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TUNNEL COST-ESTIMATING METHODS

by

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The Office, Chief of Engineers (OCE), U. S. Army recognized the need for improving capabilities for estimating tunnel costs, improving support design, and overall, making tunnels and cavities more cost competitive with aboveground alternatives. Thus, the OCE requested that the U. S. Army Engineer Waterways Experiment Station (WES) conduct a study to develop and verify reliable methods for estimating costs of tunnel construction and establish improved (more cost-effective) methods for design of tunnel and cavity support systems.

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20. ABSTRACT (Continued)

This report describes an investigation of various tunnel construction cost-estimating techniques. Manual and computer methods are described and compared, important elements of tunnel construction are discussed, and an evaluation is made of the most promising computer cost model, using case histories of three completed tunnels for which good documentation was available.

The cost-estimating methods described herein can be used to develop more comprehensive and accurate estimates for tunneling, than the method presented in EM 1110-2-502, Methodology for Areawide Planning Studies, MAPS, Part 2, Chapter 14, dated 28 November 1980. Plans are being made to improve the MAPS tunnel-cost functions to reflect the improvements identified during this study.

PREFACE

The study reported herein was performed under the RDT&E Program, Project 4A762719AT40, Work Unit E0/005 entitled "Improved Tunnel and Rock Cavity Support Systems," sponsored by the Office, Chief of Engineers (OCE), U. S. Army. Mr. D. S. Reynolds was the OCE Technical Monitor.

The investigation was conducted by the U. S. Army Engineer Waterways Experiment Station (WES) during the period FY 77-FY 80. The study was conducted under the direct supervision of Mr. J. S. Huie, Chief, Rock Mechanics Applications Group (RMAG), Geotechnical Laboratory (GL), and under the general supervision of Dr. D. C. Banks, Chief, Engineering Geology and Rock Mechanics Division; Dr. W. F. Marcuson III, Chief, GL; and Dr. P. F. Hadala, Assistant Chief, GL. Mr. R. D. Bennett, RMAG, prepared the report.

Commanders and Directors of the WES during the investigation and preparation of this report were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.8	square metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
gallons per minute	0.003785	cubic metres per minute
inches	25.4	millimetres
miles (U. S. statute)	1.61	kilometres
pounds (force) per square foot	4.882	kilograms per square metre
pounds (force) per square inch	703.1	kilograms per square metre
pounds (mass) per cubic foot	16.02	kilograms per cubic metre

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

TUNNEL COST-ESTIMATING METHODS

PART I: INTRODUCTION

Background

1. Tunnel construction in the United States has been characterized as a high-risk, high-cost business. Cost overruns and delays have been especially damaging to public support for rapid transit tunnel projects and, to a lesser extent, to water tunnels. This support is critical since most tunnels are built and maintained with taxpayers' dollars. Consequently, decision makers have been forced to consider the following difficult questions:

- a. What factors cause these overruns, what is the relative impact of each factor, and what can be done to improve the assessment of these factors?
- b. What is needed to make tunnels more competitive with aboveground alternatives?
- c. The big question: Are these projects necessary and in the best interests of the taxpayer or are there better alternatives?

2. Much research has been sponsored by public agencies to find answers to these questions. Institutional factors have been studied (Mayo et al. 1968 and 1976, and National Research Council 1974). Such factors include the business climate, the reputation of the owner, the relative demand for tunnel construction and competing construction, which influences bid prices, risk, and profitability, and the general owner-engineer-contractor relationship. The barriers to technological innovation and to increased competition through the entry of new firms into the market have been studied, and recommendations have been made for improving the current situation. This report deals with one part of the overall problem; i.e., given the natural variability of underground conditions, the productivity of various combinations of men and equipment capable of constructing a tunnel, and the uncertainty of the economic climate, how reliable can the estimate of the cost of this planned

construction be? A companion question to which answers were sought was, what is the relative cost impact of each of the identifiable items of uncertainty?

Purpose

3. The purpose of this study was to develop or adapt reliable methods for estimating tunnel construction costs that could be used by planners and designers who are not necessarily tunnel experts or estimators.

Scope

4. This report presents the results of a study of tunnel cost-estimating methods. Important elements of tunnel construction are summarized and manual methods and computer models for estimating tunnel costs are described and compared in Part II. The computer model (COSTUN) was selected for in-depth study using case histories of completed tunnels. The three types of estimates prepared for each of the three selected case histories are as follows:

- a. Estimates were prepared using all information known to be available to bidders. These estimates were compared with the engineer's estimate and contractor's bids.
- b. Estimates were prepared using all information available at completion of the tunnel. These estimates were compared with the as-built cost and the preconstruction estimates and bids.
- c. Parameter studies were made using all information known to bidders. Several estimates were prepared to assess the cost consequences of assigning different values to one factor while holding all other factors constant.

5. The results of the analysis of COSTUN using tunnel case histories are discussed in Part III, and the summary and conclusions are presented in Part IV. A complete user's guide for the COSTUN computer program is contained in Appendix A.

PART II: DESCRIPTION OF ESTIMATINC METHODS

6. In this section, a general discussion of tunneling and tunnel cost estimating is presented, and manual methods, including the use of cost curves, are discussed. Four computer models for estimating costs are described and compared.

Elements of Tunnel Construction

7. Before planning and estimating the cost of a tunnel, it is necessary to understand the different equipment and work methods that can be used to accomplish the job. Tunnel construction equipment may be divided into three main groups: (a) excavation equipment such as drills, jumbos, tunnel-boring machines, roadheaders, and mucking machines; (b) tunnel haulage equipment such as front-end loaders, trains, and conveyors; and (c) service equipment and facilities such as ventilation and air conditioning, generators, hoists, and lights. Although the selection of service equipment and haulage equipment is not much affected by the selection of the heading excavation method, the selection of excavation equipment is definitely dependent on this method. Parker (1970) and Mayo et al. (1968, 1976) provide thorough treatments of tunneling from different perspectives.

8. The actual construction of the tunnel consists of six main operations:

- a. Excavation.
- b. Muck disposal.
- c. Primary support installation.
- d. Pumping, grouting, or other ground control measures.
- e. Ventilation and air conditioning.
- f. Permanent lining installation.

The methods and timing for each of these operations may be varied to fit project requirements, site characteristics, and to some extent, designer or contractor preference. Excavation methods and equipment commonly

used are described in the following paragraphs. A more detailed discussion of various methods used in construction of tunnels and shafts is contained in EM 1110-2-2901 (Dept. of the Army, Office, Chief of Engineers (OCE), 1978).

Conventional tunnel
driving (drill and blast method)

9. Three major operations characterize this method of advancing a rock tunnel face. First, a burn cut is drilled at the center to allow room for rock expansion. Additional rings of holes are then drilled into the face on a predetermined pattern, using air or hydraulically operated drills mounted on a movable platform or jumbo. The holes are then loaded with dynamite or ANFO (a mixture of ammonium nitrate and fuel oil) and exploders that are connected to an electrical firing circuit. Men and equipment are then moved back a safe distance and the round is fired. After ventilation of powder fumes, the mucker is moved in and loads the broken rock into muck cars. Then the muck is transported to the surface and disposed of, the mucker is moved back, and the drill jumbo again advances to the tunnel heading to start another round. Depending on rock conditions, grouting to stop groundwater inflow, support placement, and exploratory drilling ahead of the face may be necessary before another round is drilled for explosives.

10. Major decisions that must be made in the planning stages of a conventionally driven tunnel include whether air, electric, or diesel power will be used and whether equipment will be rubber-tired or travel on rails. The basis for selection of power options and equipment mobility are covered in detail by Parker (1970) and are only summarized in this report.

11. Several variations may be used in conventional tunnel driving to accommodate special conditions. In good rock, full-face excavation is the favored method, but in poor rock or a mixed face, or in very large tunnels or caverns, heading and bench or multiple drift methods may be used. When heading and bench excavation is used, the top is normally driven portal to portal before excavating the bench. This practice allows the use of the drill jumbo in both operations. Prior to

about 1940, before jumbos became popular, the bench was usually excavated just behind the heading, with only a short 10 to 15-ft* working platform left.

12. Multiple-drift excavation is used when the crown must be continuously supported. Drifts may be driven at opposite springlines with rockbolts and shotcrete used for support. The rockbolts may extend transversely across the crown of the main tunnel so that it may then be safely mined. There are variations in the placement of drifts to meet special cases.

13. In a mixed-face excavation, part of the tunnel face consists of crushed rock or soft ground and the remainder is more competent rock. Forepoling or spiling is used to support the roof between the nearest steel set and the face. Sharpened wood spiles or steel rods are driven into the roof at a shallow angle from behind the nearest support and extended some distance beyond the face.

14. Blasting patterns vary for different conditions and because of contractor preference. The many options and factors that should be considered to develop an efficient blasting pattern are discussed in detail in EM 1110-2-2901 (Dept. of the Army, OCE, 1978). Blast holes are normally drilled either 8 or 12 ft deep. Two popular patterns are the angled cut and the burn cut. A combination of the two is also used. With the angled pattern, four cut holes are angled from the face to intersect at the axis and are heavily charged. Next, a ring of relief or easer holes is drilled, followed by one or more rings of enlarger holes, depending on the tunnel diameter. The outermost holes are the trim holes. Trim holes in the invert are called lifters. Successive rings are detonated after predetermined delays, starting with the cut holes at the axis. The trim holes are fired last. The lifters in the invert may be fired before or after the trim holes around the crown and spring lines, depending on the desired shape and size of the muck pile. The burn cut pattern uses one or more large diameter uncharged holes at the

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

axis to allow room for rock expansion when the outer rings are detonated. Again blasting proceeds from the easer holes to the trim holes, usually with predetermined delays between detonations of successive rings.

15. Jumbos for drilling the blast holes may run on the same track as rail muck cars or may straddle the muck car tracks on wide gauge rails, or in large tunnels, the jumbo may be rubber-tired. In small tunnels, with insufficient head space for a jumbo, lightweight air-leg drills may be used.

16. Mucking in small tunnels may be accomplished using a rail-mounted, air-operated, rocker-type shovel that loads the muck cars. In larger tunnels, an electric-powered mucker may scoop the muck onto a short conveyor section that dumps into the muck cars. The muck cars are pulled by electric or diesel-powered locomotives; if rail cars are used in steep-sloped tunnels, they may be winched. In very large tunnels, rubber-tired equipment is usually chosen for muck loading and hauling.

Tunnels driven with a shield

17. Shield-driven tunnels get their name from a steel plate shaped to fit the outside dimensions of the tunnel. The shield is used to prevent loose material from flowing or running into the excavation and must be jacked against the face. The miners excavate the face work under the front section of the shield, while supports are erected inside the rear section of the shield. As the face is excavated, the shield is jacked forward and slides past the previously erected supports. Tunnel support is transferred from the shield to the supports that may be cast iron, steel, or precast concrete segments. The annular space left by the thick shield plate is filled with pea gravel and grouted soon after jacking the shield forward. The use of a shield is dictated by poor ground that cannot be safely mined otherwise. In running ground, breastboarding at the face is required.

Tunnels driven under air pressure

18. Tunnels driven through soft ground below the water table or through crushed water-bearing rock zones require the use of compressed air in conjunction with the shield and partial or full breast boards at

the face. The air pressure is maintained by use of an air lock in the rear of the shield or at the portal. Sufficient pressure to balance the hydrostatic head is maintained forward of the air lock. Work hours are restricted proportional to the air pressure used, and a medical lock with a full-time attendant must be provided. Costs are proportionately higher for compressed air tunnels. The West Germans have recently introduced a successful slurry shield, the Hydrashield, which balances the hydrostatic pressure at the face with a bentonite slurry under pressure and thus eliminates the need for compressed air work.

19. Tunnels driven by boring machine (mole). This method of excavation replaces the cycle of drill, blast, and muck with (nearly) continuous simultaneous excavation and mucking. In soft, competent rock conditions, moles make faster progress than conventional driving methods. The mole or tunnel boring machine has a round rotating or oscillating cutterhead that may be fitted with any of several types of bits, teeth, or discs, depending on the type of material encountered. The material removed by the cutter is scooped from the invert by a muck bucket that rotates with the cutterhead. The muck is dumped on a conveyor belt and carried away from the face, either to the shaft or portal or to muck cars behind the mole. Moles may be used with shields in incompetent materials or soft ground, but better progress is made in soft, consistent rock where a shield is not necessary. Excavation in very hard rock wears down the bit very quickly; stratified rock or mixed face results in uneven thrust and excessive bearing wear and can cause large rocks to jam between the tunnel wall and rotating cutterhead.

Tunnel Estimating

20. Tunnel estimating is the art of conceiving a job on paper and properly evaluating the cost of planned construction. The assumptions and decisions that form the basis for cost computations are made by comparing cost records of similar completed projects, assuming a synthetic organization of men and equipment and rates of material usage and progress, or a combination of the two. A cost estimate can be prepared

manually or with the aid of a computer, but the basic decisions that must be made are identical and often both methods are used as a check. To develop a synthetic model, the method of excavation must be chosen, types and amount of equipment selected, progress rates assumed, crew sizes and makeup decided, and man-days required to accomplish the job estimated. The actual estimate quantifies the cost of the various inputs, including equipment, labor, materials, supplies, supervision, and escalation. Normal contingencies, risk, interest, and profits are not included in the estimate but compose the markup added to the estimate to arrive at a bid price. Engineering design and inspection are usually absorbed by the owner and are not included in the estimate. On a manual estimate, an estimator sets down all computations and afterwards presents the quantities and costs on a spread sheet that must conform to the owner's format in the request for bids. For a computer estimate, production rates, crew sizes, wage rates, and work hours are among the necessary inputs to produce a tabulated cost estimate. There are disadvantages and advantages of each method. Probably no contractor has ever submitted a tunnel bid prepared solely by a computer; a manual estimate gives them more confidence in the assumptions and calculations used and serves as a check on the black box. On the other hand, the computer method allows an owner's representative to evaluate many alternatives to optimize route selection, support design, depth of cover, shape, excavation method, and other factors to arrive at the most economically feasible option in the time available. A hand-calculated estimate may then be prepared on the most promising alternatives as a check. Obviously, then the selection of the method depends on the intended use of the estimate.

21. The following paragraphs present a discussion of the procedures for preparing a detailed manual estimate, a preliminary estimate using unit cost data, and the use of cost curves.

Manual estimates

22. The steps involved in preparing a detailed manual estimate follow:

a. Obtain and study plans and specifications.

b. Inspect site.

c. Review aerial photographs, geological reports, and boring logs.

d. Tabulate quantity takeoffs.

e. Obtain quotes from suppliers, insurance and bonding companies, and subcontractors.

f. Determine wage rates.

g. Prepare construction schedule.

h. Select excavation method.

i. Select equipment.

j. Estimate cost of equipment rental or purchase.

k. Determine crew size and makeup.

l. Estimate progress rates.

m. Estimate cost of aboveground development.

n. Estimate cost of tunnel excavation supplies.

o. Estimate cost of tunnel excavation labor.

p. Estimate cost of support and lining supplies.

q. Estimate cost of plant.

r. Estimate cost of concrete-lining labor.

s. Estimate direct cost of other bid items.

t. Tabulate all direct costs.

u. Estimate indirect costs.

v. Estimate camp costs.

w. Estimate escalation.

x. Tabulate total estimated costs of project in format required by request for bid.

All the steps above are interrelated and must be checked back and forth. For example, the initial construction schedule may be altered several times, but the contract end date must be adhered to. Thus men and equipment may have to be added to accomplish some tasks more quickly. The plans and specifications will be referred to countless times, i.e., after the site visit to check the impact of new information gained about access, labor wage rates and availability and their impacts on particular excavation methods, blasting restrictions, availability and cost of

power and water, etc. The review of geological information may indicate that a favored method of excavation or groundwater control will not work, necessitating changes. It is a good idea to prepare a checklist, and as each step is completed, compare them to determine if there are conflicts that must be resolved before moving to the next step. Quantity takeoffs must be calculated for each supply item or task and tabulated for convenient identification and cost of every aspect of the job. Requests for quotations from equipment and materials suppliers are made at the earliest possible date, even before the excavation method is chosen, to nail down these costs. These quotes serve as the basis for evaluating alternative methods and equipment.

23. Wage rates and availability are usually determined during the site visit, but they may change before the contract is awarded and so must be watched carefully. Selection of the excavation method sets the stage for many of the subsequent decisions and must be carefully weighed against required equipment purchases versus equipment currently owned, required crew makeup, manufacturer's lead time, and a host of other factors. Currently owned machines are always favored if they are suitable for the tasks. Selection of muck haulage and service equipment is not much affected by the excavation method. Tunnel length, size, shape, distance to disposal, and time allowed for completion do have a major impact on types and numbers of equipment used. Similarly, crew size and makeup are dependent on methods and equipment used. The advance rates that can be achieved are tied to all these factors; the slowest unit of production is the controlling one. For example, a tunnel boring machine may be capable of excavating 50 ft per shift, but if it is mated with a muck removal system that is slower or breaks down often, the mole will never develop that rate. In drill and blast tunnels, the length of rounds must be balanced against the capacity and cycle time of the muck removal system. Juggling men and equipment, length of rounds, etc., may be required to achieve the best possible efficiency. In some cases, more men and equipment might speed up mucking, but limited work space in small tunnels might preclude this effort. In such a case, multiple headings or alternating headings may be advantageous. To

achieve a synchronized efficient advance rate with the least possible idle time is one of the most difficult, yet necessary, tasks in tunnel construction. It cannot be done with any finality on paper but requires continuous monitoring and the ability to adapt quickly to changing conditions.

24. When the best estimate of progress rates has been arrived at, the next step is to tally the direct and indirect costs of each pay item. Direct costs may be arranged in the following categories after the equipment, crew makeup, advance rates, and quantities have been set:

a. Access and supply logistics (mobilization).

b. Tunnel excavation.

(1) Labor.
(2) Materials.
(3) Equipment.

c. Primary support.

(1) Labor.
(2) Materials.
(3) Equipment.

d. Lining.

(1) Labor.
(2) Materials.
(3) Equipment.

e. Demobilization and salvage.

25. Indirect costs must be developed next. Checklists are time-saving aids for this task and can be used for insurance, plant, field overhead, and office supervision. The effects of inflation and the data used by the contractor to develop a cash-flow forecast must be checked. In some instances, the figures may be juggled to produce a more favorable cash flow during the early stages of the contract. This practice is known as unbalancing the bid. An owner's representative is less concerned about cash flow but must consider the yearly budget requests and needs of the owner if the tunnel is publicly owned. (Most tunnels are owned by state and federal agencies). The estimated costs, when totaled, will be the basis of the build-no build decision by the owner and the bid-no bid decision by the contractor. In addition, the contractor must consider other market conditions, including interest costs, minimum

attractive rate of return, business-mix objectives, key personnel, etc., and balance this job against other tunnel jobs or other heavy construction, each with its own set of potential rewards and penalties.

26. The steps required to manually estimate the cost of tunnel construction have been outlined. According to personnel in large tunnel construction firms, the average time required to prepare a detailed tunnel estimate is three weeks and ranges from two weeks to two months.

Unit cost method

27. The unit cost method of estimating tunnel costs is a well-accepted simple technique for making preliminary or planning estimates. It relies on historical records of similar jobs. Basically, the estimator prepares quantity takeoffs for the tunnel and determines the unit cost of each item by comparison with other similar tunnels. These costs may or may not be adjusted for inflation, regional differences, etc. The sum of the unit cost times the quantities of each item yields the tunnel cost. Obviously, this simplified method may not reflect the actual cost for several reasons: (a) differences in locations, construction methods, special site conditions, etc., are not accounted for and may not be recognized; (b) if unit cost data are developed from the three lowest bids, as is often the case, the common practice of unbalancing bids will distort the unit costs. However, the total cost may not be affected much because an unbalanced bid is just a redistribution of the total cost to improve cash flow in the early stages of a project; (c) unless adjustments are made for inflation, large errors may result; (d) bidding climate influences are not accounted for, such as the number of prospective bidders and number of competing jobs. However, only the profit margin would be affected, and since profit margin ranges from about 3 to 20 percent, this omission would not negate the unit cost method's usefulness for preliminary estimates or comparison of alternatives.

Tunnel cost curves

28. One of the earliest reported developments to improve the reliability and reduce the time required for preliminary tunnel estimates was made by the California Department of Water Resources (1959). Their

need for reliable preliminary estimates to aid in route selection led to the formulation of a family of "cost curves." Case histories were analyzed to determine the cost impact of all factors involved in tunneling. They considered four major construction items affecting cost: excavation, support, dewatering, and lining. For each item, a family of cost curves was developed. Each curve represented a specified geological classification. The curves were plotted as item cost per foot of tunnel versus tunnel diameter. This work was done before moles and other tunneling advances were widely used. Consequently, the curves were representative of costs for conventionally (drill and blast) excavated tunnels, using standard steel-set support design (Proctor and White 1946). Soft ground, cut and cover, and mole excavation were not considered. Only circular-shaped tunnels were analyzed. The cost-per-foot figures were lump sum, not subdivided for labor, equipment, and materials, or profit, contingency, and overhead. Prior to the years of rapid inflation, these curves served their purpose quite well. The estimator simply entered the family of curves with a known tunnel diameter and estimated the length of each representative geological classification, then found the appropriate cost per foot for his tunnel. The cost per foot multiplied by the length was the total segment cost. Segment costs were summed over the tunnel length to produce a total estimated cost of the tunnel. Inflation and advancing technology eventually eroded the reliability of the curves, but they were a starting point for estimators in following years.

Computer methods

29. The steps involved in preparing a tunnel cost estimate with the aid of a computer are identical with those required for a manual estimate. The input data must conform to the requirements of the particular model being used. Some models have subroutines built into them that allow crew sizes, advance rates, lining thickness, and ground control measures to be calculated internally. These internal calculations may be suppressed by direct input of the required parameters, manually overriding the calculated value. Other models require that all information be input, just as in a manual estimate. Four computer models were

investigated during this study. One important aspect to remember is that although computer models unquestionably save time on computations, the data-gathering phase is not shortened and represents the bulk of the time required for tunnel estimating. Important features of each of the four models are discussed in the following paragraphs.

COSTUN - A Computer Program for Estimating Costs of Tunneling

30. COSTUN was developed in 1973 by Harza Engineering Company under contract to the Federal Railroad Administration (FRA), U. S. Department of Transportation. Complete documentation of this program is contained in Report No. FRA-ORD&D-74-16 (Wheby and Cikanek 1973). The report is available through the National Technical Information Service, Springfield, Virginia 22151. Permission by the FRA to use excerpts from this report is gratefully acknowledged. The COSTUN program has been used extensively by Harza in their tunnel work and has seen considerable use by the U. S. Army Engineer Division, New England, on the Park River Tunnel Project. Its use on this project was reported by Blackey (1979). EM 1110-2-502 (Dept. of the Army, OCE, 1980), Part II, Chapter 14, presents a method for making rough planning estimates for tunnels. The cost calculations were based on cost curves for different size tunnels and various geologic conditions developed using the COSTUN program. The method described herein allows the user to develop a more comprehensive and accurate estimate. It must be remembered, however, that the accuracy of any estimating method depends on the accuracy of the required input data.

Program philosophy and general characteristics

31. The documentation report (Wheby and Cikanek 1973) states that the program's philosophy is to duplicate the thought and reasoning processes that take place in the detailed planning, design, quantity take-offs, and estimate of cost of an actual tunnel and shaft system. To achieve this goal, construction operations that affect cost were divided into twelve components:

a. Excavation setup.

b. Excavation.

c. Muck loading.

d. Muck transporting.

e. Muck hoisting.

f. Muck disposal.

g. Supports.

h. Lining.

i. Lining formwork.

j. Grouting.

k. Pumping.

l. Air conditioning.

Each of these cost components was subdivided into labor, materials, and equipment cost subcomponents. Tunnels and shafts are considered separately in the program, but a similar division of cost components applies. The program was intended to have general application; therefore, fixed values were not assigned to these project dependent components. Rather, matrices of unit costs were developed for each component and subcomponent over a wide range of tunneling conditions, and equations were fit to these matrices and programmed. These unit costs were developed by studying past tunnel jobs, as well as current practices, and assuming synthetic organizations of men and equipment for various types and sizes of tunnel-shaft systems. Unit costs were based on 1969 Chicago prices for labor, equipment, and materials. Therefore, adjustments must be made for other times and locations. These cost adjustment factors must be provided by the user (guidelines are given herein) and consist of adjustments for labor, materials, equipment, and regional productivity differences. In addition, contractor's profit and overhead are required user input. The program does not consider the cost of any aboveground operations except cut and cover construction. Consequently, the costs of access roads, foundation underpinning, portal excavation, mitigation costs for loss of business revenue, traffic detours, right-of-way acquisition, and utility relocations must be separately calculated and added to the COSTUN estimate. Likewise, costs of architectural finish,

lighting, permanent ventilation, long-term pumping, and roadway or track construction must be separately estimated, where applicable, and added to the estimate. Since these costs and mobilization and demobilization costs may be quite significant, COSTUN is not recommended for estimating small jobs. In addition, COSTUN estimates would be inapplicable to one-of-a-kind jobs where innovative or unique equipment or techniques were used, for which there was no precedent when COSTUN was developed. In its defense, however, manual estimates for these jobs would probably be only slightly more accurate because they too base advance rates on assumptions from precedents.

32. Factors affecting the cost of a tunnel were grouped into three broad categories:

a. Site characteristics.

b. Design requirements.

c. Construction methods.

The variable factors within each category must be assigned values that form the input data. Input data for a tunnel-shaft system are stored by tunnel reach and segment numbers and shaft and segment numbers. A reach is defined as any number of contiguous segments driven from a single heading. (The number of reaches is equal to the number of faces worked.) A segment is defined as a continuous length of tunnel or shaft, within which all the factors affecting cost must be constant. The user must decide when the values of a particular factor may be averaged over a given distance and when a new segment must be created.

33. Design requirements and construction methods change abruptly when they change at all, so there is no problem in assigning segment limits based on these categories. However, site characteristics are seldom constant over any appreciable distance. Judgment and experience are necessary to determine what constitutes significant change in a factor or factors, requiring establishment of a new segment. A relatively small change in some factors, such as rock quality designation (RQD), would necessitate a new segment. Changes in other factors, such as density, are not so critical, and moderate ranges of density may be averaged within a segment. As part of this study, the impact on estimated

costs resulting from varying the input values of particular factors was examined for an expected range of values while holding all other factors constant. This sensitivity analysis provided insight into which factors were critical, requiring reliable quantitative determination, and which factors could be estimated with minimal effects on cost if the estimates were wrong.

Site characteristic factors

34. Some input factors are not required for certain tunnel types and excavation methods. Other factors, identified as optional input, may be input, or the user can allow the computer to calculate the values. Guidance on selection of parameter values is given in the documentation report (Wheby and Cikanek 1973). The required factors are as follows:

a. Rock quality designation, RQD (Deere et al. 1969).

b. Rock strength, unconfined compressive strength, psi, of intact specimen.

c. Governing shear strength, psf (the material strength that controls its behavior).

d. Saturated unit weight of soil or rock, pcf.

e. Soil angle of internal friction, PHI, undrained.

f. Soil cohesion, C, psf, undrained.

g. Equivalent angle of internal friction, PHIEQ, for materials characterized by friction and cohesion.

h. Effective grain size, D_{10}, mm.

i. Groundwater elevation - average elevation of groundwater table for each segment.

j. Sound rock elevation - the level below which the material in a cut and cover tunnel can be removed only by drill and blast methods.

k. Segment depth, ft, from average ground surface elevation to average tunnel elevation.

l. Impervious layer elevation - elevation of clay layer below which ground cannot be dewatered by pumping, or below which ground is sound rock.

m. Permeability, cm/sec, for soft ground and cut and cover segments.

n. Inflow, gpm, at the working face.

o. Distance to disposal, miles from exit shaft.

p. Cost of disposal site, dollars per acre.

q. Rock or soil temperature, degrees Fahrenheit.

r. Air temperature, degrees Fahrenheit.

Design requirement factors

35. Required input factors are listed below with options under the factors. The reader is again referred to the documentation report for complete descriptions and definitions.

a. Tunnel or shaft type.

(1) Underground heading.
(2) Cut and cover.

b. Shape.

(1) Circle.
(2) Horseshoe.
(3) Baskethandle (shape similar to horseshoe but with height approximately one-half that of same width horseshoe).
(4) Square.
(5) Single-level cut and cover box.
(6) Double-level cut and cover box.

c. Size.

(1) Characteristic finished inside dimension. Limiting tunnel and shaft sizes that may be run on COSTUN are minimum 10-ft and maximum 40-ft finished diameters.
(2) Characteristic nominal excavation dimension.
(3) Characteristic nominal excavation dimension plus overbreak.

d. Slope - tunnel slope up to 26 percent may be run on COSTUN (There are limits on the use of certain muck hauling methods for steep slopes; e.g., rail muck cars cannot be used if the slope is greater than 5 percent.).

e. Hoisting height.

f. Reach length.

g. Side slope (for cut and cover tunnels).

h. Stability number - based on Terzaghi's Tunnelman's Cround Classification System and stand-up time (Terzaghi 1950).

Construction method factors

36. Site characteristics and design requirements strongly influence the choice of construction methods, but some latitude exists. All

other things being equal, a contractor will choose methods with which he is familiar and that allow maximum use of equipment presently owned. Three of the factors listed below are required user input and three are optional; if no value is input, COSTUN will calculate them or use a default value, as explained below.

a. Construction work week - optional. If no value is input by the user, COSTUN uses a 6-day, 24-hr/day work week.

b. Soft ground stabilization method - optional. COSTUN will select the most suitable option for particular ground conditions if not input by the user.

c. Excavation method - required input. Options are conventional (drill or blast), mole (tunnel boring machine), cut and cover, hand excavation, and ripper excavation. In soft ground, the use of a shield is assumed by COSTUN.

d. Muck transport method - required input. Options considered are conveyor, trucks, rail cars, and combinations of conveyor and trucks. Limiting slope for the use of rail cars is ± 5 percent; if used on steeper slopes, they must be winched. Trucks cannot be used in compressed air or in tunnels with height less than 16 ft. Conveyors are permissible in all cases.

e. Advance rate - optional input. If not input by the user, COSTUN will calculate for each segment based on advance rate equations developed from previous jobs and equipment manufacturer's specifications. Appropriate adjustments are made, based on work hours, productivity loss during start-up, or when changing methods or starting a new segment or reach. Advance rate is one of the most critical input factors affecting the final cost estimate and should be considered carefully, whether calculated by COSTUN or input by the user.

f. Lining and support - required input. Supports are defined as the primary means of ensuring stability of the excavation. Options include rockbolts, wire mesh and shotcrete, steel sets and lagging, or segmental liners made of steel, precast concrete, or cast iron for underground headings. For cut and cover construction, slurry walls or soldier piles and lagging may be used. Lining is the secondary support. Its purpose is to protect the primary support against deterioration, as well as to enhance hydraulic properties in water tunnels. In COSTUN, the criteria presented by Deere et al. (1969) have been adopted for support and lining design. If other criteria are used in design, the COSTUN values might not conform to actual quantities and costs. Equations used by COSTUN in selecting the support and the lining type and

thickness are detailed in the text. Lining thickness and type may be input directly by the user, if desired.

37. Some factors or operations that may vary in actual tunnel construction were assumed constant based on accepted practice in 1970. These factors are discussed in detail in the documentation report and include:

a. Method and timing of lining erection.

b. Selection of specific equipment and production rates.

c. Range of conditions through which various methods are applicable.

d. Shaft inflow control methods.

38. The tunnel program philosophy and general structure have been presented. Actual user instructions for preparing a computer tunnel cost estimate using COSTUN are presented in Appendix A.

TCM - Tunnel Cost Model

39. The tunnel cost model (TCM) was developed in 1973 in its first phase* by researchers in the Civil Engineering Department at Massachusetts Institute of Technology (MIT) for the National Science Foundation's RANN (Research Applied to National Needs) Program. Permission by Dr. Michael Markow, MIT, to summarize the project's development is gratefully acknowledged. Complete documentation of the development, applications, and user instructions is contained in a comprehensive series of MIT publications.

Program philosophy and general characteristics

40. TCM is a rather large computer program, written in PL/I (IBM Machine Language I), and is run on an IBM 370/168 at MIT. Reported storage requirements range to 500K for the largest tunnel modeled. Subroutines accompanying TCM require region sizes up to 600K in which to compile.

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* A more comprehensive version was developed by Moavenzadeh and Markow (1978). Reported changes and improvements are discussed in this report in the sections in which they apply.

41. The "Summary Report" (Moavenzadeh et al. 1974a) states, "TCM was developed in an attempt to improve the assessment of uncertainty in rock tunnel cost estimates." All tunnel estimators try to assess risk and uncertainty on a job; their method usually consists of comparing the current job with similar previous ones, detailed assessment of plans and specifications, and using their experience and intuition to make subjective judgments about job risks. The philosophy behind TCM was to provide a method to quantitatively assess the impact of each item of uncertainty on costs and time. To achieve this goal, the model incorporates probability and statistics concepts that allow the user to subjectively specify the degree of confidence he has in each piece of input data. For example, instead of drawing up one geologic profile with fixed values of strength, RQD, etc., for each rock unit, the user may supply several possible values for each parameter used to describe a particular rock unit, with corresponding subjective probabilities assigned to each value. The computer model consists of three main components:

a. A geological submodel.

b. A tunnel simulator.

c. A construction submodel.

Geological submodel

42. The geological submodel stores input data according to the tunnel segment and rock unit. Unlike other computer models, more than one rock unit or type may be assigned to each segment. Each rock unit must be assigned a probability of occurrence. Typically, seven parameters may be used to describe each rock unit, such as rock type, major defects, RQD, foliation, gas, water inflow, and compressive strength.

43. Fewer or more parameters may be used as the user sees fit to describe the rock unit. This flexibility in segment and rock unit descriptions is made possible through the use of "parameter trees," as shown in Figure 1. Typical values, possible states, and construction consequences are presented in Table 1 for parameters typically used to form parameter trees.

44. In addition to the probabilistic states assigned to segments, the physical boundaries of the segments within which these states are

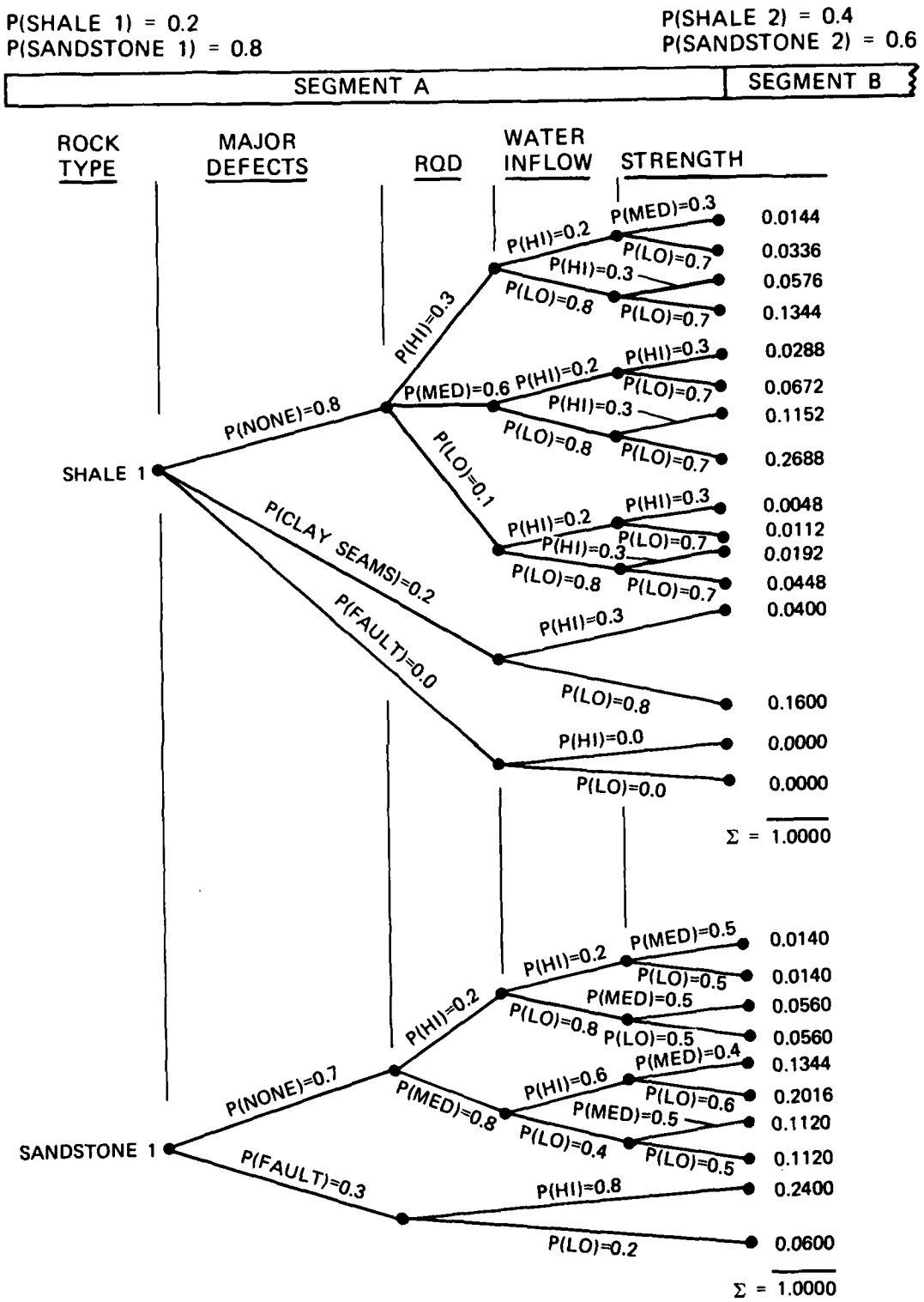

Figure 1. TCM parameter tree

valid must be identified in the input data. The process of defining segment limits and rock units within segments is interdependent. Regardless of the number of rock types possible within a segment, the sum of the probabilities of occurrence of each unit must be 1.0. For the example shown in Figure 1, the probability of encountering shale 1 in segment 1 is set at 0.2 and the probability of encountering sandstone 1 in segment 1 is 0.8. In addition, the sum of the probabilities of the right end nodes of each parameter tree must be 1.0. The extreme right node probabilities of parameter trees are obtained by cumulative multiplication of the probabilities along each continuous branch. For example, the probability of encountering shale 1 in segment 1 with no major defects, medium RQD (30-70 percent), low inflow, and low strength is given by

$$P(\text{Shale 1}) \times P(\text{No Defects}) \times P(\text{Med RQD}) \times P(\text{Low Inflow}) \times P(\text{Low Strength})$$

which for the example in Figure 1 is

$$\begin{aligned} P &= 0.2\ (0.8 \times 0.6 \times 0.8 \times 0.7) \\ &= 0.2\ (0.2688) = 0.0538 \end{aligned}$$

A new parameter tree must be created for each rock unit within the segment. In the simplified example shown, only two rock units were considered within segment 1; the most likely unit was sandstone with a probability of 0.8 and the least likely (P = 0.2) was shale. Thorough guidelines for forming segments and parameter trees are given by Vick (1974), Moavenzadeh (1974b), and Reynoso (1976). The interested reader is referred to Benjamin and Cornell (1970) or Blum and Rosenblatt (1972) for a more comprehensive treatment of probability and statistics for decision making.

45. New tunnel segments must be created when the user wishes to change the set of geological states or associated probabilities of the states. Segments may be independent, partially dependent, or completely dependent. Complete independence is assigned to segments modeled without consideration of rock types assigned in adjacent segments. Complete dependence is assigned to segments whose parameter trees are totally dependent on those of adjacent segments. The most general case, partial

dependency, is modeled using Markov dependency tables. This case would be appropriate for modeling the occurrence of a fault, for example, where the user feels that if the fault is encountered in a given segment, there is an increased (or decreased) likelihood of the fault extending into the next segment. The interested reader is referred to Barucha-Reid (1960) or Stark and Nicholls (1972) for the theoretical development and applications of Markov processes. After assimilating the parameter trees and Markov tables for segment relationships, the geological model produces and stores a user-specified number of profiles to be used by the tunnel simulator to produce estimates.

Construction submodel

46. This component calculates unit times and costs of each construction operation modeled, based on supplied input values of construction variables. Major features and functions of the submodel are:

a. Scheduling procedure - to specify the number and locations of headings and timing of operations at each heading.

b. Model of construction elements - to describe the excavation, support, dewatering, probe drilling, and lining cycles and interactions.

c. Construction method specification - to specify the methods to be used for particular geological conditions and for each heading worked.

d. Construction parameter specification - to input unit costs, times, productivity rates, and other related data.

e. Simulation routines - to compute cycle times and costs for each geological condition considered.

Cycles are calculated for excavation, mucking, muck hauling, muck hoisting, support installation, pumping, grouting, probe drilling, and lining. Aboveground costs are not considered by the simulation routines. When modeling multiple headings, construction operations are assumed to be independent. This assumption is usually acceptable unless alternating faces are worked from the same exit shaft or adit.* The model calculates approximate mobilization time and cost. It does not consider

* The latest version of TCM incorporates provisions for modeling alternating headings more realistically.

permanent pumping, ventilation, architectural finish, or roadways in its cost simulation routines. The construction submodel does not rely on data files for unit costs or cycle times for any tunneling operations. All data must be supplied by the user. The amount of detailed user input is rather large. Much of these data could be assembled only by an experienced estimator team. Owners or planners would quite likely have problems supplying some of the required input. These data are assigned values for worst case, best case, and expected case. In addition, the distribution that describes the data may be normal, beta, or uniform. After all user input has been assimilated, the construction submodel computes cycle time and costs for each construction operation modeled.

Tunnel simulator

47. The tunnel simulator combines the profiles produced by the geological submodel with the calculated cycle times and costs for each geological state and construction method produced by the construction submodel to calculate the total time and cost required to construct the tunnel through each of these profiles. The results are plotted in a scattergram such as Figure 2. It also produces a series of progress reports showing detailed advance of tunnel operations at different times. An optional file can be used to store individual simulations (each simulation constitutes one tunnel estimate). The individual results can be printed out and used in statistical analysis routines to calculate expected cost, standard deviation, etc.

User instructions

48. As mentioned earlier, TCM is a rather large and complex computer program and requires a computer with large storage capacity. Because of its size and the fact that it is written in PL/I, it was considered impractical to adapt it to the WES computer system. The only installation known to the author that currently has an operating version is MIT, and TCM is operational on the IBM 370/168 at MIT. Computers exist within the Corps and with contract vendors that could accommodate the program. However, to convert the program to Fortran IV, the computer language most familiar to noncomputer specialists, would essentially require writing a new program patterned after TCM, which probably would

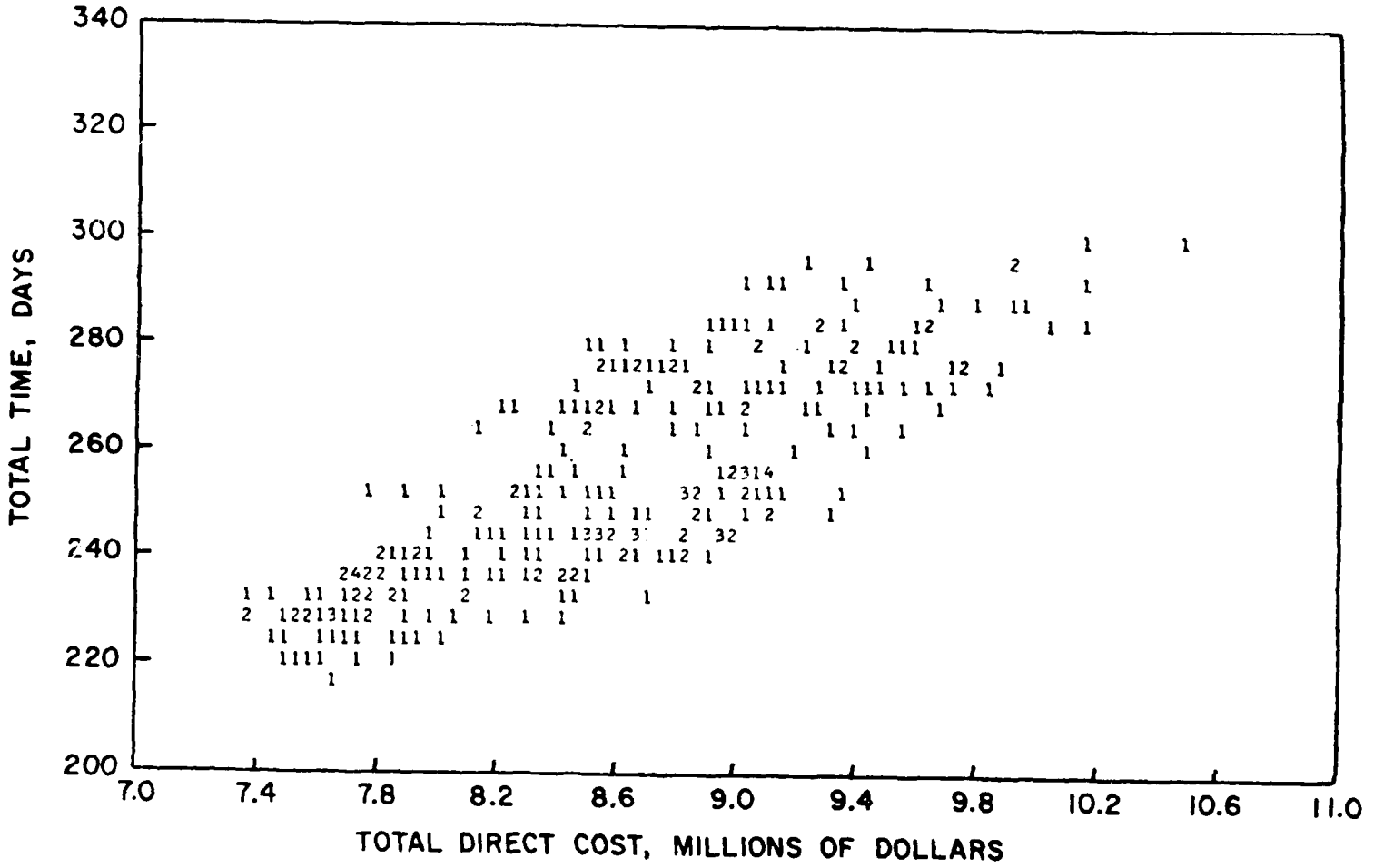

Figure 2. Scattergram: results of 300 tunnel simulations (from Moavenzadeh et al. 1974)

not be as flexible and comprehensive as the MIT version. The interested reader can secure a comprehensive user's manual (Reynoso 1975) from MIT. Therefore, instructions for using TCM are not presented in this report.

Applications

49. The program developers reported the use of TCM to prepare estimates of several tunnels (Minnot 1974 and Wyatt 1974). Normal practice was to perform several hundred simulations for each tunnel to cover all situations. The scattergrams of costs and time were then statistically analyzed to yield the expected cost and time, worst and best cases, etc. A detailed comparison of TCM estimates and actual costs was not presented in the MIT series. However, for the Harold D. Roberts Tunnel in Colorado, estimated advance rates varied significantly from actual rates. These differences were attributed to discrepancies between actual geology and model input describing geology (Wyatt 1974).

TM - Performance/Cost Tunneling Model

50. The performance/cost tunneling model (TM) was developed by General Research Corporation for the Advanced Research Projects Agency/ Bureau of Mines program in rock mechanics and rapid excavation. Its development and application are discussed by Pietrzak et al. (1972) and Hibbard et al. (1971).

General philosophy

51. In general, the program philosophy lies somewhere between COSTUN and TCM. COSTUN employs empirical equations based on regression analysis of previous tunnel jobs to determine support requirements, dewatering requirements, advance rates, etc. (There are provisions for the user to override the calculated values by supplying parameter values he thinks are more appropriate). Also, COSTUN employs a fixed geology model. The TCM program models uncertainty in its geology and construction submodels. All variable parameters affecting tunnel construction must be input by the user. In addition, the user must supply subjective probability of the occurrence of each variable state modeled.

Geology submodel

52. TM employs a user specified geology model (uncertainty is not accounted for) similar to COSTUN, with the added capability of modeling geology in three dimensions or using familiar 2-D profiles. The geology model does not consider soil profiles or mixed face. For each rock stratum, the model generates a file of material properties including density, RQD, abrasiveness, unconfined compressive strength, water inflow, and rock temperature. Parameter values are supplied by the user for each tunnel segment.

Tunneling submodel

53. The tunneling submodel simulates construction operations and conditions. The model can simulate various full-face rock excavation methods, including innovative techniques, but must be supplied with very detailed input to describe all relevant parameters. Soft ground, cut and cover, and mixed face cannot be simulated by TM. Likewise, shafts, portals, adits, and aboveground costs are not considered. Permanent pumping, roadbed or track, permanent lighting, and other architectural finish items are also omitted from consideration. Advance rates are computed using preprogrammed empirical relationships developed from a study of case histories. Construction progress reports are printed during simulation at user-specified time intervals. These status reports could be valuable aids for monitoring progress and costs and correcting problems as they occur. Information printed out includes heading position, elapsed time, average advance rate, availability, and utilization factors for each construction operation (excavation, support, dewatering, etc.).

Cost submodel

54. The cost submodel uses the input unit cost values for labor, materials, and equipment, the calculated quantities, advance rates, support requirements, dewatering and air conditioning requirements, etc., to calculate and tabulate costs accrued for each tunnel increment (measured in time, not distance). Profit and overhead, which are input by the user, are added to the costs. Cost status reports are printed for the same time intervals as the performance reports, including the cost and time of the completed tunnel.

Applications

55. The developers of this model report good correlation of calculated and actual values of advance rate, total time of construction, and cost for the Layout Tunnel. This tunnel, built in 1971-72 as part of the U. S. Bureau of Reclamation (USBUREC) Strawberry Aqueduct System, is approximately 3-1/4 miles long and 13 ft in diameter. It was moled through hard sandstone and conglomerate. The model is well suited for comparison of alternatives, but its use for detailed estimates is hampered because of the large storage requirements and detailed and extensive input data requirements.

TSC/FMA - Transportation Systems Center/Foster Miller Associates Model

56. The Transportation Systems Center/Foster Miller Associates (TSC/FMA) computer model was developed in 1979 through a cooperative effort of the Underground Technology Development Corporation and SKNH Company, under the sponsorship of the Urban Mass Transportation Administration (UMTA), United States Department of Transportation (USDOT). Complete documentation of the development and application of the model is contained in a report by Foster et al. (1979). Copies are available from the National Technical Information Service, Springfield, Virginia.

General philosophy

57. The program is run on a Wang Model 2200 computer. Data files are stored on discs. The model consists of two main data bases and supporting computations. Data Bank 1 contains factors that describe the amount of effort required to accomplish each unit operation. Data Bank 2 contains unit costs of labor, equipment, and materials required. Unit effort data were developed from analysis of 20 soft ground transit tunnels built in the United States in the last 10 years. The model is applicable to soft ground transportation tunnels and stations. Base or reference unit cost data reflect conditions prevailing in Washington, D.C., in January 1976. Costs for other times or regions may be adjusted using inflation factors similar to the method used with COSTUN, or the

actual unit costs may be determined and used in Data Bank 2. Only excavation and lining for soft ground transit tunnels are considered in the present version, although the developers report that it will be revised to make it more comprehensive as data on other operations are developed.

Applications

58. The model has been used on three sections of the Washington Metropolitan Area Transit Authority (WMATA) subway system. Section 1 consisted of 5393 ft of concrete-lined tunnel driven through moderate ground requiring some stabilization, an 800- by 75-ft station, and four vent and fan structures. The section actually analyzed was 2996 ft of tunnel, excavated by a backhoe digger arm under a shield. The actual construction costs were $5,837,000. The FMA estimate was $6,345,000, or 8.7 percent above actual cost. For the tunnel only, actual costs were $4,445,000, and the model estimate was $4,332,000, or 2.5 percent below actual cost.

59. Section 2, consisting of 8820 ft of tunnel, was driven through difficult ground and passed beneath several bridge piers and abutments. Excavation was accomplished by a backhoe digger arm under a shield. Steel segments served as both primary support and final lining. The actual project costs were $33,373,000 for those items considered by the model, which estimated the costs at $31,017,000, or 7.1 percent lower. For tunnel excavation, lining, backfill, and grouting, the actual costs were $25,721,000, and the model estimate was $24,648,000, or 4.2 percent lower.

60. Section 3 comprised 8115 ft of concrete-lined tunnel, an 800- by 75-ft cut-and-cover station, and six vent and fan structures. The section actually analyzed was 3803 ft long. Excavation was accomplished with a wheel excavator through good soft ground. Support was provided by expanded ring beams and wood lagging. The actual cost for the analyzed section was $6,443,000, and the model estimate was $6,731,000, or 4.5 percent higher. For tunnel costs only, the actual cost was $4,603,000, and the model estimate was $5,044,000, or 9.6 percent higher.

61. These results indicate that for its intended applications, the model provides estimates that are within 10 percent of actual costs,

provided there are good definitions of geology, excavation methods, and support requirements.

User instructions

62. Complete instructions for using the TSC/FMA model are available from the Transportation Systems Center, Department of Transportation, Cambridge, Massachusetts. Therefore, instructions are not repeated in this report.

Comparison of Computer Models, Cost Curves, and Manual Estimates

63. The investigation of the steps involved in estimating tunnel costs using all the methods described above clearly indicated that there is no one best method for all purposes. The choice of method must be based on the end use of the estimate. Detailed manual estimates for final design, contract documents, and contractor bids are probably here to stay. Cost curves or unit cost estimates may be useful for preliminary estimates and comparison of alternatives. Computer models may be used to good advantage for preliminary planning estimates, evaluation of alternatives, checks on manual estimates, and monitoring progress. Table 2 presents the relative advantages of the four models investigated during this project. One of the objectives of the project was to develop or adapt cost-estimating aids that planners not intimately familiar with tunneling could use. All things considered, COSTUN meets these criteria better than any of the other models studied. Therefore, it was selected for in-depth analysis, using collected tunnel case histories.

PART III: ANALYSIS OF CASE HISTORIES

64. One of the problems in this study was obtaining case histories of tunnels with sufficient information to: (a) allow a meaningful comparison of the reliability of manually prepared cost estimates with those generated by the computer program COSTUN, (b) allow a meaningful comparison of estimated and as-built costs, and (c) identify the factors responsible for overruns between estimated and as-built costs. After much studying and then discarding of several cases where complete documentation was unavailable, three tunnels were chosen that had good documentation of geology, design, construction methods, and estimates. The following paragraphs present brief descriptions of each tunnel, followed by an analysis of estimated and as-built costs and factors responsible for the differences between the two.

Nast Tunnel

65. Nast Tunnel was the first tunnel in the United States to be driven through granite with a boring machine (Larson 1975). Moles were thought to be unsuitable for hard rock tunnels prior to this job because of high cutter bit replacement costs. Indeed, on this job cutter bit costs amounted to over $1,200,000 on a winning bid price of approximately $6,800,000. Nast Tunnel is a 15,653-ft-long, 10-ft-diam water tunnel that was designed by the USBUREC and built between 1970 and 1973 in Pitkin County, Colorado. On this job contractors were allowed to bid on a drill and blast schedule and an alternative mole-driven tunnel option. Nine bids were received, six on the drill and blast schedule and three on the mole schedule. The winning contractor bid about the same amount on both options. The award was made for the schedule using the boring machine, and a Memorandum of Understanding was executed that permitted the contractor to change from mole driven to drill and blast at his option. Approximately 85 percent of the tunnel was moled; 15 percent was conventionally driven through reaches of poor quality rock.

66. All information used to develop and compare cost estimates of Nast Tunnel was provided by the USBUREC Engineering and Research Center, Denver, Colorado. Their cooperation is gratefully acknowledged. Table 3 summarizes the cost estimates prepared by the engineer, various contractors, and the COSTUN computer model. All identifiable costs not considered by the computer model were subtracted from the total bids so that a meaningful comparison could be made. Engineer estimate 1 and contractor bids 1-6 were for the conventional or drill and blast excavation schedule. Engineer estimate 2 and contractor bids 7-9 were for the mole excavation schedule. Contractor bids 1 and 7 were submitted by the same contractor, and the bid price for either option was about the same. Furthermore, when all schedule items were included, the bid prices were identical for both options. This contractor was awarded the contract, although one other bid, No. 8 in Table 3, was apparently lower. However, when the excluded costs were added back, this bid was higher than the winning bid. The winning bid was approximately 33 percent higher than the engineer estimate for either excavation option. The highest bid was nearly double the engineer estimate. There was a 45 percent spread between the winning and the highest bid.

67. COSTUN estimates 1-9 were prepared using information available at bid time. COSTUN estimate 1 represents the estimated construction cost for the most likely tunneling conditions, using mole excavation when feasible and drill and blast excavation in poor rock zones and near the inlet and outlet portals. The support and lining types and amounts used for this estimate were those called for in the plans and specifications. The total estimated tunnel costs for this run were $7,089,000, or 5 percent above the winning bid of $6,763,000 and 38 percent above the engineer estimate. COSTUN estimates 2-9 could be called "what if" estimates, in that the major input factors believed to affect construction costs were individually examined while holding all other variables constant at the expected value. Pessimistic and optimistic values were assigned to each of the major variables for each tunnel segment and reach. Some of these estimates reflected genuine uncertainty while others were used to test the sensitivity of costs to changes in a

specific variable. For example, runs 2 and 3 were made to determine the construction cost impact of varying rock strength. The actual rock strengths were known within reasonable limits from lab tests and empirical correlations, but studies have shown that stand-up time, advance rate, mole cutter bit wear, drill steel life, etc., are at least partially dependent on rock strength, among other things.

68. In run 2, the rock strengths input were 25 percent higher than expected strengths. For most types of structures, an increase in strengths is welcomed, but not necessarily for tunnel excavation. Higher strengths are associated with the harder crystalline rocks that are more abrasive. The results are higher cutter bit wear, more drill steel breakage, and overall slower advance rate, leading to increased costs. For this tunnel, the estimated consequences were nearly $500,000 (6 percent) and 100 working days (10 percent) over the estimate for most likely conditions. Run 3, which used strengths 25 percent lower than expected, resulted in estimated cost and time savings of $450,000 (6 percent) and 102 working days (10 percent) less than the estimate for most likely conditions.

69. The impact of variation in rock quality was assessed in runs 4 and 5. These runs reflected genuine uncertainty in the expected rock joint frequency, joint conditions, and degree of weathering for which the borehole data were lacking. In fact, change order No. 8, which provided for additional payment to the contractor of $767,000, was directly related to the occurrence of a major shear zone approximately 1700 ft long, which had not been detected by surface mapping or borings. The tunnel boring machine had to be moved back and the heading was advanced through this reach by the drill and blast method, using closely spaced heavy steel sets for support. In run 4, pessimistic values of RQD, approximately 33 percent lower than the expected values, were used. Estimated construction time increased 22 percent to 1203 days, or 218 days more than the expected time of 985 days. Estimated costs rose to $8,264,000, or 17 percent above the $7,089,000 expected cost. In run 5, RQD values 33 percent higher than expected were input. The estimated cost reduction was $718,000 (10 percent), while the time was cut 12 percent to 865 days.

70. In runs 6 and 7, the cost/time impact of reducing and increasing, respectively, the lining thickness by 30 percent of the design value was assessed. The specification of lining thickness is of major importance to the cost of a tunnel. The quantity of concrete that must be placed obviously increases for conservative (thicker) lining specifications. Additional cost and time penalties occur because the volume of rock that must be excavated increases proportionately. The larger the tunnel diameter and length, the more serious are the consequences. Compounding this problem is the lack of understanding of interaction between rock load and deformation and transfer of the load to the lining and support.

71. For a reduction of 30 percent in lining thickness (run 6), estimated costs were reduced by $527,000 (7 percent), and construction time was reduced by 30 days (3 percent) over the length of the tunnel. This reduction represents a $33/ft saving over the design lining thickness. A 30 percent increase in lining thickness (run 7) resulted in a 7 percent ($484,000) increase in cost and a 2 percent (24 days) increase in construction time.

72. Computer estimates 8 and 9 were made to study the impact of rock temperature in the tunnel. As expected, the results of these runs indicated that for the range of temperatures expected in Nast Tunnel, there was no effect on cost. In deep tunnels with higher temperatures, the cost of ventilation and air conditioning increases, but for shallow tunnels, such as Nast, there seems to be no effect.

73. The final cost for Nast Tunnel was $7,473,000, including change orders for differing site conditions and other unforeseen problems. This sum excludes those costs not considered by COSTUN, such as access roads, drainage ditches, the Fryingpan Conduit, and the Granite Adit portion of the job. Granite Adit is a 10-ft-diam, 777-ft-long tunnel intersecting Nast Tunnel about 4000 ft from the inlet portal. Its purpose was to convey water from Granite Creek to Nast Tunnel. During construction, it was used as an exit for muck hauling and disposal for the reaches of tunnel adjacent to it. Fryingpan Conduit is a 1500-ft-long conduit constructed of 7-ft-diam precast concrete pipe,

connecting Nast Tunnel at the outlet portal to Boustead Tunnel's inlet portal, which is a diversion tunnel through the Continental Divide.

74. The COSTUN as-built estimate totalled $7,691,000, or 3 percent above the actual cost. The changes made between the COSTUN preconstruction estimate using most likely conditions and the COSTUN as-built estimate included the allowance for the 1700-ft shear zone and a smaller shear zone approximately 300 ft long, both of which caused a change from mole excavation to the drill and blast method. In addition, one segment approximately 4000 ft long that ran under a small lake experienced minor water inflows, but the resulting cost increase was insignificant.

75. Table 4 contains a breakdown of COSTUN estimates 1-9 and the as-built estimate for labor, equipment, and materials components and the totals. Also shown is the total time required for construction of the tunnel for each estimate. Labor was the major cost component for this job and most tunnels, accounting for two thirds of the total for all estimates. Equipment and materials were nearly equal, averaging 16 and 17 percent, respectively, of the totals. Foster et al. (1979) indicate that a breakdown of 40 percent for labor, 40 percent for materials, and 20 percent for equipment is reasonable. Because tunnel jobs vary so widely in nearly all aspects, no significance should be attached to these figures for tunnels in general. The engineer estimates and contractor bids were not itemized for labor, equipment, and materials, so there is no basis for comparison of COSTUN figures except for the totals shown in Table 3. These figures show that the COSTUN best estimate of actual conditions was 5 percent above the winning bid. The COSTUN as-built estimate was 3 percent higher than the actual cost. These figures indicate very good correlation, but they do not give the total picture. The multitude of factors used to arrive at the estimated totals may or may not represent actual conditions. For example, the profit and overhead factors represent a combined 30 percent of the totals in the estimates. The actual profit and overhead, as well as the figures used in the bid, are unknown. Therefore, the reader is cautioned that although the overall accuracy of the estimates looks good, the accuracy of individual factors may not have been as good. The self-cancelling nature of random errors in these factors could still result in a balanced total estimate.

Buckskin Mountains Tunnel

76. Buckskin Mountains Tunnel, a 6.8-mile-long, 22-ft-diam irrigation tunnel, was designed by USBUREC and built near Parker, Arizona, as part of the Central Arizona Project. Prospective bidders were allowed to bid on three alternatives: (a) a 19-ft 6-in.-diam, drill and blast horseshoe-shaped tunnel; (b) a 20-ft-diam, circular-moled tunnel with cast-in-place concrete lining; and (c) a 22-ft-diam, circular-moled tunnel with a precast concrete segmental lining. The award was made for the 22-ft-diam tunnel, and construction began in 1975. The tunnel was holed through in May 1979, but final cleanup has not been completed at the time of this report. A Robbins mole was used for the entire length, except for approximately 100 ft at each portal excavated by drill and blast. The tunnel support and lining consist of 6-in.-thick precast concrete segments, installed just behind the mole. The tunnel was driven through competent andesite, but some blocky conglomerate was encountered that slowed progress. A $6-million changed conditions claim concerning this blocky zone is still pending and may add to its $60-million expected total cost.

77. Information used to develop and compare COSTUN estimates for Buckskin Mountains Tunnel was obtained from three sources: (a) the USBUREC Engineering and Research Center, Denver, Colorado, provided geology reports; (b) the U. S. Army Engineer District, Kansas City, loaned a set of job specifications, including engineer estimates and contractor bids; and (c) the personnel of the resident engineer's office, USBUREC, Parker, Arizona, provided other useful information. Table 5 summarizes the cost estimates prepared by the engineer, various contractors, and the COSTUN computer model. All identifiable costs not considered by the computer model were subtracted from the contractor bids and engineer estimates for the sake of comparison.

78. Engineer estimate 1, COSTUN estimate 1, and contractor bid 1 were for the 19-ft 6-in.-diam horseshoe-shaped tunnel on the drill and blast schedule. The engineer estimate for this option was $53,991,000, as compared with $51,641,000 for the COSTUN estimate and $65,513,000 for

the lone contractor bid on this option. Engineer estimate 2 ($47,441,000), COSTUN estimate 2 ($53,841,000), and contractor bid 2 ($71,208,000) were for the 20-ft-diam moled tunnel option with cast-in-place concrete lining. Both of the above options show a rather wide spread (27 and 50 percent, respectively), although the engineer and COSTUN estimates are within 5 and 13 percent of each other.

79. Engineer estimate 3, contractor bids 3-5, and COSTUN estimates 3-9 are for the 22-ft-diam moled tunnel with precast concrete segmental lining. COSTUN estimate 3 of $59,959,000 represents the estimated cost for the most likely conditions known at bid time, which is 27 percent higher than the engineer estimate of $47,257,000 and 33 percent higher than the winning contractor bid of $44,940,000. The highest bid of $63,493,000 was 41 percent higher than the winning bid, 34 percent higher than the engineer estimate, and 6 percent higher than the COSTUN estimate. The winning bid was 5 percent lower than the engineer estimate. At first glance, the COSTUN estimate seems to be far too high. However, the as-built cost of the tunnel was reported as approximately $60 million, which lends more credence to the COSTUN estimate.

80. COSTUN estimates 4-9 were used to check the cost impact of varying input parameters, one at a time, over a range of values. For an increase of 15 percent over the most likely RQD values (COSTUN estimate 4), the estimated cost was reduced to $52,287,000, or 13 percent below the estimate for most likely conditions. A 15 percent decrease in RQD values in COSTUN estimate 5 produced an expected cost of $75,130,000, or 25 percent higher than the $59,959,000 expected cost for most likely conditions. In COSTUN estimates 6 and 7, the unconfined compressive (UC) strengths were increased and decreased 25 percent, respectively, from the most likely values. The resulting costs were $72,054,000 for a 25 percent increase in UC strengths (20 percent above the $59,959,000 for most likely conditions) and $49,581,000 for a 25 percent decrease in UC strengths (17 percent below the expected cost for most likely conditions). The lining thickness was increased 33 percent in COSTUN estimate 8 over the actual lining thickness used in construction (6 in.) and was increased to 10 in. (67 percent) in COSTUN estimate 9. These runs produced

estimates of $61,373,000, or 2.4 percent above the total cost for the actual lining thickness used, and $62,826,000, or 4.8 percent higher, respectively. The increase in cost per linear foot of tunnel over the actual lining thickness amounted to $39 and $41, respectively, on a base cost of $1670/ft.

81. The as-built cost of Buckskin Mountains Tunnel was reported as $60 million in round figures. The COSTUN estimate representing conditions known at the end of construction totalled $61,474,000, or 2.5 percent above the actual cost. However, as mentioned earlier, a $6-million claim for changed conditions is pending and may add to the total cost. Even if the entire $6 million is awarded to the contractor, the COSTUN estimate would be only 7 percent below total cost. Thus, the COSTUN as-built estimate falls within the range of accuracy of -7 to +2.5 percent. Again, although the overall accuracy of the total cost figures looks good, the accuracy of individual components may not be as good. For example, the engineer estimate for excavation in the tunnel was $29,589,840, while the COSTUN estimate for this work was $38,495,000, or 30 percent higher. This difference is consistent with the overall spread between the engineer and the COSTUN estimate of 27 percent, cited earlier. However, the engineer estimate for furnishing and installing the segmental lining was $16,972,000, while the COSTUN estimate was $17,267,445, or 1.7 percent higher. These component costs compare favorably, but the 27 percent spread between the estimated totals is not reflected. Obviously, the difference had to be greater among the remaining component costs in order for the total 27 percent difference to be achieved.

82. Table 6 presents the breakdown of estimated costs for labor, equipment, and materials and the estimated time for construction of the tunnel for COSTUN estimates 1-9 and the COSTUN as-built estimate. The average cost of labor amounted to 60 percent of the total, while the equipment accounted for 22 percent and materials accounted for the remaining 18 percent for the 10 estimates.

83. The estimated time required to complete the tunnel ranged from 2475 to 4095 days for the three options under most likely conditions.

These figures contrast sharply with the allotted contract time of 1800 days, which the contractor met. The reasons for this discrepancy in estimated times could not be determined. Again, this case shows that even when the estimated totals agree closely, there can still be large differences in some factors or components. It is interesting to note that the least expensive alternative according to the COSTUN estimates was the 19-ft 6-in.-diam, horseshoe-shaped drill and blast option at $51,641,000, while the 20-ft-diam, circular-moled tunnel was second at $53,841,000 and the 22-ft-diam moled tunnel was the most expensive at $59,959,000. The engineer estimates are exactly reversed, with the 22-ft-diam tunnel the least expensive and the 19-ft 6-in.-diam tunnel the most expensive tunnel option.

Park River Tunnel

84. Park River Tunnel is a 22-ft-finished-diam, 9095-ft-long Corps of Engineers tunnel, that is located approximately 150 ft below street level in Hartford, Connecticut, and was designed to convey flood flows of the Park River to the Connecticut River. It passes through sandstone and shale, most of which is of good quality. One shear zone approximately 270 ft long was encountered, as predicted by exploratory borings. Prospective bidders were allowed to bid three alternatives for driving the tunnel: drill and blast excavation with a cast-in-place concrete lining, mole excavation with cast-in-place concrete lining, and mole excavation with a precast segmental concrete lining. The award was made for the mole-driven tunnel with precast segmental concrete lining. Construction began in 1977, and the tunnel was holed through in July 1980. Approximately 150 ft near the outlet portal was excavated by drill and blast for a staging area for the mole, as well as approximately 270 ft of shear zone.

85. Information used to develop and compare COSTUN estimates for Park River Tunnel was furnished by personnel of the U. S. Army Engineer Division, New England. Table 7 summarizes the cost estimates and bids. Table 8 presents a breakdown of the various COSTUN estimates for labor,

equipment, materials, and time required to build the tunnel. In addition to the data used for comparison on the two tunnels previously discussed, the estimated costs are also displayed for the two shafts associated with this project (Table 7). As with the other tunnels, all identifiable costs not considered by the COSTUN model were subtracted from the engineer estimates and contractor bids for a meaningful comparison.

86. Engineer estimate 1, contractor bid 1, and COSTUN estimate 10 are for the drill and blast option. The engineer estimate for tunnel construction was $20,916,000, as compared with the contractor bid of $24,885,000 and the COSTUN estimate of $19,476,000. For the inlet shaft, the engineer estimate was $770,000, the COSTUN estimate $1,971,000, and the contractor bid $1,800,000; for the outlet shaft, the engineer estimate was $1,100,000, the COSTUN estimate $1,981,000, and the contractor bid $3,000,000. The total project was estimated to cost $22,786,000 by the engineer, $23,428,000 by the COSTUN model, and $29,685,000 by the contractor (a spread of 30 percent).

87. Engineer estimate 2, contractor bid 2, and COSTUN estimate 11 are for the mole excavation schedule with cast-in-place lining. The engineer estimates and COSTUN estimates for the inlet and outlet shafts were unchanged, while the contractor bids were $3,500,000 for the inlet and $3,000,000 for the outlet shaft. The tunnel construction was estimated at $17,977,000 by the engineer, and $16,785,000 by COSTUN, as compared with the contractor bid of $14,096,000. Since the contractor bids for the shafts were much higher than either estimate and the bid for tunnel construction was much lower, this imbalance might have been a strategy to increase early cash flow. The estimates and bids for the total project were $19,847,000 by the engineer, $20,737,000 by the COSTUN model, and $20,596,000 by the contractor (a spread of just 4.5 percent).

88. The contractor awarded the job on the mole excavation schedule with precast lining bid $17,329,000 on the project (contractor bid 3). The bid was 3.7 percent lower than engineer estimate 3 of $17,993,000 and 5.8 percent lower than COSTUN estimate 1 of $18,405,000. Again, the

contractor bids for tunnel, inlet, and outlet shafts appear to be unbalanced. For the outlet shaft, from which tunnel excavation proceeded, the contractor bid was $4,000,000, while the engineer and COSTUN estimates were $1,100,000 and $1,981,000, respectively. This trend is apparent in every contractor bid on the project, so a comparison of the shafts and tunnel items separately is not meaningful. Only the total project estimates are compared. The next lowest bid of $17,360,000 was 3.5 percent lower than the engineer estimate. The highest bid of $50,310,000 was 280 percent of the engineer estimate. The bid spread was nearly $33,000,000, almost double the winning bid.

89. COSTUN estimates 2-9 were made to test the cost impact of varying rock properties and design lining thicknesses in the tunnel. Shaft properties and costs were held constant. In runs 2 and 3, the RQD values were increased 15 and 30 percent, respectively, over the most likely values. For the 15 percent increase in RQD, the estimated cost of the tunnel decreased to $13,555,000, or 6.2 percent lower than the $14,453,000 expected cost. The 30 percent increase in RQD resulted in a calculated 9.7 percent reduction to $13,055,000. Estimated time savings were 34 days (5.6 percent) in run 2 and 53 days (8.7 percent) in run 3. RQD values were decreased in runs 4 and 5 by 15 percent and 30 percent, respectively. The resulting increases in costs were 9.7 percent to $15,851,000 for the 15 percent decrease in RQD and 34.3 percent to $19,406,000 for the 30 percent decrease. Estimated time penalties were 53 days (8.7 percent) in run 4 and 186 days (30.4 percent) in run 5. In runs 6 and 7, the UC strengths were increased and decreased by 15 percent, respectively. Run 6 produced an estimated cost of $15,543,000, or 7.5 percent higher than the expected cost, while the 15 percent decrease in UC strengths in run 7 resulted in a 7.5 percent decrease in cost to $13,360,000. The estimated time penalty for the 15 percent increase in UC strengths was 40 days (6.5 percent) in run 6, and the estimated time savings attributed to a 15 percent reduction in UC strengths was 39 days (6.4 percent) in run 7.

90. Runs 8 and 9 were made to assess the cost impact of increasing the thickness of the precast concrete segments from 9 to 12 in.

in run 8 and to 15 in. in run 9, amounting to increases of 33 percent and 67 percent, respectively, over the design value of 9 in. The cost penalty was $650,000, or 4.5 percent, for the 12-in. liner and $1,390,000, or 9.6 percent, for the 15-in. liner. The time penalties were 7 days in run 8 (1 percent) and 13 days (2 percent) in run 9 over the expected time of 611 days for the design lining thickness.

91. The COSTUN as-built estimate is identical with the estimate for most likely conditions known at bid time. There were no big surprises in constructing this tunnel, except for some difficulties encountered during construction of the outlet shaft. Because the tunnel has only recently been completed, final as-built costs were not available but are expected to be around $23,000,000. If this estimate is correct, the COSTUN and engineer estimates are 20 and 22 percent, respectively, below the final costs.

92. Table 8 presents a breakdown of COSTUN estimates for labor, equipment, materials, and time required to build Park River Tunnel. Labor costs accounted for approximately 65 percent, equipment 19 percent, and materials 16 percent of the estimated total cost.

PART IV: SUMMARY AND CONCLUSIONS

92. The two basic methods for preparing tunnel estimates are: (a) a simulation of actual construction operations in which amounts and types of equipment and materials needed are estimated, crew productivity rates are estimated, the rates of material and labor usage and tunnel advance are set down, and a total estimated cost is computed; and (b) a comparison with similar tunnels in which the unit costs of major construction components, such as excavation, muck hauling, support and lining, and pumping are determined and applied, with or without adjustments for inflation and other factors to the present tunnel, for which the quantities of each component have been computed. Either of these methods may be performed manually or with a computer. The first approach, actual simulation, is more difficult, time-consuming, and accurate. The second approach, the unit cost method, is much easier to use and gives fair results, especially for preliminary estimates or comparison of alternatives.

93. Over the past decade, several computer models have been developed for estimating tunnel costs. The USDOT has provided the primary support for these efforts, and consequently, most of the models were developed for transportation tunnels (railroad, motor vehicle, and rapid transit).

94. Of the four computer models investigated, COSTUN satisfied more completely program objectives for a flexible, easy to use model that can be used by persons lacking an extensive background in tunneling and cost estimating. It has a wide range of applications, including rock, soft ground, and cut-and-cover tunnels, and considers various combinations of conditions and tunnel-driving methods. It also has several well-recognized shortcomings; e.g., aboveground costs are not considered, risk and uncertainty are not treated explicitly, cost equations are based on average costs for tunnels in Chicago in 1969, and method and equipment selection is based on standard practice (circa 1970).

95. Manual estimates and bid preparation will continue as the "tried and true" method for making final estimates. Computer models are

best suited for preliminary estimates, evaluation of alternatives, and checks on manual estimates.

96. The COSTUN model was evaluated using three completed tunnels for which good documentation of geology, construction methods, design, and cost data were available. All three tunnels were driven through rock, and consequently, the model's reliability for estimating costs of soft ground and cut-and-cover tunnels was not verified. For two of the three rock tunnels, COSTUN estimates were within 6 percent of the winning contractor bids and within 7 percent of the actual costs. These figures indicate very good overall accuracy of the model for rock tunnels. However, the accuracy of individual component costs estimated by COSTUN may vary over a wider range. It is difficult to test the validity of these component estimates for two reasons:

a. Contractor bids are often unbalanced to improve early cash flow. Therefore, construction costs may be overestimated for components used during the early stages of the project and underestimated for components used during latter stages.

b. Final, as-built costs are usually reported as a lump sum or with only limited itemization, precluding an item by item comparison.

97. For the three tunnels studied, a variation in rock UC strengths of ± 25 percent resulted in estimated cost savings of 6 to 17 percent for a 25 percent reduction in strengths and estimated cost increases of 6 to 20 percent for a 25 percent increase in strengths. The cost impact from a variation in strengths probably depends on the expected strengths more than any other factor. For example, if very low strengths were expected, an increase in strengths might result in a decrease in costs; however, for the tunnels studied, which were built in rock with moderate to high expected strengths, the reverse was true.

98. The estimated cost impact of varying RQD over a ± 33 percent range was a 17 to 24 percent increase in cost for a 33 percent decrease in RQD and about a 10 percent decrease in cost for a 33 percent increase in RQD. Again the cost impact probably depends on the expected RQD values more than any other factor. For example, if the expected RQD values were low, a 33 percent decrease might make tunnel excavation much more

expensive than the impact of a 33 percent reduction in high RQD values for another tunnel.

99. The savings that can be achieved through less conservative lining thickness can be quite significant. For example, 3 in. added to the precast concrete segments specified for the 22-ft-diam Park River Tunnel would have added an estimated $650,000 to the cost, or about $72/ft of tunnel. Similar effects were observed in estimates for the other two tunnels, though to a proportionally lesser scale in the 10-ft-diam Nast Tunnel.

100. In slopes and foundations, back analyses can provide knowledge of the actual strengths at failure and yield valuable data for future designs. However, with tunnels there is little historical perspective for altering design methods. Tunnel failures are rare; many have been in service for over 100 years. We know what has been successful in the past, but we do not know how conservative our empirical designs are. Much research has been and is being directed toward this problem. Tunnel experts generally admit that currently available analytical methods outstrip our ability to provide reliable input values for the variables needed for solution. Hopefully, this continued effort will lead to better understanding and more economical designs for support and lining.

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Table 1

Explanation of Typical Geological Parameters
Used to Form Parameter Trees

(TCM)

Item	Explanation
1. Rock Type	Left end node. One parameter tree must be created for each geological unit or rock type to be modeled. Rock type or lithology is used mainly to categorize engineering properties of materials. Main effect on tunneling is rate of drill bit or cutter wear associated with different rock types.
2. Major Defects	First branch of parameter tree. Describes faults (RQD = 0 by definition), clay seams, or for limestone and dolomites, solution cavities.
3. Jointing, RQD	Second branch of parameter tree. Expressed as high (70-100), medium (30-70), or low (0-30) to describe relative condition of rock. Helps in prediction of tunnel support requirements.
4. Foliation	Third branch of tree. Used for metamorphic units. When used for sedimentary rocks, refers to bedding.
5. Gas	Fourth branch of tree. Probabilities assigned to existence or nonexistence of gas. No quantitative estimate is made.
6. Water Inflow	Fifth branch of tree. Probabilities assigned to high and low inflow; no numerical values assigned to inflow rate. May be dependent on jointing and defects to some extent.
7. Compressive Strength	Sixth branch of tree. Probabilities of strength being very high (>32000 psi), high (16000-32000 psi), medium (8000-16000), or low (0-8000) are assigned. Used to assist evaluation of bit and cutter wear, advance rates, blast weights and spacings, and support requirements.

Table 2

Comparison of Computer Models

	COSTUN	TCM	TM	TSC/PMA
Applications:	-Tunnels and shafts -Circular, horseshoe, basket-handle, or cut-and-cover box Finished cross sections from 10 to 40 ft -Rock, soft ground, cut and cover -Excavation by mole, drill and blast, shield w/ripper, mole, or hand except in soft ground	-Tunnels, shafts, adits, caverns -Any shape, size -Rock only -Any excavation method	-Tunnels only -Any shape, size -Rock only -Full-face excavation by mole or drill and blast	-Soft ground only -Transit tunnels and stations -Excavation and lining only
Operation:	-Fortran IV, Honeywell GE635, Univac/108	-PL/I, IBM Machine Language I, IBM 370/168		-Wang 2200, data storage on discs
Philosophy:	-Preprogrammed standard designs keyed to geological input data for support, lining, dewatering, ventilation, etc. -Advance rate, other calculations based on empirical equations -Computed values may be overridden by user-supplied values for advance rate, lining thickness, stabilization methods, etc. -Uses fixed, user-input geology profile -Most representative of models studied to actual estimating procedures used in industry by owners and engineers -User need not be tunnel expert -Profit, overhead, adjustments for inflation of costs are input by user -Considers any geology -Alternatives can be evaluated -Cost adjustment factors used for labor, materials, equipment, and regional productivity differences	-Probabilistic geology model. User defines parameters to describe each rock unit, with associated probabilities of occurrence -All factors affecting tunnel construction must be input by user. Requires very detailed input. Model has no design capability -Breaks costs down to cycle level of operations -Tunnel simulator models uncertainty in construction operations -Very flexible but requires user with extensive background in tunneling, estimating, and statistical modeling -Contingency costs not considered. Modeling of uncertainty replaces it -Statistical inferences of best case, worst case, and expected cost and time, standard deviation, etc., can be easily made	-User input fixed 2-D or 3-D geology file -Very detailed input for construction method, equipment, crew, etc. -Advance rate calculated by model -Quantities and costs of all construction inputs calculated on per foot basis; user supplies unit cost of materials, labor, and equipment	-Program consists of 2 main data bases -Data Bank 1 describes units *of effort required* for each construction operation modeled -Data Bank 2 is a unit cost file, based on Washington, D. C., costs for 1976 -Data Banks were based on analysis of 20 tunnels built in United States in last 10 years -Adjustments may be made to Data Banks for inflation, regional differences, etc. -User input includes geometry, geology, location, time, selection of construction method, support and lining method and type, muck removal method, work week, number of bidders and site preparation requirements
Output:	-Calculated tunnel and shaft data cost and time summaries	-Progress reports of resources used versus time and progress -Scattergram of cost versus time. Each plotted point represents one tunnel estimate -Optional cost/time summaries for user-selected profiles	-Progress reports and cost reports at user-specified time intervals, including time and cost of completed tunnel	-List of input data, and detailed cost and time summaries for modeled construction operations and direct, indirect, and total project costs -Revisions are planned to take account of legal costs, financing, environmental issues, change orders, insurance, mitigation *costs, etc., as well* as more comprehensive treatment of tunnel construction operations and conditions
Advantages/ Disadvantages:	-Rather simplistic parametric relationships between geology and support design -Based on static technology/costs -Aboveground costs not considered -No treatment of uncertainty -Unsuitable for small projects	-Very detailed input data requirements -Very large storage and computer time requirements -User must have in-depth knowledge of tunneling, estimating, probability, and statistics -Aboveground costs not considered -Validity of subjective probability subject to question -Results difficult to interpret -Only the reasonableness, rather than the accuracy, of solutions can be checked. User must thoroughly verify input data	-Very detailed input requirements -User must have in-depth knowledge of tunnel estimating -Aboveground costs not considered -Limited applications. Soft ground, cut and cover, heading and bench, etc., not considered	-Limited application. Considers only soft ground tunnels and stations. Can be used to advantage for comparison of alternatives

Table 3

Nast Tunnel Cost Estimates

Owner: USBUREC
Built: 1970-1973
Length: Design length - 15,653 ft; as-built length - 15,740 ft.
Diameter: Finished - 10 ft
Shape: Circular and horseshoe
General geology: Competent granite, porphyry, some crushed zones

Construction Estimates

Estimate No.	Total Cost millions $	Cost, $/ft
Engineer 1	5.103	326
Contractor 1	6.814	435
Contractor 2	7.238	462
Contractor 3	8.156	521
Contractor 4	7.983	510
Contractor 5	8.355	534
Contractor 6	8.381	535
Contractor 7	6.763	432
Contractor 8	6.568	420
Contractor 9	9.904	633
Engineer 2	5.134	328
COSTUN 1	7.089	453
COSTUN 2	7.535	481
COSTUN 3	6.640	424
COSTUN 4	8.264	528
COSTUN 5	6.371	407
COSTUN 6	6.562	419
COSTUN 7	7.573	484
COSTUN 8	7.089	453
COSTUN 9	7.089	453
As-built Cost	7.473	477
COSTUN (As-built)	7.691	491

Comments

1. Engineer estimate 1 and Contractor bids 1-6 are for the drill and blast excavation schedule
2. Engineer estimate 2 and Contractor bids 7-9 are for the mole excavation schedule
3. COSTUN estimates are for mole excavation in good quality rock and conventional excavation in poor quality rock
4. In all estimates, costs not considered by COSTUN have been subtracted from the manual estimates for sake of comparison
5. Contractor bids 1 and 7 are from same company, drill and blast and mole schedules, respectively. This company was awarded contract with option of using either excavation method as necessary
6. COSTUN estimate 1 represents estimated costs for most likely conditions. COSTUN estimates 2-7 are for possible variations in conditions encountered, or for sensitivity analysis
7. As-built costs include costs of relevant change orders
8. COSTUN as-built estimate includes costs of 87 ft of additional tunneling, which resulted from improper alignment of mole

Table 4

Nast Tunnel COSTUN Estimates

Description	Tunnel Cost, millions $				Total Constr. Time, days
	Labor	Equipment	Materials	Total	
COSTUN 1 Best estimate of expected conditions	4.738	1.118	1.233	7.089	985
COSTUN 2 Input rock strengths 25% higher than expected strengths	5.094	1.165	1.276	7.535	1084
COSTUN 3 Input rock strengths 25% lower than expected strengths	4.385	1.059	1.196	6.640	883
COSTUN 4 Input RQD 33% lower than expected RQD	5.609	1.279	1.376	8.264	1203
COSTUN 5 Input RQD 33% higher than expected RQD	4.260	0.986	1.125	6.371	865
COSTUN 6 Reduced lining thickness from 18.5" to 12" in segs. 1, 4, 9, 11, 12 and from 14" to 10" in segs. 3, 5, 6, 7, 8, 13 (29 to 33% decrease)	4.546	1.041	0.975	6.562	955
COSTUN 7 Increased lining thickness from 18.5" to 24" in segs. 1, 4, 9, 11, 12 and from 14" to 18" in segs. 3, 5, 6, 7, 8, 10, 13 (29% increase)	4.913	1.168	1.492	7.573	1009
COSTUN 8 Decreased rock temp	4.738	1.118	1.233	7.089	985
COSTUN 9 Increased rock temp	4.738	1.118	1.233	7.089	985
As-built Cost	NA	NA	NA	7.474	1123*
COSTUN (As-built)	5.252	1.129	1.310	7.691	1079

* The number of days required for construction of the tunnel, Granite Adit, Fryingpan Conduit, and other items. No breakdown was available for the tunnel or for the number of crews working simultaneously.

