1	1
Liming (No. Applications):	1	0
Seeding (No. Applications):	1	1
Fertilizer (No. Appl.):	2	0
Tree Planting (% of Area):	10	

the method include the length of diversion ditch, intensity of interior ditching, and an estimate of the clay consolidation. Those requirements unique to the Sand Capping Method include the thickness of the sand cap, percentage of the clays capped, the pumping distance from the source of the tailings to the settling area, the thickness of the topsoil, and an estimate of the clay compaction due to the cap. Requirements common to both methods of reclamation include the number of temporary spillways installed and the number removed, the maximum allowable grade of reclaimed slopes, and a designation of the revegetation activities for the clays and dam, spoil ridges, and topsoil, if capping with tailings. While the maximum allowable grade of reclaimed slopes has been specified by state regulations, some counties have discussed the possibility of requiring flatter slopes. As a result, the model must treat this regulation as an input variable.

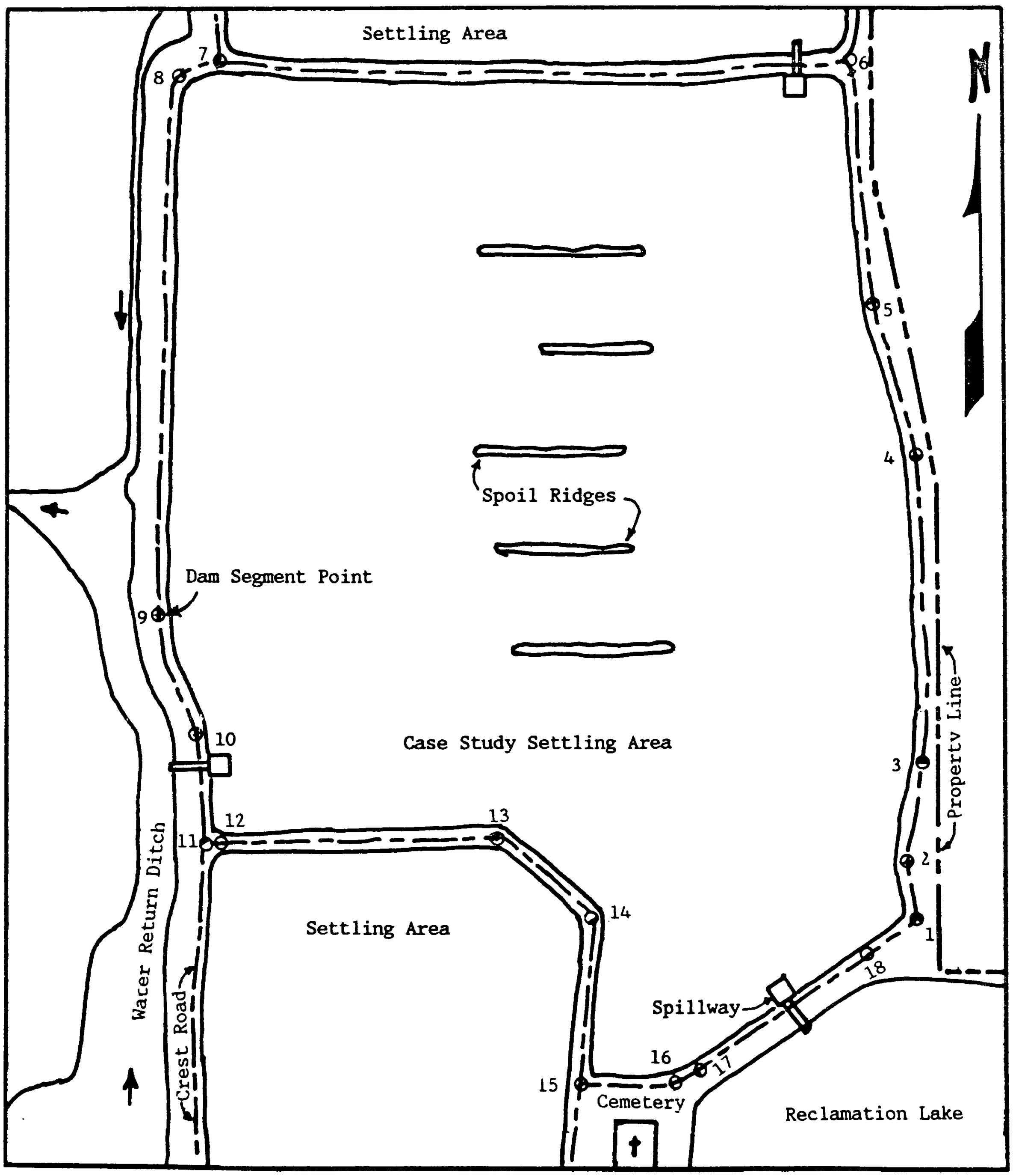
While some of these reclamation requirements are dictated by the configuration of the settling area, such as number of spillways removed, length of diversion ditch installed, etc., others are based more on judgment and past experience, such as the amount of consolidation or compaction, the percentage (or proportion) of the clays covered by tailings, and so forth. Some of these judgmental requirements can have a significant impact on the reclamation cost so that a sensitivity analysis on these variables might be justified.

Settling Area Description

A physical description of the settling area includes the dimensions for the dam, dimensions of the enclosed spoil ridges, operating level and acreage of the clays, and distances to permanent features that cannot be disturbed by reclamation activities. To create an adequate physical description of the settling area requires design drawings of the pond, including cross sections of the dam, contour maps of the surrounding area, contour maps of the enclosed spoil ridges after robbing for dam construction is complete, and design operating parameters. Figure 5 is a plan view of the settling area used in the case study and should help to visualize a settling area for this discussion.

Dam Description. Dimensions that describe the dam are the width of the dam crest, the inside slope of the dam, the outside slope of the dam, the crest elevation, the ground elevation at the outside toe of the dam, the length of the dam, and the plan view shape of the dam. To accurately describe the dam for the model, it must be divided into small segments along its length in which all dimensions and reclamation work are relatively constant. Since it would be tedious for the user to determine when the reclamation requirements change along the perimeter of the dam, the program performs this function. As a result, the user need only break the dam into segments in which the dimensions and the distances to permanent features are constant, as depicted in Figure 5 for the case study settling area. Each segment is represented by the dimensions at the beginning of the segment when going around the settling area in a counter-clockwise direction. Therefore, by specifying horizontal grid coordinates at the beginning of each segment, the segment length and the shape of the settling area can be accounted for. Within each segment, the grade of natural ground at the outside toe of the dam must be constant. The model recognizes this grade by inputting the elevation of natural ground at the outside toe of the dam for each break point. For the case study settling area, 18 segments were required to describe the dam accurately, but a settling area located in a congested location and rolling terrain could require even more.

Spoil Ridge Description. A settling area built on mined ground will have many spoil ridges enclosed in it, some of which might protrude above the clays impacting reclamation. The model allows an inventory of spoil ridges to be input



Scale: 1" = 1000'

Figure 5. Plan View of Case Study Settling Area

and will evaluate each individually. The necessary dimensions to describe each spoil ridge are the crest elevation, the crest width, the ridge length, and the side slopes of the ridge.

Operating Data. Two operating parameters are needed for the evaluation, the operating elevation of the clays and the acreage of clays under operating conditions, including any exposed spoil ridges. This acreage can be easily measured with a planimeter.

Model Logic and Equations

The general logic of the model is depicted in the SETREC flowchart of Figure 6. After the input files have been specified, the program will read the files and check them for completeness. The model calculations have been divided into eight parts which are separated by the lower case letters in the flowchart. For each part, there is a short description of the work being calculated, a detail flowchart indicates the logic of the part, the assumptions are listed, and equations presented with supporting figures. Numbers adjacent to the boxes in the flowcharts correspond to the equations in the text. Due to the large number of variables in the model, Table 3 lists the variable names used in SETREC and the equations in this chapter.

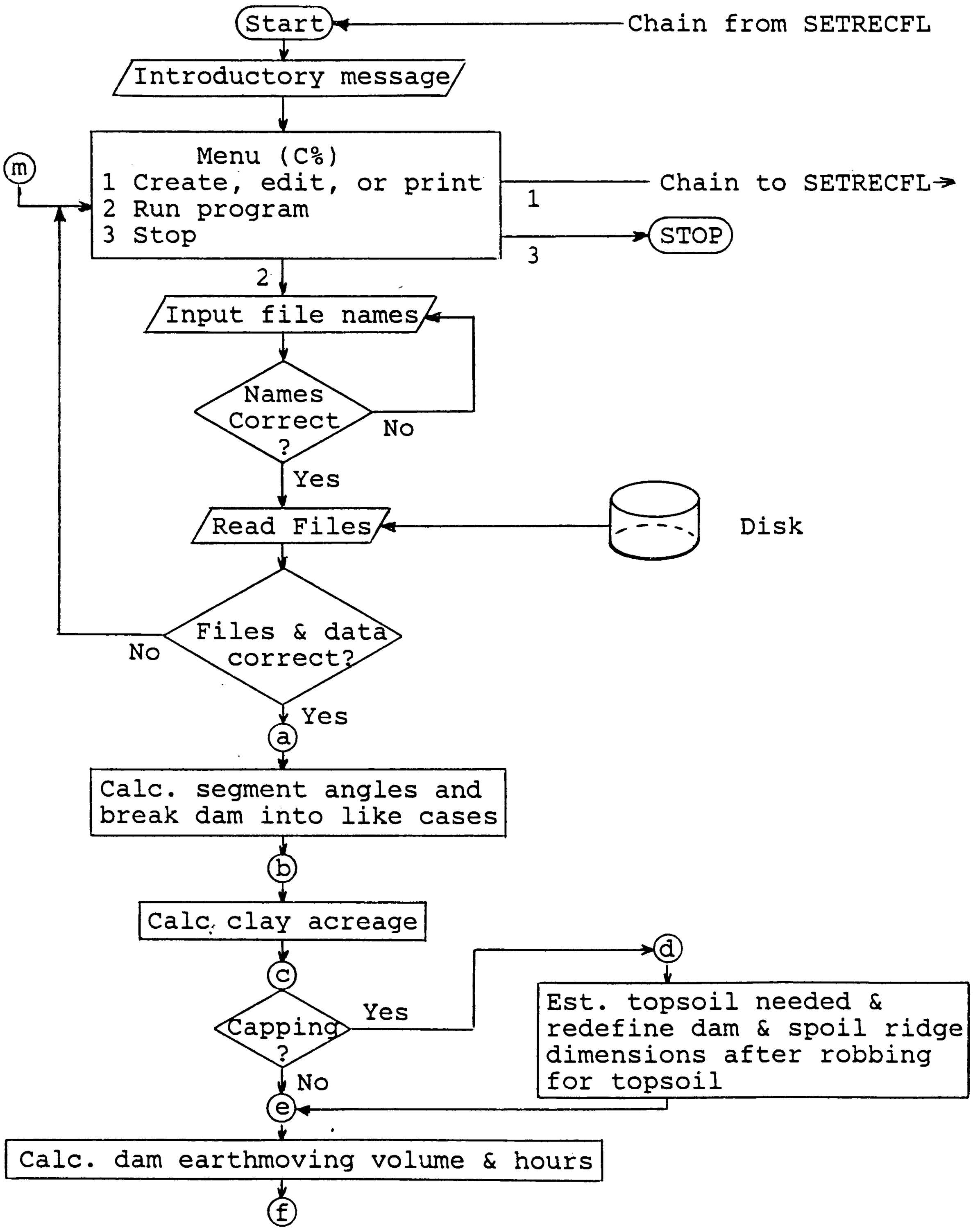


Figure 6. SETREC General Flowchart

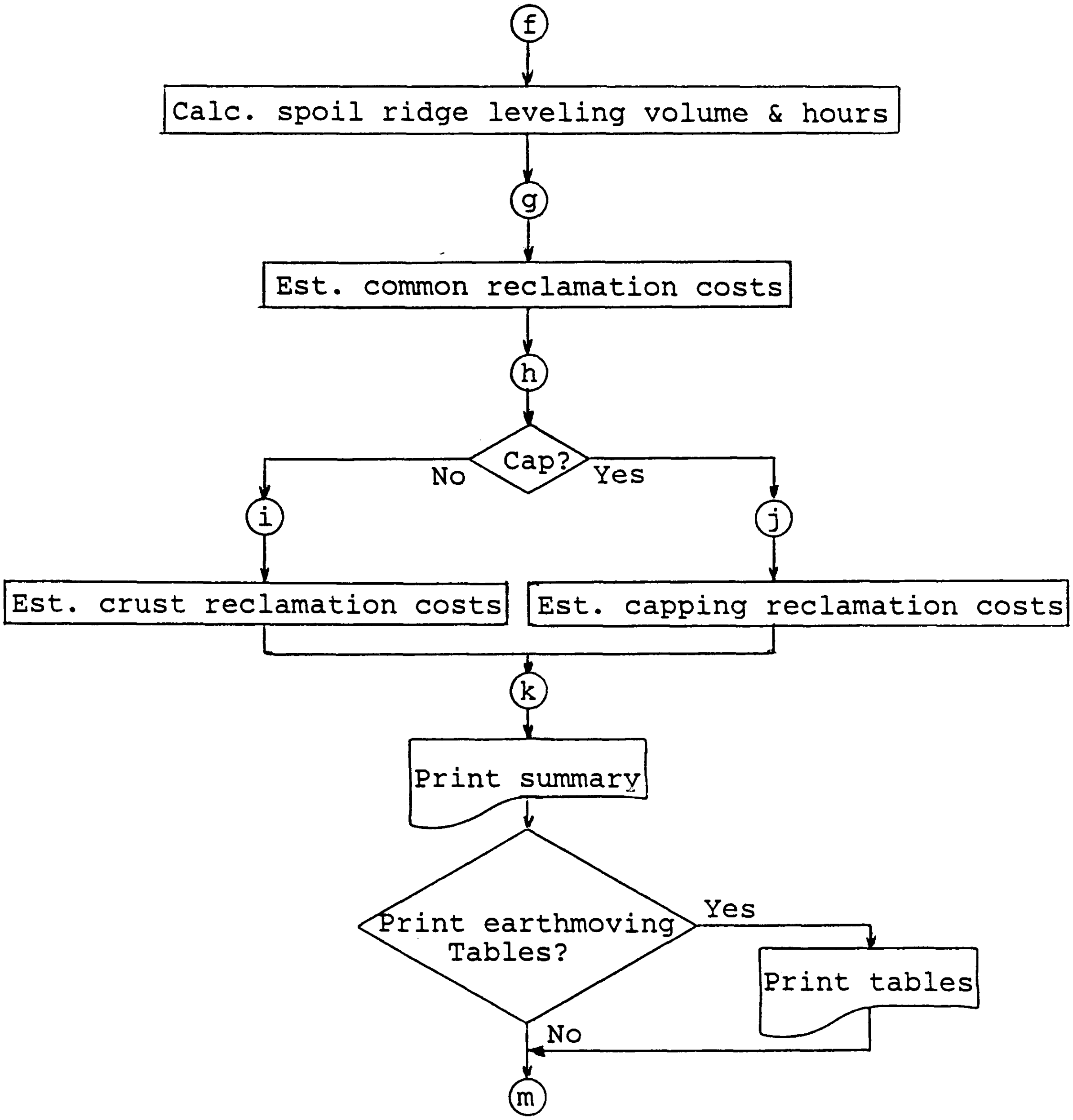


Figure 6. SETREC General Flowchart - Continued

Table 3. VARIABLE LIST: SETREC

Input Variables

AREANM$ and AREALOC$ - Descriptive name and location of settling area
SLIMES - Elevation of clays/topsoil
SLIMESAC - Operating acreage of clays including spoil ridges
NOSPILLS% - Number of permanent spillways
CRESTEL - Elevation of crest road
I%(i) - Number of dam segments
J%(i) - Number of spoil ridges
STAN(i), STAE(i) - Starting north and east segment coordinates
STNGL(i) - Outside natural ground levels at start of segment
CW(i) - Segment crest width
HO(i) - Segment outside dam slope (H:V)
HI(i) - Segment inside dam slope (H:V)
BO(i) - Segment horizontal distance between dam centerline and outside permanent feature
SPOILEL(i) - Spoil ridge crest elevation
SPOILCW(i) - Spoil ridge crest width
SPOILEN(i) - Spoil ridge length
SHO(i) - Spoil ridge slopes (H:V)
RECLAIM$ - Method of reclamation
HR - Maximum grade limitation
CONSOL - amount of clay consolidation
DIVFT - Length of diversion ditching
IDITPAC - Length of ditch/acre across clays
COMP - amount of clay compaction by sand cap
SAND - Thickness of sand cap
SANDA - Percentage of clays capped with sand
MILES - Tailings pumping distance
SOILCAP - Thickness of topsoil on cap
TIDAM% - Tilling on dam/spoil ridges (Yes/No)
LIDAM% - Liming dam/spoil ridges/cap (No. Applications)
SEDAM% - Seeding dam/spoil ridges/cap (No. Applications)
FEDAM% - Fertilizing dam/spoil ridge/cap (No. Applications)
TREES - Percent of dam/spoil ridge/cap forested
CHSLIM% - Chopping clays (Yes/No)
TISLIM% - Tilling on clays (Yes/No)
LISLIM% - Liming clays (No. Applications)
SESLIM% - Seeding clays (No. Applications)
FESLIM% - Fertilizing clays (No. Applications)
BULL$ - Standard bulldozer name
M, N - Standard bulldozer performance coefficients
BULLCST - Standard bulldozer cost/hour (include operator)

Table 3. VARIABLE LIST : SETREC - Continued

LGPBULL$ - Low Ground Pressure (LGP) bulldozer name
LGPM, LGPN - LGP bulldozer production coefficients
LGPCST - LGP bulldozer cost/hour (include operator)
DITCH$ - Standard ditching equipment name
DIT - Standard ditching equipment productivity, BCY/Hr.
DITCST - Standard ditching cost/hour (include operator)
LGPDITCH$ - LGP ditching equipment name
LGPDIT - LGP ditching equipment productivity, Ft. ditch/Hr.
LGPDITCST - LGP ditching equipment cost/hour
SCRAP$ - Scraper name
SM, SN - Scraper production coefficients
SCST - Scraper cost/hour (include operator)
PIPE$ - Pipeline name
PBCY - Pipeline pumping rate, BCY/Hr.
YARDMI - Pumping cost/BCY-Mile
TSPILLCST - Temporary spillway installation cost
RSPILLCST - Spillway removal cost
CHOP - Chopping cost/acre
TILL - Tilling cost/acre
LIME - Liming cost/acre-application
SEED - Seeding cost/acre-application
FERT - Fertilizing cost/acre-application
TREEP - Tree planting cost/acre

Calculated Output Variables

SOILCAPA - Area of clays
CAPA - Area of sand cap
SOILVOL - Volume of topsoil required
SOILBOR - Volume of topsoil hauled in to meet soil requirements
SPOILBOR - Volume of topsoil borrowed from spoil ridges
DAMBOR - Volume of topsoil borrowed from dam
TAILVOL - Volume of sand in cap
TAILPUSH - Volume of sand pushed for leveling of cap
CAPTOT - Length of perimeter ditch
TOTDAM - Total volume of dam material moved to meet grade
TOTBOR - Volume of material hauled in to meet grade requirements on the dam
TOTSPOIL - Total volume of spoil ridge material moved to meet grade
S%(i) - Dam segment identification number
CASE%(i) - Dam segment configuration (see Figure 4)
DAML(i) - Dam segment length

Table 3. VARIABLE LIST: SETREC - Continued

NGL(i) - Average segment natural ground level at outside toe
BOUNDED$ - Flag to indicate permanent feature impacted
HRI(i) - Dam reclaimed slope (H:V)
VTOE(i) - Volume of dam segment pushed to the outside
DTOE(i) - Segment average push distance to the outside
VCAP(i) - Volume of dam segment pushed on clays/cap
DCAP(i) - Segment average push distance on clays/cap
VHAUL(i) - Volume of material hauled in to meet grade requirements on the dam
VSPOIL(i) - Volume of spoil ridge pushed to meet grade requirements
DSPOIL(i) - Spoil ridge average push distance
BULLHR, DAMCST - Dam earthmoving equipment hours and cost
BOFLAG% - Flag to create error message in summary if minimum grades cannot be met
LGPHR, SPOILCST - Spoil ridge earthmoving hours and cost
TSPILL - Temporary spillway cost
RSPILL - Spillway removal cost
DIVHR, DIVCST - Diversion ditching hours and cost
PERHR, PERCST - Perimeter ditching hours and cost
IDITHR, IDITCST - Ditching across clay equipment hours and cost
PUMPHR, PUMPCST - Sand pumping hours and cost
CONTHR, CONTSCT - Cap leveling hours and cost
SPOILHR, SPOILBORCST - Spoil ridge borrowing for topsoil equipment hours and cost
DAMBORHR, DAMBORCST - Dam borrowing for topsoil equipment hours and cost
SOILHR, SOILCST - Total topsoil borrowing equipment hours and cost
DAMCHCST - Chopping cost on the dam/spoil ridges
DAMTICST - Tilling cost on the dam/spoil ridges
DAMLICST - Liming cost on the dam/spoil ridges
DAMSECST - Seeding cost on the dam/spoil ridges
DAMFECST - Fertilizing cost on the dam/spoil ridges
TREECST - Tree planting cost on the dam/spoil ridges
DAMREVCST - Total revegetation cost on the dam/spoil ridges
SLCHCST - Chopping cost on the clays
SLTICST - Tilling cost on the clays
SLLICST - Liming cost on the clays
SLSECST - Seeding cost on the clays
SLFECST - Fertilizing cost on the clays
SLREVCST - Total revegetation cost on the clays
TOTREV - Total revegetation cost
TOTREC - Total reclamation cost

Table 3. VARIABLE LIST: SETREC - Continued

General Variables

C% - SETREC Program option choice
X% - Message positioning variable
IZ%, IA%, IZ$, V, D - Dummy variables
TITLE$ - Screen header title
MESS$ - Screen message
FLNM$ - Settling area input file name
EQUIP$ - Equipment input file name
LEN(i) - Length of input file name

Calculation Variables

PRO - Proportioning variable
A - Quadratic equation second order variable coefficient
B - Quadratic equation first order variable coefficient
D - Quadratic equation constant
RAD - Quadratic equation, value under the radical
VTRAP - Quadratic equation root
VM - Quadratic equation, upper limit to root
DELTAEL - Difference between operating elevation and elevation of the clays/topsoil at reclamation
DAMAC - Area of dam, spoil ridges, and cap at reclamation
A1%, A3% - Dummy variables for calculation of angles between dam segments
ND, ED - North and east distances over dam segment
ANGL(i) - Segment bearing from north
ANGLE - Angle between adjacent dam segments
DCAPL, DTOEL - Incremental change in cap/toe fill lengths due to angle between adjacent segments
LENG - Dam segment length before dissecting
DELTA - Change in the natural ground level over the length of the dam segment
STLOC, ENLOC - Segment starting and ending point variables for dissecting dam segments into like configurations
SNGL, ENGL - Segment starting and ending natural ground level variables for dissecting dam segment into like configurations
DELTA1 - Segment change in natural ground levels for dissecting dam segment into like configurations
K1% - Number of dissected dam segments
CEL(i) - Segment crest elevation
CWI(i) - Segment crest width
TOEL(i) - Segment outside toe fill length

Table 3. VARIABLE LIST: SETREC - Continued

CAPL(i) - Segment clay/cap fill length
FLAG2% - Flag to indicate Case 2 dam configuration
BI - Horizontal distance from the dam centerline to the clay/topsoil and dam contact
X - Horizontal distance between permanent feature and the tip of the outside toe fill
X2 - Horizontal distance between the dam centerline and the outside tip of the toe fill
VFB - Vertical distance between dam crest and clays/topsoil
VF - Vertical distance between clays/topsoil and natural ground level
CS - Width of struck off dam
VW - Height of outside dam toe fill
A1, A1V - Area and volume of dam cut
A2, A2V - Area and volume of outside toe fill
VCUT - Total volume of cut
VU - Vertical distance between struck dam and intersection of outside dam cut and side of the dam
ATR - Triangular cross section represented by VU-amount of additional cutting due to permanent feature impact
R1 - Horizontal distance between dam centerline and centroid of dam cut
HS - Outside slope created by striking dam (H:V)
A3 - Parallelogram area created on clays with a Case 2 configuration
VBAL - Vertical distance for a balanced cut-and-fill, Case 3
ABALCUT - Area for a balanced cut-and-fill, Case 3
DBAL - Push distance for a balanced cut-and-fill, Case 3
DELTAC - Incremental change in clay area due to consolidation/compaction
BCYPHR - Calculated equipment productivity, BCY/Hr.
EQHR - Equipment hours
SPOILVOL - Available spoil ridge material for topsoil robbing
DAMVOL - Available dam material for topsoil robbing
DDPOIL - Scraper haulage distance from spoil ridge
DDAM - Scraper haulage distance from dam for topsoil
DTAILPUSH - Average sand push distance to level cap

It was found that certain equations were used many times in the model, so these equations were set up as user defined functions in SETREC and will be referred to when presenting equations later in this chapter.

There are four user defined functions which will calculate the area of a trapezoid, the horizontal distance from the center of its top to the trapezoid centroid, the area of an acute triangle, and the horizontal distance from the triangle centroid to its upper point. The equations for these functions are listed below along with supporting Figure 7. Everytime the program encounters a user defined function name, it will substitute the variable list in the parenthesis for the variable list in the function specification below.

1. Area of a Trapezoid:

$$FNTRAPA(H1,WID,H2,VFB) = VFB \times [WID + VFB \times (H1 + H2)/2]$$

2. Horizontal Distance from Center of Top to Trapezoid Centroid:

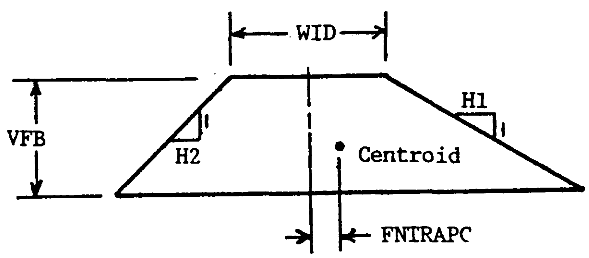
$$FNTRAPC(H1,WID,H2,VFB) = VFB \times \{(H1 - H2) \times [WID/2 + VFB \times (H1 + H2)/3]\}/[2 \times WID + VFB \times (H1 + H2)]$$

3. Area of an Acute Triangle:

$$FNTRIA(VT,FLATSLOPE,STEEPSLOPE) = VT^2 \times (FLATSLOPE - STEEPSLOPE)/2$$

4. Horizontal Distance from Acute Triangle Centroid to

(a)



(b)

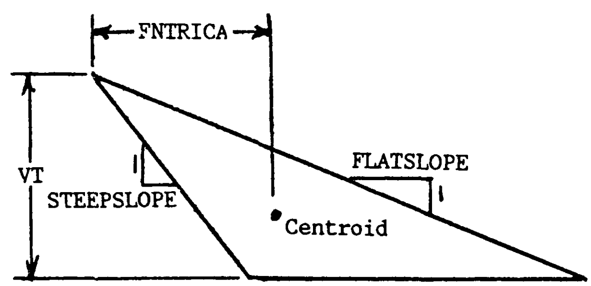


Figure 7. Figures for User Defined Functions (a) Trapezoid and (b) Acute Triangle

Upper Point:

FNTRICA(VT,FLATSLOPE,STEEPSLOPE) =

VTx(FLATSLOPE + STEEPSLOPE)/3

Calculate Segment Angles and Break Dam into Like Case

As indicated in the literature search, to reclaim the dam structure, it must be struck at the lowest possible elevation, whether at the level of the the consolidated clays, the level of the topsoil when capping, or the outside Natural Ground Level (NGL). The amount of material that will be moved, the direction of its movement, and the distance moved will be dependent upon the elevation of this strike and the dimensions of the dam structure. Thus, it is likely that some of the dam segments defined in the input file will have two or even three different sets of earthmoving requirements. These segments will have to be divided so that a single earthmoving requirement is specified for each segment.

Depending on the earthmoving requirements for an individual dam segment, material may have to be moved to the outside of the dam, the inside of the dam, or in both directions. The model estimates the volume for each location of fill by calculating the cross sectional area of the fill times the length of the fill. However, at each bend in the dam, the available space for fill at the outside and inside will increase or decrease depending on the angle of the bend. SETREC compensates for this change in volume by calculating the angle of the bend and then adjusting the length of each each fill location.

This part will determine the elevation of the clays or topsoil at the time of reclamation, the angle between adjacent dam segments, and then further divide the dam segments so that a single earthmoving requirement is specified per segment. Then, average dimensions for each small segment will be calculated to be used later for estimating dam earthmoving volumes. Figure 8 is the detail flow chart for this part.

Elevation of Clays/Topsoil at Reclamation. Adjust the operating elevation of the pond to the elevation at the time of reclamation.

1. Crust: SLIMES = SLIMES - CONSOL

   Capping: SLIMES = SLIMES - COMP + SAND + SOILCAP

Calculate Angles Between Segments. Identify three sets of N-E coordinates describing two adjacent dam segments (Segments 1 and 2 are used as examples in Figure 9):

2. Calculate north and east displacement for each segment:

   Segment 1: ND = STAN(2) - STAN(1)

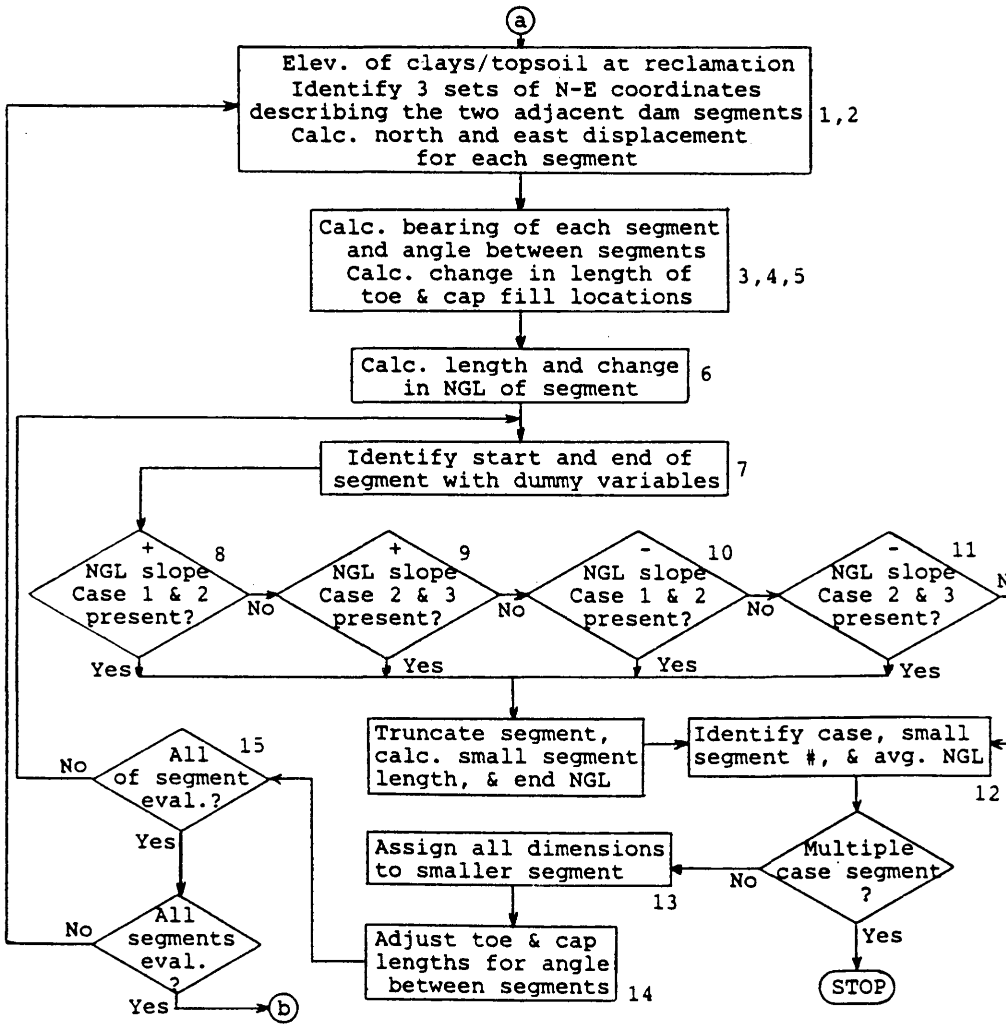


Figure 8. Flowchart: Calculate Segment Angles and Break Dam into Like Cases

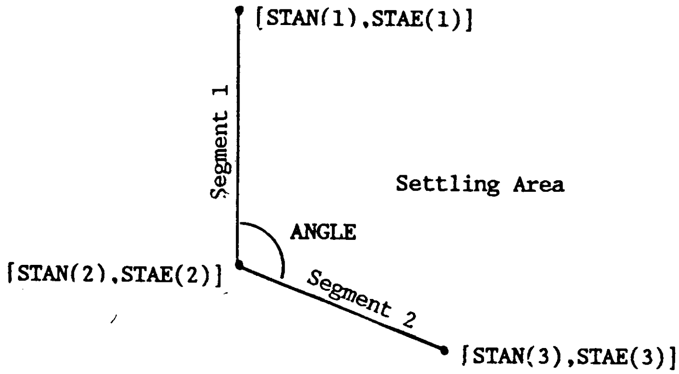


Figure 9. Defining Angle Created by Adjacent Segments

ED = STAE(2) - STAE(1)

Segment 2: ND = STAN(3) - STAN(2)

ED = STAE(3) - STAE(2)

3. Calculate bearing of each segment:

    ANGL(1) = 3.14/2

    If ND ≠ 0 Then 1st Quadrant

    ANGL(1) = Arctan |ED/ND|

    If ED => 0 and ND < 0 Then 2nd Quadrant

    ANGL(1) = 3.14 - ANGL(1)

    If ED < 0 and ND <= 0 Then 3rd Quadrant

    ANGL(1) = 3.14 + ANGL(1)

    If ED < 0 and ND => 0 Then 4th Quadrant

    ANGL(1) = 2x(3.14) - ANGL(1)

4. Calculate angle between segments:

    ANGLE = ANGL(2) - ANGL(1)

5. Calculate the change in length of the outside and

inside fill locations:

DTOEL = (3.14 - ANGLE)x{CW(1)/2
+ HO(1)x[CRESTEL - NGL(1)]}

DCAPL = (ANGLE - 3.14)x[CW(1)/2
+ HI(1)x(CRESTEL - SLIMES)]

Break Dam Segments into Like Cases. There are three possible dam configurations each which exhibit different earthmoving requirements (See Figure 10).

