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# TUNNEL COST-ESTIMATING METHODS

by

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Final Report

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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.

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## 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

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\* 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 ESTIMATING 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 Ground 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  $\pm$  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

$$P(\text{SHALE } 1) = 0.2$$

$$P(\text{SANDSTONE } 1) = 0.8$$

$$P(\text{SANDSTONE } 2) = 0.6$$

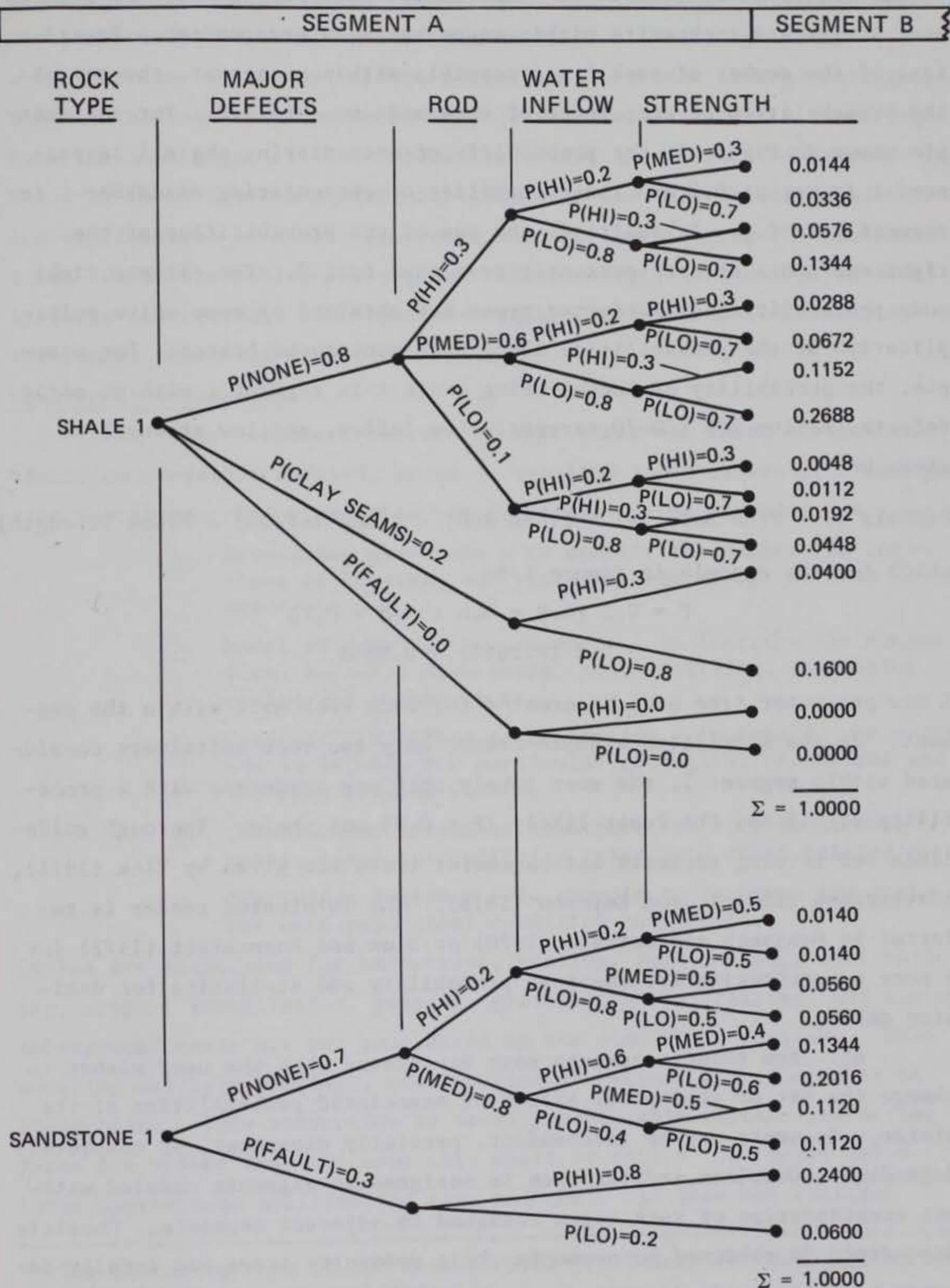


Figure 1. TCM parameter tree

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

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\* 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

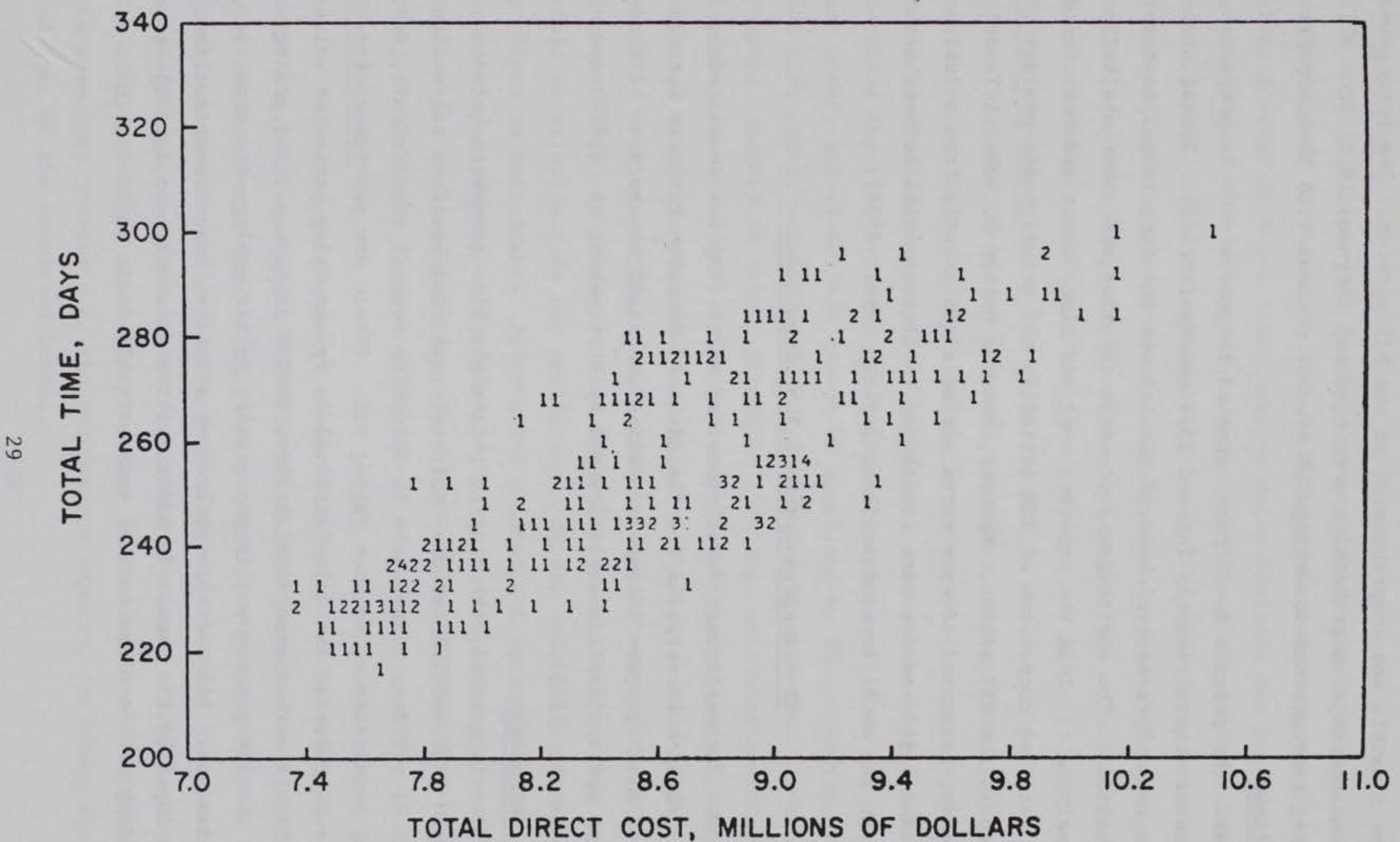


Figure 2. Scattergram: results of 300 tunnel simulations  
(from Moavenzadeh et al. 1974)

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 bored 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  $\pm$  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  $\pm$  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	TOH	TM	TSC/PMA
Applications:	<ul style="list-style-type: none"> <li>-Tunnels and shafts</li> <li>-Circular, horseshoe, basket-handle, or cut-and-cover box</li> <li>-Finished cross sections from 10 to 40 ft</li> <li>-Rock, soft ground, cut and cover</li> <li>-Excavation by mole, drill and blast; shield w/ripper, mole, or hand except in soft ground</li> </ul>	<ul style="list-style-type: none"> <li>-Tunnels, shafts, adits, caverns</li> <li>-Any shape, size</li> <li>-Rock only</li> <li>-Any excavation method</li> </ul>	<ul style="list-style-type: none"> <li>-Tunnels only</li> <li>-Any shape, size</li> <li>-Rock only</li> <li>-Full-face excavation by mole or drill and blast</li> </ul>	<ul style="list-style-type: none"> <li>-Soft ground only</li> <li>-Transit tunnels and stations</li> <li>-Excavation and lining only</li> </ul>
Operation:	<ul style="list-style-type: none"> <li>-Fortran IV, Honeywell GE635, Univac/108</li> </ul>	<ul style="list-style-type: none"> <li>-PL/I, IBM Machine Language I, IBM 370/168</li> </ul>	-	<ul style="list-style-type: none"> <li>-Wang 2200, data storage on discs</li> </ul>
Philosophy:	<ul style="list-style-type: none"> <li>-Preprogrammed standard designs keyed to geological input data for support, lining, dewatering, ventilation, etc.</li> <li>-Advance rate, other calculations based on empirical equations</li> <li>-Computed values may be overridden by user-supplied values for advance rate, lining thickness, stabilization methods, etc.</li> <li>-Uses fixed, user-input geology profile</li> <li>-Most representative of models studied to actual estimating procedures used in industry by owners and engineers</li> <li>-User need not be tunnel expert</li> <li>-Profit, overhead, adjustments for inflation of costs are input by user</li> <li>-Considers any geology</li> <li>-Alternatives can be evaluated</li> <li>-Cost adjustment factors used for labor, materials, equipment, and regional productivity differences</li> </ul>	<ul style="list-style-type: none"> <li>-Probabilistic geology model. User defines parameters to describe each rock unit, with associated probabilities of occurrence</li> <li>-All factors affecting tunnel construction must be input by user. Requires very detailed input. Model has no design capability</li> <li>-Breaks costs down to cycle level of operations</li> <li>-Tunnel simulator models uncertainty in construction operations</li> <li>-Very flexible but requires user with extensive background in tunneling, estimating, and statistical modeling</li> <li>-Contingency costs not considered. Modeling of uncertainty replaces it</li> <li>-Statistical inferences of best case, worst case, and expected cost and time, standard deviation, etc., can be easily made</li> </ul>	<ul style="list-style-type: none"> <li>-User input fixed 2-D or 3-D geology file</li> <li>-Very detailed input for construction method, equipment, crew, etc.</li> <li>-Advance rate calculated by model</li> <li>-Quantities and costs of all construction inputs calculated on per foot basis; user supplies unit cost of materials, labor, and equipment</li> </ul>	<ul style="list-style-type: none"> <li>-Program consists of 2 main data bases</li> <li>-Data Bank 1 describes units of effort required for each construction operation modeled</li> <li>-Data Bank 2 is a unit cost file, based on Washington, D. C., costs for 1976</li> <li>-Data Banks were based on analysis of 20 tunnels built in United States in last 10 years</li> <li>-Adjustments may be made to Data Banks for inflation, regional differences, etc.</li> <li>-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</li> </ul>
Output:	<ul style="list-style-type: none"> <li>-Calculated tunnel and shaft data cost and time summaries</li> </ul>	<ul style="list-style-type: none"> <li>-Progress reports of resources used versus time and progress</li> <li>-Scattergram of cost versus time. Each plotted point represents one tunnel estimate</li> <li>-Optional cost/time summaries for user-selected profiles</li> </ul>	<ul style="list-style-type: none"> <li>-Progress reports and cost reports at user-specified time intervals, including time and cost of completed tunnel</li> </ul>	<ul style="list-style-type: none"> <li>-List of input data, and detailed cost and time summaries for modeled construction operations and direct, indirect, and total project costs</li> <li>-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</li> </ul>
Advantages/ Disadvantages:	<ul style="list-style-type: none"> <li>-Rather simplistic parametric relationships between geology and support design</li> <li>-Based on static technology/costs</li> <li>-Aboveground costs not considered</li> <li>-No treatment of uncertainty</li> <li>-Unsuitable for small projects</li> </ul>	<ul style="list-style-type: none"> <li>-Very detailed input data requirements</li> <li>-Very large storage and computer time requirements</li> <li>-User must have in-depth knowledge of tunneling, estimating, probability, and statistics</li> <li>-Aboveground costs not considered</li> <li>-Validity of subjective probability subject to question</li> <li>-Results difficult to interpret</li> <li>-Only the reasonableness, rather than the accuracy, of solutions can be checked. User must thoroughly verify input data</li> </ul>	<ul style="list-style-type: none"> <li>-Very detailed input requirements</li> <li>-User must have in-depth knowledge of tunnel estimating</li> <li>-Aboveground costs not considered</li> <li>-Limited applications. Soft ground, cut and cover, heading and bench, etc., not considered</li> </ul>	<ul style="list-style-type: none"> <li>-Limited application. Considers only soft ground tunnels and stations. Can be used to advantage for comparison of alternatives</li> </ul>

Table 3  
Nast Tunnel Cost Estimates

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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

<u>Estimate No.</u>	<u>Total Cost</u> millions \$	<u>Cost, \$/ft</u>	<u>Comments</u>
Engineer 1	5.103	326	1. Engineer estimate 1 and Contractor bids 1-6 are for the drill and blast excavation schedule
Contractor 1	6.814	435	
Contractor 2	7.238	462	
Contractor 3	8.156	521	2. Engineer estimate 2 and Contractor bids 7-9 are for the mole excavation schedule
Contractor 4	7.983	510	
Contractor 5	8.355	534	
Contractor 6	8.381	535	
Contractor 7	6.763	432	3. COSTUN estimates are for mole excavation in good quality rock and conventional excavation in poor quality rock
Contractor 8	6.568	420	
Contractor 9	9.904	633	
Engineer 2	5.134	328	
COSTUN 1	7.089	453	4. In all estimates, costs not considered by COSTUN have been subtracted from the manual estimates for sake of comparison
COSTUN 2	7.535	481	
COSTUN 3	6.640	424	
COSTUN 4	8.264	528	
COSTUN 5	6.371	407	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
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	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
COSTUN (As-built)	7.691	491	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

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Table 4

Nast Tunnel COSTUN Estimates

Description	Labor	Equipment	Materials	Total	Total Constr. Time, days
Tunnel Cost, millions \$					
COSTUN 1 Best estimate of ex- pected conditions	4.738	1.118	1.233	7.089	985
COSTUN 2 Input rock strengths 25% higher than ex- pected strengths	5.094	1.165	1.276	7.535	1084
COSTUN 3 Input rock strengths 25% lower than ex- pected 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 thick- ness 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

<u>Estimate No.</u>	<u>Total Cost</u> millions \$	<u>Cost, \$/ft</u>	<u>Comments</u>
Engineer 1	53.991	1504	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
Contractor 1	65.513	1824	2. Contractor bid 2 for 20-ft-diam, circular-moled tunnel with cast-in-place concrete lining
Engineer 2	47.441	1321	3. Engineer estimate 3 and contractor bids 3-5 for 22-ft-diam, circular-moled tunnel with precast concrete segmental lining
Contractor 2	71.208	1983	4. Contractor bid 3 awarded the contract
Engineer 3	47.257	1316	5. COSTUN estimate 1 for 19-ft 6-in.-diam drill and blast tunnel
Contractor 3	44.940	1251	6. COSTUN estimate 2 for 20-ft-diam moled tunnel
Contractor 4	50.915	1418	7. COSTUN estimates 3-9 for 22-ft-diam moled tunnel with precast concrete segmental lining
Contractor 5	63.493	1768	8. COSTUN estimates 1-3 for most likely conditions known at bid time
COSTUN 1	51.641	1438	9. COSTUN estimate 4 - RQD increased 15 percent
COSTUN 2	53.841	1499	10. COSTUN estimate 5 - RQD decreased 15 percent
COSTUN 3	59.959	1670	11. COSTUN estimate 6 - UC strengths increased 25 percent
COSTUN 4	52.287	1456	12. COSTUN estimate 7 - UC strengths decreased 25 percent
COSTUN 5	75.130	2092	13. COSTUN estimate 8 - lining thickness increased 33 percent
COSTUN 6	72.054	2007	14. COSTUN estimate 9 - lining thickness increased 67 percent
COSTUN 7	49.581	1381	15. As-built cost does not include pending \$6-million claim
COSTUN 8	61.373	1709	16. In all manual estimates, costs not considered by COSTUN have been excluded for sake of comparison
COSTUN 9	62.826	1750	
As-built Cost	60.0	1671	
COSTUN (As-built)	61.474	1712	

Table 6

Buckskin Mountains Tunnel  
COSTUN Estimates

Estimate No.	Tunnel Cost, millions \$				Total Construction Time, days	Comments
	Labor	Equipment	Materials	Total		
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

Estimate No.	Tunnel	Total Cost, millions \$			Cost \$/ft Tunnel	Comments
		Inlet Shaft	Outlet Shaft	Total Project		
Engineer 1	20.916	0.770	1.100	22.786	2301	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
Contractor 1	24.885	1.800	3.000	29.685	2738	2. Engineer estimate 2, COSTUN estimate 11, and contractor bid 2 were for the mole excavation schedule with cast-in-place concrete lining
COSTUN 10	19.476	1.971	1.981	23.428	2143	3. Engineer estimate 3, contractor bids 3-10, and COSTUN estimates 1-9 were for the mole excavation schedule with precast concrete segmental lining
Engineer 2	17.977	0.770	1.100	19.847	1978	4. COSTUN estimate 1 represented costs for most likely conditions known at bid time
Contractor 2	14.096	3.500	3.000	20.596	1551	5. COSTUN estimate 2 increased RQD 15 percent
COSTUN 11	16.785	1.971	1.981	20.737	1847	6. COSTUN estimate 3 increased RQD 30 percent
Engineer 3	16.123	0.770	1.100	17.993	1774	7. COSTUN estimate 4 decreased RQD 15 percent
Contractor 3	11.829	1.500	4.000	17.329	1301	8. COSTUN estimate 5 decreased RQD 30 percent
Contractor 4	14.760	1.100	1.500	17.360	1624	9. COSTUN estimate 6 increased UC strengths 15 percent
Contractor 5	15.111	1.500	4.000	20.611	1662	10. COSTUN estimate 7 decreased UC strengths 15 percent
Contractor 6	14.293	3.500	3.000	20.793	1572	11. COSTUN estimate 8 increased lining thickness 33 percent
Contractor 7	18.270	1.050	3.400	22.720	2010	12. COSTUN estimate 9 increased lining thickness 67 percent
Contractor 8	17.689	1.000	2.600	21.289	1946	13. In all manual estimates, costs not considered by COSTUN have been subtracted for sake of comparison
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	14.453	1.971	1.981	18.405	1590	
(As-built)						

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 water-tight 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  $\phi$  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 pre-cast 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 con-  
veyor 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 de-  
fault 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. En-  
ter 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. En-  
ter 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. En-  
ter the select box option with codes 0 and 1 to be  
used for single-level and double-level box, respec-  
tively.