Table 5

Buckskin Mountains Tunnel Estimates

Owner: USBUREC
Built: 1975-1980
Length: 35,910 ft

Diameter: Finished - 22 ft
General geology: Complex volcanic rocks
Location: Near Parker, Arizona

Estimate No.	Total Cost millions $	Cost, $/ft
Engineer 1	53.991	1504
Contractor 1	65.513	1824
Engineer 2	47.441	1321
Contractor 2	71.208	1983
Engineer 3	47.257	1316
Contractor 3	44.940	1251
Contractor 4	50.915	1418
Contractor 5	63.493	1768
COSTUN 1	51.641	1438
COSTUN 2	53.841	1499
COSTUN 3	59.959	1670
COSTUN 4	52.287	1456
COSTUN 5	75.130	2092
COSTUN 6	72.054	2007
COSTUN 7	49.581	1381
COSTUN 8	61.373	1709
COSTUN 9	62.826	1750
As-built Cost	60.0	1671
COSTUN (As-built)	61.474	1712

Comments

1. Engineer estimate 1 and contractor bid 1 for 19-ft 6-in.-diam horseshoe-shaped tunnel, excavated by drill and blast, with cast-in-place concrete lining
2. Engineer estimate 2 and contractor bid 2 for 20-ft-diam, circular-moled tunnel with cast-in-place concrete lining
3. Engineer estimate 3 and contractor bids 3-5 for 22-ft-diam, circular-moled tunnel with precast concrete segmental lining
4. Contractor bid 3 awarded the contract
5. COSTUN estimate 1 for 19-ft 6-in.-diam drill and blast tunnel
6. COSTUN estimate 2 for 20-ft-diam moled tunnel
7. COSTUN estimates 3-9 for 22-ft-diam moled tunnel with precast concrete segmental lining
8. COSTUN estimates 1-3 for most likely conditions known at bid time
9. COSTUN estimate 4 - RQD increased 15 percent
10. COSTUN estimate 5 - RQD decreased 15 percent
11. COSTUN estimate 6 - UC strengths increased 25 percent
12. COSTUN estimate 7 - UC strengths decreased 25 percent
13. COSTUN estimate 8 - lining thickness increased 33 percent
14. COSTUN estimate 9 - lining thickness increased 67 percent
15. As-built cost does not include pending $6-million claim
16. In all manual estimates, costs not considered by COSTUN have been excluded for sake of comparison

Table 6

Buckskin Mountains Tunnel

COSTUN Estimates

Estimate No.	Tunnel Cost, millions $ Labor	Equipment	Materials	Total	Total Construction Time, days	Comments
COSTUN 1	28.878	11.006	11.757	51.641	2475	Drill and blast excavation - 19-ft 6-in.-diam, horseshoe-shaped tunnel
COSTUN 2	29.875	12.871	11.095	53.841	4517	Mole excavation - 20-ft-diam tunnel with cast-in-place lining
COSTUN 3	36.413	13.303	10.243	59.959	4095	Base run - 22-ft-diam moled tunnel with precast concrete segmental lining
COSTUN 4	30.937	11.625	9.725	52.287	3376	Mole excavation - 22-ft-diam tunnel; RQD increased 15 percent
COSTUN 5	47.033	16.905	11.191	75.130	5444	Same to; RQD decreased 15 percent
COSTUN 6	44.224	15.853	11.977	72.054	5088	Same to; UC increased 25 percent
COSTUN 7	29.393	11.691	8.497	49.581	3106	Same to; UC decreased 25 percent
COSTUN 8	37.149	13.688	10.536	61.373	4153	Same to; lining thickness increased 33 percent (from 6-8 in.)
COSTUN 9	37.898	14.085	10.843	62.826	4212	Same to; lining thickness increased 67 percent (from 6-10 in.)
COSTUN (As-built)	37.286	13.638	10.550	61.474	4204	

Table 7

Park River Tunnel Estimates

Owner: U. S. Army Corps of Engineers
Built: 1978-1980
Length: 9090 ft
Diameter: Finished - 22 ft
General geology: Sedimentary deposits, shale and sandstone
Location: Hartford, Connecticut

	Total Cost, millions $				Cost $/ft
Estimate No.	Tunnel	Inlet Shaft	Outlet Shaft	Total Project	Tunnel
Engineer 1	20.916	0.770	1.100	22.786	2301
Contractor 1	24.885	1.800	3.000	29.685	2738
COSTUN 10	19.476	1.971	1.981	23.428	2143
Engineer 2	17.977	0.770	1.100	19.847	1978
Contractor 2	14.096	3.500	3.000	20.596	1551
COSTUN 11	16.785	1.971	1.981	20.737	1847
Engineer 3	16.123	0.770	1.100	17.993	1774
Contractor 3	11.829	1.500	4.000	17.329	1301
Contractor 4	14.760	1.100	1.500	17.360	1624
Contractor 5	15.111	1.500	4.000	20.611	1662
Contractor 6	14.293	3.500	3.000	20.793	1572
Contractor 7	18.270	1.050	3.400	22.720	2010
Contractor 8	17.689	1.000	2.600	21.289	1946
Contractor 9	20.351	1.800	3.000	25.151	2239
Contractor 10	45.310	2.500	2.500	50.310	4985
COSTUN 1	14.453	1.971	1.981	18.405	1590
COSTUN 2	13.555	1.971	1.981	17.507	1491
COSTUN 3	13.055	1.971	1.981	17.007	1436
COSTUN 4	15.851	1.971	1.981	19.803	1744
COSTUN 5	19.406	1.971	1.981	23.358	2135
COSTUN 6	15.543	1.971	1.981	19.495	1710
COSTUN 7	13.360	1.971	1.981	17.312	1470
COSTUN 8	15.103	1.971	1.981	19.055	1661
COSTUN 9	15.843	1.971	1.981	19.795	1743
As-built Cost COSTUN (As-built)	14.453	1.971	1.981	18.405	1590

Comments

1. Engineer estimate 1, COSTUN estimate 10, and contractor bid 1 were for the drill and blast excavation schedule with cast-in-place concrete lining
2. Engineer estimate 2, COSTUN estimate 11, and contractor bid 2 were for the mole excavation schedule with cast-in-place concrete lining
3. Engineer estimate 3, contractor bids 3-10, and COSTUN estimates 1-9 were for the mole excavation schedule with precast concrete segmental lining
4. COSTUN estimate 1 represented costs for most likely conditions known at bid time
5. COSTUN estimate 2 increased RQD 15 percent
6. COSTUN estimate 3 increased RQD 30 percent
7. COSTUN estimate 4 decreased RQD 15 percent
8. COSTUN estimate 5 decreased RQD 30 percent
9. COSTUN estimate 6 increased UC strengths 15 percent
10. COSTUN estimate 7 decreased UC strengths 15 percent
11. COSTUN estimate 8 increased lining thickness 33 percent
12. COSTUN estimate 9 increased lining thickness 67 percent
13. In all manual estimates, costs not considered by COSTUN have been subtracted for sake of comparison

Table 8

Park River Tunnel COSTUN Estimates

Estimate No.	Project Cost, millions $				Total Construction Time, days	Comments
	Labor	Equipment	Materials	Total		
COSTUN 1	11.907	3.559	2.939	18.405	611	Base run
COSTUN 2	11.259	3.363	2.885	17.507	577	RQD increased 15 percent
COSTUN 3	10.897	3.260	2.850	17.007	558	RQD increased 30 percent
COSTUN 4	12.925	3.859	3.019	19.803	664	RQD decreased 15 percent
COSTUN 5	15.506	4.635	3.217	23.358	797	RQD decreased 30 percent
COSTUN 6	12.637	3.772	3.086	19.495	651	UC strength increased 15 percent
COSTUN 7	11.177	3.344	2.791	17.312	572	UC strength decreased 15 percent
COSTUN 8	12.240	3.724	3.091	19.055	618	Lining thickness increased 33 percent
COSTUN 9	12.617	3.924	3.254	19.795	624	Lining thickness increased 67 percent
COSTUN 10	15.387	3.716	4.325	23.428	699	Drill and blast option
COSTUN 11	14.442	3.462	2.833	20.737	671	Mole option with cast-in-place lining
COSTUN (As-built)	11.907	3.559	2.939	18.405	611	

APPENDIX A: USER'S GUIDE FOR PROGRAM COSTUN

Introduction

1. Documentation for the computer program COSTUN for estimating tunnel costs is presented in this appendix and includes the introduction, input data, program execution and printer output, and program listing.

2. COSTUN is available in batch mode on the WES Honeywell GE635 computer. It has been run on a Univac 1108 at the New England Division (NED) Corps Office. The program is too large for the WES Tymeshare System. The mainline program COSTUN reads the project title, profit and overhead margins, and beginning project stationing. After these data are read, a series of calls to the various subroutines is initiated. The first subroutine called is INPUT, which reads the general project information, elevations of nodal points, and specific values of all input data for each tunnel segment, tunnel reach, shaft segment, and shaft. The computer performs an extensive check of all input data, and error statements are printed out for mistakes or incompatible data. If errors are encountered that would result in inaccurate solutions, a "Fatal Error" message is printed. Less serious errors are indicated by "Warning" messages. The next subroutine called by the mainline program is SFTSET, which calculates shaft geometry. LENGTH is then called to calculate shaft lengths, hoisting heights, tunnel slopes, and lengths. After these calculations have been made, the input data are printed out by subroutine INOUT under headings "Tunnel Input Data" and "Shaft Input Data." Subsequent subroutines calculate excavated dimensions, spoil quantities, advance rates, pumping heights and quantities, and a host of other factors necessary for a complete estimate. These subroutines and their functions are listed and described by comment cards in the program listing and in the documentation report.

Input Data

3. Input data must be entered on the file cards, with all data right-justified within formats. The job control cards are placed at the front of the deck and then followed by:

Item 1. Title cards. All 10 must be included, even if blank. Any alphanumeric data may be entered in columns 1-64.

Item 2. Printout options (one card). Enter code 0 or leave blank to print all input data, 1 in column 1 to suppress nodal points, 1 in column 2 to suppress tunnel input data, 1 in column 3 to suppress shaft input data, 1 in column 4 to suppress calculated tunnel data, 1 in column 5 to suppress calculated shaft data, 1 in column 6 to suppress tunnel segment and reach costs, 1 in column 7 to suppress shaft segment and shaft costs, 1 in column 8 to suppress tunnel reach cost summary, and 1 in column 9 to suppress shaft cost summary.

Item 3. Profit and overhead margins and beginning of project stationing (one card). Columns 1-10 contain profit margin in percent, columns 11-20 overhead margin in percent, and columns 21-30 beginning project stationing, any positive or negative number between $\pm$ 10,000. As an example, enter 4059.6; not 40 + 59.6.

Item 4. Nodal point elevations. *Use one card per nodal point.* Place nodal point number in columns 2-5. Place nodal point elevations in columns 11-20. Nodal points are used to designate the ground surface elevation at each shaft or portal and the ends of shaft and tunnel segments. Tunnel segment elevations should be referenced to center-line elevations and to ground surface for cut and cover.

Item 5. Data separator (one card). Enter 999999 in columns 1-6.

Item 6. Tunnel segment data. Include one card per segment. Data for soft ground and cut-and-cover segments are continued on a second card. Columns 1-4 contain the segment number; the sequence of cards must correspond to the sequence of segments within a reach. The left nodal point number is placed in columns 5-8, right nodal point number in columns 9-12, and the horizontal length of the segment, in feet, in columns 13-20. Columns 21-24 contain the tunnel reach number. The UC strength of intact rock, in pounds per square inch (psi), is entered in columns 25-31 for rock segments only. RQD is entered in columns 32-36 in percent, with any positive number between 25 and 100, for rock or cut-and-cover segments. For cut-and-cover segments, RQD refers to material below

sound rock elevation (see columns 55-60 on continuation card). Excavation method is coded in column 39. Enter code 1 for conventional (drill and blast), 2 for moled rock, 3 for moled soft ground, 4 for soft ground hand excavation, 5 for soft ground ripper excavation, 6 for cut and cover with vertical sidewalls, and 7 for cut and cover with sloping sidewalls. The uniform advance rate is entered in feet per day in columns 40-44. If left blank, COSTUN will calculate the value.

The data base used to form the program's advance rate equations is rather small for moled rock tunnels and moled shafts. Therefore, the user should examine advance rates calculated by COSTUN for these methods to see if they appear reasonable. The uniform advance rate, whether calculated by COSTUN or input by the user, is the advance rate that would be achieved if the segment were sufficiently long to permit work crews and equipment to reach peak efficiency. However, much time is lost during project start-up, when switching to new headings, or when changing excavation methods. Thus, the average advance rate is always less than the computed uniform advance rate. The average advance rate, on which costs are based, is computed internally by COSTUN by making adjustments to the uniform advance rate, as described previously. Water inflow is coded in gallons per minute in columns 45-51 and refers to inflow at the working face. Lining type is entered in column 54 with code 0 for unlined segment, 1 for cast-in-place concrete lining, 2 for shotcrete lining, 3 for precast concrete cut-and-cover box, and 4 for precast concrete segmental lining.

4. The option for precast concrete segmental lining was not included in the original COSTUN program. This subroutine was developed by NED personnel, based on limited experience, and should be used with caution. Adjustments to the cost base for this option are anticipated as experience is gained. This option requires that a lining thickness be input in columns 55-60 and the specified shape be circular with a watertight lining and mole excavation.

5. The user must ensure that the data discussed previously for precast segments are input, or the output will be erroneous. An error message is not printed out for erroneous input on the precast segment

option. Acceptable conditions for other specified lining types, such as the unlined segment (code 0), are: (a) in rock segments if watertight lining is not required (columns 73-75), and (b) in soft ground segments provided the support type on the continuation card (columns 52-54) is code 1, 2, or 3 for cast iron segments, precast concrete segments, or steel segments, respectively. However, an unlined segment is unacceptable in cut-and-cover segments. Lining code 1 or 2 must be used in conjunction with support code 4 in soft ground segments; code 0 or 2 is unacceptable in cut-and-cover segments; and code 3 is unacceptable in rock or soft ground segments. Lining thickness is input in columns 55-60. If left blank, COSTUN will calculate the thickness of cast-in-place concrete lining (code 1 in column 54) or shotcrete (code 2 in column 54). For unlined segments, it will calculate the backplate thickness of soft ground segmental supports (code 1, 2, or 3 in column 54 of continuation card). For precast concrete segmental lining (code 4 in column 54), the thickness must be input. If a thickness is input for code 3 (cut-and-cover precast concrete box), it will be ignored. Rock or soil temperature is coded in degrees Fahrenheit in columns 61-64 for rock and soft ground segments. In column 66, the user should enter code 0 if formwork costs for cast-in-place concrete lining are to be computed and code 1 if formwork costs are to be eliminated. Code 1 should be used when the concrete is cast behind the steel liner plate that serves at the form. Groundwater elevation is input in columns 67-72. The average groundwater elevation within the segment should be used. Column 75 is used to designate whether a watertight lining is required. In this column, the user should enter code 0 for a drained lining or drained soft ground support, or for groundwater elevation below the segment invert elevation, and code 1 for watertight lining or soft ground tunnel support. A cut-and-cover lining is automatically designated watertight. Tunnel type is coded in column 80 with 1 for rock, 2 for soil, and 3 for cut and cover.

Item 7. Tunnel segment continuation card. Include one card for each soft ground or cut-and-cover segment immediately after the main segment card to which it applies. Enter data as follows:

Columns 5-8 - Left-ground surface nodal point number.

Columns 9-12 - Right-ground surface nodal point number.

Columns 13-20 - Effective grain size D_{10}, in millimetres.

Columns 21-24 - Enter the undrained angle of internal friction ϕ in degrees.

Columns 25-31 - Enter undrained soil cohesion, in pounds per square foot (psf).

Columns 32-36 - Enter saturated unit weight of soil, in pounds per cubic foot (pcf). If no value is input, COSTUN uses the default value of 120 pcf.

Columns 37-39 - Enter dewatering option; use code 0 if dewatering is not permitted. Code 1 must be used for sloping-sided open cuts if groundwater elevation is above the bottom of the trench and the impervious layer is below groundwater elevation.

Columns 40-44 - Enter average elevation of groundwater within segment.

Columns 45-51 (optional input) - Enter soil permeability, in centimetres per second (cm/sec), for the strata in which dewatering or face stabilization will occur. If no value is input, COSTUN will compute from the empirical relationship

$$K = CD_{10}^2$$

where C is an empirical factor and D_{10} is the effective grain size in millimetres.

Column 54 (support type) - Enter code 0 for sloping-sided open cuts, 1 for soft ground supported by cast iron segments, 2 for soft ground supported by precast concrete segments, 3 for soft ground supported by steel segments, 4 for soft ground supported by steel ribs and lagging (used with lining codes 1 or 2 in column 54 of main segment card), 5 for vertical-sided open cuts supported by soldier piles and lagging, and 6 for vertical-sided open cuts supported by slurry walls.

Columns 55-60 - Required only for cut and cover. Enter the average sound rock elevation within the segment, below which RQD is greater than or equal to 50.

Column 64 - Required only for cut and cover. Enter the method of bracing open cuts with code 0 for sloping-sided open cuts, 1 for exclusive use of

struts, 2 for exclusive use of tieback anchors, and 3 for struts above the box roof and tieback anchors below the box roof.

Column 66 - Required only for cut and cover. Enter the decking requirement option with codes 0 and 1 to be used for no decking, respectively.

Columns 67-72 (optional input) - Enter stability number. For vertical open cuts, enter the value above sound rock including benefits of dewatering. For soft ground tunnels, enter the value at the face, after stabilization. Leave blank for sloping-sided open cuts or when it is desired to let COSTUN compute the value. For soft ground segments, the stability number input must be between 0 and 9 if the angle of internal friction is less than 29 deg and must be between 0 and 7 if the angle of internal friction is greater than or equal to 29 deg.

Column 74 - Required only for soft ground. Enter the soft ground face stabilization method with code 0 if no stabilization method is to be used, or if 1 or 2 is entered in column 75, 1 for compressed air, 2 for dewatering, and 3 for ground injections.

Column 75 - Required only for soft ground. Enter code 1 to allow COSTUN to select method for face stabilization and check for increased stability (reduce stabilization number) based solely on input parameters and internal calculations. Use code 2 to have COSTUN select a stabilization method only if the tunnel otherwise cannot be excavated, 3 to have COSTUN use the preferred method entered in column 74 above only if the tunnel otherwise could not be excavated, and 4 if the method entered in column 74 is to be used regardless of face stability. If code 1 or 2 is entered in column 75, column 74 must be blank or contain a zero; if code 3 is entered in column 75, a method must be specified in column 74. Columns 67-72 must be blank if code 1, 2, or 3 is entered in column 75. A stability number or stabilization method must be entered in columns 67-72 if code 4 is entered in column 75.

Columns 76-80 - Required only for soft ground. Enter the air pressure, in psi, between 0 and 50 to be used for face stabilization. Zero must be entered if column 74 does not contain code 1 and if column 75 does not contain code 3 or 4. If compressed air is specified (code 1) or selected in column 74, then the air pressure must be greater than zero in columns 76-80.

Item 8. Data separator (one card). Enter 999999 in columns 1-6.

Item 9. Tunnel reach data. Include one card per reach.

Columns 1-4 - Enter the reach number.

Columns 5-8 - Enter the exit shaft number.

Columns 9-14 - Required only for rock or soft ground. Enter the characteristic finished dimension, in feet, with any number from 10 to 40.

Column 17 - Required only for rock or soft ground. Enter the tunnel shape with code 1 for circular, 2 for horseshoe, and 3 for baskethandle.

Column 20 - Required only for rock or soft ground. Enter the muck transport method with code 1 for truck, 2 for conveyor, 3 for train, and 4 for conveyor in compressed air and truck in free air.

Columns 21-25 (optional input) - Enter the number of work hours per day. If no value is input, the default value of 24 hr is used.

Columns 26-29 (optional input) - Enter the number of work days per week. Default value is 6.

Columns 30-32 - Required only for cut and cover. Enter the number of contiguous box units in a single-level cut-and-cover box.

Columns 33-37 - Required only for cut and cover. Enter finished box width, in feet. For a single-level box, width equals clear span times number of units. For a double-level box, width equals two times the single level width. Any positive number between 10 and 40 may be input.

Columns 38-42 - Required only for cut and cover. Enter finished box height, in feet. For single-level box, height equals clear height of one unit; height of double-level box equals two times clear height of one unit. Any positive number between 10 and 20 is permissible for a single-level box and between 10 and 40 for a double-level box.

Columns 43-45 - Required only for cut and cover. Enter the select box option with codes 0 and 1 to be used for single-level and double-level box, respectively.

Item 10. Data separator (one card). Enter 999999 in columns 1-6.

Item 11. Shaft segment data. Include one card per segment. Data for soft ground and cut-and-cover segments are continued on a second card. For rock shaft segments, dummy shafts, or portals, the continuation card must be omitted.

Columns 1-4 - Shaft number.

Columns 5-8 - Segment number. Enter any positive integer from 1 to 999. Within any shaft, the segment numbers must be exclusive, but in different shafts, the numbers may be duplicated. Shaft segment numbers need not be in sequence, but sequential arrangement of cards must be from top to bottom of shafts.

Columns 9-12 - Upper nodal point number. Enter the number of the nodal point at the top of the segment.

Columns 13-16 - Lower nodal point number. Enter the number of the nodal point at the bottom of the segment; if a portal, this number should be identical with the upper nodal point number.

Columns 25-32 - Required only for rock. Enter intact, UC rock strength, in psf or in psi, with any positive number. Leave blank when the shaft is a portal.

Columns 33-36 - Required only for rock. Enter RQD in percent, with any positive number from 25 to 100. Leave columns blank when the shaft is a portal.

Columns 37-39 - Required only for rock or soft ground. Enter the excavation method with code 1 for conventional rock excavation, 2 for moled rock excavation, 3 for moled soft ground excavation, or 4 for hand excavation in soft ground. Leave blank when the shaft is a portal or a dummy.*

Columns 40-45 (optional input) - Enter uniform advance rate with any positive number, in feet per working day; if blank or contains a zero, COSTUN computes the advance rate. Leave blank when the shaft is a portal or a dummy.

Columns 46-48 - Rock only. For water inflow, enter code 1 for waterbearing formations; leave blank when the shaft is a portal or for dry formations. Control of inflow in shafts is assumed to be invariant. If inflow occurs, grouting around the perimeter of the shafts is the assumed control method. Costs are based on grout holes drilled on 5-ft centers around the perimeter of the shaft for the entire thickness of the waterbearing formation.

Columns 49-51 - Lining type. For unlined segment, portal, or dummy, enter code 0 or leave blank; for cast-in-place concrete lining, code 1; for shotcrete

---

* Note: A dummy shaft is an imaginary shaft used for internal bookkeeping purposes only to separate segments constructed by different excavation methods. No costs are calculated for a dummy shaft.

lining, code 2; and for precast cut-and-cover lining, code 3. An unlined segment is acceptable in rock segments provided a watertight lining (columns 66-68) is not required; in soft ground segments provided the support type (columns 49-51 on continuation card) is code 1, 2, or 3; and in cut-and-cover segments provided the shaft is a portal or a dummy. When lining code 1 or 2 is used in conjunction with support code 4 in soft ground segments, code 1 or 2 is unacceptable in cut-and-cover segments, and code 3 is unacceptable for rock or soft ground segments.

Columns 52-57 (optional input) - For lining thickness, enter any positive number, in inches; leave blank when shaft is a portal or a dummy. A thickness may be input for code 0, 1, or 2 above; for code 0, the value input refers to the backplate thickness of segmented soft ground shaft supports (code 1, 2, or 3 in columns 49-51 of continuation card).

Columns 58-59 - For formwork to be used in conjunction with cast-in-place concrete linings in soft ground or rock segments, enter code 0 or leave blank if formwork costs are to be computed and code 1 if formwork costs are to be eliminated. Code 1 should be used if the concrete is to be cast behind a steel liner that serves as the form. Note that the cost of the steel liner is not computed by COSTUN.

Columns 60-65 - Groundwater elevation. Leave blank for a portal or a dummy shaft. Enter any number representing the average groundwater elevation for the entire shaft.

Columns 66-68 - Watertight lining or soft ground shaft support. For an unlined shaft segment, for a drained lining or drained soft ground support, for a groundwater table below the segment, or for a portal or dummy shaft, enter code 0 or leave blank; for a watertight lining or soft ground shaft support, enter code 1. Note that a cut-and-cover lining is automatically designed as watertight.

Columns 69-73 - Shaft type. For rock, dummy, or portal, enter code 1; for soft ground, code 2; and for cut and cover, code 3.

Item 12. Shaft segment continuation card. Include this card only if the segment is soft ground or cut and cover (code 2 or 3 in columns 69-73 of main card). This card must be placed immediately behind the main card to which it applies.

Columns 17-24 - Effective grain size D_{10}, in millimetres.

Columns 25-32 - For undrained soil cohesion, in psf, enter zero or blank or any positive number. Usually this value is zero for sands and gravels, but it cannot be zero if columns 37-39 below are also zero or blank.

Columns 33-36 (optional input) - For unit weight of soil, in pcf, enter zero or blank or any positive number up to 200. If no value is input, COSTUN will assume 120.

Columns 37-39 - Undrained angle of internal friction, in degrees.

Columns 40-45 - For elevation of impervious layer, enter any number representing the elevation for the segment. Not required for soft ground segments if dewatering is not permitted or if the ground is not capable of being dewatered ($D_{10} \leq 0.08$ mm or PERM ≤ 0.0006 cm/sec); not required for cut-and-cover segments.

Columns 46-48 - Dewatering permitted. For cut-and-cover segments or if lowering of the groundwater table by pumping is not permitted, enter code 0 or leave blank; if lowering of the groundwater table is permitted, enter code 1.

Columns 49-51 - Support type. For soft ground supported by cast iron segments, enter code 1; for soft ground supported by precast concrete segments, code 2; for soft ground supported by steel segments, code 3; for soft ground supported by steel ribs and lagging (used with lining code 1 or 2 in columns 49-51 on main segment card), code 4; and for cut-and-cover construction, code 5.

Columns 52-59 (optional input) - For soil permeability, in cm/sec, enter the permeability at the level in which dewatering or face stabilization will occur; omit for cut-and-cover segments. If no value is input, COSTUN will compute if needed.

Columns 60-65 (optional input) - Stability number. For soft ground segments, enter the value at the face including the effect of any stabilization methods; for cut-and-cover segments, leave blank. If no value is to be input or if it is desired to let COSTUN compute it, enter code 0 or leave blank. Otherwise, input any number from 0 to 9 if PHI < 29 or any number from 0 to 7 if PHI ≥ 29.

Columns 66-67 - Required only for soft ground. Stabilization method; in conjunction with column 68 below, the soft ground face stabilization method either preferred or desired to be used; for required use of no method or for code 1 or 2 in column 68, enter code 0 or leave blank; for stabilization by compressed air, code 1; for stabilization by dewatering, code 2; and for stabilization by ground injections, code 3.

Column 68 - Required only for soft ground. To allow COSTUN to select a face stabilization method and check for a significant reduction in the stability number based solely on input parameters, enter code 1; to have COSTUN select a stabilization method only if the tunnel could not otherwise be excavated, code 2; to have COSTUN use the preferred stabilization method (columns 66-67 above) only if the shaft could not otherwise be excavated, code 3; to have COSTUN use the given stabilization method regardless of the face stability, code 4. For code 1 or 2, a face stabilization method must not be specified in columns 66 and 67; for code 3, a method must be specified in columns 66 and 67; for codes 1, 2, and 3, a stability number must not be input in columns 60-65; and for code 4, either a stability number or a stabilization method (both are also acceptable) must be input (blank or zero in columns 66 and 67 indicates no stabilization method is to be used).

Columns 69-73 - Required only for soft ground. For the air pressure to be used for face stabilization, in psi, input any positive number from 0 to 50. If a stability number is input and the stabilization method selected is compressed air, a number greater than zero must be input; a value other than 0 must not be specified if columns 66-67 do not contain code 1 and if column 68 does not contain code 3 or 4.

Item 13. Data separator (one card). Enter 999999 in columns 1-6.

Item 14. Shaft data. Include one card per shaft.

Columns 1-4 - Shaft number.

Columns 5-10 - Shaft size. Enter the characteristic finished dimension, in feet, with any number from 10 to 40. Leave blank when the shaft is a portal or a dummy.

Columns 11-13 - Shaft shape. For a dummy or portal, enter code 0 or leave blank; for a circular shape, code 1; and for a square shape, code 2.

Columns 14-21 - Distance to disposal. Enter distance to user-selected disposal site, in miles.

Columns 22-28 - Cost of the disposal site, in dollars per acre.

Columns 29-32 - For aboveground air temperature, in degrees Fahrenheit, any positive or negative number is entered but can be omitted if all reaches associated with the shaft are cut and cover.

Columns 33-38 - Labor cost index. Calculate by dividing the cost of labor for period of consideration by costs of labor in Chicago in 1969. This value was $35.17 in Chicago in 1969 and consisted of hourly wages and fringes for heavy construction, one each; common labor plus skilled iron workers plus hoisting engineers plus tractor operators plus air compressor operator plus truck driver. This mix is representative of labor employed in tunnel construction. Rates are published monthly by Engineering News Record (ENR) for 20 cities and annually for an additional 25 cities. In addition, information on labor rates may be obtained by contacting the U. S. Bureau of Labor Statistics, union offices, or local employment offices.

Columns 39-44 - Equipment cost index. Based on ENR quarterly report of "Equipment List Price Trends, All Types of Equipment." Equipment Cost Index is calculated by dividing the index value for the period of consideration by the index value in 1969, which was 110.4 on a base of 100 for 1967.

Columns 45-50 - Material cost index. Calculate by dividing the ENR Construction Cost Index, material prices for location of the project for the period of project construction, by the Chicago index for 1969. The unit of materials to use consists of 22.5 cwt bulk cement, carload lots (prior to 1972 used 6 bbls), 1 Mfbm of pine or fir 2x4's, and 25 cwt standard structural steel shapes, W8x31, base price, FOB warehouse. The 1969 Chicago cost of these mtls was $402.50.

Columns 51-56 - Regional cost factor. Used to assess construction cost differences in various regions of the United States. Enter 0.9 for Chicago, 1.2 for San Francisco, 2.0 for New York City, 0.8 for all other areas, or any other number the user deems appropriate.

Columns 57-61 (optional input) - For work hours per day, enter any positive number from 0 to 24. If no value is input, 24 will be assumed.

Columns 62-65 (optional input) - For work days per week, enter any positive number from 0 to 7. If no value is input, 6 will be assumed.

Item 15. Data separator (one card). Enter 999999 in columns 1-6.

Item 16. End of system (one card). Enter end of system in columns 1-13.

6. At this point, input decks for additional tunnel-shaft systems may be prepared. The additional decks should start with the title cards and end with the end of system card above. The additional system data decks may be stacked for a single computer run. Final job control cards are placed behind the last end of system card.

Fatal errors

7. Data inputs that would cause material inaccuracies in the problem solution and that can be identified by internal checks in subroutines INPUT, SFTSET, and LENCTH are programmed to halt execution of the computations. Such inputs, are, therefore, called "fatal" errors. The following tabulation is a complete listing of all fatal errors checked in INPUT, SFTSET, and LENCTH. The Format Statement Number is the number of the statement in the program listing that will be printed out as a result of the error. All are checked in INPUT except as noted in paragraph 7.

Description	Format Statement No. Tunnels	Shafts
No separator card after nodal point card	1500	1500
Duplicate nodal point number	1013	1013
Nodal point < 1 or > NPMAX* NPMAX = max. no. of nodal points	1001	1001
Number of segments > NTSMAX* or NSSMAX* NTSMAX = max. no. of tunnel segments allowed NSSMAX = max. no. of shaft segments allowed	1016	1017
No separator card after tunnel segment data or tunnel type coded incorrectly	1501/2000	--

* See the program listing (paragraph 16) for present dimensions of these variables.

Description	Format Statement No. Tunnels	Shafts
Duplicate reach or shaft number	1022	1023
Segment card out of sequence	1015	1115
Nodal point card omitted	1031	1131
Excavation method coded incorrectly	1030	1029
Excavation method does not match tunnel or shaft type	2005	2210
Thickness specified; no lining	1045	1046
Lining type coded incorrectly	1043	1048
Lining type does not match tunnel or shaft type	2010	2220
Input advance rate less than zero	1065	1075
Watertight lining requirement coded incorrectly	2015	2225
No lining or support specified for watertight tunnel or shaft	2020	2230
RQD < 25 in rock tunnel or shaft	2030	2212
RQD < 0 or > 100	1062	1072
Surface nodal point out of sequence	2040	--
Surface nodal point card omitted	2045	--
Surface nodal point elevation below tunnel	2050	--
Effective grain size not specified	2055	2245
Soil strength not specified	2060	2250
Friction angle > 100 deg	2063	2253
Unit weight of soil > 200 pcf	2064	2254
Dewatering requirement coded incorrectly	2065	2255
Impervious layer above ground surface	2072	--
Impervious layer at ground surface, soil not clay	2073	--
Impervious layer above base of shaft segment	--	2262
Support type coded incorrectly	2075	2265
Support type does not match tunnel or shaft type	2080	2270
Lining type does not match support type	2085	2275
Rock elevation above ground surface	2092	--
Bracing code < 0 or > 3	2095	--
Bracing code for vertical cut ≤ 0	2100	--
Decking coded incorrectly	2105	--

Description	Format Statement No. Tunnels	Shafts
Stability number too high; excavation impossible	2115	2285
Stabilization method coded incorrectly	2120	2290
Stabilization use coded incorrectly	2125	2295
Air pressure not specified for compressed air stabilization with input stability number	2130	2300
Stability number specified; incorrect stabilization use code	2135	2305
Air pressure specified; compressed air stabilization not specified	2137	2307
Stabilization use code does not match method	2140	2310
Unacceptable stabilization method input	2147	2320
No separator card after reach data	1502	--
Reach number < 1 or > NTRMAX	1021	--
Size indicates cut-and-cover; shape code is not zero	2150	--
Shape indicates cut and cover; size in wrong column	2151	--
Duplicate reach or shaft data cards	1026	1027
Muck transport method coded incorrectly	1041	--
Shape coded incorrectly	1042	2325
Shape indicates cut and cover; muck transport method specified	2152	--
No muck transport method specified	2153	--
Work hours per day < 0 or > 24	2155	2335
Work days per week < 4 or > 7	2160	2340
Box dimension(s) not input	2165	--
Number of box units not specified for cut and cover	2175	--
Noncircular shape for mole excavation	1040	2355
Compressed air required; truck muck transport specified	2195	--
Cast iron support specified for noncircular shape	2200	2350
Tunnel is not cut and cover; no shape specified	2201	--
Shape specified is not for cut and cover	2202	--
RQD of sound rock < 25 for cut and cover	2204	--
Sloping cut through pervious ground below GWT; dewatering must be allowed	2205	--

Description	Format Statement No. Tunnels	Shafts
Segment in nonexistent reach or shaft	1200	1201
Reach or shaft number not referred to	1203	1204
Reach ends at nonexistent shaft	1202	--
Shaft number < 1 or > NSMAX	--	1034
Groundwater elevation within shaft segment	--	2240
Shaft inflow coded incorrectly	--	1047
Shape indicates a dummy shaft, size given	--	2330
Size indicates a dummy shaft, shape code not zero or blank	--	2332
Square shaft in rock	--	2345
Missing separator card after shaft segment data, or shaft type coded incorrectly		1503/2207
No separator card after shaft data	--	1504
No cut-and-cover segments in a cut-and-cover shaft (SFTSET)		1000
No cut-and-cover segment adjacent to dummy shaft (LENGTH)	--	2000

8. Fatal errors may also be detected after some preliminary processing in subroutines CALCS, AIRPRS and STABIL that are identified in the program listing. In this case, the calculated tunnel data and calculated shaft data will be printed out (unless suppressed), and then the program execution will be halted. Fatal errors in this category are listed below.

Description	Format Statement No. Tunnels	Shafts	Subroutine
Stability number too high after stabilization; excavation impossible	2000	3000	STABIL
Stabilization is required but input method not acceptable	2030	3030	STABIL
Stabilization is required but input method not effective	2035	3035	STABIL

Description	Format Statement No. Tunnels	Shafts	Subroutine
Stabilization is required but input specifies no method must be used	2050	3050	STABIL
Excavation impossible by using air pressure < 50 psi	2000	3000	AIRPRS
Haul slope too steep for a train	1020	--	CALCS
Tunnel too small for a truck	1021	--	CALCS
Slope too steep for muck transport methods	1023	--	CALCS
Truck muck transport in compressed air tunnel	1025	--	CALCS

Nonfatal errors

9. Data inputs that are beyond the range for which the cost relationships are believed to apply with accuracy are nonfatal errors. These errors will not halt execution of the program, but a warning will be printed out to call attention to their existence. Included in the category of nonfatal errors are various reminders and warnings as to the final use of certain input data.

Description	Format Statement No. Tunnels	Shafts	Subroutine
Rock strength < 500 psi	1060	1070	INPUT
Cut-and-cover segments are watertight	2017	2227	INPUT
Groundwater elevation is zero or blank, used zero	2025	2235	INPUT
RQD > 25 for soft ground tunnel	2035	2215	INPUT
Coefficient of permeability > 10 cm/sec	2061	2251	INPUT
Friction angle > 45 deg	2062	2251	INPUT
Impervious layer elevation is zero or blank, used zero	2070	2260	INPUT
Rock elevation is zero or blank, used zero	2090	--	INPUT
Cut-and-cover box deeper than 100 ft	2094	--	INPUT
Stabilization method is not acceptable	2145	2315	INPUT
Size < 10 or > 40 ft	1064	1074	INPUT

Description	Format Statement No. Tunnels	Shafts	Subroutine
Box width exceeds 40 ft	2170	--	INPUT
Box height > 20 ft for single-level box	2180	--	INPUT
Box height > 40 ft for double-level box	2185	--	INPUT
Impervious layer above tunnel, $D_{10} > 0.005$	2190	--	INPUT
RQD of sound rock is 25-50 for cut and cover	2203	--	INPUT
No excavation method specified; dummy shaft assumed	--	2208	INPUT
Dummy shaft, cost=0	--	2327	INPUT
Shaft depth > 3000 ft	--	1071	LENGTH
Reach length > 20 miles	1061	--	LENGTH
Input thickness less than standard design, input ignored	1010	1011	SIZEST/SIZESS
Input thickness appear to be inadequate for water pressure	2710	2711	SIZEST/SIZESS
Lining thickness was input for cut-and-cover box	3500	--	SIZEST/SIZESS
Groundwater below segment; input inflow ignored	3600	3605	SIZEST/SIZESS
Stabilization method not effective; no method used	2010	3010	STABIL
Input stabilization method not required	2015	3015	STABIL
Input stabilization method not acceptable nor required	2020	3020	STABIL
Stabilization method not effective; method used anyway	2025	3025	STABIL
Hand excavation used rather than input method	2040	3040	STABIL
Conveyor/truck transport used rather than input method	1030	--	CALCS

10. Several of the above messages are caused by elevations that are not associated with nodal points. INPUT makes extensive checks for missing input data. Unfortunately, the computer cannot distinguish between a zero and a blank data field. Therefore, COSTUN cannot be certain that the user meant elevation 0 or just forgot to input a number. These messages can be avoided by specifying an elevation close to zero, like 0.1 or 0.01, if elevation 0 is indeed desired.

Program Execution and Printout

Program execution

11. COSTUN is executed in core. During operation it neither refers to information stored on another tape nor generates another data tape. Therefore, no special operating instructions are necessary.

12. The program stores most data in one of five arrays (A, B, CNP, SHAFT, and TRDATA). These five arrays are stored in one main array called ARRAY. This procedure allows the user to alter the storage requirements of COSTUN. The storage requirements are a function of the allowable number of tunnel and shaft segments, tunnel reaches, and shafts. COSTUN as written provided for NTSMAX (maximum number of tunnel segments) = 300, NSSMAX (maximum number of shaft segments) = 300, NSMAX (maximum number of shafts) = 100, and NTRMAX (maximum number of reaches) = 200. The version presented in the program listing allows NTSMAX = 20, NSSMAX = 10, NSMAX = 10, and NTRMAX = 20.

13. The storage requirements can be changed by changing any or all four of these key variables in the main program. If the change is made after the initial compilation, then only the main program needs to be recompiled. If these variables are made larger, the dimension of ARRAY (first execute card in MAINLINE) must be increased. If these variables are made smaller, the dimension of ARRAY need not be changed, but failure to do so will result in paying for more computer storage than necessary. The minimum dimension of ARRAY is given by

$$\text{MARRAY} = 74 \times \text{NTSMAX} + 46 \times \text{NSSMAX} + 23 \times \text{NSMAX} + 23 \times \text{NTRMAX}$$

14. For the values originally provided for these four key variables, the minimum dimension of ARRAY was 42,900. If the dimension of ARRAY is changed to less than the minimum required dimension, a message will be printed and the computer run will terminate. Whenever the dimension of ARRAY is changed, the value of MM (fifth execute card in MAINLINE) must also be changed to that of the new dimension of ARRAY. The present dimension of ARRAY is 2630. This size allows most tunnels to be estimated without problems and saves some storage costs.

Printout

15. The printout consists of the tunnel and shaft title and all other input data, unless the suppress option, described previously in paragraph 3, is used to suppress one or more items of input data. After the selected input is printed out, the program prints out calculated tunnel data, consisting of length, slope, excavated dimensions and quantities, advance rates, lining thickness, pump rates and heads, and construction time. Position of the airlock, if used, stabilization method used, unit weights, permeability, concrete volumes, and backfill volumes are listed where appropriate for each tunnel segment within each reach. The same categories of calculated data are printed out for each shaft under the heading, "Calculated Shaft Data." Next, tunnel costs are listed by reach and segment number under column headings for excavation setup, excavation, muck loading, muck hauling, muck hoisting, muck disposal, supports, lining, lining formwork, grouting, pumping, and air conditioning, and these unit costs are tallied to obtain the segment cost per foot and total segment costs, which are printed. This process is repeated for each segment. Then a summary of reach costs is printed, applying the cost adjustment factors to labor costs, equipment costs, and material costs to obtain total reach costs. Such a printout is also prepared for each reach and for each shaft. A "Tunnel Reach Cost Summary" is printed next, applying the Regional Cost Factor to the total, followed by a similar "Shaft Cost Summary." The final output block reprints the project title and the profit and overhead margins, and then lists the project summary costs for labor, equipment, and materials, and the total costs.

Program Listing

16. A listing of program COSTUN is given below.

```
C     MAINLINE PROGRAM  ----------  COSTUN  ---------------------------
C     ******************************************************************
      DIMENSION ARRAY (2630)
      COMMON /BASIC/ NSS,NTS
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
      COMMON/F/ IERROR,ISTOP
      COMMON/G/ TUNLC,TUNEC,TUNMC,TUNTC
C     ------------------------------------------------------------------
C     WHENEVER THE DIMENSION OF 'ARRAY' IS CHANGED, THE VALUE OF MM
C     BELOW MUST ALSO BE CHANGED TO THAT OF THE NEW DIMENSION OF 'ARRAY'
      MM=2630
C     ------------------------------------------------------------------
      NSMAX=10
      NSSMAX=10
      NTRMAX=20
      NTSMAX=20
      NPMAX=NSSMAX+2*NTSMAX
C     J1 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'A' ARRAY
C     J2 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN  B' ARRAY
C     J3 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'CNP' ARRAY
C     J4 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'SHAFT' ARRAY
C     J5 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'TRDATA' ARRAY
C     J6 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN  CUMSL
      J1 = 1
C     THE NUMERICAL COEFFICIENTS ON THE NEXT 5 LINES REPRESENT THE
C     NUMBER OF ITEMS STORED IN THE  A,  B,  CNP,  SHAFT,  AND  TRDATA
C     ARRAYS, RESPECTIVELY
      J2 = J1 + 68*NTSMAX
      J3 = J2 + 43*NSSMAX
      J4 = J3 +  2*NPMAX
      J5 = J4 + 23*NSMAX
      J6 = J5 + 23*NTRMAX
      LI=5
      LO=6
C     ------------------------------------------------------------------
C     THE MINIMUM REQUIRED SIZE OF 'ARRAY' IS  J6+ NPMAX-1
C     OR 74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX
      MINARR=74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX
      IF(MM.LT.MINARR) GO TO 500
C     ------------------------------------------------------------------
   10 IERROR=0
      READ(LI,1,END=600) TITLE,LIST,PM,OM,STABEG
      WRITE(LO,2) TITLE
      WRITE(LO,3) PM,OM
      WRITE(LO,4)
      CALL INPUT    (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)
      IF(ISTOP.EQ.1) GO TO 10
  140 CALL SFTSET   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)
      IF(ISTOP.EQ.1) GO TO 10
      CALL LENGTH   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
     1 ARRAY(J6),NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)
C     ------------------------------------------------------------------
C     PRINT OUT INPUT DATA FOR TUNNELS
C     INITIALIZE
```

(Continued)

```
      IPR=0                                                             000550 0000
      NLINES=40                                                         000560 0000
      DO 5 M=1,NTS
      I=M
      ITYPE=1                                                           000580 0000
    5 CALL INOUT  (I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000590 0000
     1NLINES,IPR,NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                      000600 0000
C     PRINT OUT INPUT DATA FOR SHAFTS                                   000610 0000
C     INITIALIZE                                                        000620 0000
      IPS=0                                                             000630 0000
      NLINES=45                                                         000640 0000
      DO 6 M=1,NSS
      I=M
      ITYPE=2                                                           000660 0000
    6 CALL INOUT  (I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000670 0000
     1NLINES,IPS,NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                      000680 0000
C     ------------------------------------------------------------------ 000690 0000
C     CALCULATE TUNNEL DIMENSIONS                                       000700 0000
      DO 7 M=1,NTS
      I=M
    7 CALL SIZEST(I, ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000720 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000725
C     CALCULATE SHAFT DIMENSIONS                                        000730 0000
      DO 8 M=1,NSS
      I=M
    8 CALL SIZESS(I, ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000750 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000755
C     ------------------------------------------------------------------ 000760 0000
C     DETERMINE STABILITY NUMBER AND EXCAVATION METHOD FOR SG TUNNELS   000770 0000
      DO 20 M=1,NTS
      I=M
      ITYPE=1                                                           000790 0000
      CALL STABIL(I, ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000800 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000805
   20 CONTINUE                                                          000810 0000
C     DETERMINE STABILITY NUMBER AND EXCAVATION METHOD FOR SG SHAFTS    000820 0000
      DO 25 M=1,NSS
      ITYPE=2                                                           000840 0000
      I=M
      CALL STABIL(I, ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000850 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000855
   25 CONTINUE                                                          000860 0000
C     ------------------------------------------------------------------ 000870 0000
      CALL REACHD   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000880 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000885
      CALL ADRATE   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000890 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000895
      CALL CONSTM   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000900 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000905
      CALL PUMPHT   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000910 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000915
      CALL PUMPRT   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000920 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000925
      CALL VOLUME   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000930 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000935
      CALL EXCVOL   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000940 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000945
      CALL MUCKLD   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000950 0000
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(Continued)

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     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000955
      CALL AIRLOK   (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000960 0000
     1 ARRAY(J6),NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                      000970 0000
      CALL CALCS    (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),  000980 0000
     1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)                                 000985
      IF(IERROR.EQ.1) GO TO 10                                          000990 0000
      CALL COSTTU   (ARRAY(J1),ARRAY(J3),ARRAY(J4),ARRAY(J5),ARRAY(J6),  001000 0000
     1NTSMAX,NPMAX,NSMAX,NTRMAX,NSSMAX)                                 001005
      CALL COSTSF    (ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),          001010 0000
     1NSSMAX,NPMAX,NSMAX,NTRMAX,NTSMAX)                                 001015
      CALL NEXSET(LO,LI)                                                001020 0000
      GO TO 10                                                          001030 0000
C     ----------------------------------------------------------------- 001040 0000
C     DIMENSION OF 'ARRAY' ARRAY LESS THAN MINIMUM REQUIRED DIMENSION,  001050 0000
C     EXECUTION TERMINATED                                              001060 0000
  500 WRITE(LO,9) MM,MINARR                                             001070 0000
C     ----------------------------------------------------------------- 001080 0000
    1 FORMAT(10(16A4/),40I1,/,3F10.0)                                   001090 0000
    2 FORMAT(1H1,10(/),15X,90(1H*),/,15X,1H*,88X,1H*,/,                 001100 0000
     110(15X,1H*,12X,16A4,12X,1H*,/),                                   001110 0000
     2                  15X,1H*,88X,1H*,/,15X,90(1H*))                  001120 0000
    3 FORMAT(/////,44X,32(1H*),/,                                       001130 0000
     1 44X,1H*,22H PROFIT MARGIN .......F7.2,2H *,/,                    001140 0000
     2 44X,1H*,22H OVERHEAD MARGIN .....F7.2,2H *,/,                    001150 0000
     3   44X,32(1H*))                                                   001160 0000
    4 FORMAT(1H1)                                                       001170 0000
    9 FORMAT(1H1,/////,1X,131(1H*)//27X,78H***** EXECUTION OF 'COSTUN' S 001180 0000
     1TOPPED BECAUSE OF ERROR IN MAINLINE PROGRAM *****//22X,           001190 0000
     213HDIMENSION OF ,I7,68H GIVEN FOR 'ARRAY' IN MAINLINE PROGRAM IS L 001200 0000
     3ESS THAN MINIMUM REQUIRED//22X, 13HDIMENSION OF ,I7,              001210 0000
     429H.     ALL DATA DECKS IGNORED.//1X,131(1H*))                    001220 0000
C     ----------------------------------------------------------------- 001230 0000
  600 CONTINUE                                                          001240 0000
      STOP                                                              001245
      END                                                               001250 0000
      SUBROUTINE INPUT(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,  001260 0000
     1NTRMAX)                                                           001265
C     ----------------------------------------------------------------- 001270 0000
C     ----------------------------------------------------------------- 001280 0000
C     THE FOLLOWING DEFINES THE CONTENTS OF THE VARIOUS ARRAYS          001290 0000
C     ----------------------------------------------------------------- 001300 0000
C     CNP(I,J) .... NODAL POINT ARRAY (I = NODAL POINT NUMBER)          001310 0000
C                              J = 1  STATIONING OF THE NODAL POINT     001320 0000
C                                     (CALCULATED IN SUB LENGTH)        001330 0000
C                                  = 2  ELEVATION OF THE NODAL POINT    001340 0000
C     A(I,J) ...... TUNNEL SEGMENT ARRAY (I = LOCATION OF SEGMENT IN    001350 0000
C                        'A' ARRAY,  J = AS BELOW)                      001360 0000
C                       ITEM J = 1   SEGMENT NUMBER = NTSEG             001370 0000
C                                2   NODAL POINT TO LEFT OF SEGMENT = NPL 001380 0000
C                                3   NODAL POINT TO RIGHT OF SEGMENT = NPR 001390 0000
C                                4   REACH NUMBER = NREACH             001400 0000
C                                5   ROCK STRENGTH = RS OR JRS          001410 0000
C                                6   R.Q.D. = RQD OR JRQD               001420 0000
C                                7   EXCAVATION METHOD = MEX            001430 0000
C                                        (1=DRILL AND BLAST, 2=MOLE(ROCK), 001440 0000
C                                        3=MOLE(SOIL), 4=HAND,5=RIPPER  001450 0000
C                                        6=OPEN CUT(VERTICAL), 7=OPEN CUT 001460 0000
C                                        (SLOPING))                     001470 0000
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(Continued)

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C                 8   HEADING ADVANCE RATE = AR                  001490 0000
C                 9   GROUNDWATER INFLOW AT WORKING FACE         001490 0000
C                         = INFLOW OR GI                         001500 0000
C                10   LINING TYPE = LINING                       001510 0000
C                      (0 OR BLANK=UNLINED,1=CIP CONCRETE,       001520 0000
C                      2=SHOTCRETE,3=PRECAST CONCRETE BOX)       001530 0000
C                11   LINING THICKNESS = TL OR LT OR TSEG        001540 0000
C                12   ROCK TEMPERATURE = RTEMP OR JRTEMP         001550 0000
C                13   SUPPRESSION OF FORMWORK COSTS=NOFORM       001560 0000
C                     (0 OR BLANK=POSSIBLE COSTS,1=SUPPRESS      001570 0000
C                14   GROUNDWATER ELEVATION = ELWATR             001580 0000
C                15   WATERTIGHT LINING REQUIREMENT = LINWT      001590 0000
C                         (0 OR BLANK=NO, 1=WATERTIGHT)          001600 0000
C                16   TUNNEL SEGMENT TYPE = NTSTYP               001610 0000
C                         (1=ROCK, 2=SOFT GROUND,                001620 0000
C                         3= CUT AND COVER)                      001630 0000
C                17   SURFACE NODAL POINT TO LEFT OF TUNNEL      001640 0000
C                         SEGMENT = NPLS                         001650 0000
C                18   SURFACE NODAL POINT TO RIGHT OF            001660 0000
C                         TUNNEL SEGMENT = NPRS                  001670 0000
C                19   EFFECTIVE GRAIN SIZE = D10                 001680 0000
C                20   ANGLE OF INTERNAL FRICTION = PHI           001690 0000
C                21   SOIL COHESION = COHESN                     001700 0000
C                22   SOIL UNIT WEIGHT = GAMMA                   001710 0000
C                23   DEWATERING ALLOWED = IWATER                001720 0000
C                         (0 OR BLANK=NO, 1=ALLOWED)             001730 0000
C                24   ELEVATION OF IMPERVIOUS LAYER = ELIMP      001740 0000
C                25   SOIL PERMEABILITY = PERM                   001750 0000
C                26   SUPPORT TYPE = ISUPPT                      001760 0000
C                         (1=CAST IRON SEGMENTS, 2=CONCRETE      001770 0000
C                         SEGMENTS, 3=STEEL SEGMENTS,            001780 0000
C                         4=STEEL RIBS W/LINING, 5=SOLDIER       001790 0000
C                         PILE-LAGGING, 6=SLURRY WALL)           001800 0000
C                27   ELEVATION OF SOUND ROCK = ELROCK           001810 0000
C                28   OPEN CUT BRACING REQUIREMENT = IBRACE      001820 0000
C                         (0 OR BLANK=NONE, 1 =STRUTS            001830 0000
C                         2=ANCHORS, 3=STRUTS+ANCHORS)           001840 0000
C                29   OPEN CUT DECKING REQUIREMENT = IDECK       001850 0000
C                         (0 OR BLANK=NO, 1=DECKING USED)        001860 0000
C                30   STABILITY NUMBER = STABNO                  001870 0000
C                31   STABILIZATION METHOD = MSTAB               001880 0000
C                         (0 OR BLANK=NONE, 1=COMPRESSED         001890 0000
C                         AIR, 2=DEWATERING, 3=GROUND INJ.)      001900 0000
C                32   USE OF STABILIZATION METHOD = MUST         001910 0000
C                         (1=COSTUN SELECT, 2=COSTUN SELECT      001920 0000
C                         ONLY IF COULD NOT BE EXCAVATED,        001930 0000
C                         3=USER SELECT ONLY IF COULD NOT        001940 0000
C                         BE EXCAVATED, 4=USER SELECTS,MUST      001950 0000
C                         USE,EVEN IF MSTAB=0)                   001960 0000
C                33   AIR PRESSURE = AIRPR                       001970 0000
C                34   ACCEPTABLE INPUT STABIL.METHOD= MSTAC      001980 0000
C                         (1=ACCEPTABLE,2=UNACCEPTABLE)          001990 0000
C                35   MAX AIR QUANTITY FOR COMPRESSED AIR        002000 0000
C                         SETUP = CAVT                           002010 0000
C                36   NODAL POINT OF AIR LOCK = NPLOCK           002020 0000
C                37   MAX HEAT EXCHANGE FOR COOLING PLANT        002030 0000
C                         SETUP = QT                             002040 0000
C                38   FOR ROCK OR SOFT GROUND -----              002050 0000
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(Continued)

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C                                QUANTITY OF HEAT EXCHANGE IN SEG • Q  002060 0000
C                                FOR CUT AND COVER -----               002070 0000
C                                LENGTH OF SOLD. PILE W/ DECK. • SPDLT 002080 0000
C                                          -- OR --                    002090 0000
C                                DEPTH OF SLURRY WALL • DSLURY         002100 0000
C                           39   CHAR. EXC. DIMENSION • BE             002110 0000
C                           40   CHAR. EXC. DIMENSION AT RQD•40 • BE40 002120 0000
C                           41   CHAR. EXC. DIMENSION AT RQD•60 • BE60 002130 0000
C                           42   CHAR. EXC. DIM. W/OB • BOB            002140 0000
C                           43   FOR ROCK -----                        002150 0000
C                                CHAR. EXC. DIM. W/OB , RQD•40 • BOB40 002160 0000
C                                FOR CUT AND COVER -----               002170 0000
C                                TOTAL BOX HEIGHT • TOTBOX             002180 0000
C                           44   CHAR. EXC. DIM. W/OB , RQD•60 • BOB60 002190 0000
C                           45   SEGMENT LENGTH • TSEGL                002200 0000
C                           46   MUCK HAUL DISTANCE • DM               002210 0000
C                           47   MUCK HAUL SLOPE • HSLOPE              002220 0000
C                           48   MUCK LOADING RATE IN SEGMENT • RML    002230 0000
C                           49   ULTIMATE ADVANCE RATE • ARTULT        002240 0000
C                           50   CONSTR. TIME EXC. + LINING • CTTS     002250 0000
C                           51   EXCAVATED VOLUME • V                  002260 0000
C                           52   TOTAL DEPTH OF TRENCH • DTRNCH        002270 0000
C                           53   CUT AND COVER SIDE CUT SLOPE • SIDESL 002280 0000
C                           54   VOLUME DISPLACED BY CONC. BOX • VBOX  002290 0000
C                           55   VOLUME OF CONCRETE IN BOX • VL        002300 0000
C                           56   AREA OF BOX FORMS • FORMAR            002310 0000
C                           57   PUMPING HEIGHT • PH                   002320 0000
C                           58   LENGTH OF PIPE FOR PUMPING INFLOWS    002330 0000
C                                    UPHILL • PIPL                     002340 0000
C                           59   AVG PUMPING FLOW IN TUNNELS • FLOW    002350 0000
C                           60   RESIDUAL GROUNDWATER INFLOW • GIR     002360 0000
C                           61   PUMPING FLOW, ONE DEEP WELL • FLOWL   002370 0000
C                           62   CHAR DEPTH OF SUPPORTS • WEB/ TPLATE  002380 0000
C                           63   FOR ROCK OR SOFT GROUND -----         002390 0000
C                                SOIL LOAD  • PSOIL                    002400 0000
C                                FOR CUT AND COVER -----               002410 0000
C                                WT/FT OF WALER • WTWALE               002420 0000
C                           64   FOR ROCK OR SOFT GROUND -----        002430 0000
C                                WATER LOAD  • PWATER                  002440 0000
C                                FOR CUT AND COVER -----               002450 0000
C                                WT/FT OF STRUT • WTSTRT               002460 0000
C                           65   FOR ROCK OR SOFT GROUND -----        002470 0000
C                                PSOIL+PWATER • PTOTAL                 002480 0000
C                                FOR CUT AND COVER -----               002490 0000
C                                WT/FT OF ANCHORS • WTANCH             002500 0000
C                           66   WT/FT OF UNDECKED SOLD. PILE • WTSP  002510 0000
C                           67   WT/FT OF DECKED SOLD. PILE • WTSPD   002520 0000
C                           68   NUMBER OF WELLS • WELLS               002530 0000
C     TRDATA(I,J) . TUNNEL REACH DATA  (I•REACH NUMBER)               002540 0000
C                   ITEM  J • 1  EXIT SHAFT FOR REACH • NSHAFT        002550 0000
C                            2   TUNNEL SIZE • BF                      002560 0000
C                            3   TUNNEL SHAPE • ISHAPE                 002570 0000
C                                    (0 OR BLANK•CUT AND COVER,       002580 0000
C                                1•CIRCLE, 2•HORSESHOE, 3•BASKETHANDLE 002590 0000
C                            4   MUCK TRANSPORT METHOD • MTM          002600 0000
C                                    (0 OR BLANK•CUT AND COVER,       002610 0000
C                                    1•TRUCK,2•CONVEYOR,3•RAIL,       002620 0000
C                                    4•TRUCK+CONVEYOR IN COMP. AIR)   002630 0000
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(Continued)

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C                          5   SEGMENT SEQUENCE NUMBER AT WHICH REAC 002640 0000
C                              EXCAVATION BEGINS • NRSEG1           002650 0000
C                          6   NUMBER OF SEGMENTS IN REACH • NSEGS   002660 0000
C                                - INDICATES REACH GOES FROM RT TO L 002670 0000
C                                + INDICATES REACH GOES FROM LF TO R 002680 0000
C                          7   PEAK REACH MUCK REMOVAL RATE (CY/HR)  002690 0000
C                          8   WORK HOURS PER DAY • HOURS            002710 0000
C                                  • RMLMAX OR IPRML                 002700 0000
C                          9   WORK DAYS PER WEEK • DAYS             002720 0000
C                         10   FOR ROCK OR SOFT GROUND -----         002730 0000
C                              NUMBER OF SHIELD SETUPS • SETUSH      002740 0000
C                              FOR CUT AND COVER -----               002750 0000
C                              NUMBER OF UNITS IN BOX WIDTH • NBOX   002760 0000
C                         11   FOR ROCK OR SOFT GROUND -----         002770 0000
C                              NUMBER OF MOLE SETUPS • SETUPM        002780 0000
C                              FOR CUT AND COVER -----               002790 0000
C                              TOTAL FINISHED BOX WIDTH • BFBWDT     002800 0000
C                         12   FOR ROCK OR SOFT GROUND -----         002810 0000
C                              NUMBER OF RIPPER SETUPS • SETUPR      002820 0000
C                              FOR CUT AND COVER -----               002830 0000
C                              TOTAL FINISHED BOX HEIGHT • BFBHT     002840 0000
C                         13   DOUBLE BOX DESIGN • IBOX2             002850 0000
C                                  (0 OR BLANK•NO, 1•DOUBLE BOX)     002860 0000
C                         14   FOR ROCK OR SOFT GROUND -----         002870 0000
C                              TOTAL LENGTH IN COMPRESSED AIR • DTCA 002880 0000
C                              FOR CUT AND COVER -----               002890 0000
C                              DEWATERING TIME • TIMEDW              002900 0000
C                         15   TOTAL LENGTH REQUIRING COOLING • DTC  002910 0000
C                         16   MAX LENGTH OF CUT IN WHICH BACKFILL   002920 0000
C                                  CANNOT BE PLACED • OPEN           002930 0000
C                         17   TOTAL COST OF LABOR IN REACH • RCL    002940 0000
C                         18   TOTAL COST OF EQUIP.IN REACH • RCE    002950 0000
C                         19   TOTAL COST OF MATERIAL IN REACH • RCM 002960 0000
C                         20   TOTAL COST OF REACH • RCT             002970 0000
C                         21   MAX CC EXC VOL TO DISPOSAL • VDS      002980 0000
C                         22   VOLUME OF CC BACKFILL FROM CURRENT    002990 0000
C                                  EXCAVATION • VBACEX               003000 0000
C                         23   VOLUME OF CC BACKFILL FROM PREVIOUS   003010 0000
C                                  DISPOSAL • VBACDS                 003020 0000
C                                                                    003030 0000
C   B(I,J) ...... SHAFT SEGMENT ARRAY  (I • LOCATION OF SEGMENT IN   003040 0000
C                   'B' ARRAY,  J • AS BELOW)                        003050 0000
C                 ITEM J• 1    SHAFT NUMBER • NSHAFT                 003060 0000
C                         2    SHAFT SEGMENT NUMBER • NSSEG          003070 0000
C                         3    UPPER NODAL POINT OF SEGMENT • NPT    003080 0000
C                         4    LOWER NODAL POINT OF SEGMENT • NPB    003090 0000
C                         5    ROCK STRENGTH • RS OR JRS             003100 0000
C                         6    R.Q.D. • RQD OR JRQD                  003110 0000
C                         7    EXCAVATION METHOD • MEX               003120 0000
C                                  (0 OR BLANK•NONE, 1•DRILL AND     003130 0000
C                                  BLAST, 2•MOLE(ROCK), 3•MOLE(SOIL) 003140 0000
C                                  4•HAND)                           003150 0000
C                         8    HEADING ADVANCE RATE • AR             003160 0000
C                         9    GROUNDWATER INFLOW • GI               003170 0000
C                                  (0•DRY, 1•WET)                    003180 0000
C                        10    LINING TYPE • LINING                  003190 0000
C                                  (0•UNLINED, 1•CIP CONCRETE,       003200 0000
C                                  2•SHOTCRETE, 3•PRECAST CONCRETE   003210 0000
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C                 CUT AND COVER BOX)                    003220 0000
C          11     LINING THICKNESS = TL OR LT OR TSEG   003230 0000
C          12     SUPPRESSION OF FORMWORK COSTS=NOFORM  003240 0000
C                 (0 OR BLANK=POSSIBLE COSTS,1=SUPPRESS 003250 0000
C          13     GROUNDWATER ELEVATION = ELLATR        003260 0000
C          14     WATERTIGHT LINING REQUIREMENT = LINWT 003270 0000
C                    (0 OR BLANK=NO, 1=WATERTIGHT)      003280 0000
C          15     SHAFT SEGMENT TYPE = NSSTYP           003290 0000
C                    (1=ROCK, 2=SOFT GROUND,             003300 0000
C                    3=CUT AND COVER)                    003310 0000
C          16     EFFECTIVE GRAIN SIZE = D10            003320 0000
C          17     SOIL COHESION = COHESN                003330 0000
C          18     SOIL UNIT WEIGHT = GAMMA              003340 0000
C          19     ANGLE OF INTERNAL FRICTION = PHI      003350 0000
C          20     ELEVATION OF IMPERVIOUS LAYER = ELIMP 003360 0000
C          21     DEWATERING ALLOWED = IWATER           003370 0000
C                    (0 OR BLANK=NO, 1=ALLOWED)          003380 0000
C          22     SUPPORT TYPE = ISUPPT                 003390 0000
C                                        (1=CAST IRON    003400 0000
C                    SEGMENTS, 2=CONCRETE SEGMENTS,      003410 0000
C                    3=STEEL SEGMENTS, 4=STEEL RIBS W/   003420 0000
C                    LINING, 5=OPEN CUT)                 003430 0000
C          23     SOIL PERMEABILITY = PERM              003440 0000
C          24     STABILITY NUMBER = STABNO             003450 0000
C          25     STABILIZATION METHOD = MSTAB          003460 0000
C                    (0 OR BLANK=NONE, 1=COMPRESSED      003470 0000
C                    AIR, 2=DEWATERING, 3=GROUND INJ.)   003480 0000
C          26     USE OF STABILIZATION METHOD = MUST    003490 0000
C                    (1=COSTUN SELECT, 2=COSTUN SELECT   003500 0000
C                    ONLY IF COULD NOT BE EXCAVATED,     003510 0000
C                    3=USER SELECT ONLY IF COULD NOT     003520 0000
C                    BE EXCAVATED, 4=USER SELECTS,MUST   003530 0000
C                    USE,EVEN IF MSTAB=0)                003540 0000
C          27     AIR PRESSURE = AIRPR                  003550 0000
C          28     ACCEPTABLE INPUT STABIL.METHOD= MSTAC 003560 0000
C                    (1=ACCEPTABLE,2=UNACCEPTABLE)       003570 0000
C          29     CHAR. EXC. DIMENSION = BE             003580 0000
C          30     FOR ROCK -----                        003590 0000
C                 CHAR. EXC. DIMENSION AT RQD=40 = BE40 003600 0000
C                 FOR SOFT GROUND -----                 003610 0000
C                 SOIL LOAD  = PSOIL                    003620 0000
C          31     FOR ROCK -----                        003630 0000
C                 CHAR. EXC. DIMENSION AT RQD=60 = BE60 003640 0000
C                 FOR SOFT GROUND -----                 003650 0000
C                 PSOIL+PWATER = PTOTAL                 003660 0000
C          32     CHAR. EXC. DIM. W/OB = BOB            003670 0000
C          33     CHAR. EXC. DIM. W/OB , RQD=40 = BOB40 003680 0000
C          34     CHAR. EXC. DIM. W/OB , RQD=60 = BOB60 003690 0000
C          35     SEGMENT LENTH = SSEGL                 003700 0000
C          36     HOISTING HEIGHT = HH OR SEGDEP        003710 0000
C          37     MUCK LOADING RATE IN SEGMENT = RML    003720 0000
C          38     EXCAVATED VOLUME = V                  003730 0000
C          39     ULTIMATE ADVANCE RATE = ARSULT        003740 0000
C          40     CONSTR. TIME EXC. + LINING = CTSS     003750 0000
C          41     CHAR. DEPTH OF SUPPORTS = WEB/ TPLATE 003760 0000
C          42     PUMPING FLOW, ONE DEEP WELL = FLOWL   003770 0000
C          43     WATER LOAD  = PWATER                  003780 0000
C                                                       003790 0000
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C     SHAFT(I,J) .. SHAFT INFORMATION   (I=SHAFT NUMBER)                 003800 0000
C                   ITEM  J = 1  LOCATION IN THE 'B' ARRAY IN WHICH TH   003810 0000
C                                FIRST SHAFT SEGMENT OF SHAFT I IS       003820 0000
C                                STORED = NSSEG1                         003830 0000
C                             2  NODAL POINT AT TOP OF SHAFT = NPTS      003840 0000
C                             3  NODAL POINT AT BOTTOM OF SHAFT = NPBS   003850 0000
C                             4  NUMBER OF SEGMENTS IN THIS SHAFT        003860 0000
C                                  = NSEGS                               003870 0000
C                             5  DISTANCE TO THE DISPOSAL SITE = DDS     003880 0000
C                             6  COST OF DISPOSAL SITE = CDS OR ICDS     003890 0000
C                             7  SHAFT SIZE = BF                         003900 0000
C                             8  DEPTH OF SHAFT                          003910 0000
C                             9  TOTAL VOLUME OF EXCAVATED MATERIAL      003920 0000
C                             9  TOTAL VOLUME OF EXCAVATED MATERIAL      003920 0000
C                                    TO BE TAKEN OUT THRU THIS SHAFT     003930 0000
C                            10  PEAK MUCK REMOVAL RATE SHAFT (CY/HR)    003940 0000
C                                  = RMLMAX OR IPRML                     003950 0000
C                            11  AVERAGE SUMMER ABOVE GROUND AIR         003960 0000
C                                TEMPERATURE AT TOP OF SHAFT = AIRTEM    003970 0000
C                                    OR IARTEM                           003980 0000
C                            12  COST FACTOR FOR LABOR      = CFL        003990 0000
C                            13  COST FACTOR FOR EQUIPMENT = CFE         004000 0000
C                            14  COST FACTOR FOR MATERIALS = CFM         004010 0000
C                            15  REGIONAL COST FACTOR       = RCF        004020 0000
C                            16  SHAFT SHAPE = ISHAPS                    004030 0000
C                                    (0 OR BLANK=DUMMY, 1=CIRCULAR,      004040 0000
C                                    2=SQUARE)                           004050 0000
C                            17  WORK HOURS PER DAY = HOURS              004060 0000
C                            18  WORK DAYS PER WEEK = DAYS               004070 0000
C                            19  TOTAL COST OF LABOR IN SHAFT = SCL      004080 0000
C                            20  TOTAL COST OF EQUIP IN SHAFT = SCE      004090 0000
C                            21  TOTAL COST OF MATERIAL IN SHAFT = SCM   004100 0000
C                            22  TOTAL COST OF SHAFT = SCT               004110 0000
C                            23  PORTALS = NPORT                         004120 0000
C                                    (0=TRUE SHAFT,1=PORTAL)             004130 0000
C     LIST(I) ..... ARRAY OF PRINTOUT OPTIONS                            004140 0000
C                   ITEM  I = 1  NODAL POINT ELEVATIONS                  004150 0000
C                             2  TUNNEL INPUT DATA                       004160 0000
C                             3  SHAFT INPUT DATA                        004170 0000
C                             4  CALCULATED TUNNEL DATA                  004180 0000
C                             5  CALCULATED SHAFT DATA                   004190 0000
C                             6  TUNNEL SEGMENT AND REACH COSTS          004200 0000
C                             7  SHAFT SEGMENT AND SHAFT COSTS           004210 0000
C                             8  TUNNEL REACH COST SUMMARY               004220 0000
C                             9  SHAFT COST SUMMARY                      004230 0000
C                         10-40  UNUSED AT PRESENT                       004240 0000
C                IF THE VALUE OF LIST(I) IS ZERO OR BLANK, LISTING OF    004250 0000
C                ITEM WILL OCCUR. IF VALUE IS ONE,LISTING WILL BE        004260 0000
C                SUPPRESSED. ITEM NUMBER IS SAME AS DATA CARD COLUMN     004270 0000
C                NUMBER.                                                 004280 0000
C                                                                        004290 0000
C                                                                        004300 0000
C                                                                        004310 0000
C     ------------------------------------------------------------------ 004320 0000
C                                                                        004330 0000
C     ************   INPUT TUNNEL SYSTEM LOCATIONS AND CHARACTERISTICS  * 004340 0000
C                                                                        004350 0000
C     ------------------------------------------------------------------ 004360 0000
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C     ------------------------------------------------------------------
      COMMON /BASIC/  NSS,NTS
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
      COMMON /F/ IERROR,ISTOP
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
     1 TRDATA(NTRMAX,23)
C     ------------------------------------------------------------------
C
C
      ISTOP=0
C     ******************************************************************
C
      IPR=0
C     READ NODAL POINTS AND STORE IN CORE  ******************
C
C     INITIALIZE NODAL POINT ARRAY
      DO 15 I=1,NPMAX
   15 CNP(I,2)=-10.E30
C
C     N=NODAL POINT NUMBER,  Y=NODAL POINT ELEVATION
   20 READ(LI,1000) N,Y
C     CHECK FOR MISSING SEPARATOR CARD
      IF (Y.LT.50000.) GO TO 21
      ISTOP = 1
      WRITE (LO,1500)
      GO TO 425
   21 CONTINUE
C     CHECK FOR END OF NODAL POINT COORDINATES
      IF(N.EQ.9999) GO TO 30
      IF(N.GT.NPMAX.OR.N.LE.0) GO TO 25
C
C     CHECK FOR PREVIOUS DEFINITION OF THIS NODAL POINT
      IF(CNP(N,2).GT.-10.E29) ISTOP=1
      IF(CNP(N,2).GT.-10.E29) WRITE (LO,1013) N
      CNP(N,2)=Y
      GO TO 20
   25 WRITE(LO,1001) N,NPMAX
      ISTOP=1
      GO TO 20
C     END OF NODAL POINT INPUT
   30 CONTINUE
C
C     ******************************************************************
C
C     READ TUNNEL SEGMENT INFORMATION AND STORE  ***********
C
C     INITIALIZE TUNNEL SEGMENT ARRAY
      DO 40 I=1,NTSMAX
   40 A(I,1)=-10.E30
C     INITIALIZE THE REACH ARRAY
      DO 41 I=1,NTRMAX
   41 TRDATA(I,1)=-10.E30
C
C     I=SEGMENT SEQUENCE NUMBER
      I=0
   50 I=I+1
C     ------------------------------------------------------------------
C
```

(Continued)

```
                                  004940 0000
C     CHECK FOR MAX NUMBER OF SEGMENT CARDS                                004950 0000
      IF(I.LE.NTSMAX) GO TO 52                                             004960 0000
C     ------------------------------------------------------------------   004970 0000
C     CHECK FOR END OF TUNNEL SEGMENT DATA. NDUM=DUMMY SEGMENT NUMBER      004980 0000
   51 READ(LI,1020) NDUM                                                   004990 0000
      IF(NDUM.EQ.9999) GO TO 75                                            005000 0000
      WRITE(LO,1016)  NTSMAX                                               005010 0000
      ISTOP=1                                                              005020 0000
      GO TO 51                                                             005030 0000
C     ------------------------------------------------------------------   005040 0000
C                                                                          005050 0000
   52 CONTINUE                                                             005060 0000
C     READ SEGMENT DATA FROM CARD                                          005070 0000
      READ(LI,1005) (A(I,J),J=1,3),A(I,45) ,(A(I,J),J=4,16)                005080 0000
      NTSEG=A(I,1)                                                         005090 0000
      NREACH=A(I,4)                                                        005100 0000
      NTSTYP=A(I,16)                                                       005110 0000
C     ------------------------------------------------------------------   005120 0000
C     CHECK FOR  LAST TUNNEL CARD                                          005130 0000
      IF(NTSEG.EQ.9999) GO TO 75                                           005140 0000
C     CHECK FOR MISSING SEPARATOR CARD                                     005150 0000
      IF(NTSTYP.NE.0) GO TO 53                                             005160 0000
      ISTOP = 1                                                            005170 0000
      WRITE(LO,1501)                                                       005180 0000
   53 CONTINUE                                                             005190 0000
C     ------------------------------------------------------------------   005200 0000
C     CHECK FOR PROPER TUNNEL TYPE CODE                                    005210 0000
      IF(NTSTYP.GE.1.AND.NTSTYP.LE.3) GO TO 530                            005220 0000
      ISTOP=1                                                              005230 0000
      WRITE(LO,2000) NTSEG,NREACH                                          005240 0000
      GO TO 425                                                            005250 0000
  530 CONTINUE                                                             005260 0000
C     ------------------------------------------------------------------   005270 0000
C     READ SECOND SEGMENT DATA CARD IF NOT ROCK TUNNEL                     005280 0000
      IF(NTSTYP.GT.1) READ(LI,1006) (A(I,J),J=17,33)                       005290 0000
C     ------------------------------------------------------------------   005300 0000
C     CHECK FOR PREVIOUS USE OF REACH NUMBER                               005310 0000
      IF(I.EQ.1) GO TO 535                                                 005320 0000
      IF(NREACH.EQ.IPR) GO TO 54                                           005330 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 535                            005340 0000
      WRITE(LO,1022) NTSEG,NREACH                                          005350 0000
      ISTOP=1                                                              005360 0000
  535 TRDATA(NREACH,1)=0.                                                  005370 0000
   54 CONTINUE                                                             005380 0000
C     ------------------------------------------------------------------   005390 0000
C     CHECK THAT TUNNEL SEGMENT CARDS HAVE BEEN PROPERLY ARRANGED          005400 0000
      IF(I.EQ.1) GO TO 57                                                  005410 0000
   56 IF(A(I,2).EQ.A(I-1,3)) GO TO 57                                      005420 0000
      WRITE(LO,1015) NTSEG,NREACH                                          005430 0000
      ISTOP=1                                                              005440 0000
   57 CONTINUE                                                             005450 0000
C     ------------------------------------------------------------------   005460 0000
C     CHECK THAT ALL TUNNEL NODAL POINTS HAVE BEEN INPUT                   005470 0000
      NPL=A(I,2)                                                           005480 0000
      NPR=A(I,3)                                                           005490 0000
      ELNPL=CNP(NPL,2)                                                     005500 0000
      ELNPR=CNP(NPR,2)                                                     005510 0000
```

(Continued)

```
      ELAVG=(ELNPL+ELNPR)/2.                                            005520 0000
C     BYPASS CHECK FOR NOTAL INPUT
      GO TO 58
      IF(ELNPL.GT.-10.E29.AND.ELNPR.GT.-10.E29) GO TO 58                005530 0000
      WRITE(LO,1031) NTSEG,NREACH                                       005540 0000
      ISTOP=1                                                           005550 0000
   58 CONTINUE                                                          005560 0000
C     ------------------------------------------------------------------005570 0000
C     CHECK FOR PROPER EXCAVATION METHODS IN TUNNEL SEGMENTS            005580 0000
      MEX=A(I,7)                                                        005590 0000
      IF(MEX.GE.1.AND.MEX.LE.7) GO TO 65                                005600 0000
      ISTOP=1                                                           005610 0000
      WRITE(LO,1030)NTSEG,NREACH                                        005620 0000
   65 CONTINUE                                                          005630 0000
C     ------------------------------------------------------------------005640 0000
C     CHECK FOR PROPER EXCAVATION METHOD FOR TUNNEL TYPE SPECIFIED      005650 0000
      IF(NTSTYP.EQ.1.AND.MEX.GT.2) GO TO 650                            005660 0000
      IF(NTSTYP.EQ.2.AND.MEX.LT.3.OR.NTSTYP.EQ.2.AND.MEX.GT.5) GO TO 650 005670 0000
      IF(NTSTYP.EQ.3.AND.MEX.LT.6) GO TO 650                            005680 0000
      GO TO 655                                                         005690 0000
  650 ISTOP=1                                                           005700 0000
      WRITE(LO,2005) NTSEG,NREACH                                       005710 0000
  655 CONTINUE                                                          005720 0000
C     ------------------------------------------------------------------005730 0000
C     CHECK FOR CONTRADICTION OF SPECIFYING A THICKNESS FOR NO LINING   005740 0000
      LINING=A(I,10)                                                    005750 0000
      IF(NTSTYP.NE.1.OR.LINING.NE.0) GO TO 67                           005760 0000
      TL=A(I,11)                                                        005770 0000
      IF(TL.LE.0.001) GO TO 67                                          005780 0000
      WRITE(LO,1045) NTSEG,NREACH                                       005790 0000
      ISTOP=1                                                           005800 0000
   67 CONTINUE                                                          005810 0000
C     ------------------------------------------------------------------005820 0000
C     CHECK FOR PROPER LINING TYPE CODE                                 005830 0000
C     BYPASS CHECK FOR PROPER LINING CODE
      GO TO 70
      IF(LINING.GE.0.AND.LINING.LE.3) GO TO 68                          005840 0000
      WRITE(LO,1043) NTSEG,NREACH                                       005850 0000
      ISTOP=1                                                           005860 0000
   68 CONTINUE                                                          005870 0000
C     ------------------------------------------------------------------005880 0000
C     CHECK FOR PROPER LINING CODE FOR TUNNEL TYPE SPECIFIED            005890 0000
      IF(NTSTYP.LT.3.AND.LINING.NE.3.OR.NTSTYP.EQ.3.AND.LINING.EQ.1.OR. 005900 0000
     1NTSTYP.EQ.3.AND.LINING.EQ.3) GO TO 70                             005910 0000
      ISTOP=1                                                           005920 0000
      WRITE(LO,2010) NTSEG,NREACH                                       005930 0000
C     ------------------------------------------------------------------005940 0000
C     CHECK FOR ADVANCE RATE NOT SPECIFIED                              005950 0000
   70 AR=A(I,8)                                                         005960 0000
      IF(AR.EQ.0.0) GO TO 71                                            005970 0000
C     ------------------------------------------------------------------005980 0000
C     CHECK FOR ADVANCE RATE LESS THAN 0 FT/DAY                         005990 0000
      IF(AR.GT.0.0) GO TO 71                                            006000 0000
      ISTOP=1                                                           006010 0000
      WRITE(LO,1065) NTSEG,NREACH                                       006020 0000
C     ------------------------------------------------------------------006030 0000
C     CHECK FOR ROCK STRENGTH GREATER THAN 500 PSI                      006040 0000
   71 RS=A(I,5)                                                         006050 0000
```

(Continued)

```
      IF(RS.LT.500..AND.NTSTYP.EQ.1) WRITE(LO,1060) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER WATERTIGHT CODE
      LINWT=A(I,15)
      IF(LINWT.EQ.0.OR.LINWT.EQ.1) GO TO 710
      ISTOP=1
      WRITE(LO,2015) NTSEG,NREACH
  710 CONTINUE
C     ------------------------------------------------------------------
C     ALL CUT AND COVER BOX SEGMENTS ARE DESIGNED AS WATERTIGHT -
C     INPUT IGNORED
      IF(NTSTYP.EQ.3.AND.LINWT.EQ.0) WRITE(LO,2017) NTSEG,NREACH
C     ------------------------------------------------------------------
C     A LINING OR SUPPORT MUST BE SPECIFIED WHEN WATERTIGHTNESS REQUIRED
      ISUPPT=A(I,26)
      IF(LINWT.EQ.0.OR.LINING.GT.0) GO TO 711
      IF(NTSTYP.GT.1.AND.ISUPPT.LE.3) GO TO 711
      ISTOP=1
      WRITE(LO,2020) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF GROUNDWATER ELEVATION NOT INPUT AND WATERTIGHT REQUIRED
  711 ELWATR=A(I,14)
      IF(LINWT.EQ.1.AND.ELWATR.EQ.0.) WRITE(LO,2025) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF TUNNEL TYPE NOT ROCK AND GROUNDWATER ELEV. NOT SPECIFIED
      IF(NTSTYP.GT.1.AND.ELWATR.EQ.0) WRITE(LO,2025) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER TUNNEL CODE IF RQD IS LESS THAN 25.
      RQD=A(I,6)
      IF(NTSTYP.GT.1.OR.RQD.GE.25.)GO TO 712
      ISTOP=1
      WRITE(LO,2030) NTSEG,NREACH
  712 CONTINUE
C     ------------------------------------------------------------------
C     IS TUNNEL IN SOFT GROUND AND RQD GREATER THAN 25.
      IF(NTSTYP.EQ.2.AND.RQD.GT.25.) WRITE(LO,2035) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR RQD BETWEEN 0 AND 100.
      IF(RQD.GE.0.0.AND.RQD.LE.100.) GO TO 713
      WRITE(LO,1062) NTSEG,NREACH
      ISTOP=1
C     ------------------------------------------------------------------
C     CHECK REMAINING DATA IF TUNNEL IS NOT IN ROCK
  713 IF(NTSTYP.EQ.1) GO TO 74
C     ------------------------------------------------------------------
C     CHECK THAT TUNNEL SURFACE NODAL POINTS HAVE BEEN PROPERLY ARRANGED
      IF(I.EQ.1) GO TO 7130
C     CHECK FOR PREVIOUS SEGMENT IN ROCK
      NSTYPE=A(I-1,16)
      IF(NSTYPE.EQ.1) GO TO 7130
      NPLS=A(I,17)
      NPRS=A(I-1,18)
      IF(NPLS.EQ.NPRS) GO TO 7130
      ISTOP=1
      WRITE(LO,2040) NTSEG,NREACH
C     ------------------------------------------------------------------
 7130 NPLS=A(I,17)
      NPRS=A(I,18)
```

(Continued)

AD-A107 890 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
TUNNEL COST-ESTIMATING METHODS.(U)
OCT 81 R D BENNETT
UNCLASSIFIED WES/TR/GL-81-10 NL

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      ELNPLS=CNP(NPLS,3)
      ELNPRS=CNP(NPRS,3)
C     CHECK THAT ALL TUNNEL SURFACE NODAL POINTS HAVE BEEN INPUT
      IF(ELNPLS.GT.-10.E29.AND.ELNPRS.GT.-10.E29) GO TO 714
      ISTOP=1
      WRITE(LO,2045) NTSEG,NREACH
  714 CONTINUE
C     ------------------------------------------------------------------
C     CHECK THAT SURFACE NODAL POINT ELEVATIONS ARE ABOVE TUNNEL ELEV.
      IF(ELNPLS.GE.ELNPL.AND.ELNPRS.GE.ELNPR) GO TO 715
      ISTOP=1
      WRITE(LO,2050) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF EFFECTIVE GRAIN SIZE IS INPUT
  715 D10=A(I,19)
      IF(D10.GT.0) GO TO 716
      ISTOP=1
      WRITE(LO,2055) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK THAT PHI AND/OR COHESION ARE SPECIFIED
  716 PHI=A(I,20)
      COHESN=A(I,21)
      IF(PHI.GT.0.OR.COHESN.GT.0) GO TO 7160
      ISTOP=1
      WRITE(LO,2060) NTSEG,NREACH
 7160 CONTINUE
C     ------------------------------------------------------------------
C     CHECK FOR POSSIBLE ERROR IN PERMEABILITY INPUT
      PERM=A(I,25)
      IF(PERM.GT.10) WRITE(LO,2061) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF PHI GREATER THAN 45 - WARNING, OR GREATER THAN 100 -ERROR
      IF(PHI.GT.45.) WRITE(LO,2062) NTSEG,NREACH
      IF(PHI.LT.100.) GO TO 7165
      ISTOP=1
      WRITE(LO,2063) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF GAMMA GREATER THAN 200
 7165 GAMMA=A(I,22)
      IF(GAMMA.LE.200.) GO TO 717
      ISTOP=1
      WRITE(LO,2064) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER DEWATERING CODE
  717 IWATER=A(I,23)
      IF(IWATER.EQ.0.OR.IWATER.EQ.1) GO TO 7170
      ISTOP=1
      WRITE(LO,2065) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT
 7170 IF(NTSTYP.EQ.3) GO TO 718
      MSTAB=A(I,31)
      MUST=A(I,32)
      IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 7185
      IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.
     110.E-10.AND.PERM.LE.0.0006) GO TO 7185
C     ------------------------------------------------------------------
C     CHECK IF DEWATERING ALLOWED AND IMPERVIOUS LAYER NOT SPECIFIED
```

(Continued)

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C     OR IMPERVIOUS LAYER NOT SPECIFIED FOR CUT AND COVER                 007220 0000
  718 ELIMP=A(I,24)                                                       007230 0000
      IF(ELIMP.EQ.0.0) WRITE(LO,2070) NTSEG,NREACH                        007240 0000
C     ------------------------------------------------------------------ 007250 0000
C     CHECK IF IMPERVIOUS LAYER ELEVATION IS BELOW SURFACE ELEVATION      007260 0000
      ELSURF=(ELNPLS+ELNPRS)/2.                                           007270 0000
      IF(ELIMP.LE.ELSURF) GO TO 7180                                      007280 0000
      ISTOP=1                                                             007290 0000
      WRITE(LO,2072) NTSEG,NREACH                                         007300 0000
 7180 CONTINUE                                                            007310 0000
C     ------------------------------------------------------------------ 007320 0000
C     CHECK IF OPEN CUT IS ENTIRELY IN ROCK                               007330 0000
      ELROCK=A(I,27)                                                      007340 0000
      IF(NTSTYP.EQ.3.AND.ELROCK.EQ.ELSURF) GO TO 7185                     007350 0000
C     ------------------------------------------------------------------ 007360 0000
C     CHECK IF IMPERVIOUS LAYER IS AT THE SURFACE AND GRAIN SIZE INPUT    007370 0000
C     DOES NOT INDICATE A CLAY.                                           007380 0000
      IF(ELIMP.LT.ELSURF.OR.D10.LE.0.005) GO TO 7185                      007390 0000
      ISTOP=1                                                             007400 0000
      WRITE(LO,2073) NTSEG,NREACH                                         007410 0000
 7185 CONTINUE                                                            007420 0000
C     ------------------------------------------------------------------ 007430 0000
      IF(MEX.EQ.7) GO TO 7205                                             007440 0000
C     CHECK FOR PROPER SUPPORT CODE                                       007450 0000
      IF(ISUPPT.GE.1.AND.ISUPPT.LE.6) GO TO 719                           007460 0000
      ISTOP=1                                                             007470 0000
      WRITE(LO,2075) NTSEG,NREACH                                         007480 0000
  719 CONTINUE                                                            007490 0000
C     ------------------------------------------------------------------ 007500 0000
C     CHECK FOR PROPER SUPPORT CODE FOR TUNNEL TYPE SPECIFIED             007510 0000
      IF(NTSTYP.EQ.2.AND.ISUPPT.LE.4.OR.NTSTYP.EQ.3.AND.ISUPPT.GT.4)      007520 0000
     1GO TO 720                                                           007530 0000
      ISTOP=1                                                             007540 0000
      WRITE(LO,2080) NTSEG,NREACH                                         007550 0000
  720 CONTINUE                                                            007560 0000
C     ------------------------------------------------------------------ 007570 0000
C     CHECK FOR PROPER LINING CODE FOR SUPPORT TYPE SPECIFIED             007580 0000
      IF(ISUPPT.LE.3.AND.LINING.EQ.0) GO TO 7205                          007590 0000
      IF(ISUPPT.GT.3.AND.LINING.EQ.0) GO TO 7200                          007600 0000
      IF(ISUPPT.EQ.4.AND.LINING.NE.3) GO TO 7205                          007610 0000
      IF(ISUPPT.GT.4.AND.LINING.NE.2) GO TO 7205                          007620 0000
 7200 ISTOP=1                                                             007630 0000
      WRITE(LO,2085) NTSEG,NREACH                                         007640 0000
C     ------------------------------------------------------------------ 007650 0000
C     CHECK IF SOFT GROUND TUNNEL                                         007660 0000
 7205 IF(NTSTYP.EQ.2) GO TO 725                                           007670 0000
C     ------------------------------------------------------------------ 007680 0000
C     CHECK FOR ROCK ELEV. IF TUNNEL IN CUT AND COVER                     007690 0000
      IF(ELROCK.EQ.0.0) WRITE(LO,2090) NTSEG,NREACH                       007700 0000
C     ------------------------------------------------------------------ 007710 0000
C     CHECK IF ROCK ELEVATION IS BELOW GROUND SURFACE ELEVATION           007720 0000
      IF(ELROCK.LE.ELSURF) GO TO 7210                                     007730 0000
      ISTOP=1                                                             007740 0000
      WRITE(LO,2092) NTSEG,NREACH                                         007750 0000
 7210 CONTINUE                                                            007760 0000
C     ------------------------------------------------------------------ 007770 0000
C     CHECK IF BOX DEPTH IS GREATER THAN 100 FEET                         007780 0000
      DTUN=ELSURF-ELAVG                                                   007790 0000
```

(Continued)

```
      IF(DTUN.GT.100.) WRITE(LO,2094) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER BRACING CODE
      IBRACE=A(I,28)
      IF(IBRACE.GE.0.AND.IBRACE.LE.3) GO TO 723
      ISTOP=1
      WRITE(LO,2095) NTSEG,NREACH
  723 CONTINUE
C     ------------------------------------------------------------------
C     CHECK IF CUT AND COVER (VERTICAL) AND BRACING CODE NOT SPECIFIED
      DROCK=ELSURF-ELROCK
      IF(IBRACE.GT.0.OR.MEX.NE.6.OR.DROCK.LT.0.1) GO TO 724
      ISTOP=1
      WRITE(LO,2100) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER DECKING CODE
  724 IDECK=A(I,29)
      IF(IDECK.EQ.0.OR.IDECK.EQ.1) GO TO 74
      ISTOP=1
      WRITE(LO,2105) NTSEG,NREACH
      GO TO 74
C     ------------------------------------------------------------------
C     CHECK FOR HIGH STABILTY NUMBER - MAY RESULT THAT JOB UNEXCAVATABLE
  725 STABNO=A(I,30)
      IF(STABNO.LE.9.AND.PHI.LT.29.OR.STABNO.LE.7.AND.PHI.GE.29)
     1 GO TO 7250
      ISTOP=1
      WRITE(LO,2115) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER STABILIZATION METHOD CODE
 7250 MSTAB=A(I,31)
      IF(MSTAB.GE.0.AND.MSTAB.LE.3) GO TO 726
      ISTOP=1
      WRITE(LO,2120) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR PROPER USE CODE FOR STABILIZATION METHOD
  726 MUST=A(I,32)
      IF(MUST.GE.1.AND.MUST.LE.4) GO TO 727
      ISTOP=1
      WRITE(LO,2125) NTSEG,NREACH
C     ------------------------------------------------------------------
C     CHECK FOR AIR PRESSURE INPUT IF STABILITY NUMBER INPUT AND
C     AIR PRESSURE STABILIZATION INPUT
  727 AIRPR=A(I,33)
      IF(STABNO.GT.0.0.AND.MSTAB.EQ.1.AND.AIRPR.EQ.0.0) GO TO 7270
      GO TO 728
 7270 ISTOP=1
      WRITE(LO,2130) NTSEG,NREACH
  728 CONTINUE
C     ------------------------------------------------------------------
C     CHECK FOR USE CODE =4 WHEN STABILITY NUMBER IS SPECIFIED
      IF(STABNO.EQ.0.0.OR.MUST.EQ.4) GO TO 729
      ISTOP=1
      WRITE(LO,2135) NTSEG,NREACH
  729 CONTINUE
C     ------------------------------------------------------------------
C     CHECK IF STABILIZATION METHOD NOT COMPRESSED AIR BUT AIRPR GT 0
      IF(MSTAB.EQ.1.OR.AIRPR.EQ.0.) GO TO 7290
      ISTOP=1
```