Case 1 is a typical elevated impoundment structure where the elevation of the crust/cap is above the elevation of the natural ground level. The top drawing shows the ideal situation where the earthmoving cost is minimized by proportioning the material pushed to the outside toe of the dam and onto the crust/cap so that a minimum number of machine hours are required. Settling areas are often bordered by permanent features which cannot be impacted by reclamation, such as rights-of-way, roads, and protected watersheds. As a result, it may not be possible to achieve the ideal material balance due to the close proximity of a permanent feature as shown in the second drawing for Case 1. Then, more struck material will have to be pushed onto the crust/cap than would normally be desired. For both situations, the overburden being pushed onto the clays/cap is assumed to be 3-feet thick. Three feet of overburden is

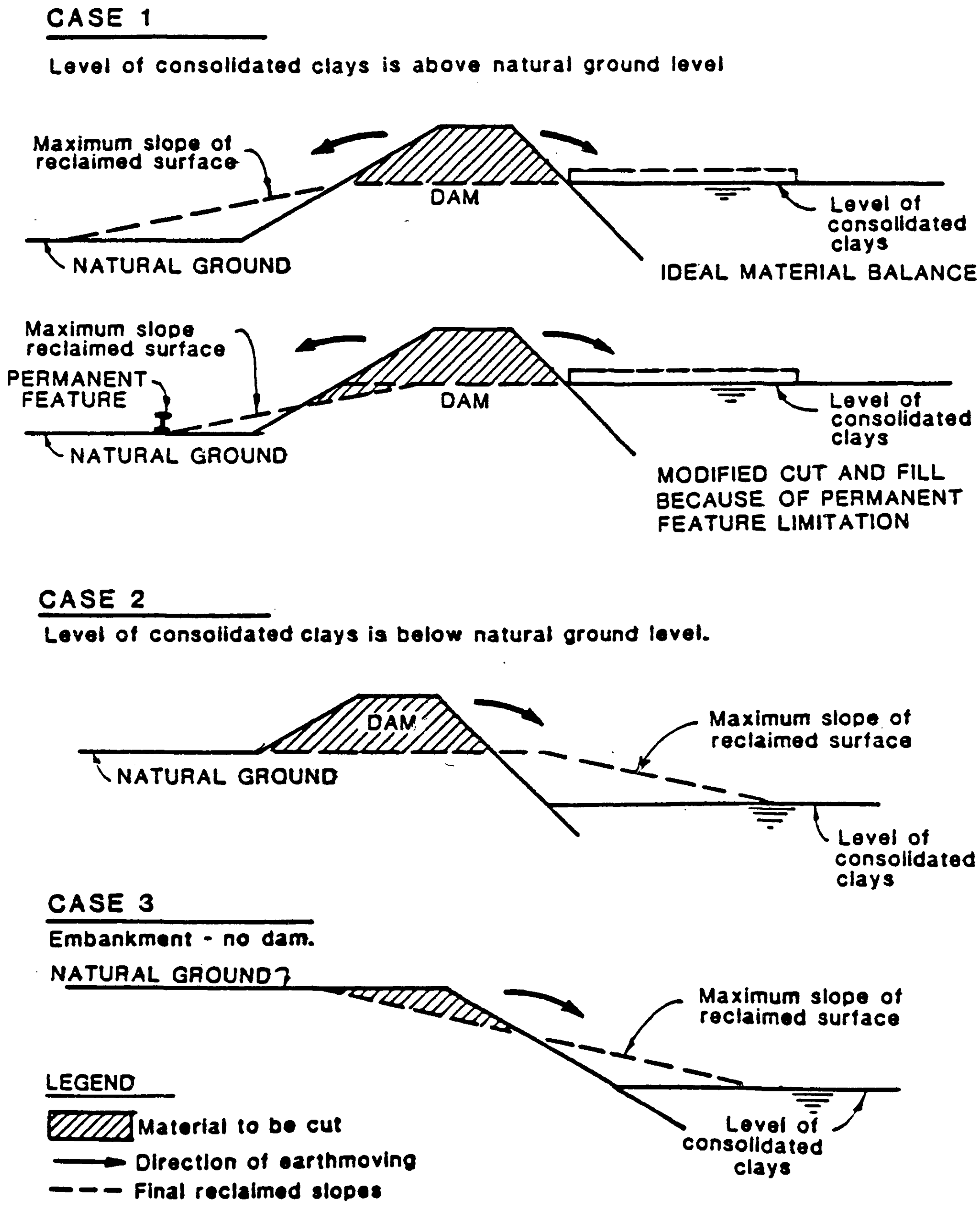


Figure 10. Reclamation Earthmoving for Three Dam Configurations (Zellars-Williams, Inc., 1983)

considered the minimum thickness for bulldozer traction and still achieve a struck dam profile.

Case 2 represents the situation where there is a dam structure, but the level of the clays/cap is below the natural ground level. In this case, the dam is struck at the natural ground level and pushed onto the clays/cap while maintaining the maximum allowable slope, but no material is pushed to the outside of the dam.

Case 3 represents an embankment, the level of the clays/cap is lower than the natural ground level and there is no dam structure. In such a case, a balanced cut-and-fill is performed to achieve the allowable grade.

In level terrain with an elevated settling area, only Case 1 would apply for the whole settling area. However, if the settling area is located on the side of a hill, all three configurations would be represented in the evaluation.

The following equations will check each dam segment to see if more than one case exists. If so, then the model will truncate the segment so that only one case is represented. Average dimensions will then be calculated for the one case segment. If any of the segment remains, it will resume the evaluation, otherwise, it will start on the next segment.

6. Calculate length and change in NGL of segment: See Figures 11 and 12

$$LENG = \sqrt{(ND)^2 + (ED)^2}$$

$$DELTA = |NGL(3) - NGL(2)|$$

7. Identify start and end of segment with dummy variables:

STLOC = 0 ; ENLOC = LENG

STNGL = NGL(2) ; ENGL = NGL(3)

8. Positive NGL slope and Case 1 & 2?

If SNGL < SLIMES < ENGL ; Pos. slope & break point 1

Truncate segment, calculate small segment length, & ENGL

ENGL = SLIMES

ENLOC = STLOC + (SLIMES - SNGL)xLENG/DELTA

9. Positive NGL and Case 2 and 3?

If SNGL < CRESTEL < ENGL ; Pos. slope & break point 2

Truncate segment, calculate small segment length, & ENGL

ENGL = CRESTEL

ENLOC = STLOC + (CRESTEL - SNGL)xLENG/DELTA

10. Negative slope and Case 1 and 2?

If SNGL > SLIMES > ENGL ; Neg. slope & break point 3

Truncate segment, calculate small segment length, & ENGL

ENGL = SLIMES

ENLOC = STLOC + (SNGL - SLIMES)xLENG/DELTA

11. Negative slope and Case 2 & 3?

If SNGL > CRESTEL > ENGL ; Neg. slope & break point 4

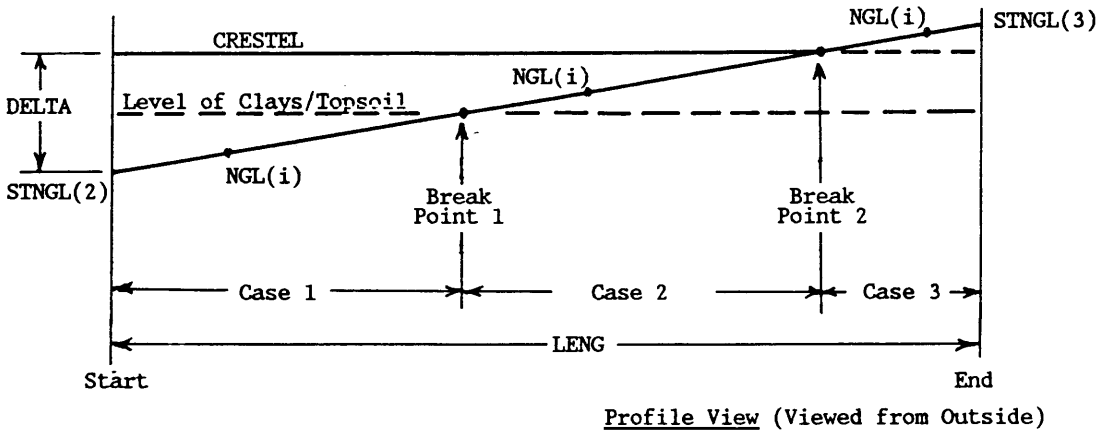


Figure 11. Breaking Dam Segment into Like Cases: Positive NGL Slope

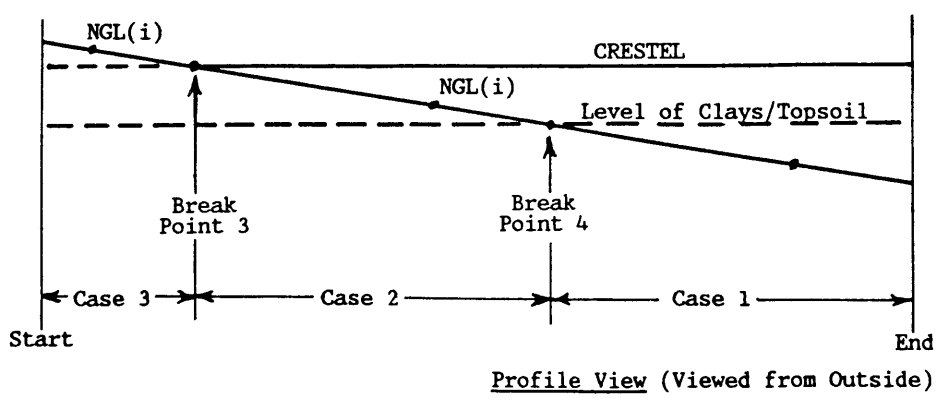


Figure 12. Breaking Dam Segment into Like Cases: Negative NGL Slope

Truncate segment, calculate small segment length, & ENGL

ENGL = CRESTEL

ENLOC = STLOC + (SNGL - CRESTEL)xLENG/DELTA

12. Identify case, small segment number, and average NGL

(NGL at centroid of outside fill)

Positive slope and Case 1:

If SNGL <= ENGL <= SLIMES

Then Case% = 1 and NGL(2) = SNGL +(ENGL-SNGL)/3

Positive slope and Case 2:

If SNGL <= ENGL <= CRESTEL and SNGL => SLIMES

Then CASE%(2) = 2 and NGL(2) = SNGL + (ENGL-SNGL)/3

Positive slope and Case 3:

If CRESTEL <= SNGL <= ENGL

Then CASE%(2) = 3 and NGL(2) = ENGL - (ENGL-SNGL)/3

Negative slope and Case 1:

If ENGL <= SNGL <= SLIMES

Then CASE%(2) = 1 and NGL(2) = ENGL + (SNGL-ENGL)/3

Negative slope and Case 2:

If ENGL <= SNGL <= CRESTEL and SLIMES <= ENGL

Then CASE%(2) = 2 and NGL(2) = ENGL + (SNGL-ENGL)/3

Negative slope and Case 3:

If CRESTEL <= ENGL <= SNGL

Then CASE%(2) = 3 and NGL(2) = SNGL - (SNGL-ENGL)/3

13. Assign all dimensions to smaller segment:

    S%(i) = 2 ; Example input segment number

    CEL(I) = CRESTEL ; Segment crest elevation

    CWI(i) = CW(2) ; Segment crest width

    DAML(i) = ENLOC - STLOC = TOEL(i) = CAPL(i) ;

        Segment cut & fill lengths

14. Adjust toe and cap lengths for angle between segments:

    If STLOC = 0 Then adjust lengths of fill locations

    TOEL(i) = TOEL(i) + DTOEL

    CAPL(i) = CAPL(i) + DCAPL

15. All of segment evaluated?

    If ENLOC ≠ LENG Then segment not completely evaluated.

    STLOC = ENLOC

    ENLOC = LENG

    SNGL = ENGL

    ENGL = STNGL(3)

Calculate Clay Acreage

Revegetation estimates use the acreage of clays at the time of reclamation. This will require reducing the operating acreage of clays by the area of any exposed spoil ridges and the area of additional dam slope exposed as a result of consolidation of the clays. Then the area of the sand cap can be estimated if the Sand Capping Method is employed. Figure 13 shows the detail flowchart for these

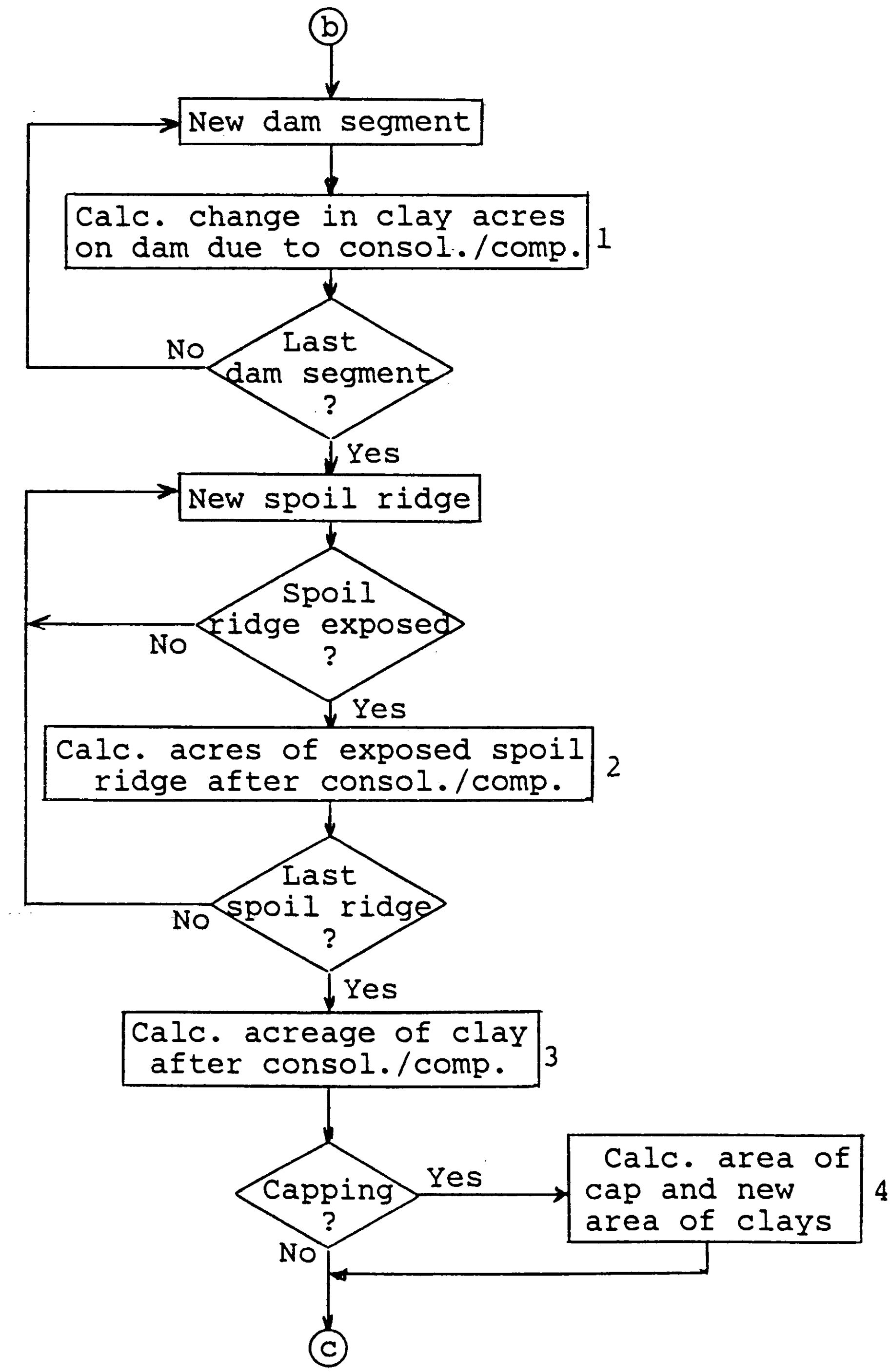


Figure 13. Flowchart: Calculating Clay Acreages

calculations along with the equations.

1. Calculate change in clay acres on dam due to consolidation/compaction:

$$DELTAC = \sum_{i=1}^{K1\%} \{CAPL(i)xHI(i)xDELTAEL\}$$

2. Calculate acres of exposed spoil ridge after consolidation/compaction:

$$DELTAC = DELTAC + \sum_{i=1}^{J\%} \{SPOILEN(i)x[SPOILCW(i) + 2xSHO(i)xVFB]\}$$

3. Calculate acres of clay after consolidation/compaction:

$$SOILCAPA = SLIMESAC - DELTAC$$

4. Calculate area of cap and new area of clays:

$$CAPA = SANDAxSOILCAPA/100$$

$$SOILCAPA = SOILCAPA - CAPA$$

Calculate Topsoil Requirements

When reclaiming with the Sand Capping Method, a topsoil layer will be produced on the cap. This part will estimate the volume required to create the topsoil and the volumes of material robbed by location to meet this need. Robbing activities will begin with exposed spoil ridges, then the dam, and if further material is needed, the remainder will be hauled in. This will reduce the spoil ridges and dam so that their new dimensions will have to be calculated along with the average haulage distances from both.

When reducing the profile of the spoil ridges and dam segments, a quadratic equation is used to estimate the height of the cut. The model will evaluate each root and choose the one which is positive and not greater than the amount available for robbing. If the user inputs dimensions that are absurd, the calculated roots may be irrational or outside of reasonable limits. The program will check for the following problems when using the quadratic equation: second order coefficient = 0, irrational numbers (negative radical), both roots negative, or both roots out of bounds. If such a problem is discovered, the program will stop operation and list the type of calculation being performed and the input dam segment it was working on when the problem developed. The quadratic equation is used in three other calculations and performs the same functions for these evaluations as well.

The model uses scrapers to perform the topsoil robbing. Scrapers are cyclic equipment, thus their productivity like other cyclic earthmoving equipment, is dependent upon the haulage distance. The haulage distance is calculated to be the distance between the centroid of the cut to the centroid of the fill location. Earthmoving equipment productivity was estimated from graphs in the Caterpillar Performance

Handbook, 15th Edition. These graphs can be represented by the following exponential equation.

$$BCY/Hour = M(\text{One Way Haulage Distance})^N$$

M and N are calculated coefficients representing the productivity of a particular piece of equipment. Once the required number of machine hours has been estimated, the earthmoving cost can be calculated based on the equipment cost per hour.

Figure 14 shows the detail flowchart for the calculations to estimate topsoil requirements.

1. Calculate volume in exposed spoil ridges:

   When SPOILEL(i) > SLIMES

   SPOILVOL =

   $$\sum_{i=1}^{J\%}\{SPOILEN(i) x FNTRAPA[SHO(i),SPOILCW(i),SHO(i),VFB]\}$$

2. Calculate required topsoil volume:

   SOILVOL = CAPA x SOILCAPA/27

3. Enough in spoil ridges for topsoil?

   If SOILVOL < SPOILVOL

   Then SPOILBOR = SOILVOL, borrow portion needed

   Else SPOILBOR = SPOILVOL, borrow all of spoil ridges

4. Calculate volume in dam above clay/topsoil level:

   Case 3: Skip

   Case 2: VFB = CEL(i) - NGL(i)

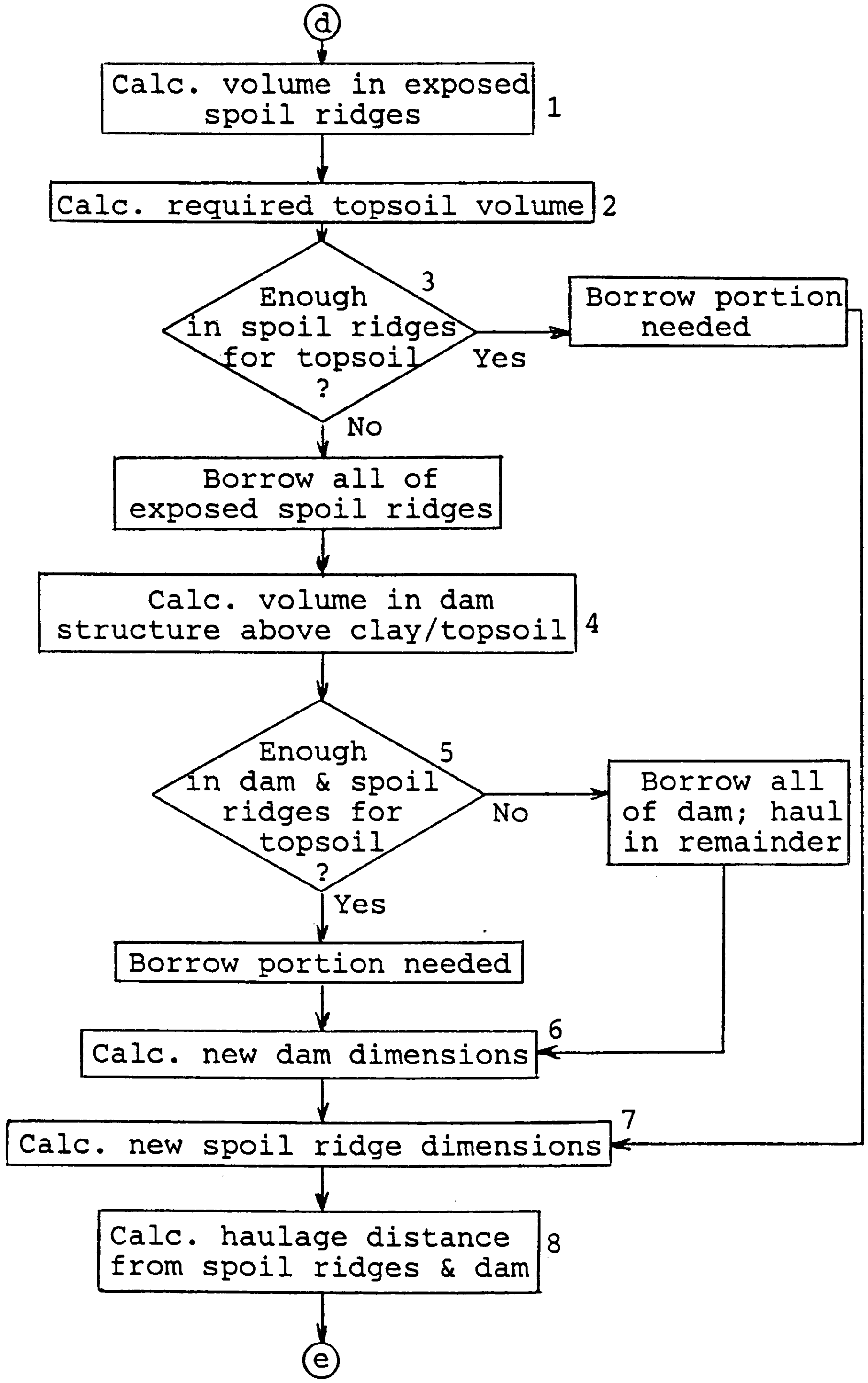


Figure 14. Flowchart: Calculating Topsoil Requirements

Case 1: VFB = CEL(i) - SLIMES

$$DAMVOL = \sum_{i=1}^{K1\%} \{DAML(i) x FNTRAPA[HO(i), CWI(i), HI(i), VFB]\}$$

5. Enough in dam & spoil ridges for topsoil requirements?

   If DAMVOL > SOILVOL - SPOILVOL

   Then DAMBOR = SOILVOL - SPOILVOL, borrow portion needed

   Else DAMBOR = DAMVOL, borrow all of dam

   SOILBOR = SOILVOL - SPOILVOL - DAMVOL

6. Calculate new dam dimensions

   Proportionally rob from all dam segments using quadratic equation (See Figure 15):

   PRO = DAMBOR/DAMVOL, proportion factor

   Calculate height of cut (VTRAP)

   Case 3: Skip

   Case 2: VM = CEL(i) - NGL(i), maximum cut height

   Case 1: VM = CEL(i) - SLIMES, maximum cut height

   Quadratic coefficients:

   A = [HO(i) + HI(i)]/2

   B = CWI(i)

   D = -PROxFNTRAPA[HI(i),CWI(i),HO(i),VM]

   If VM < VTRAP < 0 for both roots, then STOP

   Adjust dam segment dimensions:

   CEL(i) = CEL(i) - VTRAP

   CWI(i) = CWI(i) + VTRAPx[HO(i) + HI(i)]

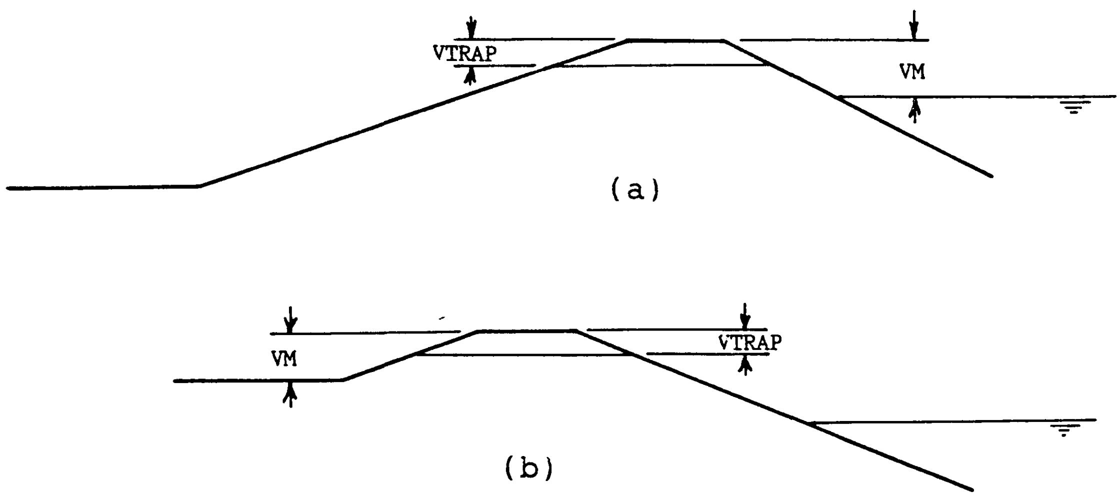


Figure 15. Robbing Topsoil from Dam
(a) Case 1 and (b) Case 2

7. Calculate new spoil ridge dimensions

Proportionally rob from all exposed spoil ridges using quadratic equation (See Figure 16):

PRO = SPOILBOR/SPOILVOL, proportion factor

Calculate height of cut (VTRAP)

VM = SPOILEL(i) - SLIMES, maximum cut height

Quadratic coefficients:

A = SHO(i)

B = SPOILCW(i)

D = PROxFNTRAPA[SHO(i),SPOILCW(i),SHO(i),VM]

If VM < VTRAP < 0 for both roots, then STOP

Adjust spoil ridge dimensions:

SPOILEL(i) = SPOILEL(i) - VTRAP

SPOILCW(i) = SPOILCW(i) + 2xSHO(i)xVTRAP

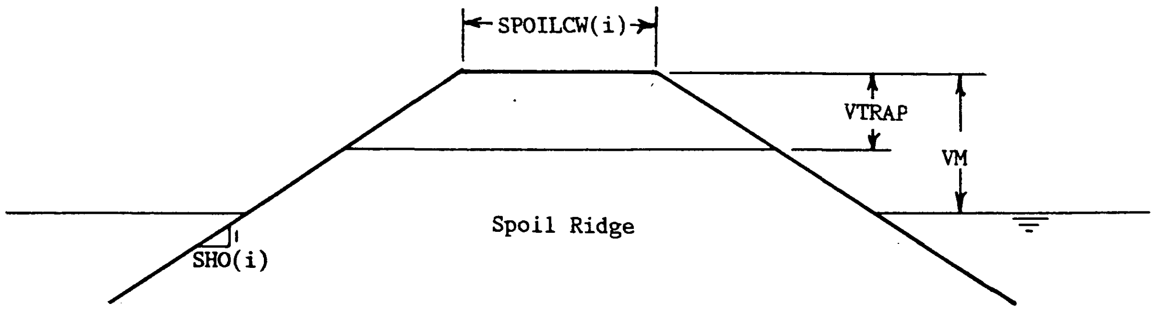


Figure 16. Robbing Topsoil from Spoil Ridges

8. Calculate haulage distances from spoil ridges and dam

Assumptions: See Figure 17

Scraper loading distance equals 200 feet.

The topsoil area is assumed circular

The inner area is to be supplied by the spoil ridges and the outer area by the dam

The average haulage distance from the spoil ridges is 200 feet + the radius which divides the spoil ridge deposition area in half.

$$DDPOIL = 200 + \sqrt{SPOILBOR x CAPA/(0.5 x SOILVOL x 3.14)}$$

The average haulage distance from the dam is 200 feet + the radius for the whole topsoil area - the radius which divides the dam deposition area in half.

$$DDAM = 200 + \sqrt{CAPA/3.14} - \sqrt{(1 - DAMBOR x 0.5/SOILVOL)/3.14}$$

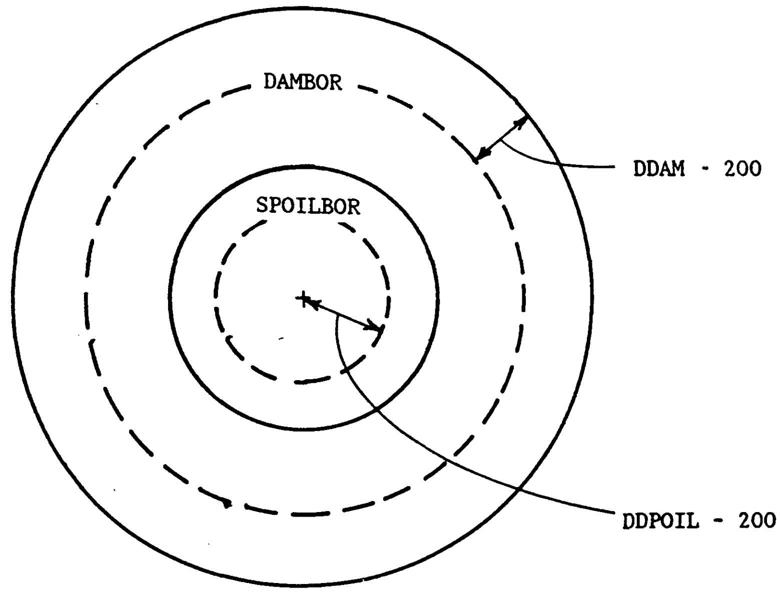


Figure 17. Haulage Distance for Topsoil Robbing

Calculate Dam Earthmoving Requirements

This part evaluates the earthmoving requirements by dam segment, then determines the required number of standard bulldozer hours, and calculates the acreage disturbed by the earthmoving activities. The earthmoving requirements will be dependent upon the dam configuration, dam dimensions, limitations to earthmoving due to permanent features, and shape of the settling area. These influencing factors can require a considerable amount of evaluation as indicated by the detail flowchart in Figure 18 and the large number of equations which follow. To better understand the implications of the earthmoving requirements, the program prints out an optional earthmoving summary listing the earthmoving volumes and push distances by dam segment.