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

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\* 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  $\leq 0.0006$  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  $\geq 29$ .

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 mtl's 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 LENGTH 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 LENGTH. 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.

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
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.

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
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	--

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
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	--

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
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.

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

<u>Description</u>	Format Statement No.		
	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
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.

<u>Description</u>	Format Statement No.		
	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
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

<u>Description</u>	<u>Format Statement No.</u>	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
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

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

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 re-prints 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 ----- 000020 0000
C ***** DIMENSION ARRAY (2630) ***** 000030 0000
C COMMON /BASIC/ NSS,NTS 000040 0000
C COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE 000060 0000
C COMMON/F/ IERROR,ISTOP 000070 0000
C COMMON/G/ TUNLC,TUNEC,TUNMC,TUNTC 000075 0000
C -----
C WHENEVER THE DIMENSION OF 'ARRAY' IS CHANGED, THE VALUE OF MM 000090 0000
C BELOW MUST ALSO BE CHANGED TO THAT OF THE NEW DIMENSION OF 'ARRAY' 000100 0000
C MM=2630 000110 0000
C -----
C NSMAX=10 000120 0000
C NSSMAX=10 000130 0000
C NTRMAX=20 000140 0000
C NTSMAX=20 000150 0000
C NPMAX=NSSMAX+2*NTSMAX 000160 0000
C J1 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'A' ARRAY 000170 0000
C J2 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'B' ARRAY 000180 0000
C J3 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'CNP' ARRAY 000190 0000
C J4 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'SHAFT' ARRAY 000200 0000
C J5 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'TRDATA' ARRAY 000210 0000
C J6 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN CUMSL 000220 0000
C J1 = 1 000230 0000
C THE NUMERICAL COEFFICIENTS ON THE NEXT 5 LINES REPRESENT THE 000240 0000
C NUMBER OF ITEMS STORED IN THE A, B, CNP, SHAFT, AND TRDATA 000250 0000
C ARRAYS, RESPECTIVELY 000260 0000
C J2 = J1 + 68*NTSMAX 000270 0000
C J3 = J2 + 43*NSSMAX 000280 0000
C J4 = J3 + 23*NPMAX 000290 0000
C J5 = J4 + 23*NSMAX 000300 0000
C J6 = J5 + 23*NTRMAX 000310 0000
C LI=5 000320 0000
C LO=6 000330 0000
C -----
C THE MINIMUM REQUIRED SIZE OF 'ARRAY' IS J6+ NPMAX-1 000340 0000
C OR 74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX 000350 0000
C MINARR=74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX 000360 0000
C IF(MM.LT.MINARR) GO TO 500 000370 0000
C -----
C 10 IERROR=0 000380 0000
C READ(LI,1,END=600) TITLE,LIST,PM,OM,STABEG 000390 0000
C WRITE(LO,2) TITLE 000400 0000
C WRITE(LO,3) PM,OM 000410 0000
C WRITE(LO,4) 000420 0000
C CALL INPUT (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000430 0000
C 1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000440 0000
C IF(ISTOP.EQ.1) GO TO 10 000450 0000
C 140 CALL SFTSET (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000460 0000
C 1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000470 0000
C IF(ISTOP.EQ.1) GO TO 10 000480 0000
C CALL LENGTH (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000485 0000
C 1 ARRAY(J6),NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000490 0000
C -----
C PRINT OUT INPUT DATA FOR TUNNELS 000500 0000
C INITIALIZE 000510 0000
C -----
C 000520 0000
C 000530 0000
C 000540 0000

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(Continued)

## COSTUN Listing (Continued)

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

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(Continued)

COSTUN Listing (Continued)

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INTSMAX,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 0000
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 0000
CALL COSTSF (ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),      001010 0000
1NSSMAX,NPMAX,NSMAX,NTRMAX,NTSMAX)          001015 0000
CALL NEXSET(LO,L1)                          001020 0000
GO TO 10                                     001030 0000
C -----
C DIMENSION OF 'ARRAY' ARRAY LESS THAN MINIMUM REQUIRED DIMENSION, 001040 0000
C EXECUTION TERMINATED                         001050 0000
C 500 WRITE(LO,9) MM,MINARR                  001060 0000
C -----
1 FORMAT(10(16A4//),40I1,/ ,3F10.0)          001070 0000
2 FORMAT(1H1,10(/),15X,90(1H*),/,15X,1H*,88X,1H*,/,           001080 0000
110(15X,1H*,12X,16A4,12X,1H*,/),           001100 0000
2     15X,1H*,88X,1H*,/,15X,90(1H*))        001110 0000
3 FORMAT(/////,44X,32(1H*),/,           001120 0000
1 44X,1H*,22H PROFIT MARGIN .....F7.2,2H *,/,           001130 0000
2 44X,1H*,22H OVERHEAD MARGIN .....F7.2,2H *,/,           001140 0000
3 44X,32(1H*))                           001150 0000
4 FORMAT(1H1)                                001160 0000
9 FORMAT(1H1,/////,1X,131(1H*)//27X,78H***** EXECUTION OF 'COSTUN' S 001170 0000
1TOPPED BECAUSE OF ERROR IN MAINLINE PROGRAM *****//22X,           001180 0000
213HDIMENSION OF ,I7,68H GIVEN FOR 'ARRAY' IN MAINLINE PROGRAM IS L 001190 0000
3ESS THAN MINIMUM REQUIRED//22X, 13HDIMENSION OF ,I7,           001200 0000
429H.    ALL DATA DECKS IGNORED//1X,131(1H*))           001210 0000
C -----
C 600 CONTINUE                               001220 0000
STOP                                         001230 0000
END                                           001240 0000
SUBROUTINE INPUT(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 001250 0000
1NTRMAX)                                     001260 0000
C -----
C THE FOLLOWING DEFINES THE CONTENTS OF THE VARIOUS ARRAYS          001270 0000
C -----
C CNP(I,J) .... NODAL POINT ARRAY (I = NODAL POINT NUMBER)          001280 0000
C J = 1 STATIONING OF THE NODAL POINT                               001290 0000
C (CALCULATED IN SUB LENGTH)                                         001300 0000
C   - 2 ELEVATION OF THE NODAL POINT                                001310 0000
C A(I,J) ..... TUNNEL SEGMENT ARRAY (I = LOCATION OF SEGMENT IN 001320 0000
C 'A' ARRAY, J = AS BELOW)                                         001330 0000
C   ITEM J = 1 SEGMENT NUMBER = NTSEG                                001340 0000
C   2 NODAL POINT TO LEFT OF SEGMENT = NPL                         001350 0000
C   3 NODAL POINT TO RIGHT OF SEGMENT = NPR                        001360 0000
C   4 REACH NUMBER = NREACH                                         001370 0000
C   5 ROCK STRENGTH = RS OR JRS                                     001380 0000
C   6 R.Q.D. = RQD OR JRQD                                         001390 0000
C   7 EXCAVATION METHOD = MEX
C     (1=DRILL AND BLAST, 2=MOLE(ROCK),
C     3=MOLE(SOIL), 4=HAND,5=RIPPER
C     6=OPEN CUT(VERTICAL), 7=OPEN CUT
C     (SLOPING))                                              001400 0000
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## COSTUN Listing (Continued)

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

(Continued)

## COSTUN Listing (Continued)

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

TRDATA(I,J) . TUNNEL REACH DATA (I=REACH NUMBER)  
ITEM J = 1

(Continued)

## COSTUN Listing (Continued)

5	SEGMENT SEQUENCE NUMBER AT WHICH REAC	002640	0000
	EXCAVATION BEGINS = NRSEG1	002650	0000
6	NUMBER OF SEGMENTS IN REACH = NSEGS	002660	0000
	- INDICATES REACH GOES FROM RT TO L	002670	0000
	+ INDICATES REACH GOES FROM LF TO R	002680	0000
7	PEAK REACH MUCK REMOVAL RATE (CY/HR)	002690	0000
8	WORK HOURS PER DAY = HOURS	002710	0000
	- RMLMAX OR IPRML	002700	0000
9	WORK DAYS PER WEEK = DAYS	002720	0000
10	FOR ROCK OR SOFT GROUND -----	002730	0000
	NUMBER OF SHIELD SETUPS = SETUSH	002740	0000
	FOR CUT AND COVER -----	002750	0000
	NUMBER OF UNITS IN BOX WIDTH = NBOX	002760	0000
11	FOR ROCK OR SOFT GROUND -----	002770	0000
	NUMBER OF MOLE SETUPS = SETUPM	002780	0000
	FOR CUT AND COVER -----	002790	0000
	TOTAL FINISHED BOX WIDTH = BFBWDT	002800	0000
12	FOR ROCK OR SOFT GROUND -----	002810	0000
	NUMBER OF RIPPER SETUPS = SETUPR	002820	0000
	FOR CUT AND COVER -----	002830	0000
	TOTAL FINISHED BOX HEIGHT = BFBHT	002840	0000
13	DOUBLE BOX DESIGN = IBOX2	002850	0000
	(0 OR BLANK=NO, 1=DOUBLE BOX)	002860	0000
14	FOR ROCK OR SOFT GROUND -----	002870	0000
	TOTAL LENGTH IN COMPRESSED AIR = DTCA	002880	0000
	FOR CUT AND COVER -----	002890	0000
	DEWATERING TIME = TIMEDU	002900	0000
15	TOTAL LENGTH REQUIRING COOLING = DTC	002910	0000
16	MAX LENGTH OF CUT IN WHICH BACKFILL	002920	0000
	CANNOT BE PLACED = OPEN	002930	0000
17	TOTAL COST OF LABOR IN REACH = RCL	002940	0000
18	TOTAL COST OF EQUIP. IN REACH = RCE	002950	0000
19	TOTAL COST OF MATERIAL IN REACH = RCM	002960	0000
20	TOTAL COST OF REACH = RCT	002970	0000
21	MAX CC EXC VOL TO DISPOSAL = UDS	002980	0000
22	VOLUME OF CC BACKFILL FROM CURRENT	002990	0000
	EXCAVATION = UBACEX	003000	0000
23	VOLUME OF CC BACKFILL FROM PREVIOUS	003010	0000
	DISPOSAL = UBACDS	003020	0000
		003030	0000
B(I,J) .....	SHAFT SEGMENT ARRAY (I = LOCATION OF SEGMENT IN	003040	0000
'B' ARRAY, J = AS BELOW)		003050	0000
ITEM J=	1 SHAFT NUMBER = NSHAFT	003060	0000
	2 SHAFT SEGMENT NUMBER = NSSEG	003070	0000
	3 UPPER NODAL POINT OF SEGMENT = NPT	003080	0000
	4 LOWER NODAL POINT OF SEGMENT = NPB	003090	0000
	5 ROCK STRENGTH = RS OR JRS	003100	0000
	6 R.Q.D. = RQD OR JRQD	003110	0000
	7 EXCAVATION METHOD = MEX	003120	0000
	(0 OR BLANK=NONE, 1=DRILL AND	003130	0000
	BLAST, 2=MOLE(ROCK), 3=MOLE(SOIL)	003140	0000
	4=HAND)	003150	0000
	8 HEADING ADVANCE RATE = AR	003160	0000
	9 GROUNDWATER INFLOW = GI	003170	0000
	(0=DRY, 1=WET)	003180	0000
	10 LINING TYPE = LINING	003190	0000
	(0=UNLINED, 1=CIP CONCRETE,	003200	0000
	2=SHOTCRETE, 3=PRECAST CONCRETE	003210	0000

(Continued)

## COSTUN Listing (Continued)

	CUT AND COVER BOX)	
11	LINING THICKNESS = TL OR LT OR TSEG	003220 0000
12	SUPPRESSION OF FORMWORK COSTS=40FORM (0 OR BLANK=POSSIBLE COSTS,1=SUPPRESS)	003230 0000
13	GROUNDWATER ELEVATION = ELLWTR	003240 0000
14	WATERTIGHT LINING REQUIREMENT = LINWT (0 OR BLANK=NO, 1=WATERTIGHT)	003250 0000
15	SHAFT SEGMENT TYPE = NSSTYP (1=ROCK, 2=SOFT GROUND, 3=CUT AND COVER)	003260 0000
16	EFFECTIVE GRAIN SIZE = D10	003270 0000
17	SOIL COHESION = COHESN	003280 0000
18	SOIL UNIT WEIGHT = GAMMA	003290 0000
19	ANGLE OF INTERNAL FRICTION = PHI	003300 0000
20	ELEVATION OF IMPERVIOUS LAYER = ELIMP	003310 0000
21	DEWATERING ALLOWED = IWATER (0 OR BLANK=NO, 1=ALLOWED)	003320 0000
22	SUPPORT TYPE = ISUPPT (1=CAST IRON SEGMENTS, 2=CONCRETE SEGMENTS, 3=STEEL SEGMENTS, 4=STEEL RIBS W/ LINING, 5=OPEN CUT)	003330 0000
23	SOIL PERMEABILITY = PERM	003340 0000
24	STABILITY NUMBER = STABNO	003350 0000
25	STABILIZATION METHOD = MSTAB (0 OR BLANK=NONE, 1=COMPRESSED AIR, 2=DEWATERING, 3=GROUN INJ.)	003360 0000
26	USE OF STABILIZATION METHOD = MUST (1=COSTUN SELECT, 2=COSTUN SELECT ONLY IF COULD NOT BE EXCAVATED, 3=USER SELECT ONLY IF COULD NOT BE EXCAVATED, 4=USER SELECTS,MUST USE, EVEN IF MSTAB=0)	003370 0000
27	AIR PRESSURE = AIRPR	003380 0000
28	ACCEPTABLE INPUT STABIL.METHOD= MSTAC (1=ACCEPTABLE,2=UNACCEPTABLE)	003390 0000
29	CHAR. EXC. DIMENSION = BE	003400 0000
30	FOR ROCK -----	003410 0000
	CHAR. EXC. DIMENSION AT RQD=40 = BE40	003420 0000
	FOR SOFT GROUND -----	003430 0000
	SOIL LOAD = PSOIL	003440 0000
31	FOR ROCK -----	003450 0000
	CHAR. EXC. DIMENSION AT RQD=60 = BE60	003460 0000
	FOR SOFT GROUND -----	003470 0000
	PSOIL+PWATER = PTOTAL	003480 0000
32	CHAR. EXC. DIM. W/OB = BOB	003490 0000
33	CHAR. EXC. DIM. W/OB , RQD=40 = BOB40	003500 0000
34	CHAR. EXC. DIM. W/OB , RQD=60 = BOB60	003510 0000
35	SEGMENT LENGTH = SSEGL	003520 0000
36	HOISTING HEIGHT = HH OR SEGDEP	003530 0000
37	MUCK LOADING RATE IN SEGMENT = RML	003540 0000
38	EXCAVATED VOLUME = V	003550 0000
39	ULTIMATE ADVANCE RATE = ARSULT	003560 0000
40	CONSTR. TIME EXC. + LINING = CTSS	003570 0000
41	CHAR. DEPTH OF SUPPORTS = WEB/ TPLATE	003580 0000
42	PUMPING FLOW, ONE DEEP WELL = FLOWL	003590 0000
43	WATER LOAD = PWATER	003600 0000

(Continued)