(Continued)

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      WRITE(LO,2137) NTSEG,NREACH                                       008390 0000
 7290 CONTINUE                                                          008400 0000
C     ------------------------------------------------------------------ 008410 0000
C     CHECK IF STABILIZATION METHOD AGREES WITH USE CODE                 008420 0000
      IF(MSTAB.GE.0.AND.MUST.EQ.4.OR.MSTAB.GT.0.AND.MUST.EQ.3.OR.        008430 0000
     1MSTAB.EQ.0.AND.MUST.LT.3) GO TO 730                                008440 0000
      ISTOP=1                                                            008450 0000
      WRITE(LO,2140) NTSEG,NREACH                                        008460 0000
  730 CONTINUE                                                           008470 0000
C     ------------------------------------------------------------------ 008480 0000
C     CHECK IF STABILIZATION METHOD IS INPUT                             008490 0000
      IF(MSTAB.EQ.0) GO TO 74                                            008500 0000
C     ------------------------------------------------------------------ 008510 0000
C     CHECK IF STABILIZATION METHOD IS ACCEPTABLE                        008520 0000
      GO TO (731,732,733), MSTAB                                         008530 0000
C     ------------------------------------------------------------------ 008540 0000
C     AIR PRESSURE -- CHECK IF SOIL IS A GRAVEL                          008550 0000
  731 IF(PERM.LT.10.E-10.AND.D10.GT.2.) GO TO 734                        008560 0000
      IF(PERM.GT.0.4) GO TO 734                                          008570 0000
C     CHECK IF SOIL IS CLAY                                              008580 0000
      IF(D10.LE.0.005) GO TO 737                                         008590 0000
C     CHECK IF TUNNEL ABOVE GROUND WATER TABLE                           008600 0000
      IF(ELWATR.LT.ELAVG) GO TO 737                                      008610 0000
C     CHECK IF WATER HEAD LESS THAN 115 FEET                             008620 0000
      IF(ELWATR-ELAVG.LE.115.) GO TO 737                                 008630 0000
      GO TO 734                                                          008640 0000
C     ------------------------------------------------------------------ 008650 0000
C     DEWATERING -- CHECK IF DEWATERING IS ALLOWED                       008660 0000
  732 IF(IWATER.EQ.0) GO TO 734                                          008670 0000
      IF(D10.LE.0.005) GO TO 734                                         008680 0000
C     CHECK IF TUNNEL IS ABOVE GROUND WATER TABLE                        008690 0000
      IF(ELWATR.LT.ELAVG) GO TO 734                                      008700 0000
C     CHECK IF SOIL IS FINE SAND OR COARSER OR IS REASONABLY PERMEABLE   008710 0000
      IF(PERM.LT.10.E-10.AND.D10.GT.0.08) GO TO 737                      008720 0000
      IF(PERM.GT.0.0006) GO TO 737                                       008730 0000
      GO TO 734                                                          008740 0000
C     ------------------------------------------------------------------ 008750 0000
C     GROUND INJECTIONS -- CHECK IF SOIL IS NOT CLAY                     008760 0000
  733 IF(D10.GT.0.005) GO TO 737                                         008770 0000
C     ------------------------------------------------------------------ 008780 0000
C     STABILIZATION METHOD IS NOT ACCEPTABLE                             008790 0000
  734 MSTAC=2                                                            008800 0000
C     CHECK IF USE CODE EQUALS 4                                         008810 0000
      IF(MUST.EQ.4) GO TO 735                                            008820 0000
      WRITE(LO,2145) NTSEG,NREACH                                        008830 0000
      GO TO 738                                                          008840 0000
  735 ISTOP=1                                                            008850 0000
      WRITE(LO,2147) NTSEG,NREACH                                        008860 0000
      GO TO 738                                                          008870 0000
C     ------------------------------------------------------------------ 008880 0000
C     STABILIZATION METHOD IS ACCEPTABLE                                 008890 0000
  737 MSTAC=1                                                            008900 0000
  738 A(I,34)=MSTAC                                                      008910 0000
   74 IPR=NREACH                                                         008920 0000
C     ------------------------------------------------------------------ 008930 0000
      GO TO 50                                                           008940 0000
C     END OF TUNNEL SEGMENT DATA                                         008950 0000
   75 CONTINUE                                                           008960 0000
```

(Continued)

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C                                                                       008970 0000
C     ****************************************************************** 008980 0000
      NTS=I-1                                                           008990 0000
C     ****************************************************************** 009000 0000
C                                                                       009010 0000
C     READ REACH DATA FOR TUNNELS                                       009020 0000
C                                                                       009030 0000
C     INITIALIZE REACH ARRAY                                            009040 0000
      DO 80 I=1,NTRMAX                                                  009050 0000
   80 TRDATA(I,1)=-10.E30                                               009060 0000
C                                                                       009070 0000
C     ---------------------------------------------------------------- 009080 0000
C     READ REACH DATA FROM CARD                                         009090 0000
   81 READ (LI,1020) NREACH,NSHAFT,BFT,ISHAPE,MTM,HOURS,DAYS,NBOX,      009100 0000
     1BFBWDT,BFBHT,IBOX2,ISEPCK                                         009110 0000
      IF(NREACH.EQ.9999) GO TO 86                                       009120 0000
C     CHECK FOR MISSING SEPARATOR CARD                                  009130 0000
      IF(ISEPCK.EQ.0) GO TO 82                                          009140 0000
      ISTOP = 1                                                         009150 0000
      WRITE (LO,1502)                                                   009160 0000
      GO TO 425                                                         009170 0000
   82 CONTINUE                                                          009180 0000
      IF(NREACH.LE.NTRMAX.AND.NREACH.GT.0) GO TO 84                     009190 0000
      WRITE(LO,1021) NREACH,NTRMAX                                      009200 0000
      ISTOP=1                                                           009210 0000
      GO TO 81                                                          009220 0000
   84 CONTINUE                                                          009230 0000
C     ---------------------------------------------------------------- 009240 0000
C     CHECK FOR FINISHED DIMENSION BETWEEN 10 AND 40 FEET               009250 0000
      IF(ISHAPE.GT.0.AND.BFT.LT.10..OR.ISHAPE.GT.0.AND.BFT.GT.40.)      009260 0000
     1WRITE(LO,1064) NREACH                                             009270 0000
C     ---------------------------------------------------------------- 009280 0000
C     CHECK IF TUNNEL SIZE INPUT AGREES WITH SHAPE CODE                 009290 0000
      IF(BFT.EQ.0.AND.ISHAPE.EQ.0.OR.BFT.GT.0.AND.ISHAPE.GT.0) GO TO 840 009300 0000
      ISTOP=1                                                           009310 0000
      IF(ISHAPE.GT.0) WRITE(LO,2150) NREACH                             009320 0000
      IF(ISHAPE.EQ.0) WRITE(LO,2151) NREACH                             009330 0000
  840 CONTINUE                                                          009340 0000
C     ---------------------------------------------------------------- 009350 0000
C     CHECK FOR PREVIOUS USE OF REACH NUMBER                            009360 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 85                          009370 0000
      WRITE(LO,1026) NREACH                                             009380 0000
      ISTOP=1                                                           009390 0000
   85 CONTINUE                                                          009400 0000
C     ---------------------------------------------------------------- 009410 0000
C     CHECK FOR PROPER MUCK TRANSPORT METHOD CODE                       009420 0000
      IF(MTM.GE.0.AND.MTM.LE.4) GO TO 850                               009430 0000
      WRITE(LO,1041) NREACH                                             009440 0000
      ISTOP=1                                                           009450 0000
  850 CONTINUE                                                          009460 0000
C     ---------------------------------------------------------------- 009470 0000
C     CHECK FOR PROPER TUNNEL SHAPE CODE                                009480 0000
      IF(ISHAPE.GE.0.AND.ISHAPE.LE.3) GO TO 851                         009490 0000
      WRITE(LO,1042) NREACH                                             009500 0000
      ISTOP=1                                                           009510 0000
  851 CONTINUE                                                          009520 0000
C     ---------------------------------------------------------------- 009530 0000
C     CHECK IF SHAPE CODE AGREES WITH MUCK TRANSPORT METHOD             009540 0000
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      IF(ISHAPE.GT.0.AND.MTM.GT.0.OR.ISHAPE.EQ.0.AND.MTM.EQ.0) GO TO 852 009550 0000
      ISTOP=1                                                            009560 0000
      IF(ISHAPE.EQ.0) WRITE(LO,2152) NREACH                              009570 0000
      IF(ISHAPE.GT.0) WRITE(LO,2153) NREACH                              009580 0000
  852 CONTINUE                                                           009590 0000
C     ------------------------------------------------------------------ 009600 0000
C     CHECK IF WORK HOURS PER DAY IN PROPER RANGE                        009610 0000
      IF(HOURS.GE.0..AND.HOURS.LE.24.) GO TO 853                         009620 0000
      ISTOP=1                                                            009630 0000
      WRITE(LO,2155) NREACH                                              009640 0000
  853 CONTINUE                                                           009650 0000
C     ------------------------------------------------------------------ 009660 0000
C     CHECK IF WORK DAYS PER WEEK IN PROPER RANGE                        009670 0000
      IF(DAYS.GE.4..AND.DAYS.LE.7..OR.DAYS.EQ.0.) GO TO 854              009680 0000
      ISTOP=1                                                            009690 0000
      WRITE(LO,2160) NREACH                                              009700 0000
  854 CONTINUE                                                           009710 0000
C     IS THIS AN UNDERGROUND HEADING RATHER THAN CUT AND COVER            009730 0000
      IF(ISHAPE.GT.0) GO TO 858                                          009740 0000
C     ------------------------------------------------------------------ 009750 0000
C     CHECK FOR INPUT VALUES FOR BOX WIDTH AND HEIGHT                    009760 0000
      IF(BFBWDT.GT.0.0.AND.BFBHT.GT.0.0) GO TO 855                       009770 0000
      ISTOP=1                                                            009780 0000
      WRITE(LO,2165) NREACH                                              009790 0000
  855 CONTINUE                                                           009800 0000
C     ------------------------------------------------------------------ 009810 0000
C     CHECK IF TOTAL CLEAR BOX WIDTH EXCEEDS 40 FEET                     009820 0000
      IF(BFBWDT.GT.40.) WRITE(LO,2170) NREACH                            009830 0000
C     ------------------------------------------------------------------ 009840 0000
C     CHECK TYPE OF BOX SECTION                                          009850 0000
      IF(IBOX2.EQ.1) GO TO 857                                           009860 0000
C     ------------------------------------------------------------------ 009870 0000
C     SINGLE LEVEL BOX -- CHECK IF NUMBER OF BOX UNITS IS SPECIFIED      009880 0000
      IF(NBOX.GT.0) GO TO 856                                            009890 0000
      ISTOP=1                                                            009900 0000
      WRITE(LO,2175) NREACH                                              009910 0000
  856 CONTINUE                                                           009920 0000
C     ------------------------------------------------------------------ 009930 0000
C     CHECK IF BOX HEIGHT IS GREATER THAN 20 FEET                        009940 0000
      IF(BFBHT.GT.20.) WRITE(LO,2180) NREACH                             009950 0000
      GO TO 858                                                          009960 0000
C     ------------------------------------------------------------------ 009970 0000
C     DOUBLE LEVEL BOX -- TWO UNITS HIGH AND TWO UNITS WIDE              009980 0000
C     CHECK IF TOTAL CLEAR BOX HEIGHT EXCEEDS 40 FEET                    009990 0000
  857 IF(BFBHT.GT.40.) WRITE(LO,2185) NREACH                             010000 0000
  858 CONTINUE                                                           010010 0000
C     ------------------------------------------------------------------ 010020 0000
      TRDATA(NREACH,1)=NSHAFT                                            010030 0000
      TRDATA(NREACH,2)=BFT                                               010040 0000
      TRDATA(NREACH,3)=ISHAPE                                            010050 0000
      TRDATA(NREACH,4)=MTM                                               010060 0000
      TRDATA(NREACH,8)=HOURS                                             010070 0000
      TRDATA(NREACH,9)=DAYS                                              010080 0000
      TRDATA(NREACH,10)=NBOX                                             010090 0000
      TRDATA(NREACH,11)=BFBWDT                                           010100 0000
      TRDATA(NREACH,12)=BFBHT                                            010110 0000
      TRDATA(NREACH,13)=IBOX2                                            010120 0000
      GO TO 81                                                           010130 0000
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C     ------------------------------------------------------------------ 010140 0000
C     END OF REACH INPUT                                                 010150 0000
   86 CONTINUE                                                           010160 0000
C     ------------------------------------------------------------------ 010170 0000
C     CHECK REACH AND SEGMENT INFORMATION FOR COMPATABILITY              010180 0000
C     ------------------------------------------------------------------ 010190 0000
      DO 87 I=1,NTS                                                      010200 0000
      NREACH=A(I,4)                                                      010210 0000
      NTSEG=A(I,1)                                                       010220 0000
      NTSTYP=A(I,16)                                                     010230 0000
      MEX=A(I,7)                                                         010240 0000
      BFT=TRDATA(NREACH,2)                                               010250 0000
      ISHAPE=TRDATA(NREACH,3)                                            010260 0000
      MTM=TRDATA(NREACH,4)                                               010270 0000
      ISUPPT=A(I,26)                                                     010280 0000
      MSTAB=A(I,31)                                                      010290 0000
      MUST=A(I,32)                                                       010300 0000
      NPL=A(I,2)                                                         010310 0000
      NPR=A(I,3)                                                         010320 0000
      ELNPL=CNP(NPL,2)                                                   010330 0000
      ELNPR=CNP(NPR,2)                                                   010340 0000
      ELAVG=(ELNPL+ELNPR)/2.                                             010350 0000
      ELWATR=A(I,14)                                                     010360 0000
      ELIMP=A(I,24)                                                      010370 0000
C     IF THE TUNNEL SEGMENT IS MOLED, ITS SHAPE MUST BE CIRCULAR         010380 0000
      IF(MEX.NE.2.AND.MEX.NE.3) GO TO 860                                010390 0000
      IF(ISHAPE.EQ.1) GO TO 860                                          010400 0000
      WRITE(LO,1040) NTSEG,NREACH                                        010410 0000
      ISTOP=1                                                            010420 0000
  860 CONTINUE                                                           010430 0000
C     ------------------------------------------------------------------ 010440 0000
C     CHECK FOR CUT AND COVER OR ROCK TUNNEL                             010450 0000
      IF(NTSTYP.NE.2) GO TO 865                                          010460 0000
C     ------------------------------------------------------------------ 010470 0000
C     CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT                      010480 0000
      IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 861                             010490 0000
      IWATER=A(I,23)                                                     010500 0000
      D10=A(I,19)                                                        010510 0000
      PERM=A(I,25)                                                       010520 0000
      IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.      010530 0000
     110.E-10.AND.PERM.LE.0.0006) GO TO 861                              010540 0000
C     CHECK IF IMPERVIOUS LAYER IS ABOVE TUNNEL WHEN DEWATERING MAY      010550 0000
C     BE USED AS A STABILIZATION METHOD                                  010560 0000
      IF(ELIMP.LT.ELAVG+BFT/2.) GO TO 861                                010570 0000
      WRITE(LO,2190) NTSEG,NREACH                                        010580 0000
      A(I,24)=ELAVG-BFT/2.                                               010590 0000
  861 CONTINUE                                                           010600 0000
C     ------------------------------------------------------------------ 010610 0000
C     CHECK IF TRUCK TRANSPORT IS SPECIFIED AND COMPRESSED AIR REQUIRED  010620 0000
      IF(MTM.NE.1.OR.MSTAB.GT.1.OR.MSTAB.EQ.0.OR.MUST.LT.4) GO TO 863    010630 0000
      ISTOP=1                                                            010640 0000
      WRITE(LO,2195) NTSEG,NREACH                                        010650 0000
  863 CONTINUE                                                           010660 0000
C     ------------------------------------------------------------------ 010670 0000
C     CAST IRON TUNNEL SUPPORT - CIRCULAR TUNNELS ONLY                   010680 0000
      IF(ISUPPT.GT.1.OR.ISHAPE.EQ.1) GO TO 865                           010690 0000
      ISTOP=1                                                            010700 0000
      WRITE(LO,2200) NTSEG,NREACH                                        010710 0000
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  865 CONTINUE                                                          010720 0000
C     ------------------------------------------------------------------ 010730 0000
C     CHECK IF SHAPE CODE AGREES WITH TUNNEL TYPE                        010740 0000
      IF(NTSTYP.LT.3.AND.ISHAPE.GT.0) GO TO 867                          010750 0000
      IF(NTSTYP.EQ.3.AND.ISHAPE.EQ.0) GO TO 867                          010760 0000
      ISTOP=1                                                            010770 0000
      IF(NTSTYP.LT.3) WRITE(LO,2201) NTSEG,NREACH                        010780 0000
      IF(NTSTYP.EQ.3) WRITE(LO,2202) NTSEG,NREACH                        010790 0000
C     ------------------------------------------------------------------ 010800 0000
C     CHECK FOR CUT AND COVER EXCAVATION                                 010810 0000
  867 IF(NTSTYP.NE.3) GO TO 87                                           010820 0000
      BFBHT=TRDATA(NREACH,13)                                            010830 0000
C     ------------------------------------------------------------------ 010840 0000
C     CHECK IF SOUND ROCK LINE IS ABOVE BASE OF TRENCH AND RQD IS LESS   010850 0000
C     THAN 50                                                            010860 0000
      RQD=A(I,6)                                                         010865 0000
      ELROCK=A(I,27)                                                     010870 0000
      IF(RQD.GE.50..OR.ELROCK.LT.ELAVG-BFBHT/2.) GO TO 869               010880 0000
      IF(RQD.GE.25.) WRITE(LO,2203) NTSEG,NREACH                         010890 0000
      IF(RQD.GE.25.) GO TO 869                                           010900 0000
      ISTOP=1                                                            010910 0000
      WRITE(LO,2204) NTSEG,NREACH                                        010920 0000
  869 CONTINUE                                                           010930 0000
C     ------------------------------------------------------------------ 010940 0000
C     CHECK FOR WATER TABLE ABOVE BASE OF TRENCH AND ABOVE IMPERVIOUS    010950 0000
C     LAYER FOR SLOPING CUT EXCAVATION -- IWATER MUST EQUAL 1            010960 0000
      IF(MEX.NE.7) GO TO 87                                              010970 0000
      IWATER=A(I,23)                                                     010980 0000
      IF(IWATER.EQ.1) GO TO 87                                           010990 0000
      IF(ELWATR.LT.ELAVG-BFBHT/2..OR.ELWATR.LE.ELIMP)  GO TO 87          011000 0000
      ISTOP=1                                                            011010 0000
      WRITE(LO,2205) NTSEG,NREACH                                        011020 0000
C     ------------------------------------------------------------------ 011030 0000
   87 CONTINUE                                                           011040 0000
C                                                                        011050 0000
C     ******************************************************************* 011060 0000
C                                                                        011070 0000
C     READ SHAFT SEGMENT DATA  ******************************            011080 0000
C                                                                        011090 0000
C     INITIALIZE SHAFT SEGMENT ARRAY                                     011100 0000
      DO 88 I=1,NSSMAX                                                   011110 0000
   88 B(I,1)=-10.E30                                                     011120 0000
C     INITIALIZE THE SHAFT ARRAY                                         011130 0000
      DO 89 I=1,NSMAX                                                    011140 0000
   89 SHAFT(I,1)=-10.E30                                                 011150 0000
      IPS=0                                                              011160 0000
      I=0                                                                011170 0000
   90 I=I+1                                                              011180 0000
C                                                                        011190 0000
C     ------------------------------------------------------------------ 011200 0000
C     CHECK FOR MAX NUMBER OF SHAFT SEGMENTS                             011210 0000
      IF(I.LE.NSSMAX) GO TO 95                                           011220 0000
C     ------------------------------------------------------------------ 011230 0000
C     CHECK FOR END OF SHAFT SEGMENT DATA. NDUM=DUMMY SEGMENT NUMBER     011240 0000
   91 READ(LI,1020) NDUM                                                 011250 0000
      IF(NDUM.EQ.9999) GO TO 130                                         011260 0000
      WRITE(LO,1017) NSSMAX                                              011270 0000
      ISTOP=1                                                            011280 0000
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      GO TO 91                                                          011290 0000
C                                                                       011300 0000
C     ------------------------------------------------------------------ 011310 0000
C     READ SHAFT SEGMENT DATA FROM CARD                                 011320 0000
   95 READ(LI,1007)          (B(I,J),J=1,15)                            011330 0000
      NSHAFT=B(I,1)                                                     011340 0000
      NSSEG=B(I,2)                                                      011350 0000
      NSSTYP=B(I,15)                                                    011360 0000
C     ------------------------------------------------------------------ 011370 0000
C     CHECK FOR LAST SHAFT CARD                                         011380 0000
      IF(NSHAFT.EQ.9999) GO TO 130                                      011390 0000
      IF(NSHAFT.LE.NSMAX.AND.NSHAFT.GT.0) GO TO 100                     011400 0000
      WRITE(LO,1034) NSHAFT,NSSEG,NSMAX                                 011410 0000
      ISTOP=1                                                           011420 0000
  100 CONTINUE                                                          011430 0000
C     ------------------------------------------------------------------ 011440 0000
C     CHECK FOR MISSING SEPARATOR CARD                                  011450 0000
      IF(NSSTYP.NE.0) GO TO 101                                         011460 0000
      ISTOP=1                                                           011470 0000
      WRITE(LO,1503)                                                    011480 0000
  101 CONTINUE                                                          011490 0000
C     ------------------------------------------------------------------ 011500 0000
C     CHECK FOR PROPER SHAFT TYPE CODE                                  011510 0000
      IF(NSSTYP.GE.1.AND.NSSTYP.LE.3) GO TO 102                         011520 0000
      ISTOP=1                                                           011530 0000
      WRITE(LO,2207) NSSEG,NSHAFT                                       011540 0000
      GO TO 425                                                         011550 0000
  102 CONTINUE                                                          011560 0000
C     ------------------------------------------------------------------ 011570 0000
C     READ SECOND SEGMENT DATA CARD IF NOT ROCK TUNNEL                  011580 0000
      IF(NSSTYP.GT.1) READ(LI,1008) (B(I,J),J=16,27)                    011590 0000
C     ------------------------------------------------------------------ 011600 0000
C     CHECK FOR PREVIOUS USE OF SHAFT NUMBER                            011610 0000
      IF(I.EQ.1) GO TO 105                                              011620 0000
      IF(NSHAFT.EQ.IPS) GO TO 106                                       011630 0000
      IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 105                          011640 0000
      WRITE(LO,1023) NSSEG,NSHAFT                                       011650 0000
      ISTOP=1                                                           011660 0000
  105 SHAFT(NSHAFT,1)=0.                                                011670 0000
  106 CONTINUE                                                          011680 0000
C     ------------------------------------------------------------------ 011690 0000
C     CHECK THAT SHAFT SEGMENT CARDS HAVE BEEN PROPERLY ARRANGED        011700 0000
      IF(I.EQ.1) GO TO 108                                              011710 0000
      IF(IPS.NE.NSHAFT) GO TO 108                                       011720 0000
      IF(B(I,3).EQ.B(I-1,4)) GO TO 108                                  011730 0000
      WRITE(LO,1115) NSSEG,NSHAFT                                       011740 0000
      ISTOP=1                                                           011750 0000
  108 CONTINUE                                                          011760 0000
C     ------------------------------------------------------------------ 011770 0000
C     CHECK THAT ALL SHAFT NODAL POINTS HAVE BEEN INPUT                 011780 0000
      NPT=B(I,3)                                                        011790 0000
      NPB=B(I,4)                                                        011800 0000
      ELNPT=CNP(NPT,2)                                                  011810 0000
      ELNPB=CNP(NPB,2)                                                  011820 0000
      IF(ELNPT.GT.-10.E29.AND.ELNPB.GT.-10.E29) GO TO 110               011830 0000
      WRITE(LO,1131) NSSEG,NSHAFT                                       011840 0000
      ISTOP=1                                                           011850 0000
  110 CONTINUE                                                          011860 0000
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C     ------------------------------------------------------------------ 011970 0000
C     CHECK FOR SHAFT BEING A PORTAL. IF SO,RECORD THIS FACT             011980 0000
      NPORT=0                                                            011990 0000
      IF(NPT.EQ.NPB) NPORT=1                                             012000 0000
      SHAFT(NSHAFT,23)=NPORT                                             012010 0000
C     IF SHAFT IS A PORTAL ,SKIP THE FOLLOWING INPUT CHECKS              012020 0000
      IF(NPT.EQ.NPB) GO TO 128                                           012030 0000
C     ------------------------------------------------------------------ 012040 0000
C     CHECK FOR PROPER EXCAVATION METHOD                                 012050 0000
      MEX=B(I,7)                                                         012060 0000
      IF(MEX.GE.0.AND.MEX.LE.4) GO TO 112                                012070 0000
      ISTOP=1                                                            012080 0000
      WRITE(LO,1029) NSSEG,NSHAFT                                        012090 0000
  112 CONTINUE                                                           012000 0000
C     ------------------------------------------------------------------ 012010 0000
C     CHECK FOR DUMMY SHAFT AND BYPASS FURTHER CHECKS                    012020 0000
      LINING=B(I,10)                                                     012030 0000
      RS=B(I,5)                                                          012040 0000
      RQD=B(I,6)                                                         012050 0000
      IF(NSSTYP.EQ.1.AND.RS.LE.0..AND.RQD.LE.0.                          012060 0000
     1 .AND.MEX.EQ.0.AND.LINING.EQ.0) GO TO 129                          012070 0000
  113 CONTINUE                                                           012080 0000
C     ------------------------------------------------------------------ 012090 0000
C     CHECK FOR PROPER EXCAVATION METHOD FOR SHAFT TYPE SPECIFIED        012100 0000
      IF(NSSTYP.EQ.1.AND.MEX.LT.1.OR.NSSTYP.EQ.1.AND.MEX.GT.2) GO TO 114 012110 0000
      IF(NSSTYP.EQ.2.AND.MEX.LT.3) GO TO 114                             012120 0000
      IF(NSSTYP.EQ.3.AND.MEX.GT.0) GO TO 114                             012130 0000
      GO TO 115                                                          012140 0000
  114 ISTOP=1                                                            012150 0000
      WRITE(LO,2210) NSSEG,NSHAFT                                        012160 0000
C     ------------------------------------------------------------------ 012170 0000
C     CHECK FOR ADVANCE RATE NOT SPECIFIED                               012180 0000
  115 AR=B(I,8)                                                          012190 0000
      IF(AR.EQ.0.0) GO TO 120                                            012200 0000
C     ------------------------------------------------------------------ 012210 0000
C     CHECK FOR ADVANCE RATE LESS THAN 0 FT/DAY                          012220 0000
      IF(AR.GT.0.0) GO TO 120                                            012230 0000
      ISTOP=1                                                            012240 0000
      WRITE(LO,1075) NSSEG,NSHAFT                                        012250 0000
C     ------------------------------------------------------------------ 012260 0000
C     CHECK FOR ROCK STRENGTH GREATER THAN 500 PSI                       012270 0000
  120 CONTINUE                                                           012280 0000
      IF(RS.LT.500..AND.NSSTYP.EQ.1) WRITE(LO,1070) NSSEG,NSHAFT         012290 0000
C     ------------------------------------------------------------------ 012300 0000
C     CHECK FOR PROPER SHAFT CODE IF RQD IS LESS THAN 25.                012310 0000
      IF(NSSTYP.GT.1.OR.RQD.GE.25.) GO TO 122                            012320 0000
      ISTOP=1                                                            012330 0000
      WRITE(LO,2212) NSSEG,NSHAFT                                        012340 0000
  122 CONTINUE                                                           012350 0000
C     ------------------------------------------------------------------ 012360 0000
C     IS SHAFT IN SOFT GROUND AND RQD GREATER THAN 25.                   012370 0000
      IF(NSSTYP.EQ.2.AND.RQD.GT.25.) WRITE(LO,2215) NSSEG,NSHAFT         012380 0000
C     ------------------------------------------------------------------ 012390 0000
C     CHECK FOR RQD BETWEEN 0 AND 100.                                   012400 0000
      IF(RQD.GE.0.0.AND.RQD.LE.100.) GO TO 126                           012410 0000
      WRITE(LO,1072) NSSEG,NSHAFT                                        012420 0000
      ISTOP=1                                                            012430 0000
  126 CONTINUE                                                           012440 0000
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C     ------------------------------------------------------------------ 012450 0000
C     CHECK FOR CONTRADICTION OF SPECIFYING A THICKNESS FOR NO LINING    012460 0000
      LINING=B(I,10)                                                     012470 0000
      IF(LINING.NE.0.OR.NSSTYP.NE.1) GO TO 127                           012480 0000
      TL=B(I,11)                                                         012490 0000
      IF(TL.LE.0.001) GO TO 127                                          012500 0000
      WRITE(LO,1046) NSSEG,NSHAFT                                        012510 0000
      ISTOP=1                                                            012520 0000
  127 CONTINUE                                                           012530 0000
C     ------------------------------------------------------------------ 012540 0000
C     CHECK FOR PROPER LINING TYPE CODE                                  012550 0000
      IF(LINING.GE.0.AND.LINING.LE.3) GO TO 1270                         012560 0000
      WRITE(LO,1048) NSSEG,NSHAFT                                        012570 0000
      ISTOP=1                                                            012580 0000
 1270 CONTINUE                                                           012590 0000
C     ------------------------------------------------------------------ 012600 0000
C     CHECK FOR PROPER LINING CODE FOR SHAFT TYPE SPECIFIED              012610 0000
      IF(NSSTYP.LT.3.AND.LINING.NE.3.OR.NSSTYP.EQ.3.AND.LINING.EQ.3)     012620 0000
     1GO TO 1272                                                         012630 0000
      ISTOP=1                                                            012640 0000
      WRITE(LO,2220) NSSEG,NSHAFT                                        012650 0000
C     ------------------------------------------------------------------ 012660 0000
C     CHECK FOR PROPER WATERTIGHT CODE                                   012670 0000
 1272 LINWT=B(I,14)                                                      012680 0000
      IF(LINWT.EQ.0.OR.LINWT.EQ.1) GO TO 1274                            012690 0000
      ISTOP=1                                                            012700 0000
      WRITE(LO,2225) NSSEG,NSHAFT                                        012710 0000
 1274 CONTINUE                                                           012720 0000
C     ------------------------------------------------------------------ 012730 0000
C     ALL CUT AND COVER BOX SEGMENTS ARE DESIGNED AS WATERTIGHT -        012740 0000
C     INPUT IGNORED                                                      012750 0000
      IF(NSSTYP.EQ.3.AND.LINWT.EQ.0) WRITE(LO,2227) NSSEG,NSHAFT         012760 0000
C     ------------------------------------------------------------------ 012770 0000
C     A LINING OR SUPPORT MUST BE SPECIFIED WHEN WATERTIGHTNESS REQUIRED 012780 0000
      ISUPPT=B(I,22)                                                     012790 0000
      IF(LINWT.EQ.0.OR.LINING.GT.0) GO TO 1276                           012800 0000
      IF(NSSTYP.GT.1.AND.ISUPPT.LE.3) GO TO 1276                         012810 0000
      ISTOP=1                                                            012820 0000
      WRITE(LO,2230) NSSEG,NSHAFT                                        012830 0000
C     ------------------------------------------------------------------ 012840 0000
C     CHECK IF GROUNDWATER ELEVATION NOT INPUT AND WATERTIGHT REQUIRED   012850 0000
 1276 ELWATR=B(I,13)                                                     012860 0000
      IF(LINWT.EQ.1.AND.ELWATR.EQ.0) WRITE(LO,2235) NSSEG,NSHAFT         012870 0000
C     ------------------------------------------------------------------ 012880 0000
C     CHECK IF SHAFT NOT IN ROCK AND GROUNDWATER ELEV NOT SPECIFIED      012890 0000
      IF(NSSTYP.GT.1.AND.ELWATR.EQ.0) WRITE(LO,2235) NSSEG,NSHAFT        012900 0000
C     ------------------------------------------------------------------ 012910 0000
C     CHECK IF GROUND WATER ELEVATION IS IN MIDDLE OF SHAFT SEGMENT      012920 0000
      IF(ELWATR.GE.ELNPT.OR.ELWATR.LE.ELNPB) GO TO 1277                  012930 0000
      ISTOP=1                                                            012940 0000
      WRITE(LO,2240) NSSEG,NSHAFT                                        012950 0000
C     ------------------------------------------------------------------ 012960 0000
C     CHECK REMAINING DATA IF SHAFT IS NOT IN ROCK                       012970 0000
 1277 IF(NSSTYP.EQ.1) GO TO 128                                          012980 0000
C     ------------------------------------------------------------------ 012990 0000
C     CHECK IF EFFECTIVE GRAIN SIZE IS INPUT                             013000 0000
      D10=B(I,16)                                                        013010 0000
      IF(D10.GT.0) GO TO 1278                                            013020 0000
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      ISTOP=1                                                           013030 0000
      WRITE(LO,2245) NSSEG,NSHAFT                                       013040 0000
C     ------------------------------------------------------------------ 013050 0000
C     CHECK THAT PHI AND/OR COHESION ARE SPECIFIED                      013060 0000
 1278 PHI=B(I,19)                                                       013070 0000
      COHESN=B(I,17)                                                    013080 0000
      IF(PHI.GT.0..OR.COHESN.GT.0.) GO TO 1279                          013090 0000
      ISTOP=1                                                           013100 0000
      WRITE(LO,2250) NSSEG,NSHAFT                                       013110 0000
 1279 CONTINUE                                                          013120 0000
C     ------------------------------------------------------------------ 013130 0000
C     CHECK FOR POSSIBLE ERROR IN PERMEABILITY INPUT                    013140 0000
      PERM=B(I,23)                                                      013150 0000
      IF(PERM.GT.10.) WRITE(LO,2251) NSSEG,NSHAFT                       013160 0000
C     ------------------------------------------------------------------ 013170 0000
C     CHECK IF PHI GREATER THAN 45 - WARNING, OR GREATER THAN 100 -ERROR 013180 0000
      IF(PHI.GT.45.) WRITE(LO,2252) NSSEG,NSHAFT                        013190 0000
      IF(PHI.LT.100.) GO TO 1280                                        013200 0000
      ISTOP=1                                                           013210 0000
      WRITE(LO,2253) NSSEG,NSHAFT                                       013220 0000
C     ------------------------------------------------------------------ 013230 0000
C     CHECK IF GAMMA GREATER THAN 200.                                  013240 0000
 1280 GAMMA=B(I,18)                                                     013250 0000
      IF(GAMMA.LE.200.) GO TO 1281                                      013260 0000
      ISTOP=1                                                           013270 0000
      WRITE(LO,2254) NSSEG,NSHAFT                                       013280 0000
C     ------------------------------------------------------------------ 013290 0000
C     CHECK FOR PROPER DEWATERING CODE                                  013300 0000
 1281 IWATER=B(I,21)                                                    013310 0000
      IF(IWATER.EQ.0.OR.IWATER.EQ.1) GO TO 1282                         013320 0000
      ISTOP=1                                                           013330 0000
      WRITE(LO,2255) NSSEG,NSHAFT                                       013340 0000
C     ------------------------------------------------------------------ 013350 0000
C     CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT                     013360 0000
 1282 MSTAB=B(I,25)                                                     013370 0000
      MUST=B(I,26)                                                      013380 0000
      IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 1284                           013390 0000
      IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.     013400 0000
     110.E-10.AND.PERM.LE.0.0006) GO TO 1284                            013410 0000
C     ------------------------------------------------------------------ 013420 0000
C     DEWATERING IS ALLOWED.  CHECK IF IMPERVIOUS LAYER IS NOT          013430 0000
C     SPECIFIED OR IF THE IMPERVIOUS LAYER IS ABOVE BASE OF SEGMENT.    013440 0000
      ELIMP=B(I,20)                                                     013450 0000
      IF(ELIMP.EQ.0.0) WRITE(LO,2260) NSSEG,NSHAFT                      013460 0000
      IF(ELIMP.LE.ELNPB) GO TO 1284                                     013470 0000
      ISTOP=1                                                           013480 0000
      WRITE(LO,2262) NSSEG,NSHAFT                                       013490 0000
 1284 CONTINUE                                                          013500 0000
C     ------------------------------------------------------------------ 013510 0000
C     CHECK FOR PROPER SUPPORT CODE                                     013520 0000
      IF(ISUPPT.GE.1.AND.ISUPPT.LE.5) GO TO 1285                        013530 0000
      ISTOP=1                                                           013540 0000
      WRITE(LO,2265) NSSEG,NSHAFT                                       013550 0000
 1285 CONTINUE                                                          013560 0000
C     ------------------------------------------------------------------ 013570 0000
C     CHECK FOR PROPER SUPPORT CODE FOR SHAFT TYPE SPECIFIED            013580 0000
      IF(NSSTYP.EQ.2.AND.ISUPPT.GT.0.OR.NSSTYP.EQ.3.AND.ISUPPT.EQ.5)    013590 0000
     1GO TO 1286                                                        013600 0000
```

(Continued)

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      ISTOP=1                                                           013610 0000
      WRITE(LO,2270) NSSEG,NSHAFT                                       013620 0000
 1286 CONTINUE                                                          013630 0000
C     ------------------------------------------------------------------ 013640 0000
C     CHECK FOR PROPER LINING CODE FOR SUPPORT TYPE SPECIFIED            013650 0000
      IF(ISUPPT.LE.3.AND.LINING.EQ.0) GO TO 1288                         013660 0000
      IF(ISUPPT.EQ.5.AND.LINING.EQ.3) GO TO 1288                         013670 0000
      IF(ISUPPT.EQ.4.AND.LINING.EQ.0) GO TO 1287                         013680 0000
      IF(ISUPPT.EQ.4.AND.LINING.NE.3) GO TO 1288                         013690 0000
 1287 ISTOP=1                                                            013700 0000
      WRITE(LO,2275) NSSEG,NSHAFT                                        013710 0000
 1288 CONTINUE                                                           013720 0000
C     ------------------------------------------------------------------ 013730 0000
C     CHECK FOR CUT AND COVER SHAFT                                      013740 0000
      IF(NSSTYP.EQ.3) GO TO 129                                          013750 0000
C     ------------------------------------------------------------------ 013760 0000
C     CHECK FOR HIGH STABILITY NUMBER - MAY RESULT IN UNEXCAVATABLE JOB  013770 0000
      STABNO=B(I,24)                                                     013780 0000
      IF(STABNO.LE.9.AND.PHI.LT.29.OR.STABNO.LE.7.AND.PHI.GE.29)         013790 0000
     1 GO TO 1289                                                        013800 0000
      ISTOP=1                                                            013810 0000
      WRITE(LO,2285) NSSEG,NSHAFT                                        013820 0000
C     ------------------------------------------------------------------ 013830 0000
C     CHECK FOR PROPER STABILIZATION CODE                                013840 0000
 1289 MSTAB=B(I,25)                                                      013850 0000
      IF(MSTAB.GE.0.AND.MSTAB.LE.3)  GO TO 1290                          013860 0000
      ISTOP=1                                                            013870 0000
      WRITE(LO,2290) NSSEG,NSHAFT                                        013880 0000
C     ------------------------------------------------------------------ 013890 0000
C     CHECK FOR PROPER USE OF STABILIZATION METHOD CODE                  013900 0000
 1290 MUST=B(I,26)                                                       013910 0000
      IF(MUST.GE.1.AND.MUST.LE.4) GO TO 1292                             013920 0000
      ISTOP=1                                                            013930 0000
      WRITE(LO,2295) NSSEG,NSHAFT                                        013940 0000
C     ------------------------------------------------------------------ 013950 0000
C     CHECK FOR AIR PRESSURE INPUT IF STABILITY NUMBER INPUT AND         013960 0000
C     AIR PRESSURE STABILIZATION INPUT                                   013970 0000
 1292 AIRPR=B(I,27)                                                      013980 0000
      IF(STABNO.GT.0.0.AND.MSTAB.EQ.1.AND.AIRPR.EQ.0.0) GO TO 1293       013990 0000
      GO TO 1294                                                         014000 0000
 1293 ISTOP=1                                                            014010 0000
      WRITE(LO,2300) NSSEG,NSHAFT                                        014020 0000
 1294 CONTINUE                                                           014030 0000
C     ------------------------------------------------------------------ 014040 0000
C     CHECK FOR USE CODE=4 WHEN STABILITY NUMBER IS SPECIFIED            014050 0000
      IF(STABNO.EQ.0.OR.MUST.EQ.4) GO TO 1296                            014060 0000
      ISTOP=1                                                            014070 0000
      WRITE(LO,2305) NSSEG,NSHAFT                                        014080 0000
 1296 CONTINUE                                                           014090 0000
C     ------------------------------------------------------------------ 014100 0000
C     CHECK IF STABILIZATION METHOD NOT COMPRESSED AIR BUT AIRPR GT 0    014110 0000
      IF(MSTAB.EQ.1.OR.AIRPR.EQ.0.) GO TO 1297                           014120 0000
      ISTOP=1                                                            014130 0000
      WRITE(LO,2307) NSSEG,NSHAFT                                        014140 0000
 1297 CONTINUE                                                           014150 0000
C     ------------------------------------------------------------------ 014160 0000
C     CHECK IF STABILIZATION METHOD AGREES WITH USE CODE                 014170 0000
      IF(MSTAB.GE.0.AND.MUST.GT.2.OR.MSTAB.EQ.0.AND.MUST.LT.3)GO TO 1298 014180 0000
```

(Continued)

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      ISTOP=1
      WRITE(LO,2310) NSSEG,NSHAFT
 1298 CONTINUE
C     ------------------------------------------------------------------
C     CHECK IF STABILIZATION METHOD IS INPUT
      IF(MSTAB.EQ.0) GO TO 128
C     ------------------------------------------------------------------
C     CHECK IF STABILIZATION METHOD IS ACCEPTABLE
      GO TO (1300,1302,1304), MSTAB
C     ------------------------------------------------------------------
C     AIR PRESSURE -- CHECK IF SOIL IS A GRAVEL
 1300 IF(PERM.LT.10.E-10.AND.D10.GT.2.) GO TO 1305
      IF(PERM.GT.0.4) GO TO 1305
C     CHECK IF SOIL IS A CLAY
      IF(D10.LE.0.005) GO TO 1308
C     CHECK IF SHAFT SEGMENT ABOVE WATER TABLE
      IF(ELWATR.LE.ELNPB) GO TO 1308
C     CHECK IF WATER HEAD LESS THAN 115 FEET
      ELAVG=(ELNPT+ELNPB)/2.
      IF(ELWATR-ELAVG.LE.115.) GO TO 1308
      GO TO 1305
C     ------------------------------------------------------------------
C     DEWATERING -- CHECK IF DEWATERING IS ALLOWED
 1302 IF(IWATER.EQ.0) GO TO 1305
C     CHECK IF SHAFT SEGMENT ABOVE WATER TABLE
      IF(ELWATR.LE.ELNPB) GO TO 1305
C     CHECK IF SOIL IS FINE SAND OR COARSER OR IS REASONABLY PERMEABLE
      IF(PERM.LT.10.E-10.AND.D10.GT.0.08) GO TO 1308
      IF(PERM.GT.0.0006) GO TO 1308
      GO TO 1305
C     ------------------------------------------------------------------
C     GROUND INJECTIONS -- CHECK IF SOIL IS NOT CLAY
 1304 IF(D10.GT.0.005) GO TO 1308
C     ------------------------------------------------------------------
C     STABILIZATION METHOD IS NOT ACCEPTABLE
 1305 MSTAC=2
C     CHECK IF USE CODE =4
      IF(MUST.EQ.4) GO TO 1306
      WRITE(LO,2315) NSSEG,NSHAFT
      GO TO 1310
 1306 ISTOP=1
      WRITE(LO,2320) NSSEG,NSHAFT
      GO TO 1310
C     ------------------------------------------------------------------
C     STABILIZATION METHOD IS ACCEPTABLE
 1308 MSTAC=1
 1310 B(I,28)=MSTAC
C     ------------------------------------------------------------------
C     CHECK FOR CORRECT GROUNDWATER CODE
  128 INFLOW=B(I,9)
      IF(INFLOW.EQ.0.OR.INFLOW.EQ.1) GO TO 129
      WRITE(LO,1047) NSSEG,NSHAFT
      ISTOP=1
C     ------------------------------------------------------------------
  129 IPS=NSHAFT
      GO TO 90
C     END OF SHAFT SEGMENT DATA
  130 CONTINUE
```

(Continued)

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C
C     ******************************************************************
      NSS=I-1
C
C     ******************************************************************
C
C     READ SHAFT PROPERTIES
C
C     INITIALIZE SHAFT DATA ARRAY
      DO 132 I=1,NSMAX
      SHAFT(I,7)=-10.E30
  132 SHAFT(I,1)=-10.E30
C
  131 READ(LI,1025,ERR=450) NSHAFT,BFS,ISHAPS,DDS,CDS,AIRTEM,CFL,CFE,
     1CFM,RCF,HOURS,DAYS
      IF(NSHAFT.EQ.9999) GO TO 139
C     CHECK FOR PREVIOUS USE OF SHAFT NUMBER
  134 IF(SHAFT(NSHAFT,1).GT.-10.E29) WRITE(LO,1027) NSHAFT
      IF(SHAFT(NSHAFT,1).GT.-10.E29) ISTOP=1
C     IF SHAFT IS PORTAL,USER CAN OMIT BFS. SET SIZE
      NPORT=SHAFT(NSHAFT,23)
      IF(NPORT.EQ.1) BFS=20.
      SHAFT(NSHAFT,5)=DDS
      SHAFT(NSHAFT,6)=CDS
      SHAFT(NSHAFT,7)=BFS
      SHAFT(NSHAFT,11)=AIRTEM
      SHAFT(NSHAFT,12)=CFL
      SHAFT(NSHAFT,13)=CFE
      SHAFT(NSHAFT,14)=CFM
      SHAFT(NSHAFT,15)=RCF
      SHAFT(NSHAFT,16)=ISHAPS
      SHAFT(NSHAFT,17)=HOURS
      SHAFT(NSHAFT,18)=DAYS
C     ------------------------------------------------------------------
C     CHECK FOR FINISHED DIMENSION BETWEEN 10 AND 40 FEET
      IF(ISHAPS.GT.0.AND.BFS.LT.10..OR.ISHAPS.GT.0.AND.BFS.GT.40.)
     1WRITE(LO,1074) NSHAFT
C     ------------------------------------------------------------------
C     CHECK FOR PROPER SHAFT SHAPE CODE
      IF(ISHAPS.GE.0.AND.ISHAPS.LE.2) GO TO 135
      ISTOP=1
      WRITE(LO,2325) NSHAFT
  135 CONTINUE
C     ------------------------------------------------------------------
C     CHECK FOR SPECIFICATION OF PORTAL, BYPASS FOLLOWING CHECKS
      IF(NPORT.EQ.1) GO TO 136
C     ------------------------------------------------------------------
C     CHECK FOR SPECIFICATION OF DUMMY SHAFT
      IF(ISHAPS.EQ.0) WRITE(LO,2327) NSHAFT
C     ------------------------------------------------------------------
C     CHECK IF SHAPE CODE AGREES WITH INPUT SHAFT SIZE
      IF(BFS.EQ.0.AND.ISHAPS.EQ.0.OR.BFS.GT.0.AND.ISHAPS.GT.0) GO TO 136
      ISTOP=1
      IF(ISHAPS.EQ.0) WRITE(LO,2330) NSHAFT
      IF(ISHAPS.GT.0) WRITE(LO,2332) NSHAFT
  136 CONTINUE
C     ------------------------------------------------------------------
C     CHECK IF WORK HOURS PER DAY IN PROPER RANGE
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(Continued)

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      IF(HOURS.GE.0..AND.HOURS.LE.24.) GO TO 137                        015350 0000
      ISTOP=1                                                           015360 0000
      WRITE(LO,2335) NSHAFT                                             015370 0000
  137 CONTINUE                                                          015380 0000
C     ----------------------------------------------------------------- 015390 0000
C     CHECK IF WORK DAYS PER WEEK IN PROPER RANGE                       015400 0000
      IF(DAYS.GE.4..AND.DAYS.LE.7..OR.DAYS.EQ.0.) GO TO 138             015410 0000
      ISTOP=1                                                           015420 0000
      WRITE(LO,2340) NSHAFT                                             015430 0000
  138 CONTINUE                                                          015440 0000
C     ----------------------------------------------------------------- 015450 0000
      SHAFT(NSHAFT,1)=0.                                                015460 0000
      GO TO 131                                                         015470 0000
C     END OF SHAFT PROPERTIES DATA                                      015480 0000
  139 CONTINUE                                                          015490 0000
C     ***************************************************************** 015500 0000
C                                                                       015510 0000
C                                                                       015520 0000
C     ----------------------------------------------------------------- 015530 0000
C     MAKE SURE THAT ALL TUNNEL SEGMENTS HAVE REACHES DEFINED FOR THEM  015540 0000
      DO 200 I=1,NTS                                                    015550 0000
      NTSEG=A(I,1)                                                      015560 0000
      NREACH=A(I,4)                                                     015570 0000
      IF(TRDATA(NREACH,1).GT.0.) GO TO 200                              015580 0000
      ISTOP=1                                                           015590 0000
      WRITE(LO,1200) NTSEG,NREACH                                       015600 0000
  200 CONTINUE                                                          015610 0000
C     ----------------------------------------------------------------- 015620 0000
C     CHECK THAT EVERY REACH NUMBER ASSIGNED HAS AT LEAST ONE TUNNEL    015630 0000
C     SEGMENT REFERRING TO IT                                           015640 0000
      DO 250 I=1,NTRMAX                                                 015650 0000
      IF(TRDATA(I,1).LT.-10.E29) GO TO 250                              015660 0000
      NREACH=I                                                          015670 0000
      JJ=0                                                              015680 0000
      DO 225 J=1,NTS                                                    015690 0000
      IF(NREACH.EQ.A(J,4)) JJ=1                                         015700 0000
  225 CONTINUE                                                          015710 0000
      IF(JJ.EQ.1) GO TO 250                                             015720 0000
      ISTOP=1                                                           015730 0000
      WRITE(LO,1203) NREACH                                             015740 0000
  250 CONTINUE                                                          015750 0000
C     ----------------------------------------------------------------- 015760 0000
C     CHECK TO MAKE SURE ALL SHAFT SEGMENTS HAVE SHAFTS DEFINED FOR THEM 015770 0000
      DO 300 I=1,NSS                                                    015780 0000
      NSSEG=B(I,2)                                                      015790 0000
      NSHAFT=B(I,1)                                                     015800 0000
      IF(SHAFT(NSHAFT,7).GT.-10.E29) GO TO 260                          015810 0000
      ISTOP=1                                                           015820 0000
      WRITE(LO,1201) NSSEG,NSHAFT                                       015830 0000
  260 CONTINUE                                                          015840 0000
C     ----------------------------------------------------------------- 015850 0000
C     CHECK FOR PORTAL OR DUMMY SHAFT                                   015860 0000
      NPORT=SHAFT(NSHAFT,23)                                            015870 0000
      ISHAPS=SHAFT(NSHAFT,16)                                           015880 0000
      IF(NPORT.EQ.1.OR.ISHAPS.EQ.0) GO TO 300                           015890 0000
C     ----------------------------------------------------------------- 015900 0000
C     CHECK IF SHAPE CODE AGREES WITH SHAFT TYPE                        015910 0000
      NSSTYP=B(I,15)                                                    015920 0000
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(Continued)

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      IF(NSSTYP.GT.1.OR.ISHAPS.LT.2) GO TO 270                          015930 0000
      ISTOP=1                                                           015940 0000
      WRITE(LO,2345) NSSEG,NSHAFT                                       015950 0000
  270 CONTINUE                                                          015960 0000
C     ------------------------------------------------------------------015970 0000
C     CAST IRON SHAFT SUPPORT - CIRCULAR SHAFTS ONLY                    015980 0000
      ISUPPT=B(I,22)                                                    015990 0000
      IF(ISHAPS.EQ.1.OR.ISUPPT.NE.1.OR.NSSTYP.NE.2) GO TO 280           016000 0000
      ISTOP=1                                                           016010 0000
      WRITE(LO,2350) NSSEG,NSHAFT                                       016020 0000
  280 CONTINUE                                                          016030 0000
C     ------------------------------------------------------------------016040 0000
C     IF THE SHAFT SEGMENT IS MOLED, ITS SHAPE MUST BE CIRCULAR         016050 0000
      MEX=B(I,7)                                                        016060 0000
      IF(MEX.NE.2.AND.MEX.NE.3) GO TO 300                               016070 0000
      IF(ISHAPS.EQ.1) GO TO 300                                         016080 0000
      ISTOP=1                                                           016090 0000
      WRITE(LO,2355) NSSEG,NSHAFT                                       016100 0000
  300 CONTINUE                                                          016110 0000
C     ------------------------------------------------------------------016120 0000
C     CHECK THAT EVERY SHAFT NUMBER ASSIGNED HAS AT LEAST ONE SHAFT     016130 0000
C     SEGMENT REFERRING TO IT                                           016140 0000
      DO 350 I=1,NSMAX                                                  016150 0000
      IF(SHAFT(I,1).LT.-10.E29) GO TO 350                               016160 0000
      NSHAFT=I                                                          016170 0000
      JJ=0                                                              016180 0000
      DO 325 J=1,NSS                                                    016190 0000
      IF(NSHAFT.EQ.B(J,1)) JJ=1                                         016200 0000
  325 CONTINUE                                                          016210 0000
      IF(JJ.EQ.1) GO TO 350                                             016220 0000
      ISTOP=1                                                           016230 0000
      WRITE(LO,1204) NSHAFT                                             016240 0000
  350 CONTINUE                                                          016250 0000
C     ------------------------------------------------------------------016260 0000
C     CHECK ALL REACHES TO MAKE SURE THAT THERE IS AN EXIT SHAFT DEFINED 016270 0000
      DO 400 I=1,NTRMAX                                                 016280 0000
      IF(TRDATA(I,1).LT.-10.E29) GO TO 400                              016290 0000
      NSHAFT=TRDATA(I,1)                                                016300 0000
      IF(SHAFT(NSHAFT,7).GT.-10.E29) GO TO 400                          016310 0000
      ISTOP=1                                                           016320 0000
      WRITE(LO,1202) I,NSHAFT                                           016330 0000
  400 CONTINUE                                                          016340 0000
C     ------------------------------------------------------------------016350 0000
C                                                                       016360 0000
C     CHECK FOR ANY STOPS  FOUND                                        016370 0000
  425 CONTINUE                                                          016380 0000
      IF(ISTOP.EQ.0) GO TO 500                                          016390 0000
C     FATAL ERRORS DETECTED WHICH MAY MAKE FURTHER CALCULATIONS         016400 0000
C     MEANINGLESS. TERMINATE RUN AND GO TO NEXT SYSTEM DATA DECK        016410 0000
      WRITE(LO,1011)                                                    016420 0000
      CALL NEXSET(LO,LI)                                                016430 0000
      RETURN                                                            016440 0000
  450 WRITE (LO,1504)                                                   016450 0000
      ISTOP = 1                                                         016460 0000
      GO TO 425                                                         016470 0000
C     IF NO FATAL ERRORS,LIST NODAL POINT DATA IF REQUESTED             016480 0000
  500 IF(LIST(1).EQ.1) RETURN                                           016490 0000
      WRITE(LO,1003)                                                    016500 0000
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(Continued)

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      DO 600 I=1,NPMAX                                                  016510 0000
  600 IF(CNP(I,2).GT.-10.E29) WRITE(LO,1004) I,CNP(I,2)                 016520 0000
      RETURN                                                            016530 0000
C                                                                       016540 0000
C                                                                       016550 0000
 1000 FORMAT(1X,I4,5X,F10.0)                                            016560 0000
 1001 FORMAT(/,' FATAL ERROR, NODAL POINT',I5,' MUST BE CHANGED TO A    016570 0000
     &NUMBER IN THE RANGE FROM 1 TO ',I4)                               016580 0000
 1002 FORMAT(4I4,F5.0,I3,F7.0,F5.0,I3,F4.0,F7.0,2I3,F5.0)               016590 0000
 1003 FORMAT(///,10X,25H NODAL POINT    ELEVATION //)                   016600 0000
 1004 FORMAT(10X,I7,8X,F9.2)                                            016610 0000
 1005 FORMAT(3F4.0,F8.0,F4.0,F7.0,F5.0,F3.0,F5.0,F7.0,F3.0,F6.0,F4.0,F2. 016620 0000
     10,F6.0,F3.0,F5.0)                                                 016630 0000
 1006 FORMAT(4X,2F4.0,F8.0,F4.0,F7.0,F5.0,F3.0,F5.0,F7.0,F3.0,F6.0,F4.0, 016640 0000
     1F2.0,F6.0,F2.0,F1.0,F5.0)                                         016650 0000
 1007 FORMAT(4F4.0,8X,F8.0,F4.0,F3.0,F6.0,2F3.0,F6.0,F2.0,F6.0,F3.0,    016660 0000
     1F5.0)                                                             016670 0000
 1008 FORMAT(16X,2F8.0,F4.0,F3.0,F6.0,2F3.0,F8.0,F6.0,F2.0,F1.0,F5.0)   016680 0000
 1011 FORMAT(///,1X,131('*'),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS I  016690 0000
     1N SUBROUTINE INPUT ',/1X,131(1H*))                                016700 0000
 1013 FORMAT(/,' FATAL ERROR, NODAL POINT',I5,' IS INPUTED ON TWO SEP   016710 0000
     1ARATE NODAL POINT CARDS')                                         016720 0000
 1015 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN REACH',I5,' IS OUT OF    016730 0000
     1SEQUENCE,CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT  016740 0000
     2S')                                                               016745
 1016 FORMAT(/,' FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'   016750 0000
     1 TUNNEL SEGMENTS ALLOWED')                                        016760 0000
 1017 FORMAT(/,' FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'   016770 0000
     1 SHAFT SEGMENTS ALLOWED')                                         016780 0000
 1020 FORMAT(2I4  ,F6.0,2I3  ,F5.0,F4.0,I3,2F5.0,I3,25X,I5)             016790 0000
 1021 FORMAT(/,' FATAL ERROR, REACH NUMBER',I5,' SHOULD BE CHANGED TO   016800 0000
     1 ONE IN THE RANGE OF 1 TO ',I5)                                   016810 0000
 1022 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' REFERS TO REACH',I5,' BU    016820 0000
     1T THIS REACH NUMBER HAS BEEN PREVIOUSLY ASSIGNED')                016830 0000
 1023 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' REFERS TO SHAFT',I5,' BU    016840 0000
     1T THIS SHAFT NUMBER HAS BEEN PREVIOUSLY ASSIGNED')                016850 0000
 1025 FORMAT(I4,F6.0,I3,F8.0,F7.0,F4.0,4F6.0,F5.0,F4.0)                 016860 0000
 1026 FORMAT(/,' FATAL ERROR, DATA FOR REACH',I5,' HAVE BEEN SUPPLIED   016870 0000
     1 ON TWO SEPARATE REACH CARDS')                                    016880 0000
 1027 FORMAT(/,' FATAL ERROR, DATA FOR SHAFT',I5,' HAVE BEEN SUPPLIED   016890 0000
     1 ON TWO SEPARATE SHAFT CARDS')                                    016900 0000
 1029 FORMAT(/,' FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN SH  016910 0000
     1AFT',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK),1,2,3,4') 016920 0000
 1030 FORMAT(/,' FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN RE  016930 0000
     1ACH', I5,' WAS NOT SPECIFIED BY USING CODE 1,2,3,4,5,6,OR 7')     016940 0000
 1031 FORMAT(/,' FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT',I5,' 016950 0000
     1  IN REACH',I5,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD 016960 0000
     2S')                                                               016970 0000
 1034 FORMAT(/,' FATAL ERROR, SHAFT',I5,' LISTED WITH SHAFT SEGMENT',   016980 0000
     1I5,' IS NOT NUMBERED IN THE RANGE OF 1 TO ',I5)                   016990 0000
 1040 FORMAT(/,' FATAL ERROR, CIRCULAR SHAPE WAS NOT SPECIFIED FOR MOL  017000 0000
     1ED EXCAVATION IN SEGMENT',I5,' IN REACH',I5)                      017010 0000
 1041 FORMAT(/,' FATAL ERROR, MUCK TRANSPORT METHOD IN REACH',I5,' WA   017020 0000
     1S NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,3,OR 4')        017030 0000
 1042 FORMAT(/,' FATAL ERROR, TUNNEL SHAPE IN REACH',I5,' WAS NOT SPE   017040 0000
     1CIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')                   017050 0000
 1043 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN REACH',I5 017060 0000
     1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')     017070 0000
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1045 FORMAT(/,' FATAL ERROR, A  LINING THICKNESS IS SPECIFIED FOR SEG   017080 0000
    1MENT',I4,' IN REACH',I4,',BUT NO LINING WAS SPECIFIED')            017090 0000
1046 FORMAT(/,' FATAL ERROR, A  LINING THICKNESS IS SPECIFIED FOR SEG   017100 0000
    1MENT',I4,' IN SHAFT',I4,',BUT NO LINING WAS SPECIFIED')            017110 0000
1047 FORMAT(/,' FATAL ERROR, GROUNDWATER INFLOW IN SEGMENT',I5,' IN S   017120 0000
    1HAFT',I5,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK) OR 1')  017130 0000
1048 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN SHAFT',I5  017140 0000
    1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')      017150 0000
1055 FORMAT(/,' FATAL ERROR, SHAFT',I5,' IS NOT NUMBERED IN THE RANG    017160 0000
    1E OF 1 TO ',I5)                                                    017170 0000
1060 FORMAT(/,' **** WARNING ****  ROCK STRENGTH IS LESS THAN 500 PSI   017180 0000
    1 IN SEGMENT',I5,' IN REACH',I5,' GETTING CLOSE TO SOFT GROUND',    017190 0000
    25X,14(1H*))                                                        017200 0000
1062 FORMAT(/,' FATAL ERROR,  RQD IN SEGMENT',I5,' IN REACH',I5,        017210 0000
    1' IS NOT A NUMBER FROM 0 TO 100')                                  017220 0000
1064 FORMAT(/,' **** WARNING ****  TUNNEL SIZE IN REACH',I5,' IS NOT    017230 0000
    1 WITHIN THE RANGE OF 10 TO 40 FEET',5X,41(1H*))                    017240 0000
1065 FORMAT(/,' FATAL ERROR, ADVANCE RATE IN SEGMENT',I5,' IN REACH',   017250 0000
    1 I5,' IS LESS THAN 0 FT/DAY')                                      017260 0000
1070 FORMAT(/,' **** WARNING ****  ROCK STRENGTH IS LESS THAN 500 PSI   017270 0000
    1 IN SEGMENT',I5,' IN SHAFT',I5,' GETTING CLOSE TO SOFT GROUND',    017280 0000
    25X,14(1H*))                                                        017290 0000
1072 FORMAT(/,' FATAL ERROR,  RQD IN SEGMENT',I5,' IN SHAFT',I5,        017300 0000
    1 'IS NOT A NUMBER FROM  0 TO 100')                                 017310 0000
1074 FORMAT(/,' **** WARNING ****   SHAFT SIZE IN SHAFT',I5,' IS NOT   017320 0000
    1 WITHIN THE RANGE OF 10 TO 40 FEET',5X,41(1H*))                    017330 0000
1075 FORMAT(/,' FATAL ERROR, ADVANCE RATE IN SEGMENT',I5,' IN SHAFT',   017340 0000
    1 I5,' IS LESS THAN 0 FT/DAY')                                      017350 0000
1115 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN SHAFT',I5,' IS OUT OF     017360 0000
    1SEQUENCE,CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT   017370 0000
    2S')                                                                017375
1131 FORMAT(/,' FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT',I5,   017380 0000
    1' IN SHAFT',I5,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD  017390 0000
    2S')                                                                017400 0000
1200 FORMAT(/,' FATAL ERROR, TUNNEL SEGMENT',I5,' REFERS TO REACH',I5   017410 0000
    1,' BUT NO SUCH REACH HAS BEEN INPUTED')                            017420 0000
1201 FORMAT(/,' FATAL ERROR, SHAFT  SEGMENT',I5,' REFERS TO SHAFT',I5   017430 0000
    1,' BUT NO SUCH SHAFT HAS BEEN INPUTED')                            017440 0000
1202 FORMAT(/,' FATAL ERROR,  REACH',I5,' REFERS TO EXIT SHAFT',I5,     017450 0000
    1 ' BUT NO SUCH SHAFT HAS BEEN INPUTED')                            017460 0000
1203 FORMAT(/,' FATAL ERROR, TUNNEL REACH',I5,' HAS BEEN ASSIGNED,BU    017470 0000
    1T NO TUNNEL SEGMENTS REFER TO IT')                                 017480 0000
1204 FORMAT(/,' FATAL ERROR, SHAFT',I5,' HAS BEEN ASSIGNED,BUT NO SH    017490 0000
    1AFT SEGMENTS REFER TO IT')                                         017500 0000
1500 FORMAT(/,' FATAL ERROR,NO SEPARATOR CARD AFTER NODAL POINT DATA')  017510 0000
1501 FORMAT(/,' FATAL ERROR, NO SEPARATOR CARD AFTER TUNNEL SEGMENT D   017520 0000
    1ATA',/25X,'-- OR --')                                              017530 0000
1502 FORMAT(/,' FATAL ERROR, NO SEPARATOR CARD AFTER TUNNEL REACH DAT   017540 0000
    1A')                                                                017550 0000
1503 FORMAT(/,' FATAL ERROR, CHECK FOR MISSING SEPARATOR CARD AFTER S   017560 0000
    1HAFT SEGMENT DATA',/25X,'-- OR --')                                017570 0000
1504 FORMAT(/,' FATAL ERROR, CHECK FOR MISSING SEPARATOR CARD AFTER S   017580 0000
    1HAFT DATA')                                                        017590 0000
2000 FORMAT(/,' FATAL ERROR, TUNNEL TYPE IN SEGMENT',I5, ' IN REACH',   017600 0000
    1I5,' WAS NOT SPECIFIED BY USING CODE 1,2,OR 3')                    017610 0000
2005 FORMAT(/,' FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN RE   017620 0000
    1ACH',I5,' DOES NOT MATCH TUNNEL TYPE SPECIFIED')                   017630 0000
2010 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN REACH',    017640 0000
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     1I5,' DOES NOT MATCH TUNNEL TYPE SPECIFIED')                          017650 0000
2015 FORMAT(/,' FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT      017660 0000
     1,I5,' IN REACH',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA     017670 0000
     2NK) OR 1')                                                           017680 0000
2017 FORMAT(/,' **** REMINDER ****   ALL CUT AND COVER TUNNEL SEGMEN       017690 0000
     1TS ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT',I5,       017700 0000
     2' IN REACH',I5/20X,'AND WATERTIGHT DESIGN USED')                     017710 0000
2020 FORMAT(/,' FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE      017720 0000
     1GMENT',I5,' IN REACH',I5,' BUT A WATERTIGHT TUNNEL WAS SPECIFIED')   017730 0000
2025 FORMAT(/,' **** WARNING ****   GROUND WATER ELEVATION IN SEGMENT'     017740 0000
     1,I5,' IN REACH',I5,' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI     017750 0000
     2LL BE USED IN',/' COMPUTATIONS',5X,114(1H*))                         017760 0000
2030 FORMAT(/,' FATAL ERROR, RQD IN SEGMENT',I5,' IN REACH',I5,' IS        017770 0000
     1LESS THAN 25 IN A ROCK TUNNEL. USE SOFT GROUND OR CUT AND COVER')    017780 0000
2035 FORMAT(/,' **** WARNING ****   RQD IN SEGMENT',I5,' IN REACH',I5,     017790 0000
     1' IS GREATER THAN 25 FOR A SOFT GROUND TUNNEL',5X,29(1H*))           017800 0000
2040 FORMAT(/,' FATAL ERROR, SURFACE NODAL POINTS ABOVE SEGMENT',I5,       017810 0000
     1' IN REACH',I5,' ARE OUT OF SEQUENCE')                               017820 0000
2045 FORMAT(/,' FATAL ERROR, ONE OR BOTH SURFACE NODAL POINTS ABOVE S      017830 0000
     1EGMENT',I5,' IN REACH',I5,' WERE NOT LISTED WITH OTHER NODAL POIN    017840 0000
     1T DATA CARDS')                                                       017850 0000
2050 FORMAT(/,' FATAL ERROR,SURFACE NODAL POINT ELEVATIONS IN SEGMENT'     017860 0000
     1,I5,' IN REACH',I5,' ARE BELOW TUNNEL ELEVATION')                    017870 0000
2055 FORMAT(/,' FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT',I5,' IN      017880 0000
     1 REACH',I5,' WAS NOT INPUT')                                         017890 0000
2060 FORMAT(/,' FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S      017900 0000
     1EGMENT',I5,' IN REACH',I5,' WAS NOT SPECIFIED')                      017910 0000
2061 FORMAT(/,' **** WARNING ****   POSSIBLE ERROR IN PERMEABILITY IN     017920 0000
     1 SEGMENT',I5,' IN REACH',I5,' - INPUT IS GREATER THAN 10 CM/SEC',    017930 0000
     25X,12(1H*))                                                          017940 0000
2062 FORMAT(/,' **** WARNING ****   FRICTION ANGLE IN SEGMENT',I5,' I      017950 0000
     1N REACH',I5,' IS GREATER THAN 45 DEGREES',5X,35(1H*))                017960 0000
2063 FORMAT(/,' FATAL ERROR, FRICTION ANGLE IN SEGMENT',I5,' IN REACH'     017970 0000
     1,I5,' IS GREATER THAN 100.CHECK FOR NUMBER SHIFTED ON DATA CARD')    017980 0000
2064 FORMAT(/,' FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT',I5,' IN       017990 0000
     1REACH',I5,' IS TOO LARGE FOR SOIL OR POOR ROCK')                     018000 0000
2065 FORMAT(/,' FATAL ERROR, DEWATERING REQUIREMENT IN SEGMENT',I5,       018010 0000
     1' IN REACH',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK)      018020 0000
     2OR 1')                                                               018030 0000
2070 FORMAT(/,' **** WARNING ****   IMPERVIOUS LAYER ELEVATION IN SEG      018040 0000
     1MENT',I5,' IN REACH',I5,' IS EITHER ZERO OR BLANK - ELEVATION ZER    018050 0000
     2O WILL BE USED'/' IN COMPUTATIONS',5X,111(1H*))                      018060 0000
2072 FORMAT(/,' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT',      018070 0000
     1I5,' IN REACH',I5,' IS ABOVE AVERAGE SURFACE ELEVATION')             018080 0000
2073 FORMAT(/,' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT',      018090 0000
     1I5,' IN REACH',I5,' IS AT THE SURFACE AND SOIL GRAIN SIZE INPUT      018100 0000
     2EXCEEDS0.005')                                                       018110 0000
2075 FORMAT(/,' FATAL ERROR, SUPPORT TYPE IN SOFT GROUND SEGMENT',        018120 0000
     1I5,' IN REACH',I5,' WAS NOT SPECIFIED BY CODE 1,2,3,4,5,OR 6')       018130 0000
2080 FORMAT(/,' FATAL ERROR, SUPPORT TYPE IN SEGMENT',I5,' IN REACH',     018140 0000
     1I5,' DOES NOT MATCH TUNNEL TYPE SPECIFIED')                          018150 0000
2085 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN REACH',      018160 0000
     1I5,' DOES NOT MATCH SUPPORT TYPE SPECIFIED')                         018170 0000
2090 FORMAT(/,' **** WARNING ****   ROCK ELEVATION IN SEGMENT',I5,        018180 0000
     1' IN REACH',I5,' IS EITHER ZERO OR BLANK - ELEVATION ZERO WILL B     018190 0000
     2E USED IN'/' COMPUTATIONS',5X,114(1H*))                              018200 0000
2092 FORMAT(/,' FATAL ERROR, ROCK ELEVATION IN SEGMENT',I5,' IN REACH'    018210 0000
     1,I5,' IS ABOVE AVERAGE SURFACE ELEVATION')                           018220 0000
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2094 FORMAT(/,' **** WARNING ****   CUT AND COVER BOX IN SEGMENT',I5,   018230 0000
    1' IN REACH',I5,' EXCEEDS 100 FEET',5X,42(1H*))                     018240 0000
2095 FORMAT(/,' FATAL ERROR, OPEN CUT BRACING IN SEGMENT',I5,' IN REA   018250 0000
    1CH',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK),1,2,OR 3')  018260 0000
2100 FORMAT(/,' FATAL ERROR, BRACING CODE FOR VERTICAL OPEN CUT IN SE   018270 0000
    1GMENT',I5,' IN REACH',I5,' WAS NOT SPECIFIED BY USING CODE 1,2,OR  018280 0000
    1 3')                                                               018290 0000
2105 FORMAT(/,' FATAL ERROR, DECKING CODE IN SEGMENT',I5,' IN REACH',   018300 0000
    1I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) OR 1')         018310 0000
2115 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN REA   018320 0000
    1CH',I5,' IS TOO HIGH, EXCAVATION IS IMPOSSIBLE')                   018330 0000
2120 FORMAT(/,' FATAL ERROR, STABILIZATION METHOD IN SEGMENT',I5,' IN   018340 0000
    1 REACH',I5,' WAS NOT SPECIFIED BY CODE ZERO(OR BLANK),1,2,OR 3')   018350 0000
2125 FORMAT(/,' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT',I5,     018360 0000
    1' IN REACH',I5,' WAS NOT SPECIFIED BY CODE 1,2,3,OR 4')            018370 0000
2130 FORMAT(/,' FATAL ERROR, AIR PRESSURE IN SEGMENT',I5,' IN REACH',   018380 0000
    1I5,' WAS NOT SPECIFIED WHEN STABILITY NUMBER WAS INPUT AND AIR P   018390 0000
    2RESSURE'/' STABILIZATION SPECIFIED')                               018400 0000
2135 FORMAT(/,' FATAL ERROR, STABILITY NUMBER WAS SPECIFIED IN SEGMEN   018410 0000
    1T',I5,' IN REACH',I5,', BUT STABILIZATION USE CODE DOES NE 4')     018420 0000
2137 FORMAT(/,' FATAL ERROR, AIR PRESSURE IS SPECIFIED IN SEGMENT',I5,  018430 0000
    1' IN REACH',I5,' BUT STABILIZATION METHOD NOT COMPRESSED AIR')     018440 0000
2140 FORMAT(/,' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT',I5,     018450 0000
    1' IN REACH',I5,' DOES NOT AGREE WITH METHOD SPECIFIED')            018460 0000
2145 FORMAT(/,' **** WARNING ****   STABILIZATION METHOD IN SEGMENT',   018470 0000
    1I5,' IN REACH',I5,' IS NOT ACCEPTABLE',5X,39(1H*))                 018480 0000
2147 FORMAT(/,' FATAL ERROR, INPUT IN SEGMENT',I5,' IN REACH',I5,       018490 0000
    1' REQUIRES USE OF AN UNACCEPTABLE STABILIZATION METHOD')           018500 0000
2150 FORMAT(/,' FATAL ERROR, TUNNEL SIZE IN REACH',I5,' INDICATES CU    018510 0000
    1T AND COVER SECTION, BUT SHAPE CODE IS NOT ZERO')                  018520 0000
2151 FORMAT(/,' FATAL ERROR, TUNNEL SHAPE IN REACH',I5,' INDICATES C    018530 0000
    1UT AND COVER SECTION, BUT SIZE IS SPECIFIED IN WRONG COLUMN')      018540 0000
2152 FORMAT(/,' FATAL ERROR, SHAPE IN REACH',I5,' INDICATES CUT AND     018550 0000
    1COVER, BUT A MUCK TRANSPORT METHOD WAS SPECIFIED')                 018560 0000
2153 FORMAT(/,' FATAL ERROR, TUNNEL REACH',I5,' IS NOT CUT AND COVER    018570 0000
    1, BUT NO MUCK TRANSPORT METHOD WAS SPECIFIED')                     018580 0000
2155 FORMAT(/,' FATAL ERROR, WORK HOURS IN REACH',I5,' WERE NOT SPEC    018590 0000
    1IFIED BY A NUMBER FROM0 TO 24')                                    018600 0000
2160 FORMAT(/,' FATAL ERROR, WORK DAYS IN REACH',I5,' WERE NOT SPECI    018610 0000
    1FIED BY A NUMBER FROM 4 TO 7')                                     018620 0000
2165 FORMAT(/,' FATAL ERROR, ONE OR BOTH BOX DIMENSIONS IN REACH',I5,   018630 0000
    1' WERE NOT INPUT')                                                 018640 0000
2170 FORMAT(/,' **** WARNING ****   TOTAL CLEAR BOX WIDTH IN REACH',   018650 0000
    1I5,' EXCEEDS 40 FEET',5X,55(1H*))                                  018660 0000
2175 FORMAT(/,' FATAL ERROR, OPEN CUT IS SPECIFIED IN REACH',I5,        018670 0000
    1' AND NUMBER OF BOX UNITS NOT SPECIFIED FOR A SINGLE LEVEL BOX')   018680 0000
2180 FORMAT(/,' **** WARNING ****   BOX HEIGHT IN REACH',I5,' IS GRE    018690 0000
    1ATER THAN 20 FEET FOR A SINGLE LEVEL BOX',5X,35(1H*))              018700 0000
2185 FORMAT(/,' **** WARNING ****   TOTAL CLEAR BOX HEIGHT IN REACH',   018710 0000
    1I5,' IS GREATER THAN 40 FEET FOR A DOUBLE BOX',5X,39(1H*))         018720 0000
2190 FORMAT(/,' **** WARNING ****   DEWATERING MAY BE USED AS A STABI   018730 0000
    1LIZATION METHOD IN SEGMENT',I5,' IN REACH',I5,' AND IMPERVIOUS LA   018740 0000
    2YER IS'/20X,' INCORRECTLY PLACED ABOVE THE TUNNEL. ELIMP WILL BE   018750 0000
    3ASSUMED AT TUNNEL INVERT.')                                        018760 0000
2195 FORMAT(/,' FATAL ERROR, COMPRESSED AIR WAS REQUIRED IN SEGMENT',   018770 0000
    1I5,' IN REACH',I5,' AND TRUCK MUCK TRANSPORT SPECIFIED')           018780 0000
2200 FORMAT(/,' FATAL ERROR, CAST IRON TUNNEL SUPPORT WAS SPECIFIED I   018790 0000
    1N SEGMENT',I5,' IN REACH',I5,', BUT CIRCULAR SHAPE NOT SPECIFIED') 018800 0000
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2201 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN REACH',I5,' IS NOT CUT    018810 0000
    1 AND COVER, BUT NO SHAPE WAS SPECIFIED')                           018820 0000
2202 FORMAT(/,' FATAL ERROR, SHAPE SPECIFIED FOR SEGMENT',I5,' IN REA   018830 0000
    1CH',I5,' IS NOT FOR CUT AND COVER')                                018840 0000
2203 FORMAT(/,' **** WARNING ****   SOUND ROCK ELEVATION LIES ABOVE B   018850 0000
    1ASE OF TRENCH IN SEGMENT',I5,' IN REACH',I5,' AND RQD IS BETWEEN   018860 0000
    225-50.'/20X,'RQD MAY BE TOO LOW FOR DESIGN AS SOUND ROCK. )        018870 0000
2204 FORMAT(/,' FATAL ERROR, SOUND ROCK ELEVATION LIES ABOVE BASE OF    018880 0000
    1 TRENCH IN SEGMENT',I5,' IN REACH',I5,' AND RQD IS LESS THAN 25.'/ 018890 0000
    2 13X,' RQD IS TOO LOW FOR DESIGN AS SOUND ROCK')                   018900 0000
2205 FORMAT(/,' FATAL ERROR, DEWATERING MUST BE ALLOWED IN SLOPING CU   018910 0000
    1T SEGMENT',I5,' IN REACH',I5,' BECAUSE WATER TABLE IS ABOVE BASE   018920 0000
    2OF TRENCH AND'/14X,' ABOVE IMPERVIOUS LAYER')                      018930 0000
2207 FORMAT(/,' FATAL ERROR, SHAFT TYPE IN SEGMENT',I5,' IN SHAFT',I5,  018940 0000
    1' WAS NOT SPECIFIED BY USING CODE 1,2,OR 3')                       018950 0000
2208 FORMAT(/,' **** WARNING *****   NO METHOD OF EXCAVATION OR LININ   018960 0000
    1G TYPE WERE INPUT FOR SEGMENT',I5,' IN SHAFT',I5,'. A DUMMY SHAFT  018970 0000
    2 IS ASSUMED')                                                      018980 0000
2210 FORMAT(/,' FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN SH   018990 0000
    1AFT',I5,' DOES NOT MATCH SHAFT TYPE SPECIFIED')                    019000 0000
2212 FORMAT(/,' FATAL ERROR, RQD IN SEGMENT',I5,' IN SHAFT',I5,' IS     019010 0000
    1LESS THAN 25 IN A ROCK SHAFT. USE SOFT GROUND OR CUT AND COVER')   019020 0000
2215 FORMAT(/,' **** WARNING ****   RQD IN SEGMENT',I5,' IN SHAFT',I5,  019030 0000
    1' IS GREATER THAN 25 FOR A SOFT GROUND SHAFT',5X,30(1H*))          019040 0000
2220 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN SHAFT',    019050 0000
    1I5,' DOES NOT MATCH SHAFT TYPE SPECIFIED')                         019060 0000
2225 FORMAT(/,' FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT'  019070 0000
    1,I5,' IN SHAFT',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA   019080 0000
    1NK) OR 1')                                                         019090 0000
2227 FORMAT(/,' **** REMINDER ****   ALL CUT AND COVER SHAFT SEGMENT    019100 0000
    1S ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT',I5,      019110 0000
    2' IN SHAFT',I5/20X,'AND WATERTIGHT DESIGN USED')                   019120 0000
2230 FORMAT(/,' FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE   019130 0000
    1GMENT',I5,' IN SHAFT',I5,' BUT A WATERTIGHT SHAFT WAS SPECIFIED')  019140 0000
2235 FORMAT(/,' **** WARNING ****   GROUND WATER ELEVATION IN SEGMENT'  019150 0000
    1,I5,' IN SHAFT',I5,' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI   019160 0000
    2LL BE USED IN'/' COMPUTATIONS',5X,114(1H*))                        019170 0000
2240 FORMAT(/,' FATAL ERROR, GROUND WATER ELEVATION LOCATED WITHIN SE   019180 0000
    1GMENT',I5,' IN SHAFT',I5,' - NEED TO DEFINE NEW SEGMENT AT GWT')   019190 0000
2245 FORMAT(/,' FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT',I5,' IN   019200 0000
    1 SHAFT',I5,' WAS NOT INPUT')                                       019210 0000
2250 FORMAT(/,' FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S   019220 0000
    1EGMENT',I5,' IN SHAFT',I5,' WAS NOT SPECIFIED')                    019230 0000
2251 FORMAT(/,' **** WARNING ****   POSSIBLE ERROR IN PERMEABILITY IN   019240 0000
    1 SEGMENT',I5,' IN SHAFT',I5,' - INPUT IS GREATER THAN 10 CM/SEC',  019250 0000
    25X,12(1H*))                                                        019260 0000
2252 FORMAT(/,' **** WARNING ****   FRICTION ANGLE IN SEGMENT',I5,' I   019270 0000
    1N SHAFT',I5,' IS GREATER THAN 45 DEGREES',5X,35(1H*))              019280 0000
2253 FORMAT(/,' FATAL ERROR, FRICTION ANGLE IN SEGMENT',I5,' IN SHAFT'  019290 0000
    1,I5,' IS GREATER THAN 100.CHECK FOR NUMBER SHIFTED ON DATA CARD')  019300 0000
2254 FORMAT(/,' FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT',I5,' IN    019310 0000
    1SHAFT',I5,' IS TOO LARGE FOR SOIL OR POOR ROCK')                   019320 0000
2255 FORMAT(/,' FATAL ERROR, DEWATERING REQUIREMENT IN SEGMENT',I5,     019330 0000
    1' IN SHAFT',I5,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK)    019340 0000
    2OR 1')                                                             019350 0000
2260 FORMAT(/,' **** WARNING ****   IMPERVIOUS LAYER ELEVATION IN SEG   019360 0000
    1MENT',I5,' IN SHAFT',I5,' IS EITHER ZERO OR BLANK - ELEVATION ZER  019370 0000
    2O WILL BE USED'/' IN COMPUTATIONS',5X,111(1H*))                    019380 0000
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2262 FORMAT(/,' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT',I5  019390 0000
    1,' IN SHAFT',I5,' IS ABOVE BASE OF SEGMENT. NEED TO DEFINE NEW I   019400 0000
    2MPERVIOUS'/' LAYER BELOW SEGMENT OR DEFINE NEW SEGMENT AT IMPERVI  019410 0000
    3OUS LAYER')                                                        019420 0000
2265 FORMAT(/,' FATAL ERROR, SUPPORT TYPE IN SOFT GROUND SEGMENT',I5,   019430 0000
    1' IN SHAFT',I5,' WAS NOT SPECIFIED BY CODE 1,2,3,4, OR 5')         019440 0000
2270 FORMAT(/,' FATAL ERROR, SUPPORT TYPE IN SEGMENT',I5,' IN SHAFT',   019450 0000
    1I5,' DOES NOT MATCH SHAFT TYPE SPECIFIED')                         019460 0000
2275 FORMAT(/,' FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN SHAFT',    019470 0000
    1I5,' DOES NOT MATCH SUPPORT TYPE SPECIFIED')                       019480 0000
2285 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN SHA   019490 0000
    1FT',I5,' IS TOO HIGH, EXCAVATION IS IMPOSSIBLE')                   019500 0000
2290 FORMAT(/,' FATAL ERROR, STABILIZATION METHOD IN SEGMENT',I5,' IN   019510 0000
    1 SHAFT',I5,' WAS NOT SPECIFIED BY CODE ZERO(OR BLANK),1,2,OR 3')   019520 0000
2295 FORMAT(/,' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT',I5,     019530 0000
    1' IN SHAFT',I5,' WAS NOT SPECIFIED BY CODE 1,2,3,OR 4')            019540 0000
2300 FORMAT(/,' FATAL ERROR, AIR PRESSURE IN SEGMENT',I5,' IN SHAFT',   019550 0000
    1I5,' WAS NOT SPECIFIED WHEN STABILITY NUMBER WAS INPUT AND AIR P   019560 0000
    2RESSURE'/' STABILIZATION SPECIFIED')                               019570 0000
2305 FORMAT(/,' FATAL ERROR, STABILITY NUMBER WAS SPECIFIED IN SEGMEN   019580 0000
    1T',I5,' IN SHAFT',I5,' BUT STABILIZATION USE CODE DOES NE 4')      019590 0000
2307 FORMAT(/,' FATAL ERROR, AIR PRESSURE IS SPECIFIED IN SEGMENT',I5,  019600 0000
    1' IN SHAFT', I5,' BUT STABILIZATION METHOD NOT COMPRESSED AIR')    019610 0000
2310 FORMAT(/,' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT',I5,     019620 0000
    1' IN SHAFT',I5,' DOES NOT AGREE WITH METHOD SPECIFIED')            019630 0000
2315 FORMAT(/,' **** WARNING ****   STABILIZATION METHOD IN SEGMENT',   019640 0000
    1I5,' IN SHAFT',I5,' IS NOT ACCEPTABLE',30(1H*))                    019650 0000
2320 FORMAT(/,' FATAL ERROR, INPUT IN SEGMENT',I5,' IN SHAFT',I5,       019660 0000
    1' REQUIRES USE OF AN UNACCEPTABLE STABILIZATION METHOD')           019670 0000
2325 FORMAT(/,' FATAL ERROR, SHAPE IN SHAFT',I5,' WAS NOT SPECIFIED     019680 0000
    1BY USING CODE ZERO(OR BLANK),1,OR 2')                              019690 0000
2327 FORMAT(/,' **** REMINDER ****   SHAFT',I5,' IS A DUMMY. IT HAS     019700 0000
    1NO CONSTRUCTION COST')                                             019710 0000
2330 FORMAT(/,' FATAL ERROR, SHAFT SHAPE IN SHAFT',I5,' INDICATES A     019720 0000
    1DUMMY SHAFT, BUT A SIZE IS SPECIFIED')                             019730 0000
2332 FORMAT(/,' FATAL ERROR, SHAFT SIZE IN SHAFT',I5,' INDICATES A D    019740 0000
    1UMMY SHAFT, BUT SHAPE CODE IS NOT ZERO')                           019750 0000
2335 FORMAT(/,' FATAL ERROR, WORK HOURS IN SHAFT',I5,' WERE NOT SPEC    019760 0000
    1IFIED BY A NUMBER FROM0 TO 24')                                    019770 0000
2340 FORMAT(/,' FATAL ERROR, WORK DAYS IN SHAFT',I5,' WERE NOT SPECI    019780 0000
    1FIED BY A NUMBER FROM 4 TO 7')                                     019790 0000
2345 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN SHAFT',I5,' IS IN ROCK    019800 0000
    1 BUT SHAPE IS SQUARE')                                             019810 0000
2350 FORMAT(/,' FATAL ERROR, CAST IRON SHAFT SUPPORT WAS SPECIFIED IN   019820 0000
    1 SEGMENT',I5,' IN SHAFT',I5,', BUT CIRCULAR SHAPE NOT SPECIFIED')  019830 0000
2355 FORMAT(/,' FATAL ERROR, CIRCULAR SHAPE WAS NOT SPECIFIED FOR MOL   019840 0000
    1ED EXCAVATION IN SEGMENT',I5,' IN SHAFT',I5)                       019850 0000
C     ------------------------------------------------------------------ 019860 0000
C                                                                        019870 0000
      END                                                                019880 0000
      SUBROUTINE SFTSET(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,  019890 0000
     1NTRMAX)                                                            019900 0000
C     ------------------------------------------------------------------ 019905
C     ------------------------------------------------------------------ 019910 0000
C                                                                        019920 0000
C     THIS SUBROUTINE WILL CREATE AN ARRAY CALLED SHAFT WHICH CONTAINS   019930 0000
C     PERTINENT SHAFT INFORMATION                                        019940 0000
                                                                         019950 0000
```

(Continued)