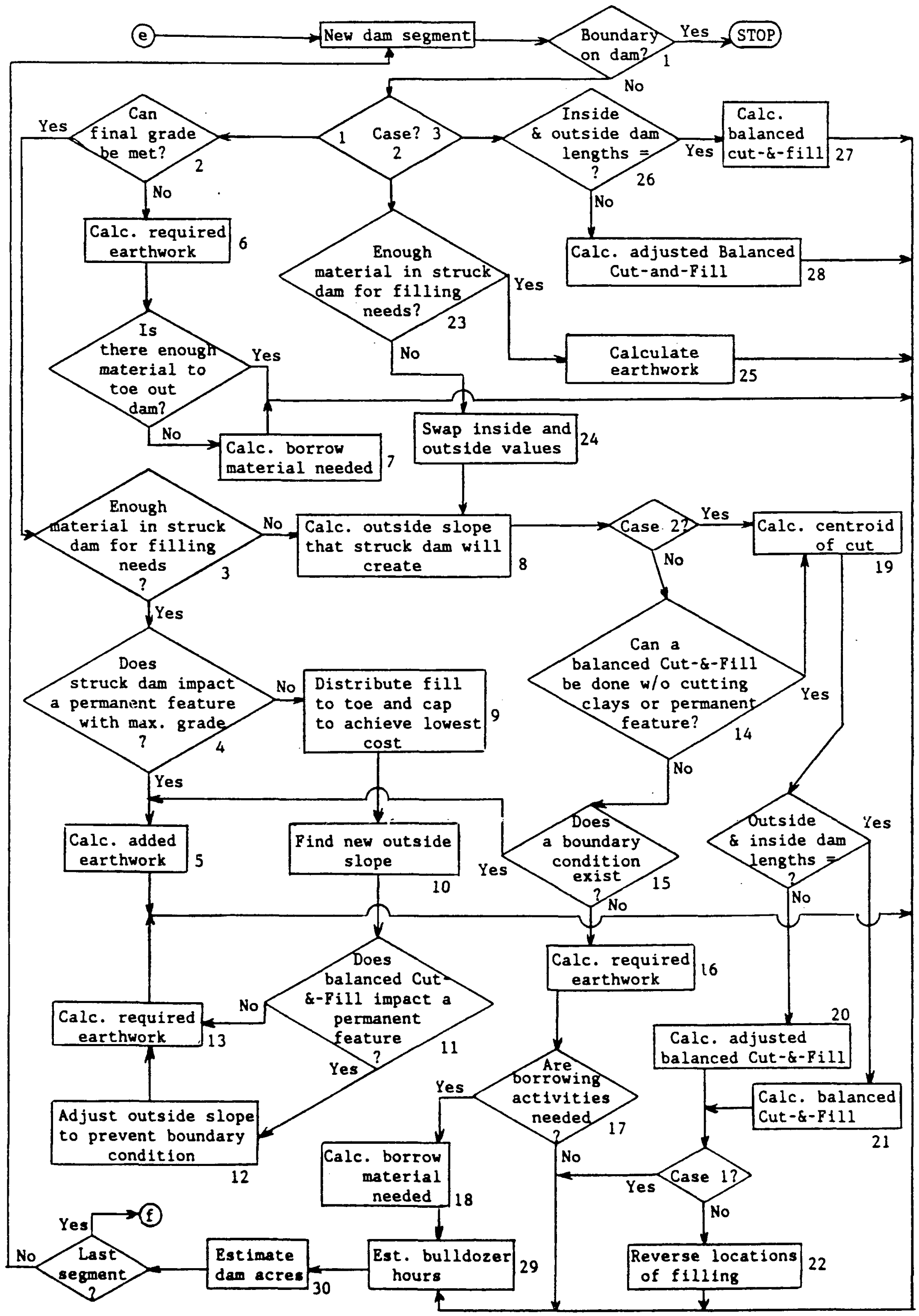


Figure 18. Flowchart: Dam Earthmoving Volume and Hours

For a case 1 configuration, if the dam is high and the maximum allowable grades are not steep, there may be insufficient material in the dam to meet the grade requirements. The model will calculate the volume needed but no cost will be applied to it.

1. Realistic boundary limit? (See Figure 19)

   If BO(i) < CWI(i)/2 + |CEL(i) - NGL(i)|xHO(i)

   Then permanent feature is on side of dam; STOP

2. Can final grade be met? (See Figure 19)

   VF = SLIMES - NGL(i), clays above natural ground

   VFB = CEL(i) - SLIMES, freeboard

   BI = CWI(i)/2 + VFBxHI(i), centerline to slimes

   CS = CWI(i) + VFBx[HO(i) + HI(i)], struck dam width

   If BO(i) + BI < VFxHR, then final grade cannot be met

3. Enough material in struck dam for filling needs? (See Figure 20)

   A1 = FNTRAPA[HO(i),CWI(i),HI(i),VFB], struck dam area

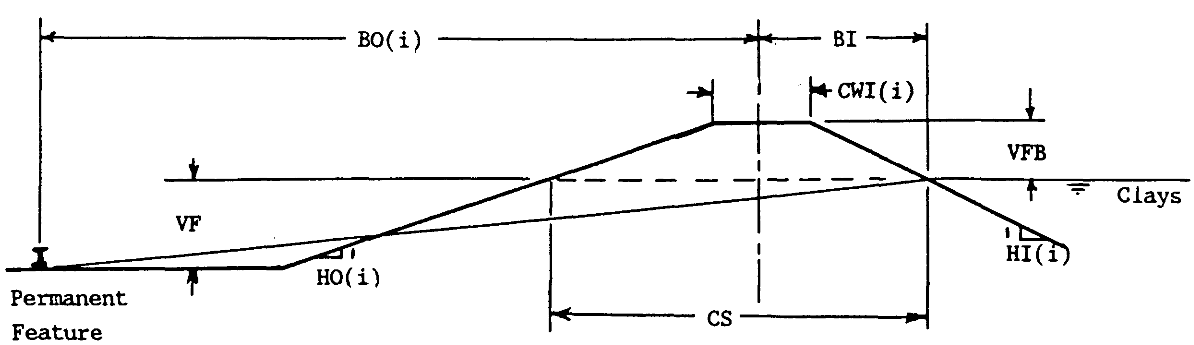


Figure 19. Case 1 Cross Section: Allowable Grade Met?

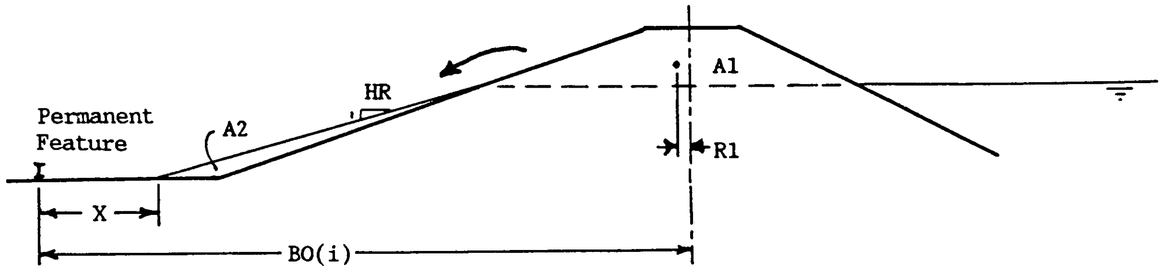


Figure 20. Case 1 Cross Section: Strike Dam to Outside

A1V = A1xDAML(i), struck dam volume

A2 = FNTRIA[VF,HRI(i),HO(i)], toe fill area

A2V = A2xTOEL(i), toe fill volume

If A1V < A2V Then insufficient material in struck dam to meet grade requirements

4. Does struck dam impact a permanent feature with maximum grade? (See Figure 20)

   VCUT = A1V/27, volume of cut

   R1 = FNTRAPC[HO(i),CWI(i),HI(i),VFB], struck dam centroid

   X = CWI(i)/2 + VFxHR + VFBxHO(i) - BO(i)

   If X <= 0 Then permanent feature not impacted

5. Calculate required earthwork: permanent feature impacted (See Figure 21)

   VU = X/[HR - HO(i)] ; ATR = FNTRIA[VU,HR,HO(i)]

   VCUT = (A1 + ATR)xDAML(i)/27, volume of dam cut

   VW = VF - VU, height of toe fill

   VTOE(i) = FNTRIA[VW,HR,HO(i)]xTOEL(i)/27

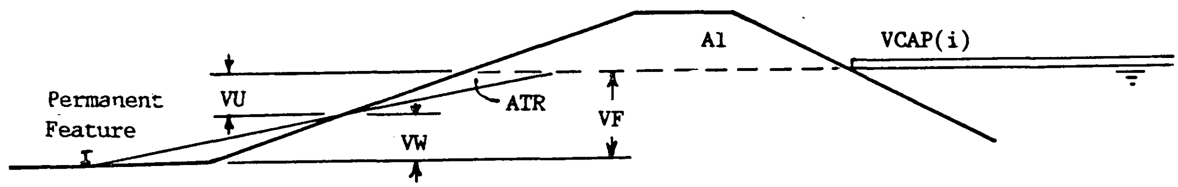


Figure 21. Case 1 Cross Section: Permanent Feature Impacts Outside Toe Filling

VCAP(i) = VCUT = VCAP(i), volume pushed on cap

DTOE(i) = FNTRICA[VW,HRI(i),HO(i)]

+ {FNTRICA[VU,HRI(i),HO(i)]xATR + A1x[CWI(i)/2

- R1 + HO(i)x(VFB + VU)]}/(A1 + ATR), toe push

If VCAP(i) > 0

Then DCAP(i) = VCAP(i)x9/CAPL(i) + CWI(i)/2 + R1

+ VFBxHI(i), cap pushing distance

6. Calculate required earthwork-final grade not met: (See Figure 19)

HRI(i) = (BO(i) + BI)/VF, grade achieved

VU = CS/[HRI(i) - HO(i)], height of cut below clays

VW = same as in 5 above, height of toe fill

A1 = same as in 3 above, area of struck dam

ATR = FNTRIA[VU,HRI(i),HO(i)], cut area below clays

VCUT = same as in 5 above

VTOE(i) = FNTRIA[VW,HRI(i),HO(i)]xTOEL(i)/27, toe

fill volume

VCAP(i) = same as in 5 above

R1 = same as in 4 above

DTOE(i) = same as in 5 above

If VCAP(i) > 0

Then DCAP(i) = same as in 5 above

7. Is there enough material to toe out dam?

If VCAP(i) < 0 Then insufficient material to toe out dam

VHAUL(i) = -VCAP(i), haul in required volume

8. Calculate outside slope that dam will create:

(See Figure 22)

HS = A1Vx2/(TOEL(i)xVFxVF) + HO(i)

9. Distribute fill to toe and cap to achieve lowest cost: Set up an algorithm to estimate required bulldozer hours, distributing material in increments from all to the toe to all to the cap so that the distribution which minimizes bulldozer hours can be estimated (Figure 23). Iterate algorithm from 0 to 50 where IZ% is the counter

D = VCUT/50, amount of increment

V = IZ%xD, volume to toe

DTOE(i) = CWI(i)/2 - R1 + VFBxHO(i)

+ VF/3x[54xV/(TOEL(i)xVFxVF) + 2xHO(i)]

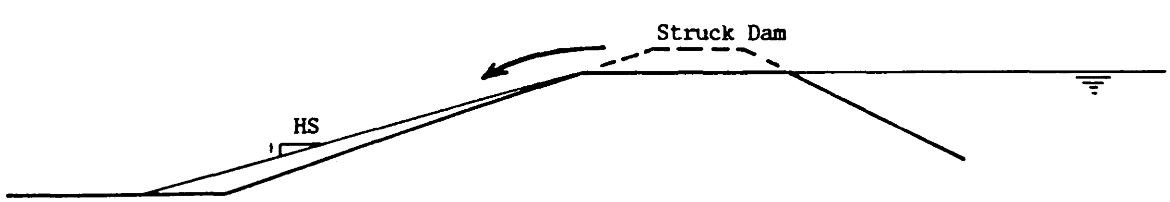


Figure 22. Case 1 Cross Section: Struck Dam Insufficient for Outside Filling

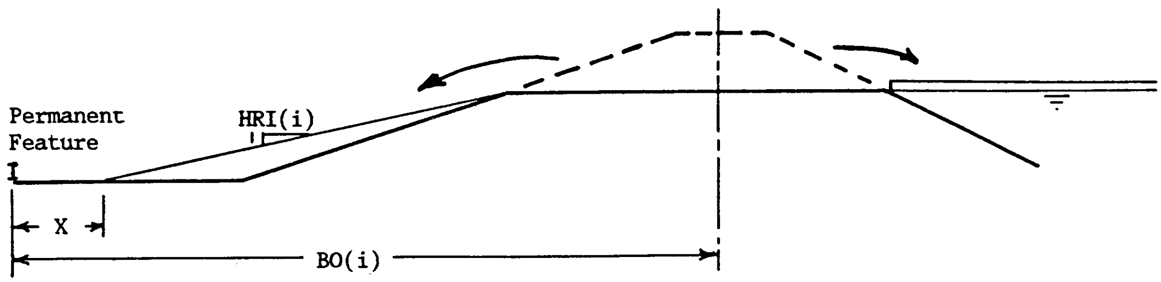


Figure 23. Case 1 Cross Section: Distributing Fill to Toe and Cap

If DTOE(i) < 50 Then DTOE(i) = 50

$$DCAP(i) = (VCUT - V)x9/CAPL(i) + CWI(i)/2 + R1 + VFBxHI(i)$$

If DCAP(i) < 50 Then DCAP(i) = 50

If DCAP(i) > 500 Then DCAP(i) = 500

$$FVTOE = V/[MxDTOE(i)]^{N} + (VCUT - V)/[MxDCAP(i)]^{N}, \text{ hours}$$

If FVTOE is smaller than previous iterations,

Then SMALL = FVTOE and VTOE(i) = V

10. Find new outside slope: (See Figure 23)

$$HS = VTOE(i)x54/[TOEL(i)xVFxVF] + HO(i)$$

If HS < HR Then VTOE(i) = A2V/27

11. Does a balanced cut-and-fill impact a permanent feature?

$$X = CWI(i)/2 + VFBxHO(i) + VFxHRI(i) - BO(i)$$

X > 0 Then a permanent feature is impacted

12. Adjust outside slope to prevent boundary condition:

$$HRI(i) = [BO(i) - CWI(i)/2 - VFBxHO(i)]/VF$$

$$VTOE(i) = FNTRIA[VF,HRI(i),HO(i)]xTOEL(i)/27$$

13. Calculate required earthwork:

VCAP(i) = same as 5 above

DTOE(i) = CWI(i)/2 - R1 + FNTRIA[VF,HRI(i),HO(i)] + VFBxHO(i)

DCAP(i) = same as 5 above

14. Can a balanced cut-and-fill be done without cutting clays or permanent feature? (See Figure 24)

X2 = CWI(i)/2 + VFBxHO(i) + VFx(HS + HR)/2

If VFx(HR - HS)/2 <= CS and X2 <= BO(i) Then balanced cut-and-fill cannot be performed

15. Does a boundary condition exist? (See Figure 24)

If X2 => BO(i) Then a permanent feature is impacted and

X = VFxHR - BO(i) + CWI(i) /2 + HO(i)xVFB

16. Calculate required earthmoving: (See Figure 21)

VU = CS/[HR - HO(i)]

VCUT = {A1 + FNTRIA[VU,HR,HO(i)]}xDAML(i)/27

VW = same as 5 above

VTOE(i) = FNTRIA[VW,HR,HO(i)]xTOEL(i)/27

VCAP(i) = same as 5 above

R1 = same as 4 above

DTOE(i) = CWI(i)/2 - R1 + HO(i)x(VFB + VU) + FNTRICA[VW,HR,HO(i)]

If VCAP(i) > 0 Then DCAP(i) = same as 5 above

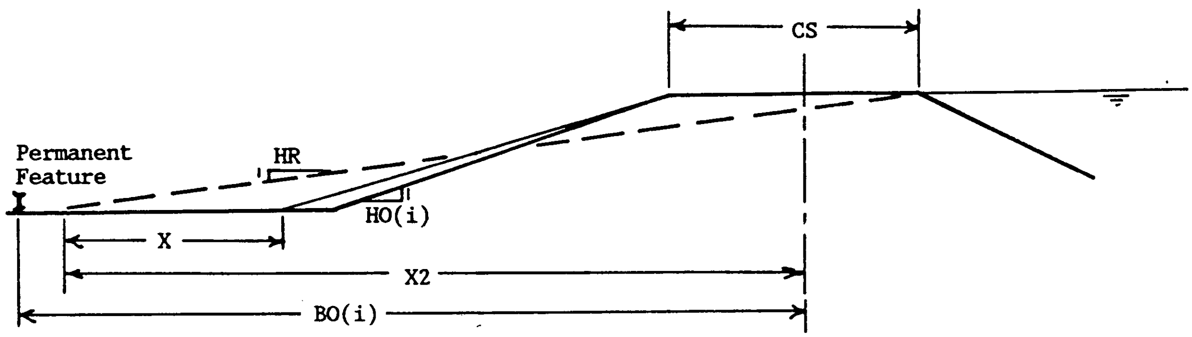


Figure 24. Case 1 Cross Section: Does a Balanced Cut-and-Fill Impact a Permanent Feature?

17. Are borrowing activities needed?

    If VCAP(i) < 0 Then insufficient material to toe out dam

18. Calculate borrow material needed:

    VHAUL(i) = -VCAP(i)

19. Calculate centroid of cut:

    R1 = same as 4 above

20. Calculate adjusted balanced cut-and-fill (Quadratic equation): (See Figure 25)

    Calculate height of cut (Quadratic equation)

    VM = VF, maximum cut height

    Quadratic coefficients

    A = [HR - HO(i)]x[DAML(i) - TOEL(i)]/2

    B = DAML(i)x[HO(i) - HR]xVF

    D = DAML(i)x[A1 + VFxVFx(HR - HO(i))]/2

    If VM < VTRAP < 0 for both roots, then STOP

    Calculate earthmoving requirements

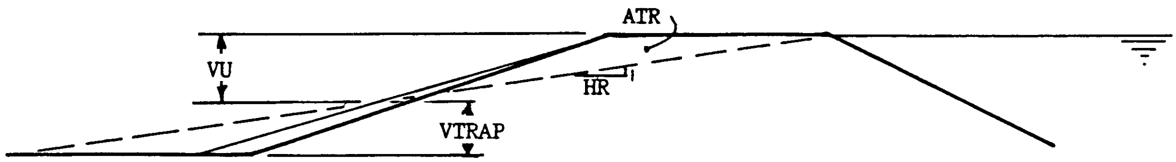


Figure 25. Case 1 Cross Section: Balanced Cut-and-Fill After Striking Dam

VU = VF - VTRAP, cut height below clays

ATR = FNTRIA[VU,HR,HO(i)]

DTOE(i) = same as 5 above

21. Calculate a balanced cut-and-fill: (See Figure 25)

VBAL = VF/2, height of cut

ABALCUT = FNTRIA[VBAL,HR,HS], area of cut

DBAL = FNTRICA[VBAL,HR,HS], average push distance

VTOE(i) = (A1 + ABALCUT)xDAML(i)/27

DTOE(i) = {ABALCUTx2xDBAL + A1x[CWI(i)/2 - R1 + HO(i)xVFB + VBALxHS + DBAL]}/(A1 + ABALCUT)

22. If Case 2, reverse fill locations:

VCAP(i) = VTOE(i)

DCAP(i) = DTOE(i)

VTOE(i) = DTOE(i) = 0

23. Enough material in struck dam for filling needs? (See Figure 26)

VF = NGL(i) - SLIMES

VFB = CEL(i) - NGL(i)

A1 = same as 3 above

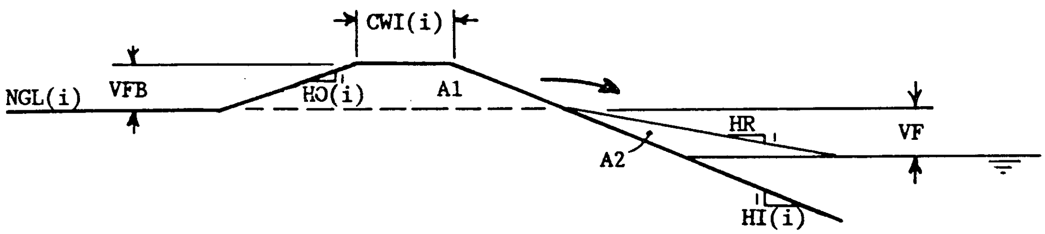


Figure 26. Case 2 Cross Section: Sufficient Material for Allowable Grade?

A1V = same as 3 above

A2 = FNTRIA[VF,HR,HI(i)]

A2V = A2xCAPL(i)

If A1V < A2V Then insufficient material in struck dam to meet grade requirements

24. Swap inside and outside values:

Swap HO(i) and HI(i)

Swap CAPL(i) and TOEL(i)

25. Calculate additional earthwork: (See Figure 27)

R1 = same as 4 above

A3 = (A1V - A2V)/CAPL(i)

If VF < 3 Then VF = 3, minimum cap thickness

DCAP(i) = R1 + CWI(i)/2 + VFBxHI(i) + {A3/2x[A3/VF
+ VFxHI(i)] + A2x[A3/VF
+ FNTRICA(VF,HRI(i),HI(i))]}xCAPL(i)/A1V

VCAP(i) = A1V/27

26. Inside and outside dam lengths equal?

VF = NGL(i) - SLIMES

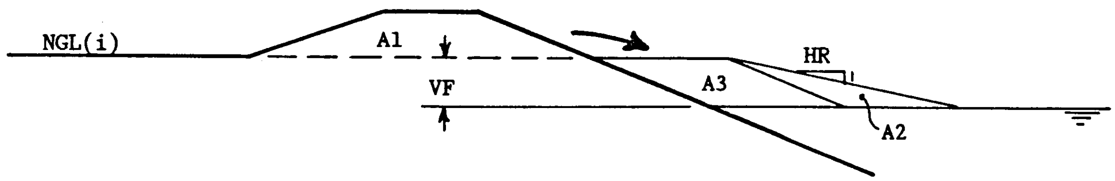


Figure 27. Case 2 Cross Section: Striking Dam Onto Clays

If DAML(i) = CAPL(i) Then equal lengths

27. Calculate a balanced cut-and-fill: (See Figure 28)

VBAL = VF/2

VCAP(i) = FNTRIA[VBAL,HR,HI(i)]xCAPL(i)/27

DCAP(i) = 2xFNTRICA[VBAL,HR,HI(i)]

28. Calculate adjusted balanced cut-and-fill

Calculate cut height (VTRAP): Quadratic Equation

VM = VF, maximum cut height

Quadratic coefficients:

A = [HR - HI(i)]x[DAML(i) - CAPL(i)]

B = 2xVFxCAPL(i)x[HR - HI(i)]

D = VFxVFxCAPL(i)x[HI(i) - HR]

If VM < VTRAP < 0 for both roots, then STOP

VCAP(i) = FNTRIA[VW,HR,HI(i)]xCAPL(i)/27

DCAP(i) = FNTRICA[VW,HR,HI(i)]

+ FNTRICA[VTRAP,HR,HI(i)]

29. Estimate bulldozer hours:

If DTOE(i) or DCAP(i) < 50 Then they = 50

If DTOE(i) or DCAP(i) > 500 Then they = 500

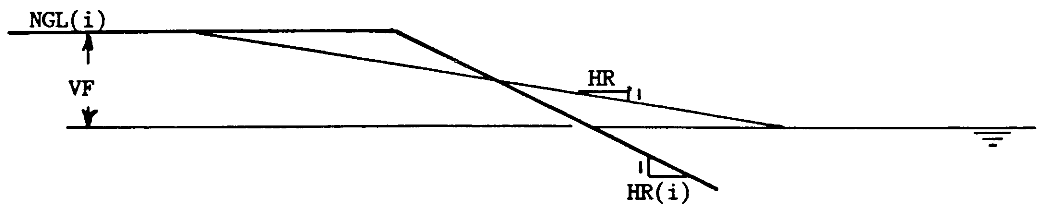


Figure 28. Case 3 Cross Section: Balanced Cut-and-Fill

BCYPHR = MxD^{N}, bulldozer productivity

EQHR = V/BCYPHR, equipment hours

BULLHR = BULLHR + EQHR, keep total of dozer hours

30. Estimate dam acreage after reclamation:

Case 3: DAMAC = DAMAC + CAPL(i)x[CWI(i) + HI(i)x5.0]

Case 2: DAMAC = DAMAC + DAML(i)x{CWI(i) + 5.0x[HO(i) + HI(i)]}

Case 1: DAMAC = DAMAC + 2xDTOE(i)xTOEL(i) + CAPL(i)x[CWI(i)/2 + 5.0xHI(i)]

After all dam segments evaluated

DAMAC = (DAMAC + DELTAC)/43560

If Capping, Then DAMAC = DAMAC + CAPA/43560

Calculate Spoil Ridge Leveling Requirements

The model assumes that spoil ridges have a flat top, exhibit a trapezoidal shape, and the dimensions for each ridge are constant throughout their full length. According to the detail flowchart in Figure 29, the program will

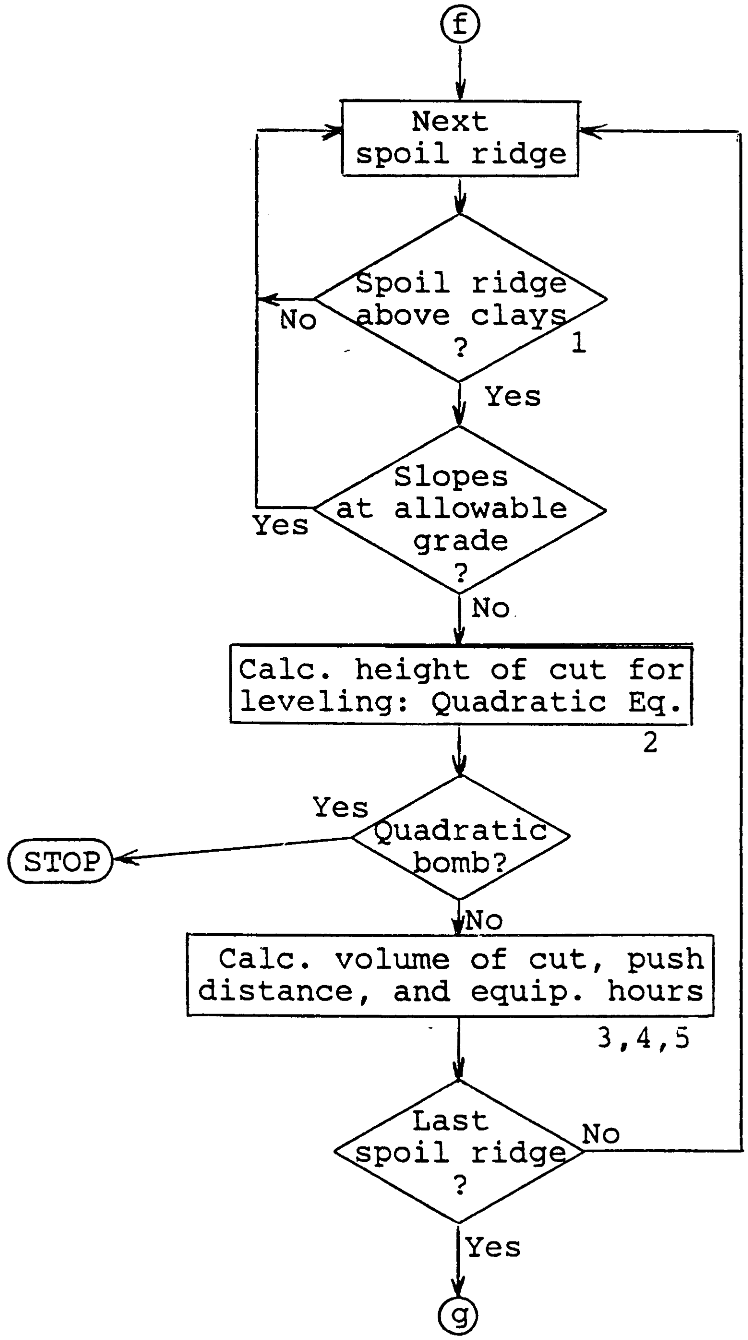


Figure 29. Flowchart: Spoil Ridge Leveling Calculations

select those spoil ridges which are exposed and exhibit slopes steeper than the maximum allowable grades for earthmoving evaluations. Those spoil ridges requiring earthmoving will be struck flat as depicted in Figure 30 to create the maximum allowable grades. The height of the cut is calculated with a quadratic equation which was discussed in the section on robbing for topsoil. A low ground pressure bulldozer is used for this work since it must perform on the clay surface. As with cyclic earthmoving equipment, it is necessary to estimate the volume moved and the average push distance so that the equipment productivity and hours can be estimated. Following are the equations for this evaluation.

1. Spoil Ridge above clays?

    Slopes at allowable grade?

    If SPOILEL(i) < SLIMES and SHO(i) < HR Then level spoil ridge

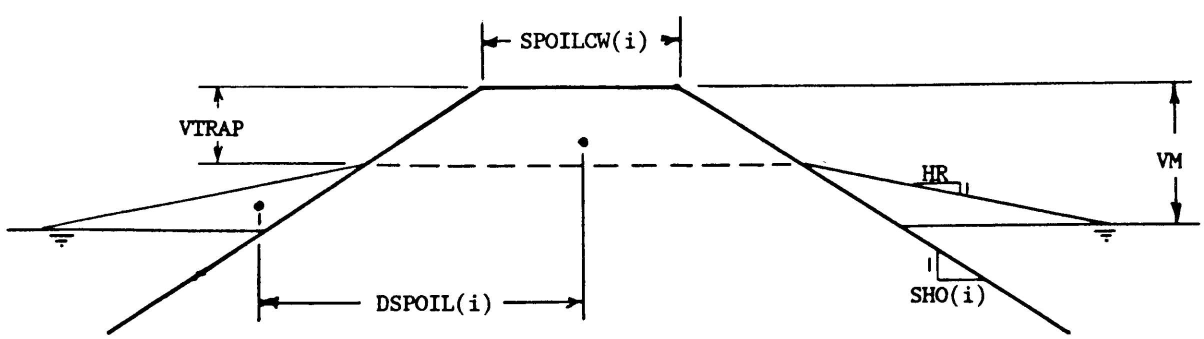


Figure 30. Striking Spoil Ridge

2. Calculate height of cut for leveling using quadratic equation

   VM = SPOILEL(i) - SLIMES, maximum cut height

   Quadratic coefficients:

   A = 2xSHO(i) - HR

   B = SPOILCW(i) + 2xVMx[HR - SHO(i)]

   D = VMxVMx(SHO(i) - HR)

   If VM < VTRAP < 0 for both roots, then STOP

3. Calculate volume of material moved:

   VSPOIL(i) = SPOILEN(i)

   x FNTRAPA[SHO(i),SPOILCW(i),SHO(i),VM]

4. Calculate average push distance:

   V = VM - VTRAP

   DSPOIL(i) = FNTRICA[V,HR,SHO(i)] + VTRAP/2

   + SPOILCW(i)/2

   If DSPOIL(i) < 50 Then DSPOIL(i) = 50

5. Calculate equipment hours:

   BCYPHR = LGPMxDSPOIL(i)^{LGPN}, bulldozer productivity

   EQHR = VSPOIL(i)/BCYPHR

   LGPHR = LGPHR + EQHR, LGP hour totalizer

Estimate Common Reclamation Costs

The costs for common reclamation activities fall into three groups: spillway costs, earthmoving costs, and revegetation costs. Once the reclamation requirements and equipment hours have been determined, cost estimation is simple as shown in the detail flowchart of Figure 31. Each group of costs will be discussed individually with the appropriate equations.

Spillway Costs. The model treats temporary spillway installations and spillway removals as unit costs. As mentioned in the literature search, the cost to install temporary spillways is relatively independent of the location. In addition, there is relatively little variation

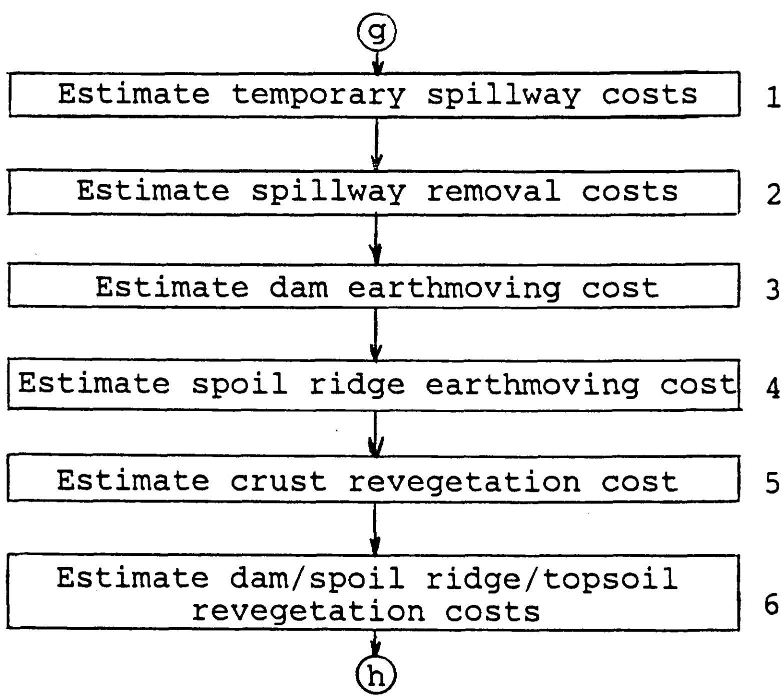


Figure 31. Flowchart: Common Reclamation Cost Estimates

in spillway removal costs. The removal unit cost must cover the cost of plugging the spillway, cutting the decant tower off four feet below final grade, and breaching the dam at the spillway to allow runoff to drain out which normally would collect due to the cone of depression around the spillway. Following are the cost equations for these activities.