## COSTUN Listing (Continued)

SHAFT(I,J) .. SHAFT INFORMATION (I=SHAFT NUMBER)  
 ITEM J = 1 LOCATION IN THE 'B' ARRAY IN WHICH THE FIRST SHAFT SEGMENT OF SHAFT I IS STORED = NSSEG1  
 2 NODAL POINT AT TOP OF SHAFT = NPTS 003840 0000  
 3 NODAL POINT AT BOTTOM OF SHAFT = NPBS 003850 0000  
 4 NUMBER OF SEGMENTS IN THIS SHAFT - NSEGS 003860 0000  
 5 DISTANCE TO THE DISPOSAL SITE = DDS 003880 0000  
 6 COST OF DISPOSAL SITE = CDS OR ICDS 003890 0000  
 7 SHAFT SIZE = BF 003900 0000  
 8 DEPTH OF SHAFT 003910 0000  
 9 TOTAL VOLUME OF EXCAVATED MATERIAL 003920 0000  
 9 TOTAL VOLUME OF EXCAVATED MATERIAL TO BE TAKEN OUT THRU THIS SHAFT 003930 0000  
 10 PEAK MUCK REMOVAL RATE SHAFT (CY/HR) - RMLMAX OR IPRML 003940 0000  
 003950 0000  
 11 AVERAGE SUMMER ABOVE GROUND AIR TEMPERATURE AT TOP OF SHAFT = AIRTEM OR IARTEM 003960 0000  
 003970 0000  
 003980 0000  
 12 COST FACTOR FOR LABOR • CFL 003990 0000  
 13 COST FACTOR FOR EQUIPMENT • CFE 004000 0000  
 14 COST FACTOR FOR MATERIALS • CFM 004010 0000  
 15 REGIONAL COST FACTOR • RCF 004020 0000  
 16 SHAFT SHAPE = ISHAPS (0 OR BLANK=DUMMY, 1=CIRCULAR, 2=SQUARE) 004030 0000  
 004040 0000  
 004050 0000  
 17 WORK HOURS PER DAY = HOURS 004060 0000  
 18 WORK DAYS PER WEEK = DAYS 004070 0000  
 19 TOTAL COST OF LABOR IN SHAFT = SCL 004080 0000  
 20 TOTAL COST OF EQUIP IN SHAFT = SCE 004090 0000  
 21 TOTAL COST OF MATERIAL IN SHAFT = SCM 004100 0000  
 22 TOTAL COST OF SHAFT = SCT 004110 0000  
 23 PORTALS = NPORT (0=TRUE SHAFT, 1=PORTAL) 004120 0000  
 004130 0000  
 LIST(I) ..... ARRAY OF PRINTOUT OPTIONS 004140 0000  
 ITEM I = 1 NODAL POINT ELEVATIONS 004150 0000  
 2 TUNNEL INPUT DATA 004160 0000  
 3 SHAFT INPUT DATA 004170 0000  
 4 CALCULATED TUNNEL DATA 004180 0000  
 5 CALCULATED SHAFT DATA 004190 0000  
 6 TUNNEL SEGMENT AND REACH COSTS 004200 0000  
 7 SHAFT SEGMENT AND SHAFT COSTS 004210 0000  
 8 TUNNEL REACH COST SUMMARY 004220 0000  
 9 SHAFT COST SUMMARY 004230 0000  
 10-40 UNUSED AT PRESENT 004240 0000  
 IF THE VALUE OF LIST(I) IS ZERO OR BLANK, LISTING OF 004250 0000  
 ITEM WILL OCCUR. IF VALUE IS ONE, LISTING WILL BE 004260 0000  
 SUPPRESSED. ITEM NUMBER IS SAME AS DATA CARD COLUMN 004270 0000  
 NUMBER. 004280 0000  
 004290 0000  
 004300 0000  
 004310 0000  
 004320 0000  
 004330 0000  
 \*\*\*\*\* INPUT TUNNEL SYSTEM LOCATIONS AND CHARACTERISTICS \* 004340 0000  
 004350 0000  
 004360 0000

(Continued)

**COSTUN Listing (Continued)**

(Continued)

## CQSTUN Listing (Continued)

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

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## COSTUN Listing (Continued)

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

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## COSTUN Listing (Continued)

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C IF(RS.LT.500..AND.NTSTYP.EQ.1) WRITE(LO,1060) NTSEG,NREACH      006060 0000
C -----
C CHECK FOR PROPER WATERTIGHT CODE                                006070 0000
C LINWT=A(I,15)                                                    006080 0000
C IF(LINWT.EQ.0.OR.LINWT.EQ.1) GO TO 710                         006090 0000
C ISTOP=1                                                       006100 0000
C WRITE(LO,2015) NTSEG,NREACH                                     006110 0000
710 CONTINUE                                                 006120 0000
C                                                     006130 0000
C ALL CUT AND COVER BOX SEGMENTS ARE DESIGNED AS WATERTIGHT - 006140 0000
C INPUT IGNORED                                                 006150 0000
C IF(NTSTYP.EQ.3.AND.LINWT.EQ.0) WRITE(LO,2017) NTSEG,NREACH    006160 0000
C -----
C A LINING OR SUPPORT MUST BE SPECIFIED WHEN WATERTIGHTNESS REQUIRED 006170 0000
C ISUPPT=A(I,26)                                                    006180 0000
C IF(LINWT.EQ.0.OR.LINING.GT.0) GO TO 711                         006190 0000
C IF(NTSTYP.GT.1.AND.ISUPPT.LE.3) GO TO 711                      006200 0000
C ISTOP=1                                                       006210 0000
C WRITE(LO,2020) NTSEG,NREACH                                     006220 0000
C                                                     006230 0000
C CHECK IF GROUNDWATER ELEVATION NOT INPUT AND WATERTIGHT REQUIRED 006240 0000
711 ELWATR=A(I,14)                                              006250 0000
C IF(LINWT.EQ.1.AND.ELWATR.EQ.0.) WRITE(LO,2025) NTSEG,NREACH    006260 0000
C -----
C CHECK IF TUNNEL TYPE NOT ROCK AND GROUNDWATER ELEV. NOT SPECIFIED 006270 0000
C IF(NTSTYP.GT.1.AND.ELWATR.EQ.0) WRITE(LO,2025) NTSEG,NREACH    006280 0000
C -----
C CHECK FOR PROPER TUNNEL CODE IF RQD IS LESS THAN 25.           006290 0000
C RQD=A(I,6)                                                       006300 0000
C IF(NTSTYP.GT.1.OR.RQD.GE.25.)GO TO 712                         006310 0000
C ISTOP=1                                                       006320 0000
C WRITE(LO,2030) NTSEG,NREACH                                     006330 0000
C                                                     006340 0000
712 CONTINUE                                                 006350 0000
C                                                     006360 0000
C IS TUNNEL IN SOFT GROUND AND RQD GREATER THAN 25.            006370 0000
C IF(NTSTYP.EQ.2.AND.RQD.GT.25.) WRITE(LO,2035) NTSEG,NREACH    006380 0000
C -----
C CHECK FOR RQD BETWEEN 0 AND 100.                                 006390 0000
C IF(RQD.GE.0.0.AND.RQD.LE.100.) GO TO 713                      006400 0000
C WRITE(LO,1062) NTSEG,NREACH                                     006410 0000
C ISTOP=1                                                       006420 0000
C -----
C CHECK REMAINING DATA IF TUNNEL IS NOT IN ROCK                 006430 0000
713 IF(NTSTYP.EQ.1) GO TO 74                                     006440 0000
C                                                     006450 0000
C                                                     006460 0000
C CHECK THAT TUNNEL SURFACE NODAL POINTS HAVE BEEN PROPERLY ARRANGED 006470 0000
C IF(I.EQ.1) GO TO 7130                                         006480 0000
C CHECK FOR PREVIOUS SEGMENT IN ROCK                           006490 0000
C NSTYPE=A(I-1,16)                                                006500 0000
C IF(NSTYPE.EQ.1) GO TO 7130                                    006510 0000
C CHECK FOR PREVIOUS SEGMENT IN ROCK                           006520 0000
C NSTYPE=A(I-1,16)                                                006530 0000
C IF(NSTYPE.EQ.1) GO TO 7130                                    006540 0000
C NPLS=A(I,17)                                                    006550 0000
C NPRS=A(I,18)                                                    006560 0000
C IF(NPLS.EQ.NPRS) GO TO 7130                                  006570 0000
C ISTOP=1                                                       006580 0000
C WRITE(LO,2040) NTSEG,NREACH                                     006590 0000
C                                                     006600 0000
C 7130 NPLS=A(I,17)                                              006610 0000
C NPRS=A(I,18)                                                    006620 0000
C                                                     006630 0000

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**COSTUN Listing (Continued)**

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C ELMPLS=CNP(NPLS,2) 006640 0000
C ELMPRS=CNP(NPRS,2) 006650 0000
C CHECK THAT ALL TUNNEL SURFACE NODAL POINTS HAVE BEEN INPUT 006660 0000
C IF(ELNPLS.GT.-10.E29.AND.ELNPRS.GT.-10.E29) GO TO 714 006670 0000
C ISTOP=1 006680 0000
C WRITE(LO,2045) NTSEG,NREACH 006690 0000
714 CONTINUE 006700 0000
C -----
C CHECK THAT SURFACE NODAL POINT ELEVATIONS ARE ABOVE TUNNEL ELEV. 006710 0000
C IF(ELNPLS.GE.ELNPL.AND.ELNPRS.GE.ELNPR) GO TO 715 006720 0000
C ISTOP=1 006730 0000
C WRITE(LO,2050) NTSEG,NREACH 006740 0000
C -----
C CHECK IF EFFECTIVE GRAIN SIZE IS INPUT 006750 0000
715 D10=A(I,19) 006760 0000
C IF(D10.GT.0) GO TO 716 006780 0000
C ISTOP=1 006790 0000
C WRITE(LO,2055) NTSEG,NREACH 006800 0000
C -----
C CHECK THAT PHI AND/OR COHESION ARE SPECIFIED 006810 0000
716 PHI=A(I,20) 006820 0000
C COHESN=A(I,21) 006830 0000
C IF(PHI.GT.0.OR.COHESN.GT.0) GO TO 7160 006840 0000
C ISTOP=1 006850 0000
C WRITE(LO,2060) NTSEG,NREACH 006860 0000
7160 CONTINUE 006870 0000
C -----
C CHECK FOR POSSIBLE ERROR IN PERMEABILITY INPUT 006880 0000
C PERM=A(I,25) 006890 0000
C IF(PERM.GT.10) WRITE(LO,2061) NTSEG,NREACH 006900 0000
C -----
C CHECK IF PHI GREATER THAN 45 - WARNING, OR GREATER THAN 100 -ERROR 006910 0000
C IF(PHI.GT.45.) WRITE(LO,2062) NTSEG,NREACH 006920 0000
C IF(PHI.LT.100.) GO TO 7165 006930 0000
C ISTOP=1 006940 0000
C WRITE(LO,2063) NTSEG,NREACH 006950 0000
C -----
C CHECK IF GAMMA GREATER THAN 200 006960 0000
7165 GAMMA=A(I,22) 006970 0000
C IF(GAMMA.LE.200.) GO TO 717 006980 0000
C ISTOP=1 006990 0000
C WRITE(LO,2064) NTSEG,NREACH 007000 0000
C -----
C CHECK FOR PROPER DEWATERING CODE 007010 0000
717 IWATER=A(I,23) 007020 0000
C IF(IWATER.EQ.0.OR.IWATER.EQ.1) GO TO 7170 007030 0000
C ISTOP=1 007040 0000
C WRITE(LO,2065) NTSEG,NREACH 007050 0000
C -----
C CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT 007060 0000
7170 IF(NTSTYP.EQ.3) GO TO 718 007070 0000
C MSTAB=A(I,31) 007080 0000
C MUST=A(I,32) 007090 0000
C IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 7185 007100 0000
C IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.0001.OR.PERM.GT. 007110 0000
C 110.E-10.AND.PERM.LE.0.0006) GO TO 7185 007120 0000
C -----
C CHECK IF DEWATERING ALLOWED AND IMPERVIOUS LAYER NOT SPECIFIED 007130 0000

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

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## COSTUN Listing (Continued)

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C IF(DTUN.GT.100.) WRITE(L0,2094) NTSEG,NREACH          007800 0000
C -----
C CHECK FOR PROPER BRACING CODE                      007810 0000
C IBRACE=A(I,2B)                                     007820 0000
C IF(IBRACE.GE.0.AND.IBRACE.LE.3) GO TO 723          007830 0000
C ISTOP=1                                            007840 0000
C WRITE(L0,2095) NTSEG,NREACH                        007850 0000
C 723 CONTINUE                                         007860 0000
C -----
C CHECK IF CUT AND COVER (VERTICAL) AND BRACING CODE NOT SPECIFIED 007880 0000
C DROCK-ELSURF-ELROCK                                007890 0000
C IF(IBRACE.GT.0.OR.MEX.NE.6.OR.DROCK.LT.0.1) GO TO 724 007900 0000
C ISTOP=1                                            007910 0000
C WRITE(L0,2100) NTSEG,NREACH                        007920 0000
C -----
C CHECK FOR PROPER DECKING CODE                      007940 0000
C 724 IDECK=A(I,29)                                    007950 0000
C IF(IDECK.EQ.0.OR.IDECK.EQ.1) GO TO 74              007960 0000
C ISTOP=1                                            007970 0000
C WRITE(L0,2105) NTSEG,NREACH                        007980 0000
C GO TO 74                                           007990 0000
C -----
C CHECK FOR HIGH STABILITY NUMBER - MAY RESULT THAT JOB UNEXCAVATABLE 008000 0000
C 725 STABNO=A(I,30)                                    008010 0000
C IF(STABNO.[E.9.AND.PHI.LT.29.OR.STABNO.LE.7.AND.PHI.GE.29) 008020 0000
C 1 GO TO 7250                                         008030 0000
C ISTOP=1                                            008040 0000
C WRITE(L0,2115) NTSEG,NREACH                        008050 0000
C -----
C CHECK FOR PROPER STABILIZATION METHOD CODE          008060 0000
C 7250 MSTAB=A(I,31)                                    008070 0000
C IF(MSTAB.GE.0.AND.MSTAB.LE.3) GO TO 726            008080 0000
C ISTOP=1                                            008090 0000
C WRITE(L0,2120) NTSEG,NREACH                        008100 0000
C -----
C CHECK FOR PROPER USE CODE FOR STABILIZATION METHOD 008110 0000
C 726 MUST=A(I,32)                                    008120 0000
C IF(MUST.GE.1.AND.MUST.LE.4) GO TO 727              008130 0000
C ISTOP=1                                            008140 0000
C WRITE(L0,2125) NTSEG,NREACH                        008150 0000
C -----
C CHECK FOR AIR PRESSURE INPUT IF STABILITY NUMBER INPUT AND 008160 0000
C AIR PRESSURE STABILIZATION INPUT                   008170 0000
C 727 AIRPR=A(I,33)                                    008180 0000
C IF(STABNO.GT.0.0.AND.MSTAB.EQ.1.AND.AIRPR.EQ.0.0) GO TO 7270 008190 0000
C GO TO 728                                           008200 0000
C 7270 ISTOP=1                                         008210 0000
C WRITE(L0,2130) NTSEG,NREACH                        008220 0000
C 728 CONTINUE                                         008230 0000
C -----
C CHECK FOR USE CODE =4 WHEN STABILITY NUMBER IS SPECIFIED 008240 0000
C IF(STABNO.EQ.0.0.OR.MUST.EQ.4) GO TO 729            008250 0000
C ISTOP=1                                            008260 0000
C WRITE(L0,2135) NTSEG,NREACH                        008270 0000
C 729 CONTINUE                                         008280 0000
C -----
C CHECK IF STABILIZATION METHOD NOT COMPRESSED AIR BUT AIRPR GT 0 008290 0000
C IF(MSTAB.EQ.1.OR.AIRPR.EQ.0.) GO TO 7290           008300 0000
C ISTOP=1                                            008310 0000
C -----
C 
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## COSTUN Listing (Continued)

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

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## COSTUN Listing (Continued)

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C                                         008970 0000
C                                         008980 0000
C                                         008990 0000
C                                         009000 0000
C                                         009010 0000
C                                         009020 0000
C                                         009030 0000
C                                         009040 0000
C                                         009050 0000
C                                         009060 0000
C                                         009070 0000
C                                         009080 0000
C                                         009090 0000
C                                         009100 0000
C                                         009110 0000
C                                         009120 0000
C                                         009130 0000
C                                         009140 0000
C                                         009150 0000
C                                         009160 0000
C                                         009170 0000
C                                         009180 0000
C                                         009190 0000
C                                         009200 0000
C                                         009210 0000
C                                         009220 0000
C                                         009230 0000
C                                         009240 0000
C                                         009250 0000
C                                         009260 0000
C                                         009270 0000
C                                         009280 0000
C                                         009290 0000
C                                         009300 0000
C                                         009310 0000
C                                         009320 0000
C                                         009330 0000
C                                         009340 0000
C                                         009350 0000
C                                         009360 0000
C                                         009370 0000
C                                         009380 0000
C                                         009390 0000
C                                         009400 0000
C                                         009410 0000
C                                         009420 0000
C                                         009430 0000
C                                         009440 0000
C                                         009450 0000
C                                         009460 0000
C                                         009470 0000
C                                         009480 0000
C                                         009490 0000
C                                         009500 0000
C                                         009510 0000
C                                         009520 0000
C                                         009530 0000
C                                         009540 0000