```
C
C
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
      COMMON /BASIC/  NSS,NTS
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
      COMMON /F/ IERROR,ISTOP
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23,,
     1 TRDATA(NTRMAX,23)
C     ------------------------------------------------------------------
C
C     INITIALIZE
C
      NPT=B(1,3)
      NPB=B(1,4)
      NSEGS=0
      I=1
      NSSEG1=1
C     ------------------------------------------------------------------
C
   10 IP=I
      I=I+1
      NSEGS=NSEGS+1
C
C     CHECK FOR LAST SHAFT SEGMENT CARD
      IF(I.GT.NSS) GO TO 30
C
C     SEE IF PREVIOUS SEGMENT WAS IN SAME SHAFT AS THIS SEGMENT
      IF(B(I,1).EQ.B(IP,1)) GO TO 20
      GO TO 30
   20 NPB=B(I,4)
      GO TO 10
   30 NSHAFT=B(IP,1)
      SHAFT(NSHAFT,1)=NSSEG1
      SHAFT(NSHAFT,2)=NPT
      SHAFT(NSHAFT,3)=NPB
      SHAFT(NSHAFT,4)=NSEGS
      IF(I.GT.NSS) GO TO 40
      NPT=B(I,3)
      NPB=B(I,4)
      NSSEG1=I
      NSEGS=0
      GO TO 10
C     ------------------------------------------------------------------
   40 CONTINUE
C     CHECK FOR SHAFTS CONTAINING BOTH CUT AND COVER AND NON-CC SEGMENTS
      DO 800 NSHAFT=1,NSMAX
      IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 800
      NSSEG1=SHAFT(NSHAFT,1)
      NSEGS=SHAFT(NSHAFT,4)
      DO 700 J=1,NSEGS
      NSSTYP=B(NSSEG1,15)
      IF(J.EQ.1) GO TO 700
      IF(NSSTYP.LT.3) GO TO 700
C     SEGMENT IS IN CUT AND COVER
      IF(NSSTYP.EQ.B(NSSEG1-1,15))GO TO 700
      ISTOP=1
      NSSEG=B(NSSEG1,2)
```

(Continued)

```
      WRITE(LO,1000) NSSEG,NSHAFT                                       020540 0000
  700 NSSEG1=NSSEG1+1                                                   020550 0000
  800 CONTINUE                                                          020560 0000
C     ------------------------------------------------------------------ 020570 0000
C     CHECK FOR ANY STOPS FOUND                                         020580 0000
      IF(ISTOP.EQ.0) RETURN                                             020590 0000
C     FATAL ERRORS DETECTED.TERMINATE RUN AND GO TO NEXT DATA DECK      020600 0000
      WRITE(LO,2000)                                                    020610 0000
      CALL NEXSET(LO,LI)                                                020620 0000
C     ------------------------------------------------------------------ 020630 0000
 1000 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN SHAFT',I5,' IS IN CUT    020640 0000
     1AND COVER,BUT NOT ALL OTHER SEGMENTS ARE')                        020650 0000
 2000 FORMAT(///,1X,119(1H*),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS I  020660 0000
     1N SUBROUTINE SFTSET' ,/1X,119(1H*))                               020670 0000
C     ------------------------------------------------------------------ 020680 0000
C     ------------------------------------------------------------------ 020690 0000
C                                                                        020700 0000
      RETURN                                                            020710 0000
      END                                                               020720 0000
```

(Continued)

```
      END                                                               020720 0000
      SUBROUTINE LENGTH     (A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,  020730 0000
     1NPMAX,NSMAX,NTRMAX)                                               020735
C     ------------------------------------------------------------------ 020740 0000
C     ------------------------------------------------------------------ 020750 0000
C     THIS SUBROUTINE CALCULATES ALL SEGMENT LENGHTS AND MUCK TRANSPORT  020760 0000
C     DISTANCES                                                          020770 0000
C     ------------------------------------------------------------------ 020780 0000
C     ------------------------------------------------------------------ 020790 0000
      COMMON /BASIC/  NSS,NTS                                            020800 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE            020810 0000
      COMMON /F/ IERROR,ISTOP                                            020820 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),  020830 0000
     1 TRDATA(NTRMAX,23),CUMSL(NPMAX)                                    020840 0000
C     ------------------------------------------------------------------ 020850 0000
C     ------------------------------------------------------------------ 020860 0000
C     CALCULATE SHAFT SEGMENT LENGTHS                                    020870 0000
      DO 20 I=1,NSS                                                      020880 0000
      NPT=B(I,3)                                                         020890 0000
      NPB=B(I,4)                                                         020900 0000
      ELNPT=CNP(NPT,2)                                                   020910 0000
      ELNPB=CNP(NPB,2)                                                   020920 0000
      SSEGL=ELNPT-ELNPB                                                  020930 0000
   20 B(I,35)=SSEGL                                                      020940 0000
C     ------------------------------------------------------------------ 020950 0000
C                                                                        020960 0000
C     CALCULATE SHAFT HOISTING DISTANCES FOR EACH SEGMENT AND EACH SHAFT 020970 0000
C     SUM .........RUNNING SUM OF SHAFT SEGMENT LENGTHS IN SHAFT I       020980 0000
C                                                                        020990 0000
      DO 50 I=1,NSMAX                                                    021000 0000
      IF(SHAFT(I,1).LT.-10.E29) GO TO 50                                 021010 0000
      NSSEG1=SHAFT(I,1)                                                  021020 0000
      NSEGS=SHAFT(I,4)                                                   021030 0000
      SUM=0.                                                             021040 0000
      DO 40 J=1,NSEGS                                                    021050 0000
      SSEGL=B(NSSEG1,35)                                                 021060 0000
      HH=SUM+.5*SSEGL                                                    021070 0000
      B(NSSEG1,36)=HH                                                    021080 0000
      SUM=SSEGL+SUM                                                      021090 0000
   40 NSSEG1=NSSEG1+1                                                    021100 0000
      SHAFT(I,8)=SUM                                                     021110 0000
C     CHECK FOR SHAFT DEPTH GREATER THAN 3000 FEET                       021120 0000
      IF(SHAFT( I,8).GT.3000.) WRITE(LO,1071) I                          021130 0000
   50 CONTINUE                                                           021140 0000
C     ------------------------------------------------------------------ 021150 0000
C     CALCULATE ACTUAL TUNNEL SEGMENT LENGTH (LENGTH ALONG THE SEGMENT). 021160 0000
C     AS AN INTERMEDIATE STEP, CALCULATE THE STATIONING OF THE TUNNEL    021170 0000
C     NODAL POINTS ALONG THE LENGTH OF THE SEGMENTS (NOT THE HORIZONTAL  021180 0000
C     LENGTH), AND THEN CALCULATE HORIZONTAL STATIONING                  021190 0000
C                                                                        021200 0000
      STA=STABEG                                                         021210 0000
      NPL=A(1,2)                                                         021220 0000
      CUMSL(NPL)=0.0                                                     021230 0000
      CNP(NPL,1)=STABEG                                                  021240 0000
      DO 60 I=1,NTS                                                      021250 0000
      TSEGL=A(I,45)                                                      021260 0000
```

(Continued)

```
      NPL=A(I,2)
      NPR=A(I,3)
      ELNPL=CNP(NPL,2)
      ELNPR=CNP(NPR,2)
      SEGL=SQRT((ELNPL-ELNPR)**2+TSEGL**2)
      CUMSL(NPR)=CUMSL(NPL)+SEGL
      STA=STA+TSEGL
C     THE NEXT STATEMENT CONVERTS TSEGL FROM HORIZ. TO TRUE LENGTH
      TSEGL=SEGL
      A(I,45)=TSEGL
   60 CNP(NPR,1)=STA
C     ------------------------------------------------------------------
C
C     CALCULATE AVERAGE MUCK TRANSPORTATION DISTANCES AND SLOPES (TO
C     MIDPOINT OF SEGMENTS) USING NODAL POINT STATIONING
C
      DO 70 I=1,NTS
      NPL=A(I,2)
      NPR=A(I,3)
      ELNPL=CNP(NPL,2)
      ELNPR=CNP(NPR,2)
      NREACH=A(I,4)
      NSHAFT=TRDATA(NREACH,1)
      NPBS=SHAFT(NSHAFT,3)
      ELNPBS=CNP(NPBS,2)
      DM=ABS(CUMSL(NPBS)-(CUMSL(NPL)+CUMSL(NPR))/2.)/5280.
      RL=DM*5280.+ABS(CUMSL(NPL)-CUMSL(NPR))/2.
C     CHECK FOR REACH LENGTH GREATER THAN 105600 FEET( 20 MILES)
      IF(RL.GT.105600.) WRITE(LO,1061) NREACH
      A(I,46)=DM
C     CALCULATE ELEVATION DIFFERENCE FROM BASE OF SHAFT TO SEG. MIDPOINT
      ELEV=ELNPBS-(ELNPL+ELNPR)/2.
      HSLOPE=ELEV/SQRT((DM*5280.)**2-ELEV**2)
   70 A(I,47)=HSLOPE
C     ------------------------------------------------------------------
C     CHECK FOR DUMMY SHAFT ADJACENT TO AT LEAST ONE CUT AND COVER REACH
      DO 200 I=1,NSMAX
      IF(SHAFT(I,1).LT.-10.E29) GO TO 200
      ISHAPS=SHAFT(I,16)
      IF(ISHAPS.NE.0) GO TO 200
      NPORT=SHAFT(I,23)
      IF(NPORT.EQ.1) GO TO 200
      NPBS=SHAFT(I,3)
      STA=CNP(NPBS,1)
      IF(STA.GT.STABEG) GO TO 100
      NTSTYP=A(1,16)
      IF(NTSTYP.EQ.3) GO TO 200
      GO TO 175
  100 STA=STA-1.0
      IJK=0
      DO 150 J=1,NTS
      NPL=A(J,2)
      NPR=A(J,3)
      IF(STA.GT.CNP(NPL,1).AND.STA.LT.CNP(NPR,1)) GO TO 160
  150 CONTINUE
  160 NTSTYP=A(J,16)
      IF(NTSTYP.EQ.3) GO TO 200
      IF(J.EQ.NTS) GO TO 175
```

(Continued)

```
      NTSTYP=A(J+1,16)                                                  021850 0000
      IF(NTSTYP.EQ.3) GO TO 200                                         021860 0000
  175 IERROR=1                                                          021870 0000
      WRITE(LO,2000) I                                                  021880 0000
  200 CONTINUE                                                          021890 0000
C     ------------------------------------------------------------------ 021900 0000
 1061 FORMAT(/,' **** WARNING ****   TOTAL LENGTH OF REACH',I5,' EXCE   021910 0000
     1EDS 20 MILES',5X,51(1H*))                                         021920 0000
 1071 FORMAT(/,' **** WARNING ****   SHAFT',I5,' IS OVER 3000 FT DEEP   021930 0000
     1,5X,63(1H*))                                                      021940 0000
 2000 FORMAT(/,' FATAL ERROR, SHAFT',I5,' IS A DUMMY SHAFT, BUT THERE   021950 0000
     1 ARE NO ADJACENT CUT AND COVER REACHES')                          021960 0000
      RETURN                                                            021970 0000
      END                                                               021980 0000
      SUBROUTINE INOUT(I,A,B,CNP,SHAFT,TRDATA,NLINES,IP,NTSMAX,NSSMAX,  021990 0000
     1NPMAX,NSMAX,NTRMAX)                                               021995
C     ------------------------------------------------------------------ 022000 0000
C     ------------------------------------------------------------------ 022010 0000
C                                                                        022020 0000
C     THIS SUBROUTINE LISTS OUT THE INPUT DATA                           022030 0000
C     SEGMENTS ARE LISTED IN THE ORDER OF APPEARANCE ALONG THE ROUTE     022040 0000
C                                                                        022050 0000
C     I= SEGMENT SEQUENCE NUMBER, NUMBER IN ORDER OF APPEARANCE          022060 0000
C                                                                        022070 0000
C     ------------------------------------------------------------------ 022080 0000
C     ------------------------------------------------------------------ 022090 0000
C                                                                        022100 0000
      COMMON /BASIC/  NSS,NTS                                           022110 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE           022120 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 022130 0000
     1 TRDATA(NTRMAX,23)                                                022140 0000
      DIMENSION FMT1(21),FMT2(15),FMT3(7),FMT4(20),FMT5(13)             022150 0000
C     ******************************************************************* 022160 0000
C     DOUBLE PRECISION STATEMENTS ARE REQUIRED FOR LITERALS HAVING       022170 0000
C     5 TO 8 CHARACTERS ON COMPUTERS THAT HAVE 4 CHARACTERS PER WORD,    022180 0000
C     SUCH AS THE IBM 360, FORTRAN IV COMPILER.                          022190 0000
C     REMOVE THE FOLLOWING DOUBLE PRECISION STATEMENTS FOR COMPUTERS     022200 0000
C     THAT HAVE  6 CHARACTERS PER WORD SUCH AS THE UNIVAC 1108,          022210 0000
C     FORTRAN V COMPILER.                                                022220 0000
C     ALL LITERALS IN THIS SUBROUTINE HAVE A MAXIMUM OF 6 CHARACTERS     022230 0000
C     TO BE COMPATABLE WITH BOTH SYSTEMS.                                022240 0000
      DOUBLE PRECISION BLANK,CONV,TMOLER,TMOLES,HANDS,RIPPER,VERTCC,    022260 0000
     1SLOPCC,HORSE,BASKET,CIRCLE,BOX,TWOBOX,SQUARE,CONVYR,TRUCK,TRAIN,  022270 0000
     2CONTRK,TNONE,WET,DRY,AND,YES,CIRSEG,CONSEG,STLSEG,STLSET,SOLDER,  022280 0000
     3SLURRY,OPENCT,AIRPRS,DEWATR,GRDINJ,USENO,PREFNO,STRUT,ANCHOR,     022290 0000
     4STRANC                                                            022300 0000
      DOUBLE PRECISION SHAPE,REMK,EXCAV,WTLIN,AR,TL,HOURS,DAYS,SUPORT,  022310 0000
     1DWATER,STABIL,GAMMA,PERM,STABNO,AIRPR,DECK,BRACE,BFT,EXMS,        022320 0000
     2SHAPS,GRDW                                                        022330 0000
      REAL*8  JBLANK,NONE,ISHOT,ICONC,IPREC,IFNEC,MUSTUS,IUSE,LTYP      022340 0000
C     ******************************************************************* 022370 0000
      CHARACTER*6 FM1/'2X,A6,'/,FM2/'A5,'/,FM3/'A5)'/,FM4/              022380 0000
     1'(1X,A4'/,
     1FM5/'1X,A4,'/,FM6/'5X,A4,'/,FM7/'1X,A6,'/,FM8/'4X,A6,'/,FM9/'A6,'/ 022390 0000
     2,FM10/'A6)'/,FM11/'(1X,I4'/,FM12/'F8.1,'/,FM13/'F5.1,'/,          022400 0000
     3FM14/'F5.1)'/,FM15/'I5,'/,FM16/'3X,I6,'/,FM17/'F7.1,'/,           022410 0000
     4FM18/'E10.2,'/,FM19/'F6.1,'/,FM20/'F6.1)'/,FM21/'F7.2,'/,         022420 0000
     5FM22/'3X,A4,'/,FM23/'I7,'/                                        022430 0000
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(Continued)

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      CHARACTER*6 FMT1/'(1X,I4',',I5,','I5,','I5,','I6,','I7,2X,','A6,',  022440 0000
     1'F7.2,'
     1,'2X,A6,','2X,A6,','F8.1,','3X,I6,','I5,','I5,','I5,','2X,A6,',     022450 0000
     2'F5.1,','A6,','F7.1,','F5.1,','F5.1)'/                              022460 0000
      CHARACTER*6 FMT2/'(10X,','I5,I5,','E10.2,','F7.1,', F5.0,',         022470 0000
     1'F7.0,'
     1 'E10.2,','I5,','A6,','F8.1,','2X,A6,','F6.1,','1X,A6,','1X,A6,',   022480 0000
     2'F6.1)'/                                                            022490 0000
      CHARACTER*6 FMT3/'(10X,','F7.1,','1X,A6,','2X,A6,','I5,','F8.2,'    022500 000
     1,'F7.2)'/
      CHARACTER*6 FMT4/'(1X,I4',',I5,','I5,','  I6,','2X,A6,','F6.2,',   022510 0000
     1'1X,A6,'
     1'F8.1,','3X,I6,','I5,','A6,','A6,','F6.1,','A6,','F7.1,','I8,',    022520 0000
     2'I7,','F9.1,','F6.1,','F5.1)'/                                      022530 0000
      CHARACTER*6 FMT5/'(20X,'  'F7.1,','F5.0,','F7.0,','E10.2,',         022540 0000
     1'E10.2,'
     1'4X,A6,','F8.1,','2X,A6,','F6.1,','2X,A6,','1X,A6,','F6.1)'/        022550 0000
C     ------------------------------------------------------------------ 022560 0000
      DATA BLANK/'      '/,JBLANK/'      '/,IBLANK/'      '/              022570 0000
      DATA  CONU/' CONU '/,TMOLER/'MOLER '/,TMOLES/'MOLES '/,HANDS/'HAND 022580 0000
     1S '/,RIPPER/'RIPPER'/,VERTCC/'VERTCC'/,SLOPCC/'SLOPCC'/            022590 0000
      DATA HORSE/'HORSE '/,BASKET/'BASKET'/,CIRCLE/'CIRCLE'/,BOX/'BOX    022600 0000
     1'/,TWOBOX/'TWOBOX'/,SQUARE/'SQUARE'/                               022610 0000
      DATA CONUYR/'CONUYR'/,TRUCK/'TRUCK '/,TRAIN/'TRAIN '/,CONTRK/'CONT 022620 0000
     1RK'/                                                               022630 0000
      DATA NONE/' NONE '/,TNONE/' NONE '/                                022640 0000
      DATA ISHOT/' SHOT '/,ICONC/' CONC '/,IPREC/'PRECST'/               022650 0000
      DATA WET/'  WET '/,DRY/'  DRY '/                                   022660 0000
      DATA ANO/'  NO  '/,YES/'  YES '/                                   022670 0000
      DATA CIRSEG/'CIRSEG'/,CONSEG/'CONSEG'/,STLSEG/'STLSEG'/,STLSET/ 'S 022680 0000
     1TLSET'/,SOLDER/'SOLDER'/,SLURRY/'SLURRY'/,OPENCT/'OPENCT'/         022690 0000
      DATA AIRPRS/'AIRPRS'/,DEWATR/'DEWATR'/,GRDINJ/'GRDINJ'/            022700 0000
      DATA USENO/'NO USE'/,PREFNO/'NOPREF'/                              022710 0000
      DATA IFNEC/'IF NEC'/,MUSTUS/' MUST '/                              022720 0000
      DATA STRUT/'STRUT '/,ANCHOR/'ANCHOR'/,STRANC/'STRANC'/             022730 0000
C     ------------------------------------------------------------------ 022740 0000
      IF(ITYPE.EQ.2) GO TO 150                                           022750 0000
      IF(LIST(2).EQ.0) GO TO 10                                          022760 0000
C     SET VALUES OF GAMMA, PERM, HOURS AND DAYS IF NOT INPUT             022770 0000
      NREACH=A(I,4)                                                      022780 0000
      NTSTYP=A(I,16)                                                     022790 0000
      IF(NTSTYP.EQ.1) GO TO 5                                            022800 0000
      IF(A(I,22).LT.0.1) A(I,22)=120.                                    022810 0000
      IF(A(I,25).GT.10.E-10) PERM=-A(I,25)                               022820 0000
      D10=A(I,19)                                                        022830 0000
      IF(A(I,25).LT.10.E-10) PERM=D10**2/10.                             022840 0000
      A(I,25)=PERM                                                       022850 0000
    5 CONTINUE                                                           022860 0000
      IF(TRDATA(NREACH,8).LT.0.1) TRDATA(NREACH,8)=24.                   022870 0000
      IF(TRDATA(NREACH,9).LT.0.1) TRDATA(NREACH,9)=6.0                   022880 0000
      RETURN                                                             022890 0000
C                                                                        022900 0000
C                                                                        022910 0000
C     ------------------------------------------------------------------ 022920 0000
   10 NLINES=NLINES+1                                                    022930 0000
      IF(NLINES.LE.40) GO TO 30                                          022940 0000
C     WRITE OUT COLUMN HEADINGS FOR TUNNEL SEGMENTS                      022950 0000
C                                                                        022960 0000
```

(Continued)

```
      WRITE(LO,1000)                                                    022970 0000
      WRITE(LO,1001)                                                    022980 0000
      WRITE(LO,1002)                                                    022990 0000
      NLINES=0                                                          023000 0000
   30 NREACH=A(I,4)                                                     023010 0000
      NTSEG=A(I,1)                                                      023020 0000
      NSHAFT=TRDATA(NREACH,1)                                           023030 0000
      DFT=TRDATA(NREACH,2)                                              023040 0000
      IPR=IP                                                            023050 0000
C     ------------------------------------------------------------------ 023060 0000
C     FIND THE HORIZONTAL SEGMENT LENGTH OF EACH SEGMENT, HSEGL,        023070 0000
C                 (HORIZONTAL SEGMENT LENGTH AS GIVEN IN THE INPUT      023080 0000
C         MUST BE CALCULATED SINCE IT WAS PREVIOUSLY DESTROYED WHEN     023090 0000
C           IT WAS CONVERTED TO LENGTH ALONG THE SEGMENT, TSEGL(I))     023100 0000
      NPL=A(I,2)                                                        023110 0000
      NPR=A(I,3)                                                        023120 0000
      SEGL=CNP(NPR,1)-CNP(NPL,1)                                        023130 0000
      LSEGL=SEGL                                                        023140 0000
C     ------------------------------------------------------------------ 023150 0000
C     FIND ALPHA NAME FOR SHAPE                                         023160 0000
   40 ISHAPE=TRDATA(NREACH,3)                                           023170 0000
      IBOX2=TRDATA(NREACH,13)                                           023180 0000
      IF(ISHAPE.EQ.0) SHAPE=BOX                                         023190 0000
      IF(ISHAPE.EQ.0.AND.IBOX2.EQ.1) SHAPE=TWOBOX                       023200 0000
      IF(ISHAPE.EQ.1) SHAPE=CIRCLE                                      023210 0000
      IF(ISHAPE.EQ.2) SHAPE=HORSE                                       023220 0000
      IF(ISHAPE.EQ.3) SHAPE=BASKET                                      023230 0000
C     ------------------------------------------------------------------ 023240 0000
C     FIND THE ALPHA NAME FOR THE LINING TYPE                           023250 0000
      LINING=A(I,10)                                                    023260 0000
      IF(LINING.EQ.0) LTYP=NONE                                         023270 0000
      IF(LINING.EQ.1) LTYP=ICONC                                        023280 0000
      IF(LINING.EQ.2) LTYP=ISHOT                                        023290 0000
      IF(LINING.EQ.3) LTYP=IPREC                                        023300 0000
      IF(LINING.EQ.4)LTYP=IPREC                                         023310 0000
C     ------------------------------------------------------------------ 023320 0000
C     FIND ALPHA NAME FOR MUCK TRANSPORT METHOD                         023330 0000
   50 MTM=TRDATA(NREACH,4)                                              023340 0000
      IF(MTM.EQ.1) REMK=TRUCK                                           023350 0000
      IF(MTM.EQ.2) REMK=CONVYR                                          023360 0000
      IF(MTM.EQ.3) REMK=TRAIN                                           023370 0000
      IF(MTM.EQ.4) REMK=CONTRK                                          023380 0000
C     ------------------------------------------------------------------ 023390 0000
C     FIND ALPHA NAME FOR METHOD OF EXCAVATION                          023400 0000
   60 MEX=A(I,7)                                                        023410 0000
      IF(MEX.EQ.1) EXCAV=CONV                                           023420 0000
      IF(MEX.EQ.2) EXCAV=TMOLER                                         023430 0000
      IF(MEX.EQ.3) EXCAV=TMOLES                                         023440 0000
      IF(MEX.EQ.4) EXCAV=HANDS                                          023450 0000
      IF(MEX.EQ.5) EXCAV=RIPPER                                         023460 0000
      IF(MEX.EQ.6) EXCAV=VERTCC                                         023470 0000
      IF(MEX.EQ.7) EXCAV=SLOPCC                                         023480 0000
C     FIND ALPHA NAME FOR WATERTIGHT REQUIREMENT                        023490 0000
      LINWT=A(I,15)                                                     023500 0000
      IF(LINWT.EQ.0) WTLIN=ANO                                          023510 0000
      IF(LINWT.EQ.1) WTLIN=YES                                          023520 0000
      NTSTYP=A(I,16)                                                    023530 0000
      IF(NTSTYP.EQ.3) WTLIN=YES                                         023540 0000
```

(Continued)

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C     ------------------------------------------------------------------ 023540 0000
   70 AR=A(I,8)                                                           023550 0000
      JRS=A(I,5)                                                          023560 0000
      JRQD=A(I,6)                                                         023570 0000
      JRTEMP=A(I,12)                                                      023580 0000
      INFLOW=A(I,9)                                                       023590 0000
      IF(INFLOW.LT.0) INFLOW=0                                            023600 0000
      TL=A(I,11)                                                          023610 0000
      IF(TL.LE.0.) TL=0.                                                  023620 0000
      ELWATR=A(I,14)                                                      023630 0000
      HOURS=TRDATA(NREACH,8)                                              023640 0000
      DAYS=TRDATA(NREACH,9)                                               023650 0000
C     ------------------------------------------------------------------ 023660 0000
C     CHECK TO SEE IF THIS IS THE SAME REACH  AS FOR PREVIOUS SEGMENT     023670 0000
   85 IF(IPR.EQ.NREACH) GO TO 90                                          023680 0000
C     SET VALUES OF HOURS AND DAYS FOR PREVIOUS REACH IF NOT INPUT        023690 0000
      IF(I.EQ.1) GO TO 88                                                 023700 0000
      N=A(I-1,4)                                                          023710 0000
      IF(TRDATA(N,8).LT.0.1) TRDATA(N,8)=24.0                             023720 0000
      IF(TRDATA(N,9).LT.0.1) TRDATA(N,9)=6.0                              023730 0000
   88 WRITE(LO,1004)                                                      023740 0000
   90 IF(IPR.EQ.NREACH) WRITE(LO,2000)                                    023750 0000
      NLINES=NLINES+1                                                     023760 0000
C     ------------------------------------------------------------------ 023770 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN     023780 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                     023790 0000
   91 IF(AR.GT.0.0) GO TO 92                                              023800 0000
      AR=BLANK                                                            023810 0000
      FMT1(11)=FM1                                                        023820 0000
   92 IF(TL.GT.0.0) GO TO 93                                              023830 0000
      TL=BLANK                                                            023840 0000
      FMT1(17)=FM2                                                        023850 0000
   93 IF(HOURS.GT.0.0) GO TO 94                                           023860 0000
      HOURS=BLANK                                                         023870 0000
      FMT1(20)=FM2                                                        023880 0000
   94 IF(DAYS.GT.0.0) GO TO 95                                            023890 0000
      DAYS=BLANK                                                          023900 0000
      FMT1(21)=FM3                                                        023910 0000
   95 IF(IPR.NE.NREACH) GO TO 98                                          023920 0000
      NREACH=IBLANK                                                       023930 0000
      FMT1(1)=FM4                                                         023940 0000
      HOURS=BLANK                                                         023950 0000
      FMT1(20)=FM2                                                        023960 0000
      DAYS=BLANK                                                          023970 0000
      FMT1(21)=FM3                                                        023980 0000
   98 IF(NTSTYP.GT.1) GO TO 100                                           023990 0000
C     ------------------------------------------------------------------ 024000 0000
C     ROCK TUNNEL                                                         024010 0000
      WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,    024020 0000
     1EXCAV,AR,JRS,JRQD,JRTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS     024030 0000
      GO TO 140                                                           024040 0000
C     ------------------------------------------------------------------ 024050 0000
C     SOFT GROUND TUNNEL OR CUT AND COVER BOX                             024060 0000
C     FIND ALPHA NAME FOR SUPPORT TYPE                                    024070 0000
  100 ISUPPT=A(I,26)                                                      024080 0000
      IF(ISUPPT.EQ.0) SUPORT=TNONE                                        024090 0000
      IF(ISUPPT.EQ.1) SUPORT=CIRSEG                                       024100 0000
      IF(ISUPPT.EQ.2) SUPORT=CONSEG                                       024110 0000
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      IF(ISUPPT.EQ.3) SUPORT=STLSEG                                     024120 0000
      IF(ISUPPT.EQ.4) SUPORT=STLSET                                     024130 0000
      IF(ISUPPT.EQ.5) SUPORT=SOLDER                                     024140 0000
      IF(ISUPPT.EQ.6) SUPORT=SLURRY                                     024150 0000
C     FIND ALPHA NAME FOR ALLOWING DEWATERING                           024160 0000
      IWATER=A(I,23)                                                    024170 0000
      IF(IWATER.EQ.0) DWATER=ANO                                        024180 0000
      IF(IWATER.EQ.1) DWATER=YES                                        024190 0000
      NPLS=A(I,17)                                                      024200 0000
      NPRS=A(I,18)                                                      024210 0000
      D10=A(I,19)                                                       024220 0000
      PHI=0.0                                                           024230 0000
      COHESN=0.0                                                        024240 0000
      IF(A(I,20).GT.0.0) PHI=A(I,20)                                    024250 0000
      IF(A(I,21).GT.0.0) COHESN=A(I,21)                                 024260 0000
      GAMMA=A(I,22)                                                     024270 0000
      ELIMP=A(I,24)                                                     024280 0000
      PERM=A(I,25)                                                      024290 0000
      STABNO=A(I,30)                                                    024300 0000
C     FIND ALPHA NAME FOR USE OF STABILIZATION METHOD                   024310 0000
      MUST=A(I,32)                                                      024320 0000
      IF(MUST.EQ.2)IUSE=IFNEC                                           024330 0000
      IF(MUST.EQ.3)IUSE=IFNEC                                           024340 0000
      IF(MUST.EQ.4)IUSE=MUSTUS                                          024350 0000
      AIRPR=A(I,33)                                                     024360 0000
C     FIND ALPHA NAME FOR STABILIZATION METHOD                          024370 0000
      MSTAB=A(I,31)                                                     024380 0000
      IF(MSTAB.EQ.0.AND.MUST.LE.2) STABIL=PREFNO                        024390 0000
      IF(MSTAB.EQ.0.AND.MUST.EQ.4) STABIL=USENO                         024400 0000
      IF(MSTAB.EQ.1) STABIL=AIRPRS                                      024410 0000
      IF(MSTAB.EQ.2) STABIL=DEWATR                                      024420 0000
      IF(MSTAB.EQ.3) STABIL=GRDINJ                                      024430 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN   024440 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                   024450 0000
C     DO NOT PRINT TEMPERATURE UNDER ROCK LISTING                       024460 0000
      JRTEMP=IBLANK                                                     024470 0000
      FMT1(14)=FM5                                                      024480 0000
  105 IF(JRS.GT.0) GO TO 106                                            024490 0000
      JRS=IBLANK                                                        024500 0000
      FMT1(12)=FM6                                                      024510 0000
  106 IF(JRQD.GT.0) GO TO 107                                           024520 0000
      JRQD=IBLANK                                                       024530 0000
      FMT1(13)=FM5                                                      024540 0000
  107 IF(GAMMA.GT.0.0) GO TO 108                                        024550 0000
      GAMMA=BLANK                                                       024560 0000
      FMT2(4)=FM7                                                       024570 0000
  108 IF(PERM.GT.0.0) GO TO 109                                         024580 0000
      PERM=BLANK                                                        024590 0000
      FMT2(7)=FM8                                                       024600 0000
  109 IF(STABNO.GT.0.0) GO TO 110                                       024610 0000
      STABNO=BLANK                                                      024620 0000
      FMT2(12)=FM9                                                      024630 0000
  110 IF(MUST.GT.1) GO TO 112                                           024640 0000
      IUSE=JBLANK                                                       024650 0000
  112 IF(AIRPR.GT.0.0) GO TO 118                                        024660 0000
      AIRPR=BLANK                                                       024670 0000
      FMT2(15)=FM10                                                     024680 0000
  118 IF(NTSTYP.EQ.3) GO TO 120                                         024690 0000
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C     ------------------------------------------------------------------ 024700 0000
C     SOFT GROUND TUNNEL                                                 024710 0000
      WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,   024720 0000
     1EXCAV,AR,JRS,JRQD,JRTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS    024730 0000
      JRTEMP=A(I,12)                                                     024740 0000
      WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTEMP,DWATER,  024750 0000
     1ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR                              024760 0000
      NLINES=NLINES+1                                                    024770 0000
      GO TO 140                                                          024780 0000
C     ------------------------------------------------------------------ 024790 0000
C     CUT AND COVER                                                      024800 0000
C     FIND ALPHA NAMES FOR DECKING REQUIREMENT                           024810 0000
  120 IDECK=A(I,29)                                                      024820 0000
      IF(IDECK.EQ.0) DECK=NO                                             024830 0000
      IF(IDECK.EQ.1) DECK=YES                                            024840 0000
C     FIND ALPHA NAME FOR BRACING SPECIFIED                              024850 0000
      IBRACE=A(I,28)                                                     024860 0000
      IF(IBRACE.EQ.0) BRACE=TNONE                                        024870 0000
      IF(IBRACE.EQ.1) BRACE=STRUT                                        024880 0000
      IF(IBRACE.EQ.2) BRACE=ANCHOR                                       024890 0000
      IF(IBRACE.EQ.3) BRACE=STRANC                                       024900 0000
      ELROCK=A(I,27)                                                     024910 0000
      NREACH=A(I,4)                                                      024920 0000
      NBOX=TRDATA(NREACH,10)                                             024930 0000
      BFBWDT=TRDATA(NREACH,11)                                           024940 0000
      BFBHT=TRDATA(NREACH,12)                                            024950 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN    024960 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                    024970 0000
C     REMOVE TUNNEL SIZE, MUCK TRANSPORT, SOIL TEMPERATURE, AND          024980 0000
C     STABILIZATION FOR CUT AND COVER.                                   024990 0000
      IF(IPR.EQ.NREACH) NREACH=IBLANK                                    025000 0000
      BFT=BLANK                                                          025010 0000
      FMT1(8)=FM7                                                        025020 0000
      REMK=BLANK                                                         025030 0000
      JRTEMP=IBLANK                                                      025040 0000
      FMT2(8)=FM5                                                        025050 0000
      IF(INFLOW.GT.0) GO TO 138                                          025060 0000
      INFLOW=IBLANK                                                      025070 0000
      FMT1(15)=FM5                                                       025080 0000
      STABIL=BLANK                                                       025090 0000
  138 WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,   025100 0000
     1EXCAV,AR,JRS,JRQD,JRTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS    025110 0000
      WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTEMP,DWATER,  025120 FMT0
     1ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR                              025130 FMT0
      WRITE(LO,FMT3) ELROCK,DECK,BRACE,NBOX,BFBWDT,BFBHT                 025140 0000
      NLINES=NLINES+2                                                    025150 0000
C     ------------------------------------------------------------------ 025160 0000
  140 NREACH=A(I,4)                                                      025170 0000
      IF(IPR.NE.NREACH) IPR=NREACH                                       025180 0000
C     SET VALUE FOR GAMMA IN THIS TUNNEL SEGMENT IF NOT INPUT            025190 0000
      IF(NTSTYP.GT.1.AND.A(I,22).LT.0.1) A(I,22)=120.0                   025200 0000
C     SET VALUE FOR PERMEABILITY IF NOT INPUT                            025210 0000
      IF(NTSTYP.GT.1.AND.A(I,25).GT.10.E-10) PERM=-PERM                  025220 0000
      IF(NTSTYP.GT.1.AND.A(I,25).LT.10.E-10) PERM=D10**2/10.             025230 0000
      A(I,25)=PERM                                                       025240 0000
      IP=IPR                                                             025250 0000
C     RESET FORMATS TO ORIGINAL IN DATA STATEMENT                        025260 0000
      FMT1(1)=FM11                                                       025270 0000
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      FMT1(11)=FM12                                                     025280 0000
      FMT1(17)=FM13                                                     025290 0000
      FMT1(20)=FM13                                                     025300 0000
      FMT1(21)=FM14                                                     025310 0000
      IF(NTSTYP.EQ.1) GO TO 145                                         025320 0000
      FMT1(14)=FM15                                                     025330 0000
      FMT1(12)=FM16                                                     025340 0000
      FMT1(13)=FM15                                                     025350 0000
      FMT2(4)=FM17                                                      025360 0000
      FMT2(7)=FM18                                                      025370 0000
      FMT2(12)=FM19                                                     025380 0000
      FMT2(15)=FM20                                                     025390 0000
      IF(NTSTYP.EQ.2) GO TO 145                                         025400 0000
      FMT1(8)=FM21                                                      025410 0000
      FMT2(8)=FM15                                                      025420 0000
      FMT1(15)=FM15                                                     025430 0000
  145 CONTINUE                                                          025440 0000
      IF(I+1.LE.NTS) RETURN                                             025450 0000
C     SET HOURS AND DAYS FOR LAST REACH IF NOT INPUT                    025460 0000
      IF(TRDATA(NREACH,8).LT.0.1)  TRDATA(NREACH,8)=24.0                025470 0000
      IF(TRDATA(NREACH,9).LT.0.1)  TRDATA(NREACH,9)=6.0                 025480 0000
      WRITE(LO,1004)                                                    025490 0000
      RETURN                                                            025500 0000
C                                                                       025510 0000
C     ******************************************************************025520 0000
C     ******************************************************************025530 0000
C     ******************************************************************025540 0000
C     ******************************************************************025550 0000
C                                                                       025560 0000
  150 IF(LIST(3).EQ.0) GO TO 200                                        025570 0000
C     SET VALUES OF GAMMA, PERM, HOURS AND DAYS IF NOT INPUT            025580 0000
      NSHAFT=B(I,1)                                                     025590 0000
      NSSTYP=B(I,15)                                                    025600 0000
      IF(NSSTYP.EQ.1) GO TO 160                                         025610 0000
      IF(B(I,18).LT.0.1) B(I,18)=120.                                   025620 0000
      IF(B(I,23).GT.10.E-10) PERM=-B(I,23)                              025630 0000
      D10=B(I,16)                                                       025640 0000
      IF(B(I,23).LT.10.E-10) PERM=D10**2/10.                            025650 0000
      B(I,23)=PERM                                                      025660 0000
  160 CONTINUE                                                          025670 0000
      IF(SHAFT(NSHAFT,17).LT.0.1) SHAFT(NSHAFT,17)=24.                  025680 0000
      IF(SHAFT(NSHAFT,18).LT.0.1) SHAFT(NSHAFT,18)=6.0                  025690 0000
      RETURN                                                            025700 0000
C     WRITE OUT THE DATA CONCERNING THE SHAFTS                          025710 0000
C                                                                       025720 0000
C                                                                       025730 0000
C     ------------------------------------------------------------------025740 0000
  200 NLINES=NLINES+1                                                   025750 0000
      IF(NLINES.LE.45) GO TO 230                                        025760 0000
C                                                                       025770 0000
      WRITE(LO,1010)                                                    025780 0000
      WRITE(LO,1011)                                                    025790 0000
      NLINES=0                                                          025800 0000
  230 NSHAFT=B(I,1)                                                     025810 0000
      NSSEG=B(I,2)                                                      025820 0000
      BFS=SHAFT(NSHAFT,7)                                               025830 0000
      NPT=B(I,3)                                                        025840 0000
      NPB=B(I,4)                                                        025850 0000
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      NPORT=SHAFT(NSHAFT,23)                                            025860 0000
      NPTS=SHAFT(NSHAFT,2)                                              025870 0000
      NPBS=SHAFT(NSHAFT,3)                                              025880 0000
      JRS=B(I,5)                                                        025890 0000
      JRQD=B(I,6)                                                       025900 0000
      NSSTYP=B(I,15)                                                    025910 0000
      IPS=IP                                                            025920 0000
C     ----------------------------------------------------------------- 025930 0000
C     FIND THE ALPHA NAME FOR THE LINING TYPE                           025940 0000
      LINING=B(I,10)                                                    025950 0000
      IF(LINING.EQ.0) LTYP=NONE                                         025960 0000
      IF(LINING.EQ.1) LTYP=ICONC                                        025970 0000
      IF(LINING.EQ.2) LTYP=ISHOT                                        025980 0000
      IF(LINING.EQ.3) LTYP=IPREC                                        025990 0000
C     ----------------------------------------------------------------- 026000 0000
C     FIND ALPHA NAME FOR EXCAVATION METHOD                             026010 0000
  240 MEX=B(I,7)                                                        026020 0000
      IF(MEX.EQ.0) EXMS=TNONE                                           026030 0000
      IF(MEX.EQ.1) EXMS=CONV                                            026040 0000
      IF(MEX.EQ.2) EXMS=TMOLER                                          026050 0000
      IF(MEX.EQ.3) EXMS=TMOLES                                          026060 0000
      IF(MEX.EQ.4) EXMS=HANDS                                           026070 0000
C     FIND ALPHA NAME FOR SHAFT SHAPE                                   026080 0000
      ISHAPS=SHAFT(NSHAFT,16)                                           026090 0000
      IF(ISHAPS.EQ.1) SHAPS=CIRCLE                                      026100 0000
      IF(ISHAPS.EQ.2) SHAPS=SQUARE                                      026110 0000
C     FIND ALPHA NAME FOR WATERTIGHT REQUIREMENT                        026120 0000
      LINWT=B(I,14)                                                     026130 0000
      IF(LINWT.EQ.0) WTLIN=ANO                                          026140 0000
      IF(LINWT.EQ.1) WTLIN=YES                                          026150 0000
      IF(NSSTYP.EQ.3) WTLIN=YES                                         026160 0000
      ELWATR=B(I,13)                                                    026170 0000
      HOURS=SHAFT(NSHAFT,17)                                            026180 0000
      DAYS=SHAFT(NSHAFT,18)                                             026190 0000
C     ----------------------------------------------------------------- 026200 0000
      AR=B(I,8)                                                         026210 0000
C     FIND ALPHA NAME FOR SHAFT GROUNDWATER INFLOW                      026220 0000
      INFLOW=B(I,9)                                                     026230 0000
      IF(INFLOW.EQ.1) GRDW=WET                                          026240 0000
      IF(INFLOW.EQ.0) GRDW=DRY                                          026250 0000
C     ----------------------------------------------------------------- 026260 0000
      TL=B(I,11)                                                        026270 0000
      IF(TL.LE.0.) TL=0.                                                026280 0000
      DDS=SHAFT(NSHAFT,5)                                               026290 0000
      IARTEM=SHAFT(NSHAFT,11)                                           026300 0000
  260 ICDS=SHAFT(NSHAFT,6)                                              026310 0000
C     ----------------------------------------------------------------- 026320 0000
C     SEE IF THE SHAFT FOR THIS SEGMENT IS SAME AS PREVIOUS SHAFT       026330 0000
  285 IF(IPS.EQ.NSHAFT) GO TO 290                                       026340 0000
C     SET VALUES OF HOURS AND DAYS FOR PREVIOUS SHAFT IF NOT INPUT      026350 0000
      IF(I.EQ.1) GO TO 288                                              026360 0000
      N=B(I-1,1)                                                        026370 0000
      IF(SHAFT(N,17).LT.0.1) SHAFT(N,17)=24.0                           026380 0000
      IF(SHAFT(N,18).LT.0.1) SHAFT(N,18)=6.0                            026390 0000
  288 WRITE(LO,1004)                                                    026400 0000
  290 IF(IPS.EQ.NSHAFT) WRITE(LO,2000)                                  026410 0000
      NLINES=NLINES+1                                                   026420 0000
C     CHECK FOR PORTAL                                                  026430 0000
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      IF(NPORT.EQ.0) GO TO 292                                          026440 0000
      WRITE(LO,2200) NSHAFT,NPTS,DDS,ICDS,IARTEM                        026450 0000
      GO TO 350                                                         026460 0000
C     ------------------------------------------------------------------026470 0000
C     DUMMY SHAFT IS INPUT WHEN NO SHAFT IS REQUIRED FOR OPEN CUT REACH 026480 0000
  292 IF(ISHAPS.NE.0) GO TO 300                                         026490 0000
      WRITE(LO,2100) NSHAFT,NSSEG,NPTS,NPBS,DDS,ICDS,IARTEM             026500 0000
      GO TO 350                                                         026510 0000
C     ------------------------------------------------------------------026520 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN   026530 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                   026540 0000
  300 IF(AR.GT.0.0) GO TO 301                                           026550 0000
      AR=BLANK                                                          026560 0000
      FMT4(8)=FM1                                                       026570 0000
  301 IF(TL.GT.0.0) GO TO 302                                           026580 0000
      TL=BLANK                                                          026590 0000
      FMT4(13)=FM9                                                      026600 0000
  302 IF(HOURS.GT.0.0) GO TO 303                                        026610 0000
      HOURS=BLANK                                                       026620 0000
      FMT4(19)=FM9                                                      026630 0000
  303 IF(DAYS.GT.0.0) GO TO 305                                         026640 0000
      DAYS=BLANK                                                        026650 0000
      FMT4(20)=FM3                                                      026660 0000
  305 IF(IPS.NE.NSHAFT) GO TO 308                                       026670 0000
      NSHAFT=IBLANK                                                     026680 0000
      FMT4(1)=FM4                                                       026690 0000
      HOURS=BLANK                                                       026700 0000
      FMT4(19)=FM9                                                      026710 0000
      DAYS=BLANK                                                        026720 0000
      FMT4(20)=FM3                                                      026730 0000
  308 IF(NSSTYP.GT.1) GO TO 310                                         026740 0000
C     ------------------------------------------------------------------026750 0000
C     ROCK SHAFT                                                        026760 0000
      WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,   026770 0000
     1GRDW,LTYP,TL,UTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS              026780 0000
      GO TO 350                                                         026790 0000
C     ------------------------------------------------------------------026800 0000
C     SOFT GROUND SHAFT OR CUT AND COVER                                026810 0000
C     FIND ALPHA NAME FOR ALLOWING DEWATERING                           026820 0000
  310 IWATER=B(I,21)                                                    026830 0000
      IF(IWATER.EQ.0) DWATER=ANO                                        026840 0000
      IF(IWATER.EQ.1) DWATER=YES                                        026850 0000
C     FIND ALPHA NAME FOR SUPPORT TYPE                                  026860 0000
      ISUPPT=B(I,22)                                                    026870 0000
      IF(ISUPPT.EQ.1) SUPORT=CIRSEG                                     026880 0000
      IF(ISUPPT.EQ.2) SUPORT=CONSEG                                     026890 0000
      IF(ISUPPT.EQ.3) SUPORT=STLSEG                                     026900 0000
      IF(ISUPPT.EQ.4) SUPORT=STLSET                                     026910 0000
      IF(ISUPPT.EQ.5) SUPORT=OPENCT                                     026920 0000
      D10=B(I,16)                                                       026930 0000
      GAMMA=B(I,18)                                                     026940 0000
      PHI=0.0                                                           026950 0000
      COHESN=0.0                                                        026960 0000
      IF(B(I,19).GT.0.0) PHI=B(I,19)                                    026970 0000
      IF(B(I,17).GT.0.0) COHESN=B(I,17)                                 026980 0000
      PERM=B(I,23)                                                      026990 0000
      ELIMP=B(I,20)                                                     027000 0000
      STABNO=B(I,24)                                                    027010 0000
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C     FIND ALPHA NAME FOR USE OF STABILIZATION METHOD                    027020 0000
      MUST=B(I,26)                                                       027030 0000
      IF(MUST.EQ.2)IUSE=IFNEC                                            027040 0000
      IF(MUST.EQ.3)IUSE=IFNEC                                            027050 0000
      IF(MUST.EQ.4)IUSE=MUSTUS                                           027060 0000
      AIRPR=B(I,27)                                                      027070 0000
C     FIND ALPHA NAME FOR STABILIZATION METHOD                           027080 0000
      MSTAB=B(I,25)                                                      027090 0000
      IF(MSTAB.EQ.0.AND.MUST.LE.2) STABIL=PREFNO                         027100 0000
      IF(MSTAB.EQ.0.AND.MUST.EQ.4) STABIL=USENO                          027110 0000
      IF(MSTAB.EQ.1) STABIL=AIRPRS                                       027120 0000
      IF(MSTAB.EQ.2) STABIL=DEWATR                                       027130 0000
      IF(MSTAB.EQ.3) STABIL=GRDINJ                                       027140 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN    027150 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                    027160 0000
      IF(GAMMA.GT.0.0) GO TO 320                                         027170 0000
      GAMMA=BLANK                                                        027180 0000
      FMT5(3)=FM7                                                        027190 0000
  320 IF(PERM.GT.0.0) GO TO 321                                          027200 0000
      PERM=BLANK                                                         027210 0000
      FMT5(6)=FM8                                                        027220 0000
  321 IF(STABNO.GT.0.0) GO TO 322                                        027230 0000
      STABNO=BLANK                                                       027240 0000
      FMT5(10)=FM9                                                       027250 0000
  322 IF(MUST.GT.1) GO TO 324                                            027260 0000
      IUSE=JBLANK                                                        027270 0000
  324 IF(AIRPR.GT.0.0) GO TO 325                                         027280 0000
      AIRPR=BLANK                                                        027290 0000
      FMT5(13)=FM10                                                      027300 0000
  325 IF(JRS.GT.0) GO TO 326                                             027310 0000
      JRS=IBLANK                                                         027320 0000
      FMT4(9)=FM6                                                        027330 0000
  326 IF(JRQD.GT.0) GO TO 329                                            027340 0000
      JRQD=IBLANK                                                        027350 0000
      FMT4(10)=FM5                                                       027360 0000
  329 IF(NSSTYP.EQ.3) GO TO 330                                          027370 0000
C     ------------------------------------------------------------------ 027380 0000
C     SOFT GROUND SHAFT                                                  027390 0000
      WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,    027400 0000
     1GRDW,LTYP,TL,WTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS               027410 0000
      WRITE(LO,0006) D10,GAMMA,PHI,COHESN,PERM,DWATER,ELIMP,SUPORT,      027420 0000
     1STABNO,STABIL,IUSE,AIRPR                                           027430 0000
      NLINES=NLINES+1                                                    027440 0000
      GO TO 350                                                          027450 0000
C     ------------------------------------------------------------------ 027460 0000
C     CUT AND COVER                                                      027470 0000
C     SHAFT IS BUILT WITHIN OPEN CUT CONSTRUCTED FOR TUNNEL              027480 0000
C     ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN    027490 0000
C     VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA                    027500 0000
C     REMOVE VARIABLES THAT DO NOT APPLY TO CUT AND COVER                027510 0000
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C     QRDW,IARTEM,DWATER,ELIMP,STABIL                                   027520 0000
  330 QRDW=BLANK                                                        027530 0000
      IARTEM=IBLANK                                                     027540 0000
      FMT4(17)=FM22                                                     027550 0000
      DWATER=BLANK                                                      027560 0000
      ELIMP=BLANK                                                       027570 0000
      FMT5(8)=FM1                                                       027580 0000
      STABIL=BLANK                                                      027590 0000
      WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,   027600 0000
     1QRDW,LTYP,TL,UTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS              027610 0000
      WRITE(LO,0006) D10,GAMMA,PHI,COHESN,PERM,DWATER,ELIMP,SUPORT,     027620 0000
     1STABNO,STABIL,IUSE,AIRPR                                          027630 0000
      NLINES=NLINES+1                                                   027640 0000
C     ------------------------------------------------------------------ 027650 0000
  360 NSHAFT=B(I,1)                                                     027660 0000
      IF(IPS.NE.NSHAFT) IPS=NSHAFT                                      027670 0000
C     SET VALUE FOR GAMMA IN THIS SHAFT SEGMENT IF NOT INPUT            027680 0000
      IF(NSSTYP.GT.1.AND.B(I,18).LT.0.1) B(I,18)=120.0                  027690 0000
      IF(NSSTYP.GT.1.AND.B(I,23).GT.10.E-10) PERM=-PERM                 027700 0000
      IF(NSSTYP.GT.1.AND.B(I,23).LT.10.E-10) PERM=D10**2/10.            027710 0000
      B(I,23)=PERM                                                      027720 0000
      IP=IPS                                                            027730 0000
C     RESET FORMATS TO ORIGINAL IN DATA STATEMENT                       027740 0000
      FMT4(1)=FM11                                                      027750 0000
      FMT4(8)=FM12                                                      027760 0000
      FMT4(13)=FM19                                                     027770 0000
      FMT4(19)=FM19                                                     027780 0000
      FMT4(20)=FM14                                                     027790 0000
      IF(NSSTYP.EQ.1) GO TO 360                                         027800 0000
      FMT5(3)=FM17                                                      027810 0000
      FMT5(6)=FM18                                                      027820 0000
      FMT5(10)=FM19                                                     027830 0000
      FMT5(13)=FM20                                                     027840 0000
      FMT4(9)=FM16                                                      027850 0000
      FMT4(10)=FM15                                                     027860 0000
      IF(NSSTYP.EQ.2) GO TO 360                                         027870 0000
      FMT4(17)=FM23                                                     027880 0000
      FMT5(8)=FM12                                                      027890 0000
  360 CONTINUE                                                          027900 0000
      IF(I+1.LE.NSS) RETURN                                             027910 0000
C     SET HOURS AND DAYS FOR LAST SHAFT IF NOT INPUT                    027920 0000
      IF(SHAFT(NSHAFT,17).LT.0.1) SHAFT(NSHAFT,17)=24.0                 027930 0000
      IF(SHAFT(NSHAFT,18).LT.0.1) SHAFT(NSHAFT,18)=6.0                  027940 0000
      WRITE(LO,1004)                                                    027950 0000
C                                                                       027960 0000
```

(Continued)

```
C     ****************************************************************** 027970 0000
      RETURN                                                             027980 0000
C                                                                        027990 0000
C     ****************************************************************** 028000 0000
C                                                                        028010 0000
 1000 FORMAT(1H1,49(1H*),'  T U N N E L  I N P U T  D A T A  ',47(1H*)// 028020 0000
     11X,'REACH SEG NP BOUNDRY EXIT  HORIZ  TUNNEL TUNNEL  MUCK    EXCAV 028030 0000
     2A- UNF ADV *ROCK PROPERTIES* INFLOW *** LINING **** GROUND HOURS D 028040 0000
     3AYS'/11X,'LEFT RIGHT SHAFT LENGTH  SHAPE  SIZE  REMOVAL   TION    028050 0000
     4RATE   STRENGTH ROD TEMP  (GPM) TYPE  THICK WAT WATER   PER  PER ' 028060 0000
     6/43X,'(FT)   METHOD  METHOD (FT/DAY)  (PSI)',7X,'(F)',15X,'(IN)  T 028070 0000
     6GT ELEV.   DAY  WEEK')                                             028080 0000
 1001 FORMAT(33(2X,2H--)/13X,'SURFACE  ',12(1H*),' SOIL PROPERTIES ',13( 028090 0000
     11H*),' DEWAT- IMPERV SUPPORT ***** STABILIZATION *****'/11X,'NP BO 028100 0000
     2UNDRY GRN SIZE UNIT WT PHI COHESION  PERM.  TEMP ERING  LAYER   TY 028110 0000
     3PE   NUMBER METHOD  USE  AIRPR'/11X,'LEFT RIGHT  (M M)    (PCF)    028120 0000
     4    (PSF)  (CM/SEC) (F)  ALLOW  ELEV.',30X,'(PSI)')                028130 0000
 1002 FORMAT(33(2X,2H--)/11X,'SOUND  *CUT AND COVER* **BOX PROPERTIES**' 028140 0000
     1/11X,'ROCK   DECKING BRACING UNITS WIDTH HEIGHT'/11X,'ELEV.',25X,  028150 0000
     2'(FT)  (FT)'//)                                                    028160 0000
 1004 FORMAT(1X,131(1H-))                                                028170 0000
 1010 FORMAT(1H1,50(1H*),'  S H A F T  I N P U T  D A T A  ',48(1H*)//   028180 0000
     11X,'SHAFT SEG NP BOUNDARY  SHAFT SHAFT EXCAVA- UNF ADV *ROCK PROP. 028190 0000
     2* INFLOW *** LINING **** DISPOSAL DISPOSAL ABOVE GROUND  HOURS DAY 028200 0000
     3S'/11X,'UPPER LOWER  SHAPE  SIZE  TION    RATE   STRENGTH ROD      028210 0000
     4   TYPE  THICK WAT DISTANCE   COST   GRND. WATER    PER  PER'/31X, 028220 0000
     5'(FT) METHOD (FT/DAY)  (PSI)',20X,'(IN)  TGT  (MILES) ($/ACRE) TEM 028230 0000
     6P  ELEV.    DAY  WEEK')                                            028240 0000
 1011 FORMAT(33(2X,2H--)/22X,11(1H*),' SOIL PROPERTIES ',10(1H*),'   DEW 028250 0000
     1AT-   IMPERV SUPPORT ***** STABILIZATION *****'/22X,'GRN SIZE UNIT 028260 0000
     2 WT PHI COHESION  PERM.     ERING    LAYER   TYPE   NUMBER METHOD  028270 0000
     3 USE  AIRPR'/23X,'(M M)    (PCF)       (PSF)  (CM/SEC)    ALLOW    028280 0000
     4 ELEV.',30X,'(PSI)'//)                                             028290 0000
 2000 FORMAT(1X)                                                         028300 0000
 2100 FORMAT(1X,I4,I5,I5,I6,10X,'THIS SHAFT IS A DUMMY',36X,F7.1,I8,I7)  028310 0000
 2200 FORMAT(I5,14X,'THIS SHAFT  AT NODAL POINT',I4,'  IS ACTUALLY A     028320 0000
     1PORTAL',14X,F10.1,I8,I7)                                           028330 0000
 0001 FORMAT(/,1X,I4,I5,I5,I5,I6,I7,2X,A6,F7.2,2X,A6,2X,A6,F8.1,3X,I6,  028331
     1I6,I5,I5,2X,A6,F5.1,A6,F7.1,F5.1,F5.1,/)                           028332
 0002 FORMAT(/ 10X,I5,I5,E10.2,F7.1,F5.0,F7.0,E10.2,I5,A6,F8.1,2X,A6,   028333
     1F6.1,1X,A6,1X,A6,F6.1,/)                                           028334
 0003 FORMAT(/,10X,F7.1,1X,A6,2X,A6,I5,F8.2,F7.2,/)                      028335
 0004 FORMAT(/,1X,I4,I5,I5,I6,2X,A6,F6.2,1X,A6,F8.1,3X,I6,I5,A6,A6,F6.1, 028336
     1A6,F7.1,I8,I7,F9.1,F6.1,F5.1,/)                                    028337
 0006 FORMAT(/,20X,E10.2,F7.1,F5.0,F7.0,E10.2,4X,A6,F8.1,2X,A6,F6.1,2X,  028338
     1A6,1X,A6,F6.1,/)                                                   028339
      END                                                                028346 0000
```

(Continued)

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      SUBROUTINE SIZEST(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX 028350 0000
     1,NTRMAX)                                                          028355
C     ------------------------------------------------------------------ 028360 0000
C     ------------------------------------------------------------------ 028370 0000
C     I=TUNNEL OR SHAFT SEGMENT NUMBER                                   028380 0000
C     THIS SUBROUTINE CALCULATES THE FOLLOWING IN TUNNELS OR SHAFTS      028390 0000
C     BE,BE40,BE60,TL,BOB,BOB40,BOB60,WEB,TPLATE,TSEG,DTRNCH,SIDEL,UBOX, 028400 0000
C     TVOL,FORMAR,WTWALE,WTSTRT,WTANCH,WTSP,WTSPD                        028410 0000
C     ------------------------------------------------------------------ 028420 0000
C     ------------------------------------------------------------------ 028430 0000
C                                                                        028440 0000
C     ******************************************************************* 028450 0000
C     GENERAL DATA                                                       028460 0000
C     ******************************************************************* 028470 0000
C                                                                        028480 0000
      COMMON /BASIC/  NSS,NTS                                            028490 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE            028500 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),  028510 0000
     1 TRDATA(NTRMAX,23)                                                 028520 0000
      REAL MIN,MAX                                                       028530 0000
C                                                                        028540 0000
C     I=TUNNEL SEGMENT SEQUENCE NUMBER                                   028550 0000
C                                                                        028560 0000
C     ITYPE=1 INDICATES TUNNEL SEGMENT                                   028570 0000
      ITYPE=1                                                            028580 0000
      NREACH=A(I,4)                                                      028590 0000
      NTSEG=A(I,1)                                                       028600 0000
      TLIN=A(I,11)                                                       028610 0000
      BFT=TRDATA(NREACH,2)                                               028620 0000
      BF=BFT                                                             028630 0000
      LINING=A(I,10)                                                     028640 0000
      MEX=A(I,7)                                                         028650 0000
      ISHAPE=TRDATA(NREACH,3)                                            028660 0000
      MSTAKE=0                                                           028670 0000
      ELWATR=A(I,14)                                                     028680 0000
      NPL=A(I,2)                                                         028690 0000
      NPR=A(I,3)                                                         028700 0000
      ELNPL=CNP(NPL,2)                                                   028710 0000
      ELNPR=CNP(NPR,2)                                                   028720 0000
      ELAVG=(ELNPL+ELNPR)/2.                                             028730 0000
      LINWT=A(I,15)                                                      028740 0000
      NTSTYP=A(I,16)                                                     028750 0000
      NSSTYP=0                                                           028760 0000
      GO TO 10                                                           028770 0000
C                                                                        028780 0000
```

(Continued)

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C     ------------------------------------------------------------------ 028790 0000
C                                                                        028800 0000
      ENTRY SIZESS(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,     028810 0000
     1NTRMAX)                                                            028815
C     I=SHAFT SEQMENT SEQUENCE NUMBER                                    028820 0000
C     ITYPE=2 INDICATES SHAFT SEGMENT                                    028830 0000
      ITYPE=2                                                            028840 0000
      TLIN=B(I,11)                                                       028850 0000
      NSHAFT=B(I,1)                                                      028860 0000
      ISHAPS=SHAFT(NSHAFT,16)                                            028870 0000
      IF(ISHAPS.EQ.0) RETURN                                             028880 0000
      NPORT=SHAFT(NSHAFT,23)                                             028890 0000
      IF(NPORT.EQ.1) RETURN                                              028900 0000
      NSSEQ=B(I,2)                                                       028910 0000
      BFS=SHAFT(NSHAFT,7)                                                028920 0000
      BF=BFS                                                             028930 0000
      LINING=B(I,10)                                                     028940 0000
      MEX=B(I,7)                                                         028950 0000
      MSTAKE=0                                                           028960 0000
      ELWATR=B(I,13)                                                     028970 0000
      LINWT=B(I,14)                                                      028980 0000
      NSSTYP=B(I,15)                                                     028990 0000
      NTSTYP=0                                                           029000 0000
      NPT=B(I,3)                                                         029010 0000
      NPB=B(I,4)                                                         029020 0000
      ELNPT=CNP(NPT,2)                                                   029030 0000
      ELNPB=CNP(NPB,2)                                                   029040 0000
      ELAVG=(ELNPT+ELNPB)/2.                                             029050 0000
C                                                                        029060 0000
C                                                                        029070 0000
C     ------------------------------------------------------------------ 029080 0000
C                                                                        029090 0000
C     CONVERT TL TO FEET                                                 029100 0000
   10 TLIN=TLIN/12.                                                      029110 0000
C     IS IT A ROCK TUNNEL OR SHAFT                                       029120 0000
      IF(NTSTYP.EQ.1.OR. NSSTYP.EQ.1) GO TO 15                           029130 0000
C     IS IT A SHAFT                                                      029140 0000
      IF(ITYPE.EQ.2) GO TO 12                                            029150 0000
      PHI=A(I,20)                                                        029160 0000
      NPLS=A(I,17)                                                       029170 0000
      NPRS=A(I,18)                                                       029180 0000
      ELNPLS=CNP(NPLS,2)                                                 029190 0000
      ELNPRS=CNP(NPRS,2)                                                 029200 0000
      ELSURF=(ELNPLS+ELNPRS)/2.                                          029210 0000
      GAMMA=A(I,22)                                                      029220 0000
      COHESN=A(I,21)                                                     029230 0000
      ISUPPT=A(I,26)                                                     029240 0000
      GO TO 13                                                           029250 0000
   12 PHI=B(I,19)                                                        029260 0000
      GAMMA=B(I,18)                                                      029270 0000
      COHESN=B(I,17)                                                     029280 0000
      ISUPPT=B(I,22)                                                     029290 0000
      NPTS=SHAFT(NSHAFT,2)                                               029300 0000
      ELSURF=CNP(NPTS,2)                                                 029310 0000
   13 PI=3.14159                                                         029320 0000
      DWATER=ELSURF-ELWATR                                               029330 0000
      ICUTHC=0                                                           029340 0000
C     IS IT A SOFT GROUND TUNNEL OR SHAFT                                029350 0000
```

(Continued)

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      IF(NTSTYP.EQ.2 .OR. NSSTYP.EQ.2) GO TO 1000                       029360 0000
      GO TO 2900                                                        029370 0000
C                                                                       029380 0000
C                                                                       029390 0000
C                                                                       029400 0000
C     ****************************************************************029410 0000
C     ROCK TUNNEL OR SHAFT                                              029420 0000
C     ****************************************************************029430 0000
C                                                                       029440 0000
C     II IS A FLOW INDICATOR                                            029450 0000
   16 II=4                                                              029460 0000
C     ----------------------------------------------------------------029470 0000
C     LINING FOR WATER PRESSURE                                         029480 0000
C     ----------------------------------------------------------------029490 0000
      PWATER=62.4*(ELWATR-ELAVG)                                        029500 0000
      IF(ITYPE.EQ.1) RQD=A(I,6)                                         029510 0000
      IF(ITYPE.EQ.2) RQD=B(I,6)                                         029520 0000
      WEB =0.                                                           029530 0000
C     IF THE WATER LOAD IS ZERO, ASSIGN PWATER=0.001 FOR ESTIMATING     029540 0000
C     LINING THICKNESS ( ZERO VALUE MAY MAKE RESULT INDEFINITE )        029550 0000
      IF(PWATER.LE.0.001) PWATER=0.001                                  029560 0000
      IF(LINWT.EQ.0) PWATER=0.001                                       029570 0000
      IF(ITYPE.EQ.2) GO TO 21                                           029580 0000
      GO TO(21,22,23),ISHAPE                                            029590 0000
   21 TL=0.5*BF*PWATER/(288000.-PWATER)                                 029600 0000
      GO TO 30                                                          029610 0000
   22 TL=0.77E-10*BF**0.86*PWATER**1.9*EXP(SQRT((16.9-1.42*ALOG(PWATER)) 029620 0000
     1**2+0.32))                                                        029630 0000
      GO TO 30                                                          029640 0000
   23 TL=3.8E-7*(7.+4.6*BF)*PWATER**1.035*EXP(SQRT((6.5-0.565*ALOG      029650 0000
     1(PWATER))**2+0.17))                                               029660 0000
C     SET MIN. CONCRETE THICKNESS TO BE 8 INCHES. IF SHOTCRETE          029670 0000
C     THICKNESS NOT INPUT, SET MIN. TO BE 3 INCHES                      029680 0000
   30 IF(LINING.EQ.1 .AND. TL.LT.0.6666) TL=0.6666                      029690 0000
      IF(LINING.EQ.2.AND.TLIN.LT.0.001.AND.TL.LT.0.25) TL=0.25          029700 0000
C     ----------------------------------------------------------------029710 0000
C     FLOW CONTROLED BY RQD VALUE                                       029720 0000
C     ----------------------------------------------------------------029730 0000
      IF(RQD.GE.60.) GO TO 200                                          029740 0000
      IF(RQD.LE.40.) GO TO 100                                          029750 0000
C     RQD LIES BETWEEN 40 AND 60,INTERPOLATION OF SIZES IS NECESSARY.   029760 0000
C     SIZE WILL BE COMPUTED FOR RQD=40 AND RQD=60 BEFORE INTERPOLATING  029770 0000
C     TO OBTAIN SIZE AT ACTUAL RQD                                      029780 0000
      II=1                                                              029790 0000
C     STORE THE ACTUAL VALUES OF LINING THICKNESS AND RQD               029800 0000
      RQDD=RQD                                                          029810 0000
      TT=TL                                                             029820 0000
C     ASSIGN A FICTICIOUS RQD FOR THE FIRST PART OF INTERPOLATION COMP  029830 0000
      RQD=40                                                            029840 0000
C     ----------------------------------------------------------------029850 0000
C      RQD IS 40 OR LESS                                                029860 0000
C     ----------------------------------------------------------------029870 0000
C     HAS A LINING THICKNESS BEEN INPUT.   IF SO,COMPUTE AND STORE      029880 0000
C     EXCAVATED DIMENSION USING THIS THICKNESS                          029890 0000
C     CHECK FOR CIRCULAR SHAPE                                          029900 0000
  100 IF(ISHAPE.EQ.1)  GO TO (110,120),MEX                              029910 0000
C     SHAPE IS HORSESHOE OR BASKETHANDLE                                029920 0000
C     COMPUTE DEPTH OF STEEL RIB SUPPORT                                029930 0000
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(Continued)

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      WEB  =(0.294*BF+3.35 )/12.                                        029940 0000
      GO TO 145                                                         029950 0000
C     CONVENTIONAL EXCAVATION                                           029960 0000
  110 WEB  =(0.254*BF+0.17-0.064*RQD)/12.                               029970 0000
      GO TO 130                                                         029980 0000
C     MOLE EXCAVATION                                                   029990 0000
  120 WEB  =(0.207*BF+0.138-0.052*RQD)/12.                              030000 0000
  130 IF(WEB*12..LT.4.0) WEB   =4./12.                                  030010 0000
C     IS SEGMENT LINED OR UNLINED                                       030020 0000
  145 IF(LINING.GT.0) GO TO 150                                         030030 0000
C     NO LINING                                                         030040 0000
      BE=BF+WEB*2.                                                      030050 0000
      TL=0.0                                                            030060 0000
      GO TO 400                                                         030070 0000
C     LINED                                                             030080 0000
C     CHECK FOR LINING TYPE                                             030090 0000
  150 IF(LINING.EQ.1) GO TO 170                                         030100 0000
C     CALCULATE EXCAVATED DIMENSION FOR SHOTCRETE                       030110 0000
      IF(TLIN.GT.0.001) GO TO 160                                       030120 0000
C     CHECK IF RIB  THICKNESS + 3 IN. .GE. THE LINING THICKNESS         030130 0000
  152 IF(WEB    +0.25 .GE. TL) GO TO 155                                030140 0000
      BE=BF+2.*TL                                                       030150 0000
      GO TO 400                                                         030160 0000
  155 BE=BF+WEB*2.+0.5                                                  030170 0000
      GO TO 400                                                         030180 0000
C     CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE  030190 0000
  160 IF(TLIN.LT.TL) MSTAKE=2                                           030200 0000
      IF(TLIN.LT.TL) GO TO 152                                          030210 0000
      TL=TLIN                                                           030220 0000
  165 IF(WEB    +0.25.GE.TL) GO TO 155                                  030230 0000
      BE=BF+2.*TLIN                                                     030240 0000
      GO TO 400                                                         030250 0000
C     CONCRETE                                                          030260 0000
  170 TLMIN=WEB    +0.333                                               030270 0000
      IF(TL.LT.TLMIN) TL=TLMIN                                          030280 0000
C     WAS A LINING THICKNESS INPUT                                      030290 0000
      IF(TLIN.GT.0.001) GO TO 175                                       030300 0000
  174 BE=BF+2.*TL                                                       030310 0000
      GO TO 400                                                         030320 0000
C     CHECK IF THE GIVEN LINING THICKNESS .GE. MINIMUM DIM. REQUIRED    030330 0000
  175 IF(TLIN.GE.TLMIN) GO TO 176                                       030340 0000
C     ERROR - TL INPUT IS NOT THICK ENOUGH, PRINT WARNING               030350 0000
C     WAS THIS A TUNNEL OR SHAFT                                        030360 0000
      IF(ITYPE.EQ.1) WRITE(LO,1010) NTSEG,NREACH                        030370 0000
      IF(ITYPE.EQ.2) WRITE(LO,1011) NSSEG,NSHAFT                        030380 0000
      MSTAKE=1                                                          030390 0000
      GO TO 174                                                         030400 0000
C     CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE  030410 0000
  176 IF(TLIN.LT.TL) GO TO 177                                          030420 0000
      BE=BF+2.*TLIN                                                     030430 0000
      TL=TLIN                                                           030440 0000
      GO TO 400                                                         030450 0000
  177 MSTAKE=2                                                          030460 0000
      GO TO 174                                                         030470 0000
C                                                                       030480 0000
C     ----------------------------------------------------------------- 030490 0000
C     RQD IS GREATER THAN OR EQUAL TO 60                                030500 0000
C     ----------------------------------------------------------------- 030510 0000
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(Continued)

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C     HAS A LINING THICKNESS BEEN INPUT                                  030520 0000
  200 IF(TLIN.GT.0.001) GO TO 230                                        030530 0000
C     IS SEGMENT LINED OR UNLINED                                        030540 0000
      IF(LINING.GT.0)GO TO 216                                           030550 0000
C     UNLINED                                                            030560 0000
      TL=0.0                                                             030570 0000
      BE=BF                                                              030580 0000
      GO TO 400                                                          030590 0000
  216 BE=BF+2.*TL                                                        030600 0000
      GO TO 400                                                          030610 0000
C     LINING TYPE                                                        030620 0000
  230 IF(LINING.EQ.2) GO TO 250                                          030630 0000
C     CONCRETE                                                           030640 0000
      IF(TLIN.LT.0.666) GO TO 260                                        030650 0000
      GO TO 250                                                          030660 0000
C     INPUT ERROR - TL INPUT IS NOT THICK ENOUGH, USE TL=0.667           030670 0000
C     IF ERROR MESSAGE WAS ALREADY PRINTED,SKIP IT NOW                   030680 0000
  260 IF(MSTAKE.EQ.1) GO TO 216                                          030690 0000
      IF(ITYPE.EQ.1) WRITE(LO,1010) NTSEG,NREACH                         030700 0000
      IF(ITYPE.EQ.2) WRITE(LO,1011) NSSEG,NSHAFT                         030710 0000
      GO TO 216                                                          030720 0000
C     CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE   030730 0000
  250 IF(TLIN.LT.TL) GO TO 275                                           030740 0000
      BE=BF+2.*TLIN                                                      030750 0000
      TL=TLIN                                                            030760 0000
      GO TO 400                                                          030770 0000
  275 MSTAKE=2                                                           030780 0000
      GO TO 216                                                          030790 0000
C     ------------------------------------------------------------------ 030800 0000
C     OVERBREAK DIMENSION                                                030810 0000
C     ------------------------------------------------------------------ 030820 0000
C     WHAT IS THE EXCAVATION METHOD                                      030830 0000
  400 IF(MEX.EQ.2) BOB=BE                                                030840 0000
      IF(MEX.EQ.1) BOB=BE+(250.-RQD)*(BE+10.)/2500.                      030850 0000
C                                                                        030860 0000
C     ------------------------------------------------------------------ 030870 0000
C     RQD BETWEEN 40 AND 60                                              030880 0000
C     ------------------------------------------------------------------ 030890 0000
      IF(II.LT.3) GO TO 450                                              030900 0000
      BE40=BE                                                            030910 0000
      BE60=BE                                                            030920 0000
      BOB40=BOB                                                          030930 0000
      BOB60=BOB                                                          030940 0000
      GO TO 600                                                          030950 0000
  450 IF(II.GE.2) GO TO 500                                              030960 0000
C     STORE BE AND BOB COMPUTED USING FICTICIOUS RQD=40                  030970 0000
      BE40=BE                                                            030980 0000
      BOB40=BOB                                                          030990 0000
C     REDEFINE RQD TO A FICTICIOUS VALUE OF 60 FOR SECOND PART OF        031000 0000
C     INTERPOLATION COMPUTATION                                          031010 0000
      RQD=60.                                                            031020 0000
C     RE-ESTABLISH INPUT   VALUE OF LINING THICKNESS FOR PURPOSES OF     031030 0000
C     THE CHECK IN STATEMENT 200                                         031040 0000
      TL=TT                                                              031050 0000
C     REDEFINE FLOW INDICATOR                                            031060 0000
      II=II+1                                                            031070 0000
      GO TO 200                                                          031080 0000
C                                                                        031090 0000
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(Continued)

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C     ------------------------------------------------------------------
C     STORE BE AND BOB COMPUTED USING FICTICIOUS RQD=60
  500 BE60=BE
      BOB60=BOB
C
C     CALCULATE BE AND BOB BY INTERPOLATING BETWEEN BE AND BOB
C     VALUES AT RQD=40 AND RQD=60
C
      BE=BE40+(RQDD-40.)/20.*(BE60-BE40)
      BOB=BOB40+(RQDD-40.)/20.*(BOB60-BOB40)
C
  550 IF(LINING.NE.1) GO TO 600
C     COMPUTE THE AVERAGE THICKNESS FOR THE CONCRETE LINING
C     WHEN THE RQD IS BETWEEN 40 AND 60
      TL=(BE-BF)/2.
C
C
C     ------------------------------------------------------------------
C     SET VARIABLES FOR SHAFT OR TUNNEL SEGMENTS
C     ------------------------------------------------------------------
  600 IF(ITYPE.EQ.2) GO TO 700
C     TUNNEL SEGMENT DATA
      A(I,39)=BE
      A(I,40)=BE40
      A(I,41)=BE60
      A(I,42)=BOB
      A(I,43)=BOB40
      A(I,44)=BOB60
      A(I,62)=WEB
      A(I,64)=PWATER
      A(I,11) = TL
      IF(MSTAKE.EQ.2) WRITE(LO,2710) NTSEG,NREACH
      GO TO 4000
C
C     SHAFT SEGMENT DATA
  700 B(I,29)=BE
      B(I,30)=BE40
      B(I,31)=BE60
      B(I,32)=BOB
      B(I,33)=BOB40
      B(I,34)=BOB60
      B(I,41)=WEB
      B(I,43)=PWATER
      B(I,11) = TL
      IF(MSTAKE.EQ.2) WRITE(LO,2711) NSSEG,NSHAFT
      GO TO 4000
C
C
C     ******************************************************************
C     SOFT GROUND TUNNELS AND SHAFTS
C     ******************************************************************
 1000 BE=BF
      N=0
      I2=0
      TANPHI=TAN(PHI*PI/180.)
C     ------------------------------------------------------------------
C     MINIMUM SUPPORT SIZE
C     ------------------------------------------------------------------
```

(Continued)

```
      GO TO(1001,1002,1003,1005),ISUPPT
C     CAST IRON SEGMENTED SUPPORT
 1001 TSEGMN=0.6666
      TPLMIN=0.05
      FF=4
      GO TO 1004
C     PRECAST CONCRETE SEGMENTED SUPPORT
 1002 TSEGMN=1
      TPLMIN=0.125
      FF=2
      GO TO 1004
C     STEEL SEGMENTED SUPPORT
 1003 TSEGMN=0.583
      TPLMIN=0.03
      FF=4
 1004 IF(TLIN.GT.0. .AND. TLIN.LT.TPLMIN) GO TO 1008
      IF(TLIN.GT.TPLMIN) GO TO 1025
      GO TO 1009
 1025 IF(ELWATR.LT.ELAVG .OR. LINWT.EQ.0) GO TO 1026
      GO TO 1009
C     WHEN WATER PRESSURE=0, INPUT  LINER THICKNESS GREATER THAN MINIMUM
C     VALUE WILL BE ACCEPTED
 1026 I2=1
      TPLATE=TLIN
      GO TO 2354
C     STEEL SEGMENTED SUPPORT
 1005 IF(LINING.EQ.2) GO TO 1006
      TLMIN=0.6666
      IF(TLIN.GT.0. .AND. TLIN.LT.TLMIN) GO TO 1008
      GO TO 1009
 1006 TLMIN=0.333
      IF(TLIN.GT.0.) TLMIN=0
      GO TO 1009
C     INPUT   LINER OR LINING THICKNESS LESS THAN MINIMUM VALUE
 1008 MSTAKE=1
C     ------------------------------------------------------------------
C     UNIT WEIGHT OF SOIL
C     ------------------------------------------------------------------
 1009 BBEE=BE
      N=N+1
      SEGDEP=ELSURF-ELAVG
C     CHECK FOR GWT ABOVE GROUND SURFACE
      IF(ELWATR.GT.ELSURF) GO TO 1045
C     CHECK FOR SEGMENT BELOW GWT
      IF(ELAVG.LT.ELWATR) GO TO 1015
C     GWT IS BELOW SEGMENT
      SIGGAH=SEGDEP*GAMMA
      IF(SEGDEP.LE.2.*BE) GO TO 1012
      GAMMAA=GAMMA
      GAMMAB=GAMMA
      GO TO 1050
 1012 GAMMAC=GAMMA
      GO TO 1050
C     SEGMENT IS BELOW GWT
 1015 SIGGAH=DWATER*GAMMA+(ELWATR-ELAVG)*(GAMMA-62.4)
      IF(SEGDEP.LE.2.*BE) GO TO 1030
      IF(DWATER.GT.2.*BE) GO TO 1020
C     SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE
```

(Continued)

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      GAMMAA=(GAMMA*DWATER+(GAMMA-62.4)*(2.*BE-DWATER))/(2.*BE)
      GAMMAB=(GAMMA-62.4)
      GO TO 1050
C     SEGMENT AND OUT ARE BOTH DEEPER THAN 2BE
 1020 GAMMAA=GAMMA
      GAMMAB=(GAMMA*(DWATER-2.*BE)+(GAMMA-62.4)*(ELWATR-ELAVG))
     1/(SEGDEP-2.*BE)
      GO TO 1050
C     SEGMENT IS WITHIN 2BE OF GROUND SURFACE
 1030 GAMMAC=(GAMMA*DWATER+(GAMMA-62.4)*(ELWATR-ELAVG))/SEGDEP
      GO TO 1050
C     OUT IS ABOVE GROUND SURFACE
 1045 GAMMAA=GAMMA-62.4
      GAMMAB=GAMMA-62.4
      GAMMAC=GAMMA-62.4
      SIGGAH=SEGDEP*(GAMMA-62.4)
C     ADJUST UNIT WEIGHTS OF SOIL FOR DRAINED SEGMENT
 1050 IF(LINUT.EQ.1) GO TO 1100
      GAMMAA=GAMMA
      GAMMAB=GAMMA
      GAMMAC=GAMMA
C     ------------------------------------------------------------------
C     EXPRESS SOIL STRENGTH IN TERMS OF EQUIVALENT PHI
C     ------------------------------------------------------------------
 1100 PHIEQR=ATAN(COHESN/SIGGAH+TANPHI)
      PHIEQ=PHIEQR*180./PI
      IF(PHIEQ.GT.45.) PHIEQ=45.
C     ------------------------------------------------------------------
C     TUNNEL AND SHAFT LOADS
C     ------------------------------------------------------------------
C     ESTABLISH SEGMENT TYPE AND SHAPE FACTORS
      IF(SEGDEP.LE.2.*BE) GO TO 1300
      F=1.0
      FSHAPE=1.0
      IF(ITYPE.EQ.1) GO TO 1110
C     SHAFT SEGMENT
      F=0.5
      FSHAPE=0.5
      IF(ISHAPS.EQ.2) F=0.6
      IF(ISHAPS.EQ.2) FSHAPE=0.6
      GO TO 1200
C     TUNNEL SEGMENT
 1110 IF(ISHAPE.EQ.3) FSHAPE=1.25
C     ------------------------------------------------------------------
 1200 PSOIL=2.*BE*GAMMAA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)*
     1 GAMMAB*FSHAPE
      GO TO 1310
 1300 F=1.0
      IF(ITYPE.EQ.1) GO TO 1301
C     SHAFT SEGMENT
      F=0.5
      IF(ISHAPS.EQ.2) F=0.6
 1301 PSOIL=SEGDEP*GAMMAC*F
C     ------------------------------------------------------------------
 1310 IF(LINUT.EQ.1) GO TO 1320
C     DRAINED
      PWATER=0
      GO TO 1330
```