1. Estimate temporary spillway installation costs:

   TSPILL = TSPILLS%xTSPILLCST

2. Estimate spillway removal costs:

   RSPILL = RSPILLS%xRSPILLCST

Earthmoving Costs. The standard bulldozer hours have been estimated for earthwork on the dam and LGP bulldozer hours estimated for earthwork on exposed spoil ridges. The earthmoving cost is based on the equipment hours and the hourly cost of this equipment.

3. Estimate dam earthmoving cost:

   DAMCST = BULLHRxBULLCST

4. Estimate spoil ridge earthmoving cost:

   SPOILCST = LGPHRxLGPCST

Revegetation. The program allows two separate revegetation efforts to be specified, one for the dam, spoil ridges, and cap, and one for the crusted clay surface. Six activities have been identified for use in establishing an ecological scheme: removing the volunteer vegetation so that the planned ecological system can be developed (chopping), tilling to prepare the soil for planting, applying lime to reduce the soil acidity, planting the appropriate seeds, fertilizing, and planting trees. The number of times each activity is performed and its intensity of application will be determined by the topsoil type and intended land use. For simplicity, the program assumes that the intensity of each application is constant. Therefore, the revegetation cost per ecological system is based on the number of times each activity is performed and the cost per application.

Chopping normally is performed on crusted clays, with the intensity of chopping being dependent upon the age of the growth to be removed. The activity is chosen by entering a 1 or 0, but entering a 2 will double the chopping cost so that degrees of chopping can be specified. This activity is contracted by the acre, so estimation of the cost is based on the cost/acre and the acreage of clay at reclamation.

Tilling, like chopping, is usually a one-time activity contracted by the acre; however, the cost per acre seldom varies. It is performed for most revegetation schemes to scarify the surface, turn under volunteer grasses, and mix the topsoil.

Crusted clays do not usually exhibit an acidity problem, but topsoils commonly do. The amount of lime used and the number of applications is dependent upon the acidity of the soil and is normally contracted by the pounds of lime applied per acre. The program estimates liming cost based on the acreage treated, the number of applications, and the cost per ton-acre. Therefore, the cost per application-acre in the equipment input file should represent the pounds of lime applied per acre.

Seed is contracted by the pounds of seed per acre and may be applied more than once. Therefore, the program estimates the cost of seeding based on the acreage planted and the number of applications necessary to achieve the minimum cover of vegetation.

Fertilizer is contracted by the pound per acre. Therefore, the cost of fertilizing is based on the acreage treated and the number of applications.

Trees are bought and planted in quantity. To meet state requirements, about 400 trees are planted to the acre. The program assumes that the cost of tree planting will be based on the percentage of upland areas that are to be forested. It classifies the dam, spoil ridges, and cap as uplands. The minimum area to be forested is an input to the program.

Listed below are the equations for revegetation on the crusted clays and dam, spoil ridges, and cap.

5. Estimate crust revegetation cost:

SLCHCST = CHSLIM%xCHOPxSOILCAPA, chopping cost

SLTICST = TISLIM%xTILLxSOILCAPA, tilling cost

SLLICST = LISLIM%xLIMExSOILCAPA, liming cost

SLSECST = SESLIM%xSEEDxSOILCAPA, seeding cost

SLFECST = FESLIM%xFERTxSOILCAPA, fertilizing cost

SLREVCST = SLCHCST + SLTICST + SLLICST + SLSECST + SLFECST, total crust revegetation cost

6. Estimated dam/spoil ridge/topsoil revegetation cost:

DAMTICST = TIDAM%xTILLxDAMAC, tilling cost

DAMLICST = LIDAM%xLIMExDAMAC, liming cost

DAMSECST = SEDAM%xSEEDxDAMAC, seeding cost

DAMFECST = FEDAM%xFERTxDAMAC, fertilizing cost

TREECST = TREESxTREEPxDAMAC/100, tree planting cost

DAMREVCST = DAMTICST + DAMLICST + DAMSECST + DAMFECST + TREECST, total dam revegetation cost

Estimate Crust Reclamation Costs

Activities unique to the Crust Development Method include the installation of a diversion ditch, a perimeter ditch, and ditching across the clay surface (See Figure 32). The assumptions for each activity will be discussed

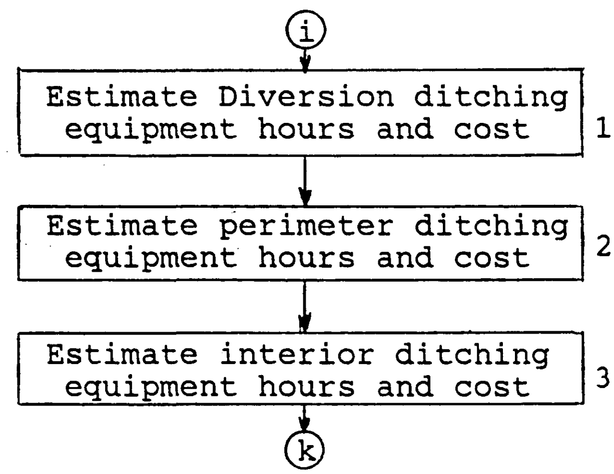


Figure 32. Flowchart: Crust Development Evaluation

followed by the equations.

The effort to dig the diversion ditch is dependent upon the length of the ditch, the cross sectional area of the ditch, and the digging rate (BCY/Hr) of the ditching equipment. The program assumes that this ditch will be dug once exhibiting a cross sectional area of 32 square feet (See Figure 33). This would represent a ditch four feet deep, four feet wide at the bottom, and with 2:1 (H:V) slopes. The cost of the ditch would then be based on the required ditching machine hours and its hourly cost.

1. Estimate diversion ditching equipment hours and cost:

DIVHR = DIVFTx32/(27xDIT), ditching hours

DIVCST = DIVHRxDITCST, ditching cost

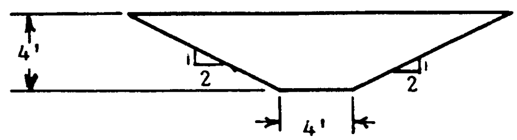


Figure 33. Diversion Ditch Cross Section

The effort to dig the perimeter ditch and two subsequent clean outs is based on the length of ditch and the digging capacity of the standard ditching equipment (BCY/Hr). The program assumes that each clean out will have to remove 50% of the original dug volume to account for clays that have slumped into the ditch and to dig the ditch deeper due to clay consolidation. The cross sectional area of the ditch is assumed to be 108 square feet (See Figure 34) creating a ditch adjacent to the dam 4.5 feet deep with a 6-foot wide bottom. The cost for the ditch will be based on the required ditching machine hours and the cost per hour of the machine.

2. Estimate perimeter ditching equipment hours and cost:

PERHR = CAPTOTx2x108/(27xDIT), ditching hours

PERCST = PERHRxDITCST, ditching cost

A regular pattern of drainage ditches will be dug across the clay surface. The intensity of this ditching will be influenced by past experience and how well the clay surface is draining. Therefore, the length of interior ditch per

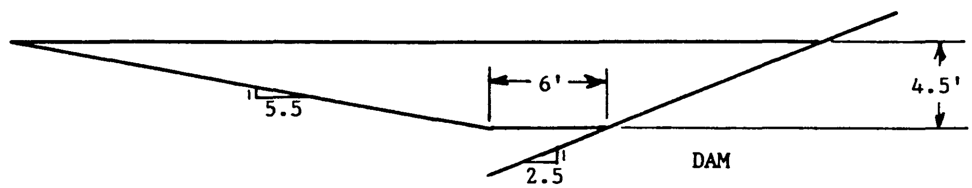


Figure 34. Perimeter Ditch Cross Section

acre is an input variable. Since these ditches are created by a plow or rotary ditching equipment, the rate of progress, not the volume dug, is the controlling influence on equipment hours and will be one of the input variables. The cost then will be based upon the estimated low ground pressure ditching equipment hours required and the cost per hour of this equipment. It will be assumed that the interior ditching will have to dug twice, but the second time only 50% of the original volume will have to be removed.

3. Estimate interior ditching equipment hours and cost:

IDITHR = SOILCAPAx1.5xIDITPAC/LGPDIT, hours ditched

IDITCST = IDITHRxLGPDITCST, ditching cost

Estimate Capping Reclamation Costs

Reclamation activities unique to the Sand Capping Method include placing the sand cap, leveling the cap, and placing a topsoil layer. Figure 35 shows the detail

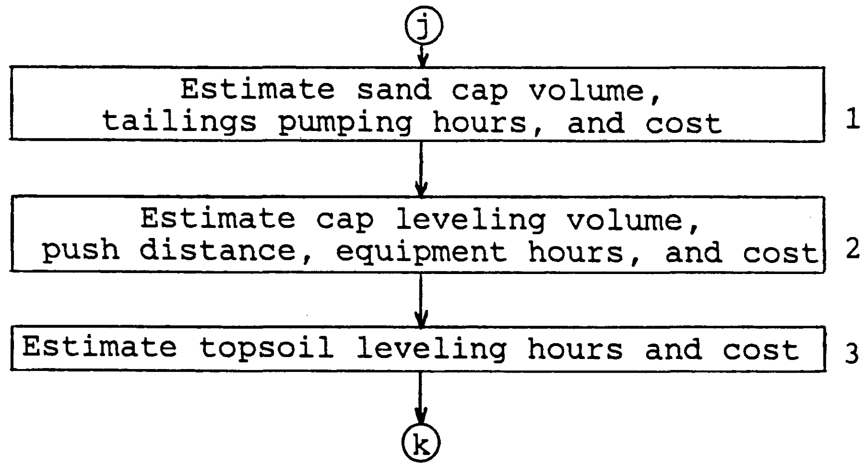


Figure 35. Flowchart: Cap Placement Evaluation

flowchart for estimating the costs for these activities. The assumptions for each activity will be discussed followed by the equations.

Placing the Sand Cap. The amount of sand tailings required is dependent upon the expected thickness of the cap and the area covered. Since the cap thickness and area covered are quite variable and difficult to estimate, they will have to be an input variable based on past experience and the age of the settling area.

Sand tailings are produced at the plant and must be pumped to the settling area. This pipeline can deliver a relatively constant rate of tailings with the rate of delivery based on the size of the pipeline. Slurry pumping costs are usually estimated by the cost per BCY-Mile and not the operating hours even though operating hours are important for scheduling the work. Therefore, the pumping distance and cost/BCY-Mile will be the input variables.

1. Estimate sand cap volume, tailings pumping hours, and cost:

   TAILVOL = (CAPA - DELTAC/3)xSAND/27, cap volume

   PUMPHR = TAILVOL/PBCY, tailings pumping hours

   PUMPCST = TAILVOLxMILESxYARDMI, pumping cost

<u>Leveling on Cap</u>. The sand cap will be built in concentric ridges around the settling area. Each ridge will have a flat triangular profile with the pipeline running along the peak. The cap will have to be leveled, but due to the triangular shape of the sand ridges, only a third of the it will have to be moved by low ground pressure bulldozers (See Figure 36). The thicker the sand cap is, the greater the spacing between sand ridges and the greater the push distance. The push distance is estimated to be from the centroid of the cut to the centroid of the fill and the bulldozer productivity is based upon the cyclic production equation outlined in the topsoil robbing section.

2. Estimate cap leveling volume, push distance, equipment hours, and cost:

   TAILPUSH = TAILVOL/3, cap leveling volume

   DTAILPUSH = SANDx20/3, average cap push distance

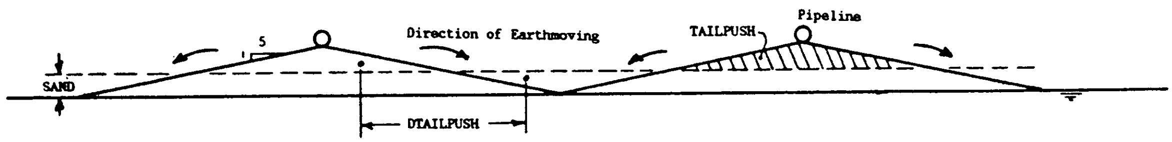


Figure 36. Leveling Sand Cap

If DTAILPUSH < 50 Then DTAILPUSH = 50

$BCYPHR = LGPM \times DTAILPUSH^{LGPN}$, LGP Dozer productivity

$CONTHR = TAILPUSH/BCYPHR$, cap leveling hours

$CONTCST = CONTHR \times LGPCST$, cap leveling cost

Placing Topsoil Layer. Volumes robbed for topsoil requirements and their haulage distances were estimated in the section on topsoil requirements. This part will calculate the scraper productivity using the equation for cyclic equipment, the equipment hours, and the cost.

3. Estimate topsoil leveling hours and cost:

$BCYPHR = SM \times DDPOIL^{SN}$, productivity on spoil ridge

$SPOILHR = SPOILBOR/BCYPHR$, spoil ridge robbing hours

$SPOILBORCST = SPOILHR \times SCST$, spoil ridge robbing cost

$BCYPHR = SM \times DDAM^{SN}$, scraper productivity for dam

$DAMBORHR = DAMBOR/BCYPHR$, dam robbing hours

$DAMBORCST = DAMBORHR \times SCST$, dam robbing cost

Following is a case study which depicts the accuracy and capability of SETREC and the cost model.

CHAPTER 5

CASE STUDY

The purpose of this chapter is to test the model under real world conditions to show its capabilities and limitations. Then, the case study settling area will be evaluated using the DNR cost model to indicate the limitations of previous models for planning reclamation programs.

Case Study Evaluation

To show the capabilities of the reclamation model, an actual settling area was chosen for the case study. At the request of the mining company which owns the settling area, it will not be identified but will be known as the Test Case Settling Area. A few modifications were made to the description of the settling area so that more of the program capabilities could be displayed. Following is a summary of the settling area description, the input for two methods of reclamation, results, and recommendations for reclamation of the Test Case Settling Area.

Settling Area Description

SETTLING AREA NAME: Test Case Settling Area

LOCATION: Central Florida

GENERAL DATA: See Settling Area Input File: (Tables 1 and 2)

Dates of Service: 1979 to 1986

Storage Capacity: 22,500 Acre-Feet

DESCRIPTION: (See Plan View, Figure 5)

The Test Case Settling Area is a large elevated settling pond with a surface of 508 acres under operating conditions. It is located on mined-out land and built into the western side of a north-south ridge. As a result, the ridge to the east is higher in elevation than the pond and is planted with orange groves. The natural ground levels slope down to a state protected watershed 2,500 feet west of the settling area. Within the settling area, there are 5 spoil ridges which may impact the cost of reclamation.

The pond is bordered on the east by the property boundary. To the north is a settling area which is scheduled to be commissioned when the Test Case Settling Area is taken out of service. To the west are reclaimed mined lands and the plant water return ditch. On the south side is another settling area which is inactive and is currently being capped with sand tailings. To the southeast is a reclamation lake located on mined land. Between the reclamation lake and the southern settling area is a cemetery which the mining company could not get permission to move.

Reclamation Requirements

The Test Case Settling Area was evaluated using the two methods of reclamation, Crust Development and Sand Capping. Currently, Crust Development is the scheduled method of reclamation for the settling area.

Reclamation activities will be limited on the east by the property boundary, on the south by the cemetery, and on the west by the plant water return ditch. All slopes will have to be reduced to a maximum grade of 4:1 (H:V) and runoff from the eastern orange groves will have to be diverted with 5,200 feet of diversion ditch. The reclamation parameters used in this test case are representative of reclamation practice in Central Florida.

The dam was broken into 18 segments (See Figure 5), each segment being relatively straight and all physical dimensions and grades constant within each segment.

Crust Development Method. Experience with settling areas of similar height have shown that 18 feet of consolidation can be expected when the clay surface has been ditched with 400 feet of ditch per acre. As a result, significant earthmoving on the dam and exposed spoil ridges can be expected.

During the crust development phase, it will be necessary to install eight temporary spillways. Two initially will be set at 140 feet Mean Sea Level (MSL), then as the clay surface subsides, three will be set at 132 feet MSL, and then three will be set at 120 feet MSL.

The crusted clay surface will be planted for use as pasture land. On the dam and spoil ridge areas, 15% will be planted with upland trees and the remainder with upland grasses. Table 1 lists the reclamation parameters for this method.

Sand Capping Method. Experience has shown that placement of a sand cap on a settling area with similar dimensions as the test case pond will compact the clays 20 feet. The cap will average 10 feet thick but will successfully cover only 60% of the clays. The sand tailings will have to be transported 1.8 miles to reach the settling area. It will be necessary to install six temporary spillways to remove the transport and decant water from the settling area.

An 8-inch layer of topsoil will have to be placed on the sand cap for revegetation. The crusted clay areas will be planted with pasture grasses. On the dam, spoil ridge, and sand cap areas, 10% will be planted with upland trees and the remainder with upland grasses. Table 2 lists the reclamation parameters for this method.

Equipment File

Standard equipment was chosen for the equipment file. All bulldozer work was performed by a Caterpillar D9L, long distance earthmoving was performed by a Caterpillar 631D Scraper, ditching was performed by a 2.5 yard small dragline, except on the clays where a GEMCO Amphibious Ditcher was used, and a standard 16 inch slurry pipeline was specified for sand tailings transport. Manufacturer reported performance parameters and local contractor rates were used for earthmoving estimates. Table 4 lists this equipment performance data along with current average revegetation unit costs.

Results

Tables 5 and 6 are the computed reclamation requirements for the Test Case Settling Area using Crust Development and Sand Capping Methods respectively. Table 7 lists the important conclusions to be drawn from this analysis.

The following observations can be made from these tables. Reclaiming the Test Case Settling Area using the Sand Capping Method is 45% more expensive than using the Crust Development Method. Due to extra pumping costs, this cost differential will go to zero if alternative tailings disposal sites are more than 3.5 miles from the plant.

Table 4. Case Study Equipment Input File

EQUIPMENT INPUT FILE

EQUIPMENT DATA

Bulldozer : CAT D9L/9S
BCY/Hr = 35150.0(Dist)^-0.91210
$ 93.72 /Hour

LGP Bulldozer : CAT D9L/9U
BCY/Hr = 47354.0(Dist)^-0.94933
$ 93.72 /Hour

Ditching Equip. : 2.5 YARD DRAGLINE
146 BCY/Hr
$ 59.35 /Hour

LGP Ditching Equip. : GEMCO AMPHIBIOUS DITCHER
1000 Ft. Ditch/Hr
$ 50 /Hour

Scraper : SCRAPER
BCY/Hr = 41300.0(Dist)^-0.64500
$ 84.21 /Hour

Slurry Pipeline : 16 INCH SLURRY LINE
740 BCY/Hour
$ .046 /BCY-Mile

RECLAMATION UNIT COSTS

Temp. Spillways ($/Installation)..	5000
Spillway Removal ($/Spillway).....	400
Revegetation	
Chop Vegetation ($/Acre)........	500
Tilling ($/Acre)................	200
Liming ($/Application-Acre).....	250
Seeding ($/Application-Acre)....	250
Fertilizer ($/Application-Acre).	125
Tree Planting ($/Acre)..........	400

Table 5. Case Study Reclamation Summary: Crust Development

RECLAMATION SUMMARY

Settling Area Input File Name: CRUST
Equipment Input File Name: EQUIP

Settling Area: TEST CASE SETTLING AREA
Settling Area Location: FLORIDA
Struck Dam Elevation : 127
Method of Reclamation: Crust Development
Dam and Spoil Ridge Acreage: 132.6
Crust Acreage: 479.8

CRUST DEVELOPMENT

DIVERSION DITCH
Length (Ft) : 5200
Equipment : 2.5 YARD DRAGLINE
Machine Hrs: 42 Cost : $ 2,505

INSIDE PERIMETER DITCH
Length (Ft) : 19,774
Equipment : 2.5 YARD DRAGLINE
Machine Hrs: 1,084 Cost : $ 64,307

INTERIOR CRUST DITCHING
Length/Acre : 400
Equipment : GEMCO AMPHIBIOUS DITCHER
Machine Hrs: 288 Cost : $ 14,394

OTHER RECLAMATION ACTIVITIES

TEMPORARY SPILLWAYS INSTALLED
Number : 8 Cost : $ 40,000

DAM EARTHWORK
BCY Moved: 786,591
Equipment : CAT D9L/9S
Machine Hrs: 3,994 Cost : $ 374,332

SPOIL RIDGE EARTHWORK
BCY Moved: 25,725
Equipment : CAT D9L/9U
Machine Hrs: 22 Cost : $ 2,088

SPILLWAY REMOVAL
Number: 3 Cost : $ 1,200

REVEGETATION - Dam/Spoil Ridges
Tilling Cost: $ 26,512
Lime(Applications): 1 Cost: $ 33,141
Seed(Applications): 1 Cost: $ 33,141
Fertilizer (Appl.): 2 Cost: $ 33,141
Trees (% of Area): 15 Cost: $ 7,954
Dam,Spoil Ridge, and Cap Revegetation Cost : $ 133,888

Table 5. Case Study Reclamation Summary:
Crust Development - Continued

REVEGETATION - Crust

Chopping		Cost: $	0
Tilling		Cost: $	95,963
Lime(Applications):	0	Cost: $	0
Seed(Applications):	1	Cost: $	119,954
Fertilizer (Appl.):	0	Cost: $	0

Crust Revegetation Cost : $ 215,917
Total Revegetation Cost : $ 349,805

TOTAL RECLAMATION COST : $ 848,631

EARTHMOVING SUMMARY: DAM

SEG	CASE NO	LENGTH	AVG NGL	BOUND LIMIT	SLOPE	*** PUSH DAM OUT *** BCY MOVED	DIST MOVED	*PUSH DAM IN* BCY MOVED	DIST MOVED	BCY HAULED IN
1	3	211	150.0	NO	4.0	0	0	376	54	0
2	3	616	150.0	NO	4.0	0	0	1,581	54	0
3	3	2,063	150.0	NO	4.0	0	0	5,026	54	0
4	3	723	150.0	NO	4.0	0	0	1,747	54	0
5	2	1,431	146.7	NO	4.0	0	0	5,288	64	0
6	2	4,110	145.0	NO	4.0	0	0	28,733	67	0
7	2	51	133.0	NO	4.0	0	0	0	0	0
7	1	91	105.7	NO	10.4	6,085	165	676	144	0
8	1	3,491	96.7	YES	4.3	110,255	137	125,238	393	0
9	1	521	100.0	YES	4.8	18,151	134	16,979	375	0
10	1	666	100.0	YES	4.8	19,513	134	25,408	399	0
11	1	120	108.7	NO	6.4	7,935	122	162	138	0
12	1	1,660	126.0	NO	658.1	20,161	286	91,846	500	0
13	1	801	126.0	YES	837.1	11,632	344	39,652	486	0
14	1	519	126.3	YES	999.0	4,696	344	28,571	500	0
14	2	519	127.3	NO	4.0	0	0	32,436	350	0
15	2	603	128.0	NO	4.0	0	0	35,787	399	0
16	2	5	127.3	NO	4.0	0	0	0	0	0
16	1	199	101.7	NO	9.0	14,214	182	1,579	152	0
17	1	1,173	89.0	NO	5.7	83,652	191	9,295	152	0
18	1	386	101.7	NO	8.3	27,557	176	3,062	156	0
18	2	234	134.7	NO	4.0	0	0	9,299	140	0

EARTHMOVING SUMMARY: SPOIL RIDGES

RIDGE NO	BCY MOVED	DIST MOVED
1	12,400	50
2	5,621	50
3	4,775	50
4	2,390	50
5	540	50

Table 6. Case Study Reclamation Summary: Sand Capping

RECLAMATION SUMMARY

Settling Area Input File Name: CAP
Equipment Input File Name: EQUIP

Settling Area: TEST CASE SETTLING AREA
Settling Area Location: FLORIDA
Struck Dam Elevation : 135.7
Method of Reclamation: Capping with Tailings
Dam, Spoil Ridge, and Cap Acreage : 385.4
Crust Acreage : 197.5

TAILINGS CAP PLACEMENT

TAILINGS CAP PLACED
  Thickness (Ft): 10 BCY: 4,704,187
  Equipment : 16 INCH SLURRY LINE
  Operating Hrs: 6,357 Cost : $ 389,507

LEVELING CAP
  BCY Moved : 1,568,062
  Equipment : CAT D9L/9U
  Machine Hrs: 1,784 Cost : $ 167,236

TOPSOIL LAYER PLACED
  Thickness (Ft): .7 BCY: 334,624
  Borrowed from Spoil Ridges: 28,644
  Dam: 305,980
  Equipment : SCRAPER
  Machine Hrs: 1,113 Cost : $ 93,709

OTHER RECLAMATION ACTIVITIES

TEMPORARY SPILLWAYS INSTALLED
  Number : 6 Cost : $ 30,000

DAM EARTHWORK
  BCY Moved: 120,082
  Equipment : CAT D9L/9S
  Machine Hrs: 223 Cost : $ 20,931

SPILLWAY REMOVAL
  Number: 3 Cost : $ 1,200

Table 6. Case Study Reclamation Summary:
Sand Capping - Continued

REVEGETATION - Dam/Cap			
Tilling		Cost: $ 77,090	
Lime(Applications):	1	Cost: $ 96,362	
Seed(Applications):	1	Cost: $ 96,362	
Fertilizer (Appl.):	2	Cost: $ 96,362	
Trees (% of Area):	10	Cost: $ 15,418	
Dam,Spoil Ridge, and Cap Revegetation Cost : $			381,594
REVEGETATION - Crust			
Chopping		Cost: $ 0	
Tilling		Cost: $ 39,507	
Lime(Applications):	0	Cost: $ 0	
Seed(Applications):	1	Cost: $ 49,384	
Fertilizer (Appl.):	0	Cost: $ 0	
Crust Revegetation Cost : $			88,891
Total Revegetation Cost : $			470,485
TOTAL RECLAMATION COST : $			1,173,067

EARTHMOVING SUMMARY: DAM

						*** PUSH DAM OUT ***		*PUSH DAM IN*		
SEG	CASE NO	LENGTH	AVG NGL	BOUND LIMIT	SLOPE	BCY MOVED	DIST MOVED	BCY MOVED	DIST MOVED	BCY HAULED IN
1	3	211	150.0	NO	4.0	0	0	167	50	0
2	3	616	150.0	NO	4.0	0	0	602	50	0
3	3	2,063	150.0	NO	4.0	0	0	1,947	50	0
4	3	723	150.0	NO	4.0	0	0	678	50	0
5	2	1,431	146.7	NO	4.0	0	0	1,267	50	0
6	2	4,110	145.0	NO	4.0	0	0	5,383	50	0
7	2	26	138.8	NO	4.0	0	0	0	0	0
7	1	116	108.6	NO	4.0	1,132	101	0	0	0
8	1	3,491	96.7	NO	4.0	48,200	106	0	0	0
9	1	521	100.0	NO	4.0	6,490	101	0	0	0
10	1	666	100.0	NO	4.0	7,718	103	0	0	0
11	1	120	108.7	NO	4.0	1,405	84	0	0	0
12	1	1,660	126.0	NO	4.7	6,854	69	2,665	61	0
13	1	801	126.0	NO	4.5	2,907	66	1,368	59	0
14	1	1,039	126.7	NO	4.9	3,772	66	1,775	59	0
15	1	603	128.0	NO	5.4	2,449	64	773	58	0
16	1	205	102.0	NO	4.0	2,001	121	0	0	0
17	1	1,173	89.0	NO	4.0	15,917	142	0	0	0
18	1	475	104.6	NO	4.0	4,111	120	0	0	0
18	2	145	140.5	NO	4.0	0	0	501	58	0

Table 7. Case Study Reclamation Liability Summary

Reclamation Method	Crust	Cap
Revegetation Cost	$349,805	$470,500
Total Reclamation Cost	$848,631	$1,173,100
Tailings Required, BCY	-	4,704,187
Expected Timetable:		
Crust Development	5 years	-
Place Sand Cap, Level, and install topsoil	-	1.8 years
Dam & Spoil Ridge Earthwork	1 year	0.4 years
Revegetation	1 year	1.0 year
Total Turnaround Time	7 years	3.2 years

Reclamation using the Sand Capping Method can reduce the reclamation turnaround time by 3.8 years but a limited amount of sand tailings may preclude this method of reclamation.

Recommendations

The above case study has shown the capabilities of the reclamation cost model program using two methods of reclamation. The conclusion drawn is that the Crust Development Method is a more cost effective technique for reclaiming the Test Case Settling Area. However, the savings created by using the Crust Development Method would go to zero if the alternative location for sand tailings disposal is 3.5 miles from the plant.

SETREC and DNR Model Comparison

The purpose of this study was not to create another cost model, but to fill a need that was not being met by existing models. This need was to speed and more accurately develop reclamation programs for clay settling areas. To more clearly show how previous models were inadequate for the job, the case study settling area was evaluated using an approximation of the DNR cost model outlined in the literature search. These results were then compared to the SETREC results to show the advantages gained through its use.

Table 8 shows a simulated output from the DNR cost model based on input from the case study settling area reclaimed using the Crust Development Method. Since the DNR model was intended to estimate reclamation costs for abandoned mined lands, it can evaluate more than just settling areas and is run on input acquired from a short field investigation. To run such an evaluation would require a one-day field investigation and a half day in the office to input the data and run the model. The advantage of this model is that many mined lands can be evaluated quickly with limited expenditures for acquisition of data to generate a magnitude order reclamation estimate representing the actual parcel.

As mentioned in the literature search, the features that made this model useful to the DNR as a budgeting tool

Table 8. DNR Cost Model: Case Study Output for Settling Area Reclaimed Without Sand

RECLAMATION COST MODEL

Company: TEST CASE SETTLING AREA   Mine:
Parcel : FLORIDA   Total Area: 599 acres
Section: Township: Range:

Input Data				Cost Data	
Dam Area					
Area	91 acres			Diversion Drainage	$2,500
Dam Perimeter	20,000 ft			Spillways	$1,200
No. of Spillways	3			Revegetation	$82,000
Water Flow	out only			Dozed Material	$452,100
Crest Width	23 ft			Pan Material	$0
Average Ht	25 ft			Pumped Tailings	$0
Present Freeboard	18 ft			Spread Tailings	$0
Outside Slope	2.5 ft/ft			Total	$537,800
Inside Slope	2.5 ft/ft				
Clay Settling Area					
Area	508 acres			Perimeter Ditching	$93,700
Vegetation Cover	0 % area			Interior Ditching	$22,860
Maturity	average			Clay Revegetation	$180,000
Clay Thickness	28 ft			Spoil Revegetation	$0
Spoil Area	15 acres			Clay Cover Chop	$0
Spoil Ht.	13 ft			Spoil Cover Chop	$0
Spoil Veg. % area				Spoil Matl Moved	$0
Light Medm Dense	0	0	0	Total	$296,560
Piles Area					
Area	0 acres			Contour Grading	$0
Ref. Height	0 ft			Capping Material	$0
Piles Veg. % area				Revegetation	$0
Light Medm Dense	0	0	0	Modify Slope	$0
Slope	0.0 ft/ft			Cover Chopping	$0
Modify Depr.	No			Total	$0

Table 8. DNR Cost Model: Case Study Output for Settling Area Reclaimed Without Sand - Continued

RECLAMATION COST MODEL
=====================

Company: TEST CASE SETTLING AREA Mine:
Parcel : FLORIDA Total Area: 599 acres
Section: Township: Range:

Input Data		Cost Data	
Lake Area			
Area	0 acres	Earth Moving	$0
Avg. Ovb. Thick	0 ft	Dewatering	$0
Avg. Matrix Thick	0 ft	Tails Pumping	$0
Avg. Total Thick	0 ft	Cover Chopping	$0
Veg. % Area		Revegetation	$0
Light Medm Dense	0 0 0	Total	$0
Tails Available	No		
		Acres Finished	0 acres
Cut Width	0 ft		
Water Surface Elev	0.0 ft MSL		
Dewatering Reqd	No		
Adjusted Grade Elev	0 ft		

Parcel Summary Cost Data

Surveying	$0
Engineering	$0
Supervision	$90,000

TOTAL PARCEL COST = $924,360

Cost per Worked Acre = $1,543

Earthmoving Summary

Upland Area	0 acres
Fluctuation Zone Area	0 acres
Island Area	0 acres
Pan cuyd Moved	0 cuyd
Pan Average Cost	$0.00/cuyd
Pan Machine Hours	0
Dozer cuyd Moved	950,000 cuyd
Dozer Average Cost	$0.48/cuyd
Dozer Hours	4,824
Total Worked Area	599 acres
Windrow Cut from Grade	0 ft

also made it inadequate as a planning tool for mining operations. Table 8 shows that the DNR model provides very little information about reclamation requirements for the two most expensive activities, earthmoving and revegetation. For earthmoving, there is only an estimate of total yards of material moved and machine hours using a generic bulldozer and pan. There is no break down of earthmoving requirements by activity or location, it does not take into account limitations to earthmoving activities, or even minimize the material moved, so that these estimated values are of little use for specifying an earthmoving program. For revegetation, most of the revegetation activities have been lumped together so the revegetation requirements and costs must be calculated by hand and then fed to the model. This does not save any evaluation time or increase its accuracy. Last, the DNR model does not include all of the reclamation activities such as installation of temporary spillways and placement of topsoil on the sand cap nor is it flexible for specifying reclamation activities.