C
C ***** READ REACH DATA FOR TUNNELS *****
C
C   INITIALIZE REACH ARRAY
C   DO 80 I=1,NTRMAX
C     TRDATA(I,1)=-10.E30
C
C   -----READ REACH DATA FROM CARD-----
C   81 READ (LI,1020) NREACH,NSHAFT,BFT,ISHAPE,MTM,HOURS,DAYS,NBOX,
C     1BFBUDT,BFBHT,IBOX2,ISEPCK
C     IF(NREACH.EQ.9999) GO TO 86
C   CHECK FOR MISSING SEPARATOR CARD
C     IF(ISEPCK.EQ.0) GO TO 82
C     ISTOP = 1
C     WRITE (LO,1502)
C     GO TO 425
C   82 CONTINUE
C     IF(NREACH.LE.NTRMAX.AND.NREACH.GT.0) GO TO 84
C     WRITE(LO,1021) NREACH,NTRMAX
C     ISTOP=1
C     GO TO 81
C   84 CONTINUE
C   -----CHECK FOR FINISHED DIMENSION BETWEEN 10 AND 40 FEET-----
C   IF(ISHAPE.GT.0.AND.BFT.LT.10..OR.ISHAPE.GT.0.AND.BFT.GT.40.) 009250 0000
C     1WRITE(LO,1064) NREACH
C   -----CHECK IF TUNNEL SIZE INPUT AGREES WITH SHAPE CODE-----
C   IF(BFT.EQ.0.AND.ISHAPE.EQ.0.OR.BFT.GT.0.AND.ISHAPE.GT.0) GO TO 840 009260 0000
C     ISTOP=1
C     IF(ISHAPE.GT.0) WRITE(LO,2150) NREACH
C     IF(ISHAPE.EQ.0) WRITE(LO,2151) NREACH
C   840 CONTINUE
C   -----CHECK FOR PREVIOUS USE OF REACH NUMBER-----
C   IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 85
C     WRITE(LO,1026) NREACH
C     ISTOP=1
C   85 CONTINUE
C   -----CHECK FOR PROPER MUCK TRANSPORT METHOD CODE-----
C   IF(MTM.GE.0.AND.MTM.LE.4) GO TO 850
C     WRITE(LO,1041) NREACH
C     ISTOP=1
C   850 CONTINUE
C   -----CHECK FOR PROPER TUNNEL SHAPE CODE-----
C   IF(ISHAPE.GE.0.AND.ISHAPE.LE.3) GO TO 851
C     WRITE(LO,1042) NREACH
C     ISTOP=1
C   851 CONTINUE
C   -----CHECK IF SHAPE CODE AGREES WITH MUCK TRANSPORT METHOD-----

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## COSTUN Listing (Continued)

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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
IF(ISHAPE.EQ.0) WRITE(LO,2152) NREACH 009560 0000
IF(ISHAPE.GT.0) WRITE(LO,2153) NREACH 009570 0000
852 CONTINUE 009580 0000
009590 0000
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
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
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
009810 0000
C CHECK IF TOTAL CLEAR BOX WIDTH EXCEEDS 40 FEET 009820 0000
IF(BFBWDT.GT.40.) WRITE(LO,2170) NREACH 009830 0000
009840 0000
C CHECK TYPE OF BOX SECTION 009850 0000
IF(IBOX2.EQ.1) GO TO 857 009860 0000
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
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
009970 0000
C DOUBLE LEVEL BOX -- TWO UNITS HIGH AND TWO UNITS WIDE 009980 0000
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
010020 0000
C 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,5)=HOURS 010070 0000
TRDATA(NREACH,6)=DAYS 010080 0000
TRDATA(NREACH,7)=NBOX 010090 0000
TRDATA(NREACH,8)=BFBWDT 010100 0000
TRDATA(NREACH,9)=BFBHT 010110 0000
TRDATA(NREACH,10)=IBOX2 010120 0000
GO TO 81 010130 0000

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## COSTUN Listing (Continued)

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C----- 010140 0030
C END OF REACH INPUT 010150 0000
C----- 010160 0000
B6 CONTINUE 010170 0000
C----- 010180 0000
C CHECK REACH AND SEGMENT INFORMATION FOR COMPATABILITY 010190 0000
C----- 010200 0000
DO 87 I=1,NTS 010210 0000
NREACH=A(I,4) 010220 0000
NTSEG=A(I,1) 010230 0000
NTSTYP=A(I,16) 010240 0000
MEX=A(I,7) 010250 0000
BFT=TRDATA(NREACH,2) 010260 0000
ISHAPE=TRDATA(NREACH,3) 010270 0000
MTM=TRDATA(NREACH,4) 010280 0000
ISUPPT=A(I,26) 010290 0000
MSTAB=A(I,31) 010300 0000
MUST=A(I,32) 010310 0000
NPL=A(I,2) 010320 0000
NPR=A(I,3) 010330 0000
ELNPL=CNP(NPL,2) 010340 0000
ELNPR=CNP(NPR,2) 010350 0000
ELAUG=(ELNPL+ELNPR)/2. 010360 0000
ELWATR=A(I,14) 010370 0000
ELIMP=A(I,24) 010380 0000
C IF THE TUNNEL SEGMENT IS MOLED, ITS SHAPE MUST BE CIRCULAR 010390 0000
IF(MEX.NE.2.AND.MEX.NE.3) GO TO 860 010400 0000
IF(ISHAPE.EQ.1) GO TO 860 010410 0000
WRITE(LO,1040) NTSEG,NREACH 010420 0000
ISTOP=1 010430 0000
860 CONTINUE 010440 0000
C----- 010450 0000
C CHECK FOR CUT AND COVER OR ROCK TUNNEL 010460 0000
IF(NTSTYP.NE.2) GO TO 865 010470 0000
C----- 010480 0000
C CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT 010490 0000
IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 861 010500 0000
IWATER=A(I,23) 010510 0000
D10=A(I,19) 010520 0000
PERM=A(I,25) 010530 0000
IF(IWATER.EQ.0.OR.PERL.LT.10.E-10.AND.D10.LE.0.08.OR.PERL.GT. 010540 0000
110.E-10.AND.PERL.LE.0.0006) GO TO 861 010550 0000
C----- 010560 0000
C CHECK IF IMPERVIOUS LAYER IS ABOVE TUNNEL WHEN DEWATERING MAY 010570 0000
BE USED AS A STABILIZATION METHOD 010580 0000
IF(ELIMP.LT.ELAUG+BFT/2.) GO TO 861 010590 0000
WRITE(LO,2190) NTSEG,NREACH 010600 0000
A(I,24)=ELAUG-BFT/2.
861 CONTINUE 010610 0000
C----- 010620 0000
C CHECK IF TRUCK TRANSPORT IS SPECIFIED AND COMPRESSED AIR REQUIRED 010630 0000
IF(MTM.NE.1.OR.MSTAB.GT.1.OR.MSTAB.EQ.0.OR.MUST.LT.4) GO TO 863 010640 0000
ISTOP=1 010650 0000
WRITE(LO,2195) NTSEG,NREACH 010660 0000
863 CONTINUE 010670 0000
C----- 010680 0000
C CAST IRON TUNNEL SUPPORT - CIRCULAR TUNNELS ONLY 010690 0000
IF(ISUPPT.GT.1.OR.ISHAPE.EQ.1) GO TO 865 010700 0000
ISTOP=1 010710 0000
WRITE(LO,2200) NTSEG,NREACH

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## COSTUN Listing (Continued)

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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
----- 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
----- 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.ELAUG-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
----- 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.ELAUG-BFBHT/2..OR.ELWATR.LE.ELIMP) GO TO 87 011000 0000
ISTOP=1                                         011010 0000
WRITE(LO,2205) NTSEG,NREACH                  011020 0000
----- 011030 0000
87 CONTINUE                                     011040 0000
----- 011050 0000
***** 011060 0000
C   READ SHAFT SEGMENT DATA *****             011070 0000
CCC 011080 0000
C   INITIALIZE SHAFT SEGMENT ARRAY            011090 0000
DO 88 I=1,NSSMAX                               011100 0000
88 B(I,1)--10.E30                             011110 0000
C   INITIALIZE THE SHAFT ARRAY                011120 0000
DO 89 I=1,NSMAX                               011130 0000
89 SHAFT(I,1)--10.E30                          011140 0000
IPS=0                                           011150 0000
I=0                                             011160 0000
90 I=I+1                                       011170 0000
----- 011180 0000
C   CHECK FOR MAX NUMBER OF SHAFT SEGMENTS  011190 0000
IF(I.LE.NSSMAX) GO TO 95                     011200 0000
----- 011210 0000
C   CHECK FOR END OF SHAFT SEGMENT DATA. NDUM=DUMMY SEGMENT NUMBER 011220 0000
91 READ(LI,1020) NDUM                         011230 0000
IF(NDUM.EQ.9999) GO TO 130                   011240 0000
WRITE(LO,1017) NSSMAX                         011250 0000
ISTOP=1                                         011260 0000
----- 011270 0000
----- 011280 0000

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## COSTUN Listing (Continued)

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C   GO TO 91                               011290 0000
CCC -----
C   READ SHAFT SEGMENT DATA FROM CARD      011300 0000
95  READ(LI,1007)          (B(I,J),J=1,15)  011310 0000
    NSHAFT=B(I,1)                           011320 0000
    NSSEG=B(I,2)                            011330 0000
    NSSTYP=B(I,15)                          011340 0000
C   -----                                 011350 0000
C   CHECK FOR LAST SHAFT CARD             011360 0000
IF(NSHAFT.EQ.9999) GO TO 130            011370 0000
IF(NSHAFT.LE.NSMAX.AND.NSHAFT.GT.0) GO TO 100 011380 0000
WRITE(LO,1034) NSHAFT,NSSEG,NSMAX       011390 0000
ISTOP=1                                  011400 0000
100 CONTINUE                             011410 0000
C   -----                                 011420 0000
C   CHECK FOR MISSING SEPARATOR CARD     011430 0000
IF(NSSTYP.NE.0) GO TO 101               011440 0000
ISTOP=1                                  011450 0000
WRITE(LO,1503)                           011460 0000
101 CONTINUE                             011470 0000
C   -----                                 011480 0000
C   CHECK FOR PROPER SHAFT TYPE CODE    011490 0000
IF(NSSTYP.GE.1.AND.NSSTYP.LE.3) GO TO 102 011500 0000
ISTOP=1                                  011510 0000
WRITE(LO,2207) NSSEG,NSHAFT            011520 0000
GO TO 425                                011530 0000
102 CONTINUE                             011540 0000
C   -----                                 011550 0000
C   READ SECOND SEGMENT DATA CARD IF NOT ROCK TUNNEL 011560 0000
IF(NSSTYP.GT.1) READ(LI,1008) (B(I,J),J=16,27) 011570 0000
C   -----                                 011580 0000
C   CHECK FOR PREVIOUS USE OF SHAFT NUMBER 011590 0000
IF(I.EQ.1) GO TO 105                  011600 0000
IF(NSHAFT.EQ.IPS) GO TO 106            011610 0000
IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 105 011620 0000
WRITE(LO,1023) NSSEG,NSHAFT           011630 0000
ISTOP=1                                  011640 0000
105 SHAFT(NSHAFT,1)=0.                 011650 0000
106 CONTINUE                            011660 0000
C   -----                                 011670 0000
C   CHECK THAT SHAFT SEGMENT CARDS HAVE BEEN PROPERLY ARRANGED 011680 0000
IF(I.EQ.1) GO TO 108                  011690 0000
IF(IPS.NE.NSHAFT) GO TO 108           011700 0000
IF(B(I,3).EQ.B(I-1,4)) GO TO 108      011710 0000
WRITE(LO,1115) NSSEG,NSHAFT           011720 0000
ISTOP=1                                  011730 0000
108 CONTINUE                            011740 0000
C   -----                                 011750 0000
C   CHECK THAT ALL SHAFT NODAL POINTS HAVE BEEN INPUT 011760 0000
NPT=B(I,3)                                011770 0000
NPB=B(I,4)                                011780 0000
ELNPT=CNP(NPT,2)                          011790 0000
ELNPB=CNP(NPB,2)                          011800 0000
IF(ELNPT.GT.-10.E29.AND.ELNPB.GT.-10.E29) GO TO 110 011810 0000
WRITE(LO,1131) NSSEG,NSHAFT            011820 0000
ISTOP=1                                  011830 0000
110 CONTINUE                            011840 0000
C   -----                                 011850 0000
C   -----                                 011860 0000

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## COSTUN Listing (Continued)

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C ----- 011870 0000
C CHECK FOR SHAFT BEING A PORTAL. IF SO, RECCRD THIS FACT 011880 0000
NPORT=0 011890 0000
IF(NPT.EQ.NPB) NPORT=1 011900 0000
SHAFT(NSHAFT,23)=NPORT 011910 0000
C IF SHAFT IS A PORTAL, SKIP THE FOLLOWING INPUT CHECKS 011920 0000
IF(NPT.EQ.NPB) GO TO 128 011930 0000
C ----- 011940 0000
C CHECK FOR PROPER EXCAVATION METHOD 011950 0000
MEX=B(I,?) 011960 0000
IF(MEX.GE.0.AND.MEX.LE.4) GO TO 112 011970 0000
ISTOP=1 011980 0000
WRITE(LO,1029) NSSEG,NSHAFT 011990 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
122 WRITE(LO,2212) NSSEG,NSHAFT 012340 0000
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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## COSTUN Listing (Continued)

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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 COUVER 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 ELEVATION 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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## COSTUN Listing (Continued)

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ISTOP=1                               013030 0000
WRITE(LO,2245) NSSEG,NSHAFT          013040 0000
-----                                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
-----                                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
-----                                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
-----                                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
-----                                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
-----                                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
-----                                013420 0000
C   DEWATERING IS ALLOWED. CHECK IF IMPERVIOUS LAYER IS NOT 013430 0000
      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
-----                                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
-----                                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

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## COSTUN Listing (Continued)

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1286 ISTOP=1                               013610 0000
      WRITE(LO,2270) NSSEG,NSHAFT          013620 0000
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
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
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

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## COSTUN Listing (Continued)

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ISTOP=1                               014190 0000
WRITE(LO,2310) NSSEG,NSHAFT          014200 0000
1298 CONTINUE                         014210 0000
C-----                                014220 0000
C CHECK IF STABILIZATION METHOD IS INPUT 014230 0000
IF(MSTAB.EQ.0) GO TO 128             014240 0000
C-----                                014250 0000
C CHECK IF STABILIZATION METHOD IS ACCEPTABLE 014260 0000
GO TO (1300,1302,1304), MSTAB       014270 0000
C-----                                014280 0000
C AIR PRESSURE -- CHECK IF SOIL IS A GRAVEL 014290 0000
1300 IF(PERM.LT.10.E-10.AND.D10.GT.2.) GO TO 1305 014300 0000
IF(PERM.GT.0.4) GO TO 1305          014310 0000
C CHECK IF SOIL IS A CLAY            014320 0000
IF(D10.LE.0.005) GO TO 1308         014330 0000
C CHECK IF SHAFT SEGMENT ABOVE WATER TABLE 014340 0000
IF(ELWATR.LE.ELNPB) GO TO 1308     014350 0000
C CHECK IF WATER HEAD LESS THAN 115 FEET 014360 0000
ELAUG=(ELNPT+ELNPB)/2.              014370 0000
IF(ELWATR-ELAUG.LE.115.) GO TO 1308 014380 0000
GO TO 1305                          014390 0000
C-----                                014400 0000
C DEWATERING -- CHECK IF DEWATERING IS ALLOWED 014410 0000
1302 IF(IWATER.EQ.0) GO TO 1305      014420 0000
C CHECK IF SHAFT SEGMENT ABOVE WATER TABLE 014430 0000
IF(ELWATR.LE.ELNPB) GO TO 1305     014440 0000
C CHECK IF SOIL IS FINE SAND OR COARSER OR IS REASONABLY PERMEABLE 014450 0000
IF(PERM.LT.10.E-10.AND.D10.GT.0.08) GO TO 1308 014460 0000
IF(PERM.GT.0.0006) GO TO 1308       014470 0000
GO TO 1305                          014480 0000
C-----                                014490 0000
C GROUND INJECTIONS -- CHECK IF SOIL IS NOT CLAY 014500 0000
1304 IF(D10.GT.0.005) GO TO 1308    014510 0000
C-----                                014520 0000
C STABILIZATION METHOD IS NOT ACCEPTABLE 014530 0000
1305 MSTAC=2                        014540 0000
C CHECK IF USE CODE =4               014550 0000
IF(MUST.EQ.4) GO TO 1306          014560 0000
WRITE(LO,2315) NSSEG,NSHAFT        014570 0000
GO TO 1310                          014580 0000
1306 ISTOP=1                        014590 0000
WRITE(LO,2320) NSSEG,NSHAFT        014600 0000
GO TO 1310                          014610 0000
C-----                                014620 0000
C STABILIZATION METHOD IS ACCEPTABLE 014630 0000
1308 MSTAC=1                        014640 0000
1310 B(I,28)=MSTAC                 014650 0000
C-----                                014660 0000
C CHECK FOR CORRECT GROUNDWATER CODE 014670 0000
128 INFLOW=B(I,9)                  014680 0000
IF(INFLOW.EQ.0.OR.INFLOW.EQ.1) GO TO 129 014690 0000
WRITE(LO,1047) NSSEG,NSHAFT        014700 0000
ISTOP=1                            014710 0000
C-----                                014720 0000
C 129 IPS-NSHAFT                   014730 0000
GO TO 90                           014740 0000
C END OF SHAFT SEGMENT DATA        014750 0000
130 CONTINUE                         014760 0000

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## COSTUN Listing (Continued)