(Continued)

```
C     WATERTIGHT                                                        032840 0000
 1320 PWATER=68.4*(ELWATR-ELAVG)                                        032850 0000
C     OUT BELOW SEGMENT                                                 032860 0000
      IF(PWATER.LT.0.) PWATER=0                                         032870 0000
 1330 IF(ISUPPT.LE.3 .AND. TLIN.GT.TPLMIN) GO TO 1331                   032880 0000
      PTOTAL=PSOIL+PWATER                                               032890 0000
      GO TO 2000                                                        032900 0000
C     INPUT   LINER THICKNESS GREATER THAN MINIMUM VALUE WILL BE CHECKED 032910 0000
C     FOR WATER PRESSURE                                                032920 0000
 1331 PTOTAL=PWATER                                                     032930 0000
C     IF PSOIL, PWATER, OR PTOTAL EQUAL 0, THEN ASSIGN A VALUE OF 0.001 032940 0000
C     FOR ESTIMATING SUPPORT SIZE                                       032950 0000
 2000 IF(PSOIL.LT.0.001) PSOIL=0.001                                    032960 0000
      IF(PWATER.LT.0.001) PWATER=0.001                                  032970 0000
      IF(PTOTAL.LT.0.001) PTOTAL=0.001                                  032980 0000
C     ----------------------------------------------------------------- 032990 0000
C     SUPPORT SIZE                                                      033000 0000
C     ----------------------------------------------------------------- 033010 0000
      GO TO(2100,2200,2300,2400),ISUPPT                                 033020 0000
C     CAST IRON SEGMENTED SUPPORT                                       033030 0000
 2100 TPLATE=7.E-6*BF**0.68*PTOTAL**0.78                                033040 0000
      GO TO 2350                                                        033050 0000
C     PRECAST CONCRETE LINER                                            033060 0000
 2200 IF(ITYPE.EQ.2) GO TO 2235                                         033070 0000
C     TUNNEL SEGMENT                                                    033080 0000
      IF(ISHAPE-2) 2210,2220,2230                                       033090 0000
 2210 TPLATE=1.55E-8*(0.1+0.046*BF)*PTOTAL**1.6*EXP(SQRT((6.6-0.56*ALOG 033100 0000
     1(PTOTAL))**2+0.016))                                              033110 0000
      GO TO 2350                                                        033120 0000
 2220 TPLATE=2.6E-7*(0.1+0.044*BF)*PTOTAL**1.38*EXP(SQRT((9.25-0.775*   033130 0000
     1ALOG(PTOTAL))**2+0.048))                                          033140 0000
      GO TO 2350                                                        033150 0000
 2230 TPLATE=6.5E-8*(0.1+0.044*BF)*PTOTAL**1.48*EXP(SQRT((11.3-0.94*    033160 0000
     1ALOG(PTOTAL))**2+0.21))                                           033170 0000
      GO TO 2350                                                        033180 0000
C     SHAFT SEGMENT                                                     033190 0000
 2235 IF(ISHAPS.EQ.1) GO TO 2210                                        033200 0000
      TPLATE=6.8E-7*(5.+4.7*BF)*PTOTAL**0.93*EXP(SQRT((5.22-0.45*ALOG   033210 0000
     1(PTOTAL))**2+0.08))                                               033220 0000
      GO TO 2350                                                        033230 0000
C     STEEL SEGMENTED SUPPORT                                           033240 0000
 2300 IF(ITYPE.EQ.2) GO TO 2335                                         033250 0000
C     TUNNEL SEGMENT                                                    033260 0000
      IF(ISHAPE-2) 2310,2320,2330                                       033270 0000
 2310 TPLATE=6.95E-7*BF**0.8*PTOTAL**0.88                               033280 0000
      GO TO 2350                                                        033290 0000
 2320 TPLATE=6.6E-4*BF**0.74*PTOTAL**0.39                               033300 0000
      GO TO 2350                                                        033310 0000
 2330 TPLATE=8.5E-4*BF**0.71*PTOTAL**0.38                               033320 0000
      GO TO 2350                                                        033330 0000
C     SHAFT SEGMENT                                                     033340 0000
 2335 IF(ISHAPS.EQ.1) GO TO 2310                                        033350 0000
      TPLATE=0.001*BF**0.75*PTOTAL**0.38                                033360 0000
 2350 IF(TPLATE.LT.TPLMIN) TPLATE=TPLMIN                                033370 0000
C     INPUT   LINER THICKNESS GREATER THAN COMPUTED VALUE WILL BE USED  033380 0000
      IF(TPLATE.LT.TLIN) TPLATE=TLIN                                    033390 0000
      IF(TLIN.GE.TPLMIN .AND. TLIN.LT.TPLATE) MSTAKE=3                  033400 0000
 2354 TSEQ=FF*TPLATE                                                    033410 0000
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      IF(TSEG.LT.TSEGMN) TSEG=TSEGMN                                    033420 0000
      BE=BF+2.*TSEG                                                     033430 0000
      IF(ITYPE.EQ.2) GO TO 2360                                         033440 0000
C     TUNNEL SEGMENT                                                    033450 0000
      A(I,39)=BE                                                        033460 0000
      A(I,62)=TPLATE                                                    033470 0000
      A(I,11)=TSEG                                                      033480 0000
      A(I,63)=PSOIL                                                     033490 0000
      A(I,64)=PWATER                                                    033500 0000
      A(I,65)=PTOTAL                                                    033510 0000
      GO TO 2600                                                        033520 0000
C     SHAFT SEGMENT                                                     033530 0000
 2360 B(I,29)=BE                                                        033540 0000
      B(I,41)=TPLATE                                                    033550 0000
      B(I,11)=TSEG                                                      033560 0000
      B(I,30)=PSOIL                                                     033570 0000
      B(I,43)=PWATER                                                    033580 0000
      B(I,31)=PTOTAL                                                    033590 0000
      GO TO 2600                                                        033600 0000
C     STEEL RIB WITH LINING                                             033610 0000
C     LINING THICKNESS                                                  033620 0000
C     FOR CUT-AND-COVER SHAFT CONCRETE LINING IS TO RESIST PSOIL+PWATER. 033630 0000
C     WHEN INPUT LINING GREATER THAN 8 IN., THICKNESS IS CHECKED FOR    033640 0000
C     WATER PRESSURE ONLY                                               033650 0000
 2400 IF(ICUTNC.EQ.1 .AND. TLIN.LT.0.666) PWATER=PSOIL+PWATER           033660 0000
      IF(ITYPE.EQ.2) GO TO 2435                                         033670 0000
C     TUNNEL SEGMENT                                                    033680 0000
      IF(ISHAPE-2) 2410,2420,2430                                       033690 0000
 2410 TL=0.5*BF*PWATER/(288000.-PWATER)                                 033700 0000
      GO TO 2445                                                        033710 0000
 2420 TL=0.77E-10*BF**0.86*PWATER**1.9*EXP(SQRT((16.9-1.42*ALOG(PWATER)) 033720 0000
     1**2+0.32))                                                        033730 0000
      GO TO 2445                                                        033740 0000
 2430 TL=3.8E-7*(7.+4.6*BF)*PWATER**1.035*EXP(SQRT((6.5-0.565*ALOG      033750 0000
     1(PWATER))**2+0.17))                                               033760 0000
      GO TO 2445                                                        033770 0000
C     SHAFT SEGMENT                                                     033780 0000
 2435 IF(ISHAPS.EQ.1) GO TO 2410                                        033790 0000
      TL=3.6E-5*(7.+4.6*BF)*PWATER**0.68*EXP(SQRT((2.-0.185*ALOG(PWATER) 033800 0000
     1)**2+0.04))                                                       033810 0000
 2445 IF(TL.LT.TLMIN) TL=TLMIN                                          033820 0000
C     INPUT   LINING THICKNESS GREATER THAN COMPUTED VALUE WILL BE USED 033830 0000
      IF(TL.LT.TLIN) TL=TLIN                                            033840 0000
      IF(TLIN.GE.TLMIN .AND. TLIN.LT.TL) MSTAKE=3                       033850 0000
      IF(ICUTNC.EQ.0) GO TO 2500                                        033860 0000
      WEB=0                                                             033870 0000
      GO TO 2545                                                        033880 0000
 2500 B1=BF+2.*TL                                                       033890 0000
C     STEEL RIB SIZE                                                    033900 0000
      IF(ITYPE.EQ.2) GO TO 2535                                         033910 0000
      IF(ISHAPE-2) 2510,2520,2530                                       033920 0000
C     TUNNEL SEGMENT                                                    033930 0000
 2510 WEB=0.0115*B1**0.39*PSOIL**0.33                                   033940 0000
      GO TO 2540                                                        033950 0000
 2520 WEB=0.066*B1**0.76*(PSOIL/1000.)**(0.6*B1**(-0.3))                033960 0000
      GO TO 2540                                                        033970 0000
 2530 WEB=0.067*B1**0.78*(PSOIL/1000.)**(0.565*B1**(-0.29))             033980 0000
      GO TO 2540                                                        033990 0000
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C       SHAFT SEGMENT                                                   034000 0000
 2535   IF(ISHAPE.EQ.1) GO TO 2510                                      034010 0000
        WEB=0.1*B1**0.7*(PSOIL/1000.)**(0.305-0.0027*B1)                034020 0000
 2540   IF(WEB.LT.0.5) WEB=0.5                                          034030 0000
 2545   BE=BF+2.*TL+2.*WEB                                              034040 0000
        IF(ITYPE.EQ.2) GO TO 2550                                       034050 0000
        A(I,39)=BE                                                      034060 0000
        A(I,68)=WEB                                                     034070 0000
        A(I,11)=TL                                                      034080 0000
        A(I,63)=PSOIL                                                   034090 0000
        A(I,64)=PWATER                                                  034100 0000
        A(I,65)=PTOTAL                                                  034110 0000
        GO TO 2600                                                      034120 0000
 2550   B(I,29)=BE                                                      034130 0000
        B(I,41)=WEB                                                     034140 0000
        B(I,11)=TL                                                      034150 0000
        B(I,30)=PSOIL                                                   034160 0000
        B(I,43)=PWATER                                                  034170 0000
        B(I,31)=PTOTAL                                                  034180 0000
C       CHECK IF INPUT THICKNESS ACCEPTED WHEN WATER PRESSURE=0         034190 0000
 2600   IF(I2.EQ.1) GO TO 4000                                          034200 0000
C       CHECK IF ASSUMED  'BE'  IS WITHIN ONE PERCENT OF COMPUTED  'BE' 034210 0000
        IF(BE/BBEE.LT.0.99 .OR. BE/BBEE.GT.1.01) GO TO 1009             034220 0000
        IF(ITYPE.EQ.2) GO TO 2605                                       034230 0000
        IF(MSTAKE.EQ.1) WRITE(LO,1010) NTSEG,NREACH                     034240 0000
        IF(MSTAKE.EQ.3) WRITE(LO,2710) NTSEG,NREACH                     034250 0000
        GO TO 4000                                                      034260 0000
 2605   IF(MSTAKE.EQ.1) WRITE(LO,1011) NSSEG,NSHAFT                     034270 0000
        IF(MSTAKE.EQ.3) WRITE(LO,2711) NSSEG,NSHAFT                     034280 0000
        GO TO 4000                                                      034290 0000
C                                                                       034300 0000
C                                                                       034310 0000
C                                                                       034320 0000
C                                                                       034330 0000
C       ******************************************************************034340 0000
C       CUT AND COVER ONLY                                              034350 0000
C       ******************************************************************034360 0000
C                                                                       034370 0000
C       ----------------------------------------------------------------034380 0000
C       DATA                                                            034390 0000
C       ----------------------------------------------------------------034400 0000
 2900   IF(ITYPE.EQ.2) GO TO 3300                                       034410 0000
        ELROCK=A(I,27)                                                  034420 0000
        ELIMP=A(I,24)                                                   034430 0000
        D10=A(I,19)                                                     034440 0000
        PERM=A(I,25)                                                    034450 0000
        DROCK=ELSURF-ELROCK                                             034460 0000
        NBOX=TRDATA(NREACH,10)                                          034470 0000
        BFBWDT=TRDATA(NREACH,11)                                        034480 0000
        BFBHT=TRDATA(NREACH,12)                                         034490 0000
        IBOX2=TRDATA(NREACH,13)                                         034500 0000
        IDECK=A(I,29)                                                   034510 0000
        IBRACE=A(I,28)                                                  034520 0000
        DTUN=ELSURF-ELAVG                                               034530 0000
        IF(IBOX2.EQ.1) GO TO 3000                                       034540 0000
        BOXWDT=BFBWDT/NBOX                                              034550 0000
        BOXHT=BFBHT                                                     034560 0000
        GO TO 3001                                                      034570 0000
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 3000 BOXWDT=BFBWDT/2.                                                  034580 0000
      BOXHT=BFBHT/2.                                                    034590 0000
      NBOX=2                                                            034600 0000
 3001 SURGE=400.                                                        034610 0000
      TROOF=0.0                                                         034620 0000
      TINVT=0.0                                                         034630 0000
      TINSB=0.0                                                         034640 0000
      TINWL=0.0                                                         034650 0000
      TEXWL=0.0                                                         034660 0000
      WTROOF=0.0                                                        034670 0000
      WTINSB=0.0                                                        034680 0000
      K=0                                                               034690 0000
C     ------------------------------------------------------------------ 034700 0000
 3002 DTRNCH=DTUN+BFBHT/2+TINVT+TINSB/2.                                034710 0000
      DSOIL=DTRNCH                                                      034720 0000
      IF(DROCK.LT.DTRNCH) DSOIL=DROCK                                   034730 0000
      TOTBOX=BFBHT+TINVT+TROOF+TINSB                                    034740 0000
      DROOF=DTRNCH-TOTBOX                                               034750 0000
      WATPRI=0                                                          034760 0000
      WATPRR=0                                                          034770 0000
      IF(DWATER.GE.DTRNCH) GO TO 3005                                   034780 0000
      WATPRI=62.4*(DTRNCH-DWATER)                                       034790 0000
      IF(DWATER.LT.DROOF) WATPRR=WATPRI-62.4*TOTBOX                     034800 0000
C     ------------------------------------------------------------------ 034810 0000
C     TRENCH PRESSURE FOR SUPPORTS                                      034820 0000
C     ------------------------------------------------------------------ 034830 0000
 3005 SIGMAT=GAMMA*DSOIL                                                034840 0000
      SIGMA1=GAMMA*DSOIL                                                034850 0000
      IWATER=A(I,23)                                                    034860 0000
      STABNO=A(I,30)                                                    034870 0000
      IF(DWATER.LT.DSOIL.AND.IWATER.EQ.0) SIGMA1=GAMMA*DWATER+(GAMMA-   034880 0000
     162.4)*(DSOIL-DWATER)                                              034890 0000
      IF(STABNO.LT.0.01) STABNO=(SIGMAT+SURGE)/(COHESN+(SIGMA1+SURGE)/2. 034900 0000
     1*(1-SIN(PHI*PI/180.))*TAN(PHI*PI/180.))                           034910 0000
      IF(ISUPPT.EQ.5.OR.MEX.EQ.7) GO TO 3010                            034920 0000
C     SLURRY WALL TRENCH SUPPORT                                        034930 0000
      TRENPR=0.3*SIGMAT                                                 034940 0000
      IF(IWATER.EQ.1.AND.D10.GT.0.005) GO TO 3025                       034950 0000
      IF(DWATER.LT.DSOIL) TRENPR=0.3 *(GAMMA*DWATER**2.+(GAMMA-62.4)*   034960 0000
     1(DSOIL-DWATER)**2.+2.*GAMMA*DWATER*(DSOIL-DWATER)+2.*62.4*(DSOIL- 034970 0000
     2DWATER)**2.)/DSOIL                                                034980 0000
      GO TO 3025                                                        034990 0000
C     SOLDIER PILE / LAGGING TRENCH SUPPORT                             035000 0000
 3010 TEMP1=0.6*GAMMA*DSOIL*(TAN(PI/180.*(45.-PHI/2.)))**2.             035010 0000
      TEMP2=2.4*COHESN*TAN(PI/180.*(45.-PHI/2.))                        035020 0000
      IF(STABNO.LE.4) GO TO 3015                                        035030 0000
      TM=1.1-0.1*STABNO                                                 035040 0000
      IF(TM.LT.0.4) TM=0.4                                              035050 0000
      TRENPR=TEMP1*(PHI+0.83)/(PHI+0.62)-TEMP2*(PHI+0.83)/(PHI+0.62)*TM 035060 0000
      GO TO 3020                                                        035070 0000
 3015 TRENPR=TEMP1*(PHI+0.14)/(PHI+0.35)-TEMP2*PHI/(PHI+0.2)            035080 0000
 3020 IF(TRENPR.LT.0.0) TRENPR=0.0                                      035090 0000
C     ------------------------------------------------------------------ 035100 0000
C     EARTH PRESSURE FOR BOX MEMBERS                                    035110 0000
 3025 ERTHPR=0.5*GAMMA*DTUN                                             035120 0000
C     ------------------------------------------------------------------ 035130 0000
C     THICKNESS OF BOX MEMBERS                                          035140 0000
C     ------------------------------------------------------------------ 035150 0000
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      ULTCOM=5.0*10.**3.                                                035160 0000
      ALLCOM=0.45*ULTCOM                                                035170 0000
      AXIALW=0.0                                                        035180 0000
      AXIALS=0.0                                                        035190 0000
      PSOIL=ERTHPR+SURGE                                                035200 0000
      J=0                                                               035210 0000
C     SOIL AND WATER LOADS ON BOX MEMBERS                               035220 0000
C     INPUT THICKNESS WILL NOT BE USED                                  035230 0000
      IF(TLIN.GT.0.0) WRITE(LO,3500) NTSEG,NREACH                       035240 0000
C     ------------------------------------------------------------------ 035250 0000
C     AXIAL LOAD AND UNIFORM LOADS                                      035260 0000
 3030 J=J+1                                                             035270 0000
      GO TO (3040,3050,3060,3070,3080),J                                035280 0000
C     ROOF SLAB                                                         035290 0000
 3040 PTOTAL=GAMMA*DROOF/1.1+WTROOF+SURGE                               035300 0000
      GO TO 3052                                                        035310 0000
 3050 TROOF=THICK/12.                                                   035320 0000
      WTROOF=150.*TROOF                                                 035330 0000
C     INVERT SLAB                                                       035340 0000
      PWATER=WATPRI-WATPRR                                              035350 0000
      PTOTAL=PTOTAL+PWATER                                              035360 0000
 3052 IF(WATPRI.EQ.0.0) GO TO 3055                                      035370 0000
      IF(WATPRR.GT.0.0) AXIALW=0.25*BOXHT*(WATPRI+WATPRR)               035380 0000
      IF(WATPRR.EQ.0.0) AXIALW=0.25*BOXHT*WATPRI*(DTRNCH-DWATER)/TOTBOX 035390 0000
 3055 IF(DROCK.GE.DTRNCH) GO TO 3057                                    035400 0000
      IF(DROCK.LE.DROOF) GO TO 3058                                     035410 0000
      PSOIL=PSOIL*(DROCK-DROOF)/TOTBOX                                  035420 0000
 3057 AXIALS=0.5*PSOIL*BOXHT                                            035430 0000
 3058 AXIAL=AXIALW+AXIALS                                               035440 0000
      SPANL=BOXWDT                                                      035450 0000
      GO TO 3100                                                        035460 0000
 3060 TINVT=THICK/12.                                                   035470 0000
C     INTERIOR SLAB                                                     035480 0000
      IF(IBOX2.EQ.1) GO TO 3062                                         035490 0000
      THICK=0.0                                                         035500 0000
      GO TO 3030                                                        035510 0000
 3062 PTOTAL=400.+WTINSB                                                035520 0000
      IF(WATPRI.EQ.0.0) GO TO 3065                                      035530 0000
      AXIALW=2.0*AXIALW                                                 035540 0000
 3065 IF(DROCK.LE.DROOF) GO TO 3067                                     035550 0000
      AXIALS=2.0*AXIALS                                                 035560 0000
 3067 AXIAL=AXIALS+AXIALW                                               035570 0000
      SPANL=BOXWDT                                                      035580 0000
      GO TO 3100                                                        035590 0000
 3070 TINSB=THICK/12.                                                   035600 0000
      WTINSB=150.*TINSB                                                 035610 0000
      K=K+1                                                             035620 0000
      IF(K.EQ.1) GO TO 3002                                             035630 0000
C     INTERIOR WALL                                                     035640 0000
      AXIAL=(GAMMA*DROOF/1.1+SURGE+WTROOF+WTINSB+400.)*BOXWDT           035650 0000
      SPANL=BOXHT                                                       035660 0000
      IF(NBOX.GT.1) GO TO 3105                                          035670 0000
      THICK=0.0                                                         035680 0000
      GO TO 3030                                                        035690 0000
 3080 TINWL=THICK/12.                                                   035700 0000
C     EXTERIOR WALL                                                     035710 0000
      AXIAL=AXIAL/2.                                                    035720 0000
      SPANL=BOXHT                                                       035730 0000
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      IF(DWATER.GE.DTRNCH.AND.ISUPPT.EQ.6.)GO TO 3105                   035740 0000
      IF(ISUPPT.EQ.6.OR.DROCK.LE.DRCOF) PSOIL=0.0                       035750 0000
      PWATER=0.0                                                        035760 0000
      IF(WATPRI.EQ.0.0) GO TO 3085                                      035770 0000
      IF(WATPRR.GT.0.0) PWATER=(WATPRI+WATPRR)/2.                       035780 0000
      IF(WATPRR.EQ.0.0) PWATER=0.5*WATPRI*(DTRNCH-DWATER)/TOTBOX        035790 0000
 3085 PTOTAL=PSOIL+PWATER                                               035800 0000
C     ------------------------------------------------------------------ 035810 0000
C     THICKNESS COMPUTATION                                             035820 0000
 3100 MOMENT=0.1*PTOTAL*SPANL**2.                                       035830 0000
      THICK=AXIAL/(24.*ALLCOM)+SQRT((AXIAL/(12.*ALLCOM))**2.+24.*MOMENT/ 035840 0000
     1ALLCOM)/2.                                                        035850 0000
      GO TO 3110                                                        035860 0000
 3105 THICK=AXIAL/18800.                                                035870 0000
C     COSTUN MINIMUM                                                    035880 0000
 3110 IF(THICK.LT.8.0) THICK=8.0                                        035890 0000
C     ACI REQUIREMENT                                                   035900 0000
      IF(THICK.LT.SPANL*12./25.) THICK=12.*SPANL/25.                    035910 0000
      IF(J.LT.5) GO TO 3030                                             035920 0000
      TEXWL=THICK/12.                                                   035930 0000
C     ------------------------------------------------------------------ 035940 0000
C     FINAL OVERALL BOX DIMENSIONS                                      035950 0000
      TOTBOX=BFBHT+TROOF+TINVT+TINSB                                    035960 0000
      WDTBOX=BFBWDT+2.*TEXWL+(NBOX-1)*TINWL                             035970 0000
      BE=WDTBOX                                                         035980 0000
C     FINAL TRENCH DEPTH                                                035990 0000
      DTRNCH=DTUN+BFBHT/2.+TINVT+TINSB/2.                               036000 0000
      DSOIL=DTRNCH                                                      036010 0000
      IF(DROCK.LT.DTRNCH) DSOIL=DROCK                                   036020 0000
      DROOF=DTRNCH-TOTBOX                                               036030 0000
      CONSTR=6.0                                                        036040 0000
      IF(DROCK.GT.DROOF.AND.ISUPPT.NE.6) BE=BE+CONSTR                   036050 0000
C     INITIALIZE                                                        036060 0000
      WTWALE=0.                                                         036070 0000
      WTSTRT=0.                                                         036080 0000
      WTANCH=0.                                                         036090 0000
      WTSP=0.                                                           036100 0000
      WTSPD=0.                                                          036110 0000
      SPDLT=0.                                                          036120 0000
      DSP=0.                                                            036130 0000
      DSPD=0.                                                           036140 0000
      SIDESL=0.                                                         036150 0000
      DSLURY=0.0                                                        036160 0000
      IF(MEX.EQ.7) GO TO 3140                                           036170 0000
      IF(DROCK.LT.0.1) GO TO 3190                                       036180 0000
      IF(ISUPPT.EQ.5) GO TO 3120                                        036190 0000
C     ------------------------------------------------------------------ 036200 0000
C     SLURRY WALL SUPPORT SYSTEM                                        036210 0000
C     ------------------------------------------------------------------ 036220 0000
C     COMPUTE LENGTH OF SLURRY WALL                                     036230 0000
C     IS ROCK LINE ABOVE TRENCH BOTTOM                                  036240 0000
      IF(DROCK.LT.DTRNCH) GO TO 3117                                    036250 0000
C     IS ROCK LINE SHALLOWER THAN 8 FT BELOW TRENCH                     036260 0000
      IF(DROCK.LT.DTRNCH+8.) GO TO 3116                                 036270 0000
C     IS GROUNDWATER TABLE BELOW TRENCH BOTTOM                          036280 0000
      IF(DWATER.GT.DTRNCH) GO TO 3115                                   036290 0000
      IF(IWATER.EQ.1 .AND.  D10.GT.0.005) GO TO 3115                    036300 0000
      IF(D10.GT.0.005) GO TO 3112                                       036310 0000
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(Continued)

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C     WEIGHTED CREEP RATIO DETERMINES SLURRY WALL PENETRATION
      CREPMN=(340.+1.55*COHESN)/COHESN
      GO TO 3113
 3112 CREPMN=4.3-1.8*ALOG10(SQRT(10.*ABS(PERM)))
 3113 DSLURY=DTRNCH+10.
      CREEP=(2.*DSLURY-DWATER-DTRNCH)/(DTRNCH-DWATER)
      IF(CREEP.GT.CREPMN) GO TO 3120
      DSLURY=(CREPMN*(DTRNCH-DWATER)+DWATER+DTRNCH)/2.
      DTIMP=ELSURF-ELIMP
      IF(DTIMP.GE.DSLURY.OR.D10.LE.0.005) GO TO 3114
C     SLURRY WALL PENETRATES IMPERVIOUS LAYER
      H1=DTIMP-DWATER
      IF(H1.LT.0.) H1=0.
      H2=DTIMP-DTRNCH
      H2DN=H2
      H2UP=DTRNCH-DTIMP
      IF(DTIMP.GE.DTRNCH) H2UP=0.
      IF(DTIMP.LT.DTRNCH) H2DN=0.
      AA=4.
      BB=4.*ABS(H2)+4*H2
      CC=H1**2.+H2**2.+2.*H1*ABS(H2)+2.*H2UP*(H2-H1)+CREPMN*(H2-H1)*
     1(H2DN+H1)
      PENIMP=(-BB+SQRT(BB**2.-4.*AA*CC))/2./AA
      IF(DTIMP.GE.DTRNCH) DSLURY=DTIMP+PENIMP
      IF(DTIMP.LT.DTRNCH) DSLURY=DTRNCH+PENIMP
C     MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL
      IF(DSLURY.LT.DTRNCH+10.) DSLURY=DTRNCH+10.
 3114 IF(DSLURY.GT.DROCK+2.) DSLURY=DROCK+2.
      GO TO 3120
C     MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL
 3115 DSLURY=DTRNCH+10.
      GO TO 3120
C     MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN ROCK
 3116 DSLURY=DROCK+2.
      GO TO 3120
C     IS ROCK LINE AT LEAST 2 FT ABOVE ROOF OF BOX
 3117 IF(DROCK+2. .LT.DROOF) GO TO 3118
      DSLURY=DTRNCH+2.
      GO TO 3120
 3118 DSLURY=DROCK+2.
C     ------------------------------------------------------------------
C     SOLDIER PILE/LAGGING SUPPORT SYSTEM
C     ------------------------------------------------------------------
 3120 TRENPR=TRENPR+SURGE
C     ANCHORS AND/OR STRUTS
      WTSTRT=0.0225*TRENPR+0.8*BE
      ANCHDI=0.94*SQRT(TRENPR/1000.)
      IF(ANCHDI.LT.0.5) ANCHDI=0.5
      WTANCH=PI*(ANCHDI/2.)**2.*0.283*12.
      IF(IBRACE.EQ.1) WTANCH=0.
      IF(IBRACE.EQ.2) WTSTRT=0.
      IF(ISUPPT.EQ.6) GO TO 3190
C     WALES
      WTWALE=SQRT(5.6*TRENPR)
      IF(WTWALE.LT.13.) WTWALE=13.
      DWALE=SQRT(6.*WTWALE)-5.0
C     SOLDIER PILES
C     NON DECKED SOLDIER PILES
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(Continued)

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      WTSP =SQRT(TRENPR)                                                036900 0000
      IF(WTSP.LT.13.) WTSP=13.                                          036910 0000
      DSP=SQRT(6.*WTSP)-5.0                                             036920 0000
      IF(IDECK.EQ.0) GO TO 3125                                         036930 0000
C     DECKED SOLDIER PILES                                              036940 0000
      SPAXAL=15.*BE/2.*400.                                             036950 0000
      WTSPD=SQRT(TRENPR)+0.222*SPAXAL/1000.*(1.0-0.25*(TRENPR/1000.)    036960 0000
     1**0.333)                                                          036970 0000
      IF(WTSPD.LT.13.) WTSPD=13.                                        036980 0000
      DSPD=SQRT(6.*WTSPD)-5.0                                           036990 0000
C     IS ROCK LINE ABOVE TRENCH BOTTOM                                  037000 0000
      IF(DROCK.LE.DTRNCH) GO TO 3124                                    037010 0000
      DPILEH=1./6.*SQRT(1.5*WTSPD)                                      037020 0000
      IF(PHI.GT.0.) GO TO 3122                                          037030 0000
      SPDLT=DTRNCH+(1.75*SPAXAL/(0.5*PI*DPILEH)-6.7*COHESN*DPILEH/2.)/  037040 0000
     1(2.*COHESN+DPILEH/2.*GAMMA)                                       037050 0000
      GO TO 3123                                                        037060 0000
 3122 CNQ=EXP(PI*TAN(PHI*PI/180.))*(TAN(PI/4.+PHI*PI/360.))**2          037070 0000
      CNC=(CNQ-1.)/TAN(PHI*PI/180.)                                     037080 0000
      IF(PHI.GT.0.) CNGAM=0.                                            037090 0000
      IF(PHI.GT.10.) CNGAM=0.3*(PHI-10.)                                037100 0000
      IF(PHI.GT.20.) CNGAM=(PHI**2-335.)/22.3                           037110 0000
      IF(PHI.GT.35.) CNGAM=8.*(PHI-35.)+40.                             037120 0000
      IF(PHI.GT.40.) CNGAM=32.*(PHI-40.)+80.                            037130 0000
      AA=GAMMA*TAN(PHI*PI/180.)                                         037140 0000
      BB=2.*COHESN+DPILEH/2.*GAMMA*CNQ                                  037150 0000
      CC=1.3*COHESN*DPILEH/2.*CNC+0.6*GAMMA*(0.5*DPILEH)**2*CNGAM       037160 0000
     1-1.75*SPAXAL/(0.5*PI*DPILEH)                                      037170 0000
      SPDLT=DTRNCH+(-BB+SQRT(BB**2-4.*AA*CC))/(2.*AA)                   037180 0000
 3123 IF(SPDLT.LT.DTRNCH+10.) SPDLT=DTRNCH+10.                          037190 0000
      IF(SPDLT.GT.DROCK+2.) SPDLT=DROCK+2.                              037200 0000
      GO TO 3125                                                        037210 0000
 3124 SPDLT=DTRNCH+2.                                                   037220 0000
C     ------------------------------------------------------------------ 037230 0000
C     FOR ROCK DESIGN, CHECK IF EXTERIOR BOX WALL IS SMALLER THAN DEPTH 037240 0000
C     OF SOLDIER PILE EMBEDDED IN WALL                                  037250 0000
 3125 IF(DROCK.GT.DROOF) GO TO 3130                                     037260 0000
      IF(DROCK+10..GT.DROOF.AND.TEXWL.LT.DSP/12.) TEXWL=DSP/12.         037270 0000
      IF(TEXWL.LT.DSPD/12.) TEXWL=DSPD/12.                              037280 0000
C     ------------------------------------------------------------------ 037290 0000
C     IN ROCK, EXCAVATED TRENCH WIDTH EQUALS BOX WIDTH                  037300 0000
      WDTBOX=BFBWDT+2*TEXWL+(NBOX-1)*TINWL                              037310 0000
      BE=WDTBOX                                                         037320 0000
      GO TO 3190                                                        037330 0000
C     ------------------------------------------------------------------ 037340 0000
C     COMPUTE FINAL EXCAVATED TRENCH WIDTH FOR BOX IN SOIL              037350 0000
 3130 IF(IDECK.EQ.0)BE=BE+(2.*DWALE+2.*DSP)/12.                         037360 0000
      IF(IDECK.EQ.1)  BE=BE+(2.*DWALE+2.*DSPD)/12.                      037370 0000
      GO TO 3190                                                        037380 0000
C     ------------------------------------------------------------------ 037390 0000
C     SIDE SLOPE FOR OPEN CUTS IN SOIL                                  037400 0000
C     ------------------------------------------------------------------ 037410 0000
C     ALL SLOPING CUTS EXCEPT CLAYS (D10.LE.0.005) WILL BE DEWATERED    037420 0000
 3140 IF(COHESN.GT.0.0) GO TO 3150                                      037430 0000
C     MATERIALS CHARACTERIZED BY PHI ONLY                               037440 0000
      SIDESL=1.25/TAN(PHI*PI/180.)                                      037450 0000
      GO TO 3190                                                        037460 0000
C     MATERIALS CHARACTERIZED BY COHESION ONLY OR BY PHI AND COHESION   037470 0000
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 3160 SIGGAH=GAMMA*DSOIL                                                037480 0000
      IF(DWATER.LT.DSOIL.AND.D10.LE.0.005) SIGGAH=GAMMA*DWATER+(GAMMA-  037490 0000
     1GB.4)*(DSOIL-DWATER)                                              037500 0000
      PHIDEV=ATAN(TAN(PHI*PI/180.)/1.25)                                037510 0000
      SIDESL=0.577                                                      037520 0000
      TEMP1=(1.0-COS(ATAN(1./SIDESL)-PHIDEV))/(4.*SIN(ATAN(1./SIDESL))  037530 0000
     1*COS(PHIDEV))                                                     037540 0000
      TEMP2=COHESN/(1.25*SIGGAH)                                        037550 0000
      IF(TEMP1.LE.TEMP2) GO TO 3190                                     037560 0000
C     ----------------------------------------------------------------- 037570 0000
C     SLOPE ANGLE IS BETWEEN PHIDEV AND 60 DEGREES                      037580 0000
      IF(PHI.EQ.0.0) MAX=11.0                                           037590 0000
      IF(PHI.GT.0.0) MAX=1/TAN(PHIDEV)                                  037600 0000
      MIN=0.577                                                         037610 0000
C     ITERATION REQUIRED TO DETERMINE DESIGN SLOPE                      037620 0000
 3160 SIDESL=(MIN+MAX)/2.                                               037630 0000
      TEMP1=(1.0-COS(ATAN(1./SIDESL)-PHIDEV))/(4.*SIN(ATAN(1./SIDESL))* 037640 0000
     1COS(PHIDEV))                                                      037650 0000
      IF(TEMP1.GT.TEMP2) GO TO 3170                                     037660 0000
      MIN=SIDESL                                                        037670 0000
      IF(MAX-MIN.LE.0.01) GO TO 3180                                    037680 0000
      GO TO 3160                                                        037690 0000
 3170 MAX=SIDESL                                                        037700 0000
      IF(MAX-MIN.LE.0.01) GO TO 3180                                    037710 0000
      GO TO 3160                                                        037720 0000
 3180 SIDESL=(MIN+MAX)/2.                                               037730 0000
C     ----------------------------------------------------------------- 037740 0000
C     SUMMARY CUT AND COVER                                             037750 0000
C     ----------------------------------------------------------------- 037760 0000
C     VOLUME DISPLACED BY BOX                                           037770 0000
 3190 VBOX=TOTBOX*WDTBOX/27.                                            037780 0000
C     ----------------------------------------------------------------- 037790 0000
C     TOTAL VOLUME OF CONCRETE PER FOOT OF BOX                          037800 0000
      VL=(WDTBOX*(TROOF+TINUT+TINSB)+BFBHT*(2*TEXWL+(NBOX-1)*TINWL))/27. 037810 0000
C     ----------------------------------------------------------------- 037820 0000
C     FORMWORK FOR CAST IN PLACE CONCRETE                               037830 0000
      FORMAR=0.                                                         037840 0000
      IF(LINING.NE.1) GO TO 3200                                        037850 0000
      FORMAR=BFBHT*(2+(NBOX-1)*2)+BFBWDT                                037860 0000
      IF(ISUPPT.EQ.5.AND.DROCK.GT.DROOF) FORMAR=FORMAR+2.*TOTBOX        037870 0000
      IF(IBOX2.EQ.1) FORMAR=FORMAR+BFBWDT                               037880 0000
C     ----------------------------------------------------------------- 037890 0000
C     STORE TRANSFERED VALUES IN 'A' ARRAY                              037900 0000
C     ----------------------------------------------------------------- 037910 0000
 3200 A(I,30)=STABNO                                                    037920 0000
      IF(ISUPPT.EQ.5) A(I,38)=SPDLT                                     037930 0000
      IF(ISUPPT.EQ.6) A(I,38)=DSLURY                                    037940 0000
      A(I,39)=BE                                                        037950 0000
      BOB=BE                                                            037960 0000
      A(I,42)=BOB                                                       037970 0000
      A(I,43)=TOTBOX                                                    037980 0000
      A(I,52)=DTRNCH                                                    037990 0000
      A(I,53)=SIDESL                                                    038000 0000
      A(I,54)=VBOX                                                      038010 0000
      A(I,55)=VL                                                        038020 0000
      A(I,56)=FORMAR                                                    038030 0000
      A(I,63)=WTWALE                                                    038040 0000
      A(I,64)=WTSTRT                                                    038050 0000
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      A(I,65)=WTANCH                                                    038060 0000
      A(I,66)=WTSP                                                      038070 0000
      A(I,67)=WTSPD                                                     038080 0000
      GO TO 4000                                                        038090 0000
C     ------------------------------------------------------------------ 038100 0000
C     CUT AND COVER SHAFTS                                              038110 0000
C     ------------------------------------------------------------------ 038120 0000
 3300 ICUTNC=1                                                          038130 0000
      ISUPPT=4                                                          038140 0000
      LINING=1                                                          038150 0000
C     REDUCE UNIT WEIGHT OF SOIL DUE TO BULKING DURING BACKFILLING       038160 0000
      GAMMA=GAMMA/1.1                                                   038170 0000
      GO TO 1000                                                        038180 0000
 4000 CONTINUE                                                          038190 0000
      IF(NSSTYP.EQ.3.OR.NTSTYP.EQ.3) RETURN                             038200 0000
C     CHECK IF FACE INFLOW INPUT WHEN GROUND WATER TABLE BELOW SEGMENT  038210 0000
      GI=A(I,9)                                                         038220 0000
      ELAVG=(ELNPL+ELNPR)/2.                                            038230 0000
      BE=A(I,39)                                                        038240 0000
      ELBOTM=ELAVG-BE/2.                                                038250 0000
      IF(ISHAPE.EQ.3) ELBOTM=ELAVG-BE/4.                                038260 0000
      IF(ITYPE.EQ.1.AND.GI.GT.0.0.AND.ELBOTM.GE.ELWATR) WRITE(LO,3600)  038270 0000
     1NTSEG,NREACH                                                      038280 0000
C     ------------------------------------------------------------------ 038290 0000
C     CHECK IF SHAFT SEGMENT IS WET WHEN WATER TABLE IS BELOW SEGMENT   038300 0000
      GI=B(I,9)                                                         038310 0000
      IF(ITYPE.EQ.2.AND.GI.GT.0.0.AND.ELNPB.GT.ELWATR) WRITE(LO,3605)   038320 0000
     1NSSEG,NSHAFT                                                      038330 0000
      RETURN                                                            038340 0000
C                                                                       038350 0000
 5000 PWATER=62.4*(ELWATR-ELAVG)
      IF(PWATER.LE.0.001)PWATER=.001
      TL=TLIN
      BF=BF+2*TL+.333
      BE40=BE
      BE60=BE
      BOB=BE
      BOB40=BOB
      BOB60=BOB
      A(I,39)=BE
      A(I,40)=BE40
      A(I,41)=BE60
      A(I,42)=BOB
      A(I,43)=BOB40
      A(I,44)=BOB60
      A(I,64)=PWATER
      A(I,11)=TL
C     ****************************************************************** 038370 0000
 1010 FORMAT(/,' **** WARNING **** ---THICKNESS INPUTED FOR SEGMENT',    038380 0000
     1 I4,' IN REACH',I4,' IS LESS THAN IN STANDARD DESIGN.  INPUT   IGN
     2ORED')                                                            038400 0000
 1011 FORMAT(/,' **** WARNING **** ---THICKNESS INPUTED FOR SEGMENT',    038410 0000
     1 I4,' IN SHAFT',I4,' IS LESS THAN IN STANDARD DESIGN.  INPUT IGN  038420 0000
     2ORED')                                                            038430 0000
 2710 FORMAT(/,' **** WARNING **** ---THICKNESS INPUTED FOR SEGMENT ',I4 038440 0000
     1,' IN REACH',I4,' APPEARS TO BE INADEQUATE FOR WATER PRESSURE.'   038450 0000
     2/,                          COMPUTED THICK. FOR WATER PRESSURE USED') 038460 0000
 2711 FORMAT(/,' **** WARNING **** ---THICKNESS INPUTED FOR SEGMENT ',I4 038470 0000
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     1,' IN SHAFT',I4,' APPEARS TO BE INADEQUATE FOR WATER PRESSURE.     038480 0000
     2/,                          COMPUTED THICK. FOR WATER PRESSURE USED') 038490 0000
 3500 FORMAT(/1X,'**** REMINDER ****    A LINING THICKNESS WAS INPUT FOR 038500 0000
     1 A CUT AND COVER BOX IN SEGMENT',I4,' IN REACH',I4,'.  INPUT IGNOR 038510 0000
     2ED')                                                               038520 0000
 3600 FORMAT(/,' **** WARNING ****    A GROUND WATER INFLOW WAS SPECIFIE 038530 0000
     1D IN SEGMENT',I5,' IN REACH',I5,' WHEN WATER TABLE IS BELOW BASE O 038540 0000
     2F TUNNEL.'/' INFLOW IGNORED IN COST COMPUTATIONS.')                038550 0000
 3605 FORMAT(/,' **** WARNING ****    WET GROUND SPECIFIED IN SEGMENT',  038560 0000
     1I5,' IN SHAFT',I5,' WHEN WATER TABLE IS BELOW SEGMENT.'/' WET GROU 038570 0000
     2ND IGNORED IN COST COMPUTATIONS.')                                 038580 0000
C     ******************************************************************* 038590 0000
C                                                                         038600 0000
C                                                                         038610 0000
      RETURN                                                              038615
      END                                                                 038620 0000
      SUBROUTINE STABIL(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX 038630 0000
     1,NTRMAX)                                                            038635
C     ------------------------------------------------------------------ 038640 0000
C     ------------------------------------------------------------------ 038650 0000
C     THIS SUBROUTINE SELECTS THE STABILITY NUMBER,STABILIZATION METHOD, 038660 0000
C     AND EXCAVATION METHOD   TO BE USED IN SOFT GROUND TUNNEL AND SHAFT 038670 0000
C     SEGMENTS                                                            038680 0000
C     ------------------------------------------------------------------ 038690 0000
C     ------------------------------------------------------------------ 038700 0000
      COMMON /BASIC/  NSS,NTS                                             038710 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE             038720 0000
      COMMON /F/ IERROR,ISTOP                                             038730 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),  038740 0000
     1 TRDATA(NTRMAX,23)                                                  038750 0000
C     ------------------------------------------------------------------ 038760 0000
C     ------------------------------------------------------------------ 038770 0000
C     DO NOT COMPUTE A STABILITY NUMBER IF ONE WAS INPUT. ALSO, DO NOT   038780 0000
C     COMPUTE ONE FOR PORTALS, DUMMY SHAFTS, AND CUT-AND-COVER SEGMENTS. 038790 0000
      IF(ITYPE.EQ.1) GO TO 1000                                           038800 0000
C     ------------------------------------------------------------------ 038810 0000
C     THIS IS A SHAFT SEGMENT                                             038820 0000
C     CHECK FOR ROCK OR CUT AND COVER SEGMENTS AND FOR A PORTAL OR       038830 0000
C     A DUMMY SHAFT                                                       038840 0000
      NSSTYP=B(I,15)                                                      038850 0000
      IF(NSSTYP.EQ.1) GO TO 500                                           038860 0000
      IF(NSSTYP.EQ.3) RETURN                                              038870 0000
      NSHAFT=B(I,1)                                                       038880 0000
      NPORT=SHAFT(NSHAFT,23)                                              038890 0000
      IF(NPORT.EQ.1) RETURN                                               038900 0000
      ISHAPS=SHAFT(NSHAFT,16)                                             038910 0000
      IF(ISHAPS.LT.1) RETURN                                              038920 0000
      BE    =B(I,29)                                                      038930 0000
      STABNO=B(I,24)                                                      038940 0000
      IF(STABNO.GT.0.01) GO TO 1830                                       038950 0000
      NSSEG =B(I,2)                                                       038960 0000
      MEX   =B(I,7)                                                       038970 0000
      ELWATR=B(I,13)                                                      038980 0000
      D10   =B(I,16)                                                      038990 0000
      COHESN=B(I,17)                                                      039000 0000
      GAMMA =B(I,18)                                                      039010 0000
      PHI   =B(I,19)                                                      039020 0000
      IWATER=B(I,21)                                                      039030 0000
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      PERM  =B(I,23)                                                    039040 0000
      MSTAB =B(I,25)                                                    039050 0000
      MUST  =B(I,26)                                                    039060 0000
      MSTAC =B(I,28)                                                    039070 0000
      SEGDEP=B(I,36)                                                    039080 0000
      NPTS  =SHAFT(NSHAFT,2)                                            039090 0000
      ELSURF=CNP(NPTS,2)                                                039100 0000
      ELAVG =ELSURF-SEGDEP                                              039110 0000
      GO TO 1003                                                        039120 0000
C     ROCK SHAFT                                                        039130 0000
  500 AIRPR=0                                                           039140 0000
      B(I,27)=AIRPR                                                     039150 0000
      MSTAB=0                                                           039160 0000
      B(I,25)=MSTAB                                                     039170 0000
      RETURN                                                            039180 0000
C     ------------------------------------------------------------------039190 0000
C     THIS IS A TUNNEL SEGMENT                                          039200 0000
 1000 NTSTYP=A(I,16)                                                    039210 0000
      IF(NTSTYP.EQ.1) GO TO 1002                                        039220 0000
      IF(NTSTYP.EQ.3) RETURN                                            039230 0000
      BE    =A(I,39)                                                    039240 0000
      STABNO=A(I,30)                                                    039250 0000
      IF(STABNO.GT.0.01) GO TO 1830                                     039260 0000
      NTSEG =A(I,1)                                                     039270 0000
      NPL   =A(I,2)                                                     039280 0000
      NPR   =A(I,3)                                                     039290 0000
      NREACH=A(I,4)                                                     039300 0000
      NEX   =A(I,7)                                                     039310 0000
      ELWATR=A(I,14)                                                    039320 0000
      NPLS  =A(I,17)                                                    039330 0000
      NPRS  =A(I,18)                                                    039340 0000
      D10   =A(I,19)                                                    039350 0000
      PHI   =A(I,20)                                                    039360 0000
      COHESN=A(I,21)                                                    039370 0000
      GAMMA =A(I,22)                                                    039380 0000
      IWATER=A(I,23)                                                    039390 0000
      ELIMP=A(I,24)                                                     039400 0000
      PERM  =A(I,25)                                                    039410 0000
      MSTAB =A(I,31)                                                    039420 0000
      MUST  =A(I,32)                                                    039430 0000
      MSTAC =A(I,34)                                                    039440 0000
      ISHAPE=TRDATA(NREACH,3)                                           039450 0000
      ELNPL =CNP(NPL,2)                                                 039460 0000
      ELNPR =CNP(NPR,2)                                                 039470 0000
      ELNPLS=CNP(NPLS,2)                                                039480 0000
      ELNPRS=CNP(NPRS,2)                                                039490 0000
      ELSURF=(ELNPLS+ELNPRS)/2.                                         039500 0000
      ELAVG =(ELNPL+ELNPR)/2.                                           039510 0000
      SEGDEP=ELSURF-ELAVG                                               039520 0000
      GO TO 1003                                                        039530 0000
C     ROCK TUNNEL                                                       039540 0000
 1002 AIRPR=0                                                           039550 0000
      A(I,33)=AIRPR                                                     039560 0000
      MSTAB=0                                                           039570 0000
      A(I,31)=MSTAB                                                     039580 0000
      RETURN                                                            039590 0000
 1003 AIRPR=0.                                                          039600 0000
C     COMPUTE STABILITY NUMBER BASED ON INPUT PARAMETERS                039610 0000
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      MSTABT=0                                                          039620 0000
      CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,  039630 0000
     1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 039640 0000
     2 SEGDEP)                                                          039650 0000
      STABNO=STABNM                                                     039660 0000
C     CHECK WHETHER A PREFERRED STABILIZATION METHOD WAS INPUT.  THE    039670 0000
C     PREFERENCE COULD BE FOR USE OF NO METHOD AT ALL.                  039680 0000
      IF(MUST.GE.3) GO TO 1500                                          039690 0000
C     NO METHOD IS PREFERRED BY USER. CHECK IF SEGMENT CAN BE EXCAVATED. 039700-
  040100 0000
C     THE PREFERRED METHOD IS DEWATERING                                040110 0000
 1010 MSTAB=2                                                           040120 0000
      MSTABT=2                                                          040130 0000
      CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,  040140 0000
     1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 040150 0000
     2 SEGDEP)                                                          040160 0000
      GO TO 1030                                                        040170 0000
C     THE PREFERRED METHOD IS COMPRESSED AIR                            040180 0000
 1015 CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 040190 0000
     1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                       040200 0000
      MSTAB=1                                                           040210 0000
 1030 IF(ITYPE.EQ.1) A(I,30)=STABNM                                     040220 0000
      IF(ITYPE.EQ.1) A(I,31)=MSTAB                                      040230 0000
      IF(ITYPE.EQ.1) A(I,33)=AIRPR                                      040240 0000
      IF(ITYPE.EQ.2) B(I,24)=STABNM                                     040250 0000
      IF(ITYPE.EQ.2) B(I,25)=MSTAB                                      040260 0000
      IF(ITYPE.EQ.2) B(I,27)=AIRPR                                      040270 0000
C     CHECK WHETHER THE SEGMENT CAN BE EXCAVATED AFTER STABILIZATION    040280 0000
 1035 IF(STABNM.LE.9. .AND.PHI.LT.29. .OR. STABNM.LE.7. .AND.PHI.GE.29.) 040290 0000
     1 GO TO 1050                                                       040300 0000
C     SEGMENT CANNOT BE EXCAVATED EVEN AFTER USING A STABILIZATION METH. 040310 0000
      IERROR=1                                                          040320 0000
      IF(ITYPE.EQ.1) WRITE(LO,2000)NTSEG,NREACH                         040330 0000
      IF(ITYPE.EQ.2) WRITE(LO,3000)NSSEG,NSHAFT                         040340 0000
      RETURN                                                            040350 0000
C     SEGMENT CAN NOW BE EXCAVATED. STORE THE NEW STABILITY NUMBER      040360 0000
 1050 STABNO=STABNM                                                     040370 0000
      GO TO 1800                                                        040380 0000
C     ------------------------------------------------------------------ 040390 0000
C     SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION         040400 0000
C     IF USER WILL ALLOW A STABILIZATION METHOD AND STABILITY NUMBER IS 040410 0000
C     HIGH,CHECK WHETHER USE OF STABILIZATION WILL DECREASE STABILITY   040420 0000
C     NUMBER BY AT LEAST 1.0                                            040430 0000
C     ------------------------------------------------------------------ 040440 0000
 1200 IF(STABNO.LE.4.) GO TO 1300                                       040450 0000
      IF(MUST.GT.1) GO TO 1300                                          040460 0000
C     USER WILL ALLOW STABILIZATION TO BE USED                          040470 0000
      IF(D10.LE. .005) GO TO 1215                                       040480 0000
      AIRPR=0.                                                          040490 0000
      IF(ELAVG.GE.ELWATR .OR.IWATER.EQ.0) GO TO 1205                    040500 0000
      IF(PERM.LT.0. .AND.ABS(PERM).GT.0.0006) GO TO 1209                040510 0000
      IF(PERM.GT.0. .AND. D10.GT.0.08) GO TO 1209                       040520 0000
C     THE FIRST CHOICE METHOD IS GROUND INJECTIONS                      040530 0000
 1205 MSTAB=3                                                           040540 0000
      COHSGI=20000.*SQRT(10.*ABS(PERM))                                 040550 0000
      STABNM=SIGMAT/(SHRSTR+COHSGI)                                     040560 0000
      IF(STABNO-STABNM.GE.1.) GO TO 1235                                040570 0000
C     DECREASE IN STABILITY NUMBER CAUSED BY USE OF GROUND INJECTIONS IS 040580 0000
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C     SMALL. IF COMPRESSED AIR IS ACCEPTABLE,CHECK IF IT GIVES GREATER   040590 0000
C     DECREASE.                                                          040600 0000
      IF(PERM.LT.0. .AND. ABS(PERM).GT.0.4) GO TO 1235                   040610 0000
      IF(PERM.GT.0. .AND.D10.GT.2.) GO TO 1235                           040620 0000
      IF(ELAVG.GE.ELWATR) GO TO 1207                                     040630 0000
      IF(ELWATR-ELAVG.GT.115.) GO TO 1235                                040640 0000
C     COMPRESSED AIR IS AN ACCEPTABLE METHOD.                            040650 0000
 1207 CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 040660 0000
     1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                        040670 0000
      MSTAB=1                                                            040680 0000
      GO TO 1235                                                         040690 0000
 1209 IF(SEGDEP.LE.150.) GO TO 1210                                      040700 0000
C     GROUND WOULD BE DEWATERED EXCEPT THAT SEGMENT IS DEEPER THAN IS    040710 0000
C     USUALLY DESIRED. TRY GROUND INJECTIONS FIRST. IF STABILITY NUMBER  040720 0000
C     DOES NOT CHANGE BY MUCH,TRY DEWATERING INSTEAD.                    040730 0000
      COHSGI=20000.*SQRT(10.*ABS(PERM))                                  040740 0000
      STABNM=SIGMAT/(SHRSTR+COHSGI)                                      040750 0000
      IF(STABNO-STABNM.GE.1.) GO TO 1235                                 040760 0000
C     THE PREFERRED METHOD IS DEWATERING                                 040770 0000
 1210 MSTAB=2                                                            040780 0000
      MSTABT=2                                                           040790 0000
      CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,  040800 0000
     1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 040810 0000
     2 SEGDEP)                                                           040820 0000
      GO TO 1235                                                         040830 0000
C     THE PREFERRED METHOD IS COMPRESSED AIR                             040840 0000
 1215 MSTAB=1                                                            040850 0000
      CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 040860 0000
     1 STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                       040870 0000
C     CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0                040880 0000
 1235 IF(STABNO-STABNM.GE.1.) GO TO 1245                                 040890 0000
C     STABILITY NUMBER DECREASE IS LESS THAN 1.0  FORGET STABILIZATION   040900 0000
C     METHOD AND EXCAVATE USING ORIGINAL GROUND CONDITIONS               040910 0000
      MSTAB=0                                                            040920 0000
      AIRPR=0.                                                           040930 0000
      IF(ITYPE.EQ.1) GO TO 1240                                          040940 0000
      WRITE(LO,3010) NSSEG,NSHAFT                                        040950 0000
      B(I,24)=STABNO                                                     040960 0000
      B(I,25)=MSTAB                                                      040970 0000
      B(I,27)=AIRPR                                                      040980 0000
      GO TO 1800                                                         040990 0000
 1240 WRITE(LO,2010) NTSEG,NREACH                                        041000 0000
      A(I,30)=STABNO                                                     041010 0000
      A(I,31)=MSTAB                                                      041020 0000
      A(I,33)=AIRPR                                                      041030 0000
      GO TO 1800                                                         041040 0000
C     STABILITY NUMBER DECREASED BY AT LEAST 1.0  USE STABILIZATION      041050 0000
C     METHOD AND NEW STABILITY NUMBER                                    041060 0000
 1245 IF(MSTAB.GT.1) AIRPR=0.                                            041070 0000
      IF(ITYPE.EQ.1) GO TO 1250                                          041080 0000
      B(I,24)=STABNM                                                     041090 0000
      B(I,25)=MSTAB                                                      041100 0000
      B(I,27)=AIRPR                                                      041110 0000
      STABNO=STABNM                                                      041120 0000
      GO TO 1800                                                         041130 0000
 1250 A(I,30)=STABNM                                                     041140 0000
      A(I,31)=MSTAB                                                      041150 0000
      A(I,33)=AIRPR                                                      041160 0000
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      STABNO=STABNM                                                     041170 0000
      GO TO 1800                                                        041180 0000
 1300 IF(ITYPE.EQ.1) A(I,30)=STABNO                                     041190 0000
      IF(ITYPE.EQ.2) B(I,24)=STABNO                                     041200 0000
      GO TO 1800                                                        041210 0000
C     ****************************************************************** 041220 0000
C     A PREFERRED STABILIZATION METHOD WAS INPUT.  THE PREFERENCE COULD 041230 0000
C     BE FOR USE OF NO METHOD AT ALL.                                   041240 0000
C     CAN THE SEGMENT BE EXCAVATED WITHOUT STABILIZATION                041250 0000
 1500 IF(STABNO.LE.9. .AND.PHI.LT.29. .OR.STABNO.LE.7. .AND.PHI.GE.29.) 041260 0000
     1 GO TO 1600                                                       041270 0000
C     ------------------------------------------------------------------ 041280 0000
C     CHECK IF USER WILL ALLOW SOME METHOD TO BE USED.                  041290 0000
      IF(MSTAB.GT.0) GO TO 1502                                         041300 0000
      IERROR=1                                                          041310 0000
      IF(ITYPE.EQ.1) WRITE(LO,2050) NTSEG,NREACH                        041320 0000
      IF(ITYPE.EQ.2) WRITE(LO,3050) NSSEG,NSHAFT                        041330 0000
      GO TO 1530                                                        041340 0000
C     ------------------------------------------------------------------ 041350 0000
C     SEGMENT CANNOT BE EXCAVATED WITHOUT STABILIZATION. CHECK WHETHER  041360 0000
C     USERS PREFERRED METHOD IS ACCEPTABLE                              041370 0000
 1502 IF(ITYPE.EQ.2) GO TO 1505                                         041380 0000
      IF(MSTAC.EQ.1) GO TO 1510                                         041390 0000
C     METHOD IS UNACCEPTABLE                                            041400 0000
      IERROR=1                                                          041410 0000
      WRITE(LO,3030) NSSEG,NSHAFT                                       041420 0000
      RETURN                                                            041430 0000
 1505 IF(MSTAC.EQ.1) GO TO 1510                                         041440 0000
C     METHOD IS UNACCEPTABLE                                            041450 0000
      IERROR=1                                                          041460 0000
      WRITE(LO,2030) NTSEG,NREACH                                       041470 0000
      RETURN                                                            041480 0000
C     ------------------------------------------------------------------ 041490 0000
C     STABILIZATION METHOD INPUT IS ACCEPTABLE                          041500 0000
C     CHECK FOR PREFERRED METHOD                                        041510 0000
 1510 IF(MSTAB.EQ.1) GO TO 1520                                         041520 0000
      IF(MSTAB.EQ.3) GO TO 1518                                         041530 0000
C     THE PREFERRED METHOD IS DEWATERING                                041540 0000
      MSTABT=2                                                          041550 0000
      CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 041560 0000
     1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 041570 0000
     2 SEGDEP)                                                          041580 0000
      GO TO 1525                                                        041590 0000
C     THE PREFERRED METHOD IS GROUND INJECTIONS                         041600 0000
 1518 COHSGI=20000.*SQRT(10.*ABS(PERM))                                 041610 0000
      STABNM=SIGMAT/(SHRSTR+COHSGI)                                     041620 0000
      GO TO 1525                                                        041630 0000
C     THE PREFERRED METHOD IS COMPRESSED AIR                            041640 0000
 1520 IF(ITYPE.EQ.1) AIRPR=A(I,33)                                      041650 0000
      IF(ITYPE.EQ.2) AIRPR=B(I,27)                                      041660 0000
C     IF AIR PRESSURE IS INPUT,USE IT AND COMPUTE STABILITY NUMBER.IF   041670 0000
C     NONE IS INPUT,COMPUTE AIR PRESSURE                                041680 0000
      IF(AIRPR.GT.0.) GO TO 1522                                        041690 0000
      CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 041700 0000
     1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                       041710 0000
      GO TO 1525                                                        041720 0000
 1522 STABNM=(SIGMAT-AIRPR*144.)/SHRSTR                                 041730 0000
C     CHECK WHETHER SEGMENT CAN BE EXCAVATED AFTER STABILIZATION        041740 0000
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 1525 IF(STABNM.LE.9. .AND.PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.)  041750 0000
     1 GO TO 1530                                                       041760 0000
C     SEGMENT CANNOT BE EXCAVATED EVEN AFTER USING A STABILIZATION METH. 041770 0000
      IERROR=1                                                          041780 0000
      IF(ITYPE.EQ.1) WRITE(LO,2035)NTSEG,NREACH                         041790 0000
      IF(ITYPE.EQ.2) WRITE(LO,3035)NSSEG,NSHAFT                         041800 0000
      IF(ITYPE.EQ.1) A(I,30)=STABNM                                     041810 0000
      IF(ITYPE.EQ.1) A(I,33)=AIRPR                                      041820 0000
      IF(ITYPE.EQ.2) B(I,24)=STABNM                                     041830 0000
      IF(ITYPE.EQ.2) B(I,27)=AIRPR                                      041840 0000
      GO TO 1830                                                        041850 0000
C     ----------------------------------------------------------------- 041860 0000
C     SEGMENT CAN NOW BE EXCAVATED                                      041870 0000
 1530 IF(ITYPE.EQ.1) GO TO 1535                                         041880 0000
      B(I,24)=STABNM                                                    041890 0000
      B(I,27)=AIRPR                                                     041900 0000
      STABNO=STABNM                                                     041910 0000
      GO TO 1800                                                        041920 0000
 1535 A(I,30)=STABNM                                                    041930 0000
      A(I,33)=AIRPR                                                     041940 0000
      STABNO=STABNM                                                     041950 0000
      GO TO 1800                                                        041960 0000
C     ----------------------------------------------------------------- 041970 0000
C     SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION METHOD  041980 0000
C     ----------------------------------------------------------------- 041990 0000
C     CHECK IF NO METHOD IS TO BE USED                                  042000 0000
 1600 IF(MSTAB.EQ.0) GO TO 1640                                         042010 0000
C     CHECK WHETHER USER REQUIRES STABILIZATION METHOD TO BE USED       042020 0000
      IF(MUST.EQ.4) GO TO 1610                                          042030 0000
C     STABILIZATION IS NOT REQUIRED.FORGET STABILIZATION AND EXCAVATE   042040 0000
C     USING THE ORIGINAL GROUND CONDITIONS.                             042050 0000
      IF(ITYPE.EQ.1) GO TO 1605                                         042060 0000
      WRITE(LO,3015) NSSEG,NSHAFT                                       042070 0000
      MSTAB=0                                                           042080 0000
      B(I,24)=STABNO                                                    042090 0000
      B(I,25)=MSTAB                                                     042100 0000
      GO TO 1800                                                        042110 0000
 1605 WRITE(LO,2015) NTSEG,NREACH                                       042120 0000
      MSTAB=0                                                           042130 0000
      A(I,30)=STABNO                                                    042140 0000
      A(I,31)=MSTAB                                                     042150 0000
      GO TO 1800                                                        042160 0000
C     ----------------------------------------------------------------- 042170 0000
C     USER REQUIRES USE OF A STABILIZATION METHOD. CHECK IF SPECIFIED   042180 0000
C     METHOD IS ACCEPTABLE. IF METHOD IS UNACCEPTABLE,BASE COSTS ON     042190 0000
C     UNSTABILIZED GROUND                                               042200 0000
 1610 IF(ITYPE.EQ.1) GO TO 1615                                         042210 0000
      IF(MSTAC.EQ.1) GO TO 1620                                         042220 0000
      WRITE(LO,3020) NSSEG,NSHAFT                                       042230 0000
      GO TO 1800                                                        042240 0000
 1615 IF(MSTAC.EQ.1) GO TO 1620                                         042250 0000
      WRITE(LO,2020) NTSEG,NREACH                                       042260 0000
      GO TO 1800                                                        042270 0000
C     ----------------------------------------------------------------- 042280 0000
C     STABILIZATION METHOD INPUT IS ACCEPTABLE                          042290 0000
C     CHECK FOR PREFERRED METHOD                                        042300 0000
 1620 IF(MSTAB.EQ.1) GO TO 1630                                         042310 0000
      IF(MSTAB.EQ.3) GO TO 1625                                         042320 0000
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C     THE PREFERRED METHOD IS DEWATERING                                042330 0000
      MSTABT=2                                                          042340 0000
      CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 042350 0000
     1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 042360 0000
     2 SEQDEP)                                                          042370 0000
      GO TO 1635                                                        042380 0000
C     THE PREFERRED METHOD IS GROUND INJECTIONS                         042390 0000
 1625 COHSGI=80000.*SQRT(10.*ABS(PERM))                                 042400 0000
      STABNM=SIGMAT/(SHRSTR+COHSGI)                                     042410 0000
      GO TO 1635                                                        042420 0000
C     THE PREFERRED METHOD IS COMPRESSED AIR                            042430 0000
 1630 IF(ITYPE.EQ.1) AIRPR=A(I,33)                                      042440 0000
      IF(ITYPE.EQ.2) AIRPR=B(I,27)                                      042450 0000
C     IF AIR PRESSURE IS INPUT,USE IT AND COMPUTE STABILITY NUMBER.IF   042460 0000
C     NONE IS INPUT,COMPUTE AIR PRESSURE                                042470 0000
      IF(AIRPR.GT.0.) GO TO 1632                                        042480 0000
      CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 042490 0000
     1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                       042500 0000
      GO TO 1635                                                        042510 0000
 1632 STABNM=(SIGMAT-AIRPR*144.)/SHRSTR                                 042520 0000
C     ------------------------------------------------------------------ 042530 0000
C     CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0               042540 0000
 1635 IF(STABNO-STABNM.GE.1.) GO TO 1640                                042550 0000
C     STABILITY NUMBER DID NOT DECREASE BY AT LEAST 1.0 INFORM USER     042560 0000
      IF(ITYPE.EQ.1) WRITE(LO,2025) NTSEG,NREACH                        042570 0000
      IF(ITYPE.EQ.2) WRITE(LO,3025) NSSEG,NSHAFT                        042580 0000
 1640 IF(ITYPE.EQ.1) A(I,30)=STABNM                                     042590 0000
      IF(ITYPE.EQ.1) A(I,33)=AIRPR                                      042600 0000
      IF(ITYPE.EQ.2) B(I,24)=STABNM                                     042610 0000
      IF(ITYPE.EQ.2) B(I,27)=AIRPR                                      042620 0000
      STABNO=STABNM                                                     042630 0000
C     ****************************************************************** 042640 0000
C     CHECK FOR ACCEPTABLE EXCAVATION METHOD FOR THE STABILITY NUMBER   042650 0000
C     TO BE USED,THE CHECK FOR COMPATIBILITY WITH SHAPE IS IN SUB INPUT 042660 0000
 1800 IF(ITYPE.EQ.1)GO TO 1805                                          042670 0000
      IF(MEX.EQ.4) GO TO 1830                                           042680 0000
      IF(MEX.EQ.3 .AND.STABNO.LE.6.) GO TO 1830                         042690 0000
C     METHOD IS UNACCEPTABLE,SELECT HAND METHODS INSTEAD                042700 0000
      MEX=4                                                             042710 0000
      B(I,7)=MEX                                                        042720 0000
      WRITE(LO,3040) NSSEG,NSHAFT                                       042730 0000
      GO TO 1830                                                        042740 0000
 1805 IF(MEX-4) 1820,1830,1810                                          042750 0000
C     RIPPER EXCAVATION                                                 042760 0000
 1810 IF(STABNO.LE.7.) GO TO 1830                                       042770 0000
      GO TO 1825                                                        042780 0000
C     MOLE EXCAVATION                                                   042790 0000
 1820 IF(STABNO.LE.6.) GO TO 1830                                       042800 0000
C     MOLE OR RIPPER ARE UNACCEPTABLE,SELECT HAND INSTEAD               042810 0000
 1825 MEX=4                                                             042820 0000
      A(I,7)=MEX                                                        042830 0000
      WRITE(LO,2040) NTSEG,NREACH                                       042840 0000
C     ****************************************************************** 042850 0000
C     IF STABILITY NUMBER IS LOW,SHIELD IS VERY THIN AND LEAVES LITTLE  042860 0000
C     SPACE FOR BACKFILL BEHIND THE LINING OR SUPPORT                   042870 0000
 1830 BOB=BE+1.0                                                        042880 0000
      IF(STABNO.LT.2.) BOB=BE                                           042890 0000
      IF(ITYPE.EQ.1) A(I,42)=BOB                                        042900 0000
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      IF(ITYPE.EQ.2) B(I,32)=BOB                                        042910 0000
      RETURN                                                            042920 0000
C     ****************************************************************** 042930 0000
 2000 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN RE   042940 0000
     1ACH',I5,' IS TOO HIGH TO ALLOW EXCAVATION,EVEN AFTER STABILIZATIO 042950 0000
     2N')                                                               042960 0000
 2010 FORMAT(/,' **** REMINDER ****  USE OF A STABILIZATION METHOD IN   042970 0000
     1SEGMENT',I5,' IN REACH',I5,' IS NOT VERY EFFECTIVE, NO METHOD USE 042980 0000
     2D')                                                               042990 0000
 2015 FORMAT(/,' **** REMINDER ****  USER PREFERRED STABILIZATION METH  043000 0000
     1OD IN SEGMENT',I5,' IN REACH',I5,' IS NOT REQUIRED, METHOD NOT US 043010 0000
     2ED')                                                              043020 0000
 2020 FORMAT(/,' **** WARNING ****  USERS STAB. METHOD IN SEGMENT',I5,  043030 0000
     1 ' IN REACH',I5,' IS NOT ACCEPTABLE NOR REQUIRED, METHOD NOT USE  043040 0000
     2D')                                                               043050 0000
 2025 FORMAT(/,' **** REMINDER **** USE OF STABILIZATION METHOD IN SEG  043060 0000
     1MENT',I5,' IN REACH',I5,' IS NOT VERY EFFECTIVE, METHOD USED ANYW 043070 0000
     2AY')                                                              043080 0000
 2030 FORMAT(/,' FATAL ERROR, USERS STAB. METHOD IN SEGMENT',I5,' IN R  043090 0000
     2EACH',I5,' IS NOT ACCEPTABLE AND STABILITY NUMBER IS TOO HIGH')   043100 0000
 2035 FORMAT(/,' FATAL ERROR, USERS STAB. METHOD IN SEGMENT',I5,' IN R  043110 0000
     1EACH',I5,' IS NOT EFFECTIVE AND STABILITY NUMBER IS TOO HIGH')    043120 0000
 2040 FORMAT(/,' **** REMINDER **** CONDITIONS IN SEGMENT',I5,' IN REA  043130 0000
     1CH',I5,' REQUIRE USE OF HAND EXCAVATION RATHER THAN INPUT METHOD') 043140 0000
 2050 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN REA  043150 0000
     1CH',I5,' REQUIRES GROUND STABILIZATION, BUT IT WAS SPECIFIED NO M 043160 0000
     2ETHOD BE USED')                                                   043170 0000
 3000 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN SH   043180 0000
     1AFT',I5,' IS TOO HIGH TO ALLOW EXCAVATION,EVEN AFTER STABILIZATIO 043190 0000
     2N')                                                               043200 0000
 3010 FORMAT(/,' **** REMINDER ****  USE OF A STABILIZATION METHOD IN   043210 0000
     1SEGMENT',I5,' IN SHAFT',I5,' IS NOT VERY EFFECTIVE, NO METHOD USE 043220 0000
     2D')                                                               043230 0000
 3015 FORMAT(/,' **** REMINDER ****  USER PREFERRED STABILIZATION METH  043240 0000
     1OD IN SEGMENT',I5,' IN SHAFT',I5,' IS NOT REQUIRED, METHOD NOT US 043250 0000
     2ED')                                                              043260 0000
 3020 FORMAT(/,' **** WARNING ****  USERS STAB. METHOD IN SEGMENT',I5,  043270 0000
     1 ' IN SHAFT',I5,' IS NOT ACCEPTABLE NOR REQUIRED, METHOD NOT USE  043280 0000
     2D')                                                               043290 0000
 3025 FORMAT(/,' **** REMINDER **** USE OF STABILIZATION METHOD IN SEG  043300 0000
     1MENT',I5,' IN SHAFT',I5,' IS NOT VERY EFFECTIVE, METHOD USED ANYW 043310 0000
     2AY')                                                              043320 0000
 3030 FORMAT(/,' FATAL ERROR, USERS STAB. METHOD IN SEGMENT',I5,' IN S  043330 0000
     1HAFT',I5,' IS NOT ACCEPTABLE AND STABILITY NUMBER IS TOO HIGH')   043340 0000
 3035 FORMAT(/,' FATAL ERROR, USERS STAB. METHOD IN SEGMENT',I5,' IN S  043350 0000
     1HAFT',I5,' IS NOT EFFECTIVE AND STABILITY NUMBER IS TOO HIGH')    043360 0000
 3040 FORMAT(/,' **** REMINDER **** CONDITIONS IN SEGMENT',I5,' IN SHA  043370 0000
     1FT',I5,' REQUIRE USE OF HAND EXCAVATION RATHER THAN INPUT METHOD') 043380 0000
 3050 FORMAT(/,' FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN SHA  043390 0000
     1FT',I5,' REQUIRES GROUND STABILIZATION, BUT IT WAS SPECIFIED NO M 043400 0000
     2ETHOD BE USED')                                                   043410 0000
C     ------------------------------------------------------------------ 043420 0000
C                                                                        043430 0000
C                                                                        043440 0000
C                                                                        043450 0000
      RETURN                                                            043455
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      END                                                               043460 0000
      SUBROUTINE STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS, 043470 0000
     1 ITYPE,PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F, 043480 0000
     2 FSHAPE,SEGDEP)                                                   043490 0000
C     ------------------------------------------------------------------ 043500 0000
C     ------------------------------------------------------------------ 043510 0000
C     THIS SUBROUTINE COMPUTES THE INITIAL STABILITY NUMBER BASED ONLY   043520 0000
C     ON INPUT GROUND PARAMETERS AND ALSO COMPUTES IT IF STABILIZATION   043530 0000
C     IS BY DEWATERING                                                   043540 0000
C     ------------------------------------------------------------------ 043550 0000
C     ------------------------------------------------------------------ 043560 0000
      PI=3.14159                                                        043570 0000
      SINPHI=SIN(PHI*PI/180.)                                           043580 0000
      TANPHI=TAN(PHI*PI/180.)                                           043590 0000
C     CHECK WHETHER THIS IS THE SECOND COMPUTATION FOR THIS SEGMENT.IF  043600 0000
C     SO,CAN BYPASS MOST OF THIS SUBROUTINE.                            043610 0000
      IF(MSTABT.EQ.2) GO TO 1150                                        043620 0000
C     COMPUTE STABILITY NUMBER FOR UNSTABILIZED GROUND                  043630 0000
C     CHECK FOR GWT ABOVE GROUND SURFACE                                043640 0000
      IF(ELWATR.GT.ELSURF) GO TO 1050                                   043650 0000
C     CHECK FOR SEGMENT BELOW GWT                                       043660 0000
      IF(ELAVG.LT.ELWATR) GO TO 1010                                    043670 0000
C     GWT IS BELOW SEGMENT                                              043680 0000
      SIGGAH=SEGDEP*GAMMA                                               043690 0000
      IF(SEGDEP.LE.2.*BE) GO TO 1000                                    043700 0000
      GAMMAA=GAMMA                                                      043710 0000
      GAMMAB=GAMMA                                                      043720 0000
      GO TO 1100                                                        043730 0000
 1000 GAMMAC=GAMMA                                                      043740 0000
      GO TO 1100                                                        043750 0000
C     SEGMENT IS BELOW GWT                                              043760 0000
 1010 DWATER=ELSURF-ELWATR                                              043770 0000
      SIGGAH=DWATER*GAMMA+(ELWATR-ELAVG)*(GAMMA-62.4)                   043780 0000
      IF(SEGDEP.LE.2.*BE) GO TO 1030                                    043790 0000
      IF(DWATER.GT.2.*BE) GO TO 1020                                    043800 0000
C     SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE 043810 0000
      GAMMAA=(GAMMA*DWATER+(GAMMA-62.4)*(2.*BE-DWATER))/(2.*BE)         043820 0000
      GAMMAB=(GAMMA-62.4)                                               043830 0000
      GO TO 1100                                                        043840 0000
C     SEGMENT AND GWT ARE BOTH DEEPER THAN 2BE                          043850 0000
 1020 GAMMAA=GAMMA                                                      043860 0000
      GAMMAB=(GAMMA*(DWATER-2.*BE)+(GAMMA-62.4)*(ELWATR-ELAVG))/(SEGDEP- 043870 0000
     1 2.*BE)                                                           043880 0000
      GO TO 1100                                                        043890 0000
C     SEGMENT IS WITHIN 2BE OF GROUND SURFACE                           043900 0000
 1030 GAMMAC=(GAMMA*DWATER+(GAMMA-62.4)*(ELWATR-ELAVG))/SEGDEP          043910 0000
      GO TO 1100                                                        043920 0000
C     GWT IS ABOVE GROUND SURFACE                                       043930 0000
 1050 GAMMAA=GAMMA-62.4                                                 043940 0000
      GAMMAB=GAMMA-62.4                                                 043950 0000
      GAMMAC=GAMMA-62.4                                                 043960 0000
      SIGGAH=SEGDEP*(GAMMA-62.4)                                        043970 0000
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(Continued)

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C     ------------------------------------------------------------------ 043980 0000
 1100 PHIEQR=ATAN(COHESN/SIGGAH+TANPHI)                                  043990 0000
      PHIEQ=PHIEQR*180./PI                                               044000 0000
      IF(PHIEQ.GT.45.) PHIEQ=45.                                         044010 0000
C     ESTABLISH SEGMENT TYPE AND SHAPE FACTORS                           044020 0000
      IF(SEGDEP.LE.2.*BE) GO TO 1300                                     044030 0000
      F=1.0                                                              044040 0000
      FSHAPE=1.0                                                         044050 0000
      IF(ITYPE.EQ.1) GO TO 1110                                          044060 0000
C     SHAFT SEGMENT                                                      044070 0000
      F=0.5                                                              044080 0000
      FSHAPE=0.5                                                         044090 0000
      IF(ISHAPS.EQ.2) F=0.6                                              044100 0000
      IF(ISHAPS.EQ.2) FSHAPE=0.6                                         044110 0000
      GO TO 1200                                                         044120 0000
C     TUNNEL SEGMENT                                                     044130 0000
 1110 IF(ISHAPE.EQ.3) FSHAPE=1.25                                        044140 0000
      GO TO 1200                                                         044150 0000
C     ------------------------------------------------------------------ 044160 0000
C     THE FOLLOWING UNIT WEIGHTS ARE FOR STABILIZATION BY DEWATERING     044170 0000
 1150 IF(SEGDEP.LE.2.*BE) GO TO 1160                                     044180 0000
      GAMMAA=GAMMA                                                       044190 0000
      GAMMAB=GAMMA                                                       044200 0000
      GO TO 1200                                                         044210 0000
 1160 GAMMAC=GAMMA                                                       044220 0000
      GO TO 1350                                                         044230 0000
C     ------------------------------------------------------------------ 044240 0000
C     SEGMENT IS DEEPER THAN 2BE                                         044250 0000
 1200 SIGMAT=2.*BE*GAMMA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)*        044260 0000
     1 GAMMA*FSHAPE                                                      044270 0000
C     INCREASE SIGMAT IF GWT IS ABOVE GROUND AND SEGMENT NOT DEWATERED   044280 0000
      IF(MSTABT.EQ.2) GO TO 1250                                         044290 0000
      IF(ELWATR.GT.ELSURF) SIGMAT=SIGMAT+(ELWATR-ELSURF)*62.4            044300 0000
 1250 SIGMA1=2.*BE*GAMMAA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)*       044310 0000
     1 GAMMAB*FSHAPE                                                     044320 0000
      GO TO 1400                                                         044330 0000
C     SEGMENT IS NO DEEPER THAN 2BE                                      044340 0000
 1300 F=1.0                                                              044350 0000
      IF(ITYPE.EQ.1) GO TO 1350                                          044360 0000
C     SHAFT SEGMENT                                                      044370 0000
      F=0.5                                                              044380 0000
      IF(ISHAPS.EQ.2) F=0.6                                              044390 0000
 1350 SIGMAT=SEGDEP*GAMMA*F                                              044400 0000
C     INCREASE SIGMAT IF GWT IS ABOVE GROUND AND SEGMENT NOT DEWATERED   044410 0000
      IF(MSTABT.EQ.2) GO TO 1375                                         044420 0000
      IF(ELWATR.GT.ELSURF) SIGMAT=SIGMAT+(ELWATR-ELSURF)*62.4            044430 0000
 1375 SIGMA1=SEGDEP*GAMMAC*F                                             044440 0000
C     ------------------------------------------------------------------ 044450 0000
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C     COMPUTE STABILITY NUMBER                                          044460 0000
 1400 FRSTRN=SIGMA1/2.*(1.-SINPHI)*TANPHI                               044470 0000
      SHRSTR=COHESN+FRSTRN                                              044480 0000
      STABNM=SIGMAT/SHRSTR                                              044490 0000
C     ------------------------------------------------------------------044500 0000
      RETURN                                                            044510 0000
      END                                                               044520 0000
      SUBROUTINE AIRPRS(AIRPR ,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,044530 0000
     1SIGMAT,STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                044540 0000
C     ------------------------------------------------------------------044550 0000
C     ------------------------------------------------------------------044560 0000
C                                                                       044570 0000
C     THIS SUBROUTINE DETERMINES THE AIR PRESSURE TO BE USED FOR SOFT   044580 0000
C     GROUND CONSTRUCTION IN COMPRESSED AIR                             044590 0000
C                                                                       044600 0000
C     ------------------------------------------------------------------044610 0000
C     ------------------------------------------------------------------044620 0000
C     CHECK FOR GRANULAR MATERIAL BELOW GWT. IF SO, AIR PRESSURE IS     044630 0000
C     CONTROLLED BY WATER HEAD                                          044640 0000
      IF(D10.GT. .005 .AND.ELAVG.LT.ELWATR) AIRPR=.433*(ELWATR-ELAVG)   044650 0000
      IF(D10.GT. .005 .AND.ELAVG.LT.ELWATR) RETURN                      044660 0000
C     ------------------------------------------------------------------044670 0000
C     AIR PRESSURE IS NOT CONTROLLED BY WATER HEAD. START BY COMPUTING  044680 0000
C     STABILITY NUMBER USING MINIMUM AIR PRESSURE OF 7 PSI.             044690 0000
      AIRPR=7.0                                                         044700 0000
      STABNM=(SIGMAT-AIRPR*144.)/SHRSTR                                 044710 0000
C     CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0               044720 0000
      IF(STABNO-STABNM.GE.1.) GO TO 1100                                044730 0000
C     DECREASE LESS THAN 1.0  COMPUTE AIR PRESURE FOR DECREASE= 1.0     044740 0000
      AIRPR=(SIGMAT-(STABNO-1.)*SHRSTR)/144.                            044750 0000
C     CHECK FOR AIR PRESSURE GREATER THAN 50 PSI                        044760 0000
      IF(AIRPR.GT.50.) GO TO 1000                                       044770 0000
C     AIR PRESSURE IS LESS THAN 50 PSI.  CAN SEGMENT BE EXCAVATED       044780 0000
      IF(STABNO-1. .LE.9. .AND.PHI.LT.29. .OR.STABNO-1. .LE.7. .AND.PHI 044790 0000
     1 .GE.29.) GO TO 1050                                              044800 0000
C     SEGMENT CANNOT BE EXCAVATED FOR STABILITY NUMBER DECREASE OF 1.0  044810 0000
C     CAUSED BY APPLICATION OF AIR PRESSURE,OR DECREASE OF 1.0 REQUIRES 044820 0000
C     AIR PRESSURE GREATER THAN 50 PSI. TRY 50 PSI                      044830 0000
 1000 AIRPR=50.                                                         044840 0000
      STABNM=(SIGMAT-AIRPR*144.)/SHRSTR                                 044850 0000
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C     CHECK WHETHER SEGMENT CAN BE EXCAVATED USING 50 PSI                044860 0000
      IF(STABNM.LE.9. .AND. PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.) 044870 0000
     1 GO TO 1200                                                        044880 0000
C     SEGMENT CANNOT BE EXCAVATED USING 50 PSI,MAXIMUM ALLOWABLE PRESS.  044890 0000
      IERROR=1                                                           044900 0000
      IF(ITYPE.EQ.1) WRITE(LO,2000) NTSEG,NREACH                         044910 0000
      IF(ITYPE.EQ.2) WRITE(LO,3000) NSSEG,NSHAFT                         044920 0000
      GO TO 1200                                                         044930 0000
C     SEGMENT CAN BE EXC USING AIR PRESSURE FOR STABNO DECREASE=1.0      044940 0000
 1050 STABNM=STABNO-1.                                                   044950 0000
      GO TO 1200                                                         044960 0000
C     ------------------------------------------------------------------ 044970 0000
C     STABILITY NUMBER DECREASE BY AT LEAST 1.0 FOR 7 PSI AIR PRESSURE.  044980 0000
C     CAN SEGMENT BE EXCAVATED                                           044990 0000
 1100 IF(STABNM.LE.9. .AND.PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.)  045000 0000
     1 GO TO 1200                                                        045010 0000
C     SEGMENT CANNOT BE EXCAVATED FOR DECREASE=1.0 USING 7 PSI. COMPUTE  045020 0000
C     AIR PRESSURE SO SEGMENT CAN BE EXCAVATED                           045030 0000
      SN=9.                                                              045040 0000
      IF(PHI.GE.29.) SN=7.                                               045050 0000
      AIRPR=(SIGMAT-SN*SHRSTR)/144.                                      045060 0000
C     CHECK FOR AIR PRESSURE GREATER THAN 50 PSI                         045070 0000
      IF(AIRPR.GT.50.) GO TO 1150                                        045080 0000
C     AIR PRESSURE LESS THAN 50 PSI                                      045090 0000
      STABNM=SN                                                          045100 0000
      GO TO 1200                                                         045110 0000
C     SEGMENT CANNOT BE EXCAVATED USING 50 PSI,MAXIMUM ALLOWABLE PRESS.  045120 0000
 1150 IERROR=1                                                           045130 0000
      IF(ITYPE.EQ.1) WRITE(LO,2000) NTSEG,NREACH                         045140 0000
      IF(ITYPE.EQ.2) WRITE(LO,3000) NSSEG,NSHAFT                         045150 0000
 1200 RETURN                                                             045160 0000
C     ------------------------------------------------------------------ 045170 0000
 2000 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN REACH',I5,' CANNOT BE     045180 0000
     1EXCAVATED USING LESS THAN 50 PSI AIR PRESSURE FOR STABILIZATION')  045190 0000
 3000 FORMAT(/,' FATAL ERROR, SEGMENT',I5,' IN SHAFT',I5,' CANNOT BE     045200 0000
     1EXCAVATED USING LESS THAN 50 PSI AIR PRESSURE FOR STABILIZATION')  045210 0000
C     ------------------------------------------------------------------ 045220 0000
      RETURN                                                             045225
      END                                                                045230 0000
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      SUBROUTINE REACHD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
     1NTRMAX)
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
C     THIS SUBROUTINE DETERMINES THE BEGINNING SEGMENT AND TOTAL
C        NUMBER OF SEGMENTS IN THE REACHES.
C
C     N1 ........... LOCATION IN (A( ARRAY OF LEFT SEGMENT IN A REACH
C     N2 ........... LOCATION IN (A( ARRAY OF RIGHT SEGMENT IN A REACH
C     I ............ TUNNEL SEGMENT SEQUENCE NUMBER
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
      COMMON /BASIC/  NSS,NTS
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
     1 TRDATA(NTRMAX,23)
C     ------------------------------------------------------------------
      N1=1
      I=0
      IPR=A(1,4)
      NREACH=IPR
      NPL=A(1,2)
      NPR=A(1,3)
      STANPL=CNP(NPL,1)
      STANPR=CNP(NPR,1)
      STAMLS=(STANPL+STANPR)/2.
      NSHAFT=TRDATA(NREACH,1)
      NPBS=SHAFT(NSHAFT,3)
      STANPB=CNP(NPBS,1)
C     ------------------------------------------------------------------
  100 I=I+1
      NREACH=A(I,4)
      IF(I.EQ.NTS+1) GO TO 200
      IF(NREACH.NE.IPR)  GO TO 200
      N2=I
      GO TO 500
C
  200 IF(STAMLS.LT.STANPB) GO TO 250
      NRSEG1=N1
      NSEGS=N2-N1+1
      GO TO 300
  250 NRSEG1=N2
      NSEGS=-(N2-N1+1)
  300 TRDATA(IPR,5)=NRSEG1
      TRDATA(IPR,6)=NSEGS
      IF(I.EQ.NTS+1) GO TO 600
C     ------------------------------------------------------------------
      NPL=A(I,2)
      NPR=A(I,3)
      STANPL=CNP(NPL,1)
      STANPR=CNP(NPR,1)
      STAMLS=(STANPL+STANPR)/2.
      NSHAFT=TRDATA(NREACH,1)
      NPBS=SHAFT(NSHAFT,3)
      STANPB=CNP(NPBS,1)
      IPR=NREACH
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      N1=I                                                              045780 0000
      N2=I                                                              045790 0000
C                                                                       045800 0000
  500 IF(I.NE.NTS+1) GO TO 100                                          045810 0000
  600 CONTINUE                                                          045820 0000
C     ------------------------------------------------------------------045830 0000
      RETURN                                                            045840 0000
      END                                                               045850 0000
      SUBROUTINE ADRATE (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,045860 0000
     1NTRMAX)                                                           045865
C     ------------------------------------------------------------------045870 0000
C     ------------------------------------------------------------------045880 0000
C                                                                       045890 0000
C     THIS SUBROUTINE COMPUTES THE ULTIMATE HEADING ADVANCE RATE FOR    045900 0000
C     SEGMENTS IN WHICH NONE WAS USER SPECIFIED AND COMPUTES THE AVERAGE 045910 0000
C     ADVANCE RATE IN ALL SEGMENTS                                      045920 0000
C                                                                       045930 0000
C     ------------------------------------------------------------------045940 0000
C     ------------------------------------------------------------------045950 0000
      COMMON /BASIC/  NSS,NTS                                           045960 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 045970 0000
     1 TRDATA(NTRMAX,23)                                                045980 0000
C     ------------------------------------------------------------------045990 0000
C     ------------------------------------------------------------------046000 0000
C     COMPUTE ADVANCE RATES IN TUNNEL SEGMENTS                          046010 0000
      DO 400 NREACH=1,NTRMAX                                            046020 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400                         046030 0000
      NRSEG1=TRDATA(NREACH,5)                                           046040 0000
      NSEGS=TRDATA(NREACH,6)                                            046050 0000
      NSEGSA=IABS(NSEGS)                                                046060 0000
C     INITIALIZE VALUES                                                 046070 0000
      PINSAR=0.                                                         046080 0000
      MEXP=0                                                            046090 0000
      DO 300 I=1,NSEGSA                                                 046100 0000
C     N=SEQUENCE NUMBER OF TUNNEL SEGMENT                               046110 0000
      IF(NSEGS.GT.0) N=NRSEG1+I-1                                       046120 0000
      IF(NSEGS.LT.0) N=NRSEG1-I+1                                       046130 0000
      MEX=A(N,7)                                                        046140 0000
      STABNO=A(N,30)                                                    046150 0000
      E=2.71828                                                         046160 0000
      AR=A(N,8)                                                         046170 0000
      TSEGL=A(N,45)                                                     046180 0000
      IF(MEX.GT.5) GO TO 1000                                           046190 0000
C     CHECK FOR EXCAVATION IN DOWNHILL DIRECTION                        046200 0000
C     IF EXCAVATION IS DOWNHILL,ULTIMATE ADVANCE RATE IS ONLY 90 PERCENT 046210 0000
C     OF ULTIMATE RATE FOR LEVEL OR UPHILL EXCAVATION                   046220 0000
      SLARF=1.0                                                         046230 0000
      NPL=A(N,2)                                                        046240 0000
      NPR=A(N,3)                                                        046250 0000
      ELNPL=CNP(NPL,2)                                                  046260 0000
      ELNPR=CNP(NPR,2)                                                  046270 0000
      SLOPE=(ELNPL-ELNPR)/(CNP(NPL,1)-CNP(NPR,1))                       046280 0000
      IF(NSEGS.GT.0 .AND. SLOPE.LT.0. .OR. NSEGS.LT.0 .AND. SLOPE.GT.0.) 046290 0000
     1  SLARF=0.9                                                       046300 0000
      BE=A(N,39)                                                        046310 0000
      RS=A(N,5)                                                         046320 0000
      RQD=A(N,6)                                                        046330 0000
      GI=A(N,9)                                                         046340 0000
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      MSTAB=A(N,31)                                                     046350 0000
      GO TO 30                                                          046360 0000
 1000 ISUPPT=A(N,26)                                                    046370 0000
      GO TO 10                                                          046380 0000
   30 IF(MEX.EQ.MEXP) GO TO 10                                          046390 0000
C     THIS IS FIRST SEGMENT IN REACH OR EXCAVATION METHOD HAS CHANGED   046400 0000
      BINSAR=0.                                                         046410 0000
      GO TO 20                                                          046420 0000
C     EXCAVATION IS SAME AS IN PREVIOUS SEGMENT                         046430 0000
   10 BINSAR=PINSAR-.05                                                 046440 0000
      IF(BINSAR.LT.0.) BINSAR=0.                                        046450 0000
   20 IF(AR.GT.0.) ARTULT=AR                                            046460 0000
      IF(AR.GT.0.) GO TO 100                                            046470 0000
C     ---------------------------------------------                     046480 0000
C     AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED,MUST COMPUTE ONE  046490 0000
C     COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS                     046500 0000
C     CHECK FOR METHOD OF EXCAVATION                                    046510 0000
 1020 IF(MEX.GT.5) GO TO 1160                                           046520 0000
C     THIS IS NOT CUT AND COVER                                         046530 0000
      ISHAPE=TRDATA(NREACH,3)                                           046540 0000
      IF(MEX.NE.2.AND.MEX.NE.3) GO TO 50                                046550 0000
      IF(MEX.EQ.2) GO TO 150                                            046560 0000
C     ---------------------------------------------                     046570 0000
C     MOLE IN SOFT GROUND                                               046580 0000
      ARTULT=(2.*(STABNO-7.)**2 +1.)/100000.*(80.-BE)**3.*SLARF         046590 0000
      GO TO 1100                                                        046600 0000
C     MOLE IN ROCK                                                      046610 0000
C     ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI   046620 0000
  150 IF(RS.LT.3000.) RS=3000.                                          046630 0000
      ARTULT=(10000000./(BE*RS))*(.6+.4*SIN(3.14159*(RQD/75.+1.167)))   046640 0000
     1*(GI+1500.)/(5.*GI+1500.)*SLARF                                   046650 0000
      GO TO 1100                                                        046660 0000
C     ---------------------------------------------                     046670 0000
C     CONVENTIONAL EXCAVATION IN ROCK OR HAND OR RIPPER EXC IN SOFT GRND 046680 0000
   50 IF(ISHAPE.EQ.1) SFA=0.785                                         046690 0000
      IF(ISHAPE.EQ.2) SFA=0.893                                         046700 0000
      IF(ISHAPE.EQ.3) SFA=0.425                                         046710 0000
      IF(MEX.EQ.1) ARTULT=((.08*BE**2.25)*RQD+1000.)*((GI+1500.)/       046720 0000
     1 (5.*GI+1500.))/(SFA*BE**1.5*E**(.035*BE)*(1.+.0025*RS/1000.))*   046730 0000
     2 SLARF*(1.-RQD*(BE-10.)/6000.)                                    046740 0000
      IF(MEX.EQ.1) GO TO 1200                                           046750 0000
      IF(MEX.EQ.4) ARTULT=(0.3*(STABNO-10.)**2 +1.)/100000.*            046760 0000
     1 (80.-BE)**3.*SLARF*0.785/SFA                                     046770 0000
      IF(MEX.EQ.5) ARTULT=(1.4*(STABNO-7.5)**2 +1.)/100000.*            046780 0000
     1 (80.-BE)**3.*SLARF*0.785/SFA                                     046790 0000
      IF(ISHAPE.NE.3) GO TO 1100                                        046800 0000
C     ---------------------------------------------                     046810 0000
C     SHAPE IS BASKETHANDLE.  CHECK FOR COMPUTED ADVANCE RATE GREATER   046820 0000
C     THAN FOR CIRCLE OF SAME BE FOR STABILITY NUMBER = 0. IF GREATER,  046830 0000
C     SET ARTULT FOR BASKETHANDLE EQUAL TO MAXIMUM RATE FOR CIRCLE.     046840 0000
      IF(MEX.EQ.4) ART=0.00031*(80.-BE)**3.*SLARF                       046850 0000
      IF(MEX.EQ.5) ART=0.0007975*(80.-BE)**3.*SLARF                     046860 0000
      IF(ARTULT.GT.ART) ARTULT=ART                                      046870 0000
C     ---------------------------------------------                     046880 0000
C     CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS     046890 0000
 1100 IF(MSTAB.NE.3) GO TO 1200                                         046900 0000
C     GROUND INJECTIONS ARE USED.CHECK FOR APPLICATION FROM INSIDE SEQ. 046910 0000
      NPLS=A(N,17)                                                      046920 0000
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      NPRS=A(N,18)                                                      046930 0000
      ELNPLS=CNP(NPLS,2)                                                046940 0000
      ELNPRS=CNP(NPRS,2)                                                046950 0000
      ELSURF=(ELNPLS+ELNPRS)/2.                                         046960 0000
      ELAVG=(ELNPL+ELNPR)/2.                                            046970 0000
      SEGDEP=ELSURF-ELAVG                                               046980 0000
      IF(ISHAPE.NE.3) GO TO 1120                                        046990 0000
      IF(SEGDEP-BE/4. .GT.50.) GO TO 1150                               047000 0000
      GO TO 1200                                                        047010 0000
 1120 IF(SEGDEP-BE/2. .GT.50.) GO TO 1150                               047020 0000
      GO TO 1200                                                        047030 0000
C     GROUND INJECTIONS ARE MADE FROM WITHIN SEGMENT AND SLOWS ADVANCE  047040 0000
 1150 ARTULT=100./(100.+ARTULT)*ARTULT                                  047050 0000
      GO TO 1200                                                        047060 0000
C     ------------------------------------------                        047070 0000
C     CUT AND COVER                                                     047080 0000
 1160 SIDESL=A(N,53)                                                    047090 0000
      IF(SIDESL.GT.0.) GO TO 1180                                       047100 0000
C     VERTICAL CUT                                                      047110 0000
      IF(ISUPPT.EQ.5) ARTULT=15.+7.*ATAN(3.-STABNO)                     047120 0000
      IF(ISUPPT.EQ.6) ARTULT=18.+5.*ATAN(4.-STABNO)                     047130 0000
      GO TO 1200                                                        047140 0000
C     SLOPING CUT                                                       047150 0000
 1180 DTRNCH=A(N,52)                                                    047160 0000
      ARTULT=15000./(SIDESL*(20.+DTRNCH)+300.)                          047170 0000
C     CONVERT COMPUTED ADVANCE RATES TO FEET/HOURS WORKED. INPUT RATES  047180 0000
C     ARE ALREADY IN FEET/HOURS WORKED                                  047190 0000
 1200 HOURS=TRDATA(NREACH,8)                                            047200 0000
      SHIFTS=1                                                          047210 0000
      IF(HOURS.GE.12.) SHIFTS=2.                                        047220 0000
      IF(HOURS.GE.21.) SHIFTS=3.                                        047230 0000
      EFFAC=1.                                                          047240 0000
      IF(HOURS/SHIFTS.GT.8.) EFFAC=1.0-0.01*(HOURS/SHIFTS-8.)**2.       047250 0000
      ARTULT=ARTULT*EFFAC*HOURS/24.                                     047260 0000
C     ------------------------------------------                        047270 0000
  100 IF(TSEGL.LE.25.*(1.-BINSAR**2.)*ARTULT) GO TO 120                 047280 0000
C     ULTIMATE ADVANCE RATE IS ATTAINED                                 047290 0000
      ARFAC=TSEGL/(25.*(1.-BINSAR)**2 *ARTULT+TSEGL)                    047300 0000
      PINSAR=1.0                                                        047310 0000
      GO TO 240                                                         047320 0000
C     ULTIMATE ADVANCE RATE NEVER ATTAINED,SEGMENT TOO SHORT            047330 0000
  120 ARFAC=.5*(BINSAR+SQRT(BINSAR**2.+.04*TSEGL/ARTULT))               047340 0000
      PINSAR=SQRT(BINSAR**2.+.04*TSEGL/ARTULT)                          047350 0000
  240 MEXP=MEX                                                          047360 0000
C     COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT           047370 0000
      A(N,49)=ARTULT                                                    047380 0000
  300 A(N,8)=ARTULT*ARFAC                                               047390 0000
  400 CONTINUE                                                          047400 0000
C     ---------------------------------------------------------------- 047410 0000
C     ---------------------------------------------------------------- 047420 0000
C     COMPUTE ADVANCE RATES IN SHAFT SEGMENTS                           047430 0000
      DO 800 NSHAFT=1,NSMAX                                             047440 0000
      IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800                          047450 0000
C     IF THE SHAFT IS A PORTAL, SKIP ADVANCE RATE COMPUTATIONS          047460 0000
      NPORT=SHAFT(NSHAFT,23)                                            047470 0000
      IF(NPORT.EQ.1) GO TO 800                                          047480 0000
      NSSEG1=SHAFT(NSHAFT,1)                                            047490 0000
      NSSEG6=SHAFT(NSHAFT,4)                                            047500 0000
```