Comparing the DNR results to the SETREC results, the following observations can be made. The DNR cost model overestimates the earthmoving volumes and cost because the earthmoving equations do not minimize the volume to be moved and the model assumes that all settling areas are elevated structures. It underestimates the cost of revegetation because it underestimates the acreage that is disturbed by earthmoving activities.

Since the DNR model provides only a cursory evaluation of reclamation requirements, development of settling area reclamation programs must still be performed by hand. An evaluation by hand would require four days per evaluation at a cost of approximately $800. SETREC on the other hand would require four hours collecting design data and one hour running the model at an approximate cost of $100. Conceivably, SETREC could save $700 per evaluation. For an average mine with ten settling areas, 5 evaluations per settling area for sensitivity analysis, and a reevaluation of reclamation requirements four times during the life of the mine, the total savings would amount to $140,000, in addition to any savings generated by having a better organized and thought out program.

The following chapter will summarize the results of this report to show that the goals for this model have been met.

CHAPTER 6

SUMMARY

This report presents a model for estimating the reclamation requirements and costs for clay settling areas common to the Florida phosphate industry. It was created with the intention of developing more accurate and better thought out reclamation programs. Therefore, it exhibits a high degree of accuracy, is flexible, and easy to use. This summary will present a short outline of settling area reclamation practice followed by a discussion of the cost model.

Reclamation of mining disturbed land became mandatory in 1975 with the Florida Department of Natural Resources (DNR) given the authority to enact reclamation regulations. To help achieve their reclamation goals, the State of Florida funded the development of reclamation technology in 1978 through the DNR and the Florida Institute for Phosphate Research. A high priority of this research was to develop alternatives to disposal of clay wastes in elevated settling ponds. The research failed to produce alternatives to settling ponds that were both technically and economically feasible, but it did develop several models to estimate their reclamation. The most comprehensive model was for the DNR and was intended for budgeting state reclamation projects of abandoned mined lands.

An investigation of settling area reclamation practice found two proven methods: the Crust Development and Sand Capping Methods. Activities were identified for each method and were classified as three types of work: stabilization of the clay surface, reclaiming the settling area structures, and revegetation. The primary difference between the Crust Development and Sand Capping reclamation methods lies in how the clay surface is stabilized. For the Crust Development Method, the upper clay layers are drained, promoting development of a stiff crust. Activities include digging a diversion ditch, a perimeter ditch around the inside of the pond, and ditches across the clay surface. For the Sand Capping Method, a cap of sand tailings is placed across the clays until displaced clays heave in the uncovered portion, stopping any further capping. Activities include placing the sand cap, leveling the cap, and building a topsoil layer on the sand tailings.

The remaining reclamation work is common to both methods. Temporary spillways must be installed and the permanent ones removed. The dam structure and any exposed spoil ridges must be struck at the level of the clays/cap and all slopes reduced to a minimum allowable grade.

Revegetation requires planning for two different ecological schemes: planting on crusted clays and planting on the dam, spoil ridges, and sand cap. While there is a significant difference between the two ecological systems, the activities to produce them are the same. They include removal of volunteer growth, tilling, liming, seeding, fertilizing, and tree planting.

Using the above reclamation technique, a model was developed and incorporated into a computer program called SETREC. SETREC was written to assist the development of reclamation programs since this type of work was previously performed by hand. While reclamation cost models for settling areas were available, such as the DNR model, they proved inadequate for planning reclamation programs as they did not accurately model the actual settling area dimensions, they were inflexible for changing reclamation standards, were too inaccurate, and did not provide sufficient work estimates for earthmoving and revegetation activities. On the other hand, SETREC was designed from the ground up for development of reclamation programs. Its use would not only speed evaluation work, but the accuracy of estimates would improve, the reclamation programs would be better thought out due to the easy of sensitivity analysis, the quality of estimates would be less sensitive to the personnel performing the work, and a considerable savings in evaluation cost would be realized. In addition, the use of this model might prevent a costly mistake due to the incorrect choice of reclamation methods.

SETREC uses two files to evaluate the reclamation requirements for a settling area: a settling area file and an equipment file. The settling area file provides information unique to the evaluation including a geometric description of the settling area, specification of reclamation requirements, and specification of the revegetation effort. The equipment input file provides information independent of the particular settling area such as equipment performance parameters and unit costs. Using this large amount of information, SETREC is able to develop an accurate and detailed estimate of the work to be performed.

The following chapter will recommend additional refinements that can be made to the cost model and propose other reclamation activities that would benefit from such cost modeling.

CHAPTER 7

RECOMMENDATIONS

A model is an analogy used to help visualize a more complex subject. As such, many compromises must be made to make the model usable, but with the aid of a computer, more complex and accurate models can be developed. The cost model presented in this study is flexible enough to handle a large amount of variability in a settling area, but there is room for refinement to improve its use and accuracy. This section will list some refinements that can be made to the model and recommend additional cost modeling that would benefit mining companies.

The program assumes cross sectional areas for the diversion and perimeter ditches and a thickness for the overburden pushed onto the clays from the dam. These values could be made input variables submitted through the settling area input file.

The program assumes that removal costs for temporary and permanent spillways are the same, but this could be modified to recognize the differences between these two costs.

To improve the revegetation evaluation, the program could be modified to evaluate three ecological systems instead of two. For each ecological system, the user could specify the intensity of lime, seed, and fertilizer for each application and the summary would report the total pounds of each supplement used.

The evaluation results would be easier to visualize if a printer plot of the settling area outline was generated with the reclamation summary along with appropriate labeling. A printer plot could also be generated when printing out the settling area input file. Fixed costs could be included in the cost evaluation such as supervision, engineering, surveying, and administrative overhead. Last, the file manipulation program, SETRECFL, could be made more flexible so that dam segments could be divided or combined on an existing file.

Computer modeling of reclamation activities for mining landscapes can produce greater accuracy and speed the evaluation time. Present reclamation models usually ignore the exact shapes of these mining disturbed landforms and estimate reclamation requirements on a grand scale. The results are fine for annual budgets, but the reclamation engineer must still produce a detailed reclamation plan by hand. Therefore, there are advantages to development of computer-aided reclamation models that would mathematically model the dimensions of the land to be reclaimed.

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APPENDIX A

PROGRAM DOCUMENTATION

Program General Data

Purpose: The purpose of SETREC is to calculate the requirements and costs for reclamation of clay settling areas found in the Florida phosphate mining district.

Language: SETREC is written in IBM Disk BASIC Version 2.1 and will require IBM Disk BASIC or Advanced BASIC Version 2.1 to be executed.

Size: SETREC (Uncompiled) - 29.1 K

SETRECFL (Uncompiled) - 24.0 K

Equipment:

Personal Computer - SETREC was written on an IBM PC with two disk drives, but it will operate on any IBM compatible equipment with at least one disk drive. Screen messages were written for a standard 24 line by 80 column display. Therefore, complete display of these messages will require a CRT with the same display size.

Printer - A printer with a width of 80 columns will be required for output of calculated results and listing of input files.

Program Structure: SETREC is composed of two programs

SETREC - Performs required calculations and prints results

SETRECFL - An input file handling program for SETREC

(Create, Edit, or Print)

<u>Program Features: Overview</u>

1. Menu Driven - Both programs are menu driven being accessible to each other via menu selection.
2. Interactive - Both programs provide informative screen messages prior to keyboard entries and they allow immediate correction of incorrect input.
3. Operational Input - Program operational control is input from the keyboard.
4. Data Input - Data is input from two disk files; default disk drive(A)

   Settling Area Input File (filename.SAI) - Descriptive input on settling area to be reclaimed and specifications on reclamation activities to be performed.

   Equipment Input File (filename.EQI) - Equipment performance parameters, equipment costs, and reclamation activity unit costs.
5. Printed Output - Calculated results, optional detailed earthmoving results, input files, and calculative error messages.
6. Error Traps - Program traps most incorrect or incomplete input with descriptive error messages.

   Keyboard Input Error - Keyboard input errors are screened when entered and resubmitted to operator for correction.

Calculative Error - Program screens for most calculative errors due to absurd input data values, prints an error message to the printer with the location of the erroneous data, and returns to the menu.

Program Operation

SETREC estimates the required reclamation effort (earthmoving volumes, feet of ditch dug, unit operations, etc.), machine hours, and costs for a specific number of activities to be performed for reclamation of a settling area. It performs this evaluation using one of two reclamation techniques, Crust Development and Sand Capping, which are outlined in Chapter 4, Methodology of Model. The results are printed out in tabular form with the option of printing a more detailed listing of earthmoving requirements. Figure 6 shows the program logic (Flowchart) for SETREC.

Operation of the program requires two previously prepared input files which can be created, edited, or printed out using the support program SETRECFL. SETRECFL can be entered via the menu in SETREC or can be executed independently. SETRECFL allows you to review or skip sections of data in each file. Only inputted values update existing data so you can skip through any section by using the RETURN key. For numeric input, SETRECFL will ignore spaces and alphabetic input. Input files are printed out in a tabular form complete with appropriate titles. Figure A-1 shows the program logic (Flowchart) for SETRECFL.

Output

The reclamation summary is divided into three main parts: general data, reclamation activities unique to the method of reclamation, and reclamation activities common to both reclamation methods (See Tables 5 and 6). In addition, there is an optional printout of the earthmoving summaries for the dam and spoil ridges. Listed below is the information provided in each portion of the output.

General Data. This is a listing of the input files, descriptive information on the settling area, final elevation after reclamation, method of reclamation, and acreages of the crust, dam, and spoil ridges after reclamation. These acreages are calculated values based on the operational pond acreage, final reclamation elevations, method of reclamation, and exposed spoil ridges.

Activities Unique to Method of Reclamation. The summary for each activity lists the amount of work

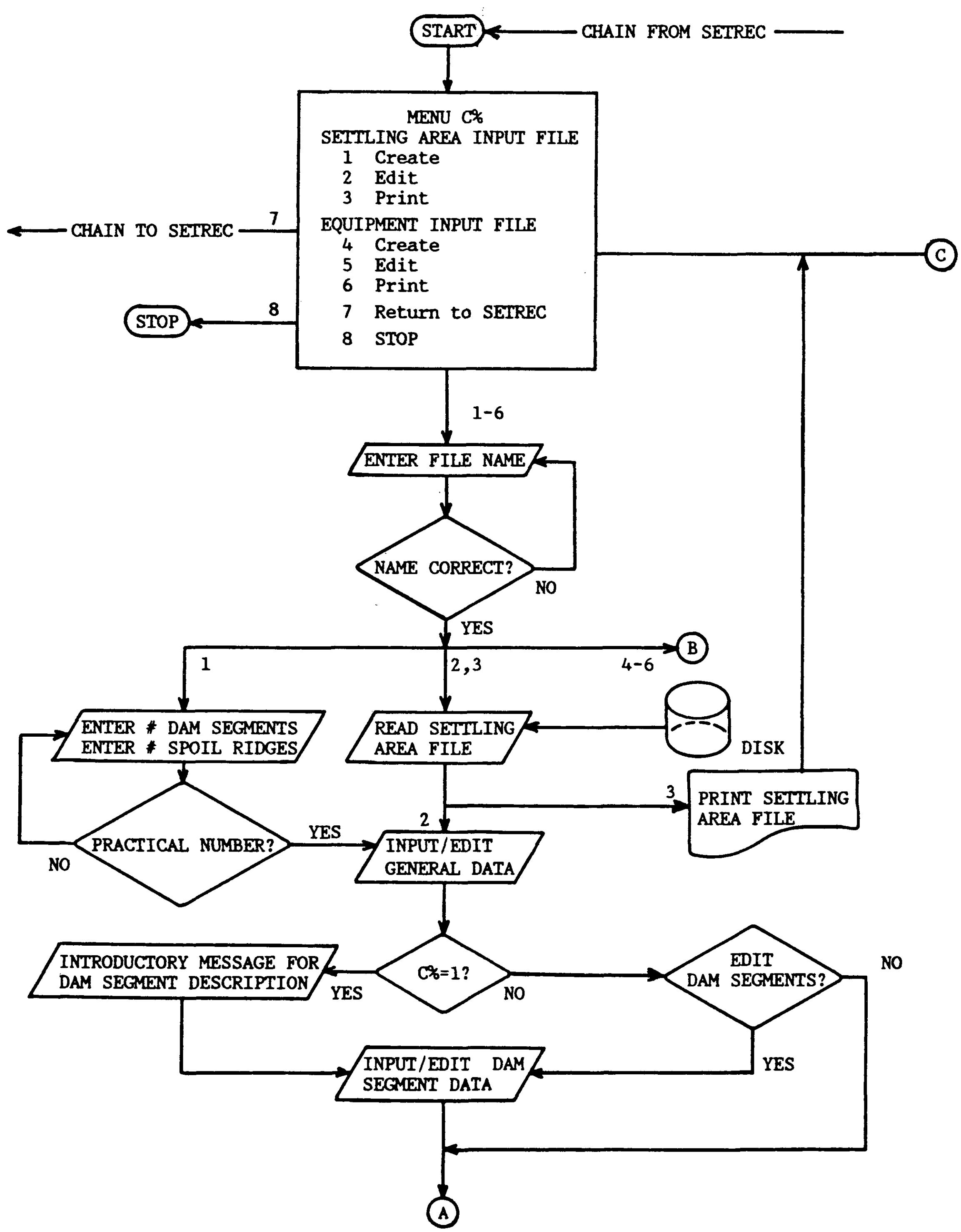

Figure A-1. SETRECFL Flowchart

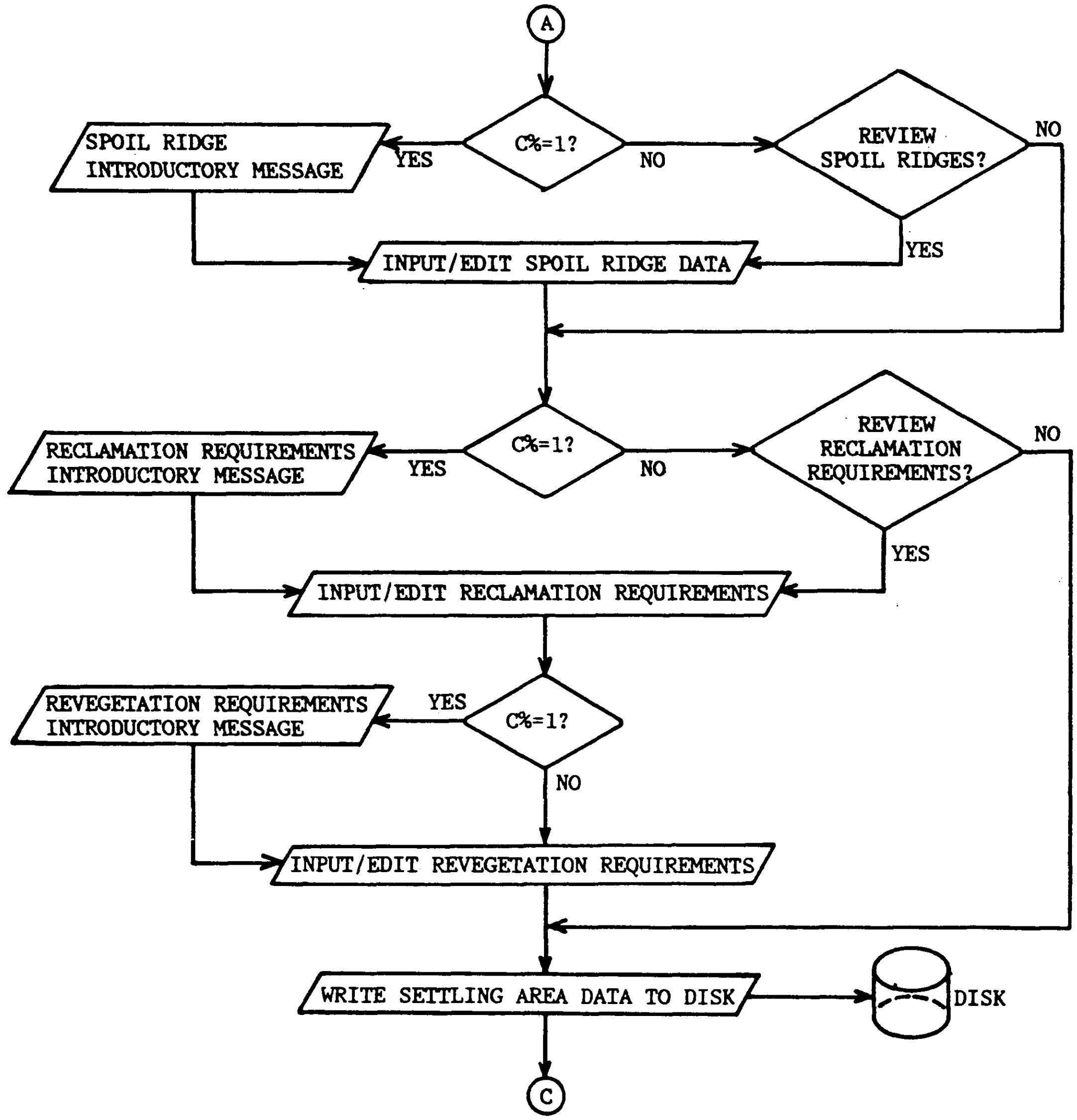

Figure A-1. SETRECFL Flowchart - Continued

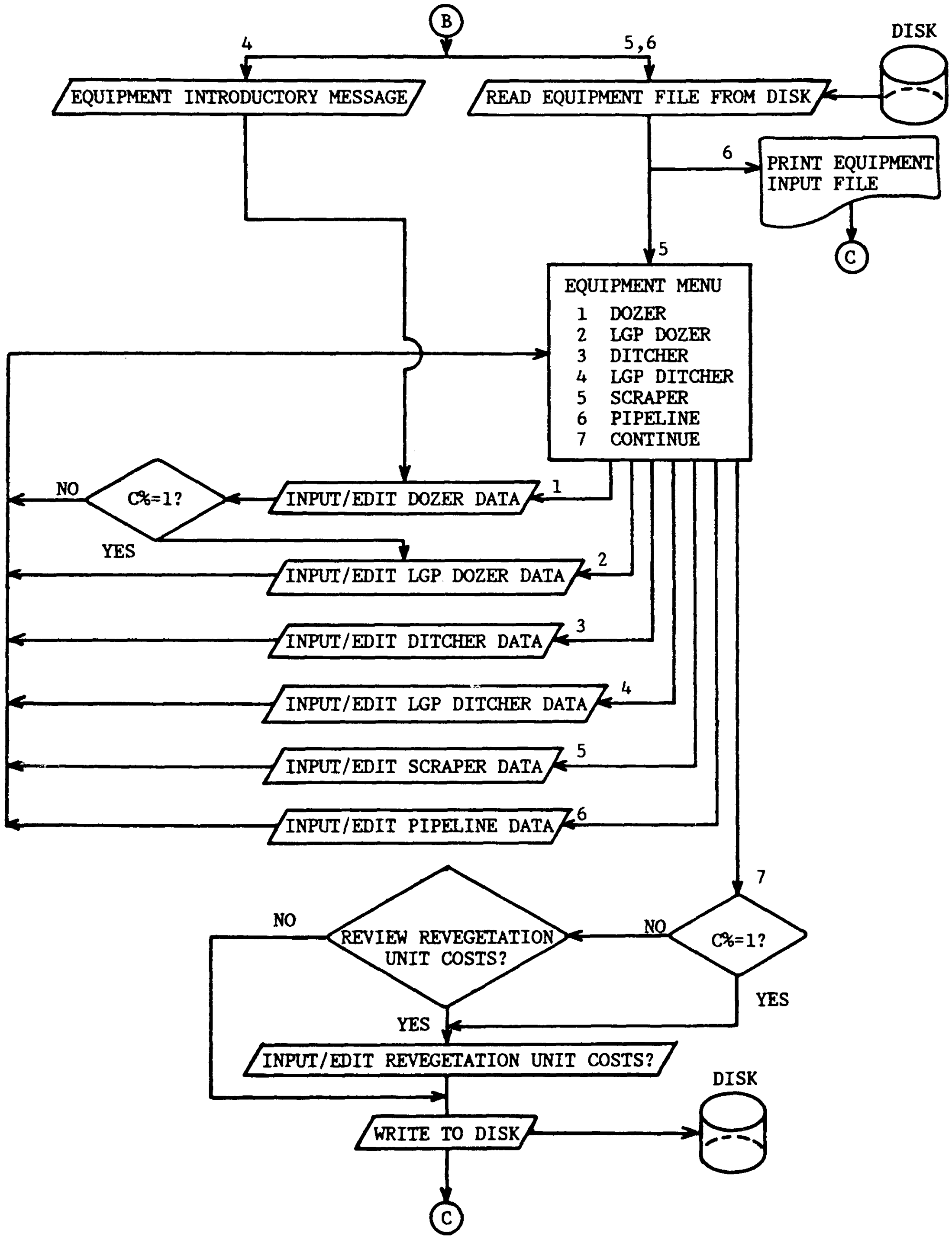

Figure A-1. SETRECFL Flowchart - Continued performed, the equipment that performed it, the required number of machine hours, and the cost.

For the Crust Development Method, the program uses conventional ditching equipment for the diversion and perimeter ditches and low ground pressure ditching equipment for interior ditching.

For the Sand Capping Method, the program uses a slurry pipeline to place the cap, levels it with low ground pressure (LGP) bulldozers, and places the topsoil with scrapers. The cap building summary includes cap thickness and operating hours for the pipeline. The topsoil placing summary includes topsoil thickness and amounts of material borrowed from the dam, spoil ridges, or any hauled in. If a volume of topsoil has to be hauled in, the cost must be added in manually.

Other Reclamation (Common) Activities. Common reclamation activities include spillway installation and removal, dam earthwork, and revegetation. Spillway installation and removal summaries list the number of spillways and the cost.

The dam earthwork summary lists the total bank cubic yards (BCY) of material moved, the amount of material that must be hauled in if there is a shortage of dam material to meet grade requirements, the standard bulldozer used, the number of machine hours, and the cost. The cost of hauling material in to meet shortages has not been accounted for and must be manually added to the reclamation cost. Also, if a permanent feature is too close to the dam and prevents cutting the dam to allowable grades, an error message will be printed with the dam earthmoving data. The grade that can be achieved will be indicated in the optional earthmoving summary. It is a good practice to print out the optional earthmoving tables just to make sure that the earthmoving numbers are in order.

The revegetation cost is summarized by the ecological system planted. There is a summary for the dam, spoil ridges, or cap, a summary for the clay crust, and a total for all revegetation efforts. These summaries list the number of applications, or proportion of area covered, and the cost. Revegetation costs are estimated using the calculated acreages in the general data, the specified revegetation effort, and revegetation unit costs. If there is any question about these costs, print out the input files.

Optional Earthmoving Summary. Is composed of two tables, one a detailed summary of earthmoving on the dam structure, and the second, a detailed summary of earthmoving on exposed spoil ridges.

The earthmoving summary for the dam presents the work performed by segment. As mentioned in the program methodology, a segment represents a length of dam which has constant dimensions and a consistent configuration. The table lists the input segment number, the dam configuration (See Figure 10), the length of the segment, the average natural ground levels outside of the dam, an indication if permanent features impacted reclamation efforts, what outside slope was achieved (H:V), the amount of material moved, where it was moved, how far it was moved, and whether any material had to be hauled in to meet required slopes.

The spoil ridge earthmoving summary lists the work performed by ridge. If there is no spoil ridge leveling performed, then the table will not be printed out. Like the dam earthmoving summary, the table lists the spoil ridge number, the amount of material moved, and the distance moved.

The program assumes that the minimum bulldozer push distance is 50 feet, the distance to load the blade, and the maximum distance that anyone would push material is 500 feet.

Input: Settling Area File

The settling area input file has 5 segments, general data, dam segment description, spoil ridge description, reclamation requirements, and revegetation requirements (See Tables 1 and 2).

General Data. Settling Area Name: Descriptive name which will be printed with the calculated results.

Settling Area Location: Descriptive location which will be printed with the calculated results.

Number of Spillways: Number of initial permanent spillways, but will not enter into any calculations.

Pond Acreage: Acreage of settling area at operating level including area covered by exposed spoil ridges.

Crest Road Elevation: Elevation of dam crest, this will be the same around the settling area.

Operating Level Elevation: Elevation of settling area when it is at its operating level.

Dam Segment Description. To represent variability in the dam, it must be broken into segments where the dam is straight, the dimensions are constant, and the slope of the ground at the outside toe is consistent. The segments should be listed from top to bottom moving in a counter-clockwise direction around the settling area. Each segment is represented by the dimensions at the beginning of the segment and include north and east coordinates, the ground elevation at the outside toe of the dam, the outside and inside slopes of the dam (H:V), the width of the dam crest, and the distance from the dam centerline to any permanent feature (Bound Limit) that cannot be impacted by earthmoving activities. If the segment represents an embankment, the outside slope of the dam is irrelevant and ignored by the program; enter 0. If the bound limit is closer than the outside toe of the dam, the program will give you an error message and put you back to the menu.

To segment a dam for evaluation, first break the dam every time it bends so that each segment is relatively straight. Then review the natural ground contours around the settling area. Every time there is a major change in the slope, start a new segment. Last, review the dam dimensions and every time there is a change in one of the input variables, break the segment. You will have broken the dam into many small segments which will have to entered into the input file. The minimum number of segments is 3 and the maximum number is 50.

Spoil Ridge Description. This is a listing of the dimensions for each of the spoil ridges within the settling area. Each spoil ridge is described by the crest elevation, crest width, ridge length, and the slope of the sides (H:V). Enter only those spoil ridges that might impact reclamation.

Reclamation Requirements. The method of reclamation and its details are specified in this section. If the Crust Development Method of reclamation is chosen, then SETRECFL will prompt for the length of diversion ditch, the intensity of ditching (ft/acre) across the clay surface, number of spillways installed and removed, the maximum allowable reclamation grades, and the estimated feet of consolidation. Since the amount of consolidation is difficult to predict and has a significant impact on earthwork, it would be wise to perform several evaluations using different amounts of consolidation.

If the Sand Capping Method of reclamation is chosen, then SETRECFL will prompt for the tailings cap thickness, topsoil thickness, number of spillways installed and removed, maximum allowable reclamation grades, estimated compaction of the clays, tailings pumping distance, and the expected percentage of clays covered before they push up and capping must stop. Input for most of these variables will have to be based upon past experience and may require several sensitivity analyses.

According to the state, the maximum allowable grade is 4:1 (H:V), but some counties may require slopes as flat as 8:1.

Revegetation. The revegetation effort has to be specified for the two soil types, dam/spoil ridges/cap and crusted clays. For each soil type, indicate whether tilling will be conducted and the number of applications of lime, seed, and fertilizer. For the dam, spoil ridges, and cap, indicate the percentage of area that will be forested and for the crusted clays indicate whether vegetation chopping will be conducted.

Input: Equipment File

The data in the equipment input file is unaffected by the settling area and method of reclamation. Thus, a single equipment file can be used to evaluate many settling areas as long as it is complete enough for the evaluation work. The equipment file specifies the machines to be used for the reclamation activities. Consequently, if you wish to perform some cost comparisons using different equipment, the equipment file will have to be changed for each new piece of equipment evaluated. The equipment input file is composed of two sections; the equipment performance and cost data and the reclamation unit costs (See Table 4).

Equipment Data. Six types of equipment are needed for the reclamation evaluations; standard bulldozer, LGP bulldozer, ditching equipment, LGP ditching equipment, scraper, and a slurry pipeline. For each type of equipment, SETRECFL will prompt for a name, performance parameters, and the cost per hour. The program does not account for operating inefficiencies, so all equipment performance parameters should already have them accounted for. Cyclic earthmoving equipment such as bulldozers and the scraper will require two performance parameters as indicated by the equation in Chapter 4, Methodology of Model. The equipment hourly cost should include all costs including the operator. Ditching equipment performance is specified by BCY/hr and low ground pressure ditching equipment performance is specified by the feet of ditch dug per hour. Slurry pipeline performance is specified by BCY/hour that it can deliver.

Reclamation Unit Costs. Reclamation unit costs include spillway installation, removal, and revegetation costs. Spillway costs are the cost per temporary spillway installation and the cost per spillway removal.

There are six revegetation activities; vegetation chopping, tilling, liming, seeding, fertilizing, and tree planting. Vegetation chopping, tilling, and tree planting are one time activities so that the unit cost is per acre. Liming, seeding, and fertilizing may be performed more than once so that the unit costs for these activities are per application-acre.

Error Messages

SETREC has two types of error messages, error messages to the screen and error messages to the printer. Error messages to the screen are created when an incorrect type of data is entered via the keyboard. Error messages to the printer are created when there are problems performing the required calculations because of incorrect values input from the disk files. When an error message is sent to the printer, operation of the program is suspended and is returned to menu.

SETRECFL does not have any error messages to the printer, but it allows you the opportunity to review each screen of data when creating/editing the input files before the changes are updated to disk. Below is a listing of the error messages that these programs produce.

SETREC

Screen Error Messages. Settling Area Input File Name: Checks for embedded spaces in name and that the file name is not longer than 8 characters.
Equipment Input File Name: Performs the same check as above.

Printer Error Messages. Printer error messages fall into two categories, errors due to incomplete data and errors due to incorrect values. The location of these errors are printed so that they can be identified and corrected.

After the input files are read, but before computation begins, the program checks the following data for completeness.

Method of Reclamation Specified: CRUST or CAP

Equipment Performance Data: Standard and LGP Bulldozers

Equipment Performance Data (CRUST): Standard and LGP Ditching Equip.

Equipment Performance Data (CAP): Scraper and Slurry Pipeline.

Input of incorrect data often will produce results that are meaningless. However, some input can create calculative problems in the program.

The program uses a quadratic equation to solve second order polynomials to adjust earthmoving volumes. If incorrect data is entered, it may be impossible to solve the quadratic equation. This equation is used in five different calculations.

The program detects incorrect data, then an error message is printed describing the type of error, the type of calculation being performed, and the location that this input came from. Listed below are the types of errors that will make it difficult to solve the quadratic equation.

Second Order Coefficient (a) = 0

Negative Radical

Both Roots Negative

Both Roots out of Bounds

Listed below are the five different types of calculations that use the quadratic equation.

1. Adjusting Dam Dimensions after Robbing Topsoil
2. Adjusting Spoil Ridge Dimensions after Robbing Topsoil
3. Case 1 or 2, performing a balanced cut-and-fill
4. Case 3, performing a balanced cut-and-fill
5. Spoil Ridge Earthmoving Balance

The only other calculative error messages are for the following.

Specifying a cap higher than the crest of the dam.

Specifying a permanent feature that is on the side of the dam.

<u>SETRECFL</u>

SETRECFL is the software for creating, editing, and printing input files. As such, no calculations are being performed so there is no need for printer error messages. This program primarily performs keyboard input of data. It allows you the opportunity to review each screen of data before the disk file is updated. Beyond that, it catches the following erroneous data.