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C   **** NSS-I-1 ****          014770 0000
C   **** READ SHAFT PROPERTIES 014780 0000
C   **** INITIALIZE SHAFT DATA ARRAY 014790 0000
C   DO 132 I=1,NSMAX          014800 0000
C   SHAFT(I,7)--10.E30        014810 0000
C   132 SHAFT(I,1)--10.E30    014820 0000
C   131 READ(LI,1025,ERR=450) NSHAFT,BFS,ISHAPS,DDS,CDS,AIRTEM,CFL,CFE,
C   1CFM,RCF,HOURS,DAYS      014830 0000
C   IF(NSHAFT.EQ.9999) GO TO 139 014840 0000
C   CHECK FOR PREVIOUS USE OF SHAFT NUMBER 014850 0000
C   134 IF(SHAFT(NSHAFT,1).GT.-10.E29) WRITE(LO,1027) NSHAFT 014860 0000
C   IF(SHAFT(NSHAFT,1).GT.-10.E29) ISTOP=1 014870 0000
C   IF SHAFT IS PORTAL, USER CAN OMIT BFS. SET SIZE 014880 0000
C   NPORT=SHAFT(NSHAFT,23)      014890 0000
C   IF(NPORT.EQ.1) BFS=20.       014900 0000
C   SHAFT(NSHAFT,5)=DDS        014910 0000
C   SHAFT(NSHAFT,6)=CDS        014920 0000
C   SHAFT(NSHAFT,7)=BFS        014930 0000
C   SHAFT(NSHAFT,11)=AIRTEM    014940 0000
C   SHAFT(NSHAFT,12)=CFL        014950 0000
C   SHAFT(NSHAFT,13)=CFE        014960 0000
C   SHAFT(NSHAFT,14)=CFM        014970 0000
C   SHAFT(NSHAFT,15)=RCF        014980 0000
C   SHAFT(NSHAFT,16)=ISHAPS     014990 0000
C   SHAFT(NSHAFT,17)=HOURS      015000 0000
C   SHAFT(NSHAFT,18)=DAYS       015010 0000
C   -----
C   CHECK FOR FINISHED DIMENSION BETWEEN 10 AND 40 FEET 015020 0000
C   IF(ISHAPS.GT.0.AND.BFS.LT.10..OR.ISHAPS.GT.0.AND.BFS.GT.40.) 015030 0000
C   1WRITE(LO,1074) NSHAFT      015040 0000
C   -----
C   CHECK FOR PROPER SHAFT SHAPE CODE 015050 0000
C   IF(ISHAPS.GE.0.AND.ISHAPS.LE.2) GO TO 135 015060 0000
C   ISTOP=1                      015070 0000
C   WRITE(LO,2325) NSHAFT        015080 0000
C   135 CONTINUE                  015090 0000
C   -----
C   CHECK FOR SPECIFICATION OF PORTAL, BYPASS FOLLOWING CHECKS 015100 0000
C   IF(NPORT.EQ.1) GO TO 136     015110 0000
C   -----
C   CHECK FOR SPECIFICATION OF DUMMY SHAFT 015120 0000
C   IF(ISHAPS.EQ.0) WRITE(LO,2327) NSHAFT 015130 0000
C   -----
C   CHECK IF SHAPE CODE AGREES WITH INPUT SHAFT SIZE 015140 0000
C   IF(BFS.EQ.0.AND.ISHAPS.EQ.0.OR.BFS.GT.0.AND.ISHAPS.GT.0) GO TO 136 015150 0000
C   ISTOP=1                      015160 0000
C   IF(ISHAPS.EQ.0) WRITE(LO,2330) NSHAFT 015170 0000
C   IF(ISHAPS.GT.0) WRITE(LO,2332) NSHAFT 015180 0000
C   136 CONTINUE                  015190 0000
C   -----
C   CHECK IF WORK HOURS PER DAY IN PROPER RANGE 015200 0000
C   015210 0000
C   015220 0000
C   015230 0000
C   015240 0000
C   015250 0000
C   015260 0000
C   015270 0000
C   015280 0000
C   015290 0000
C   015300 0000
C   015310 0000
C   015320 0000
C   015330 0000
C   015340 0000

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## COSTUN Listing (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 -----
C CHECK IF WORK DAYS PER WEEK IN PROPER RANGE      015390 0000
IF(DAYS.GE.4..AND.DAYS.LE.7..OR.DAYS.EQ.0.) GO TO 138 015400 0000
ISTOP=1                                              015410 0000
015420 0000
WRITE(LO,2340) NSHAFT                             015430 0000
138 CONTINUE                                         015440 0000
C -----
SHAFT(NSHAFT,1)=0.                                 015450 0000
GO TO 131                                           015460 0000
C END OF SHAFT PROPERTIES DATA                    015470 0000
139 CONTINUE                                         015480 0000
C *****
C
C -----
C MAKE SURE THAT ALL TUNNEL SEGMENTS HAVE REACHES DEFINED FOR THEM 015490 0000
DO 200 I=1,NTS                                     015500 0000
NTSEG=A(I,1)
NREACH=A(I,4)
IF(TRDATA(NREACH,1).GT.0.) GO TO 200             015510 0000
ISTOP=1                                              015520 0000
015530 0000
WRITE(LO,1200) NTSEG,NREACH                      015540 0000
200 CONTINUE                                         015550 0000
C -----
C CHECK THAT EVERY REACH NUMBER ASSIGNED HAS AT LEAST ONE TUNNEL 015560 0000
C SEGMENT REFERRING TO IT                         015570 0000
DO 250 I=1,NTRMAX                                015580 0000
IF(TRDATA(I,1).LT.-10.E29) GO TO 250            015590 0000
NREACH=I
JJ=0
DO 225 J=1,NTS                                     015600 0000
IF(NREACH.EQ.A(J,4)) JJ=1                         015610 0000
225 CONTINUE                                         015620 0000
IF(JJ.EQ.1) GO TO 250                           015630 0000
ISTOP=1                                              015640 0000
015650 0000
WRITE(LO,1203) NREACH                           015660 0000
250 CONTINUE                                         015670 0000
015680 0000
015690 0000
015700 0000
015710 0000
015720 0000
015730 0000
015740 0000
015750 0000
015760 0000
015770 0000
015780 0000
015790 0000
015800 0000
015810 0000
015820 0000
015830 0000
015840 0000
015850 0000
015860 0000
015870 0000
015880 0000
015890 0000
015900 0000
015910 0000
015920 0000
C -----
C CHECK TO MAKE SURE ALL SHAFT SEGMENTS HAVE SHAFTS DEFINED FOR THEM 015930 0000
DO 300 I=1,NSS                                     015940 0000
NSSEG=B(I,2)
NSHAFT=B(I,1)
IF(SHAFT(NSHAFT,7).GT.-10.E29) GO TO 260        015950 0000
ISTOP=1                                              015960 0000
015970 0000
WRITE(LO,1201) NSSEG,NSHAFT                      015980 0000
260 CONTINUE                                         015990 0000
C -----
C CHECK FOR PORTAL OR DUMMY SHAFT                 016000 0000
NPORT-SHAFT(NSHAFT,23)                           016010 0000
ISHAPS-SHAFT(NSHAFT,16)                           016020 0000
IF(NPORT.EQ.1.OR.ISHAPS.EQ.0) GO TO 300           016030 0000
C -----
C CHECK IF SHAPE CODE AGREES WITH SHAFT TYPE      016040 0000
NSSTYP=B(I,15)                                    016050 0000

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## COSTUN Listing (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,?)                                       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 CHECK FOR ANY STOPS FOUND                      016360 0000
425 CONTINUE                                     016370 0000
IF(ISTOP.EQ.0) GO TO 500                         016380 0000
C-----                                         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,L1)                            016430 0000
RETURN                                         016440 0000
450 WRITE(LO,1504)                             016450 0000
ISTOP = 1                                      016460 0000
GO TO 425                                     016470 0000
C-----                                         016480 0000
C IF NO FATAL ERRORS, LIST NODAL POINT DATA IF REQUESTED 016490 0000
500 IF(LIST(1).EQ.1) RETURN                    016500 0000
WRITE(LO,1003)

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## COSTUN Listing (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)
RETURN                      016520 0000
                           016530 0000
                           016540 0000
                           016550 0000
                           016560 0000
C                           016570 0000
C 1000 FORMAT(1X,I4,5X,F10.0) 016580 0000
1001 FORMAT(/,,'FATAL ERROR, NODAL POINT',I5,' MUST BE CHANGED TO A
&NUMBER IN THE RANGE FROM 1 TO ',I4) 016590 0000
1002 FORMAT(4I4,F5.0,I3,F7.0,F5.0,I3,F4.0,F7.0,2I3,F5.0) 016600 0000
1003 FORMAT(///,10X,25H NODAL POINT ELEVATION //) 016610 0000
1004 FORMAT(10X,I7,8X,F9.2) 016620 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.
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,
1F2.0,F6.0,F2.0,F1.0,F5.0) 016640 0000
1007 FORMAT(4F4.0,8X,F8.0,F4.0,F3.0,F6.0,2F3.0,F6.0,F2.0,F6.0,F3.0,
1F5.0) 016650 0000
1008 FORMAT(16X,2F8.0,F4.0,F3.0,F6.0,2F3.0,F8.0,F6.0,F2.0,F1.0,F5.0) 016660 0000
1011 FORMAT(///,1X,131('*'),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS I
1N SUBROUTINE INPUT ',/1X,131(1H*)) 016670 0000
1013 FORMAT(/,,'FATAL ERROR, NODAL POINT',I5,' IS INPUTED ON TWO SEP
1ARATE NODAL POINT CARDS') 016680 0000
1015 FORMAT(/,,'FATAL ERROR, SEGMENT',I5,' IN REACH',I5,' IS OUT OF
1SEQUENCE, CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT
25') 016690 0000
1016 FORMAT(/,,'FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'.
1 TUNNEL SEGMENTS ALLOWED') 016700 0000
1017 FORMAT(/,,'FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'.
1 SHAFT SEGMENTS ALLOWED') 016710 0000
1020 FORMAT(2I4 ,F6.0,2I3 ,F5.0,F4.0,I3,2F5.0,I3,25X,I5) 016720 0000
1021 FORMAT(/,,'FATAL ERROR, REACH NUMBER',I5,' SHOULD BE CHANGED TO
1 ONE IN THE RANGE OF 1 TO ',I5) 016730 0000
1022 FORMAT(/,,'FATAL ERROR, SEGMENT',I5,' REFERS TO REACH',I5,' BU
1T THIS REACH NUMBER HAS BEEN PREVIOUSLY ASSIGNED') 016740 0000
1023 FORMAT(/,,'FATAL ERROR, SEGMENT',I5,' REFERS TO SHAFT',I5,' BU
1T THIS SHAFT NUMBER HAS BEEN PREVIOUSLY ASSIGNED') 016750 0000
1025 FORMAT(I4,F6.0,I3,F8.0,F7.0,F4.0,4F6.0,F5.0,F4.0) 016760 0000
1026 FORMAT(/,,'FATAL ERROR, DATA FOR REACH',I5,' HAVE BEEN SUPPLIED
1 ON TWO SEPARATE REACH CARDS') 016770 0000
1027 FORMAT(/,,'FATAL ERROR, DATA FOR SHAFT',I5,' HAVE BEEN SUPPLIED
1 ON TWO SEPARATE SHAFT CARDS') 016780 0000
1029 FORMAT(/,,'FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN SH
1AFT',I5,' WAS NOT SPECIFIED BY USING CODE 2ZERO(OR BLANK),1,2,3,4') 016790 0000
1030 FORMAT(/,,'FATAL ERROR, EXCAVATION METHOD IN SEGMENT',I5,' IN RE
1ACH',I5,' WAS NOT SPECIFIED BY USING CODE 1,2,3,4,5,6,OR 7') 016800 0000
1031 FORMAT(/,,'FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT',I5,'.
1 IN REACH',I5,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD
25') 016810 0000
1034 FORMAT(/,,'FATAL ERROR, SHAFT',I5,' LISTED WITH SHAFT SEGMENT',
1I5,' IS NOT NUMBERED IN THE RANGE OF 1 TO ',I5) 016820 0000
1040 FORMAT(/,,'FATAL ERROR, CIRCULAR SHAPE WAS NOT SPECIFIED FOR MOL
1ED EXCAVATION IN SEGMENT',I5,' IN REACH',I5) 016830 0000
1041 FORMAT(/,,'FATAL ERROR, MUCK TRANSPORT MÉTHOD IN REACH',I5,' WA
1S NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,3,OR 4') 016840 0000
1042 FORMAT(/,,'FATAL ERROR, TUNNEL SHAPE IN REACH',I5,' WAS NOT SPE
1CIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3') 016850 0000
1043 FORMAT(/,,'FATAL ERROR, LINING TYPE IN SEGMENT',I5,' IN REACH',I5
1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3') 016860 0000
                                         016870 0000
                                         016880 0000
                                         016890 0000
                                         016900 0000
                                         016910 0000
                                         016920 0000
                                         016930 0000
                                         016940 0000
                                         016950 0000
                                         016960 0000
                                         016970 0000
                                         016980 0000
                                         016990 0000
                                         017000 0000
                                         017010 0000
                                         017020 0000
                                         017030 0000
                                         017040 0000
                                         017050 0000
                                         017060 0000
                                         017070 0000

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## COSTUN Listing (Continued)

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',IS,' IN S	017120	0000
1HAFT' IS,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK) OR 1'	017130	0000
1048 FORMAT(/,,'FATAL ERROR, LINING TYPE IN SEGMENT',IS,' IN SHAFT',IS	017140	0000
1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')	017150	0000
1055 FORMAT(/,,'FATAL ERROR, SHAFT',IS,' IS NOT NUMBERED IN THE RANG	017160	0000
1E OF 1 TO ',IS)	017170	0000
1060 FORMAT(/,,'**** WARNING **** ROCK STRENGTH IS LESS THAN 500 PSI	017180	0000
1 IN SEGMENT',IS,' IN REACH',IS,' GETTING CLOSE TO SOFT GROUND',	017190	0000
25X,14(1H*))	017200	0000
1062 FORMAT(/,,'FATAL ERROR, RQD IN SEGMENT',IS,' IN REACH',IS,	017210	0000
1' IS NOT A NUMBER FROM 0 TO 100')	017220	0000
1064 FORMAT(/,,'**** WARNING **** TUNNEL SIZE IN REACH',IS,' 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',IS,' IN REACH',	017250	0000
1 IS,' IS LESS THAN 0 FT/DAY')	017260	0000
1070 FORMAT(/,,'**** WARNING **** ROCK STRENGTH IS LESS THAN 500 PSI	017270	0000
1 IN SEGMENT',IS,' IN SHAFT',IS,' GETTING CLOSE TO SOFT GROUND',	017280	0000
25X,14(1H*))	017290	0000
1072 FORMAT(/,,'FATAL ERROR, RQD IN SEGMENT',IS,' IN SHAFT',IS,	017300	0000
1' IS NOT A NUMBER FROM 0 TO 100')	017310	0000
1074 FORMAT(/,,'**** WARNING **** SHAFT SIZE IN SHAFT',IS,' 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',IS,' IN SHAFT',	017340	0000
1 IS,' IS LESS THAN 0 FT/DAY')	017350	0000
1115 FORMAT(/,,'FATAL ERROR, SEGMENT',IS,' IN SHAFT',IS,' IS OUT OF	017360	0000
1SEQUENCE,CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT	017370	0000
25')	017375	
1131 FORMAT(/,,'FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT',IS,	017380	0000
1' IN SHAFT',IS,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD	017390	0000
25')	017400	0000
1200 FORMAT(/,,'FATAL ERROR, TUNNEL SEGMENT',IS,' REFERS TO REACH',IS	017410	0000
1,' BUT NO SUCH REACH HAS BEEN INPUTED')	017420	0000
1201 FORMAT(/,,'FATAL ERROR, SHAFT SEGMENT',IS,' REFERS TO SHAFT',IS	017430	0000
1,' BUT NO SUCH SHAFT HAS BEEN INPUTED')	017440	0000
1202 FORMAT(/,,'FATAL ERROR, REACH',IS,' REFERS TO EXIT SHAFT',IS,	017450	0000
1,' BUT NO SUCH SHAFT HAS BEEN INPUTED')	017460	0000
1203 FORMAT(/,,'FATAL ERROR, TUNNEL REACH',IS,' HAS BEEN ASSIGNED,BU	017470	0000
1T NO TUNNEL SEGMENTS REFER TO IT')	017480	0000
1204 FORMAT(/,,'FATAL ERROR, SHAFT',IS,' 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',IS,' IN REACH',	017600	0000
1IS,' WAS NOT SPECIFIED BY USING CODE 1,2,OR 3')	017610	0000
2005 FORMAT(/,,'FATAL ERROR, EXCAVATION METHOD IN SEGMENT',IS,' IN RE	017620	0000
1ACH',IS,' DOES NOT MATCH TUNNEL TYPE SPECIFIED')	017630	0000
2010 FORMAT(/,,'FATAL ERROR, LINING TYPE IN SEGMENT',IS,' IN REACH',	017640	0000

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## COSTUN Listing (Continued)