(Continued)

```
C     INITIALIZE VALUES
      PINSAR=0.
      MEXP=0
      DO 700 I=1,NSEGS
C     N=SEQUENCE NUMBER OF SHAFT SEGMENT
      N=I-1+NSSEG1
      MEX=B(N,7)
      SSEQL=B(N,35)
C     CHECK FOR SHAFT CONSTRUCTED IN CUT AND COVER
      IF(MEX.EQ.0) ARSULT=0.
      IF(MEX.EQ.0) GO TO 700
      STABNO=B(N,24)
C     D=DEPTH TO MIDPOINT OF SHAFT SEGMENT
      D=B(N,36)
      AR=B(N,8)
      RQD=B(N,6)
      GI=B(N,9)
C     FW IS AN INFLOW ADVANCE RATE FACTOR=1.0 IN DRY SHAFTS,.5 IN WET
      IF(GI.LT.1.) GO TO 440
C     SHAFT IS WET
      FW=0.5
      GO TO 450
C     SHAFT IS DRY
  440 FW=1.0
  450 BE=B(N,29)
      RS=B(N,5)
      IF(MEX.EQ.MEXP) GO TO 410
C     THIS IS FIRST SEGMENT IN SHAFT OR EXCAVATION METHOD HAS CHANGED
      BINSAR=0.
      GO TO 420
C     EXCAVATION IS SAME AS IN PREVIOUS SEGMENT
  410 BINSAR=PINSAR-.05
      IF(BINSAR.LT.0.) BINSAR=0.
  420 IF(AR.GT.0.) ARSULT=AR
      IF(AR.GT.0.) GO TO 500
C     ------------------------------------------
C     AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED,MUST COMPUTE ONE
C     COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS
C     CHECK FOR METHOD OF EXCAVATION
      IF(MEX.EQ.1 .OR. MEX.EQ.4) GO TO 1610
      IF(MEX.EQ.3) GO TO 1600
C     ------------------------------------------
C     MOLE IN ROCK
C     ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI
      IF(RS.LT.3000.) RS=3000.
      ARSULT=(5000000/(BE*RS))*(.5+RQD/200.)*FW
      GO TO 1650
C     MOLE IN SOFT GROUND
C     ------------------------------------------
 1600 ARSULT=(25.-4.*STABNO)*(1.-D/6000.)
      GO TO 1650
C     CONVENTIONAL EXCAVATION IN ROCK OR HAND EXCAVATION IN SOFT GROUND
 1610 IF(MEX.EQ.4) GO TO 1620
C     CONVENTIONAL EXCAVATION IN ROCK
      ARSULT=.05*FW*(RQD+100.)*(1.-D/6000.)
      GO TO 1650
C     HAND EXCAVATION IN SOFT GROUND
 1620 ISHAPS=SHAFT(NSHAFT,16)
```

(Continued)

```
      IF(ISHAPS.EQ.1) SFA=0.785                                         048090 0000
      IF(ISHAPS.EQ.2) SFA=1.0                                           048100 0000
      ARSULT=(10.-STABNO)*(1.-D/6000.)*0.785/SFA                        048110 0000
C     ------------------------------------------                        048120 0000
C     CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS     048130 0000
 1650 IF(MSTAB.EQ.3) GO TO 1660                                         048140 0000
      GO TO 1700                                                        048150 0000
C     GROUND INJECTIONS ARE USED.CHECK FOR APPLICATION FROM INSIDE SEG. 048160 0000
 1660 IF(D.LE.200.) GO TO 1700                                          048170 0000
C     GROUND INJECTIONS ARE MADE FROM WITHIN SEGMENT AND SLOWS ADVANCE  048180 0000
      ARSULT=100./(100.+ARSULT)*ARSULT                                  048190 0000
C     CONVERT COMPUTED ADVANCE RATES TO FEET/HOURS WORKED. INPUT RATES  048200 0000
C     ARE ALREADY IN FEET/HOURS WORKED                                  048210 0000
 1700 HOURS=SHAFT(NSHAFT,17)                                            048220 0000
      ARSULT=ARSULT*HOURS/24.                                           048230 0000
C     ------------------------------------------                        048240 0000
  500 IF(SSEGL.LE.25.*(1.-BINSAR**2.)*ARSULT) GO TO 520                 048250 0000
C     ULTIMATE ADVANCE RATE IS ATTAINED                                 048260 0000
      ARFAC=SSEGL/(25.*(1.-BINSAR)**2 *ARSULT+SSEGL)                    048270 0000
      PINSAR=1.0                                                        048280 0000
      GO TO 640                                                         048290 0000
C     ULTIMATE ADVANCE RATE NEVER ATTAINED,SEGMENT TOO SHORT            048300 0000
  520 ARFAC=.5*(BINSAR+SQRT(BINSAR**2.+.04*SSEGL/ARSULT))               048310 0000
      PINSAR=SQRT(BINSAR**2.+.04*SSEGL/ARSULT)                          048320 0000
  640 MEXP=MEX                                                          048330 0000
C     COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT           048340 0000
      B(N,39)=ARSULT                                                    048350 0000
  700 B(N,8)=ARSULT*ARFAC                                               048360 0000
  800 CONTINUE                                                          048370 0000
C     ------------------------------------------------------------------048380 0000
      RETURN                                                            048390 0000
      END                                                               048400 0000
      SUBROUTINE CONSTM (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 048410 0000
     1NTRMAX)                                                           048415
C     ------------------------------------------------------------------048420 0000
C     ------------------------------------------------------------------048430 0000
C     THIS SUBROUTINE CALCULATES SEGMENT CONSTRUCTION TIMES INCLUDING   048440 0000
C     TIME FOR LINING                                                   048450 0000
C     ------------------------------------------------------------------048460 0000
C     ------------------------------------------------------------------048470 0000
      COMMON /BASIC/  NSS,NTS                                           048480 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 048490 0000
     1 TRDATA(NTRMAX,23)                                                048500 0000
C     ------------------------------------------------------------------048510 0000
C                                                                       048520 0000
C     CALCULATE CONSTRUCTION TIME FOR TUNNEL SEGMENTS                   048530 0000
      DO 60 I=1,NTS                                                     048540 0000
C     NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND      048550 0000
C     SHOTCRETED TUNNEL SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO      048560 0000
C     CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO 048570 0000
C     BECAUSE IT IS PLACED IMMEDIATELY AFTER EXCAVATION                 048580 0000
      AL=10.E30                                                         048590 0000
      NTSTYP=A(I,16)                                                    048600 0000
      NREACH=A(I,4)                                                     048610 0000
      HOURS=TRDATA(NREACH,8)                                            048620 0000
      DAYS=TRDATA(NREACH,9)                                             048630 0000
```

(Continued)

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      IF (NTSTYP.GT.1) GO TO 40                                         048640 0000
      LINING=A(I,10)                                                    048650 0000
      IF(LINING.EQ.1) AL=3*HOURS                                        048660 0000
   40 AR=A(I,8)                                                         048670 0000
      TSEGL=A(I,45)                                                     048680 0000
   50 A(I,50)=(TSEGL/AR+TSEGL/AL)*7./DAYS                               048690 0000
C     ------------------------------------------------------------------ 048700 0000
C     CALCULATE CONSTRUCTION TIME FOR SHAFT SEGMENTS                    048710 0000
      DO 100 I=1,NSS                                                    048720 0000
C     NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND      048730 0000
C     SHOTCRETED SHAFT  SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO      048740 0000
C     CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO 048750 0000
C     BECAUSE IT IS PLACED IMMEDIATELY AFTER EXCAVATION                 048760 0000
      AL=10.E30                                                         048770 0000
      NSSTYP=B(I,15)                                                    048780 0000
      NSHAFT=B(I,1)                                                     048790 0000
      ISHAPS=SHAFT(NSHAFT,16)                                           048800 0000
      HOURS=SHAFT(NSHAFT,17)                                            048810 0000
      DAYS=SHAFT(NSHAFT,18)                                             048820 0000
      IF (NSSTYP.GT.1) GO TO 80                                         048830 0000
      LINING=B(I,10)                                                    048840 0000
      IF(LINING.EQ.1) AL=2.*HOURS                                       048850 0000
   80 AR=B(I,8)                                                         048860 0000
      SSEGL=B(I,35)                                                     048870 0000
C     NO CONSTRUCTION TIME FOR CUT AND COVER OR DUMMY SHAFT             048880 0000
      IF(NSSTYP.EQ.3.OR.ISHAPS.EQ.0) AR=10.E30                          048890 0000
  100 B(I,40)=(SSEGL/AR+SSEGL/AL)*7./DAYS                               048900 0000
C     ------------------------------------------------------------------ 048910 0000
      RETURN                                                            048920 0000
      END                                                               048930 0000
      SUBROUTINE PUMPHT (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 048940 0000
     1NTRMAX)                                                           048945
C     ------------------------------------------------------------------ 048950 0000
C     ------------------------------------------------------------------ 048960 0000
C     THIS SUBROUTINE COMPUTES PUMPING HEIGHTS FOR TUNNEL SEGMENTS      048970 0000
C     ------------------------------------------------------------------ 048980 0000
C     ------------------------------------------------------------------ 048990 0000
      COMMON /BASIC/  NSS,NTS                                           049000 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 049010 0000
     1 TRDATA(NTRMAX,23)                                                049020 0000
C     ------------------------------------------------------------------ 049030 0000
      DO 200 I=1,NTS                                                    049040 0000
      NREACH=A(I,4)                                                     049050 0000
      NTSTYP=A(I,16)                                                    049060 0000
      IF(NTSTYP.EQ.3) GO TO 100                                         049070 0000
C     ROCK OR SOFT GROUND                                               049080 0000
C     COMPUTE PUMPING HEIGHTS. PUMPING HEIGHT EQUALS SHAFT DEPTH OR     049090 0000
C     DIFFERENCE IN ELEVATION FROM TOP OF SHAFT TO MIDPOINT OF TUNNEL   049100 0000
C     SEGMENT, WHICHEVER IS GREATER                                     049110 0000
      NSHAFT=TRDATA(NREACH,1)                                           049120 0000
      NPTS=SHAFT(NSHAFT,2)                                              049130 0000
      ELTS=CNP(NPTS,2)                                                  049140 0000
      NPL=A(I,2)                                                        049150 0000
      NPR=A(I,3)                                                        049160 0000
      ELNPL=CNP(NPL,2)                                                  049170 0000
      ELNPR=CNP(NPR,2)                                                  049180 0000
C     ELEVATION AT MIDPOINT OF TUNNEL SEGMENT                           049190 0000
      ELAVG=(ELNPL+ELNPR)/2.                                            049200 0000
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      PH=ELTS-ELAVG                                                     049210 0000
C     SET HH EQUAL TO MUCK HOISTING HEIGHT(SHAFT DEPTH)                 049220 0000
      HH=SHAFT(NSHAFT,8)                                                049230 0000
      IF(HH.GE.PH) PH=HH                                                049240 0000
      GO TO 150                                                         049250 0000
C     CUT AND COVER                                                     049260 0000
  100 D10=A(I,19)                                                       049270 0000
      IF(D10.LE.0.005) PH=0                                             049280 0000
      IF(D10.LE.0.005) GO TO 150                                        049290 0000
      ELROCK=A(I,27)                                                    049300 0000
      IWATER=A(I,23)                                                    049310 0000
      ELIMP=A(I,24)                                                     049320 0000
      NPLS=A(I,17)                                                      049330 0000
      NPRS=A(I,18)                                                      049340 0000
      ELNPLS=CNP(NPLS,2)                                                049350 0000
      ELNPRS=CNP(NPRS,2)                                                049360 0000
      ELSURF=(ELNPLS+ELNPRS)/2.                                         049370 0000
      DROCK=ELSURF-ELROCK                                               049380 0000
      DTRNCH=A(I,52)                                                    049390 0000
      MEX=A(I,7)                                                        049400 0000
      ISUPPT=A(I,26)                                                    049410 0000
      ELWATR=A(I,14)                                                    049420 0000
      DSLURY=A(I,38)                                                    049430 0000
C     PH=THE SMALLER OF (ELSURF-ELIMP) AND DTRNCH, EXCEPT FOR SUMP      049440 0000
C     PUMPING, FOR WHICH PH=DTRNCH                                      049450 0000
      IF(DTRNCH.GE.ELSURF-ELIMP) PH=ELSURF-ELIMP                        049460 0000
      IF(DTRNCH.LT.ELSURF-ELIMP) PH=DTRNCH                              049470 0000
      IF(IWATER.EQ.0 .OR.ISUPPT.EQ.5 .AND. DROCK.LT.DTRNCH)PH=DTRNCH    049480 0000
      IF(IWATER.EQ.0.AND.ISUPPT.EQ.6.AND.DSLURY.GE.ELSURF-ELIMP) PH=0   049490 0000
      IF(ELWATR.LT.ELSURF-DTRNCH) PH=0                                  049500 0000
C     STORE PUMPING HEIGHT                                              049510 0000
  150 A(I,57)=PH                                                        049520 0000
  200 CONTINUE                                                          049530 0000
C     ------------------------------------------------------------------049540 0000
      RETURN                                                            049550 0000
      END                                                               049560 0000
      SUBROUTINE PUMPRT (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,049570 0000
     1NTRMAX)                                                           049575
C     ------------------------------------------------------------------049580 0000
C     ------------------------------------------------------------------049590 0000
C     FLOW RATE TO BE PUMPED FROM TUNNEL AND DEWATERING FOR TUNNELS     049600 0000
C     AND SHAFTS.                                                       049610 0000
C     ------------------------------------------------------------------049620 0000
C     ------------------------------------------------------------------049630 0000
C                                                                       049640 0000
      COMMON /BASIC/  NSS,NTS                                           049650 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 049660 0000
     1 TRDATA(NTRMAX,23)                                                049670 0000
C                                                                       049680 0000
C     ******************************************************************049690 0000
C     TUNNELS                                                           049700 0000
C     ******************************************************************049710 0000
C                                                                       049720 0000
      DO 400 NREACH=1,NTRMAX                                            049730 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400                         049740 0000
      NRSEG1=TRDATA(NREACH,5)                                           049750 0000
      NSEGS=TRDATA(NREACH,5)                                            049760 0000
      NSEGSA=IABS(NSEGS)                                                049770 0000
```

(Continued)

```
C     INITIALIZE VALUES                                                 049780 0000
      FLRT=0.                                                           049790 0000
      TUBE=0.0                                                          049800 0000
      ZZ=0.0                                                            049810 0000
      Z=0.                                                              049820 0000
      DO 300    I=1,NSEGSA                                              049830 0000
C     N=SEQUENCE NUMBER OF TUNNEL SEGMENT                               049840 0000
      IF(NSEGS.GT.0) N=NRSEG1+I-1                                       049850 0000
      IF(NSEGS.LT.0) N=NRSEG1-I+1                                       049860 0000
      NTSTYP=A(N,16)                                                    049870 0000
      PERM=A(N,26)                                                      049880 0000
      D10=A(N,19)                                                       049890 0000
      IWATER=A(N,23)                                                    049900 0000
      NSTAB=A(N,31)                                                     049910 0000
      BE=A(N,39)                                                        049920 0000
      ELROCK=A(N,27)                                                    049930 0000
      MEX=A(N,7)                                                        049940 0000
      ELWATR=A(N,14)                                                    049950 0000
      NPL=A(N,2)                                                        049960 0000
      NPR=A(N,3)                                                        049970 0000
      ELNPL=CNP(NPL,2)                                                  049980 0000
      ELNPR=CNP(NPR,2)                                                  049990 0000
      ELAVG=(ELNPL+ELNPR)/2.                                            050000 0000
      IF(NTSTYP.EQ.3) GO TO 200                                         050010 0000
C     ----------------------------------------------------------------- 050020 0000
C     ROCK OR SOFT GROUND TUNNELS                                       050030 0000
C     ----------------------------------------------------------------- 050040 0000
C     HEADING INFLOW AND RESIDUAL FLOW IN TUNNELS                       050050 0000
      GI=A(N,9)                                                         050060 0000
      ELBOTM=ELAVG-BE/2.                                                050070 0000
      ISHAPE=TRDATA(NREACH,3)                                           050080 0000
      IF(ISHAPE.EQ.3) ELBOTM=ELAVG-BE/4.                                050090 0000
C     IF GROUNDWATER BELOW TUNNEL, GI = 0                               050100 0000
      IF(ELWATR.LT.ELBOTM) GI=0.                                        050110 0000
      IF(NTSTYP.EQ.2) GO TO 140                                         050120 0000
C     ROCK TUNNELS                                                      050130 0000
C     ESTABLISH RESIDUAL INFLOW(GPM/FT) AND INFLOW AT FACE FOR PUMPING  050140 0000
C     IN GPM                                                            050150 0000
      IF(GI.GE.100.) GO TO 135                                          050160 0000
      GIR=0.001*GI                                                      050170 0000
      GIF=GI                                                            050180 0000
      GO TO 155                                                         050190 0000
  135 GIR=0.1                                                           050200 0000
      GIF=100.                                                          050210 0000
      GO TO 155                                                         050220 0000
C     SOFT GROUND TUNNELS                                               050230 0000
  140 GIF=GI                                                            050240 0000
      GIR=0.                                                            050250 0000
  155 A(N,60)=GIR                                                       050260 0000
      R=FLRT                                                            050270 0000
      TSEGL=A(N,45)                                                     050280 0000
      FLRT=0.5*GIR*TSEGL                                                050290 0000
C     AVERAGE FLOW TO BE PUMPED AND CHARGED TO NTH SEGMENT              050300 0000
      FLOW=Z+R+FLRT+GIF                                                 050310 0000
      A(N,59)=FLOW                                                      050320 0000
      Z=FLOW-GIF                                                        050330 0000
C     THE FOLLOWING WILL DETERMINE THE LENGTH OF PIPE REQUIRED          050340 0000
C     FOR THE SEGMENT WHEN PUMPING UPHILL.   IT IS ASSUMED THAT NO PIPE 050350 0000
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(Continued)

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C     IS REQUIRED WHEN THE THE WATER MAY RUN DOWN THE SEGMENT IN THE
C     DIRECTION OF THE EXIT SHAFT.
      NPL=A(N,2)
      NPR=A(N,3)
      ELEVD=CNP(NPR,2)-CNP(NPL,2)
C     SLOPE IS POSITIVE WHEN UPHILL IN THE DIRECTION OF HEADING ADVANCE
C      SS= SIGN OF THE SLOPE(ACTUAL VALUE IS IMMATERIAL)
      SS=ELEVD*MSEQS
C     ESTABLISH THE PIPE LENGTH REQUIRED
      PIPE=0.0
      IF(SS.LT.0) PIPE=0.5*TSEGL
C     DETERMINE THE CUMULATIVE PIPE LENGTHS REQUIRED
      A(N,58)=ZZ+TUBE+PIPE
      TUBE=PIPE
      ZZ=A(N,58)
      IF(NTSTYP.EQ.2) GO TO 160
C     ROCK TUNNELS
      GO TO 300
C
C
C     DEWATERING FOR SOFT GROUND TUNNELS
  160 IF(MSTAB.NE.2 .OR.ABS(PERM).LE. 0.0006) GO TO 250
      HEADU=0
      ELIMP=A(N,24)
C     IF DEWATERING METHOD USED, WATER TABLE ABOVE IMPERVIOUS LAYER, AND
C     WATER TABLE ABOVE ELAVG, THEN SET FOLLOWING VALUES
      IF(ELIMP.GE.ELBOTM) DRAWDN=ELWATR-ELIMP
      IF(ELIMP.LT.ELBOTM) DRAWDN=ELWATR-ELBOTM
      DIMP=ELBOTM-ELIMP
      GO TO 210
C     ------------------------------------------------------------------
C     CUT AND COVER DEWATERING
C     ------------------------------------------------------------------
  200 NPLS=A(N,17)
      NPRS=A(N,18)
      ELNPLS=CNP(NPLS,2)
      ELNPRS=CNP(NPRS,2)
      ELSURF=(ELNPLS+ELNPRS)/2.
      IF(D10.LE.0.005) GO TO 250
      ELIMP=A(N,24)
      DTRNCH=A(N,52)
      ISUPPT=A(N,26)
      PERM=ABS(PERM)
      IF(ISUPPT.NE.6 .OR. IWATER.EQ.1) GO TO 205
C     CHECK FOR SLURRY WALL PENETRATING IMPERVIOUS LAYER
      DSLURY=A(N,38)
      IF(DSLURY.GE.ELSURF-ELIMP.OR.DSLURY.GE.ELSURF-ELROCK) GO TO 250
  205 HEADU=-7.*(ALOG10(PERM)+1.)
      IF(HEADU.GT.21.) HEADU=21.
      IF(HEADU.LT.0.0) HEADU=0.
C     HEADU=0 FOR SUMP PUMPING
      IF(IWATER.EQ.0.OR. ISUPPT.EQ.5.AND.ELROCK.GT.ELSURF-DTRNCH)HEADU=0
      DRAWDN=DTRNCH-(ELSURF-ELWATR)
      DIMP=ELSURF-ELIMP-DTRNCH
      IF(DIMP.LT.0.0) DRAWDN=ELWATR-ELIMP
  210 IF(DIMP.LT.0.) DIMP=0
C     DEWATERING IS NOT NEEDED IF GROUNDWATER BELOW BOTTOM OF EXC.
      IF(DRAWDN.LE.0.) GO TO 250
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      HEAD=DRAWDN+DIMP+HEADU                                            050940 0000
      PERM=ABS(PERM)                                                    050950 0000
      FLOWDU=0.75*(0.73+0.27*(HEAD-DIMP)/HEAD)*(HEAD**2-DIMP**2)        050960 0000
     1/(HEAD-SQRT(HEAD*DIMP))*PERM                                      050970 0000
      IF(IWATER.EQ.0) GO TO 240                                         050980 0000
C     IS IT SOLDIER PILE WITH LAGGING AND ROCK LINE ABOVE TRENCH BOTTOM 050990 0000
      IF(ISUPPT.NE.5) GO TO 215                                         051000 0000
      IF(ELROCK.GT.ELSURF-DTRNCH) GO TO 240                             051010 0000
C     WELL CAPACITY AND NUMBER OF WELLS                                 051020 0000
  215 IF(FLOWDU.LE.0.7) GO TO 220                                       051030 0000
      IF(FLOWDU.GT.400.) GO TO 230                                      051040 0000
      FLOWL=15.*FLOWDU**1.2                                             051050 0000
      WELLSP=15.*FLOWDU**0.2                                            051060 0000
      GO TO 235                                                         051070 0000
  220 FLOWL=10                                                          051080 0000
      WELLSP=10                                                         051090 0000
      GO TO 235                                                         051100 0000
  230 FLOWL=20000                                                       051110 0000
      WELLSP=20000/FLOWDU                                               051120 0000
  235 WELLS=2./WELLSP                                                   051130 0000
      GO TO 260                                                         051140 0000
C     STORE FLOW FROM SUMP PUMPS                                        051150 0000
  240 A(N,61)=FLOWDU*2.                                                 051160 0000
      WELLS=0                                                           051170 0000
      A(N,68)=WELLS                                                     051180 0000
      GO TO 300                                                         051190 0000
  250 FLOWL=0                                                           051200 0000
      WELLS=0                                                           051210 0000
C     STORE WELL CAPACITY AND NUMBER OF WELLS PER FT OF TUNNEL          051220 0000
  260 A(N,61)=FLOWL                                                     051230 0000
      A(N,68)=WELLS                                                     051240 0000
  300 CONTINUE                                                          051250 0000
  400 CONTINUE                                                          051260 0000
C                                                                       051270 0000
C     ******************************************************************051280 0000
C     SHAFTS-- DEWATERING ONLY                                          051290 0000
C     ******************************************************************051300 0000
C                                                                       051310 0000
      DO 700 NSHAFT=1,NSMAX                                             051320 0000
      IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 700                          051330 0000
      NSSEG1=SHAFT(NSHAFT,1)                                            051340 0000
      NSEGS=SHAFT(NSHAFT,4)                                             051350 0000
      DO 600 I=1,NSEGS                                                  051360 0000
      N=NSSEG1+I-1                                                      051370 0000
      NSSTYP=B(N,15)                                                    051380 0000
      PERM=B(N,23)                                                      051390 0000
      MSTAB=B(N,25)                                                     051400 0000
      MEX=B(N,7)                                                        051410 0000
      BE=B(N,29)                                                        051420 0000
      IF(NSSTYP.NE.2) GO TO 550                                         051430 0000
C     SOFT GROUND SHAFTS                                                051440 0000
      IF(MSTAB.NE.2 .OR. ABS(PERM).LE. 0.0006) GO TO 550                051450 0000
      ELWATR=B(N,13)                                                    051460 0000
      NPB=B(N,4)                                                        051470 0000
      ELNPB=CNP(NPB,2)                                                  051480 0000
C     DEWATERING NOT NEEDED IF GROUNDWATER BELOW BOTTOM OF SHAFT SEGMENT 051490 0000
      IF(ELWATR.LE.ELNPB) GO TO 550                                     051500 0000
      NPTS=SHAFT(NSHAFT,2)                                              051510 0000
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      ELSURF=CNP(NPTS,2)                                                051520 0000
      ISHAPS=SHAFT(NSHAFT,16)                                           051530 0000
      ELIMP=B(N,20)                                                     051540 0000
      DRAWDN=ELWATR-ELNPB                                               051550 0000
      DIMP=ELNPB-ELIMP                                                  051560 0000
      HEAD=DRAWDN+DIMP                                                  051570 0000
      PERM=ABS(PERM)                                                    051580 0000
      FLOWDW=0.75*(0.73+0.27*(HEAD-DIMP)/HEAD)*(HEAD**2-DIMP**2)        051590 0000
     1/(HEAD-SQRT(HEAD*DIMP))*PERM                                      051600 0000
      WELLS=3                                                           051610 0000
      SFP=3.14                                                          051620 0000
      IF(ISHAPS.EQ.2) SFP=4                                             051630 0000
      WELLSP=SFP*(BE+20.)/3.                                            051640 0000
      FLOWL=FLOWDW*WELLSP                                               051650 0000
      GO TO 560                                                         051660 0000
C     ROCK OR CUT AND COVER SHAFTS                                      051670 0000
  550 FLOWL=0                                                           051680 0000
C     STORE WELL CAPACITY                                               051690 0000
  560 B(N,42)=FLOWL                                                     051700 0000
  600 CONTINUE                                                          051710 0000
  700 CONTINUE                                                          051720 0000
      RETURN                                                            051730 0000
      END                                                               051740 0000
      SUBROUTINE VOLUME (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 051750 0000
     1NTRMAX)                                                           051755
C     ------------------------------------------------------------------ 051760 0000
C     ------------------------------------------------------------------ 051770 0000
C     THIS SUBROUTINE COMPUTES THE EXCAVATED VOLUME PER LINEAR FOOT OF   051780 0000
C     TUNNEL AND SHAFT                                                   051790 0000
C     ------------------------------------------------------------------ 051800 0000
C     ------------------------------------------------------------------ 051810 0000
      COMMON /BASIC/  NSS,NTS                                           051820 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 051830 0000
     1 TRDATA(NTRMAX,23)                                                051840 0000
C     ------------------------------------------------------------------ 051850 0000
C     TUNNEL VOLUME INCLUDING OVERBREAK IN SOLID CUBIC YARDS/FOOT        051860 0000
      DO 10 I=1,NTS                                                     051870 0000
      NTSTYP=A(I,16)                                                    051880 0000
C     CHECK IF     SEGMENT EXCAVATED BY CUT AND COVER                   051890 0000
      IF(NTSTYP.EQ.3) GO TO 55                                          051900 0000
C     TUNNEL                                                            051910 0000
      BOB=A(I,42)                                                       051920 0000
      NREACH=A(I,4)                                                     051930 0000
      ISHAPE=TRDATA(NREACH,3)                                           051940 0000
C     CHECK THE SHAPE OF TUNNEL                                         051950 0000
      IF(ISHAPE.EQ.1) SFA=0.785                                         051960 0000
      IF(ISHAPE.EQ.2) SFA=0.893                                         051970 0000
      IF(ISHAPE.EQ.3) SFA=0.425                                         051980 0000
      V=BOB**2*SFA/27.                                                  051990 0000
      GO TO 10                                                          052000 0000
C     ------------------------------------------------------------------ 052010 0000
C     CUT AND COVER                                                      052020 0000
   55 BE=A(I,39)                                                        052030 0000
      DTRNCH=A(I,62)                                                    052040 0000
      NPLS=A(I,17)                                                      052050 0000
      NPRS=A(I,18)                                                      052060 0000
      SIDESL=A(I,63)                                                    052070 0000
C     COMPUTE THE DEPTH OF ROCK                                         052080 0000
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(Continued)

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      ELROCK=A(I,27)                                                    052090 0000
      ELSURF=0.5*(CNP(NPLS,2)+CNP(NPRS,2))                              052100 0000
      DROCK=ELSURF-ELROCK                                               052110 0000
C     COMPUTE THE EXCAVATED VOLUME IF CUT IS ENTIRELY IN SOIL           052120 0000
      VROCK=0.                                                          052130 0000
      VSOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.                               052140 0000
      IF(DROCK.GE.DTRNCH) GO TO 88                                      052150 0000
C     COMPUTE THE EXCAVATED VOLUME IF CUT IS IN PART SOIL-PART ROCK     052160 0000
      VROCK=BE*(DTRNCH-DROCK)/27.                                       052170 0000
      VSOIL=(BE+DROCK*SIDESL)*DROCK/27.                                 052180 0000
   88 V=VROCK+VSOIL                                                     052190 0000
   10 A(I,51)=V                                                         052200 0000
C     ------------------------------------------------------------------ 052210 0000
C     SHAFT                                                             052220 0000
      DO 20 I=1,NSS                                                     052230 0000
      BOB=B(I,32)                                                       052240 0000
      SFA=0.785                                                         052250 0000
      NSHAFT=B(I,1)                                                     052260 0000
      ISHAPS=SHAFT(NSHAFT,16)                                           052270 0000
      NSSTYP=B(I,15)                                                    052280 0000
      IF(ISHAPS.EQ.2) SFA=1.                                            052290 0000
      V=0.                                                              052300 0000
      IF(ISHAPS.EQ.0) GO TO 20                                          052310 0000
      IF(NSSTYP.NE.3) V=BOB**2*SFA/27.                                  052320 0000
   20 B(I,38)=V                                                         052330 0000
      RETURN                                                            052340 0000
      END                                                               052350 0000
      SUBROUTINE EXCVOL (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 052360 0000
     1NTRMAX)                                                           052365
C     ------------------------------------------------------------------ 052370 0000
C     ------------------------------------------------------------------ 052380 0000
C     CALCULATES THE EXCAVATED VOLUME TO EXIT FROM EACH SHAFT AND       052390 0000
C     LENGTH OF TRENCH TEMPORARILY LEFT OPEN IN CUT-AND-COVER EXCAVATION 052400 0000
C     ------------------------------------------------------------------ 052410 0000
C     ------------------------------------------------------------------ 052420 0000
      COMMON /BASIC/  NSS,NTS                                           052430 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 052440 0000
     1 TRDATA(NTRMAX,23)                                                052450 0000
C     ------------------------------------------------------------------ 052460 0000
C                                                                       052470 0000
C     INITIALIZE TOTAL EXCAVATED VOLUME                                 052480 0000
      DO 100 N=1,NSMAX                                                  052490 0000
  100 SHAFT(N,9)=0.0                                                    052500 0000
C     CALCULATE VOLUME FROM CUT AND COVER REACH                         052510 0000
C     ------------------------------------------------------------------ 052520 0000
      DO 1000 I=1,NTRMAX                                                052530 0000
      IF (TRDATA(I,1).LT.0) GO TO 1000                                  052540 0000
      NRSEG1=TRDATA(I,5)                                                052550 0000
      NTSTYP=A(NRSEG1,16)                                               052560 0000
      IF(NTSTYP.NE.3) GO TO 1000                                        052570 0000
      NSHAFT=TRDATA(I,1)                                                052580 0000
      NSEGS=TRDATA(I,6)                                                 052590 0000
      DAYS=TRDATA(I,9)                                                  052600 0000
      NSEGSA=IABS(NSEGS)                                                052610 0000
      VTEXC=0.                                                          052620 0000
      VTBOX=0.                                                          052630 0000
      PINSAR=0.                                                         052640 0000
      M=NRSEG1                                                          052650 0000
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      L=0                                                               052660 0000
      VTDS=0.                                                           052670 0000
 1100 T1=0.                                                             052680 0000
      L=L+1                                                             052690 0000
      TSEGL =A(M,45)                                                    052700 0000
      V     =A(M,51)                                                    052710 0000
      VBOX  =A(M,54)                                                    052720 0000
      AR    =A(M, 8)                                                    052730 0000
      ARTULT=A(M,49)                                                    052740 0000
      LINING=A(M,10)                                                    052750 0000
      CTTS1 =TSEGL/AR                                                   052760 0000
C     ADVANCE RATE FACTOR AT END POINTS OF SEGMENT                      052770 0000
      BINSAR=PINSAR-0.05                                                052780 0000
      IF(BINSAR.LT.0.) BINSAR=0.                                        052790 0000
      TMULT=(1.-BINSAR)/0.02                                            052800 0000
      PINSAR=BINSAR+0.02*CTTS1                                          052810 0000
      IF(PINSAR.GT.1.)PINSAR=1.                                         052820 0000
C     TIME REQUIRED FOR TRENCH TO BE LEFT OPEN                          052830 0000
      IF(LINING.EQ.1) TIMEOP=30.*DAYS/7.+10.                            052840 0000
      IF(LINING.EQ.3) TIMEOP=10.                                        052850 0000
      VTEXC=VTEXC+V*TSEGL                                               052860 0000
      VTBOX=VTBOX+VBOX*TSEGL                                            052870 0000
      IF(CTTS1.GT.TIMEOP) T1=CTTS1-TIMEOP                               052880 0000
C     COMPUTE THE LENGTH OF OPEN WITHOUT BACKFILL                       052890 0000
 1200 IF(CTTS1.LE.TMULT) OPENT=ARTULT*(CTTS1-T1)*(BINSAR+0.01*(CTTS1+T1) 052900 0000
     1 )                                                                052910 0000
      IF(CTTS1.GT.TMULT) OPENT=ARTULT*(BINSAR*(TMULT-T1)+0.01*(TMULT**2 052920 0000
     1 -T1**2)+CTTS1-TMULT)                                             052930 0000
      IF(T1.GT.TMULT) OPENT=ARTULT*(CTTS1-T1)                           052940 0000
C     CALCULATE VOLUME OF DISPOSAL AND BACKFILL                         052950 0000
      VTDST=(0.1*VTEXC+VTBOX+(V-VBOX)*OPENT)/1.1                        052960 0000
      VBFT=(V-VBOX)*OPENT                                               052970 0000
      T2=TIMEOP-CTTS1+T1                                                052980 0000
      PIN2=PINSAR                                                       052990 0000
      N=M+NSEGS/NSEGSA                                                  053000 0000
      LL=L+1                                                            053010 0000
C     CHECK IF THE NEXT SEGMENT IS INVOLVED                             053020 0000
      IF(T2.LE.0.) GO TO 1500                                           053030 0000
C     CHECK FOR END OF REACH                                            053040 0000
 1300 IF(LL.GT.NSEGSA) GO TO 1500                                       053050 0000
      TSEGL =A(N,45)                                                    053060 0000
      V2    =A(N,51)                                                    053070 0000
      VBOX2 =A(N,54)                                                    053080 0000
      AR    =A(N, 8)                                                    053090 0000
      ARTU2 =A(N,49)                                                    053100 0000
      CTTS2 =TSEGL/AR                                                   053110 0000
      BIN2=PIN2-0.05                                                    053120 0000
      IF(BIN2.LT.0.) BIN2=0.                                            053130 0000
C     CHECK IF MORE SEGMENTS INVOLVED                                   053140 0000
      IF(T2.LE.CTTS2) GO TO 1400                                        053150 0000
      LL=LL+1                                                           053160 0000
      T2=T2-CTTS2                                                       053170 0000
      N=N+NSEGS/NSEGSA                                                  053180 0000
      VTDST=VTDST+V2*TSEGL                                              053190 0000
      VBFT=VBFT+(V2-VBOX2)*TSEGL                                        053200 0000
      PIN2=BIN2+0.02*CTTS2                                              053210 0000
      IF(PIN2.GT.1.) PIN2=1.                                            053220 0000
      OPENT=OPENT+TSEGL                                                 053230 0000
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      GO TO 1300                                                        053240 0000
 1400 TMULT2=(1.-BIN2)/0.02                                             053260 0000
C     COMPUTE LENGTH WITHOUT BACKFILL IN THE LAST SEGMENT OF OPEN       053260 0000
      IF(T2.LE.TMULT2) OPENT2=ARTU2*T2*(BIN2+0.01*T2)                   053270 0000
      IF(T2.GT.TMULT2) OPENT2=ARTU2*(BIN2*TMULT2+0.01*TMULT2**2         053280 0000
     1 +T2-TMULT2)                                                      053290 0000
C     COMPUTE VOLUME OF DISPOSAL AND BACKFILL                           053300 0000
      VTDST=VTDST+V2*OPENT2                                             053310 0000
      VBFT=VBFT+(V2-VBOX2)*OPENT2                                       053320 0000
      OPENT=OPENT+OPENT2                                                053330 0000
C     MAXIMUM VOLUME IN LENGTH 'OPEN'                                   053340 0000
 1500 IF(VTDS.GT.VTDST) GO TO 1600                                      053350 0000
      VTDS=VTDST                                                        053360 0000
      VBF=VBFT                                                          053370 0000
      OPEN=OPENT                                                        053380 0000
C     CHECK IF LAST SEGMENT OF REACH                                    053390 0000
 1600 IF (L.GE.NSEGSA) GO TO 2100                                       053400 0000
      IF(LL.GT.NSEGSA) GO TO 1700                                       053410 0000
      T1=T1+1.                                                          053420 0000
      IF(T1.LT.CTTS1) GO TO 1200                                        053430 0000
      M=M+NSEGS/NSEGSA                                                  053440 0000
      GO TO 1100                                                        053450 0000
C     ------------------------------------------------------------------ 053460 0000
C     COMPUTE THE TOTAL VOLUME OF EXCAVATION AND BOX IN A REACH         053470 0000
 1700 MM=M+1                                                            053480 0000
      DO 2000 J=MM,N                                                    053490 0000
      TSEGL=A(J,45)                                                     053500 0000
      V=A(J,51)                                                         053510 0000
      VBOX=A(J,54)                                                      053520 0000
      VTEXC=VTEXC+V*TSEGL                                               053530 0000
 2000 VTBOX=VTBOX+VBOX*TSEGL                                            053540 0000
 2100 VDS=VTDS/VTEXC                                                    053550 0000
      SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+VTDS                              053560 0000
C     BACKFILL VOLUME                                                   053570 0000
      VBACDS=VBF/1.1/(VTEXC-VTBOX)                                      053580 0000
      VBACEX=0.909-VBACDS                                               053590 0000
C     STORE VALUES IN ARRAY                                             053600 0000
      TRDATA(I,16)=OPEN                                                 053610 0000
      TRDATA(I,21)=VDS                                                  053620 0000
      TRDATA(I,22)=VBACEX                                               053630 0000
      TRDATA(I,23)=VBACDS                                               053640 0000
 1000 CONTINUE                                                          053650 0000
C     ------------------------------------------------------------------ 053660 0000
C     CALCULATE VOLUME FROM TUNNEL SEGMENT                              053670 0000
      DO 200 N=1,NTS                                                    053680 0000
      NREACH=A(N,4)                                                     053690 0000
      NSHAFT=TRDATA(NREACH,1)                                           053700 0000
      NTSTYP=A(N,16)                                                    053710 0000
      IF(NTSTYP.EQ.3) GO TO 200                                         053720 0000
      V=A(N,51)                                                         053730 0000
      TSEGL=A(N,45)                                                     053740 0000
      SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+V*TSEGL                           053750 0000
  200 CONTINUE                                                          053760 0000
C     ------------------------------------------------------------------ 053770 0000
C     CALCULATE VOLUME FROM SHAFT SEGMENT                               053780 0000
      DO 300 N=1,NSS                                                    053790 0000
      NSHAFT=B(N,1)                                                     053800 0000
      NSSTYP=B(N,15)                                                    053810 0000
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      IF(NSSTYP.EQ.3) GO TO 300                                         053820 0000
      U=B(N,38)                                                         053830 0000
      SSEGL=B(N,35)                                                     053840 0000
      SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+U*SSEGL                           053850 0000
  300 CONTINUE                                                          053860 0000
C     ------------------------------------------------------------------ 053870 0000
      RETURN                                                            053880 0000
      END                                                               053890 0000
      SUBROUTINE MUCKLD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 053900 0000
     1NTRMAX)                                                           053905
C     ------------------------------------------------------------------ 053910 0000
C     ------------------------------------------------------------------ 053920 0000
C     CALCULATES REQUIRED MUCK LOADING RATES IN EACH SEGMENT AND        053930 0000
C     MAXIMUM RATE IN EACH REACH OR SHAFT BASED ON ULTIMATE ADVANCE RATE 053940 0000
C     ------------------------------------------------------------------ 053950 0000
C     ------------------------------------------------------------------ 053960 0000
      COMMON /BASIC/  NSS,NTS                                           053970 0000
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 053980 0000
     1 TRDATA(NTRMAX,23)                                                053990 0000
C     ------------------------------------------------------------------ 054000 0000
C     MUCK LOADING RATE IN TUNNEL SEGMENTS AND MAXIMUM RATE IN REACH    054010 0000
      DO 400 NREACH=1,NTRMAX                                            054020 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400                         054030 0000
C                                                                       054040 0000
      HOURS=TRDATA(NREACH,8)                                            054050 0000
      NRSEG1=TRDATA(NREACH,5)                                           054060 0000
      NSEGS=TRDATA(NREACH,6)                                            054070 0000
      NSEGSA=IABS(NSEGS)                                                054080 0000
C                                                                       054090 0000
      RMLMAX=0                                                          054100 0000
C                                                                       054110 0000
      DO 300  I=1,NSEGSA                                                054120 0000
C     N=SEQUENCE NUMBER OF TUNNEL SEGMENT                               054130 0000
      IF(NSEGS.GT.0) N=NRSEG1+I-1                                       054140 0000
      IF(NSEGS.LT.0) N=NRSEG1-I+1                                       054150 0000
      NTSTYP=A(N,16)                                                    054160 0000
      IF (NTSTYP.EQ.3) GO TO 300                                        054170 0000
      MEX=A(N,7)                                                        054180 0000
      U=A(N,51)                                                         054190 0000
      ARTULT=A(N,49)                                                    054200 0000
C     CALCULATE  MUCK LOADING RATE                                      054210 0000
      IF(MEX.EQ.1) GO TO 200                                            054220 0000
      RML=3.*U*ARTULT/HOURS                                             054230 0000
      GO TO 250                                                         054240 0000
  200 IF(5.*HOURS/ARTULT.GE.2) RML=5.*U                                 054250 0000
      IF(5.*HOURS/ARTULT.LT.2.) RML=2.*U*ARTULT/HOURS                   054260 0000
  250 IF(RMLMAX.LT.RML) RMLMAX=RML                                      054270 0000
      A(N,48)=RML                                                       054280 0000
  300 CONTINUE                                                          054290 0000
C                                                                       054300 0000
  350 TRDATA(NREACH,7)=RMLMAX                                           054310 0000
  400 CONTINUE                                                          054320 0000
C     ------------------------------------------------------------------ 054330 0000
C     MUCK LOADING RATE IN SHAFT SEGMENTS AND MAXIMUM RATE IN SHAFTS    054340 0000
      DO 800 NSHAFT=1,NSMAX                                             054350 0000
      IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800                          054360 0000
C                                                                       054370 0000
      HOURS=SHAFT(NSHAFT,17)                                            054380 0000
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      NSSEQ1=SHAFT(NSHAFT,1)
      NSEQS=SHAFT(NSHAFT,4)
C
      RMLMAX=0
C
      DO 700 I=1,NSEQS
      N=I-1+NSSEQ1
C     N=SEQUENCE NUMBER OF SHAFT SEGMENT
C     CHECK FOR CUT AND COVER OR DUMMY SHAFT - NO RML COMPUTED
      MEX=B(N,7)
      IF(MEX.EQ.0) GO TO 700
      V=B(N,38)
      ARSULT=B(N,39)
      IF(MEX.EQ.1) GO TO 600
      RML=3.*V*ARSULT/HOURS
      GO TO 650
  600 IF(5.*HOURS/ARSULT.GE.12.) RML=5.*V/6.
      IF(5.*HOURS/ARSULT.LT.12.) RML=2.*V*ARSULT/HOURS
  650 IF(RMLMAX.LT.RML) RMLMAX=RML
      B(N,37)=RML
  700 CONTINUE
C
  750 SHAFT(NSHAFT,10)=RMLMAX
  800 CONTINUE
C     ------------------------------------------------------------------
      RETURN
      END
      SUBROUTINE AIRLOK(A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,NPMAX,
     1NSMAX,NTRMAX)
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
C     THIS SUBROUTINE DETERMINES THE LOCATIONS OF AIR LOCKS AND COOLING
C     PLANT IN A REACH AND COMPUTES THE COOLING AND VENTILATION
C     REQUIREMENTS OF TUNNEL SEGMENTS AND MAXIMUM REQUIREMENT IN A REACH
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
      COMMON /BASIC/  NSS,NTS
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
     1 TRDATA(NTRMAX,23),CUMSL(NPMAX)
C     ------------------------------------------------------------------
      DO 200 J=1,NTRMAX
      IF(TRDATA(J,1).LT.0) GO TO 200
      ISHAPE=TRDATA(J,3)
      IF(ISHAPE.EQ.0) GO TO 200
C     INITIALIZATION
      NRSEQ1=TRDATA(J,5)
      NSEQS=TRDATA(J,6)
      NSHAFT=TRDATA(J,1)
      DTC=0.
      QT=0.
      AIRTEM=SHAFT(NSHAFT,11)
      NSEQSA=IABS(NSEQS)
      KOOL=0
      DTCA=0.
      CAUT=0.
      M=0
      N1=1
      NPBS=SHAFT(NSHAFT,3)
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      HH=SHAFT(NSHAFT,8)                                                054960 0000
      NPLOCK=0                                                          054970 0000
      IF(ISHAPE.EQ.1) SFA=0.785                                         054980 0000
      IF(ISHAPE.EQ.2) SFA=0.893                                         054990 0000
      IF(ISHAPE.EQ.3) SFA=0.425                                         055000 0000
C     DETERMINE THE STATION OF THE FARTHEST    POINT OF COMPRESSED AIR  055010 0000
C     SEGMENT IN A REACH                                                055020 0000
      DO 50 N=1,NSEGSA                                                  055030 0000
      IF(NSEGS.LT.0) GO TO 10                                           055040 0000
C     I = SEQUENCE NUMBER OF SEGMENT                                    055050 0000
      I=NRSEG1+N-1                                                      055060 0000
      NPFEND=A(I,3)                                                     055070 0000
      GO TO 20                                                          055080 0000
   10 I=NRSEG1-N+1                                                      055090 0000
      NPFEND=A(I,2)                                                     055100 0000
   20 MSTAB=A(I,31)                                                     055110 0000
      TSEGL=A(I,45)                                                     055120 0000
      IF(MSTAB.NE.1) GO TO 50                                           055130 0000
      DTCA=DTCA+TSEGL                                                   055140 0000
      CUMFCA=CUMSL(NPFEND)                                              055150 0000
   50 CONTINUE                                                          055160 0000
C     ------------------------------------------------------------------ 055170 0000
C     DETERMINE THE LOCATION OF AIR LOCK FOR A SEGMENT IN COMPRESSED AIR 055180 0000
      DO 100 N=1,NSEGSA                                                 055190 0000
      IF (NSEGS.LT.0) GO TO 60                                          055200 0000
      I=NRSEG1+N-1                                                      055210 0000
      NPFEND=A(I,3)                                                     055220 0000
      NPREND=A(I,2)                                                     055230 0000
      NPS=A(I,17)                                                       055240 0000
      GO TO 65                                                          055250 0000
   60 I=NRSEG1-N+1                                                      055260 0000
      NPFEND=A(I,2)                                                     055270 0000
      NPREND=A(I,3)                                                     055280 0000
      NPS=A(I,18)                                                       055290 0000
   65 BE=A(I,39)                                                        055300 0000
      PH=A(I,57)                                                        055310 0000
      TSEGL=A(I,45)                                                     055320 0000
      DM=A(I,46)                                                        055330 0000
      RTEMP=A(I,12)                                                     055340 0000
      MSTAB=A(I,31)                                                     055350 0000
      IF(MSTAB.NE.1) GO TO 85                                           055360 0000
      PERM=A(I,25)                                                      055370 0000
      D10=SQRT(10.*ABS(PERM))                                           055380 0000
      IF(D10.LE.0.005) D10=0.005                                        055390 0000
C     ------------------------------------------------------------------ 055400 0000
      M=M+1                                                             055410 0000
C     COMPUTE VENTILATION QUANTITY FOR THE SEGMENT IN COMPRESSED AIR    055420 0000
      CAV=(28.5+10.*ALOG10(D10))*SFA*BE**2                              055430 0000
C     CHECK THE FIRST COMPRESSED AIR SEGMENT                            055440 0000
      IF(M.NE.1) GO TO 70                                               055450 0000
C     CHECK IF COOLING PLANT FOR FIRST AIR LOCK TO BE MOVED FROM        055460 0000
C     SHAFT TO ABOVE THE LOCK                                           055470 0000
      IF(ABS(CUMFCA-CUMSL(NPBS))+HH.LE.12000..AND.DTC.GT.0.) GO TO 75   055480 0000
      GO TO 71                                                          055490 0000
C     CHECK SEPARATION BETWEEN TWO COMPRESSED AIR SEGMENTS              055500 0000
   70 IF(ABS(CUMSL(M-1)-CUMSL(NPREND)).GT.5000..AND.                    055510 0000
     1 ABS(CUMFCA-CUMSL(NPREND)).GT.2000.) GO TO 71                     055520 0000
C     CHECK THE STATIONING OF THE SEGMENT END POINT TO DETERMINE THE    055530 0000
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C     POSITION THE AIR LOCK                                              055540 0000
      LOCK=IABS(NPLOCK)                                                  055550 0000
      IF(ABS(CUMSL(NPFEND)-CUMSL(LOCK))+DTHLOK.LE.10000.) GO TO 80       055560 0000
      IF(ABS(CUMFCA-CUMSL(LOCK))+DTHLOK.LE.12000.) GO TO 80              055570 0000
C     STORE THE HEAT EXCHANGE AND COMPRESSED AIR QUANTITIES WITHIN       055580 0000
C     COMPRESSED AIR SEGMENTS.                                           055590 0000
   71 N2=N-1                                                             055600 0000
      DO 72 NN=N1,N2                                                     055610 0000
      II=NRSEG1+(NN-1)*NSEGS/NSEGSA                                      055620 0000
      A(II,36)=CAUT                                                      055630 0000
   72 A(II,37)=QT                                                        055640 0000
      N1=N                                                               055650 0000
      CAUT=0.                                                            055660 0000
      KOOL=1                                                             055670 0000
C     KOOL  = INDICATOR FOR THE LOCATION OF COOLING PLANT                055680 0000
      QT=0.                                                              055690 0000
C     SET UP THE LOCK                                                    055700 0000
   75 NPLOCK=NPREND                                                      055710 0000
      DTHLOK=CNP(NPS,2)-CNP(NPLOCK,2)                                    055720 0000
      DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPBS))                               055730 0000
C     COMPUTE THE LENGTH OF PIPE FOR COOLING IN COMPRESSED AIR SEGMENT   055740 0000
   80 IF(KOOL.EQ.0) PUMPLT=5280.*DM+HH                                   055750 0000
      IF(KOOL.EQ.1) PUMPLT=5280.*DM-DLOCK+DTHLOK                         055760 0000
C     NPLOCK = NEGATIVE IF COOLING PLANT OF FIRST AIR LOCK MOVED FROM    055770 0000
C     SHAFT TO TOP OF LOCK                                               055780 0000
      IF (KOOL.EQ.1.AND.M.EQ.1.AND.DTC.GT.0.) NPLOCK=-NPLOCK             055790 0000
C     COMPUTE THE QUANTITY OF COOLED AIR REQUIRED IN COMPRESSED AIR      055800 0000
C     SEGMENT                                                            055810 0000
      Q=CAU*(74.00+0.031*PUMPLT)+SQRT(CAU)*PUMPLT                        055820 0000
     1 *(0.23+0.0454*(RTEMP-85.))+239.*PUMPLT                            055830 0000
      IF(CAU.GT.CAUT) CAUT=CAU                                           055840 0000
      M=NPFEND                                                           055850 0000
      GO TO 90                                                           055860 0000
C     ------------------------------------------------------------------ 055870 0000
C     COMPUTE QUANTITY OF COOLED AIR REQUIRED IN FREE AIR SEGMENT        055880 0000
   85 IF (KOOL.EQ.1) DM=DM-DLOCK/5280.                                   055890 0000
      Q=SFA*BE**2*(150.*PH /(AIRTEM+460.)+0.03*5280.*DM+54.*AIRTEM       055900 0000
     1 -4000.)+5280.*DM*SQRT(SFA*BE**2)*(0.35*RTEMP-29.)+2.4*DM*5280.    055910 0000
   90 IF(Q.LE.0.) GO TO 95                                               055920 0000
      DTC=DTC+TSEGL                                                      055930 0000
      IF(Q.GT.QT) QT=Q                                                   055940 0000
C     STORE THE LOCK POSITION AND HEAT EXCHANGE QUANTITY                 055950 0000
   95 A(I,38)=Q                                                          055960 0000
      A(I,36)=NPLOCK                                                     055970 0000
C     CHECK THE LAST SEGMENT IN A REACH                                  055980 0000
      IF (N.NE.NSEGSA) GO TO 100                                         055990 0000
      DO 99 NN=N1,N                                                      056000 0000
      II=NRSEG1+(NN-1)*NSEGS/NSEGSA                                      056010 0000
      A(II,35)=CAUT                                                      056020 0000
   99 A(II,37)=QT                                                        056030 0000
  100 CONTINUE                                                           056040 0000
      TRDATA(J,14)=DTCA                                                  056050 0000
      TRDATA(J,15)=DTC                                                   056060 0000
  200 CONTINUE                                                           056070 0000
      RETURN                                                             056080 0000
      END                                                                056090 0000
      SUBROUTINE CALCS (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,  056100 0000
     1NTRMAX)                                                            056105
```

(Continued)

```
C     ------------------------------------------------------------------
C     THIS SUBROUTINE OUTPUTS CALCULATED TUNNEL AND SHAFT DATA
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
      COMMON /BASIC/  NSS,NTS
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
      COMMON/F/ IERROR,ISTOP
      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
     1 TRDATA(NTRMAX,23)
C     ******************************************************************
C     REFER TO COMMENT ON DOUBLE PRECISION LITERALS IN SUBROUTINE 4.
      DOUBLE PRECISION TNONE,AIRPRS,DEWATR,GRDINJ,SUMP,STABIL
C     ******************************************************************
      DATA TNONE/' NONE '/,AIRPRS/'AIRPRS'/,DEWATR/'DEWATR'/,
     1GRDINJ/'GRDINJ'/,SUMP/' SUMP '/
C     ------------------------------------------------------------------
C
C     OUTPUT CALCULATED TUNNEL DATA
C
      ITYPE=1
      NLINES=40
      IPR=0
C     N=SEGMENT SEQUENCE NUMBER
      DO 100 N=1,NTS
      NLINES=NLINES+1
      IF(LIST(4).EQ.1) GO TO 10
      IF(NLINES.LT.40) GO TO 10
      NLINES=0
      WRITE(LO,3000)
      WRITE(LO,3010)
   10 NREACH=A(N,4)
      NPL=A(N,2)
      NPR=A(N,3)
      NTSEG=A(N,1)
      BE= A(N,39)
      NTSTYP=A(N,16)
      IF(NTSTYP.EQ.3) GO TO 40
C     ------------------------------------------------------------------
      ISHAPE=TRDATA(NREACH,3)
      MTM=TRDATA(NREACH,4)
      HSLOPE=A(N,47)
      IF(MTM.NE.3) GO TO 20
C     CHECK FOR MAXIMUM SLOPE FOR TRAIN
      IF(ABS(HSLOPE).LE.0.05) GO TO 30
      WRITE(LO,1020) NTSEG,NREACH
      NLINES=NLINES +1
      IERROR=1
      GO TO 30
   20 IF(MTM.NE.1) GO TO 30
C     ------------------------------------------------------------------
C     CHECK FOR TUNNEL CROWN HIGH ENOUGH TO HANDLE A TRUCK
      IF(ISHAPE.LE.2.AND.BE.LT.16.) GO TO 25
      IF(ISHAPE.EQ.3.AND.BE.LT.30.) GO TO 25
      GO TO 30
   25 WRITE(LO,1021) NTSEG,NREACH
      NLINES=NLINES +1
      IERROR=1
   30 CONTINUE
```

(Continued)

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C     ------------------------------------------------------------------ 056690 0000
C     CHECK FOR TOO STEEP A SLOPE FOR MUCK HAUL BY TRUCK OR CONVEYOR      056700 0000
      IF(ABS(MSLOPE).LE.0.26) GO TO 32                                    056710 0000
      WRITE(LO,1023) NTSEG,NREACH                                         056720 0000
      NLINES=NLINES+1                                                     056730 0000
      IERROR=1                                                            056740 0000
C     ------------------------------------------------------------------ 056750 0000
C     CHECK SOFT GROUND TUNNEL FOR ALL TRUCK IN COMPRESSED AIR SEGMENTS   056760 0000
   32 IF(NTSTYP.EQ.1) GO TO 40                                            056770 0000
      MSTAB=A(N,31)                                                       056780 0000
      MUST=A(N,32)                                                        056790 0000
      IF(MSTAB.NE.1) GO TO 40                                             056800 0000
      IF(MUST.LT.3.OR.MTM.NE.1) GO TO 35                                  056810 0000
      IERROR=1                                                            056820 0000
      WRITE(LO,1025) NTSEG,NREACH                                         056830 0000
      NLINES=NLINES+1                                                     056840 0000
   35 CONTINUE                                                            056850 0000
      IF(MUST.LT.3.AND.MTM.EQ.1) WRITE(LO,1030) NTSEG,NREACH              056860 0000
      IF(MUST.LT.3.AND.MTM.EQ.1) MTM=4                                    056870 0000
      TRDATA(NREACH,4)=MTM                                                056880 0000
   40  CONTINUE                                                           056890 0000
      IF(LIST(4).EQ.1) GO TO 70                                           056900 0000
C     ------------------------------------------------------------------ 056910 0000
C     CONVERT NODAL POINT STATIONING TO INTEGER VALUES                    056920 0000
      STA=CNP(NPL,1)                                                      056930 0000
      ISTA=STA/100.                                                       056940 0000
      ISTA2=STA-ISTA*100                                                  056950 0000
      ITENS=ISTA2/10.                                                     056960 0000
      IHUNS=ISTA2-ITENS*10                                                056970 0000
      IHUNS=IABS(IHUNS)                                                   056980 0000
      ICTTS=A(N,50)                                                       056990 0000
      LSEGL=A(N,45)                                                       057000 0000
      IPRML=TRDATA(NREACH,7)                                              057010 0000
      IFL=A(N,59)                                                         057020 0000
      IPH=A(N,57)                                                         057030 0000
      BOB=A(N,42)                                                         057040 0000
      ARTULT=A(N,49)                                                      057050 0000
      TL=A(N,11)*12.                                                      057060 0000
      BFT=TRDATA(NREACH,2)                                                057070 0000
      AR=A(N,8)                                                           057080 0000
C     ------------------------------------------------------------------ 057090 0000
C     EXCAVATED VOLUMES                                                   057100 0000
   50 VSOIL=0.0                                                           057110 0000
      VROCK=0.0                                                           057120 0000
      V=A(N,51)                                                           057130 0000
      IF(NTSTYP.EQ.1) VROCK=V                                             057140 0000
      IF(NTSTYP.EQ.2) VSOIL=V                                             057150 0000
      IF(NTSTYP.LT.3) GO TO 60                                            057160 0000
C     CUT AND COVER                                                       057170 0000
      DTRNCH=A(N,52)                                                      057180 0000
      NPLS=A(N,17)                                                        057190 0000
      NPRS=A(N,18)                                                        057200 0000
      SIDESL=A(N,53)                                                      057210 0000
C     COMPUTE THE DEPTH OF ROCK                                           057220 0000
      ELROCK=A(N,27)                                                      057230 0000
      ELSURF=0.5*(CNP(NPLS,2)+CNP(NPRS,2))                                057240 0000
      DROCK=ELSURF-ELROCK                                                 057250 0000
C     COMPUTE THE EXCAVATED VOLUME IF CUT IS ENTIRELY IN SOIL             057260 0000
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(Continued)

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      VROCK=0.                                                          057270 0000
      VSOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.                               057280 0000
      IF(DROCK.GE.DTRNCH) GO TO 60                                      057290 0000
C     COMPUTE THE EXCAVATED VOLUME IF CUT IS IN PART SOIL-PART ROCK     057300 0000
      VROCK=BE*(DTRNCH-DROCK)/27.                                       057310 0000
      VSOIL=(BE+DROCK*SIDESL)*DROCK/27.                                 057320 0000
   60 IVTR=VROCK                                                        057330 0000
      IVTS=VSOIL                                                        057340 0000
C     ------------------------------------------------------------------ 057350 0000
      IF(NTSTYP.EQ.1) GO TO 70                                          057360 0000
      ISUPPT=A(N,26)                                                    057370 0000
      GAMMA=A(N,22)                                                     057380 0000
      PERM=ABS(A(N,25))                                                 057390 0000
      IFLOWL=A(N,61)                                                    057400 0000
      STABNO=A(N,30)                                                    057410 0000
      IF(NTSTYP.EQ.3) GO TO 65                                          057420 0000
C     ------------------------------------------------------------------ 057430 0000
C     SOFT GROUND TUNNEL                                                057440 0000
      AIRPR=A(N,33)                                                     057450 0000
      MSTAB=A(N,31)                                                     057460 0000
      IF(MSTAB.EQ.0) STABIL=TNONE                                       057470 0000
      IF(MSTAB.EQ.1) STABIL=AIRPRS                                      057480 0000
      IF(MSTAB.EQ.2) STABIL=DEWATR                                      057490 0000
      IF(MSTAB.EQ.3) STABIL=GRDINJ                                      057500 0000
      GO TO 70                                                          057510 0000
C     ------------------------------------------------------------------ 057520 0000
C     CUT AND COVER                                                     057530 0000
   65 VL  =A(N,55)                                                      057540 0000
      SIDESL=A(N,53)                                                    057550 0000
      WELLS=A(N,68)                                                     057560 0000
      DSLURY=0.0                                                        057570 0000
      SPDLT=0.0                                                         057580 0000
      STABIL=TNONE                                                      057590 0000
      IF(IFLOWL.GT.0) STABIL=SUMP                                       057600 0000
      IF(IFLOWL.GT.0.AND.WELLS.GT.0.0) STABIL=DEWATR                    057610 0000
      OPEN=TRDATA(NREACH,16)                                            057620 0000
      VBACEX=TRDATA(NREACH,22)                                          057630 0000
      VBACDS=TRDATA(NREACH,23)                                          057640 0000
      V=A(N,51)                                                         057650 0000
      VBOX=A(N,54)                                                      057660 0000
      BACKFL=(VBACEX+VBACDS)*(V-VBOX)*1.1                               057670 0000
C     CHECK IF SEGMENT IN SAME REACH                                    057680 0000
   70 IF(IPR.EQ.NREACH) GO TO 85                                        057690 0000
C     ------------------------------------------------------------------ 057700 0000
C     CALCULATE CONSTRUCTION TIME FOR THE REACH  (CTR)                  057710 0000
      NSEGS=TRDATA(NREACH,6)                                            057720 0000
      NSEGSA=IABS(NSEGS)                                                057730 0000
      HOURS=TRDATA(NREACH,8)                                            057740 0000
      DAYS=TRDATA(NREACH,9)                                             057750 0000
      CTR=0.0                                                           057760 0000
      ALOCK=0.0                                                         057770 0000
      ICTR=0                                                            057780 0000
      MEXP=0                                                            057790 0000
      SETUSH=0.0                                                        057800 0000
      SETUPM=0.0                                                        057810 0000
      SETUPR=0.0                                                        057820 0000
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      TIMEDW=0.0                                                        057830 0000
      TIMECR=0.0                                                        057840 0000
      L=0                                                               057850 0000
      DO 730 I=1,NSEGSA                                                 057860 0000
      NN=N+I-1                                                          057870 0000
      CTTS=A(NN,50)                                                     057880 0000
      MEX=A(NN,7)                                                       057890 0000
  702 IF(MEX.GE.6) GO TO 705                                            057900 0000
C     SOFT GROUND OR ROCK TUNNEL                                        057910 0000
      CALL SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE)                   057920 0000
      IF(I.EQ.1) NPLOCK=A(NN,36)                                        057930 0000
      IF (A(NN,36).EQ.0) GO TO 730                                      057940 0000
C     CALCULATE NUMBER OF AIR LOCK SETUPS                               057950 0000
      IF(ALOCK.LT.1.) GO TO 703                                         057960 0000
      IF (A(NN,36).EQ.NPLOCK) GO TO 730                                 057970 0000
      ALOCK=ALOCK+0.25                                                  057980 0000
      GO TO 704                                                         057990 0000
  703 ALOCK=1.                                                          058000 0000
  704 NPLOCK=A(NN,36)                                                   058010 0000
      GO TO 730                                                         058020 0000
C     ------------------------------------------------------------------ 058030 0000
C     CUT AND COVER                                                     058040 0000
  705 ELWATR =A(NN,14)                                                  058050 0000
      D10=A(NN,19)                                                      058060 0000
      IWATER=A(NN,23)                                                   058070 0000
      ELIMP=A(NN,24)                                                    058080 0000
      PERM=A(NN,25)                                                     058090 0000
      FLOWL=A(NN,61)                                                    058100 0000
      NPLS=A(NN,17)                                                     058110 0000
      NPRS=A(NN,18)                                                     058120 0000
      DTRNCH=A(NN,52)                                                   058130 0000
      ELROCK=A(NN,27)                                                   058140 0000
      ELNPLS=CNP(NPLS,2)                                                058150 0000
      ELNPRS=CNP(NPRS,2)                                                058160 0000
C     CALULATE THE EXTRA CURING TIME FOR CIP CONCRETE                   058170 0000
      IF(L.LT.0) GO TO 708                                              058180 0000
      MM=NN                                                             058190 0000
      IF(NSEGS.GT.0) MM=N+NSEGSA-I                                      058200 0000
      LINING=A(MM,10)                                                   058210 0000
      IF(LINING.EQ.1) GO TO 707                                         058220 0000
      CTR=CTR+CTTS                                                      058230 0000
      GO TO 708                                                         058240 0000
  707 TIMECR=30.-CTR                                                    058250 0000
      IF(TIMECR.LT.0.) TIMECR=0.                                        058260 0000
      L=-1                                                              058270 0000
  708 IF(D10.LE.0.005.OR.IWATER.EQ.0) GO TO 730                         058280 0000
      IF(PERM.GT.0.0.AND.D10.GT.0.08) GO TO 709                         058290 0000
      IF(PERM.LT.0.0.AND.ABS(PERM).GT.0.0006) GO TO 709                 058300 0000
      TIMEDW=30.                                                        058310 0000
      GO TO 730                                                         058320 0000
  709 ELSURF=0.5*(ELNPLS+ELNPRS)                                        058330 0000
      DWATER=ELSURF-ELWATR                                              058340 0000
      DRAWDN=DTRNCH-DWATER                                              058350 0000
      DROCK=ELSURF-ELROCK                                               058360 0000
      PERM=ABS(PERM)                                                    058370 0000
      IF(DROCK.LT.DTRNCH.AND.ISUPPT.EQ.5) GO TO 730                     058380 0000
C     CHECK IF WATER TABLE BELOW BASE OF CUT                            058390 0000
      IF(DRAWDN.LE.0.) GO TO 730                                        058400 0000
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      DIMP=ELSURF-ELIMP-DTRNCH                                          058410 0000
C     CHECK IF IMPERVIOUS LAYER ABOVE BASE OF CUT                       058420 0000
      IF(DIMP.GE.0.0) GO TO 710                                         058430 0000
      DRAWDN=ELWATR-ELIMP                                               058440 0000
      DIMP=0.0                                                          058450 0000
  710 HEADV=-7.*(ALOG10(PERM)+1.)                                       058460 0000
C     CHECK IF VACUUM HEAD GREATER THAN 21 FEET                         058470 0000
      IF(HEADV.GT.21.) HEADV=21.0                                       058480 0000
C     CHECK IF VACUUM HEAD LESS THAN 0 FEET                             058490 0000
      IF(HEADV.LT.0.0) HEADV=0.0                                        058500 0000
      HEAD=DRAWDN+HEADV+DIMP                                            058510 0000
      PIPED=0.5*FLOWL**0.4                                              058520 0000
C     MINIMUM PIPE SIZE                                                 058530 0000
      IF(PIPED.LT.1.) PIPED=1.                                          058540 0000
C     DRAWDOWN  TIME                                                    058550 0000
      EXPT=2.5*DRAWDN*ALOG10(240.*(HEAD-SQRT(HEAD*DIMP))/PIPED)/(DRAWDN 058560 0000
     1+HEADV)/(0.73+0.27*(DRAWDN+HEADV)/HEAD)-5.0                       058570 0000
      TIMET=0.00267*PIPED**2*10.**EXPT/PERM/DRAWDN                      058580 0000
C     CHECK FOR MAXIMUM SEGMENT DEWATERING TIME IN REACH                058590 0000
      IF(TIMEDW.LT.TIMET) TIMEDW=TIMET                                  058600 0000
  730 ICTR=ICTR+CTTS                                                    058610 0000
      ICTR=ICTR+14.*SETUSH+28.*SETUPM+7.*SETUPR+14.*ALOCK               058620 0000
C     ------------------------------------------------------------------ 058630 0000
C     CHECK FOR CUT AND COVER REACH                                     058640 0000
      NTSTYP=A(N ,16)                                                   058650 0000
      IF(NTSTYP.EQ.3) GO TO 740                                         058660 0000
      TRDATA(NREACH,10)=SETUSH                                          058670 0000
      TRDATA(NREACH,11)=SETUPM                                          058680 0000
      TRDATA(NREACH,12)=SETUPR                                          058690 0000
      GO TO 750                                                         058700 0000
  740 ICTR=ICTR+70./DAYS+TIMECR+TIMEDW                                  058710 0000
      TRDATA(NREACH,14)=TIMEDW                                          058720 0000
  750 IF(LIST(4).EQ.1) GO TO 100                                        058730 0000
      WRITE(LO,2222)                                                    058740 0000
      NLINES=NLINES+1                                                   058750 0000
      IF(NTSTYP.EQ.1) GO TO 73                                          058760 0000
      PERM=ABS(A(N,25))                                                 058770 0000
      GAMMA=A(N,22)                                                     058780 0000
      IFLOWL=A(N,61)                                                    058790 0000
   73 CONTINUE                                                          058800 0000
C     ------------------------------------------------------------------ 058810 0000
      IF(NTSTYP.EQ.3) GO TO 80                                          058820 0000
C     ROCK OR SOFT GROUND TUNNEL                                        058830 0000
      WRITE(LO,3001) NREACH,NTSEG,ISTA,ITENS,IHUNS,LSEGL,BFT,BE,BOB,AR, 058840 0000
     1ARTULT,TL,IUTS,IUTR  ,IFL,IPH,ICTTS,ICTR,IPRML,HOURS,DAYS         058850 0000
      IF(NTSTYP.EQ.1) GO TO 100                                         058860 0000
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C     ------------------------------------------------------------------ 058870 0000
C     SOFT GROUND TUNNEL                                                 058880 0000
      IF(MSTAB.NE.1) GO TO 75                                            058890 0000
C     AIR LOCK NODAL POINTS                                              058900 0000
      NPLOCK=A(N,36)                                                     058910 0000
      STA=CNP(NPLOCK,1)                                                  058920 0000
      ISTA=STA/100.                                                      058930 0000
      ISTA2=STA-ISTA*100                                                 058940 0000
      ITENS=ISTA2/10.                                                    058950 0000
      IHUNS=ISTA2-ITENS*10                                               058960 0000
      IHUNS=IABS(IHUNS)                                                  058970 0000
      WRITE(LO,3002) ISTA,ITENS,IHUNS,STABNO,STABIL,AIRPR,IFLOWL,GAMMA,  058980 0000
     1PERM                                                               058990 0000
      NLINES=NLINES+1                                                    059000 0000
      GO TO 100                                                          059010 0000
C     AIR PRESSURE NOT USED                                              059020 0000
   75 WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM                     059030 0000
      NLINES=NLINES+1                                                    059040 0000
      GO TO 100                                                          059050 0000
C     ------------------------------------------------------------------ 059060 0000
C     CUT AND COVER                                                      059070 0000
   80 WRITE(LO,3004) NREACH,NTSEG,ISTA,ITENS,IHUNS,LSEGL,AR,ARTULT,IVTS, 059080 0000
     1 IVTR,IPH,ICTTS,ICTR,HOURS,DAYS                                    059090 0000
      IF(ISUPPT.EQ.5)  SPDLT=A(N,38)                                     059100 0000
      IF(ISUPPT.EQ.6) DSLURY=A(N,38)                                     059110 0000
      WRITE(LO,3005) STABNO,STABIL,IFLOWL,GAMMA,PERM,VL  ,BE,SIDESL,     059120 0000
     1DSLURY,SPDLT,BACKFL,OPEN                                           059130 0000
      NLINES=NLINES+1                                                    059140 0000
      GO TO 100                                                          059150 0000
C     ------------------------------------------------------------------ 059160 0000
C     THIS SEGMENT IN SAME REACH AS PREVIOUS SEGMENT                     059170 0000
   85 IF(LIST(4).EQ.1) GO TO 100                                         059180 0000
      WRITE(LO,2150)                                                     059190 0000
      NLINES=NLINES+1                                                    059200 0000
C     ------------------------------------------------------------------ 059210 0000
      IF(NTSTYP.EQ.3) GO TO 95                                           059220 0000
C     ROCK OR SOFT GROUND TUNNEL                                         059230 0000
      WRITE(LO,3011) NTSEG,ISTA,ITENS,IHUNS,LSEGL,BFT,BE,BOB,AR,ARTULT,  059240 0000
     1TL,IVTS,IVTR,IFL,IPH,ICTTS                                         059250 0000
      IF(NTSTYP.EQ.1) GO TO 100                                          059260 0000
C     ------------------------------------------------------------------ 059270 0000
C     SOFT GROUND TUNNEL                                                 059280 0000
      IF(MSTAB.NE.1) GO TO 90                                            059290 0000
C     AIR LOCK NODAL POINTS                                              059300 0000
      NPLOCK=A(N,36)                                                     059310 0000
      STA=CNP(NPLOCK,1)                                                  059320 0000
      ISTA=STA/100.                                                      059330 0000
      ISTA2=STA-ISTA*100                                                 059340 0000
      ITENS=ISTA2/10.                                                    059350 0000
      IHUNS=ISTA2-ITENS*10                                               059360 0000
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      IHUNS=IABS(IHUNS)                                                 059370 0000
      WRITE(LO,3002) ISTA,ITENS,IHUNS,STABNO,STABIL,AIRPR,IFLOWL,GAMMA,  059380 0000
     1PERM                                                              059390 0000
      NLINES=NLINES+1                                                   059400 0000
      GO TO 100                                                         059410 0000
C     AIR PRESSURE NOT USED                                             059420 0000
   90 WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM                    059430 0000
      NLINES=NLINES+1                                                   059440 0000
      GO TO 100                                                         059450 0000
C     ----------------------------------------------------------------- 059460 0000
C     CUT AND COVER                                                     059470 0000
   95 WRITE(LO,3014) NTSEG,ISTA,ITENS,IHUNS,LSEGL,AR,ARTULT,IUTS,IUTR,  059480 0000
     1IPH,ICTTS                                                         059490 0000
      IF(ISUPPT.EQ.5)  SPDLT=A(N,38)                                    059500 0000
      IF(ISUPPT.EQ.6) DSLURY=A(N,38)                                    059510 0000
      WRITE(LO,3015) STABNO,STABIL,IFLOWL,GAMMA,PERM,VL  ,BE,SIDESL,    059520 0000
     1DSLURY,SPDLT,BACKFL                                               059530 0000
      NLINES=NLINES+1                                                   059540 0000
  100 IPR=NREACH                                                        059550 0000
      IF(LIST(4).EQ.0) WRITE(LO,2222)                                   059560 0000
C     ----------------------------------------------------------------- 059570 0000
C                                                                       059580 0000
C     OUTPUT CALCULATED SHAFT DATA                                      059590 0000
C                                                                       059600 0000
      IF(LIST(5).EQ.1) GO TO 300                                        059610 0000
      IPS=0                                                             059620 0000
      ITYPE=2                                                           059630 0000
      NLINES=40                                                         059640 0000
      DO 200 N=1,NSS                                                    059650 0000
      NLINES=NLINES+1                                                   059660 0000
      IF(NLINES.LT.40) GO TO 102                                        059670 0000
      NLINES=0                                                          059680 0000
      WRITE(LO,2000)                                                    059690 0000
      WRITE(LO,2010)                                                    059700 0000
  102 NSHAFT=B(N,1)                                                     059710 0000
      NSSEG=B(N,2)                                                      059720 0000
      BE=B(N,29)                                                        059730 0000
      BOB=B(N,32)                                                       059740 0000
      ARSULT=B(N,39)                                                    059750 0000
      IPRML=SHAFT(NSHAFT,10)                                            059760 0000
      ICTSS=B(N,40)                                                     059770 0000
      IADS=SHAFT(NSHAFT,9)*0.00003                                      059780 0000
      LSEGL=B(N,35)                                                     059790 0000
      NPB=B(N,4)                                                        059800 0000
      IELNPB=CNP(NPB,2)                                                 059810 0000
      TL=B(N,11)*12.                                                    059820 0000
       R=B(N,8)                                                         059830 0000
      NPORT=SHAFT(NSHAFT,23)                                            059840 0000
      NSSTYP=B(N,15)                                                    059850 0000
C     ----------------------------------------------------------------- 059860 0000
C     EXCAVATED VOLUMES                                                 059870 0000
      VROCK=0.0                                                         059880 0000
      VSOIL=0.0                                                         059890 0000
      V=B(N,38)                                                         059900 0000
      IF(NSSTYP.EQ.1) VROCK=V                                           059910 0000
      IF(NSSTYP.EQ.2) VSOIL=V                                           059920 0000
      IVSR=VROCK                                                        059930 0000
      IVSS=VSOIL                                                        059940 0000
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(Continued)

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C     ------------------------------------------------------------------ 059950 0000
      IF(NSSTYP.EQ.1) GO TO 110                                           059960 0000
      GAMMA=B(N,18)                                                       059970 0000
      PERM=ABS(B(N,23))                                                   059980 0000
      IF(NSSTYP.EQ.3) GO TO 110                                           059990 0000
C     SOFT GROUND SHAFT                                                   060000 0000
      AIRPR=B(N,27)                                                       060010 0000
      IFLOWL=B(N,42)                                                      060020 0000
      STABNO=B(N,24)                                                      060030 0000
      MSTAB=B(N,25)                                                       060040 0000
      IF(MSTAB.EQ.0) STABIL=TNONE                                         060050 0000
      IF(MSTAB.EQ.1) STABIL=AIRPRS                                        060060 0000
      IF(MSTAB.EQ.2) STABIL=DEWATR                                        060070 0000
      IF(MSTAB.EQ.3) STABIL=GRDINJ                                        060080 0000
C     ------------------------------------------------------------------ 060090 0000
C     CHECK IF SEGMENT IN SAME SHAFT AS PREVIOUS SEGMENT                  060100 0000
  110 IF(IPS.EQ.NSHAFT) GO TO 160                                         060110 0000
C     CONVERT STATIONING OF SHAFT TO INTEGER VALUES                       060120 0000
      NPTS=SHAFT(NSHAFT,2)                                                060130 0000
      NPBS=SHAFT(NSHAFT,3)                                                060140 0000
      STA=CNP(NPBS,1)                                                     060150 0000
      ISTA=STA/100.                                                       060160 0000
      ISTA2=STA-ISTA*100                                                  060170 0000
      ITENS=ISTA2/10.                                                     060180 0000
      IHUNS=ISTA2-ITENS*10                                                060190 0000
      IHUNS=IABS(IHUNS)                                                   060200 0000
      BFS=SHAFT(NSHAFT,7)                                                 060210 0000
C     ------------------------------------------------------------------ 060220 0000
C     CHECK FOR PORTAL                                                    060230 0000
      IF(NPORT.EQ.0) GO TO 112                                            060240 0000
      WRITE(LO,2200) NSHAFT,ISTA,ITENS,IHUNS,IELNPB,IADS                  060250 0000
      GO TO 200                                                           060260 0000
C     ------------------------------------------------------------------ 060270 0000
C     CHECK FOR DUMMY SHAFT                                               060280 0000
  112 ISHAPS=SHAFT(NSHAFT,16)                                             060290 0000
      IF(ISHAPS.GT.0) GO TO 115                                           060300 0000
      WRITE(LO,2100) NSHAFT,ISTA,ITENS,IHUNS,IELNPB,IADS                  060310 0000
      GO TO 200                                                           060320 0000
C     ------------------------------------------------------------------ 060330 0000
C     CALCULATE CONSTRUCTION TIME FOR THE SHAFT   (CTS)                   060340 0000
  115 NSEGS=SHAFT(NSHAFT,4)                                               060350 0000
      ICTS=0                                                              060360 0000
      MEXP=0                                                              060370 0000
      SETUSH=0.0                                                          060380 0000
      SETUPM=0.0                                                          060390 0000
      DO 120 I=1,NSEGS                                                    060400 0000
      NN=N+I-1                                                            060410 0000
      CTSS=B(NN,40)                                                       060420 0000
      MEX=B(NN,7)                                                         060430 0000
      NSSTYP=B(NN,15)                                                     060440 0000
C     CHECK FOR SHAFT NOT CONSTRUCTED IN CUT AND COVER                    060450 0000
      IF(NSSTYP.NE.3) CALL SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE)     060460 0000
  120 ICTS=ICTS+CTSS                                                      060470 0000
      ICTS=ICTS+14.*SETUSH+28.*SETUPM                                     060480 0000
C     ------------------------------------------------------------------ 060490 0000
  130 WRITE(LO,2222)                                                      060500 0000
      NLINES=NLINES+1                                                     060510 0000
      NSSTYP=B(N,15)                                                      060520 0000
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AD-A107 890 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
TUNNEL COST-ESTIMATING METHODS.(U)
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      HOURS=SHAFT(NSHAFT,17)                                            060530 0000
      DAYS=SHAFT(NSHAFT,18)                                             060540 0000
      IF(NSSTYP.EQ.3) GO TO 150                                         060550 0000
      WRITE(LO,2001) NSHAFT,NSSEG,ISTA,ITENS,IHUNS,IELNPB,LSEGL,BFS,BE, 060560 0000
     1BOB,AR,ARSULT,TL,IVSS,IVSR,IADS,ICTSS,ICTS,IPRML,HOURS,DAYS       060570 0000
      IF(NSSTYP.EQ.1) GO TO 200                                         060580 0000
C     ------------------------------------------------------------------ 060590 0000
C     SOFT GROUND SHAFT                                                 060600 0000
      IF(MSTAB.NE.1) GO TO 140                                          060610 0000
C     COMPRESSED AIR USED                                               060620 0000
      WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM              060630 0000
      NLINES=NLINES+1                                                   060640 0000
      GO TO 200                                                         060650 0000
C     NO COMPRESSED AIR                                                 060660 0000
  140 WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM                    060670 0000
      NLINES=NLINES+1                                                   060680 0000
      GO TO 200                                                         060690 0000
C     ------------------------------------------------------------------ 060700 0000
C     CUT AND COVER                                                     060710 0000
  150 WRITE(LO,2004) NSHAFT,NSSEG,ISTA,ITENS,IHUNS,IELNPB,LSEGL,BFS,TL, 060720 0000
     1IADS,HOURS,DAYS                                                   060730 0000
      WRITE(LO,2005) GAMMA,PERM                                         060740 0000
      NLINES=NLINES+1                                                   060750 0000
      GO TO 200                                                         060760 0000
C     ------------------------------------------------------------------ 060770 0000
C     THIS SEGMENT IN SAME SHAFT AS PREVIOUS SEGMENT                    060780 0000
  160 WRITE(LO,2150)                                                    060790 0000
      NLINES=NLINES+1                                                   060800 0000
      IF(NSSTYP.EQ.3) GO TO 170                                         060810 0000
      WRITE(LO,2011) NSSEG,IELNPB,LSEGL,BFS,BE,BOB,AR,ARSULT,TL,IVSS,   060820 0000
     1IVSR,ICTSS                                                        060830 0000
      IF(NSSTYP.EQ.1) GO TO 200                                         060840 0000
C     ------------------------------------------------------------------ 060850 0000
C     SOFT GROUND SHAFT                                                 060860 0000
      IF(MSTAB.NE.1) GO TO 165                                          060870 0000
C     COMPRESSED AIR USED                                               060880 0000
      WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM              060890 0000
      NLINES=NLINES+1                                                   060900 0000
      GO TO 200                                                         060910 0000
C     NO COMPRESSED AIR                                                 060920 0000
  165 WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM                    060930 0000
      NLINES=NLINES+1                                                   060940 0000
      GO TO 200                                                         060950 0000
C     ------------------------------------------------------------------ 060960 0000
C     CUT AND COVER                                                     060970 0000
  170 WRITE(LO,2012) NSSEG,IELNPB,LSEGL,BFS,TL                          060980 0000
      WRITE(LO,2005) GAMMA,PERM                                         060990 0000
      NLINES=NLINES+1                                                   061000 0000
  200 IPS=NSHAFT                                                        061010 0000
      WRITE(LO,2222)                                                    061020 0000
C     ------------------------------------------------------------------ 061030 0000
  300 IF(IERROR.EQ.0) RETURN                                            061040 0000
C     FATAL ERRORS DETECTED WHICH MAY MAKE COST CALCULATIONS            061050 0000
C     MEANINGLESS. TERMINATE RUN AND GO TO NEXT SYSTEM DATA DECK        061060 0000
      WRITE(LO,1022)                                                    061070 0000
      CALL NEXSET(LO,LI)                                                061080 0000
      RETURN                                                            061090 0000
C     ------------------------------------------------------------------ 061100 0000
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C                                                                       061110 0000
C     ****************************************************************** 061120 0000
 1020 FORMAT(/,35H FATAL ERROR, HAUL SLOPE IN SEGMENT,I5,9H IN REACH,    061130 0000
     1 I5,42H EXCEEDS 5 PERCENT --TOO STEEP FOR A TRAIN)                 061140 0000
 1021 FORMAT(/,' FATAL ERROR, EXCAVATED DIMENSION IN SEGMENT',I5,' IN    061150 0000
     1REACH',I5,' IS TOO SMALL FOR A TRUCK,USE TRAIN OR CONVEYOR')       061160 0000
 1022 FORMAT(//,1X,100(1H*),/,10X,' EXECUTION HALTED AFTER SUBROUTINE    061170 0000
     1 CALCS DUE TO ERRORS   ',/,1X,100(1H*))                            061180 0000
 1023 FORMAT(/,' FATAL ERROR, SLOPE OF SEGMENT',I5,' IN REACH',I5,       061190 0000
     1 ' EXCEEDS 26 PERCENT --TOO STEEP FOR MUCK TRANSPORT METHODS CON   061200 0000
     2SIDERED')                                                          061210 0000
 1025 FORMAT(/,' FATAL ERROR, ALL TRUCK MUCK TRANSPORT IS SPECIFIED IN   061220 0000
     1 SEGMENT',I5,' IN REACH',I5,' IN WHICH COMPRESSED AIR IS USED')    061230 0000
 1030 FORMAT(/' **** REMINDER **** USE OF COMPRESSED AIR IN SEGMENT',    061240 0000
     1I5,' IN REACH',I5,' REQUIRES USE OF CONVEYOR-TRUCK TRANSPORT MET   061250 0000
     2HOD RATHER'/20X,'THAN INPUT METHOD')                               061260 0000
 2000 FORMAT(1H1,42(1H*),'  C A L C U L A T E D  S H A F T  D A T A  ',  061270 0000
     146(1H*)//,' SHAFT SEG STATION  ELEV AT LENGTH *SHAFT DIMENSIONS* * 061280 0000
     2*ADVANCE RATES**  LINING *EXCAV VOLUME* SIZE OF  CONSTRUCTION RML- 061290 0000
     3 HOURS DAYS'/12X,'ALONG   BOTTOM   (FT)  FINISH EXCAV EXCAV   AVER 061300 0000
     4AGE UNIFORM  THICK   SOIL   ROCK   DISPOSAL  TIME (DAYS) MAX   PER 061310 0000
     5  PER'/12X,'TUNNEL  OF SEG          (FT)  (FT) W/O.B.    USED    061320 0000
     6        (IN)  (CY/FT)(CY/FT)   AREA    SEG  SHAFT  (CY/  DAY  WEEK 061330 0000
     7'/12X,'ALIGN.',36X,'(FT/DAY) (FT/DAY)',24X,'(ACRES)',16X,'HR)')    061340 0000
 2001 FORMAT(1X,I4,I5,I6,1H+,2I1,I7,I8,F7.2,2F6.2,2F8.1,F9.2,2I7,2I8,   061350 0000
     12I6,2F6.1)                                                         061360 0000
 2002 FORMAT(21X,F5.1,2X,A6,6X,I9,1X,F11.1,E9.2)                         061370 0000
 2003 FORMAT(21X,F5.1,2X,A6,F6.1,I9,1X,F11.1,E9.2)                       061380 0000
 2004 FORMAT(1X,I4,I5,I6,1H+,2I1,I7,I8,F7.2,28X,F9.2,14X,I8,20X,2F6.1)   061390 0000
 2005 FORMAT(55X,F6.1,E9.2)                                              061400 0000
 2010 FORMAT(   33(2H--,2H  )/21X,'***STABILIZATION***  DEWATERING *SOIL 061410 0000
     1 PROPERTIES*'/21X,'NUMBER METHOD AIRPR  (GPM/WELL)   UNIT WT   PER 061420 0000
     2M'/35X,'(PSI)',16X,'(PCF) (CM/SEC)'//)                             061430 0000
 2011 FORMAT(5X,I5,8X,2I8,F7.2,2F6.2,2F8.1,F9.2,2I7,8X,I8)               061440 0000
 2012 FORMAT(5X,I5,8X,2I8,F7.2,28X,F9.2)                                 061450 0000
 2150 FORMAT(1X)                                                         061460 0000
 2100 FORMAT(1X,131(1H-)/1X,I4,5X,I6,1H+,2I1,I7,22X,' THIS SHAFT IS A    061470 0000
     1DUMMY',22X,I8)                                                     061480 0000
 2200 FORMAT(1X,131(1H-)/1X,I4,5X,I6,1H+,2I1,I7,22X,' THIS SHAFT IS A    061490 0000
     1PORTAL',21X,I8)                                                    061500 0000
 2222 FORMAT(1X,131(1H-))                                                061510 0000
 3000 FORMAT(1H1,41(1H*),'  C A L C U L A T E D  T U N N E L  D A T A  ' 061520 0000
     1,45(1H*)//,' REACH SEG  STATION SLOPE  *TUNNEL DIMENSIONS* **ADVAN 061530 0000
     2CE RATES**  LINING *EXCAV VOLUME*  PUMP   PUMP  CONSTRUCTION RML-  061540 0000
     3HOURS DAYS'/12X,'AT LEFT LENGTH FINISH EXCAV EXCAV    AVERAGE UNIF 061550 0000
     4ORM   THICK   SOIL   ROCK   FLOW  HEIGHT  TIME (DAYS) MAX   PER  P 061560 0000
     5ER'/12X,'OF SEG   (FT)   (FT)  (FT)  W/O.B.    USED            (I 061570 0000
     6N)  (CY/FT)(CY/FT)  RATE   (FT)   SEG  REACH  (CY/  DAY  WEEK'/40X 061580 0000
     7 '(FT)   (FT/DAY) (FT/DAY)',25X,'(GPM)',22X,'HR)')                 061590 0000
 3001 FORMAT(1X,I4,I5,I6,1H+,2I1,I6,2F7.2,F6.2,F8.1,F9.1,F9.2,2I7,I8,I7, 061600 0000
     13I6,2F6.1)                                                         061610 0000
 3002 FORMAT(11X,I5,1H+,2I1,F7.1,2X,A6,F6.1,I9,1X,F11.1,E9.2)            061620 0000
 3004 FORMAT(1X,I4,I5,I6,1H+,2I1,I6,20X,F8.1,F9.1,9X,2I7,8X,I7,2I6,6X,   061630 0000
     12F6.1)                                                             061640 0000
 3005 FORMAT(21X,F5.1,2X,A6,6X,I9,1X,F11.1,E9.2,F8.1,F8.2,F6.2,2F7.1,    061650 0000
     1F8.0,T114,' ',F8.0,T122,' ')                                       061660 0000
 3010 FORMAT(   33(2H--,2H  )/12X,'AIRLOCK  ***STABILIZATION***  DEWATER 061670 0000
     1ING *SOIL PROPERTIES*  CONCRETE *CUT AND COVER SEGMENT PROPERTIES* 061680 0000
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     2  REACH'/12X,'STATION  NUMBER METHOD AIRPR  (GPM/WELL)   UNIT WT   061690 0000
     3 PERM      BOX      BASE SIDE *SUPORT LENGTH*  BACKFL   OPEN'/12X,  061700 0000
     4'SG TUN',17X,'(PSI) SUMP(GPM/FT)   (PCF)  (CM/SEC)  VOLUME  WIDTH  061710 0000
     5SLOPE SLURRY  DECKED  VOLUME  LENGTH'/72X,'(CY/FT)   (FT)        W 061720 0000
     6ALL  SOLDIER (CY/FT)   (FT)'//)                                   061730 0000
 3011 FORMAT(5X,I5,I6,1H+,2I1,I6,2F7.2,F6.2,F8.1,F9.1,F9.2,2I7,I8,I7,I6) 061740 0000
 3014 FORMAT(5X,I5,I6,1H+,2I1,I6,20X,F8.1,F9.1,9X,2I7,8X,I7,I6)          061750 0000
 3015 FORMAT(21X,F5.1,2X,A6,6X,I9,1X,F11.1,E9.2,F8.1,F8.2,F6.2,2F7.1,    061760 0000
     1F8.0,T114,' ')                                                    061770 0000
C    ******************************************************************* 061780 0000
C                                                                        061790 0000
C                                                                        061800 0000
      RETURN                                                             061805
      END                                                                061810 0000
      SUBROUTINE SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE)              061820 0000
C     ------------------------------------------------------------------ 061830 0000
C     THIS SUBROUTINE COMPUTES THE NUMBER OF SETUP FOR SHIELD, MOLE,     061840 0000
C     AND RIPPER EXCAVATION                                              061850 0000
C     ------------------------------------------------------------------ 061860 0000
      IF(ITYPE.EQ.2) GO TO 500                                           061870 0000
C     TUNNEL                                                             061880 0000
      IF(MEX.LE.1.OR.MEX.GE.>1`/~E10 600                                 061890 0000
      IF(MEX.LT.3) GO TO 100                                             061900 0000
C     SHIELD SETUP                                                       061910 0000
      IF(SETUSH.GE.1..AND.(MEXP.LT.3.OR.MEXP.GE.6)) SETUSH=SETUSH+0.25   061920 0000
      IF(SETUSH.LT.1.) SETUSH=1.                                         061930 0000
  100 IF(MEX.GT.3) GO TO 400                                             061940 0000
C     ------------------------------------------------------------------ 061950 0000
C     MOLE SETUP                                                         061960 0000
      IF (SETUPM.GE.1.) GO TO 150                                        061970 0000
C     FIRST MOLE SETUP                                                   061980 0000
      SETUPM=1.                                                          061990 0000
      GO TO 600                                                          062000 0000
  150 IF(MEXP.EQ.2.OR.MEXP.EQ.3) GO TO 200                               062010 0000
C     RESETUP                                                            062020 0000
      SETUPM=SETUPM+0.25                                                 062030 0000
      GO TO 600                                                          062040 0000
C     CHANGE CUTTER                                                      062050 0000
  200 IF(MEXP.NE.MEX) SETUPM=SETUPM+0.125                                062060 0000
      GO TO 600                                                          062070 0000
C     RIPPER SETUP                                                       062080 0000
  400 IF(MEX.EQ.4) GO TO 600                                             062090 0000
C     RESETUP                                                            062100 0000
      IF(MEXP.NE.5.AND.SETUPR.GE.1.) SETUPR=SETUPR+0.25                  062110 0000
      IF(SETUPR.LT.1.) SETUPR=1.                                         062120 0000
      GO TO 600                                                          062130 0000
C     ------------------------------------------------------------------ 062140 0000
C     SHAFT                                                              062150 0000
  500 IF(MEX.LT.2) GO TO 600                                             062160 0000
C     SHIELD SETUP                                                       062170 0000
      IF(MEX.GE.3.AND.SETUSH.LT.1.) SETUSH=1.                            062180 0000
      IF(MEX.EQ.4) GO TO 600                                             062190 0000
      IF(SETUPM.LT.1.) GO TO 550                                         062200 0000
C     CHANGE CUTTER                                                      062210 0000
      IF(MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+0.125                     062220 0000
      GO TO 600                                                          062230 0000
C     FIRST SETUP                                                        062240 0000
  550 SETUPM=1.                                                          062250 0000
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  600 MEXP=MEX                                                          062260 0000
      RETURN                                                            062270 0000
      END                                                               062280 0000
      SUBROUTINE COSTTU(A,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NPMAX,NSMAX,    062290 0000
     1NTRMAX,NSSMAX)                                                            062295
C      COSTTU COLLECTS ALL OF THE TUNNEL COSTS AND OUTPUTS THEM         062300 0000
C     ------------------------------------------------------------------ 062310 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE           062330 0000
      COMMON/G/ TUNLC,TUNEC,TUNMC,TUNTC                                 062340 0000
      DIMENSION IL(12),IE(12),IM(12),CF(3)                              062350 0000
      DIMENSION  A(NTSMAX,68),            CNP(NPMAX,2),SHAFT(NSMAX,23), 062360 0000
     1 TRDATA(NTRMAX,23),CUMSL(NPMAX)                                   062370 0000
C     ------------------------------------------------------------------ 062380 0000
      INTEGER  SLCPF,SECPF,SMCPF,TLC,TEC,TMC                            062390 0000
      INTEGER TCES,TCE,TCML,TCMT,TCMH,TCMD,TCTS,TCL,TCFW,               062400 0000
     1        TCG,TCP,TCAC,TSCPF,  TSC                                  062410 0000
      INTEGER RCL,RCE,RCM,RCT                                           062420 0000
      INTEGER TUNLC,TUNEC,TUNMC,TUNTC                                   062430 0000
C     ------------------------------------------------------------------ 062440 0000
C     CALCULATE TUNNEL COSTS A REACH AT A TIME                          062450 0000
      ITYPE=1                                                           062460 0000
C                                                                       062470 0000
      TUNLC=0                                                           062480 0000
      TUNEC=0                                                           062490 0000
      TUNMC=0                                                           062500 0000
      TUNTC=0                                                           062510 0000
C                                                                       062520 0000
      DO  950  NREACH=1,NTRMAX                                          062530 0000
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 950                         062540 0000
      NSHAFT=TRDATA(NREACH,1)                                           062550 0000
      BF=TRDATA(NREACH,2)                                               062560 0000
      ISHAPE=TRDATA(NREACH,3)                                           062570 0000
      RTM=TRDATA(NREACH,4)                                              062580 0000
      NRSEG1=TRDATA(NREACH,5)                                           062590 0000
      NSEGS=TRDATA(NREACH,6)                                            062600 0000
      RMLMAX=TRDATA(NREACH,7)                                           062610 0000
      HOURS =TRDATA(NREACH,8)                                           062620 0000
      DAYS =TRDATA(NREACH,9)                                            062630 0000
      SETUSH=TRDATA(NREACH,10)                                          062640 0000
      SETUPM=TRDATA(NREACH,11)                                          062650 0000
      SETUPR=TRDATA(NREACH,12)                                          062660 0000
      DTCA =TRDATA(NREACH,14)                                           062670 0000
      DTC =TRDATA(NREACH,15)                                            062680 0000
      IF(ISHAPE.EQ.1) SFA=0.785                                         062690 0000
      IF(ISHAPE.EQ.1) SFP=3.14                                          062700 0000
      IF(ISHAPE.EQ.2) SFA=0.893                                         062710 0000
      IF(ISHAPE.EQ.2) SFP=3.57                                          062720 0000
      IF(ISHAPE.EQ.3) SFA=0.425                                         062730 0000
      IF(ISHAPE.EQ.3) SFP=2.66                                          062740 0000
C                                                                       062750 0000
      NBOX =TRDATA(NREACH,10)                                           062760 0000
      BFBUDT =TRDATA(NREACH,11)                                         062770 0000
      BFBHT =TRDATA(NREACH,12)                                          062780 0000
      IBOX2 =TRDATA(NREACH,13)                                          062790 0000
      TIMEDW=TRDATA(NREACH,14)                                          062800 0000
      OPEN =TRDATA(NREACH,16)                                           062810 0000
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      VDS =TRDATA(NREACH,21)                                            062820 0000
      VBACEX=TRDATA(NREACH,22)                                          062830 0000
      VBACDS=TRDATA(NREACH,23)                                          062840 0000
C                                                                       062850 0000
      NPBS=SHAFT(NSHAFT,3)                                              062860 0000
      DDS=SHAFT(NSHAFT,5)                                               062870 0000
      CDS=SHAFT(NSHAFT,6)                                               062880 0000
      HH=SHAFT(NSHAFT,8)                                                062890 0000
      NSEGSA=IABS(NSEGS)                                                062900 0000
C     ------------------------------------------------------------------062910 0000
C     DETERMINE NUMBER OF SHIFTS IN A WORK DAY                          062920 0000
      SHIFTS=1.                                                         062930 0000
      IF(HOURS.GE.12.) SHIFTS=2.                                        062940 0000
      IF(HOURS.GE.21.) SHIFTS=3.                                        062950 0000
C     CALCULATE COST FACTORS FOR LENGTH OF WORK WEEK                    062960 0000
      IF(HOURS/SHIFTS.LE.8.) CFLWWK=(6.08+0.192*(DAYS-4.)**2            062970 0000
     1 +0.384*SHIFTS)*SHIFTS/HOURS                                      062980 0000
      IF(HOURS/SHIFTS.GT.8.) CFLWWK=(0.76+0.024*(DAYS-4.)**2            062990 0000
     1 +0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS)                             063000 0000
      CFEWWK=(3.75+30./HOURS)/DAYS                                      063010 0000
C     ------------------------------------------------------------------063020 0000
      ALOCK=1.0                                                         063030 0000
      CLIND=0.                                                          063040 0000
      UCMCP=0.                                                          063050 0000
      IF(ISHAPE.EQ.0.OR.DTCA.EQ.0.) GO TO 5                             063060 0000
C     CALCULATE COST OF INSTALLATION OF CONVEYOR IN FREE AIR FOR        063070 0000
C     CONVEYOR+TRUCK TRANSPORT, AND COST OF COMPRESSED AIR PIPING       063080 0000
      CALL CVINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1,         063090 0000
     1 CLIND,UCMCP,NTSMAX,NPMAX)                                        063100 0000
C     ------------------------------------------------------------------063110 0000
C     CALCULATE NUMBER OF AIR LOCK LOCATIONS AND LENGTH OF LOCK         063120 0000
      CALL LOCKLT(A,NSEGS,RMLMAX,MTM,ALOCK,ALOCKL,NTSMAX,NRSEG1)        063130 0000
C     ------------------------------------------------------------------063140 0000
    5 RL=0.0                                                            063150 0000
      DO 10 IJ=1,NSEGSA                                                 063160 0000
      IF(NSEGS.GT.0) I=NRSEG1+IJ-1                                      063170 0000
      IF(NSEGS.LT.0) I=NRSEG1-IJ+1                                      063180 0000
      TSEGL=A(I,45)                                                     063190 0000
   10 RL=RL+TSEGL                                                       063200 0000
C     ------------------------------------------------------------------063210 0000
      RCL=0.                                                            063220 0000
      RCE=0.                                                            063230 0000
      RCM=0.                                                            063240 0000
      RCT=0.                                                            063250 0000
      NLINES=60                                                         063260 0000
C                                                                       063270 0000
C     CALCULATE TUNNEL COSTS FOR EACH SEGMENT                           063280 0000
C                                                                       063290 0000
C                                                                       063300 0000
      DO 900 IS=1,NSEGSA                                                063310 0000
C     I=SEQUENCE NUMBER OF TUNNEL SEGMENT                               063320 0000
      I=NRSEG1+IS-1                                                     063330 0000
      NPS=A(I,17)                                                       063340 0000
      IF(NSEGS.GT.0) GO TO 110                                          063350 0000
      I=NRSEG1-IS+1                                                     063360 0000
      NPS=A(I,18)                                                       063370 0000
  110 NPL   =A(I,2)                                                     063380 0000
      NPR   =A(I,3)                                                     063390 0000
```