File Name: Like SETREC, it checks for embedded spaces and names longer than 8 characters

Menu Selection: It will only accept the numbers listed in the menu selection list

Number of Dam Segments: Allows specification of 3 to 50 segments

Number of Spoil Ridges: Allows specification of 0 to 50 spoil ridges

Reclamation Method: Allows specification of only the two methods

APPENDIX B

SETREC - PROGRAM CODING

```
10     REM *****************************************************************
20     REM **  COST MODEL PROGRAM FOR RECLAMATION OF CLAY SETTLING AREAS IN    *
30     REM **            CENTRAL FLORIDA PHOSPHATE DISTRICT                    *
40     REM **                                                                  *
50     REM **               WRITTEN BY: James P. Schmid                        *
60     REM **               DATE: May 7, 1986                                  *
70     REM **               REVISION: 2                                        *
80     REM **                                                                  *
90     REM **  PURPOSE:  To calculate reclamation cost and requirements for    *
100    REM **            a clay settling area.                                 *
110    REM **                                                                  *
120    REM *****************************************************************
130    GOTO 480: REM Start Program
140    REM ************************** Subroutines ****************************
150    REM
160    DIM STAN(I%),STAE(I%),STNGL(I%),CW(I%),HO(I%),HI(I%),BO(I%),SPOILEL(J%),SP
OILCW(J%),SPOILEN(J%),SHO(J%),VSPOIL(J%),DSPOIL(J%)
170    IA%=I%*3: DIM S%(IA%),DAML(IA%),CEL(IA%),NGL(IA%),CASE%(IA%)
180    DIM CAPL(IA%),TOEL(IA%),CWI(IA%),BOUNDED$(IA%),HRI(IA%),VTOE(IA%),DTOE(IA%
)
190    DIM VCAP(IA%),DCAP(IA%),VHAUL(IA%):RETURN
200    ERASE STAE,STAN,STNGL,CW:RETURN
210    ERASE SPOILEL,SPOILCW,SPOILEN,SHO,HI,HO,BO,S%,DAML,CEL,NGL,CASE%
220    ERASE CAPL,TOEL,CWI,BOUNDED$,HRI,VTOE,DTOE,VCAP,DCAP,VHAUL,VSPOIL
230    ERASE DSPOIL:RETURN
240    CLS:RETURN: REM Clear Screen and Home Cursor
250    PRINT CHR$(7);: RETURN: REM Bell
260    FOR IZ% = 1 TO 6
270      GOSUB 250
280    NEXT IZ%
290    RETURN: REM Long Bell
300    REM Quadratic Equation Routine
310    IF A=0 THEN VTRAP=-1:LPRINT " A = 0":RETURN
320    RAD=B*B-4*A*D
330    IF RAD<0 THEN VTRAP=-1:LPRINT "NEGATIVE RADICAL":RETURN
340    VTRAP=(-B+SQR(RAD))/2/A
350    IF VTRAP<0 OR VTRAP>VM*1.01 THEN VTRAP=(-B-SQR(RAD))/2/A
360    IF VTRAP<0 THEN LPRINT "SECOND ROOT IS NEGATIVE"
370    IF VTRAP> VM*1.01 THEN VTRAP=-1:LPRINT "SECOND ROOT OUT OF BOUNDS"
380    RETURN
390    IA%=0:IF IZ$="" OR LEN(IZ$)>8 THEN IA%=1
400    FOR IZ% = 1 TO LEN(IZ$)
410      IF MID$(IZ$,IZ%,1)=" " THEN IA%=1
420    NEXT IZ%:RETURN: REM Incorrect file name routine
430    GOSUB 240:PRINT TAB(10);"ESTIMATION OF SETTLING AREA RECLAMATION COSTS AND
 REQUIREMENTS"
440    PRINT TAB(10);"=========================================================
==="
450    IF TITLE$ = "" THEN FLNM$ = ""
460    PRINT TAB(10);TITLE$;FLNM$;TAB(53);MESS$:RETURN
470    REM
480    REM ************************ Define Functions *************************
490    REM
500    DEF FNTRAPA(INSLOPE,WID,OUTSLOPE,VFB)=VFB*(WID+VFB*(OUTSLOPE+INSLOPE)/2!)
510    DEF FNTRIA(VT,FLATSLOPE,STEEPSLOPE)=VT*VT/2!*(FLATSLOPE-STEEPSLOPE)
520    DEF FNTRICA(V,FLATSLOPE,STEEPSLOPE)=V*(FLATSLOPE+STEEPSLOPE)/3!
530    DEF FNTRAPC(H1,WID,H2,V)=V*((H1-H2)*(WID/2!+V*(H2+H1)/3!))/(2!*WID+V*(H1+H
2))
540    REM
550    REM *************** Introductory Screen Message ************************
560    REM
570    TITLE$="":MESS$="":GOSUB 430:X%=15:PRINT:PRINT:PRINT TAB(X%);"To evaluate
the cost of reclaiming a settling area,"
580    PRINT TAB(X%);"you will need the following information in two input":PRINT
```

```
 TAB(X%);"files.":PRINT:PRINT TAB(X%+5);"Settling Area File:"
590   PRINT TAB(X%+8);"Detailed Description of Settling Area"
600   PRINT TAB(X%+8);"Reclamation Requirements":PRINT TAB(X%+5);"Equipment File
:"
610   PRINT TAB(X%+8);"Equipment Performance Data":PRINT TAB(X%+8);"Cost Data":P
RINT
620   PRINT TAB(X%+13);"Hit RETURN to Continue.";:INPUT "",IZ$
630   REM
640   REM **************************** Main Menu ******************************
650   REM
660   MESS$="Program Option Menu":GOSUB 430:PRINT:PRINT:X%=25
670   PRINT:PRINT TAB(X%+3);"Input File Manipulation";:PRINT TAB(X%+5);"Settling
 Area"
680   PRINT TAB(X%+7);"Create ........... 1";:PRINT TAB(X%+7);"Edit ............
. 1"
690   PRINT TAB(X%+7);"Print ............ 1";:PRINT TAB(X%+5);"Equipment"
700   PRINT TAB(X%+7);"Create ........... 1";:PRINT TAB(X%+7);"Edit ............
. 1"
710   PRINT TAB(X%+7);"Print ............ 1";:PRINT:PRINT TAB(X%+3);"Run Program
 .......... 2"
720   PRINT TAB(X%+3);"Exit Program ......... 3":PRINT
730   PRINT:PRINT TAB(X%):GOSUB 250:INPUT "ENTER DESIRED PROGRAM OPTION: ";C%
740   IF C%<>1 AND C%<>2 AND C%<>3 THEN GOSUB 260:GOTO 540: REM Wrong Entry Alar
m
750   ON C% GOTO 800,820,760
760   GOSUB 240:END: REM Exit Program
770   REM
780   REM ******** Chain to File Manipulating Program (SETRECFL) **************
790   REM
800   MESS$="":GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(18);"Loading File Manipulat
ion Program (SETRECFL)":CHAIN "SETRECFL"
810   REM
820   REM************************** Main Program ******************************
830   REM Enter Settling Area File Name *****
840   REM
850   MESS$="    Running Program":GOSUB 430:X%=29:PRINT:PRINT:PRINT
860   PRINT TAB(X%);"Enter Input File Names"
870   PRINT TAB(X%);"----------------------":PRINT
880   PRINT TAB(X%);"Settling Area File: ";:INPUT "",IZ$:GOSUB 390
890   IF IA%=1 THEN GOSUB 260:GOTO 880
900   FLNM$=IZ$
910   REM
920   REM Enter Equipment File Name *****
930   REM
940   PRINT TAB(X%);"Equipment File: ";:INPUT "",IZ$:GOSUB 390
950   IF IA%=1 THEN GOSUB 260: GOTO 940
960   EQUIP$=IZ$:IZ$=""
970   PRINT:PRINT TAB(X%-7);"Are These File Names Correct? (Y/N): ";:INPUT "",IZ
$
980   IF IZ$="N" THEN GOTO 850
990   REM
1000  REM Read Settling Area Input File *****
1010  REM
1020  TITLE$="Area File: ":GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(28);"Retrieving
 Input Files."
1030  OPEN "I",#1,FLNM$+".SAI"
1040  INPUT #1,I%,J%:GOSUB 160
1050  INPUT #1,AREANM$,AREALOC$
1060  INPUT #1,SLIMES,SLIMESAC,NOSPILL%,CRESTEL
1070  FOR IZ% = 1 TO I%
1080    INPUT #1,STAN(IZ%),STAE(IZ%),STNGL(IZ%),CW(IZ%),HO(IZ%),HI(IZ%),BO(IZ%)
1090  NEXT IZ%
1100  IF J%=0 THEN GOTO 1140
1110  FOR IZ% = 1 TO J%
```

```
1120    INPUT #1,SPOILEL(IZ%),SPOILCW(IZ%),SPOILEN(IZ%),SHO(IZ%)
1130  NEXT IZ%
1140  INPUT #1,RECLAIM$,HR,TSPILLS%,RSPILLS%
1150  IF RECLAIM$<>"CRUST" AND RECLAIM$<>"CAP" THEN CLOSE #1:LPRINT "Method of r
eclamation not specified.  Please check.":GOSUB 200:GOSUB 210:GOTO 540
1160  IF RECLAIM$="CRUST" THEN INPUT #1,CONSOL,DIVFT,IDITPAC ELSE INPUT #1,COMP,
SAND,MILES,SOILCAP,SANDA
1170  INPUT #1,TIDAM%,LIDAM%,SEDAM%,FEDAM%,TREES
1180  INPUT #1,CHSLIM%,TISLIM%,LISLIM%,SESLIM%,FESLIM%
1190  CLOSE #1
1200  REM
1210  REM Read Equipment Input File ******
1220  REM
1230  OPEN "I",#1,EQUIP$+".EQI"
1240  FOR IZ% = 1 TO 8
1250    ON IZ% GOTO 1260,1270,1280,1290,1300,1310,1320,1330
1260    INPUT #1,X%,BULL$,M,N,BULLCST:GOTO 1340
1270    INPUT #1,X%,LGPBULL$,LGPM,LGPN,LGPCST:GOTO 1340
1280    INPUT #1,X%,DITCH$,DIT,DITCST:GOTO 1340
1290    INPUT #1,X%,LGPDITCH$,LGPDIT,LGPDITCST:GOTO 1340
1300    INPUT #1,X%,SCRAP$,SM,SN,SCST:GOTO 1340
1310    INPUT #1,X%,PIPE$,PBCY,YARDMI:GOTO 1340
1320    INPUT #1,X%,TSPILLCST,RSPILLCST:GOTO 1340
1330    INPUT #1,X%,CHOP,TILL,LIME,SEED,FERT,TREEP
1340  NEXT IZ%
1350  CLOSE #1
1360  REM
1370  REM Check Equipment File for completeness *****
1380  REM
1390  IF M=0 OR LGPM=0 THEN LPRINT"INCOMPLETE EQUIPMENT DATA FILE. PLEASE CHECK.
":GOSUB 200:GOSUB 210:GOTO 540
1400  IF DIT=0 AND RECLAIM$="CRUST" THEN LPRINT "THERE IS NO PERFORMANCE DATA ON
 THE DITCHING EQUIPMENT. PLEASE CHECK":GOSUB 200:GOSUB 210:GOTO 540
1410  IF LGPDIT=0 AND RECLAIM$="CRUST" THEN LPRINT"THERE IS NO PERFORMANCE DATA
FOR LGP DITCHING EQUIPMENT, THIS IS NECESSARY FOR THE CRUST DEVELOPMENT METHOD."
:GOSUB 200:GOSUB 210:GOTO 540
1420  IF PBCY=0 AND RECLAIM$="CAP" THEN LPRINT"THERE IS NO PUMPING DATA FOR THE
SLURRY PIPELINE, THIS IS NECESSARY FOR THE CAPPING METHOD.":GOSUB 200:GOSUB 210:
GOTO 540
1430  IF SM=0 AND RECLAIM$="CAP" THEN LPRINT "THERE IS NO SCRAPER DATA.  THIS IS
 NECESSARY FOR BUILDING THE":LPRINT "TOPSOIL CAP FOR THE CAPPING METHOD":GOSUB 2
00:GOSUB 210:GOTO 540
1440  REM
1450  REM************************ Dissect Area File ****************************

1460  TITLE$="Area File: ":GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(22);"Dissecting
 Area File into Like Cases."
1470  IF RECLAIM$="CAP" THEN DELTAEL=SAND-COMP+SOILCAP ELSE DELTAEL=-CONSOL
1480  SLIMES=SLIMES+DELTAEL
1490  IF SLIMES>CRESTEL THEN LPRINT "YOU CANNOT BUILD A CAP HIGHER THAN THE CRES
T ROAD ELEVATION.":GOSUB 200:GOSUB 210:GOTO 540
1500  REM
1510  REM Calculate Angle Between Segments **********
1520  REM
1530  K1%=0
1540  FOR IZ% = 1 TO I%
1550    IF IZ%=1 THEN A1%=I%:A3%=IZ%+1:GOTO 1580
1560    IF IZ%=I% THEN A3%=1:A1%=IZ%-1:GOTO 1580
1570    A1%=IZ%-1:A3%=IZ%+1
1580    FOR IA% = 1 TO 2:REM Angle Routine
1590      ND=STAN(A1%)-STAN(IZ%):ED=STAE(A1%)-STAE(IZ%)
1600      IF IA%=2 THEN ND=STAN(A3%)-STAN(IZ%):ED=STAE(A3%)-STAE(IZ%)
1610      ANGL(IA%)=3.1416/2!
1620      IF ND<>0! THEN ANGL(IA%)=ATN(ABS(ED)/ABS(ND))
```

```
1630      IF ED>=0! AND ND<0! THEN ANGL(IA%)=3.1416-ANGL(IA%)
1640      IF ED<0! AND ND<0! THEN ANGL(IA%)=3.1416+ANGL(IA%)
1650      IF ED<0! AND ND>=0! THEN ANGL(IA%)=2!*3.1416-ANGL(IA%)
1660    NEXT IA%
1670    ANGLE=ANGL(2)-ANGL(1)
1680    IF ANGLE<0! THEN ANGLE=2!*3.1416+ANGL(2)-ANGL(1)
1690    DCAPL=(ANGLE-3.1416)*(CW(IZ%)/2!+HI(IZ%)*(CRESTEL-SLIMES))
1700    DTOEL=(3.1416-ANGLE)*(CW(IZ%)/2!+HO(IZ%)*(CRESTEL-STNGL(IZ%)))
1710    REM
1720    REM Dissect Segments into Like Cases ******
1730    REM
1740    LENG=SQR((STAN(IZ%)-STAN(A3%))^2!+(STAE(IZ%)-STAE(A3%))^2!)
1750    DELTA=ABS(STNGL(IZ%)-STNGL(A3%))
1760    STLOC=0!:ENLOC=LENG
1770    SNGL=STNGL(IZ%):ENGL=STNGL(A3%)
1780    IF SNGL<SLIMES AND SLIMES<ENGL THEN ENGL=SLIMES:PRO=(SLIMES-SNGL)/DELTA:
ENLOC=STLOC+PRO*LENG:GOTO 1820:REM Case 1,2 and maybe 3, positive slope
1790    IF SNGL<CRESTEL AND CRESTEL<ENGL THEN ENGL=CRESTEL:PRO=(CRESTEL-SNGL)/DE
LTA:ENLOC=STLOC+PRO*LENG:GOTO 1820: REM Case 2 and 3, positive slope
1800    IF SNGL>SLIMES AND SLIMES>ENGL THEN ENGL=SLIMES:PRO=(SNGL-ENGL)/DELTA:EN
LOC=STLOC+PRO*LENG:GOTO 1820:REM Case 1,2, and maybe 3, negative slope
1810    IF SNGL>CRESTEL AND CRESTEL>ENGL THEN ENGL=CRESTEL:PRO=(SNGL-ENGL)/DELTA
:ENLOC=STLOC+PRO*LENG:REM Case 2 and 3, negative slope
1820    K1%=K1%+1:DELTA1=ABS(ENGL-SNGL)
1830    IF SNGL<=ENGL AND ENGL<=CRESTEL AND SNGL>=SLIMES THEN CASE%(K1%)=2:NGL(K
1%)=SNGL+DELTA1/3!:GOTO 1910
1840    IF SNGL<=ENGL AND ENGL<=SLIMES THEN CASE%(K1%)=1:NGL(K1%)=SNGL+DELTA1/3!
:GOTO 1910
1850    IF SNGL<=ENGL AND SNGL>=CRESTEL THEN CASE%(K1%)=3:NGL(K1%)=ENGL-DELTA1/3
!:GOTO 1910
1860    IF SNGL>=ENGL AND SNGL<=SLIMES THEN CASE%(K1%)=1:NGL(K1%)=ENGL+DELTA1/3!
:GOTO 1910
1870    IF SNGL>=ENGL AND SNGL<=CRESTEL AND ENGL>=SLIMES THEN CASE%(K1%)=2:NGL(K
1%)=ENGL+DELTA1/3!:GOTO 1910
1880    IF SNGL>=ENGL AND ENGL>=CRESTEL THEN CASE%(K1%)=3:NGL(K1%)=SNGL-DELTA1/3
!:GOTO 1910
1890    LPRINT TAB(11);"Difficulty in breaking segment number ";IZ%;" into like
cases."
1900    LPRINT TAB(34);"Please check.":GOSUB 200:GOSUB 210:GOTO 640
1910    DAML(K1%)=ENLOC-STLOC:CAPL(K1%)=DAML(K1%):TOEL(K1%)=DAML(K1%):S%(K1%)=IZ
%
1920    CEL(K1%)=CRESTEL:CWI(K1%)=CW(IZ%)
1930    IF STLOC=0! THEN CAPL(K1%)=DAML(K1%)+DCAPL:TOEL(K1%)=DAML(K1%)+DTOEL
1940    IF CAPL(K1%)<0! THEN CAPL(K1%)=0!
1950    IF TOEL(K%)<0 THEN TOEL(K%)=1
1960    IF ENLOC<>LENG THEN STLOC=ENLOC:ENLOC=LENG:SNGL=ENGL:ENGL=STNGL(A3%):GOT
O 1780
1970  NEXT IZ%
1980  GOSUB 200
1990  REM
2000  REM Determine New Slimes Acreages *****
2010  REM
2020  GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(22);"Calculating Reclamation Require
ments"
2030  DELTAC=0!
2040  FOR IZ% = 1 TO K1%
2050    DELTAC=DELTAC-CAPL(IZ%)*HI(S%(IZ%))*DELTAEL
2060  NEXT IZ%
2070  IF J%=0 THEN GOTO 2160
2080  SPOILVOL=0
2090  FOR IZ% = 1 TO J%
2100    IF SPOILEL(IZ%)<SLIMES THEN GOTO 2150
2110    VFB=SPOILEL(IZ%)-SLIMES
2120    DELTAC=DELTAC+SPOILEN(IZ%)*(SPOILCW(IZ%)+2*SHO(IZ%)*VFB)
```

```
2130    IF RECLAIM$="CRUST" THEN GOTO 2150
2140    SPOILVOL=SPOILVOL+FNTRAPA(SHO(IZ%),SPOILCW(IZ%),SHO(IZ%),VFB)*SPOILEN(IZ%)/27
2150  NEXT IZ%
2160  SOILCAPA=SLIMESAC*43560!-DELTAC
2170  IF RECLAIM$="CRUST" THEN GOTO 2660
2180  REM
2190  REM Estimate Topsoil Requirements *****
2200  REM
2210    CAPA=SOILCAPA*SANDA/100:SOILCAPA=SOILCAPA-CAPA
2220  SOILVOL=CAPA*SOILCAP/27:SOILBOR=0
2230  IF SOILVOL<=SPOILVOL THEN SPOILBOR=SOILVOL:DAMBOR=0:GOTO 2490
2240  REM
2250  REM Robbing for Topsoil *****
2260  REM
2270  SPOILBOR=SPOILVOL:DAMVOL=0!
2280  FOR IZ% = 1 TO K1%
2290    IF CASE%(IZ%)=3 THEN GOTO 2320
2300    IF CASE%(IZ%)=1 THEN VFB=CEL(IZ%)-SLIMES ELSE VFB=CEL(IZ%)-NGL(IZ%)
2310    DAMVOL=DAMVOL+DAML(IZ%)*FNTRAPA(HI(S%(IZ%)),CWI(IZ%),HO(S%(IZ%)),VFB)/27

2320  NEXT IZ%
2330  IF SOILVOL<=SPOILVOL+DAMVOL THEN DAMBOR=SOILVOL-SPOILVOL:PRO=DAMBOR/DAMVOL:GOTO 2350
2340  SOILBOR=SOILVOL-DAMVOL-SPOILVOL:DAMBOR=DAMVOL:PRO=1!
2350  FOR IZ% = 1 TO K1%
2360    IF CASE%(IZ%)=3 THEN GOTO 2470
2370    IF CASE%(IZ%)=1 THEN VM=CEL(IZ%)-SLIMES ELSE VM=CEL(IZ%)-NGL(IZ%)
2380    A=(HO(S%(IZ%))+HI(S%(IZ%)))/2!
2390    B=CWI(IZ%)
2400    D=-PRO*FNTRAPA(HI(S%(IZ%)),CWI(IZ%),HO(S%(IZ%)),VM)
2410    GOSUB 300
2420    IF VTRAP => 0 THEN GOTO 2450
2430    LPRINT "Program bombed while trying to adjust dam volumes after robbing topsoil"
2440    LPRINT "in dam segment ";S%(IZ%);:LPRINT ". Please check.":GOSUB 210:GOTO 540
2450    CEL(IZ%)=CEL(IZ%)-VTRAP
2460    CWI(IZ%)=CWI(IZ%)+VTRAP*(HO(S%(IZ%))+HI(S%(IZ%)))
2470  NEXT IZ%
2480  PRO=1!:GOTO 2500
2490  PRO=SOILVOL/SPOILVOL
2500  FOR IZ% = 1 TO J%
2510    IF SPOILEL(IZ%)<SLIMES THEN GOTO 2610
2520    VM=SPOILEL(IZ%)-SLIMES
2530    A=SHO(IZ%):B=SPOILCW(IZ%)
2540    D=-PRO*FNTRAPA(SHO(IZ%),SPOILCW(IZ%),SHO(IZ%),VM)
2550    GOSUB 300
2560    IF VTRAP => 0 THEN GOTO 2590
2570    LPRINT "Program bombed while trying to adjust spoil ridge volumes after robbing"
2580    LPRINT "topsoil in spoil ridge ";IZ%;:LPRINT ". Please check.":GOSUB 210:GOTO 540
2590    SPOILEL(IZ%)=SPOILEL(IZ%)-VTRAP
2600    SPOILCW(IZ%)=SPOILCW(IZ%)+2!*VTRAP*SHO(IZ%)
2610  NEXT IZ%
2620  DDPOIL=200+SQR(SPOILBOR*CAPA*.5/SOILVOL/3.1416)
2630  IF DAMBOR=0 THEN GOTO 2650
2640  DDAM=200+SQR(CAPA/3.1416)-SQR((1-DAMBOR/SOILVOL/2)/3.1416)
2650  REM
2660  REM***************** Start Dam Earthwork Calculations *****************
2670  REM
2680  CAPTOT=0!:BULLHR=0:TOTBOR=0:TOTDAM=0:DAMAC=0:BOFLAG%=0
2690  FOR K% = 1 TO K1%
```

```
2700     BOUNDED$(K%)="NO":HRI(K%)=HR
2710     IF BO(S%(K%))>CWI(K%)/2!+ABS(CEL(K%)-NGL(K%))*HO(S%(K%)) THEN GOTO 2740
2720     LPRINT "Boundary limit on side of dam? Please check the boundary limit"
2730     LPRINT "and outside dam slope in segment number ";S%(K%):GOSUB 210:GOTO
540
2740     VHAUL(K%)=0!:VTOE(K%)=0!:DTOE(K%)=0!:VCAP(K%)=0!:DCAP(K%)=0!
2750     IF HO(S%(K%))>HR THEN HO(S%(K%))=HR
2760     IF HI(S%(K%))>HR THEN HI(S%(K%))=HR
2770     ON CASE%(K%) GOTO 2780,3660,3790
2780     VF=SLIMES-NGL(K%):VFB=CEL(K%)-SLIMES:BI=CWI(K%)/2!+VFB*HI(S%(K%)):CS=CWI
(K%)+VFB*(HO(S%(K%))+HI(S%(K%)))
2790     FLAG2%=0
2800     IF BO(S%(K%))+BI<VF*HR THEN GOTO 3520
2810     A1=FNTRAPA(HI(S%(K%)),CWI(K%),HO(S%(K%)),VFB):A1V=A1*DAML(K%)
2820     A2=FNTRIA(VF,HRI(K%),HO(S%(K%))):A2V=A2*TOEL(K%)
2830     IF A1V<A2V THEN GOTO 3140
2840     VCUT=A1V/27
2850     R1=FNTRAPC(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB)
2860     X=CWI(K%)/2+VF*HR+VFB*HO(S%(K%))-BO(S%(K%))
2870     IF X<=0 THEN GOTO 2940
2880     BOUNDED$(K%)="YES"
2890     VU=X/(HR-HO(S%(K%))):ATR=FNTRIA(VU,HR,HO(S%(K%))):VCUT=A1V+ATR*DAML(K%)/
27
2900     V=VF-VU:VTOE(K%)=FNTRIA(V,HR,HO(S%(K%)))*TOEL(K%)/27
2910     VCAP(K%)=VCUT-VTOE(K%):DCAP(K%)=VCAP(K%)*9/CAPL(K%)+CWI(K%)/2+R1+VFB*HI(
S%(K%))
2920     DTOE(K%)=FNTRICA(V,HR,HO(S%(K%)))+(A1*(CWI(K%)/2-R1+HO(S%(K%))*(VFB+VU))
+ATR*FNTRICA(VU,HR,HO(S%(K%))))/(ATR+A1)
2930     GOTO 3990
2940     D=VCUT/50
2950     FOR IZ% = 0 TO 50
2960       V=IZ%*D
2970       DTOE(K%)=CWI(K%)/2-R1+VFB*HO(S%(K%))+VF/3*(54*V/TOEL(K%)/VF/VF+2*HO(S%
(K%)))
2980       IF DTOE(K%)<50 THEN DTOE(K%)=50
2990       DCAP(K%)=(VCUT-V)*9/CAPL(K%)+CWI(K%)/2+R1+VFB*HI(S%(K%))
3000       IF DCAP(K%)<50 THEN DCAP(K%)=50
3010       IF DCAP(K%)>500 THEN DCAP(K%)=500
3020       FVTOE=V/(M*DTOE(K%)^N)+(VCUT-V)/(M*DCAP(K%)^N)
3030       IF IZ%=0 THEN SMALL=FVTOE:VTOE(K%)=V:GOTO 3050
3040       IF FVTOE<SMALL THEN SMALL=FVTOE:VTOE(K%)=V
3050     NEXT IZ%
3060     IF VTOE(K%)>VCUT THEN VTOE(K%)=VCUT
3070     HS=VTOE(K%)*54/TOEL(K%)/VF/VF+HO(S%(K%))
3080     IF HS=> HR THEN HRI(K%)=HS ELSE VTOE(K%)=A2V/27:HRI(K%)=HR
3090     X=CWI(K%)/2+VFB*HO(S%(K%))+VF*HRI(K%)-BO(S%(K%))
3100     IF X>0 THEN HRI(K%)=(BO(S%(K%))-CWI(K%)/2-VFB*HO(S%(K%)))/VF:VTOE(K%)=FN