115, ' DOES NOT MATCH TUNNEL TYPE SPECIFIED')	017650	0000
2015 FORMAT(/, ' FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT 1,15, ' IN REACH',15, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA 2NK) OR 1')	017660	0000
2017 FORMAT(/, ' **** REMINDER **** ALL CUT AND COVER TUNNEL SEGMENT 1TS ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT',15, 2' IN REACH',15/20X, 'AND WATERTIGHT DESIGN USED')	017670	0000
2020 FORMAT(/, ' FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE 1GMENT',15, ' IN REACH',15, ' BUT A WATERTIGHT TUNNEL WAS SPECIFIED')	017680	0000
2025 FORMAT(/, ' **** WARNING **** GROUND WATER ELEVATION IN SEGMENT 1,15, ' IN REACH',15, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI 2LL BE USED IN',/ COMPUTATIONS',5X,114(1H*))	017690	0000
2030 FORMAT(/, ' FATAL ERROR, ROD IN SEGMENT',15, ' IN REACH',15, ' IS 1LESS THAN 25 IN A ROCK TUNNEL. USE SOFT GROUND OR CUT AND COVER')	017700	0000
2035 FORMAT(/, ' **** WARNING **** RQD IN SEGMENT',15, ' IN REACH',15, 1' IS GREATER THAN 25 FOR A SOFT GROUND TUNNEL',5X,29(1H*))	017710	0000
2040 FORMAT(/, ' FATAL ERROR, SURFACE NODAL POINTS ABOVE SEGMENT',15, 1' IN REACH',15, ' ARE OUT OF SEQUENCE')	017720	0000
2045 FORMAT(/, ' FATAL ERROR, ONE OR BOTH SURFACE NODAL POINTS ABOVE S 1EGMENT',15, ' IN REACH',15, ' WERE NOT LISTED WITH OTHER NODAL POIN 1T DATA CARDS')	017730	0000
2050 FORMAT(/, ' FATAL ERROR, SURFACE NODAL POINT ELEVATIONS IN SEGMENT' 1,15, ' IN REACH',15, ' ARE BELOW TUNNEL ELEVATION')	017740	0000
2055 FORMAT(/, ' FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT',15, ' IN 1 REACH',15, ' WAS NOT INPUT')	017750	0000
2060 FORMAT(/, ' FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S 1EGMENT',15, ' IN REACH',15, ' WAS NOT SPECIFIED')	017760	0000
2061 FORMAT(/, ' **** WARNING **** POSSIBLE ERROR IN PERMEABILITY IN 1 SEGMENT',15, ' IN REACH',15, ' - INPUT IS GREATER THAN 10 CM/SEC', 25X,12(1H*))	017770	0000
2062 FORMAT(/, ' **** WARNING **** FRICTION ANGLE IN SEGMENT',15, ' I 1N REACH',15, ' IS GREATER THAN 45 DEGREES',5X,35(1H*))	017780	0000
2063 FORMAT(/, ' FATAL ERROR, FRICTION ANGLE IN SEGMENT',15, ' IN REACH' 1,15, ' IS GREATER THAN 100. CHECK FOR NUMBER SHIFTED ON DATA CARD')	017790	0000
2064 FORMAT(/, ' FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT',15, ' IN 1REACH',15, ' IS TOO LARGE FOR SOIL OR POOR ROCK')	017800	0000
2065 FORMAT(/, ' FATAL ERROR, Dewatering requirement in segment',15, 1' IN REACH',15, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) 2OR 1')	017810	0000
2070 FORMAT(/, ' **** WARNING **** IMPERVIOUS LAYER ELEVATION IN SEG 1MENT',15, ' IN REACH',15, ' IS EITHER ZERO OR BLANK - ELEVATION ZER 20 WILL BE USED',/ COMPUTATIONS',5X,111(1H*))	017820	0000
2072 FORMAT(/, ' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT', 115, ' IN REACH',15, ' IS ABOVE AVERAGE SURFACE ELEVATION')	017830	0000
2073 FORMAT(/, ' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT', 115, ' IN REACH',15, ' IS AT THE SURFACE AND SOIL GRAIN SIZE INPUT 2EXCEEDS0.005')	017840	0000
2075 FORMAT(/, ' FATAL ERROR, SUPPORT TYPE IN SOFT GROUND SEGMENT', 115, ' IN REACH',15, ' WAS NOT SPECIFIED BY CODE 1,2,3,4,5,OR 6')	017850	0000
2080 FORMAT(/, ' FATAL ERROR, SUPPORT TYPE IN SEGMENT',15, ' IN REACH', 115, ' DOES NOT MATCH TUNNEL TYPE SPECIFIED')	017860	0000
2085 FORMAT(/, ' FATAL ERROR, LINING TYPE IN SEGMENT',15, ' IN REACH', 115, ' DOES NOT MATCH SUPPORT TYPE SPECIFIED')	017870	0000
2090 FORMAT(/, ' **** WARNING **** ROCK ELEVATION IN SEGMENT',15, 1' IN REACH',15, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WILL B 2E USED IN',/ COMPUTATIONS',5X,114(1H*))	017880	0000
2092 FORMAT(/, ' FATAL ERROR, ROCK ELEVATION IN SEGMENT',15, ' IN REACH' 1,15, ' IS ABOVE AVERAGE SURFACE ELEVATION')	017890	0000
	017900	0000
	017910	0000
	017920	0000
	017930	0000
	017940	0000
	017950	0000
	017960	0000
	017970	0000
	017980	0000
	017990	0000
	018000	0000
	018010	0000
	018020	0000
	018030	0000
	018040	0000
	018050	0000
	018060	0000
	018070	0000
	018080	0000
	018090	0000
	018100	0000
	018110	0000
	018120	0000
	018130	0000
	018140	0000
	018150	0000
	018160	0000
	018170	0000
	018180	0000
	018190	0000
	018200	0000
	018210	0000
	018220	0000

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COSTUN Listing (Continued)

2094 FORMAT(/, ' **** WARNING **** CUT AND COVER BOX IN SEGMENT', IS, 1' IN REACH', IS, ' EXCEEDS 100 FEET', 5X, 42(1H*))	018230 0000
2095 FORMAT(/, ' FATAL ERROR, OPEN CUT BRACING IN SEGMENT', IS, ' IN REA 1CH', IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK), 1,2, OR 3')	018240 0000
2100 FORMAT(/, ' FATAL ERROR, BRACING CODE FOR VERTICAL OPEN CUT IN SE 1GMENT', IS, ' IN REACH', IS, ' WAS NOT SPECIFIED BY USING CODE 1,2,OR 1 3')	018250 0000
2105 FORMAT(/, ' FATAL ERROR, DECKING CODE IN SEGMENT', IS, ' IN REACH', 1IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) OR 1')	018260 0000
2115 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER IN SEGMENT', IS, ' IN REA 1CH', IS, ' IS TOO HIGH, EXCAVATION IS IMPOSSIBLE')	018270 0000
2120 FORMAT(/, ' FATAL ERROR, STABILIZATION METHOD IN SEGMENT', IS, ' IN 1 REACH', IS, ' WAS NOT SPECIFIED BY CODE ZERO(OR BLANK), 1,2, OR 3')	018280 0000
2125 FORMAT(/, ' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT', IS, 1' IN REACH', IS, ' WAS NOT SPECIFIED BY CODE 1,2,3,OR 4')	018290 0000
2130 FORMAT(/, ' FATAL ERROR, AIR PRESSURE IN SEGMENT', IS, ' IN REACH', 1IS, ' WAS NOT SPECIFIED WHEN STABILITY NUMBER WAS INPUT AND AIR P PRESSURE// STABILIZATION SPECIFIED')	018300 0000
2135 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER WAS SPECIFIED IN SEGMENT 1T, IS, ' IN REACH', IS, ' BUT STABILIZATION USE CODE DOES NE 4')	018310 0000
2137 FORMAT(/, ' FATAL ERROR, AIR PRESSURE IS SPECIFIED IN SEGMENT', IS, 1' IN REACH', IS, ' BUT STABILIZATION METHOD NOT COMPRESSED AIR')	018320 0000
2140 FORMAT(/, ' FATAL ERROR, STABILIZATION USE CODE IN SEGMENT', IS, 1' IN REACH', IS, ' DOES NOT AGREE WITH METHOD SPECIFIED')	018330 0000
2145 FORMAT(/, ' **** WARNING **** STABILIZATION METHOD IN SEGMENT', 1IS, ' IN REACH', IS, ' IS NOT ACCEPTABLE', 5X, 39(1H*))	018340 0000
2147 FORMAT(/, ' FATAL ERROR, INPUT IN SEGMENT', IS, ' IN REACH', IS, 1' REQUIRES USE OF AN UNACCEPTABLE STABILIZATION METHOD')	018350 0000
2150 FORMAT(/, ' FATAL ERROR, TUNNEL SIZE IN REACH', IS, ' INDICATES CU 1T AND COUER SECTION, BUT SHAPE CODE IS NOT ZERO')	018360 0000
2151 FORMAT(/, ' FATAL ERROR, TUNNEL SHAPE IN REACH', IS, ' INDICATES C 1UT AND COUER SECTION, BUT SIZE IS SPECIFIED IN WRONG COLUMN')	018370 0000
2152 FORMAT(/, ' FATAL ERROR, SHAPE IN REACH', IS, ' INDICATES CUT AND 1COUER, BUT A MUCK TRANSPORT METHOD WAS SPECIFIED')	018380 0000
2153 FORMAT(/, ' FATAL ERROR, TUNNEL REACH', IS, ' IS NOT CUT AND COUER 1, BUT NO MUCK TRANSPORT METHOD WAS SPECIFIED')	018390 0000
2155 FORMAT(/, ' FATAL ERROR, WORK HOURS IN REACH', IS, ' WERE NOT SPEC 1IFIED BY A NUMBER FROM 0 TO 24')	018400 0000
2160 FORMAT(/, ' FATAL ERROR, WORK DAYS IN REACH', IS, ' WERE NOT SPECI 1IFIED BY A NUMBER FROM 4 TO 7')	018410 0000
2165 FORMAT(/, ' FATAL ERROR, ONE OR BOTH BOX DIMENSIONS IN REACH', IS, 1' WERE NOT INPUT')	018420 0000
2170 FORMAT(/, ' **** WARNING **** TOTAL CLEAR BOX WIDTH IN REACH', 1IS, ' EXCEEDS 40 FEET', 5X, 55(1H*))	018430 0000
2175 FORMAT(/, ' FATAL ERROR, OPEN CUT IS SPECIFIED IN REACH', IS, 1' AND NUMBER OF BOX UNITS NOT SPECIFIED FOR A SINGLE LEVEL BOX')	018440 0000
2180 FORMAT(/, ' **** WARNING **** BOX HEIGHT IN REACH', IS, ' IS GRE ATER THAN 20 FEET FOR A SINGLE LEVEL BOX', 5X, 35(1H*))	018450 0000
2185 FORMAT(/, ' **** WARNING **** TOTAL CLEAR BOX HEIGHT IN REACH', 1IS, ' IS GREATER THAN 40 FEET FOR A DOUBLE BOX', 5X, 39(1H*))	018460 0000
2190 FORMAT(/, ' **** WARNING **** DEWATERING MAY BE USED AS A STABI LIZATION METHOD IN SEGMENT', IS, ' IN REACH', IS, ' AND IMPERVIOUS LA 2YER IS/20X, INCORRECTLY PLACED ABOVE THE TUNNEL. ELIMP WILL BE 3ASSUMED AT TUNNEL INVERT')	018470 0000
2195 FORMAT(/, ' FATAL ERROR, COMPRESSED AIR WAS REQUIRED IN SEGMENT', 1IS, ' IN REACH', IS, ' AND TRUCK MUCK TRANSPORT SPECIFIED')	018480 0000
2200 FORMAT(/, ' FATAL ERROR, CAST IRON TUNNEL SUPPORT WAS SPECIFIED I 1N SEGMENT', IS, ' IN REACH', IS, ' BUT CIRCULAR SHAPE NOT SPECIFIED')	018490 0000

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## COSTUN Listing (Continued)

2201	FORMAT(/, 'FATAL ERROR, SEGMENT', IS, ' IN REACH', IS, ' IS NOT CUT 1 AND COVER, BUT NO SHAPE WAS SPECIFIED')	018810 0000
2202	FORMAT(/, 'FATAL ERROR, SHAPE SPECIFIED FOR SEGMENT', IS, ' IN REA 1CH', IS, ' IS NOT FOR CUT AND COVER')	018820 0000
2203	FORMAT(/, ' **** WARNING **** SOUND ROCK ELEVATION LIES ABOVE B 1ASE OF TRENCH IN SEGMENT', IS, ' IN REACH', IS, ' AND RQD IS BETWEEN 225-50. /20X, 'RQD MAY BE TOO LOW FOR DESIGN AS SOUND ROCK.')	018830 0000
2204	FORMAT(/, 'FATAL ERROR, SOUND ROCK ELEVATION LIES ABOVE BASE OF 1 TRENCH IN SEGMENT', IS, ' IN REACH', IS, ' AND RQD IS LESS THAN 25. / 2 13X, 'RQD IS TOO LOW FOR DESIGN AS SOUND ROCK')	018840 0000
2205	FORMAT(/, 'FATAL ERROR, DEWATERING MUST BE ALLOWED IN SLOPING CU 1T SEGMENT', IS, ' IN REACH', IS, ' BECAUSE WATER TABLE IS ABOVE BASE 2OF TRENCH AND /14X, ' ABOVE IMPERVIOUS LAYER')	018850 0000
2207	FORMAT(/, 'FATAL ERROR, SHAFT TYPE IN SEGMENT', IS, ' IN SHAFT', IS, 1' WAS NOT SPECIFIED BY USING CODE 1,2,OR 3')	018860 0000
2208	FORMAT(/, ' **** WARNING **** NO METHOD OF EXCAVATION OR LININ 1G TYPE WERE INPUT FOR SEGMENT', IS, ' IN SHAFT', IS, '. A DUMMY SHAFT 2 IS ASSUMED')	018870 0000
2210	FORMAT(/, 'FATAL ERROR, EXCAVATION METHOD IN SEGMENT', IS, ' IN SH 1AFT', IS, ' DOES NOT MATCH SHAFT TYPE SPECIFIED')	018880 0000
2212	FORMAT(/, 'FATAL ERROR, RQD IN SEGMENT', IS, ' IN SHAFT', IS, ' IS 1LESS THAN 25 IN A ROCK SHAFT. USE SOFT GROUND OR CUT AND COVER')	018890 0000
2215	FORMAT(/, ' **** WARNING **** RQD IN SEGMENT', IS, ' IN SHAFT', IS, 1' IS GREATER THAN 25 FOR A SOFT GROUND SHAFT', 5X,30(1H*))	018900 0000
2220	FORMAT(/, 'FATAL ERROR, LINING TYPE IN SEGMENT', IS, ' IN SHAFT', 1IS, ' DOES NOT MATCH SHAFT TYPE SPECIFIED')	018910 0000
2225	FORMAT(/, 'FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT' 1, IS, ' IN SHAFT', IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA 1NK) OR 1')	018920 0000
2227	FORMAT(/, ' **** REMINDER **** ALL CUT AND COVER SHAFT SEGMENT 1S ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT', IS, 2' IN SHAFT', IS/20X, 'AND WATERTIGHT DESIGN USED')	018930 0000
2230	FORMAT(/, 'FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE 1GMENT', IS, ' IN SHAFT', IS, ' BUT A WATERTIGHT SHAFT WAS SPECIFIED')	018940 0000
2235	FORMAT(/, ' **** WARNING **** GROUND WATER ELEVATION IN SEGMENT' 1, IS, ' IN SHAFT', IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI 2LL BE USED IN /, COMPUTATIONS', 5X,114(1H*))	018950 0000
2240	FORMAT(/, 'FATAL ERROR, GROUND WATER ELEVATION LOCATED WITHIN SE 1GMENT', IS, ' IN SHAFT', IS, ' - NEED TO DEFINE NEW SEGMENT AT GWT')	018960 0000
2245	FORMAT(/, 'FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT', IS, ' IN 1 SHAFT', IS, ' WAS NOT INPUT')	018970 0000
2250	FORMAT(/, 'FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S 1EGMENT', IS, ' IN SHAFT', IS, ' WAS NOT SPECIFIED')	018980 0000
2251	FORMAT(/, ' **** WARNING **** POSSIBLE ERROR IN PERMEABILITY IN 1 SEGMENT', IS, ' IN SHAFT', IS, ' - INPUT IS GREATER THAN 10 CM/SEC', 25X,12(1H*))	018990 0000
2252	FORMAT(/, ' **** WARNING **** FRICTION ANGLE IN SEGMENT', IS, ' I 1N SHAFT', IS, ' IS GREATER THAN 45 DEGREES', 5X,35(1H*))	019000 0000
2253	FORMAT(/, 'FATAL ERROR, FRICTION ANGLE IN SEGMENT', IS, ' IN SHAFT' 1, IS, ' IS GREATER THAN 100. CHECK FOR NUMBER SHIFTED ON DATA CARD')	019010 0000
2254	FORMAT(/, 'FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT', IS, ' IN 1SHAFT', IS, ' IS TOO LARGE FOR SOIL OR POOR ROCK')	019020 0000
2255	FORMAT(/, 'FATAL ERROR, DEWATERING REQUIREMENT IN SEGMENT', IS, 1' IN SHAFT', IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) 2OR 1')	019030 0000
2260	FORMAT(/, ' **** WARNING **** IMPERVIOUS LAYER ELEVATION IN SEG 1MENT', IS, ' IN SHAFT', IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZER 20 WILL BE USED /, COMPUTATIONS', 5X,111(1H*))	019040 0000
		019050 0000
		019060 0000
		019070 0000
		019080 0000
		019090 0000
		019100 0000
		019110 0000
		019120 0000
		019130 0000
		019140 0000
		019150 0000
		019160 0000
		019170 0000
		019180 0000
		019190 0000
		019200 0000
		019210 0000
		019220 0000
		019230 0000
		019240 0000
		019250 0000
		019260 0000
		019270 0000
		019280 0000
		019290 0000
		019300 0000
		019310 0000
		019320 0000
		019330 0000
		019340 0000
		019350 0000
		019360 0000
		019370 0000
		019380 0000

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**COSTUN Listing (Continued)**

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## COSTUN Listing (Continued)

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C          019960 0000
C          019970 0000
C          019980 0000
C          019990 0000
C          020000 0000
C          020010 0000
C          020020 0000
C          020030 0000
C          020040 0000
C          020050 0000
C          020060 0000
C          020070 0000
C          020080 0000
C          020090 0000
C          020100 0000
C          020110 0000
C          020120 0000
C          020130 0000
C          020140 0000
C          020150 0000
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C          020170 0000
C          020180 0000
C          020190 0000
C          020200 0000
C          020210 0000
C          020220 0000
C          020230 0000
C          020240 0000
C          020250 0000
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C          020280 0000
C          020290 0000
C          020300 0000
C          020310 0000
C          020320 0000
C          020330 0000
C          020340 0000
C          020350 0000
C          020360 0000
C          020370 0000
C          020380 0000
C          020390 0000
C          020400 0000
C          020410 0000
C          020420 0000
C          020430 0000
C          020440 0000
C          020450 0000
C          020460 0000
C          020470 0000
C          020480 0000
C          020490 0000
C          020500 0000
C          020510 0000
C          020520 0000
C          020530 0000

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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)  

-----  

INITIALIZE  

NPT=B(1,3)  

NPB=B(1,4)  

NSEGS=0  

I=1  

NSSEG1=1  

-----  

10 IP=I  

I=I+1  

NSEGS=NSEGS+1  

-----  

CHECK FOR LAST SHAFT SEGMENT CARD  

IF(I.GT.NSS) GO TO 30  

-----  

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  

-----  

40 CONTINUE  

-----  

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  

SEGMENT IS IN CUT AND COVER  

IF(NSSTYP.EQ.B(NSSEG1-1,15))GO TO 700  

ISTOP=1  

NSSEG=B(NSSEG1,2)