(Continued)

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      ELNPL =CNP(NPL,2)                                                 063400 0000
      ELNPR =CNP(NPR,2)                                                 063410 0000
      ELAVG =0.5*(ELNPL+ELNPR)                                          063420 0000
      RS=A(I,5)                                                         063430 0000
      RQD=A(I,6)                                                        063440 0000
      MEX=A(I,7)                                                        063450 0000
      AR=A(I,8)                                                         063460 0000
      GI=A(I,9)                                                         063470 0000
C     THE VARIABLE  FOR LINING TYPE  IS CALLED L1(ONE)N1(ONE)NG IN THIS 063480 0000
C                                              --     --     --         063490 0000
C     SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING 063500 0000
C     WHICH COMPUTES LINING COSTS                                       063510 0000
      L1N1NG=A(I,10)                                                    063520 0000
      TL    =A(I,11)                                                    063530 0000
      TSEG  =A(I,11)                                                    063540 0000
      NOFORM=A(I,13)                                                    063550 0000
      ELWATR=A(I,14)                                                    063560 0000
      LINWT =A(I,15)                                                    063570 0000
      NTSTYP=A(I,16)                                                    063580 0000
      IF(NTSTYP.EQ.1) GO TO 115                                         063590 0000
      NPLS  =A(I,17)                                                    063600 0000
      NPRS  =A(I,18)                                                    063610 0000
C     CALCULATE AVERAGE SURFACE ELEVATION                               063620 0000
      ELNPLS=CNP(NPLS,2)                                                063630 0000
      ELNPRS=CNP(NPRS,2)                                                063640 0000
      ELSURF=0.5*(ELNPLS+ELNPRS)                                        063650 0000
C     DEPTH OF TUNNEL                                                   063660 0000
      DTUN=ELSURF-ELAVG                                                 063670 0000
C     CALCULATE DEPTH OF ROCK SURFACE                                   063680 0000
      ELROCK=A(I,27)                                                    063690 0000
      DROCK=ELSURF-ELROCK                                               063700 0000
C                                                                       063710 0000
  115 ELBOTM=ELAVG-0.5*BE                                               063720 0000
      IF(ISHAPE.EQ.3) ELBOTM=ELAVG-0.25*BE                              063730 0000
C                                                                       063740 0000
      D10   =A(I,19)                                                    063750 0000
      PHI   =A(I,20)                                                    063760 0000
      PERM=A(I,25)                                                      063770 0000
      ISUPPT=A(I,26)                                                    063780 0000
      IBRACE=A(I,28)                                                    063790 0000
      IDECK=A(I,29)                                                     063800 0000
      STABNO=A(I,30)                                                    063810 0000
      MSTAB=A(I,31)                                                     063820 0000
      AIRPR=A(I,33)                                                     063830 0000
      CAVT  =A(I,35)                                                    063840 0000
      QT    =A(I,37)                                                    063850 0000
      Q     =A(I,38)                                                    063860 0000
      BE    =A(I,39)                                                    063870 0000
      BE40  =A(I,40)                                                    063880 0000
      BE60  =A(I,41)                                                    063890 0000
```

(Continued)

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      BOB    =A(I,42)
      BOB40  =A(I,43)
      BOB60  =A(I,44)
C
      TSEQL  =A(I,45)
      DM     =A(I,46)
      HSLOPE=A(I,47)
      RAL    =A(I,48)
      V      =A(I,51)
C
      TOTBOX=A(I,43)
      DTRNCH=A(I,52)
      SIDESL=A(I,53)
      VBOX   =A(I,54)
      VL     =A(I,55)
      FORMAR=A(I,56)
C
      PH     =A(I,57)
      PIPL   =A(I,58)
      FLOW   =A(I,59)
      GIR    =A(I,60)
      FLOWL  =A(I,61)
C
      WEB    =A(I,62)
      TPLATE=A(I,62)
      WTWALE=A(I,63)
      WTSTRT=A(I,64)
      WTANCH=A(I,65)
      WTSP  =A(I,66)
      WTSPD  =A(I,67)
C
      WELLS  =A(I,68)
      SPDLT  =A(I,38)
      DSLURY=A(I,38)
      PSOIL  =A(I,63)
      PWATER=A(I,64)
      PTOTAL=A(I,65)
      IWATER=A(I,23)
C     ------------------------------------------------------------------
C     LABOR COST FACTOR IN COMPRESSED AIR
      CFLCA=AIRPR**2/400.+1.5
      IF(NTSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1.
C     COST FACTOR FOR TRAVEL TIME TO THE FACE
      Y=0.3*SHIFTS*(0.76+0.024*(DAYS-4.)**2+0.048*SHIFTS)
      IF(HOURS/SHIFTS.LT.8.) Y=Y*5.*(HOURS/SHIFTS+0.2*DM-8.)/DM
      IF(Y.LT.0.) Y=0.
      IF(NTSTYP.EQ.3) Y=0.
C
      CLES=0.
      CEES=0.
      CMES=0.
      CLAC=0.
      CEAC=0.
      CMAC=0.
      IF(NTSTYP.EQ.3) GO TO 750
      IF(MSTAB.NE.1) GO TO 750
      IF(IS.NE.1) GO TO 700
      DLOCK=0.
```

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      NPLOCK= ABS(A(I,36))                                              064480 0000
      DTHLOK=HH                                                         064490 0000
      PUMPLT=DTHLOK+DM*5280.                                            064500 0000
      GO TO 750                                                         064510 0000
C     CALCULATE LENGTH OF PIPING FOR COMPRESSED AIR                     064520 0000
  700 IF( ABS(A(I,36)).EQ.NPLOCK) GO TO 720                             064530 0000
      NPLOCK= ABS(A(I,36))                                              064540 0000
      DTHLOK=CNP(NPS,2)-CNP(NPLOCK,2)                                   064550 0000
      DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPBS))                              064560 0000
  720 PUMPLT=DM*5280.-DLOCK+DTHLOK                                      064570 0000
      IF(DLOCK.GT.0.001) HSFA=(CNP(NPBS,2)-CNP(NPLOCK,2))/DLOCK         064580 0000
      HSCA=(CNP(NPLOCK,2)-ELAVG)/(DM*5280.-DLOCK)                       064590 0000
C     ----------------------------------------------------------------- 064600 0000
C     CALCULATE SETUP COST FOR TUNNEL SEGMENT I                         064610 0000
  750 CALL CSETUP(A,B,NSEGS,NRSEG1,BE,HH,ITYPE,I ,SETUSH,SETUPM,SETUPR, 064620 0000
     1 CLES,CEES,CMES,CFLWWK,CFEWWK,NTSTYP,DSES,DMES,DRES,NTSMAX,NSSMAX) 064630 0000
C     ----------------------------------------------------------------- 064640 0000
C     CALCULATE COST OF EXCAVATION IN TUNNEL SEGMENT I                  064650 0000
      CALL COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPE,SFA,SFP,          064660 0000
     1          PSOIL,STABNO,DTRNCH,DROCK,SIDESL,VBOX,VSOIL,VROCK,PHI,  064670 0000
     2          DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLWWK,CFEWWK,NTSTYP)      064680 0000
C     ----------------------------------------------------------------- 064690 0000
C     CALCULATE COST OF MUCK LOADING IN TUNNEL SEGMENT I                064700 0000
      CALL CMUKLD(CLML,CEML,CMML,ITYPE,MEX,AR,DM,V,Y,RML,RMLMAX,        064710 0000
     1                MSTAB,CFLCA,CFLWWK,CFEWWK,HOURS)                  064720 0000
C     ----------------------------------------------------------------- 064730 0000
C     CALCULATE MUCK TRANSPORTATION AND HOISTING COSTS FOR              064740 0000
C     TUNNEL SEGMENT I                                                  064750 0000
      CALL CMTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR,         064760 0000
     1HSFA,V,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPE,RL,UCLT,UCET,Y,UCLMH, 064770 0000
     2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,VBACEX,VBACDS,VBOX, 064780 0000
     3   VSOIL,VROCK,TOTBOX,CFLWWK,CFEWWK,CFLCA,DDS,NTSTYP,DTRNCH,DROCK) 064790 0000
C     ----------------------------------------------------------------- 064800 0000
C     CALCULATE MUCK DISPOSAL COST FOR TUNNEL SEGMENT I                 064810 0000
      CALL CMUKDP(CLMD,CEMD,CMMD,AR,V,CDS,DDS,VDS,NTSTYP,HOURS,         064820 0000
     1          CFLWWK,CFEWWK,ITYPE)                                    064830 0000
C     ----------------------------------------------------------------- 064840 0000
C     CALCULATE COST OF TUNNEL SUPPORTS FOR TUNNEL SEGMENT I            064850 0000
      IF(LINING.EQ.4.AND.NTSTYP.EQ.1)GO TO 1900
      IF(LINING.NE.4.OR.NTSTYP.NE.1)GO TO 2000
 1900 CALL ROCK(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,
     1ITYPE,Y,NSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,
     2BOB,LINWT,MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,SFA,LINING,DM,
     3CLL,CEL,CML,CLFW,CEFW,CMFW)
      GO TO 2500
 2000 CONTINUE
      CALL CTSUP(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,ITYPE, 064860 0000
     1     Y,DM,NTSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,BOB,LINWT, 064870 0000
     2     MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,DSLURY,DTRNCH,IDECK,DROCK,    064880 0000
     3     WTSTRT,WTWALE,SPDLT,WTSPD,WTSP,WTANCH,TOTBOX,IBRACE,SFA)      064890 0000
C     ----------------------------------------------------------------- 064900 0000
C     CALCULATE COST OF LINING AND FORMWORK IN TUNNEL SEGMENT I         064910 0000
      CALL LINING1(CLL,CEL,CML,CLFW,CEFW,CMFW,ITYPE,LINING,RQD,MEX,     064920 0000
     1WEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPE,BE,UCLT,UCET,MTM,           064930 0000
     2UCLMH,UCEMH,SFA,NOFORM,AR,NTSTYP,PSOIL,PWATER,VL,SFP,             064940 0000
     3FORMAR,HOURS,CFLCA,CFLWWK,CFEWWK)                                 064950 0000
 2500 CONTINUE
C     ----------------------------------------------------------------- 064960 0000
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C     CALCULATE QROUTING COSTS FOR TUNNEL SEGMENT I                     064970 0000
      CALL CQROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPE,BE,AR,RS,NTSTYP,MSTAB,    064980 0000
     1            DTUN,HH,HOURS,CFLWWK,CFEWWK,SSEGL,PERM,SFP,DTG,TIMEG) 064990 0000
C     ------------------------------------------------------------------ 065000 0000
C     CALCULATE COST OF PUMPING FOR TUNNEL SEGMENT I                    065010 0000
      CALL CPUMP(CLP,CEP,CMP,NTSTYP,FLOW,PH,PIPL,AR,ITYPE,              065020 0000
     1           ELSURF,ELBOTM,DAYS,LINING,PUMPTM,HEX,DTRNCH,DROCK,FLOWL, 065030 0000
     2           WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPB,IWATER,CFLWWK,CFEWWK) 065040 0000
C     ------------------------------------------------------------------ 065050 0000
C     CALCULATE COST OF AIR CONDITIONING AND COMPRESSED AIR FOR TUNNEL  065060 0000
C     SEGMENT I                                                         065070 0000
      CALL CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NTSTYP,MSTAB,ITYPE, 065080 0000
     1           AIRPR,    SFA,ISHAPE,HH,CAVT,ALOCK,DTC,DTCA,PUMPLT,DM, 065090 0000
     2            ALOCKL,UCMCP,CFLWWK,CFEWWK,DAYS,Y,PERM)              065100 0000
C     ------------------------------------------------------------------ 065110 0000
C                                                                       065120 0000
C                                                                       065130 0000
C     ------------------------------------------------------------------ 065140 0000
      IF(LIST(6).EQ.1) GO TO 810                                        065150 0000
      IF(NLINES+10.LT.60) GO TO 810                                     065160 0000
      WRITE(LO,1000)                                                    065170 0000
      NLINES=6                                                          065180 0000
C     ------------------------------------------------------------------ 065190 0000
C     CALCULATE COST FACTORS                                            065200 0000
  810 POP=(1.+0.01*OM)*(1.+0.01*PM)                                     065210 0000
C     CF(1),CF(2) AND CF(3) ARE COMPOSITE COST FACTORS FOR L, E, AND M. 065220 0000
      CFL=SHAFT(NSHAFT,12)                                              065230 0000
      CFE=SHAFT(NSHAFT,13)                                              065240 0000
      CFM=SHAFT(NSHAFT,14)                                              065250 0000
      RCF=SHAFT(NSHAFT,15)                                              065260 0000
      CF(1)=POP*CFL*RCF                                                 065270 0000
      CF(2)=POP*CFE*RCF                                                 065280 0000
      CF(3)=POP*CFM*RCF                                                 065290 0000
C     ------------------------------------------------------------------ 065300 0000
C     MULTIPLY BY COMPOSITE COST FACTORS AND THEN OBTAIN SEGMENT        065310 0000
C     COSTS PER FOOT TO THE NEAREST DOLLAR                              065320 0000
      IL( 1)=CLES*CF(1)+.5                                              065330 0000
      IE( 1)=CEES*CF(2)+.5                                              065340 0000
      IM( 1)=CMES*CF(3)+.5                                              065350 0000
      IL( 2)=CLE *CF(1)+.5                                              065360 0000
      IE( 2)=CEE *CF(2)+.5                                              065370 0000
      IM( 2)=CME *CF(3)+.5                                              065380 0000
      IL( 3)=CLML*CF(1)+.5                                              065390 0000
      IE( 3)=CEML*CF(2)+.5                                              065400 0000
      IM( 3)=CMML*CF(3)+.5                                              065410 0000
      IL( 4)=CLMT*CF(1)+.5                                              065420 0000
      IE( 4)=CEMT*CF(2)+.5                                              065430 0000
      IM( 4)=CMMT*CF(3)+.5                                              065440 0000
      IL( 5)=CLMH*CF(1)+.5                                              065450 0000
      IE( 5)=CEMH*CF(2)+.5                                              065460 0000
      IM( 5)=CMMH*CF(3)+.5                                              065470 0000
      IL( 6)=CLMD*CF(1)+.5                                              065480 0000
      IE( 6)=CEMD*CF(2)+.5                                              065490 0000
      IM( 6)=CMMD*CF(3)+.5                                              065500 0000
      IL( 7)=CLTS*CF(1)+.5                                              065510 0000
      IE( 7)=CETS*CF(2)+.5                                              065520 0000
      IM( 7)=CMTS*CF(3)+.5                                              065530 0000
      IL( 8)=CLL *CF(1)+.5                                              065540 0000
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      IE( 8)=CEL *CF(2)+.5                                              065550 0000
      IM( 8)=CML *CF(3)+.5                                              065560 0000
      IL( 9)=CLFW*CF(1)+.5                                              065570 0000
      IE( 9)=CEFW*CF(2)+.5                                              065580 0000
      IM( 9)=CMFW*CF(3)+.5                                              065590 0000
      IL(10)=CLG *CF(1)+.5                                              065600 0000
      IE(10)=CEG *CF(2)+.5                                              065610 0000
      IM(10)=CMG *CF(3)+.5                                              065620 0000
      IL(11)=CLP *CF(1)+.5                                              065630 0000
      IE(11)=CEP *CF(2)+.5                                              065640 0000
      IM(11)=CMP *CF(3)+.5                                              065650 0000
      IL(12)=CLAC*CF(1)+.5                                              065660 0000
      IE(12)=CEAC*CF(2)+.5                                              065670 0000
      IM(12)=CMAC*CF(3)+.5                                              065680 0000
C     ------------------------------------------------------------------ 065690 0000
C     CALCULATE SEGMENT COST/FOOT FOR LABOR, EQUIPMENT AND MATERIALS    065700 0000
      SLCPF=0                                                           065710 0000
      SECPF=0                                                           065720 0000
      SMCPF=0                                                           065730 0000
      DO 815 LL=1,12                                                    065740 0000
      SLCPF=SLCPF+IL(LL)                                                065750 0000
      SECPF=SECPF+IE(LL)                                                065760 0000
  815 SMCPF=SMCPF+IM(LL)                                                065770 0000
      TSCPF=SLCPF+SECPF+SMCPF                                           065780 0000
C     ------------------------------------------------------------------ 065790 0000
C     CALCULATE TOTAL SEGMENT COST/FOOT FOR EACH COST COMPONENT         065800 0000
      TCES = IE( 1)+IM( 1)+IL( 1)                                       065810 0000
      TCE  = IE( 2)+IM( 2)+IL( 2)                                       065820 0000
      TCML = IE( 3)+IM( 3)+IL( 3)                                       065830 0000
      TCMT = IE( 4)+IM( 4)+IL( 4)                                       065840 0000
      TCMH = IE( 5)+IM( 5)+IL( 5)                                       065850 0000
      TCMD = IE( 6)+IM( 6)+IL( 6)                                       065860 0000
      TCTS = IE( 7)+IM( 7)+IL( 7)                                       065870 0000
      TCL  = IE( 8)+IM( 8)+IL( 8)                                       065880 0000
      TCFW = IE( 9)+IM( 9)+IL( 9)                                       065890 0000
      TCG  = IE(10)+IM(10)+IL(10)                                       065900 0000
      TCP  = IE(11)+IM(11)+IL(11)                                       065910 0000
      TCAC = IE(12)+IM(12)+IL(12)                                       065920 0000
C     ------------------------------------------------------------------ 065930 0000
C     CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS             065940 0000
      TLC = SLCPF*TSEGL/1000.                                           065950 0000
      TEC = SECPF*TSEGL/1000.                                           065960 0000
      TMC = SMCPF*TSEGL/1000.                                           065970 0000
      TSC = TLC+TEC+TMC                                                 065980 0000
C     ------------------------------------------------------------------ 065990 0000
      IF(LIST(6).EQ.1) GO TO 840                                        066000 0000
C     WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL      066010 0000
      ITSEGL=TSEGL                                                      066020 0000
      NTSEG=A(I,1)                                                      066030 0000
      WRITE(LO,1001) NREACH,NTSEG,(IL(JJJ),JJJ=1,12),SLCPF,TLC          066040 0000
      WRITE(LO,1002)              (IE(JJJ),JJJ=1,12),SECPF,TEC          066050 0000
      WRITE(LO,1003)              (IM(JJJ),JJJ=1,12),SMCPF,TMC          066060 0000
      WRITE(LO,1004) TCES,TCE,TCML,TCMT,TCMH,TCMD,TCTS,TCL,TCFW,        066070 0000
     1TCG,TCP,TCAC,TSCPF,ITSEGL,  TSC                                   066080 0000
C                                                                       066090 0000
      NLINES=NLINES+5                                                   066100 0000
C                                                                       066110 0000
C     ACCUMULATE TUNNEL SEGMENT COSTS INTO COST OF REACH                066120 0000
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  840 RCL=RCL+TLC                                                       066130 0000
      RCE=RCE+TEC                                                       066140 0000
      RCM=RCM+TMC                                                       066150 0000
      RCT=RCL+RCE+RCM                                                   066160 0000
C     END OF COSTS ON A SEGMENT BASIS                                   066170 0000
  900 CONTINUE                                                          066180 0000
C     ------------------------------------------------------------------ 066190 0000
C     LIST OUT REACH COSTS                                              066200 0000
  850 IF(LIST(6).EQ.1) GO TO 860                                        066210 0000
      WRITE(LO,1007) SHAFT(NSHAFT,12),RCL, SHAFT(NSHAFT,15),            066220 0000
     1 SHAFT(NSHAFT,13),RCE,SHAFT(NSHAFT,14),RCM,CFLWWK,RCT,CFEWWK      066230 0000
      NLINES=NLINES+7                                                   066240 0000
C                                                                       066250 0000
C     ------------------------------------------------------------------ 066260 0000
C     ACCUMULATE COSTS OF ALL REACHES                                   066270 0000
  860 TUNLC=TUNLC+RCL                                                   066280 0000
      TUNEC=TUNEC+RCE                                                   066290 0000
      TUNMC=TUNMC+RCM                                                   066300 0000
      TUNTC=TUNTC+RCT                                                   066310 0000
C                                                                       066320 0000
      TRDATA(NREACH,17)=RCL                                             066330 0000
      TRDATA(NREACH,18)=RCE                                             066340 0000
      TRDATA(NREACH,19)=RCM                                             066350 0000
      TRDATA(NREACH,20)=RCT                                             066360 0000
C     END OF COSTS ON A REACH BASIS                                     066370 0000
  950 CONTINUE                                                          066380 0000
      RETURN                                                            066390 0000
C                                                                       066400 0000
C     ------------------------------------------------------------------ 066410 0000
C     ------------------------------------------------------------------ 066420 0000
 1000 FORMAT(1H1,47(1H*),27H  T U N N E L   C O S T S  ,46(1H*)//       066430 0000
     1120H REACH SEG  ****************** COST IN DOLLARS PER FOOT OF TUNNE 066440 0000
     2L ********************  SEG   SEGMENT    SEGMENT                 / 066450 0000
     3120H  NO   NO    EXC    EXC  MUCK  MUCK  MUCK  MUCK SUP-   LIN-   066460 0000
     4LIN GROUT PUMP-  AIR-  COST  LENGTH        COST                 / 066470 0000
     5120H            SETUP        LOAD  TRAN HOIST  DISP PORTS   ING  F 066480 0000
     6ORM          ING  COND ($/FT)  (FEET)    ($1000)                 066490 0000
     7  /,1X,119(1H-))                                                  066500 0000
 1001 FORMAT(/1X,I3,I5,2H L,13I6,8X,I12)                                066510 0000
 1002 FORMAT(9X,      2H E,13I6,8X,I12)                                 066520 0000
 1003 FORMAT(9X,      2H M,13I6,8X,I12)                                 066530 0000
 1004 FORMAT(9X,      2H T,13I6,I8,I12)                                 066540 0000
 1007 FORMAT(1X,119(1H-),//, 9X, 14HREGIONAL  COST,6X,10HCOST INDEX,10X, 066550 0000
     1 10H -- LABOR    ,F5.2,5X,31HTOTAL REACH LABOR COST .........,I9/ 066560 0000
     2 9X,9HFACTOR    ,F5.2,26X,10HEQUIPMENT ,F5.2,5X,                 066570 0000
     3                          31HTOTAL REACH EQUIPMENT COST ....,I9/ 066580 0000
     4 49X,10HMATERIALS ,F5.2,5X,31HTOTAL REACH MATERIALS COST ....,I9/ 066590 0000
     5 43X,16HLABOR WORK WEEK ,F5.2,5X,                                 066600 0000
     6 31HTOTAL REACH COST ...............,I9/                          066610 0000
     7 43X,16HEQUIP WORK WEEK ,F5.2)                                    066620 0000
C     ------------------------------------------------------------------ 066630 0000
C                                                                       066640 0000
      END                                                               066650 0000
      SUBROUTINE COSTSF(B,CNP,SHAFT,TRDATA,NSSMAX,NPMAX,NSMAX,NTRMAX,   066660 0000
     1NTSMAX)
C     ------------------------------------------------------------------ 066670 0000
```

(Continued)

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C     ------------------------------------------------------------------ 066680 0000
C     COSTSF COLLECTS ALL OF THE SHAFT COSTS AND OUTPUTS THEM            066690 0000
C     ------------------------------------------------------------------ 066700 0000
C     ------------------------------------------------------------------ 066710 0000
      DIMENSION IL(11),IE(11),IM(11),CF(3)                               066720 0000
      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE            066740 0000
      COMMON/Q/ TUNLC,TUNEC,TUNMC,TUNTC                                  066750 0000
      DIMENSION B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),TRDATA(NTRMAX, 066760 0000
     1   23)                                                             066770 0000
C     ------------------------------------------------------------------ 066780 0000
      INTEGER  SLCPF,SECPF,SMCPF,TLC,TEC,TMC                             066790 0000
      INTEGER TCES,TCE,TCML,      TCMH,TCMD,TCTS,TCL,TCFW,TCP,TCAC,      066800 0000
     1        TCG,TSCPF,TSC                                              066810 0000
      INTEGER SCL,SCE,SCM,SCT                                            066820 0000
      INTEGER TUNLC,TUNEC,TUNMC,TUNTC                                    066830 0000
      INTEGER SFTTLC,SFTTEC,SFTTMC,SFTTC                                 066840 0000
      INTEGER TLABOR,TEQUIP,TMATER,TCOST                                 066850 0000
      INTEGER RCL,RCE,RCM,RCT                                            066860 0000
C     ------------------------------------------------------------------ 066870 0000
C     CALCULATE COSTS A SHAFT AT A TIME                                  066880 0000
      Y=0.0                                                              066890 0000
      ITYPE=2                                                            066900 0000
C                                                                        066910 0000
C                                                                        066920 0000
      SFTTLC=0                                                           066930 0000
      SFTTEC=0                                                           066940 0000
      SFTTMC=0                                                           066950 0000
      SFTTC=0                                                            066960 0000
      DO  950  NSHAFT=1,NSMAX                                            066970 0000
      IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 950                           066980 0000
      BF=SHAFT(NSHAFT,7)                                                 066990 0000
      NSSEG1=SHAFT(NSHAFT,1)                                             067000 0000
      NSEGS=SHAFT(NSHAFT,4)                                              067010 0000
      RMLMAX=SHAFT(NSHAFT,10)                                            067020 0000
      DDS=SHAFT(NSHAFT,5)                                                067030 0000
      CDS=SHAFT(NSHAFT,6)                                                067040 0000
C                                                                        067050 0000
      ISHAPS=SHAFT(NSHAFT,16)                                            067060 0000
      HOURS =SHAFT(NSHAFT,17)                                            067070 0000
      DAYS  =SHAFT(NSHAFT,18)                                            067080 0000
      NPORT =SHAFT(NSHAFT,23)                                            067090 0000
      SFA=0.785                                                          067100 0000
      SFP=3.14                                                           067110 0000
      IF(ISHAPS.EQ.2) SFA=1.0                                            067120 0000
      IF(ISHAPS.EQ.2) SFP=4.0                                            067130 0000
C     DETERMINE NUMBER OF SHIFTS PER WORK DAY                            067140 0000
      SHIFTS=1.                                                          067150 0000
      IF(HOURS.GE.12.) SHIFTS=2.                                         067160 0000
      IF(HOURS.GE.21.) SHIFTS=3.                                         067170 0000
C     CALCULATE COST FACTOR FOR LENGTH OF WORK WEEK                      067180 0000
      IF(HOURS/SHIFTS.LE.8.) CFLWWK=(6.08+0.192*(DAYS-4.)**2             067190 0000
     1                       +0.384*SHIFTS)*SHIFTS/HOURS                 067200 0000
      IF(HOURS/SHIFTS.GT.8.) CFLWWK=(0.76+0.024*(DAYS-4.)**2             067210 0000
     1                       +0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS)        067220 0000
      CFEWWK=(3.75+30./HOURS)/DAYS                                       067230 0000
C     ------------------------------------------------------------------ 067240 0000
C     CALCULATE LENGTH OF SEGMENTS REQUIRE GROUTING AND PUMPING          067250 0000
      DTG=0.                                                             067260 0000
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(Continued)

```
      DTP=0.
      DO 10 NN=1,NSEGS
      II=NSSEG1+NN-1
      MSTAB=B(II,25)
      SSEGL =B(II,35)
      HH    =B(II,36)
      FLOWL=B(II,42)
      IF(FLOWL.GT.0.) DTP=DTP+SSEGL
      IF(MSTAB.NE.3.OR.HH.GT.200.) GO TO 10
      DTG=DTG+SSEGL
      TIMEG=0.33+(HH+0.5*SSEGL)/20.
   10 CONTINUE
C     ------------------------------------------------------------------
      SCL=0.
      SCE=0.
      SCM=0.
      SCT=0.
      NLINES=60
C
C     CALCULATE SHAFT COSTS FOR EACH SEGMENT
C
C
      DO 900 ISS=1,NSEGS
C     I=SEQUENCE NUMBER OF SHAFT SEGMENT
      I=NSSEG1+ISS-1
C     CHECK FOR A PORTAL OR A DUMMY SHAFT
      IF(NPORT.EQ.0.AND.ISHAPS.NE.0) GO TO 67
C     THIS SHAFT IS A PORTAL OR A DUMMY SHAFT
      IF(LIST(7).EQ.0) WRITE(LO,3005) NSHAFT
      GO TO 860
   67 NPB=B(I,4)
      ELNPB=CNP(NPB,2)
      RS=B(I,5)
      RQD=B(I,6)
      MEX=B(I,7)
      AR=B(I,8)
      GI=B(I,9)
C     THE VARIABLE  FOR LINING TYPE  IS CALLED L1(ONE)N1(ONE)NG IN THIS
C                                                 --     --     --
C     SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING
C     WHICH COMPUTES LINING COSTS
      L1N1NG=B(I,10)
      TL=B(I,11)
      TSEG  =B(I,11)
      NOFORM=B(I,12)
      ELWATR=B(I,13)
      LINWT =B(I,14)
      NSSTYP=B(I,15)
      D10   =B(I,16)
C
      PHI   =B(I,19)
      ELIMP =B(I,20)
      IWATER=B(I,21)
      ISUPPT=B(I,22)
      PERM=B(I,23)
      STABNO=B(I,24)
      MSTAB =B(I,25)
      AIRPR =B(I,27)
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(Continued)

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C                                                                       067850 0000
      BE     =B(I,29)                                                   067860 0000
      BE40   =B(I,30)                                                   067870 0000
      BE60   =B(I,31)                                                   067880 0000
      BOB    =B(I,32)                                                   067890 0000
      BOB40  =B(I,33)                                                   067900 0000
      BOB60  =B(I,34)                                                   067910 0000
C                                                                       067920 0000
      SSEGL  =B(I,35)                                                   067930 0000
      HH     =B(I,36)                                                   067940 0000
      PH=B(I,36)                                                        067950 0000
      RML    =B(I,37)                                                   067960 0000
      U      =B(I,38)                                                   067970 0000
      WEB    =B(I,41)                                                   067980 0000
      TPLATE=B(I,41)                                                    067990 0000
      FLOWL  =B(I,42)                                                   068000 0000
C                                                                       068010 0000
      PSOIL  =B(I,30)                                                   068020 0000
      PTOTAL=B(I,31)                                                    068030 0000
      PWATER=B(I,43)                                                    068040 0000
C     LABOR COST FACTOR IN COMPRESSED AIR                               068050 0000
      CFLCA=AIRPR**2/400.+1.5                                           068060 0000
      IF(NSSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1.                           068070 0000
C                                                                       068080 0000
C     ------------------------------------------------------------------068090 0000
C     CALCULATE SETUP COST  FOR SHAFT SEGMENT I                         068100 0000
      CALL CSETUP(A,B,NSEGS,NSSEG1,BE,HH,ITYPE,I   ,SETUSH,SETUPM,SETUPR,068110 0000
     1 CLES,CEES,CMES,CFLWWK,CFEWWK,NSSTYP,DSES,DMES,DRES,NTSMAX,NSSMAX)068120 0000
C     ------------------------------------------------------------------068130 0000
C                                                                       068140 0000
C     CALCULATE PUMPING TIME                                            068150 0000
      PUMPTM=0.                                                         068160 0000
      IF(FLOWL.LE.0.) GO TO 700                                         068170 0000
      PUMPTM=(5.+14.*SETUSH+28.*SETUPM)/DTP+7./DAYS/AR                  068180 0000
      AL=2.*HOURS                                                       068190 0000
      IF(LINING.EQ.1) PUMPTM=PUMPTM+(30.+SHAFT(NSHAFT,8)/AL*7./DAYS)    068200 0000
     1                /DTP                                              068210 0000
      IF(LINING.EQ.2) PUMPTM=PUMPTM+30./DTP                             068220 0000
  700 CONTINUE                                                          068230 0000
C     ------------------------------------------------------------------068240 0000
C     CALCULATE COST OF EXCAVATION IN SHAFT SEGMENT I                   068250 0000
      CALL COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPS,SFA,SFP,          068260 0000
     1          PSOIL,STABNO,DTRNCH,DROCK,SIDESL,VBOX,VSOIL,VROCK,PHI,  068270 0000
     2          DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLWWK,CFEWWK,NSSTYP)      068280 0000
C     ------------------------------------------------------------------068290 0000
C     CALCULATE COST OF MUCK LOADING IN SHAFT SEGMENT I                 068300 0000
      CALL CMUKLD(CLML,CEML,CMML,ITYPE,MEX,AR,DM,U,Y,RML,RMLMAX,        068310 0000
     1                  MSTAB,CFLCA,CFLWWK,CFEWWK,HOURS)                068320 0000
C     ------------------------------------------------------------------068330 0000
C     CALCULATE MUCK HOISTING COSTS FOR SHAFT SEGMENT I                 068340 0000
      CALL CMTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR,         068350 0000
     1HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPS,RL,UCLT,UCET,Y,UCLMH,068360 0000
     2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,VBACEX,VBACDS,VBOX,068370 0000
     3   VSOIL,VROCK,TOTBOX,CFLWWK,CFEWWK,CFLCA,DDS,NSSTYP,DTRNCH,DROCK)068380 0000
C     ------------------------------------------------------------------068390 0000
C     CALCULATE MUCK DISPOSAL COST FOR SHAFT SEGMENT I                  068400 0000
      CALL CMUKDP(CLMD,CEMD,CMMD,AR,U,CDS,DDS,VDS,NSSTYP,HOURS,         068410 0000
     1            CFLWWK,CFEWWK,ITYPE)                                  068420 0000
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C     ------------------------------------------------------------------ 068430 0000
C     CALCULATE COST OF SHAFT SUPPORTS  FOR SHAFT SEGMENT I              068440 0000
      CALL CTSUP(CLTS,CETS,CMTS,RQD,MEX,ISHAPS,BE,AR,RS,BE40,BE60,ITYPE, 068450 0000
     1     Y,DM,NSSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,BOB,LINWT, 068460 0000
     2     MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,DSLURY,DTRNCH,IDECK,DROCK,    068470 0000
     3     WTSTRT,WTWALE,SPDLT,WTSPD,WTSP,WTANCH,TOTBOX,IBRACE,SFA)      068480 0000
C     ------------------------------------------------------------------ 068490 0000
C     CALCULATE COST OF LINING AND FORMWORK IN SHAFT SEGMENT I           068500 0000
      CALL LINING1(CLL,CEL,CML,CLFW,CEFW,CMFW,ITYPE,LINING,RQD,MEX,      068510 0000
     1WEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPS,BE,UCLT,UCET,MTM,            068520 0000
     2UCLMW,UCEMW,SFA,NOFORM,AR,NSSTYP,PSOIL,PWATER,VL,SFP,              068530 0000
     3FORMAR,HOURS,CFLCA,CFLWWK,CFEWWK)                                  068540 0000
C     ------------------------------------------------------------------ 068550 0000
C     CALCULATE GROUTING COSTS FOR SHAFT SEGMENT I                       068560 0000
      CALL CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPS,BE,AR,RS,NSSTYP,MSTAB,     068570 0000
     1            DTUN,HH,HOURS,CFLWWK,CFEWWK,SSEGL,PERM,SFP,DTG,TIMEG)  068580 0000
C     ------------------------------------------------------------------ 068590 0000
C     CALCULATE COST OF PUMPING FOR SHAFT SEGMENT I                      068600 0000
      CALL CPUMP(CLP,CEP,CMP,NSSTYP,FLOW,PH,PIPL,AR,ITYPE,               068610 0000
     1          ELSURF,ELBOTM,DAYS,LINING,PUMPTM,MEX,DTRNCH,DROCK,FLOWL, 068620 0000
     2          WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPB,IWATER,CFLWWK,CFEWWK) 068630 0000
C     ------------------------------------------------------------------ 068640 0000
C     CALCULATE COST OF AIR CONDITIONING  AND COMPRESSED AIR             068650 0000
C     FOR SHAFT SEGMENT I                                                068660 0000
      CALL CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NSSTYP,MSTAB,ITYPE,  068670 0000
     1          AIRPR,    SFA,ISHAPS,HH,CAUT,ALOCK,DTC,DTCA,PUMPLT,DM,  068680 0000
     2           ALOCKL,UCMCP,CFLWWK,CFEWWK,DAYS,Y,PERM)                 068690 0000
C     ------------------------------------------------------------------ 068700 0000
C                                                                        068710 0000
C                                                                        068720 0000
C     ------------------------------------------------------------------ 068730 0000
      IF(LIST(7).EQ.1) GO TO 810                                         068740 0000
      IF(NLINES+11.LT.60) GO TO 810                                      068750 0000
      WRITE(LO,2000)                                                     068760 0000
      NLINES=6                                                           068770 0000
C     ------------------------------------------------------------------ 068780 0000
C     CALCULATE COST FACTORS                                             068790 0000
  810 POP=(1.+0.01*OM)*(1.+0.01*PM)                                      068800 0000
C     CF(1),CF(2) AND CF(3) ARE COMPOSITE COST FACTORS FOR L, E, AND M   068810 0000
      CFL=SHAFT(NSHAFT,12)                                               068820 0000
      CFE=SHAFT(NSHAFT,13)                                               068830 0000
      CFM=SHAFT(NSHAFT,14)                                               068840 0000
      RCF=SHAFT(NSHAFT,15)                                               068850 0000
      CF(1)=POP*CFL*RCF                                                  068860 0000
      CF(2)=POP*CFE*RCF                                                  068870 0000
      CF(3)=POP*CFM*RCF                                                  068880 0000
C     ------------------------------------------------------------------ 068890 0000
C     MULTIPLY BY COMPOSITE COST FACTORS AND THEN OBTAIN SEGMENT         068900 0000
C     COSTS PER FOOT TO THE NEAREST DOLLAR                               068910 0000
      IL( 1)=CLES*CF(1)+.5                                               068920 0000
      IE( 1)=CEES*CF(2)+.5                                               068930 0000
      IM( 1)=CMES*CF(3)+.5                                               068940 0000
      IL( 2)=CLE *CF(1)+.5                                               068950 0000
      IE( 2)=CEE *CF(2)+.5                                               068960 0000
      IM( 2)=CME *CF(3)+.5                                               068970 0000
      IL( 3)=CLML*CF(1)+.5                                               068980 0000
      IE( 3)=CEML*CF(2)+.5                                               068990 0000
      IM( 3)=CMML*CF(3)+.5                                               069000 0000
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      IL( 4)=CLMH*CF(1)+.5                                              069010 0000
      IE( 4)=CEMH*CF(2)+.5                                              069020 0000
      IM( 4)=CMMH*CF(3)+.5                                              069030 0000
      IL( 5)=CLMD*CF(1)+.5                                              069040 0000
      IE( 5)=CEMD*CF(2)+.5                                              069050 0000
      IM( 5)=CMMD*CF(3)+.5                                              069060 0000
      IL( 6)=CLTS*CF(1)+.5                                              069070 0000
      IE( 6)=CETS*CF(2)+.5                                              069080 0000
      IM( 6)=CMTS*CF(3)+.5                                              069090 0000
      IL( 7)=CLL *CF(1)+.5                                              069100 0000
      IE( 7)=CEL *CF(2)+.5                                              069110 0000
      IM( 7)=CML *CF(3)+.5                                              069120 0000
      IL( 8)=CLFW*CF(1)+.5                                              069130 0000
      IE( 8)=CEFW*CF(2)+.5                                              069140 0000
      IM( 8)=CMFW*CF(3)+.5                                              069150 0000
      IL( 9)=CLG *CF(1)+.5                                              069160 0000
      IE( 9)=CEG *CF(2)+.5                                              069170 0000
      IM( 9)=CMG *CF(3)+.5                                              069180 0000
      IL(10)=CLP *CF(1)+.5                                              069190 0000
      IE(10)=CEP *CF(2)+.5                                              069200 0000
      IM(10)=CMP *CF(3)+.5                                              069210 0000
      IL(11)=CLAC*CF(1)+.5                                              069220 0000
      IE(11)=CEAC*CF(2)+.5                                              069230 0000
      IM(11)=CMAC*CF(3)+.5                                              069240 0000
C     ------------------------------------------------------------------ 069250 0000
C     CALCULATE SEGMENT COST/FOOT FOR LABOR, EQUIPMENT AND MATERIALS    069260 0000
      SLCPF=0                                                           069270 0000
      SECPF=0                                                           069280 0000
      SMCPF=0                                                           069290 0000
      DO 815 LL=1,11                                                    069300 0000
      SLCPF=SLCPF+IL(LL)                                                069310 0000
      SECPF=SECPF+IE(LL)                                                069320 0000
  815 SMCPF=SMCPF+IM(LL)                                                069330 0000
      TSCPF=SLCPF+SECPF+SMCPF                                           069340 0000
C     ------------------------------------------------------------------ 069350 0000
C     CALCULATE TOTAL SEGMENT COST/FOOT FOR EACH COST COMPONENT         069360 0000
      TCES = IE( 1)+IM( 1)+IL( 1)                                       069370 0000
      TCE  = IE( 2)+IM( 2)+IL( 2)                                       069380 0000
      TCML = IE( 3)+IM( 3)+IL( 3)                                       069390 0000
      TCMH = IE( 4)+IM( 4)+IL( 4)                                       069400 0000
      TCMD = IE( 5)+IM( 5)+IL( 5)                                       069410 0000
      TCTS = IE( 6)+IM( 6)+IL( 6)                                       069420 0000
      TCL  = IE( 7)+IM( 7)+IL( 7)                                       069430 0000
      TCFW = IE( 8)+IM( 8)+IL( 8)                                       069440 0000
      TCG  = IE( 9)+IM( 9)+IL( 9)                                       069450 0000
      TCP  = IE(10)+IM(10)+IL(10)                                       069460 0000
      TCAC = IE(11)+IM(11)+IL(11)                                       069470 0000
C     ------------------------------------------------------------------ 069480 0000
C     CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS             069490 0000
      TLC = SLCPF*SSEGL/1000.                                           069500 0000
      TEC = SECPF*SSEGL/1000.                                           069510 0000
      TMC = SMCPF*SSEGL/1000.                                           069520 0000
      TSC = TLC+TEC+TMC                                                 069530 0000
C     ------------------------------------------------------------------ 069540 0000
      IF(LIST(7).EQ.1) GO TO 840                                        069550 0000
C     WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL      069560 0000
      ISSEGL=SSEGL                                                      069570 0000
      NSSEG=B(I,2)                                                      069580 0000
```

(Continued)

```
      WRITE(LO,2001) NSHAFT,NSSEG,(IL(JJJ),JJJ=1,11),SLCPF,TLC
      WRITE(LO,2002)          (IE(JJJ),JJJ=1,11),SECPF,TEC
      WRITE(LO,2003)          (IM(JJJ),JJJ=1,11),SMCPF,TMC
      WRITE(LO,2004) TCES,TCE,TCML,TCMH,TCMD,TCTS,TCL,TCFW,
     1 TCQ,TCP,TCAC,TSCPF,ISSEGL,TSC
C
      NLINES=NLINES+5
C
C     ACCUMULATE SHAFT SEGMENT COSTS INTO COST OF SHAFT
  840 SCL=SCL+TLC
      SCE=SCE+TEC
      SCM=SCM+TMC
      SCT=SCL+SCE+SCM
C     END OF COSTS ON A SEGMENT BASIS
  900 CONTINUE
C     ------------------------------------------------------------------
C     LIST OUT TOTAL COST OF SHAFT
  850 IF(LIST(7).EQ.1) GO TO 860
      WRITE(LO,1004) SHAFT(NSHAFT,12),SCL,SHAFT(NSHAFT,15),
     1 SHAFT(NSHAFT,13),SCE,SHAFT(NSHAFT,14),SCM,CFLWWK,SCT,CFEWWK
      NLINES=NLINES+7
C
C     ------------------------------------------------------------------
C     ACCUMULATE COSTS OF ALL SHAFTS
  860 SFTTLC=SFTTLC+SCL
      SFTTEC=SFTTEC+SCE
      SFTTMC=SFTTMC+SCM
      SFTTC=SFTTLC+SFTTEC+SFTTMC
C
      SHAFT(NSHAFT,19)=SCL
      SHAFT(NSHAFT,20)=SCE
      SHAFT(NSHAFT,21)=SCM
      SHAFT(NSHAFT,22)=SCT
C     END OF COSTS ON A SHAFT BASIS
  950 CONTINUE
C     ------------------------------------------------------------------
C     PRINT REACH COST SUMMARIES
      IF(LIST(8).EQ.1) GO TO 965
      WRITE(LO,1500)
      NLINES=5
      DO 960 NREACH=1,NTRMAX
      IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 960
      NSHAFT=TRDATA(NREACH,1)
      RCL=TRDATA(NREACH,17)
      RCE=TRDATA(NREACH,18)
      RCM=TRDATA(NREACH,19)
      RCT=TRDATA(NREACH,20)
      WRITE(LO,1501) NREACH,NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),
     1 JJ=12,14),RCL,RCE,RCM,RCT
      NLINES=NLINES+2
      IF(NLINES.LT.58) GO TO 960
      WRITE(LO,1500)
      NLINES=5
  960 CONTINUE
  965 CONTINUE
C     ------------------------------------------------------------------
C     PRINT SHAFT COST SUMMARIES
      IF(LIST(9).EQ.1) GO TO 975
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      WRITE(LO,1600)                                                    070170 0000
      NLINES=5                                                          070180 0000
      DO 970 NSHAFT=1,NSMAX                                             070190 0000
      IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 970                          070200 0000
      SCL=SHAFT(NSHAFT,19)                                              070210 0000
      SCE=SHAFT(NSHAFT,20)                                              070220 0000
      SCM=SHAFT(NSHAFT,21)                                              070230 0000
      SCT=SHAFT(NSHAFT,22)                                              070240 0000
      WRITE(LO,1601) NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),JJ=12,14) 070250 0000
     1  SCL,SCE,SCM,SCT                                                 070260 0000
      NLINES=NLINES+2                                                   070270 0000
      IF(NLINES.LT.58) GO TO 970                                        070280 0000
      WRITE(LO,1600)                                                    070290 0000
      NLINES=5                                                          070300 0000
  970 CONTINUE                                                          070310 0000
  975 CONTINUE                                                          070320 0000
C     ------------------------------------------------------------------ 070330 0000
C     TOTAL PROJECT CONSTRUCTION COSTS                                  070340 0000
      TLABOR=TUNLC+SFTTLC                                               070350 0000
      TEQUIP=TUNEC+SFTTEC                                               070360 0000
      TMATER=TUNMC+SFTTMC                                               070370 0000
      TCOST=TUNTC+SFTTC                                                 070380 0000
C     ------------------------------------------------------------------ 070390 0000
C     PRINT PROJECT SUMMARY SHEET                                       070400 0000
      WRITE(LO,2) TITLE                                                 070410 0000
      WRITE(LO,1005) PM,TUNLC,OM,TUNEC,TUNMC,TUNTC                      070420 0000
      WRITE(LO,1006) SFTTLC,SFTTEC,SFTTMC,SFTTC                         070430 0000
      WRITE(LO,1007) TLABOR,TEQUIP,TMATER,TCOST                         070440 0000
C     ------------------------------------------------------------------ 070450 0000
      RETURN                                                            070460 0000
C                                                                       070470 0000
C     ------------------------------------------------------------------ 070480 0000
    2 FORMAT(1H1,10(/),50X,70(1H*),/,50X,1H*,68X,1H*,                   070490 0000
     110(/,50X,1H*,2X,16A4,2X,1H*),                                     070500 0000
     3     /,50X,1H*,68X,1H*,/,50X,70(1H*),///)                         070510 0000
 1004 FORMAT(1X,119(1H-),//, 7X, 14HREGIONAL  COST,6X,10HCOST INDEX,10X 070520 0000
     110H -- LABOR ,F5.2,      5X,25HSHAFT LABOR COST .........,I9/     070530 0000
     2 7X,9HFACTOR   ,F5.2,26X,10HEQUIPMENT ,F5.2,5X,                   070540 0000
     3                                25HSHAFT EQUIPMENT COST ....,I9/  070550 0000
     4 47X,10HMATERIALS ,F5.2,       5X,25HSHAFT MATERIALS COST ....,I9/ 070560 0000
     5 41X,16HLABOR WORK WEEK ,F5.2,5X,25HSHAFT COST ...............,I9/ 070570 0000
     6 41X,16HEQUIP WORK WEEK ,F5.2)                                    070580 0000
 1005 FORMAT(50X,17HPROFIT MARGIN     ,F5.2,3X,                         070590 0000
     1            36HTOTAL TUNNEL  LABOR COST.....($1000),I9/,          070600 0000
     2   50X,17HOVERHEAD MARGIN   ,F5.2,3X,                             070610 0000
     3            36HTOTAL TUNNEL  EQUIPMENT COST.........,I9/,         070620 0000
     4         75X,36HTOTAL TUNNEL  MATERIAL COST.........,I9/,         070630 0000
     5         75X,36HTOTAL TUNNEL  COST..................,I9/)        070640 0000
 1006 FORMAT(//,75X,36HTOTAL  SHAFT  LABOR COST.............,I9/        070650 0000
     1          75X,36HTOTAL  SHAFT  EQUIPMENT COST.........,I9/        070660 0000
     2          75X,36HTOTAL  SHAFT  MATERIAL COST..........,I9/        070670 0000
     3          75X,36HTOTAL  SHAFT  COST...................,I9)        070680 0000
 1007 FORMAT(//,75X,35HTOTAL PROJECT LABOR COST ...........,I10/        070690 0000
     1        75X,35HTOTAL PROJECT EQUIPMENT COST........,I10/          070700 0000
     2        75X,35HTOTAL PROJECT MATERIAL COST.........,I10/          070710 0000
     3        75X,35HTOTAL PROJECT COST..................,    I10)      070720 0000
 1500 FORMAT(1H1,1X,34(1H*),50H  T U N N E L  R E A C H  C O S T  S U M 070730 0000
     1M A R Y  ,35(1H*)//    14X,19HEXIT     REGIONAL  ,8(1H*),         070740 0000
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(Continued)

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     2 12HCOST INDEXES,6(1H*),10X,17(1H*),15H COSTS ($1000) ,16(1H*)/,    070750 0000
     3 3X,62HREACH      SHAFT   COST FACTOR  LABOR   EQUIP   MATL,        070760 0000
     4 16X,41HLABOR    EQUIPMENT    MATERIAL      TOTAL,/,1X,119(1H-)/)   070770 0000
 1501 FORMAT(4X,I3,8X,I3,7X,F4.2,2X,3(4X,F4.2),11X,4(3X,I9)/)             070780 0000
 1600 FORMAT(1H1,1X,41(1H*),37H  S H A F T  C O S T  S U M M A R Y  ,     070790 0000
     1 41(1H*)//   23X,10HREGIONAL  ,6(1H*),12HCOST INDEXES,6(1H*),       070800 0000
     2 10X,17(1H*),15H COSTS ($1000) ,16(1H*)/,3X,5HSHAFT,14X,             070810 0000
     3 33HCOST FACTOR  LABOR   EQUIP   MATL,18X,                           070820 0000
     4 41HLABOR    EQUIPMENT    MATERIAL      TOTAL,/,1X,119(1H-)/)       070830 0000
 1601 FORMAT(4X,I3,18X,F4.2,2X,3(4X,F4.2),11X,4(3X,I9)/)                  070840 0000
 2000 FORMAT(1H1,45(1H*),23H  S H A F T   C O S T  ,52(1H*)//             070850 0000
     1180H SHAFT SEG  ********************** COST IN DOLLARS PER FOOT OF SHAFT  070860 0000
     2**********************  SEG   SEGMENT  SEGMENT                      / 070870 0000
     3180H  NO   NO    EXC    EXC  MUCK   MUCK   MUCK SUP-   LIN-   LIN GR 070880 0000
     4OUT PUMP-  AIR-  COST  LENGTH    COST                              / 070890 0000
     5180H                SETUP        LOAD HOIST  DISP PORTS   ING  FORM  070900 0000
     6      ING  COND ($/FT)  (FEET)  ($1000)                              070910 0000
     7   /,1X,119(1H-))                                                    070920 0000
 2001 FORMAT(/,1X,I3,I5,2H L,12I6,8X,I10)                                  070930 0000
 2002 FORMAT(9X,      2H E,12I6,8X,I10)                                    070940 0000
 2003 FORMAT(9X,      2H M,12I6,8X,I10)                                    070950 0000
 2004 FORMAT(9X,      2H T,12I6,I8,I10)                                    070960 0000
 3005 FORMAT(1H1,6H SHAFT,I4,' IS A PORTAL OR A DUMMY SHAFT     ALL CO     070970 0000
     1STS ARE ZERO')                                                       070980 0000
C    ------------------------------------------------------------------   070990 0000
C                                                                          071000 0000
      RETURN                                                               071005
      END                                                                  071010 0000
      SUBROUTINE CUINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1,      071020 0000
     1CLIND,UCMCP,NTSMAX,NPMAX)                                            071030 0000
      DIMENSION  A(NTSMAX,68),              CNP(NPMAX,2),CUMSL(NPMAX)      071050 0000
C    ------------------------------------------------------------------   071060 0000
C     THIS SUBROUTINE COMPUTES THE TOTAL LENGTH OF SEGMENTS WHICH ARE     071070 0000
C     EXCAVATED IN FREE AIR BUT NEED CONVEYOR BELT FOR FURTHER            071080 0000
C     EXCAVATION IN COMPRESSED AIR.  IT ALSO COMPUTES THE COST OF         071090 0000
C     COMPRESSED AIR PIPING                                               071100 0000
C    ------------------------------------------------------------------   071110 0000
      DTFACN=0.                                                            071120 0000
      UCMCP=0.                                                             071130 0000
      NSEGSA=IABS(NSEGS)                                                   071140 0000
C    ------------------------------------------------------------------   071150 0000
      DO 100 I=1,NSEGSA                                                    071160 0000
      J=NSEGSA-I+1                                                         071170 0000
      N=NRSEG1+J-1                                                         071180 0000
      IF(NSEGS.LT.0) N=NRSEG1-J+1                                          071190 0000
      MSTAB=A(N,31)                                                        071200 0000
      DM=A(N,46)                                                           071210 0000
      TSEGL=A(N,45)                                                        071220 0000
C     CHECK LAST SEGMENT IN THE REACH AND SET LOCK POSITION               071230 0000
      IF(I.EQ.1) NPLOCK=A(N,2)                                             071240 0000
C     CHECK THE POSITION OF AIR LOCK FOR THIS SEGMENT WITH THE POSITION   071250 0000
C     FOR THE NEXT SEGMENT IN COMPRESSED AIR                              071260 0000
      IF( ABS(A(N,36)).EQ.NPLOCK) GO TO 50                                 071270 0000
C     CHECK IF THE SEGMENT IN COMPRESSED AIR                              071280 0000
      IF(MSTAB.NE.1) GO TO 100                                             071290 0000
   10 NPLOCK= ABS(A(N,36))                                                 071300 0000
      DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPBS))                                 071310 0000
C     FIND THE SURFACE NODAL POINT OF AIR LOCK                            071320 0000
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(Continued)

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      DO 80 K=1,J
      IF(NSEGS.LT.0) GO TO 60
      NN=NRSEG1+K-1
      NPREND=A(NN,2)
      NPS=A(NN,17)
      GO TO 70
   60 NN=NRSEG1-K+1
      NPREND=A(NN,3)
      NPS=A(NN,18)
   70 IF(NPLOCK.EQ.NPREND) GO TO 90
   80 CONTINUE
C     CALCULATE COST OF COMPRESSED AIR PIPING
   90 DTHLOK=CNP(NPS,2)-CNP(NPLOCK,2)
      PUMPLT=DM*5280.-DLOCK+DTHLOK
      CAVT=A(N,35)
      UCMCP=UCMCP+(26.+0.0018*CAVT-0.000000015*CAVT**2)*PUMPLT/DTCA
      GO TO 100
   50 IF (MSTAB.NE.1) DTFACN=DTFACN+TSEGL
      IF(MSTAB.EQ.1.AND.I.EQ.1) GO TO 10
  100 CONTINUE
C     COMPUTE THE INSTALLATION COST OF CONVEYOR IN THE FREE AIR SEGMENTS
      CLIND=(0.31*SQRT(RMLMAX+40.)+1.38)*DTFACN/DTCA
      RETURN
      END
      SUBROUTINE LOCKLT(A,NSEGS,RMLMAX,MTM,ALOCK,ALOCKL,NTSMAX,NRSEG1)
      DIMENSION A(NTSMAX,68)
C     ------------------------------------------------------------------
C     LOCKLT COMPUTES NUMBER OF AIR LOCK LOCATIONS AND LENGTH OF AIR
C     LOCK IN A REACH
C     ------------------------------------------------------------------
      ALOCK=1.
      ALOCKL=30.
      M=0
      NSEGSA=IABS(NSEGS)
C     ------------------------------------------------------------------
C     NUMBER OF AIR LOCK LOCATIONS IN REACH
      DO 100 II=1,NSEGSA
      I=NRSEG1+(II-1)*NSEGS/NSEGSA
      MSTAB=A(I,31)
      IF(MSTAB.NE.1) GO TO 100
      M=M+1
C     FIRST COMPRESSED AIR SEGMENT
      IF(M.NE.1) GO TO 10
      NPLOCK=A(I,36)
      IF(NPLOCK.LT.0) M=-1000000
   10 IF(NPLOCK.NE.A(I,36)) ALOCK=ALOCK+1.
C     ------------------------------------------------------------------
C     LENGTH OF AIR LOCK
      IF(MTM.NE.3) GO TO 100
      AR=A(I,8)
      DM=A(I,46)
      CARS=(1.+0.7/(DM+2.))*RMLMAX*(0.06+0.12*DM**0.333
     1     +AR*(0.06+0.023*DM-0.12*DM**0.333)/300.)
      IF(CARS.LT.1.) CARS=1.
      ENGINE=CARS/11.
      IF(ENGINE.LT.1.) ENGINE=1.
      ALOKLT=17.*(CARS/ENGINE+1.)
      IF(ALOCKL.LT.ALOKLT) ALOCKL=ALOKLT
```

(Continued)

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  100 CONTINUE                                                          071910 0000
C     ------------------------------------------------------------------ 071920 0000
C     ALOCK = NEGATIVE FOR COOLING PLANT FOR FIRST LOCK MOVED FROM SHAFT 071930 0000
C     TO GROUND SURFACE ABOVE SECOND LOCK POSITION                       071940 0000
      IF(M.LT.0) ALOCK=-ALOCK                                            071950 0000
      RETURN                                                             071960 0000
      END                                                                071970 0000
      SUBROUTINE CSETUP(A,B,NSEGS,NSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,     071980 0000
     1SETUPR,CLES,CEES,CMES,CFLWWK,CFEWWK,NSTYP,DSES,DMES,DRES,NTSMAX,   071990 0000
     2NSSMAX)                                                            071995
C     ------------------------------------------------------------------ 072000 0000
C     CSETUP DETERMINES THE AVERAGE COSTS INVOLVED IN SETTING UP THE     072010 0000
C     NECESSARY EQUIPMENT TO EXCAVATE EACH SEGMENT                       072020 0000
C     ------------------------------------------------------------------ 072030 0000
      DIMENSION  A(NTSMAX,68),B(NSSMAX,43)                               072050 0000
C     ------------------------------------------------------------------ 072060 0000
      IF(NSTYP.EQ.3) GO TO 500                                           072070 0000
C     INITIALIZE                                                         072080 0000
      UCLSS=0.                                                           072090 0000
      UCESS=0.                                                           072100 0000
      UCMSS=0.                                                           072110 0000
      UCLMS=0.                                                           072120 0000
      UCEMS=0.                                                           072130 0000
      UCMMS=0.                                                           072140 0000
      UCLRS=0.                                                           072150 0000
      UCERS=0.                                                           072160 0000
      UCMRS=0.                                                           072170 0000
C     ------------------------------------------------------------------ 072180 0000
      IF(ITYPE.EQ.2) GO TO 200                                           072190 0000
C     TUNNEL                                                             072200 0000
C     FIRST SEGMENT IN THE REACH                                         072210 0000
      IF(I.NE.NSEG1) GO TO 150                                           072220 0000
C     DETERMINE THE TOTAL LENGTH OF SHIELD, MOLE AND RIPPER EXCAVATED    072230 0000
C     SEGMENTS IN A REACH                                                072240 0000
      DSES=0.0000001                                                     072250 0000
      DMES=0.0000001                                                     072260 0000
      DRES=0.0000001                                                     072270 0000
      NSEGSA=IABS(NSEGS)                                                 072280 0000
      DO 100 NN=1,NSEGSA                                                 072290 0000
      M=NSEG1+(NN-1)*NSEGS/NSEGSA                                        072300 0000
      MEX=A(M,7)                                                         072310 0000
      TSEGL=A(M,45)                                                      072320 0000
      IF(MEX.LE.1.OR.MEX.GE.6) GO TO 100                                 072330 0000
C     SHIELD                                                             072340 0000
      IF(MEX.GE.3) DSES=DSES+TSEGL                                       072350 0000
C     MOLE                                                               072360 0000
      IF(MEX.LE.3) DMES=DMES+TSEGL                                       072370 0000
C     RIPPER                                                             072380 0000
      IF(MEX.EQ.5) DRES=DRES+TSEGL                                       072390 0000
  100 CONTINUE                                                           072400 0000
  150 MEX=A(I,7)                                                         072410 0000
      IF(MEX.LE.1.OR.MEX.GE.6) GO TO 400                                 072420 0000
C     SHIELD SET UP COSTS                                                072430 0000
      IF(MEX.LT.3) GO TO 160                                             072440 0000
      UCLSS=(20000.+3.*HH+45.*BE**2)*SETUSH                              072450 0000
      UCESS=(2000.+0.04*BE*HH+21.*BE**2)*SETUSH                          072460 0000
      UCMSS=(700.+0.1*HH+2.5*(BE-6.)**2)*SETUSH                          072470 0000
C     MOLE SETUP COSTS                                                   072480 0000
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(Continued)

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  160 IF(MEX.GT.3) GO TO 170                                            072490 0000
      UCLMS=(50000.+15.*HH+152.*(BE+12.)**2)*SETUPM                     072500 0000
      UCEMS=(25000.+6.*HH+234.*(BE-10.)**2)*SETUPM                      072510 0000
      UCMMS=25.*BE**2*SETUPM                                            072520 0000
C     RIPPER SETUP COSTS                                                072530 0000
  170 IF(MEX.NE.5) GO TO 400                                            072540 0000
      UCLRS=(4000.+HH*(1.+0.05*BE)+6.8*BE**2)*SETUPR                    072550 0000
      UCERS=(1000.+0.7*HH+1.5*(BE+5.)**2)*SETUPR                        072560 0000
      UCMRS=(150.+0.09*HH+0.2*BE**2)*SETUPR                             072570 0000
      GO TO 400                                                         072580 0000
C     ----------------------------------------------------------------- 072590 0000
C     SHAFT                                                             072600 0000
  200 IF(I.NE.NSEG1) GO TO 350                                          072610 0000
      DSES=0.0000001                                                    072620 0000
      DMES=0.0000001                                                    072630 0000
      DRES=0.0000001                                                    072640 0000
C     DETERMINE THE TOTAL LENGTH OF SHIELD AND MOLE EXCAVATED           072650 0000
C     SEGMENTS IN A SHAFT                                               072660 0000
      SETUSH=0.                                                         072670 0000
      SETUPM=0.                                                         072680 0000
      DO 300 NN=1,NSEGS                                                 072690 0000
      M=NSEG1+NN-1                                                      072700 0000
      MEX=B(M,7)                                                        072710 0000
      SSEGL=B(M,35)                                                     072720 0000
      IF(MEX-2) 300,220,210                                             072730 0000
C     SHIELD                                                            072740 0000
  210 DSES=DSES+SSEGL                                                   072750 0000
      IF(SETUSH.LT.1.) SETUSH=1.                                        072760 0000
      IF(MEX.EQ.4) GO TO 300                                            072770 0000
C     MOLE                                                              072780 0000
  220 DMES=DMES+SSEGL                                                   072790 0000
      IF (SETUPM.LT.1.) GO TO 250                                       072800 0000
      IF(MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+0.125                    072810 0000
      GO TO 300                                                         072820 0000
  250 SETUPM=1.                                                         072830 0000
  300 MEXP=MEX                                                          072840 0000
C     ----------------------------------------------------------------- 072850 0000
  350 MEX=B(I,7)                                                        072860 0000
C     SHIELD SETUP COSTS                                                072870 0000
      IF(MEX.LT.3) GO TO 360                                            072880 0000
      UCLSS=(2000.+930.*BE)*SETUSH                                      072890 0000
      UCESS=(500.+14.*(BE-5.)**2)*SETUSH                                072900 0000
      UCMSS=(300.+(BE-3.)**2)*SETUSH                                    072910 0000
C     MOLE SETUP COSTS                                                  072920 0000
  360 IF(.NOT.(MEX.EQ.2.OR.MEX.EQ.3)) GO TO 400                         072930 0000
      UCLMS=(130.*(BE+5.)**2+65000.)*SETUPM                             072940 0000
      UCEMS=(165.*(BE-10.)**2+20000.)*SETUPM                            072950 0000
      UCMMS=(30.*(BE-10.)**2+3200.)*SETUPM                              072960 0000
C     ----------------------------------------------------------------- 072970 0000
C     TOTAL SETUP COSTS                                                 072980 0000
  400 CLES=(UCLSS/DSES+UCLMS/DMES+UCLRS/DRES)*CFLWWK                    072990 0000
      CEES=(UCESS/DSES+UCEMS/DMES+UCERS/DRES)*CFEWWK                    073000 0000
      CMES=UCMSS/DSES+UCMMS/DMES+UCMRS/DRES                             073010 0000
      RETURN                                                            073020 0000
C                                                                       073030 0000
  500 CLES=0.                                                           073040 0000
      CEES=0.                                                           073050 0000
      CMES=0.                                                           073060 0000
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      RETURN                                                            073070 0000
      END                                                               073080 0000
      SUBROUTINE COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPE,SFA,SFP,    073090 0000
     1            PSOIL,STABNO,DTRNCH,DROCK,SIDESL,UBOX,USOIL,UROCK,FHI, 073100 0000
     2            DCENT,HOURS,V,DM,MSTAB,CFLCA,CFLWWK,CFEWWK,NSTYP)     073110 0000
C     ---------------------------------------------------------------- 073120 0000
C     ---------------------------------------------------------------- 073130 0000
C     COEX CALCULATES EXCAVATION COSTS IN TUNNELS AND SHAFTS            073140 0000
C     ---------------------------------------------------------------- 073150 0000
C     ---------------------------------------------------------------- 073160 0000
      IF(NSTYP.NE.2) GO TO 110                                          073170 0000
C     CALCULATE WEIGHT OF SHIELD                                        073180 0000
      F=1.                                                              073190 0000
      IF(ISHAPE.EQ.3) F=1.56                                            073200 0000
      IF(ITYPE.EQ.2.AND.ISHAPE.EQ.2) F=2.                               073210 0000
      WTSHLD=(0.037*SQRT(81.+F*BE**2)-0.038)*PSOIL*STABNO**2*SFP        073220 0000
C     ---------------------------------------------------------------- 073230 0000
  110 IF(ITYPE.EQ.2) GO TO 100                                          073240 0000
C     CALCULATE UNIT COST OF TUNNEL EXCAVATION                          073250 0000
C     CHECK TUNNEL EXCAVATION METHODS                                   073260 0000
      GO TO (120,220,320,420,520,620,620),MEX                           073270 0000
C     ROCK TUNNEL                                                       073280 0000
C     CONVENTIONAL EXCAVATION                                           073290 0000
  120 GO TO (121,122,123),ISHAPE                                        073300 0000
C     SHAPE IS CIRCLE                                                   073310 0000
  121 UCL=0.07*(BE+40.)**2-100.                                         073320 0000
      UCE=0.046*(BE+15.)**2                                             073330 0000
      UCM=SFA*SQRT(RS)*BE**2/2000.+(0.11*(BE+10.)**2-25.)/AR            073340 0000
      GO TO 124                                                         073350 0000
C     SHAPE IS HORSESHOE                                                073360 0000
  122 UCL=0.08*(BE+40.)**2-110.                                         073370 0000
      UCE=0.05*(BE+15.)**2+4.                                           073380 0000
      UCM=SFA*SQRT(RS)*BE**2/2000. + (0.12*(BE+10.)**2-22.)/AR          073390 0000
      GO TO 124                                                         073400 0000
C     SHAPE IS BASKETHANDLE                                             073410 0000
  123 UCL=0.1*BE**2+60.                                                 073420 0000
      UCE=0.04*(BE+5.)**2+17.                                           073430 0000
      UCM=SFA*SQRT(RS)*BE**2/2000. + (0.13*(BE-5.)**2+14.)/AR           073440 0000
  124 CONTINUE                                                          073450 0000
      GO TO 800                                                         073460 0000
C     MOLE EXCAVATION                                                   073470 0000
  220 UCL=0.021*BE**2+55.                                               073480 0000
      UCE=0.048*BE**2                                                   073490 0000
      UCM=(5000.+RS+120000./AR)*BE**2/220000.                           073500 0000
      GO TO 800                                                         073510 0000
C     ---------------------------------------------------------------- 073520 0000
C     SOFT GROUND TUNNEL                                                073530 0000
C     MOLED                                                             073540 0000
  320 UCL=(55.+0.021*BE**2)*CFLCA                                       073550 0000
      UCE=0.048*BE**2+0.000035*WTSHLD                                   073560 0000
      UCM=(0.045+0.02*HOURS/AR)*BE**2+(0.5+0.05*BE)*HOURS/AR            073570 0000
      GO TO 800                                                         073580 0000
C     HAND EXCAVATED                                                    073590 0000
  420 UCL=(0.1*(BE+5.)**2+30.)*CFLCA                                    073600 0000
      UCE=0.02*(BE+7.)**2+0.000035*WTSHLD                               073610 0000
      UCM=(0.5+0.25*BE)*HOURS/AR                                        073620 0000
      GO TO 800                                                         073630 0000
C     RIPPER EXCAVATED                                                  073640 0000
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  520 UCL=(50.+0.01*(BE+4.)**2)*CFLCA                                   073650 0000
      UCE=12.+0.2*BE+0.000035*WTSHLD                                    073660 0000
      UCM=(2.0+0.09*BE)*HOURS/AR                                        073670 0000
      GO TO 800                                                         073680 0000
C     ****************************************************************** 073690 0000
C     CUT AND COVER                                                     073700 0000
  620 IF(DROCK.GE.DTRNCH) GO TO 700                                     073710 0000
C     OPEN CUT INVOLVING ROCK EXCAVATION                                073720 0000
      VROCK=BE*(DTRNCH-DROCK)/27.                                       073730 0000
      UCLROK=71.+0.55*AR*VROCK/HOURS                                    073740 0000
      UCEROK=15.+(0.4+0.0035*DTRNCH)*AR*VROCK/HOURS                     073750 0000
      UCMROK=(1.1+0.0006*(DTRNCH+DROCK))*VROCK                          073760 0000
      IF(UCLROK.LT.84.75) UCLROK=84.75                                  073770 0000
      IF(AR*VROCK/HOURS.LT.25.) UCEROK=15.+(0.4+0.0035*DTRNCH)*25.      073780 0000
      IF(DROCK.GT.0.) GO TO 650                                         073790 0000
C     ALL ROCK , NO SOIL EXCAVATION                                     073800 0000
      VSOIL=0.                                                          073810 0000
      DCENT=0.                                                          073820 0000
      UCLSOL=0.                                                         073830 0000
      UCESOL=0.                                                         073840 0000
      UCMSOL=0.                                                         073850 0000
      GO TO 750                                                         073860 0000
C     SOME ROCK, SOME SOIL EXCAVATION                                   073870 0000
C     ----------------------------------------------------------------- 073880 0000
C     SOIL EXCAVATION                                                   073890 0000
  650 VSOIL=(BE+DROCK*SIDESL)*DROCK/27.                                 073900 0000
      DCENT=DROCK*(1.5*BE+DROCK*SIDESL)/(BE+DROCK*SIDESL)/3.            073910 0000
      IF(SIDESL.LT.1.) GO TO 670                                        073920 0000
      IF(AR*VSOIL/HOURS.LE.500.) GO TO 670                              073930 0000
C     SOIL EXCAVATED BY SCRAPERS                                        073940 0000
  660 SCRAPR=AR*VSOIL/HOURS/(290.-0.9*DCENT)                            073950 0000
      IF(SCRAPR.LT.1.) SCRAPR=1.                                        073960 0000
      PUSHER=SCRAPR/4.                                                  073970 0000
      IF(PUSHER.LT.1.) PUSHER=1.                                        073980 0000
      UCLSOL=17.+8.0*(SCRAPR+PUSHER)                                    073990 0000
      UCESOL=19.*SCRAPR+10.*PUSHER                                      074000 0000
      UCMSOL=(5.5*SCRAPR+3.0*PUSHER)*HOURS/AR                           074010 0000
      GO TO 750                                                         074020 0000
C     SOIL EXCAVATED BY DRAGLINE                                        074030 0000
  670 BUCMIN=10.-0.7*SQRT(160.-DROCK)                                   074040 0000
  680 BUCKET=2.5*(AR*VSOIL/HOURS/(1.05-0.00014*(PHI-50.)**2)-40.)       074050 0000
     1       /(170.-DCENT)                                              074060 0000
      IF(BUCKET.LT.BUCMIN) BUCKET=BUCMIN                                074070 0000
      UCLSOL=19.0                                                       074080 0000
      UCESOL=13.0+0.85*BUCKET**2                                        074090 0000
      UCMSOL=1.1*BUCKET*VSOIL/(40.+0.4*(170.-DCENT)*BUCKET)             074100 0000
     1       /(1.05-0.00014*(PHI-50.)**2)                               074110 0000
      GO TO 750                                                         074120 0000
C     ----------------------------------------------------------------- 074130 0000
C     SOIL EXCAVATION ONLY, NO ROCK EXCAVATION                          074140 0000
  700 VROCK=0.                                                          074150 0000
      UCLROK=0.                                                         074160 0000
      UCEROK=0.                                                         074170 0000
      UCMROK=0.                                                         074180 0000
      VSOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.                               074190 0000
      DCENT=DTRNCH*(1.5*BE+DTRNCH*SIDESL)/(BE+DTRNCH*SIDESL)/3.         074200 0000
      IF(SIDESL.LT.1) GO TO 720                                         074210 0000
      IF(AR*VSOIL/HOURS.GT.500.) GO TO 660                              074220 0000
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(Continued)

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  720 BUCMIN=10.-0.7*SQRT(160.-DTRNCH)                                  074230 0000
      GO TO 680                                                         074240 0000
C     ------------------------------------------------------------------ 074250 0000
C     COSTS OF BACKFILL                                                 074260 0000
  750 V=VROCK+VSOIL                                                     074270 0000
      UCLBAK=82.0                                                       074280 0000
      UCEBAK=32.0                                                       074290 0000
      IF(AR*(V-VBOX)/HOURS.LE.1200.) GO TO 760                          074300 0000
      UCLBAK=82.*(V-VBOX)*AR/HOURS/1200.                                074310 0000
      UCEBAK=32.*(V-VBOX)*AR/HOURS/1200.                                074320 0000
  760 UCMBAK=0.01*(V-VBOX)                                              074330 0000
      UCL=UCLROK+UCLSOL+UCLBAK                                          074340 0000
      UCE=UCEROK+UCESOL+UCEBAK                                          074350 0000
      UCM=UCMROK+UCMSOL+UCMBAK                                          074360 0000
      GO TO 800                                                         074370 0000
C     ******************************************************************* 074380 0000
C     CALCULATE UNIT COSTS OF SHAFT EXCAVATION                          074390 0000
  100 IF(NSTYP.EQ.3) GO TO 500                                          074400 0000
      GO TO (140,240,340,440),MEX                                       074410 0000
C     ROCK SHAFT                                                        074420 0000
C     CONVENTIONAL                                                      074430 0000
  140 UCL=30.+4.25*BE                                                   074440 0000
      UCE=8.+2.2*BE                                                     074450 0000
      UCM=(0.01+RS/2000000.)*BE**2 + (.8+RS/40000.+3.4/AR)*BE + 5.      074460 0000
      GO TO 800                                                         074470 0000
      MOLED                                                             074480 0000
  240 UCL=0.032*BE**2+84.                                               074490 0000
      UCE=0.072*BE**2                                                   074500 0000
      UCM=(5000.+RS+120000./AR)*BE**2/150000.                           074510 0000
      GO TO 800                                                         074520 0000
C     ------------------------------------------------------------------ 074530 0000
C     SOFT GROUND SHAFT                                                 074540 0000
C     MOLED                                                             074550 0000
  340 UCL=(0.032*BE**2+84.0)*CFLCA                                      074560 0000
      UCE=0.072*BE**2+0.000035*WTSHLD                                   074570 0000
      UCM=(0.045+0.03*HOURS)*BE**2+(0.5+0.05*BE)*HOURS/AR               074580 0000
      GO TO 800                                                         074590 0000
C     HAND/SHIELD                                                       074600 0000
  440 IF(ISHAPE.EQ.1) UCL=63.0*CFLCA                                    074610 0000
      IF(ISHAPE.EQ.2) UCL=70.0*CFLCA                                    074620 0000
      UCE=7.40+0.000035*WTSHLD                                          074630 0000
      UCM=(3.70+0.05*BE)*HOURS/AR                                       074640 0000
  800 CLE=UCL*(HOURS*CFLWWK+Y*DM)/AR                                    074650 0000
      CEE=UCE*HOURS*CFEWWK/AR                                           074660 0000
      CME=UCM                                                           074670 0000
      GO TO 900                                                         074680 0000
C                                                                       074690 0000
  500 CLE=0.                                                            074700 0000
      CEE=0.                                                            074710 0000
      CME=0.                                                            074720 0000
C                                                                       074730 0000
  900 RETURN                                                            074740 0000
      END                                                               074750 0000
      SUBROUTINE CMUKLD(CLML,CEML,CMML,ITYPE,MEX,AR,DM,V,Y,RMY,RMLMAX,  074760 0000
     1                  MSTAB,CFLCA,CFLWWK,CFEWWK,HOURS)                074770 0000
C     ------------------------------------------------------------------ 074780 0000
C     ------------------------------------------------------------------ 074790 0000
C     CMUKLD CALCULATES THE COST OF MUCK LOADING IN TUNNELS AND SHAFTS   074800 0000
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(Continued)