TRIA(VF,HRI(K%),HO(S%(K%)))*TOEL(K%)/27:BOUNDED$(K%)="YES"
3110     VCAP(K%)=VCUT-VTOE(K%):DTOE(K%)=-R1+CWI(K%)/2+FNTRICA(VF,HRI(K%),HO(S%(K
%)))+VFB*HO(S%(K%))
3120     DCAP(K%)=VCAP(K%)*9/CAPL(K%)+CWI(K%)/2+R1+VFB*HI(S%(K%))
3130     GOTO 3990
3140     HS=A1V*2/TOEL(K%)/VF/VF+HO(S%(K%))
3150     X2=CWI(K%)/2!+VFB*HO(S%(K%))+VF*(HS+HR)/2!
3160     IF FLAG2%=1 THEN GOTO 3300
3170     IF .5*VF*(HR-HS)<=CS AND X2<=BO(S%(K%)) THEN GOTO 3300
3180     REM XI Beginning ****
3190     IF X2>=BO(S%(K%)) THEN X=VF*HR-BO(S%(K%))+CWI(K%)/2+HO(S%(K%))*VFB:GOTO
2880
3200     BOUNDED$(K%)="NO":VU=CS/(HR-HO(S%(K%)))
3210     VCUT=(A1+FNTRIA(VU,HR,HO(S%(K%))))*DAML(K%)/27
3220     VW=VF-VU
3230     VTOE(K%)=FNTRIA(VW,HR,HO(S%(K%)))*TOEL(K%)/27
3240     VCAP(K%)=VCUT-VTOE(K%)
```

```
3250    R1=FNTRAPC(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB)
3260    DTOE(K%)=-R1+CWI(K%)/2+HO(S%(K%))*(VFB+VU)+FNTRICA(VW,HR,HO(S%(K%)))
3270    IF VCAP(K%)>0! THEN DCAP(K%)=VCAP(K%)*9/CAPL(K%)+CWI(K%)/2+R1+VFB*HI(S%(
K%)):GOTO 3990
3280    VHAUL(K%)=-VCAP(K%):VCAP(K%)=0!:GOTO 3990
3290    REM XI End ********
3300    REM X Beginning ***
3310    BOUNDED$(K%)="NO"
3320    R1=FNTRAPC(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB)
3330    IF TOEL(K%) = DAML(K%) THEN GOTO 3460
3340    A=(HR-HO(S%(K%)))*(DAML(K%)-TOEL(K%))/2
3350    B=DAML(K%)*(HO(S%(K%))-HR)*VF
3360    D=DAML(K%)*(A1+VF*VF*(HR-HO(S%(K%)))/2)
3370    VM=VF
3380    GOSUB 300
3390    IF VTRAP<0 THEN LPRINT "ERROR WHILE TRYING TO SOLVE THE QUADRATIC EQUATI
ON FOR A BALANCED CUT AND FILL.":LPRINT "PLEASE CHECK SEGMENT ";S%(K%):GOSUB 210
:GOTO 540
3400    ATOE=FNTRIA(VTRAP,HR,HO(S%(K%))):VTOE(K%)=ATOE*TOEL(K%)/27
3410    VU=VF-VTRAP
3420    ATR=FNTRIA(VU,HR,HO(S%(K%)))
3430    DTOE(K%)=FNTRICA(VTRAP,HR,HO(S%(K%)))+(A1*(CWI(K%)/2-R1+HO(S%(K%))*(VFB+
VU))+ATR*FNTRICA(VU,HR,HO(S%(K%))))/(A1+ATR)
3440    IF FLAG2%=1 THEN VCAP(K%)=VTOE(K%):DCAP(K%)=DTOE(K%):VTOE(K%)=0:DTOE(K%)
=0
3450    GOTO 3990
3460    VBAL=VF/2
3470    ABALCUT=FNTRIA(VBAL,HR,HS)
3480    DBAL=FNTRICA(VBAL,HR,HS)
3490    VTOE(K%)=(A1+ABALCUT)*DAML(K%)/27
3500    DTOE(K%)=(ABALCUT*2*DBAL+A1*(CWI(K%)/2-R1+HO(S%(K%))*VFB+VBAL*HS+DBAL))/
(A1+ABALCUT):GOTO 3440
3510    REM X End *********
3520    REM V Beginning **
3530    BOUNDED$(K%)="YES"
3540    HRI(K%)=(BO(S%(K%))+BI)/VF
3550    BOFLAG%=1
3560    VU=CS/(HRI(K%)-HO(S%(K%)))
3570    VW=VF-VU:A1=FNTRAPA(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB):ATR=FNTRIA(VU,HRI
(K%),HO(S%(K%)))
3580    VCUT=(A1+ATR)*DAML(K%)/27
3590    VTOE(K%)=(FNTRIA(VW,HRI(K%),HO(S%(K%))))*TOEL(K%)/27
3600    VCAP(K%)=VCUT-VTOE(K%)
3610    R1=FNTRAPC(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB)
3620    DTOE(K%)=FNTRICA(VW,HRI(K%),HO(S%(K%)))+(FNTRICA(VU,HRI(K%),HO(S%(K%)))*
ATR+A1*(CWI(K%)/2-R1+HO(S%(K%))*(VFB+VU)))/(A1+ATR)
3630    IF VCAP(K%)>0! THEN DCAP(K%)=VCAP(K%)*9/CAPL(K%)+CWI(K%)/2+R1+VFB*HI(S%(
K%)):GOTO 3990
3640    VHAUL(K%)=-VCAP(K%)
3650    VCAP(K%)=0!:GOTO 3990
3660    REM Case 2 *******
3670    IF CEL(K%)=NGL(K%) THEN CASE%(K%)=3:GOTO 3790
3680    IF CAPL(K%)=0 THEN VCAP(K%)=0:DCAP(K%)=0:GOTO 3990
3690    VF=NGL(K%)-SLIMES:FLAG2%=1
3700    VFB=CEL(K%)-NGL(K%):A1=FNTRAPA(HI(S%(K%)),CWI(K%),HO(S%(K%)),VFB)
3710    A1V=A1*DAML(K%)
3720    A2=FNTRIA(VF,HR,HI(S%(K%))):A2V=A2*CAPL(K%)
3730    IF A1V<A2V THEN SWAP HO(S%(K%)),HI(S%(K%)):SWAP CAPL(K%),TOEL(K%):GOTO 3
140
3740    R1=FNTRAPC(HO(S%(K%)),CWI(K%),HI(S%(K%)),VFB)
3750    A3=(A1V-A2V)/CAPL(K%)
3760    IF VF<3 THEN VF=3
3770    DCAP(K%)=R1+CWI(K%)/2+VFB*HI(S%(K%))+(A3/2*(A3/VF+VF*HI(S%(K%)))+A2*(A3/
VF+FNTRICA(VF,HRI(K%),HI(S%(K%)))))*CAPL(K%)/A1V
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3780    VCAP(K%)=A1V/27:GOTO 3990
3790    REM Case 3 *******
3800    IF HI(S%(K%))>HR THEN GOTO 4220
3810    VF=NGL(K%)-SLIMES
3820    IF DAML(K%)=CAPL(K%) THEN GOTO 3950
3830    A=(HR-HI(S%(K%)))*(DAML(K%)-CAPL(K%))
3840    B=2*VF*CAPL(K%)*(HR-HI(S%(K%)))
3850    D=VF*VF*CAPL(K%)*(HI(S%(K%))-HR)
3860    VM=VF
3870    GOSUB 300
3880    IF VTRAP => 0 THEN GOTO 3910
3890    LPRINT "Error while trying to solve the quadratic equation for a Case 3"

3900    LPRINT "Balanced Cut-and-Fill, check segment number ";S%(K%):GOSUB 210:G
OTO 540
3910    VW=VF-VTRAP
3920    VCAP(K%)=FNTRIA(VW,HR,HI(S%(K%)))*CAPL(K%)/27
3930    DCAP(K%)=FNTRICA(VW,HR,HI(S%(K%)))+FNTRICA(VTRAP,HR,HI(S%(K%)))
3940    GOTO 3990
3950    VBAL=VF/2
3960    VCAP(K%)=FNTRIA(VBAL,HR,HI(S%(K%)))*CAPL(K%)/27
3970    DCAP(K%)=2*FNTRICA(VBAL,HR,HI(S%(K%)))
3980    REM
3990    REM Dam Earthmoving Totals ****
4000    IF CASE%(K%)=2 OR CASE%(K%)=3 THEN VTOE(K%)=0:DTOE(K%)=0
4010    TOTDAM=VCAP(K%)+VTOE(K%)+TOTDAM+VHAUL(K%)
4020    IF DTOE(K%)<50 AND DTOE(K%)>0 THEN DTOE(K%)=50
4030    IF DTOE(K%)>500 THEN DTOE(K%)=500
4040    IF DCAP(K%)<50 AND DCAP(K%)>0 THEN DCAP(K%)=50
4050    IF DCAP(K%)>500 THEN DCAP(K%)=500
4060    FOR IZ% = 1 TO 2
4070      IF IZ%=1 THEN V=VTOE(K%):D=DTOE(K%) ELSE V=VCAP(K%):D=DCAP(K%)
4080      IF V=0 THEN EQHR=0:GOTO 4110
4090      BCYPHR=M*D^N
4100      EQHR=V/BCYPHR
4110      BULLHR=BULLHR+EQHR
4120    REM
4130    NEXT IZ%
4140    TOTBOR=TOTBOR+VHAUL(K%)
4150    REM
4160    REM Estimate Dam Acreage ****
4170    REM
4180    CAPTOT=CAPTOT+CAPL(K%)
4190    IF CASE%(K%)=3 THEN DAMAC=CAPL(K%)*(CWI(K%)+HI(S%(K%))*5!)+DAMAC
4200    IF CASE%(K%)=1 THEN DAMAC=2*DTOE(K%)*TOEL(K%)+CAPL(K%)*(CWI(K%)/2+5!*HI(
S%(K%)))+DAMAC
4210    IF CASE%(K%)=2 THEN DAMAC=DAML(K%)*(CWI(K%)+5!*(HO(S%(K%))+HI(S%(K%))))+
DAMAC
4220   NEXT K%
4230   DAMAC=(DAMAC+DELTAC)/43560!
4240   SOILCAPA=SOILCAPA/43560!:IF RECLAIM$="CAP" THEN DAMAC=DAMAC+CAPA/43560!
4250   REM
4260   REM Spoil Ridge Earthmoving Calculations ***
4270   REM
4280   IF J%=0 THEN GOTO 4460
4290   LGPHR=0:TOTSPOIL=0
4300   FOR K% = 1 TO J%
4310     IF SPOILEL(K%)<=SLIMES THEN GOTO 4440
4320     IF HR<=SHO(K%) THEN GOTO 4440
4330     VM=SPOILEL(K%)-SLIMES:A=2*SHO(K%)-HR
4340     B=SPOILCW(K%)+2*VM*(HR-SHO(K%))
4350     D=VM*VM*(SHO(K%)-HR):GOSUB 300
4360     IF VTRAP<0 THEN LPRINT "Error while trying to solve quadratic equation f
or spoil ridge ";K%:LPRINT "Please check.":GOSUB 210:GOTO 540
```

```
4370    VSPOIL(K%)=FNTRAPA(SHO(K%),SPOILCW(K%),SHO(K%),VTRAP)*SPOILEN(K%)/27
4380    V=VM-VTRAP:TOTSPOIL=TOTSPOIL+VSPOIL(K%)
4390    DSPOIL(K%)=FNTRICA(V,HR,SHO(K%))+VTRAP*SHO(K%)+SPOILCW(K%)/2
4400    IF DSPOIL(K%)<50 THEN DSPOIL(K%)=50
4410    BCYPHR=LGPM*DSPOIL(K%)^LGPN
4420    EQHR=VSPOIL(K%)/BCYPHR
4430    LGPHR=LGPHR+EQHR
4440  NEXT K%
4450  REM
4460  REM ************************ Cost Section ******************************
4470  REM Common Costs *****
4480  REM
4490  TSPILL=TSPILLS%*TSPILLCST
4500  RSPILL=RSPILLS%*RSPILLCST
4510  DAMCST=BULLHR*BULLCST
4520  SPOILCST=LGPHR*LGPCST
4530  REM
4540  REM Crust Development Costs *******
4550  REM
4560  IF RECLAIM$="CAP" THEN GOTO 4610
4570  DIVHR=DIVFT*32/27/DIT:DIVCST=DIVHR*DITCST
4580  PERHR=CAPTOT*2*108/27/DIT:PERCST=PERHR*DITCST
4590  IDITHR=SOILCAPA*1.5*IDITPAC/LGPDIT:IDITCST=IDITHR*LGPDITCST:GOTO 4770
4600  REM
4610  REM Capping Costs *******
4620  REM
4630  TAILVOL=(CAPA-DELTAC/3!)*SAND/27!
4640  TAILPUSH=TAILVOL/3!
4650  DTAILPUSH=SAND*20/3
4660  IF DTAILPUSH<50 THEN DTAILPUSH=50
4670  PUMPHR=TAILVOL/PBCY:PUMPCST=TAILVOL*MILES*YARDMI
4680  BCYPHR=LGPM*DTAILPUSH^LGPN
4690  CONTHR=TAILPUSH/BCYPHR:CONTCST=CONTHR*LGPCST
4700  BCYPHR=SM*DDPOIL^SN
4710  SPOILHR=SPOILBOR/BCYPHR:SPOILBORCST=SPOILHR*SCST
4720  IF DAMBOR=0 THEN DAMBORCST=0:GOTO 4750
4730  BCYPHR=SM*DDAM^SN
4740  DAMBORHR=DAMBOR/BCYPHR:DAMBORCST=DAMBORHR*SCST
4750  SOILCST=SPOILBORCST+DAMBORCST:SOILHR=SPOILHR+DAMBORHR
4760  REM
4770  REM Dam Revegetation Costs *****
4780  REM
4790  DAMTICST=TIDAM%*TILL*DAMAC
4800  DAMLICST=LIDAM%*LIME*DAMAC
4810  DAMSECST=SEDAM%*SEED*DAMAC
4820  DAMFECST=FEDAM%*FERT*DAMAC
4830  TREECST=TREES*TREEP*DAMAC/100
4840  DAMREVCST=DAMTICST+DAMLICST+DAMSECST+DAMFECST+TREECST
4850  REM
4860  REM Crust Revegetation Costs *****
4870  REM
4880  SLCHCST=CHSLIM%*CHOP*SOILCAPA
4890  SLTICST=TISLIM%*TILL*SOILCAPA
4900  SLLICST=LISLIM%*LIME*SOILCAPA
4910  SLSECST=SESLIM%*SEED*SOILCAPA
4920  SLFECST=FESLIM%*FERT*SOILCAPA
4930  SLREVCST=SLCHCST+SLTICST+SLLICST+SLSECST+SLFECST
4940  REM
4950  REM Total Costs *******
4960  REM
4970  TOTREV=DAMREVCST+SLREVCST
4980  TOTREC=TOTREV+TSPILL+RSPILL+DAMCST+SPOILCST
4990  IF RECLAIM$="CAP" THEN TOTRECCST=TOTREC+PUMPCST+CONTCST+SOILCST ELSE TOTRE
CCST=TOTREC+DIVCST+PERCST+IDITCST
```

```
5000  REM
5010  REM Print Summary Sheet *****
5020  REM
5030  GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(26);"Printing Reclamation Summary"
5040  X%=12:LPRINT TAB(X%+6);CHR$(14);"RECLAMATION SUMMARY"
5050  LPRINT:LPRINT TAB(X%);"Settling Area Input File Name: ";FLNM$
5060  LPRINT TAB(X%);"Equipment Input File Name: ";EQUIP$:LPRINT
5070  LPRINT TAB(X%);"Settling Area: ";AREANM$
5080  LPRINT TAB(X%);"Settling Area Location: ";AREALOC$
5090  LPRINT TAB(X%);"Struck Dam Elevation : ";SLIMES
5100  IF RECLAIM$="CAP" THEN IZ$="Capping with Tailings" ELSE IZ$="Crust Develop
ment"
5110  REM
5120  REM Print Summary of Crusting Costs ****
5130  REM
5140  LPRINT TAB(X%);"Method of Reclamation: ";IZ$
5150  IF RECLAIM$="CAP" THEN GOTO 5380
5160  LPRINT TAB(X%);"Dam and Spoil Ridge Acreage: ";:LPRINT USING "#####.#";DAM
AC
5170  LPRINT TAB(X%);"Crust Acreage: ";:LPRINT USING "#####.#";SOILCAPA:LPRINT
5180  LPRINT TAB(X%+17);CHR$(27);"E";"CRUST DEVELOPMENT";CHR$(27);"F":LPRINT
5190  LPRINT TAB(X%);"DIVERSION DITCH"
5200  LPRINT TAB(X%);"  Length (Ft) : ";DIVFT
5210  LPRINT TAB(X%);"  Equipment : ";DITCH$
5220  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "#####,";DIVHR;
5230  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";DIVCST:LPRINT
5240  LPRINT TAB(X%);"INSIDE PERIMETER DITCH"
5250  LPRINT TAB(X%);"  Length (Ft) : ";:LPRINT USING "######,";CAPTOT
5260  LPRINT TAB(X%);"  Equipment : ";DITCH$
5270  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "######,";PERHR;
5280  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";PERCST:LPRINT
5290  LPRINT TAB(X%);"INTERIOR CRUST DITCHING"
5300  LPRINT TAB(X%);"  Length/Acre : ";IDITPAC
5310  LPRINT TAB(X%);"  Equipment : ";LGPDITCH$
5320  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "######,";IDITHR;
5330  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";IDITCST:LPRINT
5340  GOTO 5630
5350  REM
5360  REM Print Summary of Capping Costs ****
5370  REM
5380  LPRINT TAB(X%);"Dam, Spoil Ridge, and Cap Acreage : ";:LPRINT USING "#####
.#";DAMAC
5390  LPRINT TAB(X%);"Crust Acreage : ";:LPRINT USING "#####.#";SOILCAPA:LPRINT
5400  LPRINT TAB(X%+14);CHR$(27);"E";"TAILINGS CAP PLACEMENT";CHR$(27);"F":LPRIN
T
5410  LPRINT TAB(X%);"TAILINGS CAP PLACED"
5420  LPRINT TAB(X%);"  Thickness (Ft): ";SAND;TAB(X%+25);"BCY: ";:LPRINT USING
"#########,";TAILVOL
5430  LPRINT TAB(X%);"  Equipment : ";PIPE$
5440  LPRINT TAB(X%);"  Operating Hrs: ";:LPRINT USING "#######,";PUMPHR;
5450  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";PUMPCST:LPRINT
5460  LPRINT TAB(X%);"LEVELING CAP"
5470  LPRINT TAB(X%);"  BCY Moved : ";:LPRINT USING "#########,";TAILPUSH
5480  LPRINT TAB(X%);"  Equipment : ";LGPBULL$
5490  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "#######,";CONTHR;
5500  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";CONTCST:LPRINT
5510  LPRINT TAB(X%);"TOPSOIL LAYER PLACED"
5520  LPRINT TAB(X%);"  Thickness (Ft): ";SOILCAP;TAB(X%+25);"BCY: ";:LPRINT USI
NG "#########,";SOILVOL
5530  LPRINT TAB(X%);"  Borrowed from Spoil Ridges: ";:LPRINT USING "#########,"
;SPOILBOR
5540  LPRINT TAB(X%);"                               Dam: ";:LPRINT USING "#########,"
;DAMBOR
5550  IF SOILBOR = 0 THEN GOTO 5570
```

```
5560 LPRINT TAB(X%);"                          Hauled in: ";:LPRINT USING "#########,"
;SOILBOR
5570  LPRINT TAB(X%);"  Equipment : ";SCRAP$
5580  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "#######,";SOILHR;
5590  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";SOILCST:LPRINT
5600  REM
5610  REM Print Summary of Common Reclamation Costs ******
5620  REM
5630  LPRINT:LPRINT TAB(X%+11);CHR$(27);"E";"OTHER RECLAMATION ACTIVITIES";CHR$(
27);"F":LPRINT
5640  LPRINT TAB(X%);"TEMPORARY SPILLWAYS INSTALLED"
5650  LPRINT TAB(X%);"  Number : ";TSPILLS%;TAB(X%+38);"Cost : $";:LPRINT USING
"#########,";TSPILL:LPRINT
5660  LPRINT TAB(X%);"DAM EARTHWORK"
5670  LPRINT TAB(X%);"  BCY Moved: ";:LPRINT USING "##########,";TOTDAM;
5680  IF TOTBOR>0 THEN LPRINT TAB(X%+26);"Hauled in: ";:LPRINT USING "#######,";
TOTBOR ELSE LPRINT
5690  IF BOFLAG%=1 THEN LPRINT TAB(X%);"  Check earthmoving table, cannot make g
rade."
5700  LPRINT TAB(X%);"  Equipment : ";BULL$
5710  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "#######,";BULLHR;
5720  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";DAMCST:LPRINT
5730  IF LGPHR=0 THEN GOTO 5790
5740  LPRINT TAB(X%);"SPOIL RIDGE EARTHWORK"
5750  LPRINT TAB(X%);"  BCY Moved: ";:LPRINT USING "#########,";TOTSPOIL
5760  LPRINT TAB(X%);"  Equipment : ";LGPBULL$
5770  LPRINT TAB(X%);"  Machine Hrs: ";:LPRINT USING "#######,";LGPHR;
5780  LPRINT TAB(X%+38);"Cost : $";:LPRINT USING "#########,";SPOILCST:LPRINT
5790  LPRINT TAB(X%);"SPILLWAY REMOVAL"
5800  LPRINT TAB(X%);"  Number: ";RSPILLS%;TAB(X%+38);"Cost : $";:LPRINT USING "
#########,";RSPILL:LPRINT
5810  IF RECLAIM$="CAP" THEN IZ$="Dam/Cap" ELSE IZ$="Dam/Spoil Ridges"
5820  REM
5830  REM Print Summary of Dam Revegetation Costs *****
5840  REM
5850  LPRINT TAB(X%);"REVEGETATION - ";IZ$
5860  LPRINT TAB(X%);"  Tilling                    Cost: $";:LPRINT USING "######
#,";DAMTICST
5870  LPRINT TAB(X%);"  Lime(Applications): ";LIDAM%;TAB(X%+28);"Cost: $";:LPRIN
T USING "#######,";DAMLICST
5880  LPRINT TAB(X%);"  Seed(Applications): ";SEDAM%;TAB(X%+28);"Cost: $";:LPRIN
T USING "#######,";DAMSECST
5890  LPRINT TAB(X%);"  Fertilizer (Appl.): ";FEDAM%;TAB(X%+28);"Cost: $";:LPRIN
T USING "#######,";DAMFECST
5900  LPRINT TAB(X%);"  Trees  (% of Area): ";TREES;TAB(X%+28);"Cost: $";:LPRINT
 USING "#######,";TREECST
5910  LPRINT TAB(X%);"Dam,Spoil Ridge, and Cap Revegetation Cost : $";:LPRINT US
ING "#########,";DAMREVCST:LPRINT
5920  REM
5930  REM Print Summary of Crust Revegetation Costs ****
5940  REM
5950  LPRINT TAB(X%);"REVEGETATION - Crust"
5960  LPRINT TAB(X%);"  Chopping                   Cost: $";:LPRINT USING "######
#,";SLCHCST
5970  LPRINT TAB(X%);"  Tilling                    Cost: $";:LPRINT USING "######
#,";SLTICST
5980  LPRINT TAB(X%);"  Lime(Applications): ";LISLIM%;TAB(X%+28);"Cost: $";:LPRI
NT USING "#######,";SLLICST
5990  LPRINT TAB(X%);"  Seed(Applications): ";SESLIM%;TAB(X%+28);"Cost: $";:LPRI
NT USING "#######,";SLSECST
6000  LPRINT TAB(X%);"  Fertilizer (Appl.): ";FESLIM%;TAB(X%+28);"Cost: $";:LPRI
NT USING "#######,";SLFECST
6010  LPRINT TAB(X%+19);"Crust Revegetation Cost : $";:LPRINT USING "#########,"
;SLREVCST
```

```
6020  REM
6030  REM Print Total Costs *****
6040  REM
6050  LPRINT TAB(X%+19);"Total Revegetation Cost : $";:LPRINT USING "#########,"
;TOTREV:LPRINT
6060  LPRINT TAB(X%+26);"TOTAL RECLAMATION COST : $";:LPRINT USING "##########,"
;TOTRECCST
6070  REM
6080  REM Print Dam Earthmoving Summary *******
6090  REM
6100  GOSUB 430:PRINT:PRINT:PRINT:PRINT TAB(10);"Do you wish to print the earthm
oving summary tables? (Y/N): ";:INPUT "",IZ$
6110  IF IZ$<>"Y" THEN GOTO 6460
6120  LPRINT:LPRINT:LPRINT TAB(28);CHR$(27);"E";"EARTHMOVING SUMMARY: DAM";CHR$(
27);"F":LPRINT
6130  LPRINT TAB(33);"*** PUSH DAM OUT *** *PUSH DAM IN*
6140  LPRINT TAB(33);"-------------------- -------------     BCY"
6150  LPRINT TAB(10);"CASE         AVG  BOUND           BCY    DIST    BCY   DIST
 HAULED"
6160  LPRINT TAB(7);"SEG NO LENGTH  NGL  LIMIT SLOPE   MOVED  MOVED   MOVED MOVE
D    IN"
6170  LPRINT TAB(7);"--- -- ------ ----- ----- -----  ------- ----- ------- ----
-  ------"
6180  FOR IZ% = 1 TO K1%
6190    LPRINT TAB(8);:LPRINT USING "##";S%(IZ%);
6200    LPRINT TAB(12);:LPRINT USING "#";CASE%(IZ%);
6210    LPRINT TAB(15);:LPRINT USING "####,";DAML(IZ%);
6220    LPRINT TAB(21);:LPRINT USING "###.#";NGL(IZ%);
6230    LPRINT TAB(28);:LPRINT USING "\ \";BOUNDED$(IZ%);
6240    IF HRI(IZ%)>999 THEN HRI(IZ%)=999
6250    LPRINT TAB(33);:LPRINT USING "###.#";HRI(IZ%);
6260    LPRINT TAB(39);:LPRINT USING "#######,";VTOE(IZ%);
6270    LPRINT TAB(48);:LPRINT USING "####,";DTOE(IZ%);
6280    LPRINT TAB(53);:LPRINT USING "#######,";VCAP(IZ%);
6290    LPRINT TAB(62);:LPRINT USING "####,";DCAP(IZ%);
6300    LPRINT TAB(68);:LPRINT USING "######,";VHAUL(IZ%)
6310  NEXT IZ%
6320  REM
6330  REM Print Spoil Ridge Earthmoving Summary *****
6340  REM
6350  IF SPOILCST=0 THEN GOTO 6460
6360  LPRINT:LPRINT:LPRINT TAB(23);CHR$(27);"E";"EARTHMOVING SUMMARY: SPOIL RIDG
ES";CHR$(27);"F":LPRINT
6370  LPRINT TAB(29);"RIDGE    BCY     DIST"
6380  LPRINT TAB(29);"  NO    MOVED    MOVED"
6390  LPRINT TAB(29);"-----  -------   -----"
6400  FOR IZ% = 1 TO J%
6410    IF VSPOIL(IZ%)=0 THEN GOTO 6450
6420    LPRINT TAB(31);:LPRINT USING "##";IZ%;
6430    LPRINT TAB(35);:LPRINT USING "#######,";VSPOIL(IZ%);
6440    LPRINT TAB(46);:LPRINT USING "####,";DSPOIL(IZ%)
6450  NEXT IZ%
6460  GOSUB 210:GOTO 540
```