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## COSTUN Listing (Continued)

```

      WRITE(LO,1000) NSSEG,NSHAFT          020540 0000
700  NSSEG1=NSSEG1+1                   020550 0000
800  CONTINUE                         020560 0000
C   -----
C   CHECK FOR ANY STOPS FOUND          020570 0000
C   IF(ISTOP.EQ.0) RETURN              020580 0000
C   FATAL ERRORS DETECTED.TERMINATE RUN AND GO TO NEXT DATA DECK 020590 0000
      WRITE(LO,2000)                   020600 0000
      CALL NEXSET(LO,L1)               020610 0000
C   -----
1000 FORMAT(/, ' FATAL ERROR, SEGMENT', I5, ' IN SHAFT', I5, ' IS IN CUT' 020620 0000
1AND COVER,BUT NOT ALL OTHER SEGMENTS ARE') 020630 0000
2000 FORMAT(///,1X,119(1H*),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS I 020640 0000
1N SUBROUTINE SFTSET' ,/1X,119(1H*)) 020650 0000
C   -----
C   -----
C   -----
C   RETURN                           020660 0000
END                            020670 0000
                                020680 0000
                                020690 0000
                                020700 0000
                                020710 0000
                                020720 0000

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## COSTUN Listing (Continued)

```

END 020720 0000
SUBROUTINE LENGTH (A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,
1NPMAX,NSMAX,NTRMAX) 020730 0000
----- 020735 0000
C 020740 0000
C THIS SUBROUTINE CALCULATES ALL SEGMENT LENGTHS AND MUCK TRANSPORT 020750 0000
C DISTANCES 020760 0000
C----- 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),
1 TRDATA(NTRMAX,23),CUMSL(NPMAX) 020830 0000
----- 020840 0000
C----- 020850 0000
C----- 020860 0000
C----- 020870 0000
C----- 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
----- 020950 0000
C----- 020960 0000
C----- 020970 0000
C----- 020980 0000
C----- 020990 0000
DO 50 I=1,NSS 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----- 021120 0000
C----- 021130 0000
C----- 021140 0000
C----- 021150 0000
C----- 021160 0000
C----- 021170 0000
C----- 021180 0000
C----- 021190 0000
C----- 021200 0000
C----- 021210 0000
C----- 021220 0000
C----- 021230 0000
C----- 021240 0000
C----- 021250 0000
C----- 021260 0000
50 CONTINUE
----- 021270 0000
C----- 021280 0000
C----- 021290 0000
C----- 021300 0000
C----- 021310 0000
C----- 021320 0000
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C----- 021970 0000
C----- 021980 0000
C----- 021990 0000
C----- 022000 0000
C----- 022010 0000
C----- 022020 0000
C----- 022030 0000
C----- 022040 0000
C----- 022050 0000
C----- 022060 0000
C----- 022070 0000
C----- 022080 0000
C----- 022090 0000
C----- 022100 0000
C----- 022110 0000
C----- 022120 0000
C----- 022130 0000
C----- 022140 0000
C----- 022150 0000
C----- 022160 0000
C----- 022170 0000
C----- 022180 0000
C----- 022190 0000
C----- 022200 0000
C----- 022210 0000
C----- 022220 0000
C----- 022230 0000
C----- 022240 0000
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C----- 022270 0000
C----- 022280 0000
C----- 022290 0000
C----- 022300 0000
C----- 022310 0000
C----- 022320 0000
C----- 022330 0000
C----- 022340 0000
C----- 022350 0000
C----- 022360 0000
C----- 022370 0000
C----- 022380 0000
C----- 022390 0000
C----- 022400 0000
C----- 022410 0000
C----- 022420 0000
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C----- 022490 0000
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C----- 022700 0000
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C----- 022720 0000
C----- 022730 0000
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C----- 022770 0000
C----- 022780 0000
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C----- 023030 0000
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C----- 023100 0000
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C----- 023150 0000
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C----- 023170 0000
C----- 023180 0000
C----- 023190 0000
C----- 023200 0000
C----- 023210 0000
C----- 023220 0000
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C----- 023250 0000
C----- 023260 0000
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C----- 023290 0000
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C----- 023390 0000
C----- 023400 0000
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C----- 023680 0000
C----- 023690 0000
C----- 023700 0000
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C----- 023900 0000
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C----- 023920 0000
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C----- 023950 0000
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C----- 023970 0000
C----- 023980 0000
C----- 023990 0000
C----- 024000 0000
C----- 024010 0000
C----- 024020 0000
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C----- 024100 0000
C----- 024110 0000
C----- 024120 0000
C----- 024130 0000
C----- 024140 0000
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C----- 024160 0000
C----- 024170 0000
C----- 024180 0000
C----- 024190 0000
C----- 024200 0000
C----- 024210 0000
C----- 024220 0000
C----- 024230 0000
C----- 024240 0000
C----- 024250 0000
C----- 024260 0000
C----- 024270 0000
C----- 024280 0000
C----- 024290 0000
C----- 024300 0000
C----- 024310 0000
C----- 024320 0000
C----- 024330 0000
C----- 024340 0000
C----- 024350 0000
C----- 024360 0000
C----- 024370 0000
C----- 024380 0000
C----- 024390 0000
C----- 024400 0000
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C----- 024470 0000
C----- 024480 0000
C----- 024490 0000
C----- 024500 0000
C----- 024510 0000
C----- 024520 0000
C----- 024530 0000
C----- 024540 0000
C----- 024550 0000
C----- 024560 0000
C----- 024570 0000
C----- 024580 0000
C----- 024590 0000
C----- 024600 0000
C----- 024610 0000
C----- 024620 0000
C----- 024630 0000
C----- 024640 0000
C----- 024650 0000
C----- 024660 0000
C----- 024670 0000
C----- 024680 0000
C----- 024690 0000
C----- 024700 0000
C----- 024710 0000
C----- 024720 0000
C----- 024730 0000
C----- 024740 0000
C----- 024750 0000
C----- 024760 0000
C----- 024770 0000
C----- 024780 0000
C----- 024790 0000
C----- 024800 0000
C----- 024810 0000
C----- 024820 0000
C----- 024830 0000
C----- 024840 0000
C----- 024850 0000
C----- 024860 0000
C----- 024870 0000
C----- 024880 0000
C----- 024890 0000
C----- 024900 0000
C----- 024910 0000
C----- 024920 0000
C----- 024930 0000
C----- 024940 0000
C----- 024950 0000
C----- 024960 0000
C----- 024970 0000
C----- 024980 0000
C----- 024990 0000
C----- 025000 0000
C----- 025010 0000
C----- 025020 0000
C----- 025030 0000
C----- 025040 0000
C----- 025050 0000
C----- 025060 0000
C----- 025070 0000
C----- 025080 0000
C----- 025090 0000
C----- 025100 0000
C----- 025110 0000
C----- 025120 0000
C----- 025130 0000
C----- 025140 0000
C----- 025150 0000
C----- 025160 0000
C----- 025170 0000
C----- 025180 0000
C----- 025190 0000
C----- 025200 0000
C----- 025210 0000
C----- 025220 0000
C----- 025230 0000
C----- 025240 0000
C----- 025250 0000
C----- 025260 0000
C----- 025270 0000
C----- 025280 0000
C----- 025290 0000
C----- 025300 0000
C----- 025310 0000
C----- 025320 0000
C----- 025330 0000
C----- 025340 0000
C----- 025350 0000
C----- 025360 0000
C----- 025370 0000
C----- 025380 0000
C----- 025390 0000
C----- 025400 0000
C----- 025410 0000
C----- 025420 0000
C----- 025430 0000
C----- 025440 0000
C----- 025450 0000
C----- 025460 0000
C----- 025470 0000
C----- 025480 0000
C----- 025490 0000
C----- 025500 0000
C----- 025510 0000
C----- 025520 0000
C----- 025530 0000
C----- 025540 0000
C----- 025550 0000
C----- 025560 0000
C----- 025570 0000
C----- 025580 0000
C----- 025590 0000
C----- 025600 0000
C----- 025610 0000
C----- 025620 0000
C----- 025630 0000

```

## COSTUN Listing (Continued)

```

NPL=A(I,2) 021270 0000
NPR=A(I,3) 021280 0000
ELNPL=CNP(NPL,2) 021290 0000
ELNPR=CNP(NPR,2) 021300 0000
SEGL=SQRT((ELNPL-ELNPR)**2+TSEGL**2) 021310 0000
CUMSL(NPR)=CUMSL(NPL)+SEGL 021320 0000
STA=STA+TSEGL 021330 0000
C THE NEXT STATEMENT CONVERTS TSEGL FROM HORIZ. TO TRUE LENGTH 021340 0000
TSEGL=SEGL 021350 0000
A(I,45)=TSEGL 021360 0000
60 CNP(NPR,1)=STA 021370 0000
----- 021380 0000
C CALCULATE AVERAGE MUCK TRANSPORTATION DISTANCES AND SLOPES (TO 021390 0000
MIDPOINT OF SEGMENTS) USING NODAL POINT STATIONING 021400 0000
C DO 70 I=1,NTS 021410 0000
NPL=A(I,2) 021420 0000
NPR=A(I,3) 021430 0000
ELNPL=CNP(NPL,2) 021440 0000
ELNPR=CNP(NPR,2) 021450 0000
NREACH=A(I,4) 021460 0000
NSHAFT=TRDATA(NREACH,1) 021470 0000
NPBS=SHAFT(NSHAFT,3) 021480 0000
ELNPBS=CNP(NPBS,2) 021490 0000
DM=ABS(CUMSL(NPBS)-(CUMSL(NPL)+CUMSL(NPR))/2.)/5280. 021500 0000
RL=DM*5280.+ABS(CUMSL(NPL)-CUMSL(NPR))/2. 021510 0000
C CHECK FOR REACH LENGTH GREATER THAN 105600 FEET( 20 MILES) 021520 0000
IF(RL.GT.105600.) WRITE(LO,1061) NREACH 021530 0000
A(I,46)=DM 021540 0000
C CALCULATE ELEVATION DIFFERENCE FROM BASE OF SHAFT TO SEG. MIDPOINT 021550 0000
ELEU=ELNPBS-(ELNPL+ELNPR)/2. 021560 0000
HSLOPE=ELEU/SQRT((DM*5280.)**2-ELEU**2) 021570 0000
70 A(I,47)=HSLOPE 021580 0000
----- 021590 0000
C CHECK FOR DUMMY SHAFT ADJACENT TO AT LEAST ONE CUT AND COVER REACH 021600 0000
DO 200 I=1,NSMAX 021610 0000
IF(SHAFT(I,1).LT.-10.E29) GO TO 200 021620 0000
ISHAPS=SHAFT(I,16) 021630 0000
IF(ISHAPS.NE.0) GO TO 200 021640 0000
NPORT=SHAFT(I,23) 021650 0000
IF(NPORT.EQ.1) GO TO 200 021660 0000
NPBS=SHAFT(I,3) 021670 0000
STA=CNP(NPBS,1) 021680 0000
IF(STA.GT.STABEG) GO TO 100 021690 0000
NTSTYP=A(1,16) 021700 0000
IF(NTSTYP.EQ.3) GO TO 200 021710 0000
GO TO 175 021720 0000
100 STA=STA-1.0 021730 0000
IJK=0 021740 0000
DO 150 J=1,NTS 021750 0000
NPL=A(J,2) 021760 0000
NPR=A(J,3) 021770 0000
IF(STA.GT.CNP(NPL,1).AND.STA.LT.CNP(NPR,1)) GO TO 160 021780 0000
150 CONTINUE 021790 0000
160 NTSTYP=A(J,16) 021800 0000
IF(NTSTYP.EQ.3) GO TO 200 021810 0000
IF(J.EQ.NTS) GO TO 175 021820 0000
----- 021830 0000
021840 0000

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(Continued)

## COSTUN Listing (Continued)

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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 0000
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----- I= SEGMENT SEQUENCE NUMBER, NUMBER IN ORDER OF APPEARANCE 022050 0000
C----- 022060 0000
C----- 022070 0000
C----- 022080 0000
C----- 022090 0000
C----- COMMON /BASIC/ NSS,NTS 022100 0000
C----- COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE 022120 0000
C----- DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 022130 0000
1 TRDATA(NTRMAX,23) 022140 0000
C----- 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 U 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
C----- DOUBLE PRECISION BLANK,CONU,TMOLER,TMOLES,HANDS,RIPPER,VERTCC, 022260 0000
1 SLOPCC,HORSE,BASKET,CIRCLE,BOX,TWOBX,SQUARE,CONVYR,TRUCK,TRAIN, 022270 0000
2 CONTRK,TNONE,WET,DRY,ANO,YES,CIRSEG,CONSEG,STLSEG,STLSET,SOLDER, 022280 0000
3 SLURRY,OPENCT,AIRPRS,DEWATR,GRDINJ,USENO,PREFNO,STRUT,ANCHOR, 022290 0000
4 STRANC 022300 0000
C----- DOUBLE PRECISION SHAPE,REMK,EXCAU,WTLIN,AR,TL,HOURS,DAYS,SUPORT, 022310 0000
1 DWATER,STABIL,GAMMA,PERM,STABNO,AIRPR,DECK,BRACE,BFT,EXMS, 022320 0000
2 SHAPS,GRDW 022330 0000
C----- REALX8 JBLANK,NONE,ISHOT,ICONC,IPREC,IFNEC,MUSTUS,IUSE,LTYP 022340 0000
C----- ***** 022370 0000
C----- CHARACTER*6 FM1/'2X,A6,'/,FM2/'A5,'/,FM3/'A5')//,FM4/ 022380 0000
1 '(1X,A4', 022390 0000
1 FM5/'1X,A4,'/,FM6/'5X,A4,'/,FM7/'1X,A6,'/,FM8/'4X,A6,'/,FM9/'A6,'/ 022400 0000
2 ,FM10/'A6')//,FM11/'(1X,I4//,FM12/'F8.1,'/,FM13/'F5.1,'/, 022410 0000
3 FM14/'F5.1')//,FM15/'I5,'/,FM16/'3X,I6,'/,FM17/'F7.1,'/, 022420 0000
4 FM18/'E10.2,'/,FM19/'F6.1,'/,FM20/'F6.1')//,FM21/'F7.2,'/, 022430 0000
5 FM22/'3X,A4,'/,FM23/'I7,'/

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(Continued)

## COSTUN Listing (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) //,I5.' ,I5.' ,I5.' ,2X,A6,' , 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) //,I5.' ,A6,' ,F8.1,' ,2X,A6,' ,F6.1,' ,1X,A6,' ,1X,A6,' , 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,' ,I5,' ,I6,' ,2X,A6,' ,F6.2,' , 022510 0000
1'1X,A6,' ,3X,I6,' ,I5,' ,A6,' ,A6,' ,F6.1,' ,A6,' ,F7.1,' ,I8,' , 022520 0000
2'I7,' ,F9.1,' ,F6.1,' ,F5.1) //,I8.' ,F7.1,' ,F5.0,' ,F7.0,' ,E10.2,' , 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) //,I5.' , 022550 0000
----- 022560 0000
C DATA BLANK//,JBLANK//,IBLANK//, 022570 0000
DATA CONU//,CONU//,TMOLER//,MOLER//,TMOLES//,MOLES//,HANDS//,HAND 022580 0000
1S '//,RIPPER//,RIPPER//,UERTCC//,UERTOC//,SLOPOCC//,SLOPOCC//, 022590 0000
DATA HORSE//,HORSE//,BASKET//,BASKET//,CIRCLE//,CIRCLE//,BOX//,BOX 022600 0000
1'TWOBLOCK//,TWOBLOCK//,SQUARE//,SQUARE//, 022610 0000
DATA CONVYR//,CONVYR//,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
----- 022740 0000
C IF(ITYPE.EQ.2) GO TO 150 022750 0000
C 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
----- 022900 0000
C C C
C 10 NLLINES-NLLINES+1 022910 0000
C IF(NLLINES.LE.40) GO TO 30 022920 0000
C WRITE OUT COLUMN HEADINGS FOR TUNNEL SEGMENTS 022930 0000
----- 022940 0000
C C C
C 022950 0000
C 022960 0000

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(Continued)

## COSTUN Listing (Continued)

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```

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

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(Continued)

## COSTUN Listing (Continued)

```

C -----
70 AR=A(I,8) 023540 0000
JRS=A(I,5) 023550 0000
JRQD=A(I,6) 023560 0000
JRTEMP=A(I,12) 023570 0000
INFLOW=A(I,9) 023580 0000
IF(INFLOW.LT.0) INFLOW=0 023590 0000
TL=A(I,11) 023600 0000
IF(TL.LE.0.) TL=0. 023610 0000
ELWATR=A(I,14) 023620 0000
HOURS=TRDATA(NREACH,8) 023630 0000
DAYS=TRDATA(NREACH,9) 023640 0000
023650 0000
023660 0000
023670 0000
023680 0000
023690 0000
023700 0000
023710 0000
023720 0000
023730 0000
023740 0000
023750 0000
023760 0000
023770 0000
023780 0000
023790 0000
023800 0000
023810 0000
023820 0000
023830 0000
023840 0000
023850 0000
023860 0000
023870 0000
023880 0000
023890 0000
023900 0000
023910 0000
023920 0000
023930 0000
023940 0000
023950 0000
023960 0000
023970 0000
023980 0000
023990 0000
024000 0000
024010 0000
024020 0000
024030 0000
024040 0000
024050 0000
024060 0000
024070 0000
024080 0000
024090 0000
024100 0000
024110 0000
-----
```

C CHECK TO SEE IF THIS IS THE SAME REACH AS FOR PREVIOUS SEGMENT

C 85 IF(IPR.EQ.NREACH) GO TO 90

C SET VALUES OF HOURS AND DAYS FOR PREVIOUS REACH IF NOT INPUT

C IF(I.EQ.1) GO TO 88

N=A(I-1,4)