```
C     ------------------------------------------------------------------ 074810 0000
C     ------------------------------------------------------------------ 074820 0000
      IF(MEX.EQ.1.OR.MEX.EQ.4) GO TO 100                                 074830 0000
C     ------------------------------------------------------------------ 074840 0000
C     LOADING COSTS ARE ZERO FOR MOLE OR RIPPER EXCAVATION AND FOR       074850 0000
C     CUT-AND-COVER SEGMENTS                                             074860 0000
   50 CLML=0                                                             074870 0000
      CEML=0                                                             074880 0000
      CMML=0                                                             074890 0000
      GO TO 300                                                          074900 0000
C     ------------------------------------------------------------------ 074910 0000
C     CHECK FOR TUNNEL OR SHAFT                                          074920 0000
  100 IF(ITYPE.EQ.2) GO TO 200                                           074930 0000
C     ------------------------------------------------------------------ 074940 0000
C     TUNNELS                                                            074950 0000
      UCL=9.30*CFLCA                                                     074960 0000
      UCE=3.50                                                           074970 0000
      IF(RMLMAX.GT.100.) UCE=6.60                                        074980 0000
      IF(RMLMAX.GT.300.) UCE=12.90                                       074990 0000
      UCM=0.02                                                           075000 0000
      GO TO 250                                                          075010 0000
C     ------------------------------------------------------------------ 075020 0000
C     SHAFTS                                                             075030 0000
  200 IF (MEX.EQ.4) GO TO 50                                             075040 0000
      UCL=9.30*CFLCA                                                     075050 0000
      UCE=3.50                                                           075060 0000
      UCM=1.50                                                           075070 0000
C     ------------------------------------------------------------------ 075080 0000
C     CALCULATE MUCK LOADING COSTS                                       075090 0000
  250 CLML=UCL*(HOURS*CFLWWK+Y*DM)/AR                                    075100 0000
      CEML=UCE*HOURS*CFEWWK/AR                                           075110 0000
      CMML=UCM*V                                                         075120 0000
  300 RETURN                                                             075130 0000
      END                                                                075140 0000
      SUBROUTINE CMTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR,    075150 0000
     1HSFA,V,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPE,RL,UCLT,UCET,Y,UCLMH, 075160 0000
     2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,VBACEX,VBACDS,VBOX,  075170 0000
     3    VSOIL,VROCK,TOTBOX,CFLWWK,CFEWWK,CFLCA,DDS,NSTYP,DTRNCH,DROCK) 075180 0000
C     ------------------------------------------------------------------ 075190 0000
C     ------------------------------------------------------------------ 075200 0000
C     CMTAH CALCULATES MUCK TRANSPORT COSTS IN TUNNELS AND MUCK HOISTING 075210 0000
C     COSTS IN TUNNELS AND SHAFTS.  IT ALSO CALCULATES COST OF TRANSPORT 075220 0000
C     FOR BACKFILL IN CUT-AND-COVER TUNNEL.                              075230 0000
C     ------------------------------------------------------------------ 075240 0000
C     SHAFT OR TUNNEL                                                    075250 0000
      IF(ITYPE.EQ.2) GO TO 600                                           075260 0000
C                                                                        075270 0000
C     ------------------------------------------------------------------ 075280 0000
      IF(NSTYP.EQ.3) GO TO 2000                                          075290 0000
C     COST OF MUCK TRANSPORT IN TUNNELS                                  075300 0000
      GO TO (20,60,40,80),MTM                                            075310 0000
C     ------------------------------------------------                   075320 0000
C     TRUCK TRANSPORT     Z= TRUCK VOLUME/4                              075330 0000
   20 IF(ISHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2                        075340 0000
      IF(ISHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)**4/22000.                     075350 0000
      TRUCKS=0.06*RMLMAX/Z*DM*0.7                                        075360 0000
      IF(TRUCKS.LT.1.) TRUCKS=1.                                         075370 0000
C     ------------------------------------------------                   075380 0000
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(Continued)

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      UCL=7.7*TRUCKS+7.1                                                075390 0000
      UCE=(1.5+3.1*Z)*TRUCKS                                            075400 0000
      UCM=0.05*(1.+0.77*ABS(HSLOPE))*DM                                 075410 0000
      GO TO 400                                                         075420 0000
C     ------------------------------------------                        075430 0000
C     RAIL TRANSPORT - FREE AIR                                         075440 0000
C     CALCULATION OF NUMBER OF CARS                                     075450 0000
   40 CONTINUE                                                          075460 0000
      CARS=(0.06+0.12*DM**0.333)*RMLMAX                                 075470 0000
     1    + AR/300.*(0.06+0.023*DM-0.12*DM**0.333)*RMLMAX               075480 0000
      IF(MSTAB.EQ.1) GO TO 1000                                         075490 0000
   44 IF(CARS.LT.1.) CARS=1.                                            075500 0000
C     ------------------------------------------                        075510 0000
C     CALCULATION OF NUMBER OF ENGINES                                  075520 0000
      ENGINE=CARS/11.                                                   075530 0000
   55 IF(ENGINE.LT.1.) ENGINE=1.                                        075540 0000
      UCL=15.*ENGINE+7.14*(DM+1.)+AR/12.                                075550 0000
      UCE=5.8*ENGINE+CARS+1.4*DM                                        075560 0000
      UCM=0.03*DM                                                       075570 0000
      GO TO 400                                                         075580 0000
C     ------------------------------------------                        075590 0000
C     RAIL TRANSPORT - COMPRESSED AIR                                   075600 0000
C                                                                       075610 0000
 1000 DCR=0.1*DM*5280.                                                  075620 0000
      DCA=DM-DLOCK/5280.                                                075630 0000
      IF(DCR.GT.500.) DCR=500.                                          075640 0000
      CARS=(1.+0.7/(DM+2.))*CARS                                        075650 0000
      IF(CARS.LT.1.) CARS=1.                                            075660 0000
      ENGINE=CARS/11.                                                   075670 0000
      IF(ENGINE.LT.1.) ENGINE=1.                                        075680 0000
C     CALCULATE NUMBER OF CREWS INSIDE AND OUTSIDE THE AIR LOCK         075690 0000
      CREWAD=1.-ENGINE**4/4000.                                         075700 0000
      IF(CREWAD.LT.0.) CREWAD=0.                                        075710 0000
      CREWS=ENGINE+CREWAD                                               075720 0000
      CREWCA=1.+(CREWS-2.)*(DM*5280.-DLOCK-0.5*DCR)/(DM*5280.-1.5*DCR)  075730 0000
      IF(DLOCK.LT.DCR) CREWCA=CREWS-1.                                  075740 0000
      IF(DM*5280.-DLOCK.LT.0.5*DCR) CREWCA=1.                           075750 0000
      UCL=1.5*(CREWS+(CFLCA-1.)*CREWCA)+AR*CFLCA/12.                    075760 0000
     1    +7.14*(DM+1.)*(DLOCK/5280.+DCA*CFLCA)/DM                      075770 0000
      UCE=9.3*ENGINE+CARS+1.4*DM                                        075780 0000
      UCM=0.033*DM                                                      075790 0000
      GO TO 400                                                         075800 0000
C     ------------------------------------------------------------------075810 0000
C     CONVEYOR TRANSPORT - FREE AIR                                     075820 0000
   60 UCL=(0.013*AR+0.6*DM)*SQRT(RMLMAX+40.)+0.06*AR-1.1*DM             075830 0000
      IF(HSLOPE.GE.0.0) UCECON=((1.+4.* HSLOPE)*SQRT(RMLMAX+40.)-26.*   075840 0000
     1  HSLOPE-1.5)*DM                                                  075850 0000
      IF(HSLOPE.LT.0.0) UCECON=(SQRT(RMLMAX+40.)+6.* HSLOPE-1.5)*DM     075860 0000
      IF(HSLOPE.GE.0.0) UCMCON=(0.01+0.23*HSLOPE)*DM                    075870 0000
      IF(HSLOPE.LT.0.0) UCMCON=0.01*DM                                  075880 0000
      UCEMT=0.                                                          075890 0000
      UCMMT=0.                                                          075900 0000
C     ------------------------------------------------------------------075910 0000
      IF(MSTAB.NE.1) GO TO 1100                                         075920 0000
C     CONVEYOR TRANSPORT - COMPRESSED AIR                               075930 0000
      DCA=DM-DLOCK/5280.                                                075940 0000
      UCL=UCL*(DLOCK/5280.+DCA*CFLCA)/DM+7.7*CFLCA+16.8                 075950 0000
C     COST OF MUCK TRANSFER IN AIR LOCK                                 075960 0000
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(Continued)

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      UCEMT=8.10                                                        075970 0000
      IF(RMLMAX.LE.100.) UCEMT=4.50                                     075980 0000
      IF(RMLMAX.GT.300) UCEMT=14.90                                     075990 0000
      UCMMT=0.02                                                        076000 0000
 1100 UCE=UCECON+UCEMT                                                  076010 0000
      UCM=UCMCON+UCMMT                                                  076020 0000
C     STORE COST VALUES FOR USE IN LINING COMPUTATIONS  (SUB LINING)    076030 0000
      UCLT=(0.6*SQRT(RMLMAX+40.)-1.1)*DM                                076040 0000
      UCET=UCE                                                          076050 0000
      GO TO 400                                                         076060 0000
C     ----------------------------------------------------------------- 076070 0000
C     ----------------------------------------------------------------- 076080 0000
C     CONVEYOR AND TRUCK (FOR COMPRESSED AIR SEGMENT ONLY)              076090 0000
   80 IF(MSTAB.NE.1) GO TO 20                                           076100 0000
      IF(DLOCK.LE.0.001) GO TO 60                                       076110 0000
      DCA=DM-DLOCK/5280.                                                076120 0000
C     TRUCKS IN FREE AIR                                                076130 0000
      IF(ISHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2                       076140 0000
      IF(ISHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)**4/22000.                    076150 0000
      TRUCKS=0.06*RMLMAX/Z*(DLOCK/5280.)**0.7                           076160 0000
      IF(TRUCKS.LT.1.) TRUCKS=1.                                        076170 0000
      UCETR=(1.5+3.1*Z)*TRUCKS                                          076180 0000
      UCMTR=0.05*(1.+0.77*ABS(HSFA   ))*DLOCK/5280.                     076190 0000
C     CONVEYOR IN COMPRESSED AIR                                        076200 0000
      UCECON=DCA*((1.+4.*HSCA   )*SQRT(RMLMAX+40.)-26.*HSCA  -1.5)      076210 0000
      UCMCON=DCA*(0.01+0.23*HSCA)                                       076220 0000
      IF(HSCA  .GE.0.) GO TO 1200                                       076230 0000
      UCECON=DCA*(SQRT(RMLMAX+40.)+6.*HSCA  -1.5)                       076240 0000
      UCMCON=0.01*DCA                                                   076250 0000
C     COST OF MUCK TRANSFER IN AIR LOCK                                 076260 0000
 1200 UCEMT=8.10                                                        076270 0000
      IF(RMLMAX.LE.100.) UCEMT=4.50                                     076280 0000
      IF(RMLMAX.GT.300.) UCEMT=14.9                                     076290 0000
      UCMMT=0.02                                                        076300 0000
      UCL=(((0.013*AR+0.6*DCA)*SQRT(RMLMAX+40.)+0.06*AR-1.1*DCA)*CFLCA  076310 0000
     1   +7.7*(TRUCKS+CFLCA)+23.9+CLIND*AR/HOURS                        076320 0000
      UCE=UCECON+UCEMT+UCETR                                            076330 0000
      UCM=UCMCON+UCMMT+UCMTR                                            076340 0000
C     ----------------------------------------------------------------- 076350 0000
C     CALCULATE MUCK TRANSPORT COSTS                                    076360 0000
C     ----------------------------------------------                    076370 0000
  400 CLMT=UCL*HOURS*CFLWWK/AR                                          076380 0000
      CEMT=UCE*HOURS/AR*CFEWWK                                          076390 0000
      CMMT=UCM*V                                                        076400 0000
      IF(HH.GT.0.) GO TO 500                                            076410 0000
C     SHAFT IS A PORTAL, HOISTING COSTS ARE ZERO                        076420 0000
  300 UCL=0.                                                            076430 0000
      UCE=0.                                                            076440 0000
      UCM=0.                                                            076450 0000
      UCLIND=0.                                                         076460 0000
      GO TO 700                                                         076470 0000
C     COST OF BACKFILL TRANSPORT IN CUT AND COVER                       076480 0000
 2000 DCENT=(DCENT*VSOIL-VBOX*(DTRNCH-TOTBOX/2.))/(V-VBOX)              076490 0000
      IF(DROCK.LT.DTRNCH) DCENT=DCENT+VROCK*(DTRNCH+DROCK)/2./(V-VBOX)  076500 0000
      TRUCKS=(0.02+(OPEN+DCENT/0.1)/75000.)*VBACEX*(V-VBOX)*AR/HOURS    076510 0000
      IF(TRUCKS.LT.1.) TRUCKS=1                                         076520 0000
      UCL=(10.+(15.5+4.7*DDS)*VBACDS*(V-VBOX)*AR/1000.)*24./HOURS       076530 0000
     1   +8.20+6.25*TRUCKS                                              076540 0000
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      UCE=(6.+(12.5+2.1*DDS)*VBACDS*(V-VBOX)*AR/1000.)*24./HOURS
     1   +8.40+2.70*TRUCKS
      UCM=0.055*DDS*VBACDS+0.00005*(OPEN+DCENT/0.1)*VBACEX
     1   +2.2*HOURS/AR/(V-VBOX)
C     CALCULATE COST OF BACKFILL TRANSPORT PER FOOT OF TUNNEL
      CLMT=UCL*HOURS/AR*CFLWWK
      CEMT=UCE*HOURS/AR*CFEWWK
      CMMT=UCM*(V-VBOX)
C     RESET UNIT COSTS TO ZERO SO MUCK HOISTING COST WILL BE ZERO IN
C     CUT-AND-COVER
      GO TO 300
C     ***********************************************************************
C     CALCULATE UNIT COST OF MUCK HOISTING IN TUNNELS
  500 UCL=35.+0.003*HH*(1.+0.002*RMLMAX)+0.016*RMLMAX
      UCE=10. + 0.03*RMLMAX
      UCM=0.05
      UCLIND=(50000.+0.04*(900.+HH)*RMLMAX)/RL
      GO TO 700
C     ---------------------------------------------------------------------
C     CALCULATE UNIT COST OF MUCK HOISTING IN SHAFTS
  600 UCL=0.
      UCE=0.
      UCM=0.
      UCLIND=0.
      IF(NSTYP.EQ.3) GO TO 800
      UCL=29. + 0.002*HH*(1.+0.008*RMLMAX)
      UCE=3.+0.04*RMLMAX
      UCM=0.05
      UCLIND=0.
C     ---------------------------------------------------------------------
C     CALCULATE MUCK HOISTING COSTS
  700 CLMH=(HOURS*UCL/AR+UCLIND)*CFLWWK
      CEMH=HOURS*UCE/AR*CFEWWK
      CMMH=UCM*V*HH/1000.
      GO TO 750
  800 CLMH=0.
      CEMH=0.
      CMMH=0
  750 CONTINUE
C     STORE COST VALUES FOR USE IN LINING COMPUTATION
      UCLMH=UCL
      UCEMH=UCE
C
      RETURN
      END
      SUBROUTINE CMUKDP(CLMD,CEMD,CMMD,AR,V,CDS,DDS,VDS,NSTYP,HOURS,
     1           CFLWWK,CFEWWK,ITYPE)
C     ---------------------------------------------------------------------
C     ---------------------------------------------------------------------
C     CMUKDP CALCULATES THE COST OF MUCK DISPOSAL FOR TUNNELS AND SHAFTS
C     ---------------------------------------------------------------------
C     ---------------------------------------------------------------------
      IF(ITYPE.EQ.2.AND.NSTYP.EQ.3) GO TO 100
C
C     CALCULATE UNIT COST OF MUCK DISPOSAL
      VMKDP=V
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(Continued)

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      IF (NSTYP.EQ.3) VMKDP=VDS*V                                       077120 0000
      UCL=(10.+(15.5+4.7*DDS)*VMKDP*AR/1000.)*24./HOURS                 077130 0000
      UCE=(8.+(12.5+2.10*DDS)*VMKDP*AR/1000.)*24./HOURS                 077140 0000
      UCM=0.055*DDS                                                     077150 0000
      UCDS=CDS*VMKDP*0.00003                                            077160 0000
C     CALCULATE COST OF MUCK DISPOSAL                                   077170 0000
      CLMD=UCL*HOURS/AR*CFLWUK                                          077180 0000
      CEMD=UCE*HOURS/AR*CFEWUK                                          077190 0000
      CMMD=UCDS+UCM*VMKDP                                               077200 0000
      GO TO 200                                                         077210 0000
C                                                                       077220 0000
  100 CLMD=0.                                                           077230 0000
      CEMD=0.                                                           077240 0000
      CMMD=0.                                                           077250 0000
C                                                                       077260 0000
  200 RETURN                                                            077270 0000
      END                                                               077280 0000
      SUBROUTINE CTSUP(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60 077290 0000
     1,ITYPE,Y,DM,NSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,         077300 0000
     2BOB,LINUT,MSTAB,CFLCA,HOURS,CFLWUK,CFEWUK,DSLURY,DTRNCH,IDECK,    077310 0000
     3DROCK,WTSTRT,WTWALE,SPDLT,WTSPD,WTSP,WTANCH,TOTBOX,IBRACE,SFA)    077320 0000
C     ------------------------------------------------------------------ 077330 0000
C     ------------------------------------------------------------------ 077340 0000
C     CTSUP CALCULATES THE COST OF SUPPORTS IN TUNNELS AND SHAFTS        077350 0000
C     ------------------------------------------------------------------ 077360 0000
C     ------------------------------------------------------------------ 077370 0000
C     IS IT A ROCK TUNNEL OR SHAFT                                       077380 0000
      IF(NSTYP.EQ.1) GO TO 5                                            077390 0000
C     II IS A FLOW INDICATOR                                            077400 0000
      II=4                                                              077410 0000
C     IS IT A SOFT GROUND TUNNEL OR SHAFT                               077420 0000
      IF(NSTYP.EQ.2) GO TO 1000                                         077430 0000
      GO TO 1500                                                        077440 0000
C                                                                       077450 0000
C     ****************************************************************** 077460 0000
C     ROCK TUNNELS AND SHAFTS                                           077470 0000
C     ****************************************************************** 077480 0000
C                                                                       077490 0000
    5 IF(ITYPE.EQ.2) ISHAPE=1                                           077500 0000
      E=2.71828                                                         077510 0000
      IF(RQD.GT.40..AND.RQD.LT.60.) GO TO 10                            077520 0000
      IF(RQD.LE.40.) GO TO 40                                           077530 0000
C     RQD .GE. 60    ROCK BOLTS USED                                    077540 0000
   20 II=4                                                              077550 0000
  510 GO TO (200,210),MEX                                               077560 0000
C     CONVENTIONAL EXCAVATION                                           077570 0000
  200 IF(ISHAPE.LT.3) GO TO 220                                         077580 0000
C     ------------------------------------------------------------------ 077590 0000
C     F IS A ROCK BOLT WEIGHT FACTOR, FF IS A WIRE MESH WEIGHT FACTOR    077600 0000
C     SHAPE IS BASKETHANDLE                                             077610 0000
      F=1.6                                                             077620 0000
      FF=0.74                                                           077630 0000
      GO TO 230                                                         077640 0000
C     SHAPE IS CIRCLE OR HORSESHOE                                      077650 0000
  220 F=1.0                                                             077660 0000
      FF=1.0                                                            077670 0000
      GO TO 230                                                         077680 0000
C     MOLE EXCAVATION                                                   077690 0000
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  210 F=0.56                                                            077700 0000
      FF=1.0                                                            077710 0000
C     CALCULATE WEIGHT OF ROCK BOLTS                                    077720 0000
  230 WRB=(F*8.56*BE*E**(0.026*BE)*(100-RQD)**2)/(158.-RQD)**2          077730 0000
      GO TO(240,250),ITYPE                                              077740 0000
C     CALCULATE WEIGHT OF WIRE MESH IN TUNNELS                          077750 0000
  240 WWM=FF*3.3*BE*(1.-0.01*RQD)                                       077760 0000
C     ------------------------------------------------------------------ 077770 0000
C     UNIT COSTS OF ROCK BOLT SUPPORTS IN TUNNELS                       077780 0000
      UCL=0.02*WRB*AR                                                   077790 0000
      IF(BE.LE.16.) UCE=1.76                                            077800 0000
      IF(BE.GT.16..AND.WRB*AR.LE.1000.) UCE=9.35                        077810 0000
      IF(BE.GT.16..AND.WRB*AR.GT.1000.) UCE=9.35+0.0023*(WRB*AR-1000.)  077820 0000
      UCM=0.32*WWM+(0.23+RS/530000.)*WRB                                077830 0000
      GO TO 300                                                         077840 0000
C     ------------------------------------------------------------------ 077850 0000
C     WEIGHT OF WIRE MESH IN SHAFTS                                     077860 0000
  250 WWM=FF*4.*BE                                                      077870 0000
C     ------------------------------------------------------------------ 077880 0000
C     UNIT COSTS OF ROCK BOLT SUPPORTS IN SHAFTS                        077890 0000
      UCL=0.0                                                           077900 0000
      IF(MEX.EQ.1) UCE=0.0                                              077910 0000
      IF(MEX.EQ.2) UCE=1.76                                             077920 0000
      UCM=0.32*WWM+(0.23+RS/530000.)*WRB                                077930 0000
      GO TO 300                                                         077940 0000
C     ------------------------------------------------------------------ 077950 0000
C     RQD IS BETWEEN 40 AND 60,INTERPOLATION OF COSTS IS NECESSARY.     077960 0000
C     COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE       077970 0000
C     INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD.                      077980 0000
C                                                                       077990 0000
C     STORE THE CORRECT VALUES OF RQD AND BE                            078000 0000
   10 RQDD=RQD                                                          078010 0000
      BBE=BE                                                            078020 0000
C     ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE 078030 0000
      BE=BE40                                                           078040 0000
      RQD=40                                                            078050 0000
      II=1                                                              078060 0000
      GO TO 410                                                         078070 0000
C     RQD .LE. 40   STEEL SETS USED                                     078080 0000
   40 II=4                                                              078090 0000
  410 GO TO (420,430,440),ISHAPE                                        078100 0000
C     SHAPE IS CIRCLE                                                   078110 0000
  420 GO TO (450,460),MEX                                               078120 0000
C     ------------------------------------------------------------------ 078130 0000
C     FACTOR FOR WEIGHT OF STEEL SUPPORTS=F                             078140 0000
C     CONVENTIONAL EXCAVATION                                           078150 0000
  450 F=0.56*((RQD-20.)/100.)**2+1.22                                   078160 0000
C     FBL=  FACTOR FOR BLOCKING AND LAGGING                             078170 0000
      FBL=1.0                                                           078180 0000
      GO TO 470                                                         078190 0000
C     MOLE EXCAVATION                                                   078200 0000
  460 F=1.0                                                             078210 0000
      FBL=0.81                                                          078220 0000
C     WEIGHT OF STEEL SUPPORTS                                          078230 0000
  470 WST=F*E**(SQRT(ABS(0.7*BE-6.))+3.7-2*((RQD+20.)/100.)**2)         078240 0000
      GO TO 480                                                         078250 0000
C     SHAPE IS HORSESHOE                                                078260 0000
  430 WST=E**(SQRT(ABS(0.85*BE-7.))+0.8+0.3*SQRT(100.-RQD))             078270 0000
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(Continued)

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      FBL=1.+0.012*BE                                                   078280 0000
      GO TO 480                                                         078290 0000
C     SHAPE IS BASKETHANDLE                                             078300 0000
  440 WST=E**(SQRT(ABS(0.92*BE-6.))+0.82+0.22*SQRT(100.-RQD))           078310 0000
      FBL=1.+0.003*BE                                                   078320 0000
C     QUANTITY OF BLOCKING AND LAGGING                                  078330 0000
  480 BL=FBL*BE*(0.0018+0.0056*((117.-RQD)/100.)**2)                    078340 0000
      GO TO (490,500),ITYPE                                             078350 0000
C     ------------------------------------------------------------------ 078360 0000
C     UNIT COSTS OF STEEL SUPPORTS IN TUNNELS                           078370 0000
  490 IF(MEX.EQ.1) YY=1.1                                               078380 0000
      IF(MEX.EQ.2) YY=1.0                                               078390 0000
      UCL=YY*(0.001*WST*AR+0.4*BE)                                      078400 0000
      UCE=YY*(6.+0.0002*WST*AR)                                         078410 0000
      UCM=36.*YY/AR+0.095*WST+150.*BL                                   078420 0000
      GO TO 300                                                         078430 0000
C     ------------------------------------------------------------------ 078440 0000
C     UNIT COSTS OF STEEL SUPPORTS IN SHAFT                             078450 0000
  500 UCL=1.1/3.*(0.001*WST*AR+0.4*BE)                                  078460 0000
      UCE=1.1/3.*(6.+0.0002*WST*AR)                                     078470 0000
      UCM=0.095*WST+150.*BL                                             078480 0000
C     ------------------------------------------------------------------ 078490 0000
C     COST OF SUPPORTS                                                  078500 0000
C                                                                       078510 0000
  300 CLTS=(HOURS*CFLWWK+Y*DM)*UCL/AR                                   078520 0000
      CETS=HOURS*CFEWWK*UCE/AR                                          078530 0000
      CMTS=UCM                                                          078540 0000
C     ------------------------------------------------------------------ 078550 0000
      IF(II.GE.3) GO TO 700                                             078560 0000
      IF(II.GE.2) GO TO 600                                             078570 0000
C     STORE COSTS COMPUTED USING FICTITIOUS RQD=40                      078580 0000
      CL40=CLTS                                                         078590 0000
      CE40=CETS                                                         078600 0000
      CM40=CMTS                                                         078610 0000
C     REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF       078620 0000
C     INTERPOLATION COMPUTATION                                         078630 0000
      RQD=60                                                            078640 0000
      BE=BE60                                                           078650 0000
C     REDEFINE FLOW INDICATOR                                           078660 0000
      II=II+1                                                           078670 0000
      GO TO 510                                                         078680 0000
C     STORE COSTS COMPUTED USING FICTITIOUS RQD=60                      078690 0000
  600 CL60=CLTS                                                         078700 0000
      CE60=CETS                                                         078710 0000
      CM60=CMTS                                                         078720 0000
C     ------------------------------------------------------------------ 078730 0000
C     INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN SUPPORT COSTS      078740 0000
      CLTS=CL40+((RQDD-40)/20)*(CL60-CL40)                              078750 0000
      CETS=CE40+((RQDD-40)/20)*(CE60-CE40)                              078760 0000
      CMTS=CM40+((RQDD-40)/20)*(CM60-CM40)                              078770 0000
C     ------------------------------------------------------------------ 078780 0000
C     REINSTATE ORIGINAL VALUES OF RQD AND BE                           078790 0000
      RQD=RQDD                                                          078800 0000
      BE=BBE                                                            078810 0000
  700 RETURN                                                            078820 0000
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(Continued)

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C                                                                       078830 0000
C     ******************************************************************078840 0000
C     SOFT GROUND TUNNELS OR SHAFTS                                     078850 0000
C     ******************************************************************078860 0000
C                                                                       078870 0000
C     ESTABLISH SHAPE FACTOR BASED ON PERIMETER                         078880 0000
 1000 IF(ITYPE.EQ.2) GO TO 1035                                         078890 0000
      GO TO(1010,1020,1030 ),ISHAPE                                     078900 0000
C     CIRCULAR                                                          078910 0000
 1010 SFP=3.14                                                          078920 0000
      GO TO 1050                                                        078930 0000
C     HORSESHOE                                                         078940 0000
 1020 SFP=3.57                                                          078950 0000
      GO TO 1050                                                        078960 0000
C     BASKETHANDLE                                                      078970 0000
 1030 SFP=2.66                                                          078980 0000
      GO TO 1050                                                        078990 0000
C     SHAFT SEGMENT                                                     079000 0000
 1035 IF(ISHAPE.EQ.1) GO TO 1010                                        079010 0000
C     SQUARE                                                            079020 0000
      SFP=4                                                             079030 0000
 1050 PERMTR=0.5*(BE+BF)*SFP                                            079040 0000
      GO TO(1060,1070,1060,1300),ISUPPT                                 079050 0000
C     SEGMENTED CAST IRON OR STEEL SUPPORTS                             079060 0000
 1060 S=3                                                               079070 0000
      GO TO 1080                                                        079080 0000
C     SEGMENTED CONCRETE SUPPORTS                                       079090 0000
 1070 S=4                                                               079100 0000
 1080 TWEB=TPLATE                                                       079110 0000
      IF(TWEB.GT.1.) TWEB=1                                             079120 0000
      AREA=S*TPLATE+2.*TWEB*(TSEG-TPLATE)                               079130 0000
C     CALCULATE SUPPORT QUANTITIES                                      079140 0000
      GO TO(1110,1120,1190),ISUPPT                                      079150 0000
C     ------------------------------------------------------------------079160 0000
C     SEGMENTED CAST IRON SUPPORTS                                      079170 0000
 1110 WCI=450.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR     079180 0000
      YY=0.13*WCI                                                       079190 0000
      GO TO 1200                                                        079200 0000
C     ------------------------------------------------------------------079210 0000
C     SEGMENTED CONCRETE SUPPORTS                                       079220 0000
 1120 VL=1./27.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR    079230 0000
      IF(ITYPE.EQ.2) GO TO 1175                                         079240 0000
C     TUNNEL SEGMENT                                                    079250 0000
      GO TO (1150,1160,1170),ISHAPE                                     079260 0000
C     CIRCULAR                                                          079270 0000
 1150 RST=0.01                                                          079280 0000
      GO TO 1185                                                        079290 0000
C     HORSESHOE                                                         079300 0000
 1160 RST=0.032-0.16E-6*PTOTAL                                          079310 0000
      PMINT=54000./BF**1.5                                              079320 0000
      RSTMNT=0.032-0.16E-6*PMINT                                        079330 0000
      GO TO 1180                                                        079340 0000
C     BASKETHANDLE                                                      079350 0000
 1170 RST=0.032-0.16E-6*PTOTAL                                          079360 0000
      PMINT=60000./BF**1.7                                              079370 0000
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(Continued)

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      RSTMNT=0.032-0.18E-6*PMINT                                        079380 0000
      GO TO 1180                                                        079390 0000
C     SHAFT SEGMENT                                                     079400 0000
 1175 IF(ISHAPE.EQ.1) GO TO 1150                                        079410 0000
C     SQUARE                                                            079420 0000
      RST=0.034-0.13E-6*PTOTAL                                          079430 0000
      PMINT=50000./BF**1.9                                              079440 0000
      RSTMNT=0.034-0.13E-6*PMINT                                        079450 0000
 1180 IF(PTOTAL.LT.PMINT) RST=0.01+(RSTMNT-0.01)/PMINT*PTOTAL           079460 0000
      IF(RST.LT.0.01) RST=0.01                                          079470 0000
 1185 WREIN=491.*RST*VL*27.                                             079480 0000
      YY=99.*VL+0.15*WREIN                                              079490 0000
      GO TO 1200                                                        079500 0000
C     ----------------------------------------------------------------- 079510 0000
C     SEGMENTED STEEL SUPPORTS                                          079520 0000
 1190 WST=491.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR     079530 0000
      YY=0.095*WST                                                      079540 0000
 1200 IF(ITYPE.EQ.2) GO TO 1210                                         079550 0000
C     TUNNEL SEGMENT                                                    079560 0000
      Y3=1                                                              079570 0000
      GO TO 1230                                                        079580 0000
C     SHAFT SEGMENT                                                     079590 0000
C     IS COMPRESSED AIR USED                                            079600 0000
 1210 IF(MSTAB.EQ.1) GO TO 1220                                         079610 0000
      Y3=0.333                                                          079620 0000
      GO TO 1230                                                        079630 0000
 1220 Y3=1.25                                                           079640 0000
 1230 UCL=Y3*(50.+0.04*BE**2)*((CFLCA-1.)*2./3.+1.)                     079650 0000
      IF(ITYPE.EQ.2) UCL=Y3*(50.+0.04*BE**2)                            079660 0000
      UCE=Y3*(5.5+0.003*(BE+10.)**2)                                    079670 0000
      UCM=Y3*(2.1+0.001*BE**2)*HOURS/AR+YY                              079680 0000
C     ----------------------------------------------------------------- 079690 0000
C     ADD COST FOR CAULKING SEGMENTED SUPPORTS IN WATERTIGHT TUNNELS    079700 0000
C     AND SHAFTS                                                        079710 0000
      IF(LINWT.EQ.1) GO TO 1240                                         079720 0000
      GO TO 1350                                                        079730 0000
 1240 IF(ITYPE.EQ.2) GO TO 1250                                         079740 0000
C     TUNNEL SEGMENT                                                    079750 0000
      IF(ISHAPE.EQ.1) GO TO 1260                                        079760 0000
C     HORSESHOE OR BASKETHANDLE                                         079770 0000
      SEGN=6                                                            079780 0000
      GO TO 1270                                                        079790 0000
 1250 IF(ISHAPE.EQ.1) GO TO 1260                                        079800 0000
C     SQUARE                                                            079810 0000
      SEGN=8                                                            079820 0000
      GO TO 1270
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      GO TO 1270
C     CIRCULAR
 1260 SEGN=3
 1270 CJOINT=BE*SFP/S+SEGN
      IF(ITYPE.EQ.1) UCL=UCL+0.175*CJOINT*AR*CFLCA/HOURS
      IF(ITYPE.EQ.2) UCL=UCL+0.175*CJOINT*AR/HOURS
      UCE=UCE+0.025*CJOINT*AR/HOURS
      UCM=UCM+0.3*CJOINT
      GO TO 1350
C     ------------------------------------------------------------------
C     STEEL RIB SUPPORT
 1300 S=10.-0.65*ALOG(PSOIL)
      IF(S.GT.6.) S=6
      AREA=1./144.*EXP(4.26*SQRT (WEB-0.33))
      WST=491.*AREA*SFP*(BE-WEB)/S
      BLTHCK=1./535.*SQRT(PSOIL)*(9.5-0.65*ALOG(PSOIL))
C     ASSUME MINIMUM LAGGING THICKNESS TO BE 5 INCHES
      IF(BLTHCK.LT.5./12.)BLTHCK=5./12.
      BL=BLTHCK*12.*SFP*(BE-BLTHCK)/1000.
      IF(ITYPE.EQ.2) GO TO 1320
C     TUNNEL SEGMENT
      YY=1.1
      Y3=39.6
      GO TO 1340
C     SHAFT SEGMENT
C     IS COMPRESSED AIR USED
 1320 IF(MSTAB.EQ.1) GO TO 1330
      YY=1.1/3.
      Y3=0
      GO TO 1340
 1330 YY=1.4
      Y3=50
 1340 UCL=YY*(0.001*WST*AR+0.4*BE)*((CFLCA-1.)*2./3.+1.)
      IF(ITYPE.EQ.2) UCL=YY*(0.001*WST*AR+0.4*BE)
      UCE=YY*(6.+0.0002*WST*AR)
      UCM=Y3/AR+0.095*WST+150.*BL
C     ADD COST FOR BACKFILL GROUT
 1350 VBACKG=SFA*(DOD**2-BE**2)
      IF(ITYPE.EQ.1) UCL=UCL+1.3*VBACKG*AR*CFLCA/HOURS
      IF(ITYPE.EQ.2) UCL=UCL+1.3*VBACKG*AR/HOURS
      UCE=UCE+0.5*VBACKG*AR/HOURS
      UCM=UCM+1.2*VBACKG
      GO TO 300
C
C     ******************************************************************
C     CUT AND COVER
C     ******************************************************************
C     SET COSTS=0
 1500 UCL=0
      UCE=0
      UCM=0
C     IS IT A SHAFT
      IF(ITYPE.EQ.1) GO TO 1505
      CLTS=0.
      CETS=0.
```

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      CMTS=0.                                                           080380 0000
      RETURN                                                            080390 0000
C     FOR SLOPING CUT, ONLY COST OF ROCK BOLTS WILL BE COMPUTED         080400 0000
 1505 IF(MEX.EQ.7) GO TO 1750                                           080410 0000
C     IF OPEN CUT IS ENTIRELY IN ROCK, ONLY COST OF ROCK BOLTS IS       080420 0000
C     COMPUTED FOR SUPPORTS                                             080430 0000
      IF(DROCK.LT.0.1) GO TO 1760                                       080440 0000
      DROOF=DTRNCH-TOTBOX                                               080450 0000
      IF(ISUPPT.EQ.6) GO TO 1510                                        080460 0000
      GO TO 1515                                                        080470 0000
C     ------------------------------------------------------------------ 080480 0000
C     SLURRY WALL                                                       080490 0000
C     ------------------------------------------------------------------ 080500 0000
 1510 IF(DROCK.LE.DROOF-2.) SLURRY=0.5*DROCK/12.                        080510 0000
      IF(DROCK.GT.DROOF-2.) SLURRY=0.5*DTRNCH/12.                       080520 0000
      IF(SLURRY.LT.1.5) SLURRY=1.5                                      080530 0000
      UCL=UCL+145.*DSLURY*SLURRY/2600.*AR/HOURS                         080540 0000
      UCE=UCE+181.*DSLURY*SLURRY/2600.*AR/HOURS                         080550 0000
      UCM=UCM+(1.4*SLURRY-0.6)*DTRNCH*1.15                              080560 0000
C     ------------------------------------------------------------------ 080570 0000
C     WALES AND STRUTS                                                  080580 0000
C     ------------------------------------------------------------------ 080590 0000
C     WALERS AND STRUTS ARE SPACED 10 FEET VERTICALLY.                  080600 0000
C     ACTUAL NUMBER OF STRUTS AND WALERS REQUIRED IS DSOIL/10 - 1       080610 0000
C     BECAUSE RESTRAINT AT BOTTOM OF SOLDIER PILE ACTS AS A STRUT.      080620 0000
C     IF ACTUAL NUMBER REQUIRED IS LESS THAN ONE, THEN USE ONE.         080630 0000
C     IS ROCK LINE ABOVE TRENCH BOTTOM                                  080640 0000
 1515 IF(DROCK.LT.DTRNCH) GO TO 1520                                    080650 0000
      STRUT=(DTRNCH/10.-1.)/15.*BE*WTSTRT                               080660 0000
      IF(IBRACE.EQ.3) STRUT=(DROOF/10.-1.)/15.*BE*WTSTRT                080670 0000
      WALE=(DTRNCH/10.-1.)*2.*WTWALE                                    080680 0000
      GO TO 1560                                                        080690 0000
 1520 STRUT=(DROCK/10.-1.)/15.*BE*WTSTRT                                080700 0000
      IF(IBRACE.EQ.3 .AND. DROOF.LT.DROCK) STRUT=(DROOF/10.-1.)/15.*    080710 0000
     1BE*WTSTRT                                                         080720 0000
C     IS DECKING REQUIRED                                               080730 0000
      IF(IDECK.EQ.1) GO TO 1540                                         080740 0000
      WALE=(DROCK/10.-1.)*2.*WTWALE                                     080750 0000
      GO TO 1560                                                        080760 0000
 1540 WALE=(DROCK/10.-1.)*2.*WTWALE+((DTRNCH-DROCK)/10.-1.)*2.*13.      080770 0000
C     VERTICAL CUTS IN SOIL LESS THAN 20 FEET HAVE ONE STRUT            080780 0000
 1560 IF(STRUT.LT.BE*WTSTRT/15.) STRUT=BE*WTSTRT/15.                    080790 0000
C     THERE ARE TWO WALES FOR EVERY STRUT AND A MINIMUM OF TWO WALES    080800 0000
C     CONNECTING DECKED SOLDIER PILES IN ROCK                           080810 0000
      IF(IDECK.EQ.1.AND.DROCK.LT.DTRNCH.AND.WALE.LT.2.*WTWALE+26.)      080820 0000
     1 WALE=2.*WTWALE+26.                                               080830 0000
      IF(WALE.LT.2.*WTWALE) WALE=2.*WTWALE                              080840 0000
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C     NO STRUTS IF COMPLETELY SUPPORTED BY ANCHORS                          080850 0000
      IF(IBRACE.EQ.2) STRUT=0                                               080860 0000
C     NO WALES FOR SLURRY WALL                                              080870 0000
      IF(ISUPPT.EQ.6) WALE=0                                                080880 0000
C     NO COSTS OF WALES AND STRUTS FOR SLURRY WALL SUPPORTED BY ANCHORS     080890 0000
      IF(ISUPPT.EQ.6 .AND. IBRACE.EQ.2) GO TO 1570                          080900 0000
      UCL=UCL+45.+1.3*SQRT(WALE+STRUT)                                      080910 0000
      UCE=UCE+15.+0.45*SQRT(WALE+STRUT)                                     080920 0000
      UCM=UCM+0.095*WALE+0.24*STRUT                                         080930 0000
C     ------------------------------------------------------------------    080940 0000
C     ADD COST OF SOLDIER PILES                                             080950 0000
C     ------------------------------------------------------------------    080960 0000
 1570 IF(ISUPPT.EQ.6) GO TO 1605                                            080970 0000
      IF(DROCK.LT.DTRNCH) GO TO 1580                                        080980 0000
      SPLT=DTRNCH+10.                                                       080990 0000
      GO TO 1600                                                            081000 0000
 1580 SPLT=DROCK+10.                                                        081010 0000
 1600 IF(IDECK.EQ.0) SPDLT=SPLT                                             081020 0000
      IF(IDECK.EQ.0) WTSPD=WTSP                                             081030 0000
      GO TO 1610                                                            081040 0000
C     SOLDIER PILES EMBEDED IN SLURRY WALL                                  081050 0000
 1605 SPLT=DSLURY                                                           081060 0000
      SPDLT=DSLURY                                                          081070 0000
      WTSP=13                                                               081080 0000
      WTSPD=13                                                              081090 0000
 1610 PILE=(2.*SPLT*WTSP+SPDLT*WTSPD)*2./15.                                081100 0000
      DWTAVG=SQRT(6. *(2.*WTSP*SPLT+WTSPD*SPDLT)/(2.*SPLT+SPDLT))           081110 0000
      SPLTAV=(2.*SPLT+SPDLT)/3.                                             081120 0000
      UCL=UCL+(0.009*(DWTAVG+7.)**2-0.2)*0.4*SPLTAV*AR/HOURS                081130 0000
      UCE=UCE+0.02*DWTAVG*SPLTAV*AR/HOURS                                   081140 0000
      UCM=UCM+0.012*DWTAVG*SPLTAV+0.1*PILE                                  081150 0000
C     ------------------------------------------------------------------    081160 0000
C     ADD COST OF LAGGING                                                   081170 0000
C     ------------------------------------------------------------------    081180 0000
C     NO LAGGING FOR SLURRY WALL                                            081190 0000
      IF(ISUPPT.EQ.6) GO TO 1710                                            081200 0000
      IF(DROCK.LT.DTRNCH) GO TO 1660                                        081210 0000
      IF(DTRNCH.GT.25.) GO TO 1640                                          081220 0000
      BL=DTRNCH*3.*2./1000.                                                 081230 0000
      GO TO 1700                                                            081240 0000
 1640 BL=(25.*3.+(DTRNCH-25.)*4.)*2./1000.                                  081250 0000
      GO TO 1700                                                            081260 0000
 1660 IF(DROCK.GT.25.) GO TO 1680                                           081270 0000
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      BL=DROCK*3.*2./1000.                                              081280 0000
      GO TO 1700                                                        081290 0000
 1600 BL=(25.*3.+(DROCK-25.)*4)*2./1000.                                081300 0000
 1700 UCL=UCL+53.*AR*BL/HOURS/0.6                                       081310 0000
      UCE=UCE+1.4                                                       081320 0000
      UCM=UCM+20.*BL                                                    081330 0000
C     ------------------------------------------------------------------081340 0000
C     ADD COST OF TIEBACK ANCHORS                                       081350 0000
C     ------------------------------------------------------------------081360 0000
C     NO TIEBACK ANCHORS IF COMPLETELY SUPPORTED BY STRUTS              081370 0000
 1710 IF(IBRACE.EQ.1) GO TO 1750                                        081380 0000
      IF(DROCK.LT.DTRNCH) GO TO 1720                                    081390 0000
      ANCHLT=0.3*DTRNCH+20.                                             081400 0000
      DSOIL=DTRNCH                                                      081410 0000
C     Y1=PORTION SUPPORTED BY TIEBACK ANCHORS                           081420 0000
      Y1=1                                                              081430 0000
      IF(IBRACE.EQ.3) Y1=TOTBOX/DTRNCH                                  081440 0000
      GO TO 1740                                                        081450 0000
 1720 ANCHLT=0.3*DROCK+20.                                              081460 0000
      DSOIL=DROCK                                                       081470 0000
C     Y1=PORTION SUPPORTED BY ANCHORS                                   081480 0000
      IF(IBRACE.EQ.3 .AND. DROCK.LT.DROOF) Y1=1                         081490 0000
      IF(IBRACE.EQ.3 .AND. DROCK.GT.DROOF) Y1=(DROCK-DROOF)/DROCK       081500 0000
 1740 ANCHDI=SQRT(WTANCH/2.67)                                          081510 0000
      GRTAKE=1.88*DSOIL                                                 081520 0000
      UBF=(ANCHLT-20.)*0.785*(1-(ANCHDI/12.)**2)/27.*0.04*DSOIL         081530 0000
      UCLAN=3.*ANCHLT*DSOIL *AR/HOURS/(10.-80./ANCHLT)*Y1               081540 0000
      IF(UCLAN.LT.75.) UCLAN=75                                         081550 0000
      UCEAN=0.7*ANCHLT*DSOIL *AR/HOURS/(10.-80./ANCHLT)*Y1              081560 0000
      IF(UCEAN.LT.17.5) UCEAN=17.5                                      081570 0000
      UCMAN=(ANCHDI**2*(0.8-0.003*ANCHLT)*0.04*ANCHLT*DSOIL +80.*GRTAKE 081580 0000
     1  /27.+6.75*UBF)*Y1                                               081590 0000
      UCL=UCL+UCLAN                                                     081600 0000
      UCE=UCE+UCEAN                                                     081610 0000
      UCM=UCM+UCMAN                                                     081620 0000
C     ------------------------------------------------------------------081630 0000
C     ADD COST OF ROCK BOLTS                                            081640 0000
C     ------------------------------------------------------------------081650 0000
 1750 IF(DROCK.LT.DTRNCH) GO TO 1760                                    081660 0000
      GO TO 1800                                                        081670 0000
 1760 ANCHLT=0.25*(DTRNCH-DROCK)+250./RQD                               081680 0000
      UCLRB=110.*ANCHLT*(DTRNCH-DROCK)*AR/HOURS/(1.2+130./(110.-RQD))**2 081690 0000
     1/(50.-0.25*ANCHLT)                                                081700 0000
      IF(UCLRB.LT.54.) UCLRB=54.                                        081710 0000
      UCERB=20.*ANCHLT*(DTRNCH-DROCK)*AR/HOURS/(1.2+130./(110.-RQD))**2 081720 0000
     1/(50.-0.25*ANCHLT)                                                081730 0000
      IF(UCERB.LT.10.) UCERB=10                                         081740 0000
      UCMRB=1.5*ANCHLT*(DTRNCH-DROCK)/(1.2+130./(110.-RQD))**2          081750 0000
      UCL=UCL+UCLRB                                                     081760 0000
      UCE=UCE+UCERB                                                     081770 0000
      UCM=UCM+UCMRB                                                     081780 0000
 1800 IF(MEX.EQ.7) GO TO 300                                            081790 0000
C     ------------------------------------------------------------------081800 0000
C     DECKING                                                           081810 0000
C     ------------------------------------------------------------------081820 0000
C     IS DECKING REQUIRED                                               081830 0000
      IF(IDECK.EQ.1) GO TO 1820                                         081840 0000
      GO TO 300                                                         081850 0000
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C       ADD COST OF TIMBER                                                  081860 0000
 1820   UCL=UCL+0.072*DE*AR/HOURS                                           081870 0000
        UCE=UCE+0.009*DE*AR/HOURS                                           081880 0000
        UCM=UCM+0.18*DE                                                     081890 0000
C       ADD COST OF GIRDERS AND STRINGERS                                   081900 0000
        UCL=UCL+15.+(5.3*DE+580.)**2/40000.                                 081910 0000
        UCE=UCE+6.5+7.*(DE+100.)**2/10000.                                  081920 0000
        UCM=UCM+0.16*(5.3*DE+30.)                                           081930 0000
        GO TO 300                                                           081940 0000
        END                                                                 081950 0000
        SUBROUTINE LINING1(CLL,CEL,CML,CLFW,CEFW,CMFW,ITYPE,LINING,RQD,MEX 081960 0000
       1,WED,TL,DOB,DOB40,DF,Y,DM,DOB60,ISHAPE,DE,UCLT,UCET,MTM,            081970 0000
       2UCLMH,UCEMH,SFA,NOFORM,AR,NSTYP,PSOIL,PWATER,VL,SFP,                081980 0000
       3FORMAR,HOURS,CFLCA,CFLWWK,CFEWWK)                                   081990 0000
C       ------------------------------------------------------------------- 082000 0000
C       ------------------------------------------------------------------- 082010 0000
C       LINING CALCULATES THE LINING COSTS AND THE FORMWORK COST FOR A      082020 0000
C       TUNNEL OR SHAFT SEGMENT                                             082030 0000
C       ------------------------------------------------------------------- 082040 0000
        IF(NSTYP.EQ.3) GO TO 910                                            082050 0000
C       ***************************   ROCK OR SOFT GROUND   ************** 082060 0000
C       II IS A FLOW INDICATOR                                              082070 0000
C       ------------------------------------------------------------------- 082080 0000
C       ------------------------------------------------------------------- 082090 0000
C                                                                           082100 0000
C       IS SEGMENT LINED                                                    082110 0000
        IF(LINING.GT.0) GO TO 37                                            082120 0000
C       SEGMENT IS UNLINED --- SET ALL COSTS TO ZERO                        082130 0000
        CLL=0.0                                                             082140 0000
        CEL=0.0                                                             082150 0000
        CML=0.0                                                             082160 0000
      2 CLFW=0.0                                                            082170 0000
        CEFW=0.0                                                            082180 0000
        CMFW=0.0                                                            082190 0000
        RETURN                                                              082200 0000
C                                                                           082210 0000
C                                                                           082220 0000
C       ------------------------------------------------------------------- 082230 0000
C       RATIO OF REINFORCEMENT TO CONCRETE BY VOLUME                        082240 0000
C       ------------------------------------------------------------------- 082250 0000
C       SET MINIMUM STEEL REQUIREMENTS                                      082260 0000
   37   IF(NSTYP.EQ.1) RSTMIN=0.005                                         082270 0000
        IF(NSTYP.EQ.2) RSTMIN=0.01                                          082280 0000
        IF(ITYPE.EQ.2) GO TO 49                                             082290 0000
C       TUNNEL SEGMENT                                                      082300 0000
        GO TO(41,42,45),ISHAPE                                              082310 0000
C       CIRCLE                                                              082320 0000
   41   RST=RSTMIN                                                          082330 0000
        GO TO 4                                                             082340 0000
C       HORSESHOE                                                           082350 0000
   42   RST=0.014-7.3E-8*PWATER                                             082360 0000
        IF(LINING.EQ.1) PMINT=195000/DF**1.7                                082370 0000
        IF(LINING.EQ.2) PMINT=36500/DF**1.6                                 082380 0000
   44   RSTMNT=0.014-7.3E-8*PMINT                                           082390 0000
        GO TO 48                                                            082400 0000
C       BASKETHANDLE                                                        082410 0000
   45   RST=0.014-6.6E-8*PWATER                                             082420 0000
        IF(LINING.EQ.1) PMINT=280000/DF**1.9                                082430 0000
```

(Continued)

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   48 IF(LININQ.EQ.2) PMINT=56000/BF**1.8                                082440 0000
   47 RSTMNT=0.014-6.6E-8*PMINT                                          082450 0000
      GO TO 48                                                           082460 0000
C     SHAFT SEGMENT                                                      082470 0000
C     IS IT CIRCULAR SHAPE                                               082480 0000
   49 IF(ISHAPE.EQ.1) GO TO 41                                           082490 0000
      RST=0.015-6.25E-8*PWATER                                           082500 0000
      IF(LINING.EQ.1) PMINT=175000/BF**1.9                               082510 0000
   50 IF(LINING.EQ.2) PMINT=31000/BF**1.8                                082520 0000
   51 RSTMNT=0.015-6.25E-8*PMINT                                         082530 0000
   48 IF(PWATER.LE.PMINT) RST=RSTMIN+(RSTMNT-RSTMIN)*PWATER/PMINT        082540 0000
      IF(RST.LT.RSTMIN) RST=RSTMIN                                       082550 0000
C     ------------------------------------------------------------------ 082560 0000
C     IS IT A SOFT GROUND TUNNEL OR SHAFT                                082570 0000
    4 IF(NSTYP.EQ.2) GO TO 40                                            082580 0000
C     ROCK TUNNELS OR SHAFTS                                             082590 0000
C     CHECK RQD                                                          082600 0000
    5 IF(RQD.LE.40.) GO TO 40                                            082610 0000
      IF(RQD.GE.60.) GO TO 20                                            082620 0000
C     RQD IS BETWEEN 40 AND 60,INTERPOLATION OF COSTS IS NECESSARY.      082630 0000
C     COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE        082640 0000
C     INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD.                       082650 0000
   10 II=1                                                               082660 0000
C     STORE THE CORRECT VALUES OF RQD AND BOB                            082670 0000
      RQDD=RQD                                                           082680 0000
      BBOB=BOB                                                           082690 0000
C     ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE  082700 0000
      RQD=40.                                                            082710 0000
      BOB=BOB40                                                          082720 0000
      GO TO 55                                                           082730 0000
C     RQD .GE. 60                                                        082740 0000
   20 II=4                                                               082750 0000
   30 F=1.                                                               082760 0000
      GO TO (200,300),LINING                                             082770 0000
C     RQD .LE. 40                                                        082780 0000
   40 II=4.                                                              082790 0000
   55 IF(LINING.EQ.1) GO TO 200                                          082800 0000
C     IS THIS A SOFT GROUND TUNNEL OR SHAFT                              082810 0000
      IF(NSTYP.EQ.2) GO TO 300                                           082820 0000
      S=0.05*RQD+1.25                                                    082830 0000
C     TL IS STORED IN FEET                                               082840 0000
   59 IF(     TL.LT.WEB) GO TO 70                                        082850 0000
C     F IS A FACTOR FOR INCREASING SHOTCRETE VOLUME OVER STEEL SETS      082860 0000
   60 F=1.                                                               082870 0000
      GO TO 300                                                          082880 0000
   70 F=(S+WEB/4.)/S                                                     082890 0000
      GO TO 300                                                          082900 0000
C                                                                        082910 0000
C     ****************************************************************** 082920 0000
C     CONCRETE LINING                                                    082930 0000
C     ------------------------------------------------------------------ 082940 0000
  200 VL=SFA/27.*(BOB**2-BF**2)                                          082950 0000
      VLREIN=SFA/27.*(BE**2.-BF**2.)                                     082960 0000
      IF(NSTYP.EQ.2) VL=4./27.*SFA*TL*(BF+TL)                            082970 0000
      IF(NSTYP.EQ.2) VLREIN=VL                                           082980 0000
      WREIN=491.*RST*VLREIN*27.                                          082990 0000
      GO TO(220,260),ITYPE                                               083000 0000
  220 IF(NSTYP.EQ.2) GO TO 230                                           083010 0000
```

(Continued)

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C     ------------------------------------------                        083020 0000
C     UNIT COST OF LINING MATERIAL TRANSPORT IN TUNNELS ONLY             083030 0000
      GO TO (221,225,223,221),MTM                                        083040 0000
C     TRUCK TRANSPORT,      Z=TRUCK VOLUME/4                             083050 0000
  221 IF(ISHAPE.LE.2) Z=5.-0.001*(70.-BE)**2                             083060 0000
      IF(ISHAPE.EQ.3) Z=4.5-(BE-50.)**4/44000.                           083070 0000
      TRUCKS=(0.28*DM+0.48)*VL/Z                                         083080 0000
      IF(TRUCKS.LT.1.0) TRUCKS=1.                                        083090 0000
      UCLT=7.7*TRUCKS+7.1                                                083100 0000
      UCET=(1.5+3.1*Z)*TRUCKS                                            083110 0000
      GO TO 226                                                          083120 0000
C     RAIL TRANSPORT                                                     083130 0000
  223 CARS=(0.42*DM+1.5)*VL                                              083140 0000
      IF(CARS.LT.1.0) CARS=1.0                                           083150 0000
      ENGINE=CARS/10.                                                    083160 0000
      IF(ENGINE.LT.1.0) ENGINE=1.                                        083170 0000
      UCLT=15.*ENGINE+21.*DM**0.82                                       083180 0000
      UCET=5.8*ENGINE+CARS+1.4*DM                                        083190 0000
      GO TO 226                                                          083200 0000
  225 CONTINUE                                                           083210 0000
C     CONVEYOR -- UCET AND UCLT WERE COMPUTED IN SUBROUTINE CMTAH        083220 0000
  226 AL=3.*HOURS                                                        083230 0000
      GO TO 240                                                          083240 0000
  230 UCLT=0                                                             083250 0000
      UCET=0                                                             083260 0000
      UCEMH=0                                                            083270 0000
      AL=AR                                                              083280 0000
C     UNIT COSTS OF LINING IN TUNNEL                                     083290 0000
  240 UCL=(0.0018*(VL*AL/HOURS+160.)**2-12.+UCLT)*CFLCA                  083300 0000
      UCE=5.+0.3*VL*AL/HOURS+UCET+UCEMH                                  083310 0000
      UCM=13.+0.15*WREIN/VL                                              083320 0000
      GO TO 400                                                          083330 0000
C     ------------------------------------------                         083340 0000
C     UNIT COST OF SHAFT LINING                                          083350 0000
  260 UCL= 25.+3.0*VL+UCLMH                                              083360 0000
      UCE=7.+0.40*VL+UCEMH                                               083370 0000
      UCM=13.+0.15*WREIN/VL                                              083380 0000
      AL=2.*HOURS                                                        083390 0000
      GO TO 400                                                          083400 0000
C     ******************************************************************083410 0000
C                                                                        083420 0000
C     SHOTCRETE LINING                                                   083430 0000
  300 VL=4.*SFA/27.*TL*F*(BOB-TL)                                        083440 0000
      IF(NSTYP.EQ.2) VL=4./27.*SFA*TL*(BF+TL)                            083450 0000
      VLREIN=VL                                                          083460 0000
      AL=AR                                                              083470 0000
      WREIN=491.*RST*VLREIN*27.                                          083480 0000
C     ------------------------------------------                         083490 0000
C     COST OF LINING MATERIAL TRANSPORT IN SHOTCRETED TUNNELS IS         083500 0000
C     INCLUDED IN MUCK TRANSPORT AND HOISTING COSTS.                     083510 0000
C     CALCULATE UNIT COSTS OF TUNNEL AND SHAFT LINING                    083520 0000
      UCL=(0.036*(VL*AL/HOURS+40.)**2.+10.)*CFLCA                        083530 0000
      IF(ITYPE.EQ.2) UCL=0.035*(VL*AL/HOURS+40.)**2+10.                  083540 0000
      UCE=0.004*(VL*AL/HOURS+100.)**2.-23.                               083550 0000
      UCM=14.+0.15*WREIN/VL                                              083560 0000
C     ******************************************************************083570 0000
C                                                                        083580 0000
  400 CONTINUE                                                           083590 0000
```

(Continued)

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C     CALCULATE LINING COSTS                                                083600 0000
      IF(LINING.EQ.2) UCLMH=0.                                              083610 0000
      IF(ITYPE.EQ.1)CLL=(HOURS*CFLWWK+Y*DM)/AL*UCL+HOURS*CFLWWK*UCLMH/AL   083620 0000
      IF(ITYPE.EQ.2) CLL=HOURS*UCL*CFLWWK/AL                                083630 0000
      CEL=HOURS*CFEWWK*UCE/AL                                               083640 0000
      CML=VL*UCM                                                            083650 0000
C     ----------------------------------------                              083660 0000
      IF(II.GE.3) GO TO 525                                                 083670 0000
      IF(II.GE.2) GO TO 500                                                 083680 0000
C     STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=40                   083690 0000
      CL40=CLL                                                              083700 0000
      CE40=CEL                                                              083710 0000
      CM40=CML                                                              083720 0000
C     REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF           083730 0000
C     INTERPOLATION COMPUTATION                                             083740 0000
      RQD=60                                                                083750 0000
      BOB=BOB60                                                             083760 0000
C     REDEFINE FLOW INDICATOR                                               083770 0000
      II=II+1                                                               083780 0000
      GO TO 30                                                              083790 0000
C     ------------------------------------------------------------------    083800 0000
C                                                                           083810 0000
C     STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=60                   083820 0000
  500 CL60=CLL                                                              083830 0000
      CE60=CEL                                                              083840 0000
      CM60=CML                                                              083850 0000
C     INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN LINING COSTS           083860 0000
      CLL=CL40+(RQDD-40.)/20.*(CL60-CL40)                                   083870 0000
      CEL=CE40+(RQDD-40.)/20.*(CE60-CE40)                                   083880 0000
      CML=CM40+(RQDD-40.)/20.*(CM60-CM40)                                   083890 0000
C     ------------------------------------------------------------------    083900 0000
C     REINSTATE ORIGINAL VALUES OF RQD AND BOB                              083910 0000
      RQD=RQDD                                                              083920 0000
      BOB=BBOB                                                              083930 0000
C     ------------------------------------------------------------------    083940 0000
C     UNIT COST OF FORMWORK EQUALS ZERO FOR SHOTCRETE                       083950 0000
  525 IF(LINING.EQ.2) GO TO 2                                               083960 0000
C     LINING IS CONCRETE. CHECK FOR SUPPRESSED FORMWORK COSTS               083970 0000
      IF(NOFORM.GT.0) GO TO 2                                               083980 0000
      IF(ITYPE.EQ.2) GO TO 550                                              083990 0000
C     UNIT COST OF FORMWORK IN TUNNELS                                      084000 0000
      UCL=9.*BF*CFLCA                                                       084010 0000
      IF(ISHAPE.EQ.1) X=2.2                                                 084020 0000
      IF(ISHAPE.EQ.2) X=2.0                                                 084030 0000
      IF(ISHAPE.EQ.3) X=1.6                                                 084040 0000
      UCE=15.+X*BF                                                          084050 0000
      UCM=0.18*BF                                                           084060 0000
      AL=3.*HOURS                                                           084070 0000
      IF(NSTYP.EQ.2) AL=AR                                                  084080 0000
      GO TO 700                                                             084090 0000
C     UNIT COST OF FORMWORK IN SHAFTS                                       084100 0000
  550 IF(ISHAPE.EQ.1) SFP=3.14                                              084110 0000
      IF(ISHAPE.EQ.2) SFP=4.                                                084120 0000
      UCL=25.+4.*BF                                                         084130 0000
      UCE=(10.+1.5*BF)*SFP/3.14                                             084140 0000
      UCM=0.7*BF                                                            084150 0000
      AL=2.*HOURS                                                           084160 0000
      GO TO 700                                                             084170 0000
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C     COMPUTE FORMWORK COSTS                                            084180 0000
  700 CLFW=(HOURS*CFLWWK+Y*DM)*UCL/AL                                   084190 0000
      CEFW=HOURS*CFEWWK*UCE/AL                                          084200 0000
      CMFW=UCM                                                          084210 0000
      GO TO 1000                                                        084220 0000
C     ***********************   CUT AND COVER   ************************ 084230 0000
  910 IF(ITYPE.EQ.2) GO TO 940                                          084240 0000
C     TUNNEL                                                            084250 0000
      IF(LINING.EQ.3) GO TO 930                                         084260 0000
C     ------------------------------------------------------------------ 084270 0000
C     CIP BOX                                                           084280 0000
      UCL=480.-0.075*(70.-VL)**2                                        084290 0000
      UCE=55.-0.008*(65.-VL)**2                                         084300 0000
      UCM=26.*VL                                                        084310 0000
      HOURCR=VL  *AR/(110.-0.03*(VL  -60.)**2)                          084320 0000
      IF(HOURCR.LT.8.) HOURCR=8                                         084330 0000
      CLL=UCL*HOURCR/AR*CFLWWK                                          084340 0000
      CEL=UCE*HOURCR/AR*CFEWWK                                          084350 0000
      CML=UCM                                                           084360 0000
      HOURCR=FORMAR*AR/(680.-0.004*(FORMAR-400.)**2)                    084370 0000
      IF(HOURCR.LT.8) HOURCR=8                                          084380 0000
      CLFW=(100.+0.85*FORMAR)*HOURCR/AR*CFLWWK                          084390 0000
      CEFW=(8.+(FORMAR+100.)**2/4500.)*HOURCR/AR*CFEWWK                 084400 0000
      CMFW=0.35*FORMAR                                                  084410 0000
      RETURN                                                            084420 0000
C     ------------------------------------------------------------------ 084430 0000
C     PRECAST CONCRETE BOX                                              084440 0000
  930 UCL=(0.07*(VL  +10.)**2-7.)*50./VL                                084450 0000
      UCE=(0.007*(VL  +80.)**2-45.)*50./VL                              084460 0000
      UCM=104.*VL                                                       084470 0000
      HOURCR=VL*AR/50.                                                  084480 0000
      IF(HOURCR.LT.8.) HOURCR=8                                         084490 0000
      CLL=UCL*HOURCR/AR*CFLWWK                                          084500 0000
      CEL=UCE*HOURCR/AR*CFEWWK                                          084510 0000
      CML=UCM                                                           084520 0000
      GO TO 2                                                           084530 0000
C     ------------------------------------------------------------------ 084540 0000
C     SHAFT                                                             084550 0000
  940 IF(ISHAPE.EQ.2) GO TO 945                                         084560 0000
      SFP=3.14                                                          084570 0000
      GO TO 950                                                         084580 0000
  945 SFP=4                                                             084590 0000
  950 VL=(BF+TL)*TL*SFP/27.                                             084600 0000
      UCL= 0.07*(VL  +10.)**2-7.                                        084610 0000
      UCE= 0.007*(VL  +80.)**2-45.                                      084620 0000
      UCM=104.*VL                                                       084630 0000
      CLL=UCL*CFLWWK                                                    084640 0000
      CEL=UCE*CFEWWK                                                    084650 0000
      CML=UCM                                                           084660 0000
      GO TO 2                                                           084670 0000
 1000 RETURN                                                            084680 0000
      END                                                               084690 0000
      SUBROUTINE CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPE,BE,AR,RS,NSTYP,     084700 0000
     1MSTAB,    DTUN,HH,HOURS,CFLWWK,CFEWWK,SSEGL,PERM,SFP,DTG,TIMEG)   084710 0000
C     ------------------------------------------------------------------ 084720 0000
C     ------------------------------------------------------------------ 084730 0000
C     ------------------------------------------------------------------ 084740 0000
C     CGROUT CALCULATES THE COST OF GROUTING IN A TUNNEL OR SHAFT        084750 0000
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C     SEGMENT                                                           084760 0000
C     ----------------------------------------------------------------- 084770 0000
C     ----------------------------------------------------------------- 084780 0000
C                                                                       084790 0000
      IF(NSTYP.EQ.2) GO TO 500                                          084800 0000
      IF(NSTYP.EQ.3) GO TO 650                                          084810 0000
C     ***************************   ROCK   ***************************** 084820 0000
      IF(ITYPE.EQ.2) GO TO 300                                          084830 0000
C     ----------------------------------------------------------------- 084840 0000
C     TUNNEL                                                            084850 0000
      IF(GI.GE.100.) GO TO 150                                          084860 0000
C     COST OF GROUTING EQUALS ZERO                                      084870 0000
  100 CLG=0                                                             084880 0000
      CEG=0                                                             084890 0000
      CMG=0                                                             084900 0000
      RETURN                                                            084910 0000
  150 IF(ISHAPE.EQ.1) SFP=3.14                                          084920 0000
      IF(ISHAPE.EQ.2) SFP=3.57                                          084930 0000
      IF(ISHAPE.EQ.3) SFP=2.66                                          084940 0000
      GT=0.005*SFP*BE*(1.+.01*GI)                                       084950 0000
      GO TO 400                                                         084960 0000
C     ----------------------------------------------------------------- 084970 0000
C     SHAFT                                                             084980 0000
  300 IF(GI.LT.1.) GO TO 100                                            084990 0000
C     SHAFT IS WET,GROUTING REQUIRED                                    085000 0000
      SFP=3.14                                                          085010 0000
      GT=0.01*SFP*BE                                                    085020 0000
  400 CONTINUE                                                          085030 0000
      HL=SFP*BE/4.                                                      085040 0000
      UCL=0                                                             085050 0000
      UCE=33.-0.015*(BE-46.)**2                                         085060 0000
      UCM=1.25*GT+RS*HL/200000.+0.075*HL-0.05*(BE-46.)**2/AR+100./AR    085070 0000
      GO TO 1000                                                        085080 0000
C                                                                       085090 0000
C     ***********************   SOFT GROUND   ************************** 085100 0000
C     IS IT A SHAFT                                                     085110 0000
  500 IF(ITYPE.EQ.2) GO TO 640                                          085120 0000
C     ----------------------------------------------------------------- 085130 0000
C     TUNNEL                                                            085140 0000
C     STABILIZED BY GROUND INJECTIONS                                   085150 0000
      IF(MSTAB.EQ.3) GO TO 550                                          085160 0000
      GO TO 650                                                         085170 0000
C     IS TUNNEL CROWN DEEPER THAN 50 FT                                 085180 0000
  550 IF(ISHAPE.LE.2.AND. DTUN-BE/2..GT.50.) GO TO 600                  085190 0000
      IF(ISHAPE.EQ.3 .AND. DTUN-BE/4..GT.50.) GO TO 600                 085200 0000
C     GROUTING FROM GROUND SURFACE                                      085210 0000
      TIMEQ=0.6+DTUN/20.+BE/40.                                         085220 0000
      IF(ISHAPE.EQ.3) TIMEQ=0.6+DTUN/20.+BE/80.                         085230 0000
      UCL=79.*(BE+10.)/25.*TIMEQ*AR/HOURS                               085240 0000
      UCE=15.*(BE+10.)/25.*TIMEQ*AR/HOURS                               085250 0000
      UCM=3.*TIMEQ*(BE+10.)/25.+0.25*(BE+10.)**2*(0.55+0.15*ALOG10(SQRT 085260 0000
     1(10.*ABS(PERM))))/(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))         085270 0000
      IF(ISHAPE.EQ.3) UCM=3.*TIMEQ*(BE+10.)/25.+0.25*(BE+10.)*(0.5*BE+  085280 0000
     110.)*(0.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))/(1.55+0.15*ALOG10(SQ 085290 0000
     2RT(10.*ABS(PERM))))                                               085300 0000
      GO TO 1000                                                        085310 0000
C     GROUTING FROM EXCAVATION FACE                                     085320 0000
  600 UCL=0                                                             085330 0000
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      UCE=3.4*BE                                                        085340 0000
      UCM=0.14*BE+0.8*(0.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))/          085350 0000
     1(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))*BE*SFP                    085360 0000
      GO TO 1000                                                        085370 0000
C     ------------------------------------------------------------------085380 0000
C     SHAFT                                                             085390 0000
C     STABILIZED BY GROUND INJECTIONS                                   085400 0000
  640 IF(MSTAB.EQ.3) GO TO 700                                          085410 0000
  650 CLG=0.                                                            085420 0000
      CEG=0.                                                            085430 0000
      CMG=0.                                                            085440 0000
      RETURN                                                            085450 0000
C     IS SEGMENT MIDPOINT DEEPER THAN 200 FT                            085460 0000
  700 IF(HH.GT.200.) GO TO 600                                          085470 0000
C     GROUTING FROM GROUND SURFACE                                      085480 0000
      UCL=79.*TIMEG*(BE+5.)*SFP/5./DTG*AR/HOURS                         085490 0000
      UCE=15.*TIMEG*(BE+5.)*SFP/5./DTG*AR/HOURS                         085500 0000
      UCM=0.6*TIMEG*(BE+5.)*SFP/DTG+0.64*(0.55+0.15*ALOG10(SQRT(10.*ABS 085510 0000
     1(PERM))))*(BE+5.)*SFP/(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))     085520 0000
C     ------------------------------------------------------------------085530 0000
C     COST OF GROUTING                                                  085540 0000
 1000 CLG=UCL*HOURS*CFLWWK/AR                                           085550 0000
      CEG=UCE*HOURS*CFEWWK/AR                                           085560 0000
      CMG=UCM                                                           085570 0000
      RETURN                                                            085580 0000
      END                                                               085590 0000
      SUBROUTINE CPUMP(CLP,CEP,CMP,NSTYP,FLOW,PH,PIPL,AR,               085600 0000
     1ITYPE,ELSURF,ELBOTM,DAYS,LINING,PUMPTM,MEX,DTRNCH,DROCK,FLOWL,    085610 0000
     2WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPB,IWATER,CFLWWK,CFEWWK)         085620 0000
C     ------------------------------------------------------------------085630 0000
C     ------------------------------------------------------------------085640 0000
C     CPUMP CALCULATES THE PUMPING COSTS                                085650 0000
C     PUMPING TIME COMPUTED IN COSTSF IS FOR SOFT GROUND SHAFT ONLY     085660 0000
C     ASSUME PUMPING 24 HR A DAY , 7 DAYS A WEEK OPERATION              085670 0000
C     ------------------------------------------------------------------085680 0000
C     ------------------------------------------------------------------085690 0000
C                                                                       085700 0000
      IF(NSTYP.EQ.3) GO TO 300                                          085710 0000
C     ROCK OR SOFT GROUND                                               085720 0000
      IF(NSTYP.EQ.2) GO TO 100                                          085730 0000
C     ------------------------------------------------------------------085740 0000
C     ROCK                                                              085750 0000
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(Continued)

```
C     SET COSTS=0
      UCL=0.
      UCE=0.
      UCM=0.
      GO TO 800
C     ------------------------------------------------------------------
C     DEEP WELL PUMPING
C     ------------------------------------------------------------------
C     SOFT GROUND
  100 IF(ITYPE.EQ.2) GO TO 250
C     ------------------------------------------------------------------
C     TUNNEL
      WELLLN=ELSURF-ELBOTM
C     PROVIDE 5 DAYS PUMPING AHEAD OF EXCAVATION TO REVERSE FLOW
C     PROVIDE 50 FT FINISHED LINING PAST PUMP BEFORE STOPPING ITEM
      IF(ISUPPT.LE.3) GO TO 180
C     STEEL RIBS WITH LINING
C     PROVIDE THE GREATER OF TIME TO FINISH 50 FT LINING AHEAD OF PUMP,
C     OR 30 CALENDAR DAYS FOR CURING OF CONCRETE
C     SHOTCRETE IS PLACED UP TO THE FACE.  CONCRETE IS KEPT 150 FT
C     BEHIND FACE.
      IF(50./AR*7./DAYS.GE.30.) GO TO 150
C     ------------------------------------------------------------------
C     PUMPING TIME CONTROLLED BY CURING TIME
C     CONCRETE
      IF(LINING.EQ.1) PUMPTM=35.+150./AR*7./DAYS
C     SHOTCRETE
      IF(LINING.EQ.2) PUMPTM=35.
      GO TO 450
C     ------------------------------------------------------------------
C     PUMPING TIME CONTROLLED BY PLACING RATE OF LINING
C     CONCRETE
  150 IF(LINING.EQ.1) PUMPTM=5.+200./AR*7./DAYS
C     SHOTCRETE
      IF(LINING.EQ.2) PUMPTM=5.+50./AR*7./DAYS
      GO TO 450
C     SEGMENTED SUPPORT
  180 PUMPTM=5.+50./AR*7./DAYS
      GO TO 450
C     ------------------------------------------------------------------
C     SHAFT
  250 IF(ELWATR.LT.ELNPB) GO TO 950
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```
C     PUMPING TIME DETERMINED IN COSTSF                                 086180 0000
      WELLS=3                                                           086190 0000
C     NO WELLS IF FLOW=0                                                086200 0000
      IF(FLOWL.LT.0.0001) WELLS=0                                       086210 0000
C     CONSIDER 1 FT LENGTH OF SHAFT                                     086220 0000
      WELLLN=1                                                          086230 0000
      GO TO 450                                                         086240 0000
C     ----------------------------------------------------------------- 086250 0000
C     CUT-AND-COVER                                                     086260 0000
  300 IF(ITYPE.EQ.2) GO TO 950                                          086270 0000
C     TUNNEL                                                            086280 0000
      IF(ELWATR.LT.ELSURF-DTRNCH) GO TO 950                             086290 0000
      IF(IWATER.EQ.0) GO TO 900                                         086300 0000
C     IS IT SOLDIER PILE WITH LAGGING                                   086310 0000
      IF(ISUPPT.EQ.5) GO TO 350                                         086320 0000
      IF(DROCK.LT.DTRNCH .AND. ELWATR.LT.ELSURF-DROCK) GO TO 950        086330 0000
      GO TO 400                                                         086340 0000
C     IS ROCK LINE ABOVE TRENCH BOTTOM                                  086350 0000
  350 IF(DROCK.LT.DTRNCH) GO TO 900                                     086360 0000
  400 PUMPTM=(1./AR+(TIMEDW+10.)/RL)*7./DAYS                            086370 0000
      IF(LINING.EQ.1) PUMPTM=(1./AR+(TIMEDW+40.)/RL)*7./DAYS            086380 0000
      WELLLN=DTRNCH                                                     086390 0000
      IF(WELLLN.GT.DROCK) WELLLN=DROCK                                  086400 0000
  450 PIPED=0.5*FLOWL**0.4                                              086410 0000
      IF(PIPED.LT.1.) PIPED=1                                           086420 0000
C     SETUP COST OF DEEP WELLS                                          086430 0000
      UCL=(0.4*PIPED+3.2)*WELLLN*WELLS*AR/24.*DAYS/7.*CFLWUK/1.12       086440 0000
      UCE=(0.15*PIPED+1.)*WELLLN*WELLS*AR/24.*DAYS/7.*CFEWUK/0.715      086450 0000
      UCM=(0.75*PIPED+3.)*WELLLN*WELLS*AR/24.*DAYS/7.                   086460 0000
C     OPERATING COST OF DEEP WELLS                                      086470 0000
      UCL=UCL+0.85*WELLS*PUMPTM*AR*DAYS/7.                              086480 0000
      UCE=UCE+0.000265*FLOWL*PH*(0.0026+7./(2000.+0.000265*FLOWL*PH))*  086490 0000
     1WELLS*PUMPTM*AR*DAYS/7.                                           086500 0000
      UCM=UCM+5.*PH*FLOWL/1000000.*WELLS*PUMPTM*AR*DAYS/7.              086510 0000
C     SETUP                                                             086520 0000
C     IS IT CUT-AND-COVER                                               086530 0000
      IF(NSTYP.EQ.3) GO TO 1000                                         086540 0000
C     SOFT GROUND                                                       086550 0000
      IF(ITYPE.EQ.2) GO TO 1000                                         086560 0000
C     ----------------------------------------------------------------- 086570 0000
C     PUMPING FROM TUNNEL                                               086580 0000
C     ----------------------------------------------------------------- 086590 0000
```

(Continued)

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C     ------------------------------------------------------------------
  800 IF(FLOW.GT.0.) GO TO 850
C     NO COST IF FLOW IS ZERO
      GO TO 1000
  850 IF(PH.LE.0.) GO TO 1000
      UCL=UCL+5.+11.*PH/3000.+0.003*PIPL
      UCE=UCE+(0.25+PH/2000.)*FLOW/500.
      UCM=UCM+5.*PH/1000.*FLOW/1000.
      GO TO 1000
C     ------------------------------------------------------------------
C     SUMP PUMPING
C     ------------------------------------------------------------------
  900 PUMPTM=(1./AR+10./RL)*7./DAYS
      IF(LINING.EQ.1) PUMPTM=(1./AR+40./RL)*7./DAYS
      UCL=5.*PUMPTM/500.*AR*DAYS/7.
      UCE=0.4*PUMPTM/500.*AR*DAYS/7.
      UCM=(0.15+0.0000044*PH*FLOWL)*PUMPTM/500.*AR*DAYS/7.
      GO TO 1000
C     SHAFT
  950 CLP=0.
      CEP=0.
      CMP=0.
      RETURN
C     ------------------------------------------------------------------
C     CALCULATE PUMPING COSTS
 1000 CLP=UCL*24/AR*7./DAYS*1.12
      CEP=UCE*24./AR*7./DAYS*0.715
      CMP=UCM*24./AR*7./DAYS
      RETURN
      END
      SUBROUTINE CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NSTYP,MSTAB,
     1    ITYPE,AIRPR,    SFA,ISHAPE,HH,CAVT,ALOCK,DTC,DTCA,PUMPLT,DM,
     2          ALOCKL,UCMCP,CFLWWK,CFEWWK,DAYS,Y,PERM)
C     ------------------------------------------------------------------
C     CAIRC COMPUTES THE COSTS OF VENTILATIOM, AIR COOLING,
C     COMPRESSED AIR, AND AIR LOCKS
C     ------------------------------------------------------------------
      IF(NSTYP.EQ.3) GO TO 400
      IF(NSTYP.EQ.1) GO TO 50
      D10=SQRT(10.*ABS(PERM))
      IF(D10.LT.0.005) D10=0.005
C     SHAFT OR TUNNEL
   50 IF(ITYPE.EQ.2) GO TO 300
C     ***************************   TUNNELS   ************************
C     CHECK COOLING REQUIREMENT
      IF(Q.GT.0.) GO TO 100
C     NO COOLING
      UCLC=0.
      UCLMC=0.
      UCEC=0.
      UCMC=0.
      GO TO 200
C     COST OF SETUP AND OPERATION OF COOLING PLANT
  100 IF(ALOCK.GT.0.) UCLMC=QT*ALOCK/48.
      IF(ALOCK.LT.0.) UCLMC=QT*(1.-ALOCK)/48.
      UCLC=8.20
      UCEC=0.0000013*QT
      UCMC=0.0000009*Q
```

(Continued)

```
C     ------------------------------------------------------------------
  200 IF(MSTAB.NE.1) GO TO 60
C     COMPRESSED AIR
      CAV=(28.5+10.*ALOG10(D10))*SFA*BE**2
      ALOKA=ABS(ALOCK)
      UCLCA=16.4
C     COSTS OF AIR LOCK AND SETUP
      UCLLKA=20.4
      UCLLOK=(38000.+3.*HH)*(1.+0.25*(ALOKA-1.))
      UCELOK=(10000.+0.8*HH)*(1.+0.25*(ALOKA-1.))
      ALOCKD=BF
      IF(ISHAPE.EQ.3) ALOCKD=0.5*BF
      IF(ALOCKD.GT.15.) ALOCKD=15.
      IF(ALOCKL.LT.30.) ALOCKL=30.
      WALOCK=16.*ALOCKD*(ALOCKL+ALOCKD)
      VBULK=5.*(SFA*BF**2-0.785*ALOCKD**2)/27.
      UCMLOK=(1200.+0.1*HH)*(1.+0.25*(ALOKA-1.))+140.*VBULK*ALOKA
C     COST OF COMPRESSED AIR PLANT, SETUP AND OPERATION
      UCLMCA=0.075*(30000.+14.4*CAVT)*ALOKA
      UCECA=2.3+0.0011*CAVT
      UCMCA=0.003*CAV*(((AIRPR+14.7)/14.7+0.000123*PUMPLT)**0.242-1.)
      CLAC=(UCLLKA*HOURS/AR+UCLMC/DTC+(UCLMCA+UCLLOK)/DTCA)*CFLWWK
     1 +(UCLCA +UCLC)*24./AR*7./DAYS*1.12
      CEAC= (UCEC+UCECA)*24./AR*7./DAYS*0.715+UCELOK/DTCA*CFEWWK
      CMAC=(UCMC+UCMCA)*24./AR*7./DAYS+UCMCP+UCMLOK/DTCA
     1 +0.000015*WALOCK*HOURS/AR
      GO TO 500
C     ------------------------------------------------------------------
C     CALCULATE UNIT COSTS OF VENTILATION
   60 UCLV=3.*DM
      UCEV=0.5+0.625*SFA*BE**2/1000.
      UCMV=3.3*SFA*BE**2*DM/1000.
      UCMDFV=3.+SFA*BE**2/200.
      CLAC=UCLV*(HOURS*CFLWWK+0.5*Y*DM)/AR
      IF(DTC.GT.0.) CLAC=CLAC+(UCLMC/DTC+HOURS*UCLC/AR/4.)*CFLWWK
      CEAC=(UCEV+UCEC*HOURS/AR/4.)*CFEWWK
      CMAC=UCMDFV+HOURS*UCMV/AR+UCMC*HOURS/AR/4.
      GO TO 500
C     ****************************   SHAFTS   ***************************
C     COMPRESSED AIR AND COOLING COSTS
  300 IF(NSTYP.EQ.1.OR.MSTAB.NE.1) GO TO 400
      CAV=(28.5+10.*ALOG10(D10))*SFA*BE**2
      Q=75.*CAV+20.*SQRT(CAV)+5000.
      UCLCA=8.20
      UCEC=0.0000013*Q
      UCECA=2.3+0.0011*CAV
      UCMC=0.0000009*Q
      UCMCA=0.003*CAV*(((AIRPR+14.7)/14.7+0.0025)**0.242-1.)
      CLAC=UCLCA*24./AR*1.12
      CEAC=(UCEC+UCECA)*24./AR*0.715
      CMAC=(UCMC+UCMCA)*24./AR
      GO TO 500
  400 CLAC=0.
      CEAC=0.
      CMAC=0.
C     ------------------------------------------------------------------
  500 RETURN
      END
```

(Continued)

```
      SUBROUTINE NEXSET(LO,LI)                                          087750 0000
      DIMENSION A(4),B(4)                                               087760 0000
      DATA A/4HEND ,4HOF S,4HYSTE,4HM                                   087770 0000
      WRITE(LO,1) A                                                     087780 0000
    5 READ(LI,2) B                                                      087790 0000
      DO 10 I=1,4                                                       087800 0000
      IF(A(I).NE.B(I)) GO TO 5                                          087810 0000
   10 CONTINUE                                                          087820 0000
      RETURN                                                            087830 0000
    1 FORMAT(1H1,4A4)                                                   087840 0000
    2 FORMAT(4A4)                                                       087850 0000
      END                                                               087860 0000
      SUBROUTINE ROCK(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,
     1ITYPE,Y,NSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTCTAL,BOB,LINUT,
     2MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,SFA,LINING,DM,CLL,CEL,CML,
     3CLFW,CEFW,CMFW)
 1010 SFP=3.14
      YY=0.0
      S=4.0
      Y3=1.0
      UCL=Y3*(50.+.04*BE**2)
      UCE=Y3*(5.5+.003*(BE+10.)**2)
      UCM=Y3*(2.1+.001*BE**2)*HOURS/AR+YY
 1260 SEGN=3.
 1270 CJOINT=BE*SFP/S+SEGN
      UCL=UCL+.175*CJOINT*AR/HOURS
      UCE=UCE+.025*CJOINT*AR/HOURS
      UCM=UCM+.3*CJOINT
      VBACKG=SFA*(BE**2-(BE-.333)**2)
      UCL=UCL+1.3*VBACKG*AR/HOURS
      UCE=UCE+.5*VBACKG*AR/HOURS
      UCM=UCM+1.2*VBACKG
      CLTS=(HOURS*CFLWWK+Y*DM)*UCL/AR
      CETS=HOURS*CFEWWK*UCE/AR
      CMTS=UCM
      CLL=0.0
      CEL=0.0
      CML=0.0
      CLFW=0.0
      CEFW=0.0
      CMFW=0.0
      RETURN
      END
```

(Concluded)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Bennett, Robert D.
Tunnel cost-estimating methods / by Robert D. Bennett (Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.
238 p. in various pagings : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; GL-81-10)
Cover title.
"October 1981."
Final report.
"Prepared for Office, Chief of Engineers, U.S. Army under Project 4A762719AT40, Work Unit E0/005."
References: p. 50-52.

1. Cost. 2. Cost effectiveness. 3. Tunnels. I. United States. Army. Corps of Engineers. Office of the Chief of Engineers. II. U.S. Army Engineer Waterways Experiment Station. Geotechnical Laboratory. III. Title IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; GL-81-10.
TA7.W34m no.GL-81-10

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