APPENDIX C

SETRECFL - PROGRAM CODING

```
10    REM**********************************************************************
20    REM**  COST MODEL PROGRAM FOR RECLAMATION OF CLAY SETTLING AREAS IN    **
30    REM    CENTRAL FLORIDA PHOSPHATE DISTRICT-FILE MANIPULATING PROGRAM    **
40    REM                                                                    **
50    REM**            WRITTEN BY: James P. Schmid                           **
60    REM**                  DATE: May 7, 1986                               **
70    REM**                                                                  **
80    REM**  PURPOSE: To create, edit, or print data input files for        **
90    REM**            settling areas and equipment.                         **
100   REM**                                                                  **
110   REM**********************************************************************
120   GOTO 270: REM Start Program
130   REM********************** Subroutines **********************************
135   REM
140   DIM STAN(I%),STAE(I%),STNGL(I%),HO(I%),HI(I%),BO(I%),CW(I%)
150   DIM SPOILEL(J%),SPOILCW(J%),SPOILEN(J%),SHO(J%):RETURN
160   CLS:RETURN: REM Clear screen and Home Cursor
170   PRINT CHR$(7);:RETURN: REM Bell
180   FOR IZ% =1 TO 6
190     GOSUB 170
200   NEXT IZ%
210   RETURN: REM Long Bell
220   GOSUB 160:PRINT TAB(10);"ESTIMATION OF SETTLING AREA RECLAMATION COSTS AND
 REQUIREMENTS"
230   PRINT TAB(10);"=============================================================
==="
240   IF TITLE$ = "" THEN I$ = ""
250   PRINT TAB(10);TITLE$;I$;TAB(50);MESS$: RETURN
255   REM
260   REM************************** Main Menu *********************************
265   REM
270   MESS$="File Manipulation Menu":TITLE$="":GOSUB 220:B%=25
280   PRINT:PRINT:PRINT TAB(B%+5);"Settling Area File"
290   PRINT TAB(B%+7);"Create ............ 1":PRINT TAB(B%+7);"Edit ..........
.... 2"
300   PRINT TAB(B%+7);"Print ............. 3":PRINT TAB(B%+5);"Equipment File"
310   PRINT TAB(B%+7);"Create ............ 4":PRINT TAB(B%+7);"Edit ..........
.... 5"
320   PRINT TAB(B%+7);"Print ............. 6":PRINT TAB(B%+5);"Return to Main M
enu .. 7"
330   PRINT TAB(B%+5);"Exit Program ......... 8":PRINT
340   GOSUB 170:PRINT TAB(B%-9):INPUT "ENTER DESIRED PROGRAM FILE MANIPULATION O
PTION: ";C%
350   IF C%<>1 AND C%<>2 AND C%<>3 AND C%<>4 AND C%<>5 AND C%<>6 AND C%<>7 AND C
%<>8 THEN GOSUB 180:GOTO 260: REM Wrong Entry Alarm
360   ON C% GOTO 390,390,390,390,390,390,380,370
365   REM
370   GOSUB 160:END:REM Exit Program
375   REM
380   MESS$="":GOSUB 220:PRINT:PRINT:PRINT:PRINT TAB(23);"Loading Main Program (
SETREC)":CHAIN "SETREC"
385   REM
390   REM********************* Input File Name ********************************
395   REM
400   B$(1)="Bulldozer":B$(2)="LGP Bulldozer":B$(3)="Ditching Equip."
410   B$(4)="LGP Ditching Equip.":B$(5)="Scraper":B$(6)="Slurry Pipeline"
420   IF C%=1 OR C%=2 OR C%=3 THEN NAM1$="settling area":TITLE$="Area File: "
430   IF C%=4 OR C%=5 OR C%=6 THEN NAM1$="equipment":TITLE$="Equip File: "
440   IF C%=1 THEN MESS$="   Create an Area File":NAM$="created"
450   IF C%=2 THEN MESS$="     Edit an Area File":NAM$="edited"
460   IF C%=3 THEN MESS$="    Print an Area File":NAM$="printed"
470   IF C%=4 THEN MESS$="  Create an Equip File":NAM$="created"
480   IF C%=5 THEN MESS$="    Edit an Equip File":NAM$="edited"
490   IF C%=6 THEN MESS$="   Print an Equip File":NAM$="printed"
500   GOSUB 220
```

```
510   PRINT:PRINT:PRINT:PRINT TAB(15);"Enter name of ";NAM1$;" file to be ";NAM$
;"."
520   PRINT TAB(15);"Please do not include spaces, special symbols, or"
530   PRINT TAB(15);"make it longer than 8 characters long."
540   PRINT:PRINT TAB(24):INPUT "           File Name: ",I$
550   IF I$="" OR LEN(I$)>8 THEN GOSUB 180:GOTO 390
560   FOR IZ% = 1 TO LEN(I$)
570     IF MID$(I$,IZ%,1) <> " " THEN GOTO 600
580     GOSUB 180:PRINT TAB(25);"Please, no spaces in the name.":PRINT TAB(25);"
Hit RETURN to continue.";
590     INPUT "",IX$:GOTO 390
600   NEXT IZ%
610   PRINT:PRINT TAB(15);:INPUT "Is this the correct file name? (Y/N): ",IX$
620   IF IX$="N" THEN GOTO 390
630   ON C% GOTO 640,730,730,2890,2750,2750: REM Transfer control
633   REM
634   REM Create a Settling Area File, Specify Earthmoving Data *******
635   REM
640   GOSUB 220:PRINT:PRINT:PRINT TAB(15);"Enter number of dam segments to be in
put to describe"
650   PRINT TAB(15);"the impounding structure: ";:INPUT "",I%
660   IF I%>=3 AND I%<=50 THEN GOTO 680
670   GOSUB 180:PRINT TAB(15);"Be realistic, enter a number between 3 and 50: ";
:INPUT "",I%:GOTO 660
680   PRINT TAB(15);"Enter number of spoil piles to be input to describe"
690   PRINT TAB(15);"spoil ridges within the settling area: ";:INPUT "",J%
700   IF J%>=0 AND J%<=50 THEN GOSUB 140:GOTO 880
710   GOSUB 180:PRINT TAB(15);"Be realistic, enter a number between 0 and 50: ";
:INPUT "",J%:GOTO 700
720   GOSUB 140
724   REM
725   REM Read Settling Area Input File *********
726   REM
730   OPEN "I",#1,I$+".SAI"
740   INPUT #1,I%,J%:GOSUB 140
750   INPUT #1,AREANM$,AREALOC$
760   INPUT #1,SLIMES,SLIMESAC,NOSPILL%,CRESTEL
770   FOR IZ% = 1 TO I%
780     INPUT #1,STAN(IZ%),STAE(IZ%),STNGL(IZ%),CW(IZ%),HO(IZ%),HI(IZ%),BO(IZ%)
785   NEXT IZ%
790   IF J%=0 THEN GOTO 830
800   FOR IZ% = 1 TO J%
810     INPUT #1,SPOILEL(IZ%),SPOILCW(IZ%),SPOILEN(IZ%),SHO(IZ%)
820   NEXT IZ%
830   INPUT #1,RECLAIM$,HR,TSPILLS%,RSPILLS%
840   IF RECLAIM$="CRUST" THEN INPUT #1,CONSOL,DIVFT,IDITPAC ELSE INPUT #1,COMP,
SAND,MILES,SOILCAP,SANDA
850   INPUT #1,CHDAM%,TIDAM%,LIDAM%,SEDAM%,FEDAM%,TREES
860   INPUT #1,CHSLIM%,TISLIM%,LISLIM%,SESLIM%,FESLIM%
870   CLOSE #1
875   REM
880   REM**************** Settling Area Data Input/Editing ********************
885   REM
890   IF C%=3 THEN GOTO 4160
900   GOSUB 220:X%=15:PRINT
910   PRINT TAB(27);"Settling Area General Data":PRINT
920   PRINT TAB(50);"(New Data or C/R)":PRINT
930   PRINT TAB(X%);"Settling Area Name ..... ";AREANM$;"  ";:INPUT "",IZ$
940   IF IZ$<>"" THEN AREANM$=IZ$
950   PRINT TAB(X%);"Settling Area Location.. ";AREALOC$;"  ";:INPUT "",IZ$
960   IF IZ$<>"" THEN AREALOC$=IZ$
970   PRINT TAB(X%);"No. of Spillways........ ";NOSPILL%;"  ";:INPUT "",IZ$
980   IF IZ$<>"" THEN NOSPILL%=VAL(IZ$)
990   PRINT TAB(X%);"Crest Road Elevation.... ";CRESTEL;"  ";:INPUT "",IZ$
1000  IF IZ$<>"" THEN CRESTEL=VAL(IZ$)
```

```
1010  PRINT TAB(X%);"Operating Level Elev.... ";SLIMES;"  ";:INPUT "",IZ$
1020  IF IZ$<>"" THEN SLIMES=VAL(IZ$)
1030  PRINT TAB(X%);"Pond Acreage........... ";SLIMESAC;"  ";:INPUT "",IZ$
1040  IF IZ$<>"" THEN SLIMESAC=VAL(IZ$)
1050  PRINT:PRINT TAB(X%-4);"Is the above data correct? (Y/N): ";:INPUT "",IZ$
1060  IF IZ$="N" THEN GOTO 880
1070  IF C%=2 THEN GOSUB 220:PRINT:PRINT:PRINT TAB(25);"Review Dam Segments? (Y/
N): ";:INPUT "",IZ$:IF IZ$<>"Y" THEN GOTO 1460
1080  IF C%=2 THEN GOTO 1240
1084  REM
1085  REM Create a Settling Area File: Dam Segment Introductory Screen *******
1086  REM
1090  GOSUB 220:PRINT:Y%=17
1100  PRINT TAB(Y%+6);"Dam Segment Description Requirements":PRINT
1110  PRINT TAB(Y%);"To evaluate earthmoving requirements for the dam"
1120  PRINT TAB(Y%);"structure, the dam must be divided into segments"
1130  PRINT TAB(Y%);"of consistant dimensions.  The following are the"
1140  PRINT TAB(Y%);"dimensions that will be needed to describe each"
1150  PRINT TAB(Y%);"segment.  Please see documentation for a more"
1160  PRINT TAB(Y%);"complete discussion of segment description.":PRINT
1170  PRINT TAB(Y%+3);"Starting Coordinates (N,E)"
1180  PRINT TAB(Y%+3);"Starting Ground Elevation, Outside Dam Toe"
1190  PRINT TAB(Y%+3);"Dam Crest Width"
1200  PRINT TAB(Y%+3);"Outside Dam Slope (H:V)"
1210  PRINT TAB(Y%+3);"Inside Dam Slope (H:V)"
1220  PRINT TAB(Y%+3);"Distance from Dam C/L to Boundary Limit":PRINT
1230  PRINT TAB(Y%+11);"Hit RETURN to Continue.";:INPUT "",IZ$
1234  REM
1235  REM Create/Edit Settling Area Dam Segments *******
1236  REM
1240  FOR IZ% = 1 TO I%
1250    GOSUB 220:X%=15:PRINT
1260    PRINT TAB(X%+14);"Dam Segment Description":PRINT
1270    PRINT TAB(X%+35);"(New Data or C/R)":PRINT
1280    PRINT TAB(X%);"Segment Number................. ";IZ%
1290    PRINT TAB(X%);"Starting Coordinate,N.......... ";STAN(IZ%);"  ";:INPUT "
",IZ$
1300    IF IZ$<>"" THEN STAN(IZ%)=VAL(IZ$)
1310    PRINT TAB(X%);"Starting Coordinate,E.......... ";STAE(IZ%);"  ";:INPUT "
",IZ$
1320    IF IZ$<>"" THEN STAE(IZ%)=VAL(IZ$)
1330    PRINT TAB(X%);"Starting Outside Dam Toe Elev.. ";STNGL(IZ%);"  ";:INPUT
"",IZ$
1340    IF IZ$<>"" THEN STNGL(IZ%)=VAL(IZ$)
1350    PRINT TAB(X%);"Dam Crest Width................ ";CW(IZ%);"  ";:INPUT "",
IZ$
1360    IF IZ$<>"" THEN CW(IZ%)=VAL(IZ$)
1370    PRINT TAB(X%);"Outside Dam Slope (H:V)........ ";HO(IZ%);"  ";:INPUT "",
IZ$
1380    IF IZ$<>"" THEN HO(IZ%)=VAL(IZ$)
1390    PRINT TAB(X%);"Inside Dam Slope (H:V)......... ";HI(IZ%);"  ";:INPUT "",
IZ$
1400    IF IZ$<>"" THEN HI(IZ%)=VAL(IZ$)
1410    PRINT TAB(X%);"Boundary Limit Distance........ ";BO(IZ%);"  ";:INPUT "",
IZ$
1420    IF IZ$<>"" THEN BO(IZ%)=VAL(IZ$)
1430    PRINT:PRINT TAB(X%+11);"Is all Data Correct? (Y/N): ";:INPUT "",IZ$
1440    IF IZ$="N" THEN GOTO 1250
1450  NEXT IZ%
1460  IF C%=2 THEN GOSUB 220:PRINT:PRINT:PRINT TAB(18);"Review Data on Enclosed
Spoil Ridges? (Y/N): ";:INPUT "",IZ$:IF IZ$<>"Y" THEN GOTO 1750
1470  IF J%=0 THEN GOTO 1750
1480  IF C%=2 THEN GOTO 1600
1484  REM
1485  REM Create a Settling Area File: Spoil Ridge Introductory Screen *******
```

```
1486  REM
1490  GOSUB 220:Y%=15:PRINT
1500  PRINT TAB(Y%+9);"Enclosed Spoil Ridge Description":PRINT
1510  PRINT TAB(Y%);"To evaluate earthmoving requirements for spoil"
1520  PRINT TAB(Y%);"ridges that are enclosed within the settling area"
1530  PRINT TAB(Y%);"and protruding above the slimes, the dimensions for"
1540  PRINT TAB(Y%);"each spoil ridge are needed.  The following are the"
1550  PRINT TAB(Y%);"dimensions that will be needed to describe each"
1560  PRINT TAB(Y%);"spoil ridge.":PRINT
1570  PRINT TAB(Y%+16);"Crest Elevation":PRINT TAB(Y%+16);"Crest Width"
1580  PRINT TAB(Y%+16);"Ridge Length":PRINT TAB(Y%+16);"Ridge Slope (H/V)"
1590  PRINT:PRINT TAB(Y%+14);"Hit RETURN to Continue.";:INPUT "",IZ$
1594  REM
1595  REM Create/Edit Spoil Ridge Description ********
1596  REM
1600  FOR IZ% = 1 TO J%
1610    GOSUB 220:Y%=30:PRINT
1620    PRINT TAB(Y%-6);"Enclosed Spoil Ridge Description":PRINT
1630    PRINT TAB(Y%+20);"(New Data or C/R)":PRINT
1640    PRINT TAB(Y%);"Crest Elevation...... ";SPOILEL(IZ%);"  ";:INPUT "",IZ$
1650    IF IZ$<>"" THEN SPOILEL(IZ%)=VAL(IZ$)
1660    PRINT TAB(Y%);"Crest Width.......... ";SPOILCW(IZ%);"  ";:INPUT "",IZ$
1670    IF IZ$<>"" THEN SPOILCW(IZ%)=VAL(IZ$)
1680    PRINT TAB(Y%);"Ridge Length......... ";SPOILEN(IZ%);"  ";:INPUT "",IZ$
1690    IF IZ$<>"" THEN SPOILEN(IZ%)=VAL(IZ$)
1700    PRINT TAB(Y%);"Ridge Slope (H:V).... ";SHO(IZ%);"  ";:INPUT "",IZ$
1710    IF IZ$<>"" THEN SHO(IZ%)=VAL(IZ$)
1720    PRINT:PRINT TAB(Y%-4);"Is all Data Correct? (Y/N): ";:INPUT "",IZ$
1730    IF IZ$="N" THEN GOTO 1610
1740  NEXT IZ%
1750  IF C%=1 THEN GOTO 1780
1760  GOSUB 220:PRINT:PRINT:PRINT TAB(18)"Review Reclamation Requirements? (Y/N)
: ";:INPUT "", IZ$
1770  IF IZ$<>"Y" THEN GOTO 2570
1780  IF C%=2 THEN GOTO 1890
1784  REM
1785  REM Create a Settling Area File: Reclamation Introductory Screen ********
1786  REM
1790  GOSUB 220:Y%=15:PRINT
1800  PRINT TAB(Y%+13);"Reclamation Requirements":PRINT
1810  PRINT TAB(Y%);"It will be necessary to specify the details and"
1820  PRINT TAB(Y%);"intensity of the reclamation to be performed. There"
1830  PRINT TAB(Y%);"are two methods of settling area reclamation:":PRINT
1840  PRINT TAB(Y%+13);"1. Capping with Tailings"
1850  PRINT TAB(Y%+13);"2. Crust Development":PRINT
1860  PRINT TAB(Y%);"Once you have chosen a method, the appropriate data"
1870  PRINT TAB(Y%);"will be requested.":PRINT
1880  PRINT TAB(Y%+13);"Hit RETURN to Continue.";:INPUT "",IZ$
1884  REM
1885  REM Create/Edit Reclamation Requirements *********
1886  REM
1890  GOSUB 220:X%=15:PRINT
1900  PRINT TAB(X%+13);"Reclamation Requirements":PRINT
1910  PRINT TAB(X%+35);"(New Data or C/R)":PRINT
1920  PRINT TAB(X%);"Method: CRUST or CAP.............. ";RECLAIM$;"  ";:INPUT "
",IZ$
1930  IF IZ$<>"" THEN RECLAIM$=IZ$
1940  IF RECLAIM$<>"CAP" AND RECLAIM$<>"CRUST" THEN GOSUB 180:GOTO 1890
1950  IF RECLAIM$="CAP" THEN GOTO 2030
1960  PRINT TAB(X%);"Est. Slimes Consolidation (Ft).... ";CONSOL;"  ";:INPUT "",
IZ$
1970  IF IZ$<>"" THEN CONSOL=VAL(IZ$)
1980  PRINT TAB(X%);"Diversion Ditch Length (Ft)....... ";DIVFT;"  ";:INPUT "",I
Z$
1990  IF IZ$<>"" THEN DIVFT=VAL(IZ$)
```

```
2000  PRINT TAB(X%);"Slimes Interior Ditching (Ft/Ac).. ";IDITPAC;"  ";:INPUT ""
,IZ$
2010  IF IZ$<>"" THEN IDITPAC=VAL(IZ$)
2020  GOTO 2130
2030  PRINT TAB(X%);"Est. Slimes Compaction (Ft)....... ";COMP;"  ";:INPUT "",IZ
$
2040  IF IZ$<>"" THEN COMP=VAL(IZ$)
2050  PRINT TAB(X%);"Tailings Cap Thickness (Ft)....... ";SAND;"  ";:INPUT "",IZ
$
2060  IF IZ$<>"" THEN SAND=VAL(IZ$)
2070  PRINT TAB(X%);"Area Covered by Tailings (%)...... ";SANDA;"  ";:INPUT "",I
Z$
2080  IF IZ$<>"" THEN SANDA=VAL(IZ$)
2090  PRINT TAB(X%);"Tailings Pumping Distance (Miles). ";MILES;"  ";:INPUT "",I
Z$
2100  IF IZ$<>"" THEN MILES=VAL(IZ$)
2110  PRINT TAB(X%);"Topsoil Thickness (Ft)............ ";SOILCAP;"  ";:INPUT ""
,IZ$
2120  IF IZ$<>"" THEN SOILCAP=VAL(IZ$)
2130  PRINT TAB(X%);"Max. Reclaimed Slopes (H:V)....... ";HR;"  ";:INPUT "",IZ$
2140  IF IZ$<>"" THEN HR=VAL(IZ$)
2150  PRINT TAB(X%);"Temp. Spillways Installed (No.)... ";TSPILLS%;"  ";:INPUT "
",IZ$
2160  IF IZ$<>"" THEN TSPILLS%=VAL(IZ$)
2170  PRINT TAB(X%);"Spillways Removed (No.)........... ";RSPILLS%;"  ";:INPUT "
",IZ$
2180  IF IZ$<>"" THEN RSPILLS%=VAL(IZ$)
2190  PRINT:PRINT TAB(X%+11);"Is all Data Correct? (Y/N): ";:INPUT "",IZ$
2200  IF IZ$="N" THEN GOTO 1890
2210  GOTO 2310
2215  REM
2220  REM Create/Edit Revegetation Requirements ********
2225  REM
2230  GOSUB 220:PRINT
2240  PRINT TAB(X%+14);"Revegetation: ";IX$
2250  PRINT TAB(X%+35);"(New Data or C/R)":PRINT:RETURN
2260  PRINT TAB(X%);"Chop Vegetation(1-Yes/0-No)... ";:RETURN
2270  PRINT TAB(X%);"Tilling (1-Yes/0-No).......... ";:RETURN
2280  PRINT TAB(X%);"Liming (No. Applications).....";:RETURN
2290  PRINT TAB(X%);"Seeding (No. Applications)....";:RETURN
2300  PRINT TAB(X%);"Fertilizer (No. Applications).";:RETURN
2310  IX$="Dam/Cap":GOSUB 2220:GOSUB 2260:PRINT CHDAM%;"  ";:INPUT "",IZ$
2320  IF IZ$<>"" THEN CHDAM%=VAL(IZ$)
2330  GOSUB 2270:PRINT TIDAM%;"  ";:INPUT "",IZ$
2340  IF IZ$<>"" THEN TIDAM%=VAL(IZ$)
2350  GOSUB 2280:PRINT LIDAM%;"  ";:INPUT "",IZ$
2360  IF IZ$<>"" THEN LIDAM%=VAL(IZ$)
2370  GOSUB 2290:PRINT SEDAM%;"  ";:INPUT "",IZ$
2380  IF IZ$<>"" THEN SEDAM%=VAL(IZ$)
2390  GOSUB 2300:PRINT FEDAM%;"  ";:INPUT "",IZ$
2400  IF IZ$<>"" THEN FEDAM%=VAL(IZ$)
2410  PRINT TAB(X%);"Tree Planting (% of Area).....";TREES;"  ";:INPUT "",IZ$
2420  IF IZ$<>"" THEN TREES=VAL(IZ$)
2430  PRINT:PRINT TAB(X%+11);"Is all Data Correct? (Y/N): ";:INPUT "",IZ$
2440  IF IZ$="N" THEN GOTO 2310
2450  IX$="Slimes":GOSUB 2220:GOSUB 2260:PRINT CHSLIM%;"  ";:INPUT "",IZ$
2460  IF IZ$<>"" THEN CHSLIM%=VAL(IZ$)
2470  GOSUB 2270:PRINT TISLIM%;"  ";:INPUT "",IZ$
2480  IF IZ$<>"" THEN TISLIM%=VAL(IZ$)
2490  GOSUB 2280:PRINT LISLIM%;"  ";:INPUT "",IZ$
2500  IF IZ$<>"" THEN LISLIM%=VAL(IZ$)
2510  GOSUB 2290:PRINT SESLIM%;"  ";:INPUT "",IZ$
2520  IF IZ$<>"" THEN SESLIM%=VAL(IZ$)
2530  GOSUB 2300:PRINT FESLIM%;"  ";:INPUT "",IZ$
2540  IF IZ$<>"" THEN FESLIM%=VAL(IZ$)
```

```
2550  PRINT:PRINT TAB(X%+11);"Is all Data Correct (Y/N): ";:INPUT "",IZ$
2560  IF IZ$="N" THEN GOTO 2450
2564  REM
2565  REM Write Settling Area File to Disk *********
2566  REM
2570  OPEN "O",#1,I$+".SAI"
2580  WRITE #1,I%,J%
2590  WRITE #1,AREANM$,AREALOC$
2600  WRITE #1,SLIMES,SLIMESAC,NOSPILL%,CRESTEL
2610  FOR IZ% = 1 TO I%
2620    WRITE #1,STAN(IZ%),STAE(IZ%),STNGL(IZ%),CW(IZ%),HO(IZ%),HI(IZ%),BO(IZ%)
2630  NEXT IZ%
2640  IF J%=0 THEN GOTO 2680
2650  FOR IZ% = 1 TO J%
2660    WRITE #1,SPOILEL(IZ%),SPOILCW(IZ%),SPOILEN(IZ%),SHO(IZ%)
2670  NEXT IZ%
2680  WRITE #1,RECLAIM$,HR,TSPILLS%,RSPILLS%
2690  IF RECLAIM$="CRUST" THEN WRITE #1,CONSOL,DIVFT,IDITPAC ELSE WRITE #1,COMP,
SAND,MILES,SOILCAP,SANDA
2700  WRITE #1,CHDAM%,TIDAM%,LIDAM%,SEDAM%,FEDAM%,TREES
2710  WRITE #1,CHSLIM%,TISLIM%,LISLIM%,SESLIM%,FESLIM%
2720  CLOSE #1
2730  ERASE STAN,STAE,STNGL,HO,HI,BO,SPOILEL,SPOILCW,SPOILEN,SHO,CW
2740  GOTO 260
2744  REM
2745  REM Input Equipment File from Disk ********
2746  REM
2750  OPEN "I",#1,I$+".EQI"
2760  FOR IZ% = 1 TO 8
2770    ON IZ% GOTO 2780,2790,2800,2810,2820,2830,2840,2850
2780    INPUT #1,X%,BULL$,M,N,BULLCST:GOTO 2860
2790    INPUT #1,X%,LGPBULL$,LGPM,LGPN,LGPCST:GOTO 2860
2800    INPUT #1,X%,DITCH$,DIT,DITCST:GOTO 2860
2810    INPUT #1,X%,LGPDITCH$,LGPDIT,LGPDITCST:GOTO 2860
2820    INPUT #1,X%,SCRAP$,SM,SN,SCST:GOTO 2860
2830    INPUT #1,X%,PIPE$,PBCY,YARDMI:GOTO 2860
2840    INPUT #1,X%,TSPILLCST,RSPILLCST:GOTO 2860
2850    INPUT #1,X%,CHOP,TILL,LIME,SEED,FERT,TREEP
2860  NEXT IZ%
2870  CLOSE #1
2880  IF C%=5 THEN GOTO 3060 ELSE GOTO 4830
2884  REM
2885  REM Create an Equipment File: Introductory Screen *********
2886  REM
2890  GOSUB 220:X%=13:PRINT
2900  PRINT TAB(X%+15);"Equipment and Cost Data":PRINT
2910  PRINT TAB(X%);"This file contains equipment performance and cost data."
2920  PRINT TAB(X%);"You will need information on the following equipment."
2930  PRINT TAB(X%+8);"1. Bulldozer":PRINT TAB(X%+8);"2. Low Ground Pressure (LG
P) Bulldozer"
2950  PRINT TAB(X%);"Depending on the method of reclamation, you may need"
2960  PRINT TAB(X%);"information on the following equipment."
2965  PRINT TAB(X%+8);"1. Ditching Equipment"
2970  PRINT TAB(X%+8);"2. Low Ground Pressure (LGP) Ditching Equip."
2980  PRINT TAB(X%+8);"3. Scraper":PRINT TAB(X%+8);"4. Slurry Pipeline"
2990  PRINT TAB(X%);"You will need costs for the following reclamation work."
3000  PRINT TAB(X%+8);"1. Temp. Spillway Installation"
3010  PRINT TAB(X%+8);"2. Spillway Removal"
3020  PRINT TAB(X%+8);"3. Revegetation (Chopping, Tilling, Liming,"
3030  PRINT TAB(X%+8);"   Seeding, Fertilizing, and Tree Planting)"
3040  PRINT:PRINT TAB(X%+15);"Hit RETURN to Continue.";:INPUT "",IZ$
3050  Y%=1:IZ%=1:GOTO 3190
3054  REM
3055  REM Create/Edit Equipment Data ********
3056  REM
```

```
3060  GOSUB 220:X%=15:PRINT
3070  PRINT TAB(X%+13);"Create/Edit Equip. Data":PRINT
3080  PRINT TAB(X%+14);"Bulldozer........... 1":PRINT TAB(X%+14);"LGP Bulldozer.
...... 2"
3090  PRINT TAB(X%+14);"Ditching Equip...... 3":PRINT TAB(X%+14);"LGP Ditching E
quip.. 4"
3100  PRINT TAB(X%+14);"Scraper............. 5":PRINT TAB(X%+14);"Slurry Pipelin
e..... 6"
3110  PRINT TAB(X%+14);"Continue............ 7":PRINT
3120  PRINT TAB(X%+16);"Enter Selection: ";:INPUT "",IZ%
3130  IF IZ%<1 OR IZ%>7 THEN GOSUB 180:GOTO 3060
3140  ON IZ% GOTO 3190,3300,3420,3500,3580,3680,3770
3150  GOSUB 220:PRINT:PRINT TAB(X%+12);"Equipment Data: ";B$(IZ%);:PRINT
3160  PRINT TAB(X%+30);"(New Data of C/R)":PRINT:RETURN
3170  PRINT TAB(X%+7);"Production Rate, BCY/Hr = M(Dist)^N":RETURN
3180  PRINT TAB(X%+7);"Cost ($/Scheduled Hr) : ";:RETURN
3190  GOSUB 3150
3200  PRINT TAB(X%+7);"Name: ";BULL$;"  ";:INPUT "",IZ$
3210  IF IZ$<>"" THEN BULL$=IZ$
3220  GOSUB 3170:PRINT TAB(X%+7);"M : ";M;"  ";:INPUT "",IZ$
3230  IF IZ$<>"" THEN M=VAL(IZ$)
3240  PRINT TAB(X%+7);"N : ";N;"  ";:INPUT "",IZ$
3250  IF IZ$<>"" THEN N=VAL(IZ$)
3260  GOSUB 3180:PRINT BULLCST;:INPUT"",IZ$
3270  IF IZ$<>"" THEN BULLCST=VAL(IZ$)
3280  IF Y%=1 THEN IZ%=2:GOTO 3300
3290  GOTO 3060
3300  GOSUB 3150
3310  PRINT TAB(X%+7);"Name: ";LGPBULL$;"  ";:INPUT "",IZ$
3320  IF IZ$<>"" THEN LGPBULL$=IZ$
3330  GOSUB 3170:PRINT TAB(X%+7);"M : ";LGPM;"  ";:INPUT "",IZ$
3340  IF IZ$<>"" THEN LGPM=VAL(IZ$)
3350  PRINT TAB(X%+7);"N : ";LGPN;"  ";:INPUT "",IZ$
3360  IF IZ$<>"" THEN LGPN=VAL(IZ$)
3370  GOSUB 3180:PRINT LGPCST;"  ";:INPUT "",IZ$
3380  IF IZ$<>"" THEN LGPCST=VAL(IZ$)
3390  Y%=0
3400  GOTO 3060
3410  PRINT TAB(X%+7);"Production Rate,R (Ft. Ditch/Hr)":RETURN
3420  GOSUB 3150
3430  PRINT TAB(X%+7);"Name: ";DITCH$;"  ";:INPUT "",IZ$
3440  IF IZ$<>"" THEN DITCH$=IZ$
3445  PRINT TAB(X%+7);"Production Rate,R (BCY/Hr)"
3450  PRINT TAB(X%+7);"R : ";DIT;"  ";:INPUT "",IZ$
3460  IF IZ$<>"" THEN DIT=VAL(IZ$)
3470  GOSUB 3180:PRINT DITCST;"  ";:INPUT "",IZ$
3480  IF IZ$<>"" THEN DITCST=VAL(IZ$)
3490  GOTO 3060
3500  GOSUB 3150
3510  PRINT TAB(X%+7);"Name: ";LGPDITCH$;"  ";:INPUT "",IZ$
3520  IF IZ$<>"" THEN LGPDITCH$=IZ$
3530  GOSUB 3410:PRINT TAB(X%+7);"R : ";LGPDIT;"  ";:INPUT "",IZ$
3540  IF IZ$<>"" THEN LGPDIT=VAL(IZ$)
3550  GOSUB 3180:PRINT LGPDITCST;"  ";:INPUT "",IZ$
3560  IF IZ$<>"" THEN LGPDITCST=VAL(IZ$)
3570  GOTO 3060
3580  GOSUB 3150
3590  PRINT TAB(X%+7);"Name: ";SCRAP$;"  ";:INPUT "",IZ$
3600  IF IZ$<>"" THEN SCRAP$=IZ$
3610  GOSUB 3170:PRINT TAB(X%+7);"M : ";SM;"  ";:INPUT "",IZ$
3620  IF IZ$<>"" THEN SM=VAL(IZ$)
3630  PRINT TAB(X%+7);"N : ";SN;"  ";:INPUT "",IZ$
3640  IF IZ$<>"" THEN SN=VAL(IZ$)
3650  GOSUB 3180:PRINT SCST;"  ";:INPUT "",IZ$
3660  IF IZ$<>"" THEN SCST=VAL(IZ$)
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```
3670  GOTO 3060
3680  GOSUB 3150
3690  PRINT TAB(X%+7);"Name: ";PIPE$;"  ";:INPUT "",IZ$
3700  IF IZ$<>"" THEN PIPE$=IZ$
3710  PRINT TAB(X%+7);"Pumping Rate,R (BCY/Hr)"
3720  PRINT TAB(X%+7);"R : ";PBCY;"  ";:INPUT "",IZ$
3730  IF IZ$<>"" THEN PBCY=VAL(IZ$)
3740  PRINT TAB(X%+7);"Cost ($/BCY-Mile): ";YARDMI;"  ";:INPUT "",IZ$
3750  IF IZ$<>"" THEN YARDMI=VAL(IZ$)
3760  GOTO 3060
3770  IF C%=4 THEN GOTO 3800
3780  GOSUB 220:PRINT:PRINT:PRINT TAB(21);"Review Reclamation Unit Costs? (Y/N):
 ";:INPUT "",IZ$
3790  IF IZ$<>"Y" THEN GOTO 4020
3794  REM
3795  REM Create/Edit Revegetation Unit Costs *********
3796  REM
3800  GOSUB 220:PRINT:X%=20
3810  PRINT TAB(X%+9);"Reclamation Unit Costs":PRINT
3820  PRINT TAB(X%+35);"(New Data or C/R)":PRINT
3830  PRINT TAB(X%);"Temp. Spillways($/Installation). ";TSPILLCST;"  ";:INPUT ""
,IZ$
3840  IF IZ$<>"" THEN TSPILLCST=VAL(IZ$)
3850  PRINT TAB(X%);"Spillway Removal($/Spillway).... ";RSPILLCST;"  ";:INPUT ""
,IZ$
3860  IF IZ$<>"" THEN RSPILLCST=VAL(IZ$)
3870  PRINT TAB(X%);"Revegetation"
3880  PRINT TAB(X%);"  Chopping ($/Acre)............ ";CHOP;"  ";:INPUT "",IZ$
3890  IF IZ$<>"" THEN CHOP=VAL(IZ$)
3900  PRINT TAB(X%);"  Tilling ($/Acre)............. ";TILL;"  ";:INPUT "",IZ$
3910  IF IZ$<>"" THEN TILL=VAL(IZ$)
3920  PRINT TAB(X%);"  Liming ($/Application-Acre)... ";LIME;"  ";:INPUT "",IZ$
3930  IF IZ$<>"" THEN LIME=VAL(IZ$)
3940  PRINT TAB(X%);"  Seeding ($/Application-Acre).. ";SEED;"  ";:INPUT "",IZ$
3950  IF IZ$<>"" THEN SEED=VAL(IZ$)
3960  PRINT TAB(X%);"  Fertilizer ($/Application-Ac). ";FERT;"  ";:INPUT "",IZ$
3970  IF IZ$<>"" THEN FERT=VAL(IZ$)
3980  PRINT TAB(X%);"  Tree Planting ($/Acre)........ ";TREEP;"  ";:INPUT "",IZ$

3990  IF IZ$<>"" THEN TREEP=VAL(IZ$)
4000  PRINT:PRINT TAB(X%+6);"Is all Data Correct? (Y/N): ";:INPUT "",IZ$
4010  IF IZ$="N" THEN GOTO 3800
4014  REM
4015  REM Write Equipment File to Disk ********
4016  REM
4020  OPEN "O",#1,I$+".EQI"
4030  FOR IZ% = 1 TO 8
4040    ON IZ% GOTO 4050,4060,4070,4080,4090,4100,4110,4120
4050    WRITE #1,IZ%,BULL$,M,N,BULLCST:GOTO 4130
4060    WRITE #1,IZ%,LGPBULL$,LGPM,LGPN,LGPCST:GOTO 4130
4070    WRITE #1,IZ%,DITCH$,DIT,DITCST:GOTO 4130
4080    WRITE #1,IZ%,LGPDITCH$,LGPDIT,LGPDITCST:GOTO 4130
4090    WRITE #1,IZ%,SCRAP$,SM,SN,SCST:GOTO 4130
4100    WRITE #1,IZ%,PIPE$,PBCY,YARDMI:GOTO 4130
4110    WRITE #1,IZ%,TSPILLCST,RSPILLCST:GOTO 4130
4120    WRITE #1,IZ%,CHOP,TILL,LIME,SEED,FERT,TREEP
4130  NEXT IZ%
4140  CLOSE #1
4150  GOTO 260
4155  REM
4160  REM Print Settling Area Input File **********
4165  REM
4170  GOSUB 220:PRINT:PRINT:PRINT TAB(23);"Printing Settling Area Input File"
4180  X%=20:LPRINT TAB(X%-4);CHR$(14);"SETTLING AREA INPUT FILE"
4190  LPRINT:LPRINT TAB(X%-10);"Settling Area Name: ";AREANM$
```

```
4200  LPRINT TAB(X%-10);"Settling Area Location: ";AREALOC$
4210  LPRINT TAB(X%-10);"Number of Spillways: ";NOSPILL%;TAB(X%+29);"Crest Road
Elev: ";CRESTEL
4220  LPRINT TAB(X%-10);"Pond Acreage: ";SLIMESAC;TAB(X%+29);"Operating Level El
ev: ";SLIMES
4230  LPRINT:LPRINT TAB(X%+8);CHR$(27);"E";"DAM SEGMENT DESCRIPTION";CHR$(27);"F
":LPRINT
4240  LPRINT TAB(X%-10);"STARTING COORDINATES  STARTING  DAM SLOPES   CREST  BOU
NDARY"
4250  LPRINT TAB(X%-10);"   NORTH       EAST       ELEV  OUTSIDE INSIDE WIDTH  DIS
TANCE"
4260  LPRINT TAB(X%-10);"---------  ---------  ------  -----  -----  -----  ---
-----"
4270  FOR IZ% = 1 TO I%
4280  LPRINT TAB(X%-10);:LPRINT USING "#######.#";STAN(IZ%);
4290  LPRINT TAB(X%+1);:LPRINT USING "#######.#";STAE(IZ%);
4300  LPRINT TAB(X%+12);:LPRINT USING "####.#";STNGL(IZ%);
4310  LPRINT TAB(X%+21);:LPRINT USING "###.#";HO(IZ%);
4320  LPRINT TAB(X%+28);:LPRINT USING "###.#";HI(IZ%);
4330  LPRINT TAB(X%+35);:LPRINT USING "###.#";CW(IZ%);
4340  LPRINT TAB(X%+42);:LPRINT USING "####.#";BO(IZ%)
4350  NEXT IZ%
4360  IF J%=0 THEN GOTO 4470
4370  LPRINT:LPRINT:LPRINT TAB(X%+8);CHR$(27);"E";"SPOIL RIDGE DESCRIPTION";CHR$
(27);"F":LPRINT
4380  LPRINT TAB(X%+4);"CREST    CREST    RIDGE   SPOIL"
4390  LPRINT TAB(X%+4);" ELEV    WIDTH   LENGTH   SLOPES"
4400  LPRINT TAB(X%+4);"------   -----   ------   ------"
4410  FOR IZ% = 1 TO J%
4420    LPRINT TAB(X%+4);:LPRINT USING "####.#";SPOILEL(IZ%);
4430    LPRINT TAB(X%+13);:LPRINT USING "###.#";SPOILCW(IZ%);
4440    LPRINT TAB(X%+21);:LPRINT USING "####.#";SPOILEN(IZ%);
4450    LPRINT TAB(X%+30);:LPRINT USING "###.#";SHO(IZ%)
4460  NEXT IZ%
4470  LPRINT:LPRINT:LPRINT TAB(X%+8);CHR$(27);"E";"RECLAMATION REQUIREMENTS";CHR
$(27);"F":LPRINT
4480  IF RECLAIM$="CAP" THEN IZ$="Tailings Cap" ELSE IZ$="Crust Development"
4490  LPRINT TAB(X%-13);"Method of Reclamation: ";IZ$
4500  IF RECLAIM$="CAP" THEN GOTO 4540
4510  LPRINT TAB(X%-13);"Diversion Ditch Length (Ft):";:LPRINT USING "#####.#";D
IVFT;
4520  LPRINT TAB(X%+24);"Int. Ditch Length (Ft/Ac):";:LPRINT USING "###.#";IDITP
AC
4530  GOTO 4560
4540  LPRINT TAB(X%-13);"Tailings Cap Thickness (Ft) :  ";:LPRINT USING "##.#";S
AND;
4550  LPRINT TAB(X%+24);"Topsoil Thickness (Ft) :   ";:LPRINT USING "##.#";SOILC
AP
4560  LPRINT TAB(X%-13);"Temporary Spillways (No.):     ";:LPRINT USING "##";TSP
ILLS%;
4570  LPRINT TAB(X%+24);"Spillways Removed (No.):   ";:LPRINT USING "##";RSPILLS
%
4580  LPRINT TAB(X%-13);"Max. Reclaimed Slopes(H:V):     ";:LPRINT USING "##.#";H
R;
4590  IF RECLAIM$="CAP" THEN GOTO 4610
4600  LPRINT TAB(X%+24);"Est. Consolidation (Ft):   ";:LPRINT USING "##.#";CONSO
L:GOTO 4640
4610  LPRINT TAB(X%+24);"Estimated Compaction (Ft): ";:LPRINT USING "##.#";COMP
4620  LPRINT TAB(X%-13);"Dist. Tails Pumped (Miles) :   ";:LPRINT USING "##.#";M
ILES;
4630  LPRINT TAB(X%+24);"Area Covered by Cap (%) :  ";:LPRINT USING "##.#";SANDA

4640  LPRINT:LPRINT:LPRINT TAB(X%+14);CHR$(27);"E";"REVEGETATION";CHR$(27);"F":L
PRINT
4650  LPRINT TAB(X%+27);"DAM/CAP";
```

```
4660  LPRINT TAB(X%+37);"SLIMES"
4670  LPRINT TAB(X%+27);"-------";
4680  LPRINT TAB(X%+37);"------"
4690  LPRINT TAB(X%);"Chop Vegetation(1-Yes/0-No):";CHDAM%;
4700  LPRINT TAB(X%+38);CHSLIM%
4710  LPRINT TAB(X%);"Tilling (1-Yes/0-No):       ";TIDAM%;
4720  LPRINT TAB(X%+38);TISLIM%
4730  LPRINT TAB(X%);"Liming (No. Applications):  ";LIDAM%;
4740  LPRINT TAB(X%+38);LISLIM%
4750  LPRINT TAB(X%);"Seeding (No. Applications): ";SEDAM%;
4760  LPRINT TAB(X%+38);SESLIM%
4770  LPRINT TAB(X%);"Fertilizer (No. Appl.):     ";FEDAM%;
4780  LPRINT TAB(X%+38);FESLIM%
4790  LPRINT TAB(X%);"Tree Planting (% of Area):  ";TREES
4800  GOTO 260
4810  LPRINT ;" Ft. Ditch/Hr";:RETURN
4820  LPRINT TAB(X%);"BCY/Hr =";:LPRINT USING "######.#";A;:LPRINT ;"(Dist)^";:L
PRINT USING "##.#####";B:RETURN
4825  REM
4830  REM Print Equipment File *******
4835  REM
4840  GOSUB 220:PRINT:PRINT:PRINT TAB(25);"Printing Equipment Input File"
4850  X%=25:LPRINT TAB(X%-5);CHR$(14);"EQUIPMENT INPUT FILE"
4860  LPRINT:LPRINT TAB(X%+8);CHR$(27);"E";"EQUIPMENT DATA";CHR$(27);"F":LPRINT
4870  LPRINT TAB(X%);B$(1);" : ";BULL$
4880  A=M:B=N:GOSUB 4820
4890  LPRINT TAB(X%);"$";BULLCST;"/Hour":LPRINT
4900  LPRINT TAB(X%);B$(2);" : ";LGPBULL$
4910  A=LGPM:B=LGPN:GOSUB 4820
4920  LPRINT TAB(X%);"$";LGPCST;"/Hour":LPRINT
4930  LPRINT TAB(X%);B$(3);" : ";DITCH$
4940  LPRINT TAB(X%);DIT;" BCY/Hr"
4950  LPRINT TAB(X%);"$";DITCST;"/Hour":LPRINT
4960  IF LGPDITCH$="" THEN GOTO 5000
4970  LPRINT TAB(X%);B$(4);" : ";LGPDITCH$
4980  LPRINT TAB(X%);LGPDIT;:GOSUB 4810
4990  LPRINT TAB(X%);"$";LGPDITCST;"/Hour":LPRINT
5000  IF SCRAP$="" THEN GOTO 5040
5010  LPRINT TAB(X%);B$(5);" : ";SCRAP$
5020  A=SM:B=SN:GOSUB 4820
5030  LPRINT TAB(X%);"$";SCST;"/Hour":LPRINT
5040  IF PIPE$="" THEN GOTO 5080
5050  LPRINT TAB(X%);B$(6);" : ";PIPE$
5060  LPRINT TAB(X%);PBCY;" BCY/Hour"
5070  LPRINT TAB(X%);"$";YARDMI;"/BCY-Mile"
5080  LPRINT:LPRINT TAB(X%+4);CHR$(27);"E";"RECLAMATION UNIT COSTS";CHR$(27);"F"
:LPRINT:X%=22
5090  LPRINT TAB(X%);"Temp. Spillways ($/Installation).. ";TSPILLCST
5100  LPRINT TAB(X%);"Spillway Removal ($/Spillway)..... ";RSPILLCST
5110  LPRINT TAB(X%);"Revegetation"
5120  LPRINT TAB(X%);"  Chop Vegetation ($/Acre)........ ";CHOP
5130  LPRINT TAB(X%);"  Tilling ($/Acre)................ ";TILL
5140  LPRINT TAB(X%);"  Liming ($/Application-Acre)..... ";LIME
5150  LPRINT TAB(X%);"  Seeding ($/Application-Acre).... ";SEED
5160  LPRINT TAB(X%);"  Fertilizer ($/Application-Acre). ";FERT
5170  LPRINT TAB(X%);"  Tree Planting ($/Acre).......... ";TREEP
5180  GOTO 260
```