IF(TRDATA(N,8).LT.0.1) TRDATA(N,8)=24.0

IF(TRDATA(N,9).LT.0.1) TRDATA(N,9)=6.0

88 WRITE(LO,1004)

90 IF(IPR.EQ.NREACH) WRITE(LO,2000)

NLINES=NLINES+1

C ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN

C VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA

91 IF(AR.GT.0.0) GO TO 92

AR=BLANK

FMT1(11)=FM1

92 IF(TL.GT.0.0) GO TO 93

TL=BLANK

FMT1(17)=FM2

93 IF(HOURS.GT.0.0) GO TO 94

HOURS=BLANK

FMT1(20)=FM2

94 IF(DAYS.GT.0.0) GO TO 95

DAYS=BLANK

FMT1(21)=FM3

95 IF(IPR.NE.NREACH) GO TO 98

NREACH=IBLANK

FMT1(1)=FM4

HOURS=BLANK

FMT1(20)=FM2

DAYS=BLANK

FMT1(21)=FM3

98 IF(NTSTYP.GT.1) GO TO 100

C -----

C ROCK TUNNEL

WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,

1EXCAU,AR,JRS,JRQD,JRTTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS

GO TO 140

C -----

C SOFT GROUND TUNNEL OR CUT AND COVER BOX

C FIND ALPHA NAME FOR SUPPORT TYPE

100 ISUPPT=A(I,26)

IF(ISUPPT.EQ.0) SUPPORT=TNONE

IF(ISUPPT.EQ.1) SUPPORT=CIRSEG

IF(ISUPPT.EQ.2) SUPPORT=CONSEG

(Continued)

## COSTUN Listing (Continued)

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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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## COSTUN Listing (Continued)

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C -----
C SOFT GROUND TUNNEL                               024700 0000
C WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK, 024710 0000
1 EXCAV,AR,JRS,JRQD,JRTTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS 024720 0000
C JRTEMP=A(I,12)                                     024730 0000
C WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTTEMP,DWATER, 024740 0000
1 ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR           024750 0000
C NLINES=NLINE$+1                                    024760 0000
C GO TO 140                                         024770 0000
C -----                                           024780 0000
C CUT AND COVER                                     024790 0000
C FIND ALPHA NAMES FOR DECKING REQUIREMENT        024800 0000
120 IDECK=A(I,29)                                   024810 0000
C IF(IDECK.EQ.0) DECK=ANO                         024820 0000
C IF(IDECK.EQ.1) DECK=YES                          024830 0000
C FIND ALPHA NAME FOR BRACING SPECIFIED          024840 0000
C IBRACE=A(I,28)                                    024850 0000
C IF(IBRACE.EQ.0) BRACE=TNONE                      024860 0000
C IF(IBRACE.EQ.1) BRACE=STRUT                       024870 0000
C IF(IBRACE.EQ.2) BRACE=ANCHOR                     024880 0000
C IF(IBRACE.EQ.3) BRACE=STRANG                     024890 0000
C ELROCK=A(I,27)                                    024900 0000
C NREACH=A(I,4)                                     024910 0000
C NBOX=TRDATA(NREACH,10)                           024920 0000
C BFBWDT=TRDATA(NREACH,11)                          024930 0000
C BFBHT=TRDATA(NREACH,12)                           024940 0000
C ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN 024950 0000
C VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA   024960 0000
C REMOVE TUNNEL SIZE, MUCK TRANSPORT, SOIL TEMPERATURE, AND      024970 0000
C STABILIZATION FOR CUT AND COVER.                  024980 0000
C IF(IPR.EQ.NREACH) NREACH=IBLANK                 024990 0000
C BFT=BLANK                                         025000 0000
C FMT1(8)=FM7                                       025010 0000
C REMK=BLANK                                         025020 0000
C JRTEMP=IBLANK                                     025030 0000
C FMT2(8)=FMS                                       025040 0000
C IF(INFLOW.GT.0) GO TO 138                        025050 0000
C INFLOW=IBLANK                                     025060 0000
C FMT1(15)=FM5                                      025070 0000
C STABIL=BLANK                                     025080 0000
C -----                                           025090 0000
138 WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK, 025100 0000
1 EXCAV,AR,JRS,JRQD,JRTTEMP,INFLOW,LTYP,TL,WTLIN,ELWATR,HOURS,DAYS 025110 0000
C WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTTEMP,DWATER, 025120 FMT0
1 ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR           025130 FMT0
C WRITE(LO,FMT3) ELROCK,DECK,BRACE,NBOX,BFBWDT,BFBHT 025140 0000
C NLINES=NLINE$+2                                    025150 0000
C -----                                           025160 0000
C 140 NREACH=A(I,4)                                025170 0000
C IF(IPR.NE.NREACH) IPR=NREACH                     025180 0000
C SET VALUE FOR GAMMA IN THIS TUNNEL SEGMENT IF NOT INPUT 025190 0000
C 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
C IF(NTSTYP.GT.1.AND.A(I,25).GT.10.E-10) PERM--PERM 025220 0000
C IF(NTSTYP.GT.1.AND.A(I,25).LT.10.E-10) PERM=D10**2/10. 025230 0000
C A(I,25)=PERM                                     025240 0000
C IPR=IPR                                         025250 0000
C RESET FORMATS TO ORIGINAL IN DATA STATEMENT    025260 0000
C FMT1(1)=FM11                                     025270 0000

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## COSTUN Listing (Continued)

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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(NSTTYP.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(NSTTYP.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
C 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
NSTTYP=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 200 NLINES=NLINES+1 025720 0000
IF(NLINES.LE.45) GO TO 230 025730 0000
C
NLINES=0                025740 0000
230 NSHAFT=B(I,1)          025750 0000
NSSEG=B(I,2)          025760 0000
BFS=SHAFT(NSHAFT,7)      025770 0000
NPT=B(I,3)          025780 0000
NPB=B(I,4)          025790 0000

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## COSTUN Listing (Continued)

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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
----- 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
----- 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-CONU          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
----- 026200 0000
C   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
----- 026260 0000
C   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
----- 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
----- 026430 0000
C   CHECK FOR PORTAL

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## COSTUN Listing (Continued)

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IF(NPORT.EQ.0) GO TO 292          026440 0000
WRITE(LO,2200) NSHAFT,NPTS,DDS,ICDS,IARTEM
GO TO 350                         026450 0000
                                     026460 0000
C-----                                026470 0000
C DUMMY SHAFT IS INPUT WHEN NO SHAFT IS REQUIRED FOR OPEN CUT REACH 026480 0000
292 IF(ISSHAPS.NE.0) GO TO 300      026490 0000
WRITE(LO,2100) NSHAFT,NSSEG,NPTS,NPBS,DDS,ICDS,IARTEM
GO TO 350                         026500 0000
                                     026510 0000
C-----                                026520 0000
C 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 C ROCK SHAFT                      026760 0000
WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,
1GRDW,LTYP,TL,UTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS
GO TO 350                           026770 0000
                                     026780 0000
                                     026790 0000
C-----                                026800 0000
C 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=COMSEG       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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COSTUN Listing (Continued)

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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
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 SOFT GROUND SHAFT                                     027380 0000
WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD, 027390 0000
1GRDW,LTYP,TL,WTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS        027400 0000
WRITE(LO,0006) D10,GAMMA,PHI,COHESN,PERM,DWATER,ELIMP,SUPPORT, 027410 0000
1STABNO,STABIL,IUSE,AIRPR                                027420 0000
NLINES=NLINES+1                                           027430 0000
GO TO 350                                                 027440 0000
-----
C CUT AND COVER                                         027450 0000
SHAFT IS BUILT WITHIN OPEN CUT CONSTRUCTED FOR TUNNEL       027460 0000
ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN 027470 0000
VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA            027480 0000
REMOVE VARIABLES THAT DO NOT APPLY TO CUT AND COVER        027490 0000
                                                027500 0000
                                                027510 0000

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## COSTUN Listing (Continued)

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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,
      1QRDW,LTYP,TL,UTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS      027600 0000
      WRITE(LO,0006) D10,GAMMA,PHI,COHESN,PERM,DWATER,ELIMP,SUPPORT,
      1STABNO,STABIL,IUSE,AIRPR               027610 0000
      NLINES=NLINES+1                         027620 0000
      027630 0000
      027640 0000
      027650 0000
C   -----
  350 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
      027960 0000
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## COSTUN Listing (Continued)

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C ***** RETURN ***** 027970 0000
C ***** ***** 027980 0000
C ***** ***** 027990 0000
C ***** ***** 028000 0000
C ***** ***** 028010 0000
C 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 BOUNDARY EXIT HORIZ TUNNEL TUNNEL MUCK EXCAU 028030 0000
2A- UNF ADV *ROCK PROPERTIESZ INFLOW *** LINING **** GROUND HOURS D 028040 0000
3AYS'/11X,'LEFT RIGHT SHAFT LENGTH SHAPE SIZE REMOVAL TION 028050 0000
4RATE STRENGTH RQD TEMP (GPM) TYPE THICK WAT WATER PER PER 028060 0000
5/43X,(FT) METHOD METHOD (FT/DAY) (PSI)',7X,'(F)',15X,'(IN) T 028070 0000
6GT ELEU. 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 ELEU.,30X,'(PSI)') 028130 0000
1002 FORMAT(33(2X,2H--)/11X,'SOUND XCUT AND COVER% **BOX PROPERTIES**' 028140 0000
1/11X,'ROCK DECKING BRACING UNITS WIDTH HEIGHT'/11X,'ELEV.',25X, 028150 0000
2'(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 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 RQD 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 ELEU. 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 ELEU.,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,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,I6,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 028345 0000

```

(Continued)

## COSTUN Listing (Continued)

```

SUBROUTINE SIZEST(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX 028350 0000
1,NTRMAX) 028355
----- 028360 0000
----- 028370 0000
----- 028380 0000
----- 028390 0000
----- 028400 0000
----- 028410 0000
----- 028420 0000
----- 028430 0000
----- 028440 0000
----- 028450 0000
----- 028460 0000
----- 028470 0000
----- 028480 0000
----- 028490 0000
----- 028500 0000
----- 028510 0000
----- 028520 0000
----- 028530 0000
----- 028540 0000
----- 028550 0000
----- 028560 0000
----- 028570 0000
----- 028580 0000
----- 028590 0000
----- 028600 0000
----- 028610 0000
----- 028620 0000
----- 028630 0000
----- 028640 0000
----- 028650 0000
----- 028660 0000
----- 028670 0000
----- 028680 0000
----- 028690 0000
----- 028700 0000
----- 028710 0000
----- 028720 0000
----- 028730 0000
----- 028740 0000
----- 028750 0000
----- 028760 0000
----- 028770 0000
----- 028780 0000

```

C

I=TUNNEL OR SHAFT SEGMENT NUMBER  
 THIS SUBROUTINE CALCULATES THE FOLLOWING IN TUNNELS OR SHAFTS  
 BE, BE40, BE60, TL, BOB, BOB40, BOB60, WEB, TPLATE, TSEG, DTRNCH, SIDEL, UBOX,  
 TUOL, FORMAR, UTWALE, WTSTRT, UTANCH, UTSP, UTSPD

\*\*\*\*\*  
 GENERAL DATA  
 \*\*\*\*\*

COMMON /BASIC/ NSS,NTS  
 COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE  
 DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),  
 1 TRDATA(NTRMAX,23)  
 REAL MIN,MAX

C

I=TUNNEL SEGMENT SEQUENCE NUMBER

ITYPE=1 INDICATES TUNNEL SEGMENT  
 ITYPE=1  
 NREACH=A(I,4)  
 NTSEG=A(I,1)  
 TLIN=A(I,11)  
 BFT=TRDATA(NREACH,2)  
 BF=BFT  
 LINING=A(I,10)  
 MEX=A(I,7)  
 ISHAPE=TRDATA(NREACH,3)  
 MSTAKE=0  
 ELWATR=A(I,14)  
 NPL=A(I,2)  
 NPR=A(I,3)  
 ELNPL=CNP(NPL,2)  
 ELNPR=CNP(NPR,2)  
 ELAUG=(ELNPL+ELNPR)/2.  
 LINWT=A(I,15)  
 NTSTYP=A(I,16)  
 NSSTYP=0  
 GO TO 10

C

-

(Continued)

## COSTUN Listing (Continued)

```

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

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(Continued)

**COSTUN Listing (Continued)**

```

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

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(Continued)

## COSTUN Listing (Continued)

```

WEB = (0.294*BF+3.35 )/12.          029946 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 -----
C RQD IS GREATER THAN OR EQUAL TO 60 030480 0000
C -----
C -----
C -----

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(Continued)

## COSTUN Listing (Continued)

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```

C HAS A LINING THICKNESS BEEN INPUT          030520 0000
C 200 IF(TLIN.GT.0.001) GO TO 230          030530 0000
C IS SEGMENT LINED OR UNLINED             030540 0000
C IF(LINING.GT.0)GO TO 216                030550 0000
C UNLINED                                030560 0000
C TL=0.0                                  030570 0000
C BE=BF                                  030580 0000
C GO TO 400                               030590 0000
C 216 BE=BF+2.*TL                         030600 0000
C GO TO 400                               030610 0000
C LINING TYPE                            030620 0000
C 230 IF(LINING.EQ.2) GO TO 250          030630 0000
C CONCRETE                                030640 0000
C IF(TLIN.LT.0.666) GO TO 260          030650 0000
C 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
C 260 IF(MSTAKE.EQ.1) GO TO 216          030690 0000
C IF(ITYPE.EQ.1) WRITE(LO,1010) NTSEG,NREACH 030700 0000
C IF(ITYPE.EQ.2) WRITE(LO,1011) NSSEG,NSHAFT 030710 0000
C GO TO 216                               030720 0000
C CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE 030730 0000
C 250 IF(TLIN.LT.TL) GO TO 275          030740 0000
C BE=BF+2.*TLIN                           030750 0000
C TL=TLIN                                030760 0000
C GO TO 400                               030770 0000
C 275 MSTAKE=2                            030780 0000
C GO TO 216                               030790 0000
C -----
C OVERBREAK DIMENSION                     030800 0000
C -----
C WHAT IS THE EXCAVATION METHOD          030810 0000
C 400 IF(MEX.EQ.2) BOB=BE                030820 0000
C IF(MEX.EQ.1) BOB=BE+(250.-RQD)*(BE+10.)/2500. 030830 0000
C 030840 0000
C -----
C RQD BETWEEN 40 AND 60                  030850 0000
C -----
C 030860 0000
C IF(II.LT.3) GO TO 450                030870 0000
C BE40=BE                                030880 0000
C BE60=BE                                030890 0000
C BOB40=BOB                             0308910 0000
C BOB60=BOB                             0308920 0000
C GO TO 600                               0308930 0000
C 450 IF(II.GE.2) GO TO 500          0308940 0000
C STORE BE AND BOB COMPUTED USING FICTITIOUS RQD=40 0308950 0000
C BE40=BE                                0308960 0000
C BOB40=BOB                             0308970 0000
C REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF 0308980 0000
C INTERPOLATION COMPUTATION            0308990 0000
C RQD=60.                                 031000 0000
C RE-ESTABLISH INPUT VALUE OF LINING THICKNESS FOR PURPOSES OF 031010 0000
C THE CHECK IN STATEMENT 200            031020 0000
C TL=TT                                  031030 0000
C REDEFINE FLOW INDICATOR              031040 0000
C II=II+1                                031050 0000
C GO TO 200                               031060 0000
C 031070 0000
C 031080 0000
C 031090 0000

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(Continued)

## COSTUN Listing (Continued)

```

C ----- 031100 0000
C STORE BE AND BOB COMPUTED USING FICTICIOUS RQD=60 031110 0000
C 500 BE60=BE 031120 0000
C BOB60=BOB 031130 0000
C ----- 031140 0000
C CALCULATE BE AND BOB BY INTERPOLATING BETWEEN BE AND BOB 031150 0000
C VALUES AT RQD=40 AND RQD=60 031160 0000
C ----- 031170 0000
C BE=BE40+(RQDD-40.)/20.*(BE60-BE40) 031180 0000
C BOB=BOB40+(RQDD-40.)/20.*(BOB60-BOB40) 031190 0000
C ----- 031200 0000
C 550 IF(LINING.NE.1) GO TO 600 031210 0000
C COMPUTE THE AVERAGE THICKNESS FOR THE CONCRETE LINING 031220 0000
C WHEN THE RQD IS BETWEEN 40 AND 60 031230 0000
C TL=(BE-BF)/2. 031240 0000
C ----- 031250 0000
C 031260 0000
C ----- 031270 0000
C SET VARIABLES FOR SHAFT OR TUNNEL SEGMENTS 031280 0000
C ----- 031290 0000
C 600 IF(ITYPE.EQ.2) GO TO 700 031300 0000
C TUNNEL SEGMENT DATA 031310 0000
A(I,39)=BE 031320 0000
A(I,40)=BE40 031330 0000
A(I,41)=BE60 031340 0000
A(I,42)=BOB 031350 0000
A(I,43)=BOB40 031360 0000
A(I,44)=BOB60 031370 0000
A(I,62)=WEB 031380 0000
A(I,64)=PWATER 031390 0000
A(I,11) = TL 031400 0000
IF(MSTAKE.EQ.2) WRITE(LO,2710) NTSEG,NREACH 031410 0000
GO TO 4000 031420 0000
C ----- 031430 0000
C SHAFT SEGMENT DATA 031440 0000
C 700 B(I,29)=BE 031450 0000
B(I,30)=BE40 031460 0000
B(I,31)=BE60 031470 0000
B(I,32)=BOB 031480 0000
B(I,33)=BOB40 031490 0000
B(I,34)=BOB60 031500 0000
B(I,41)=WEB 031510 0000
B(I,43)=PWATER 031520 0000
B(I,11) = TL 031530 0000
IF(MSTAKE.EQ.2) WRITE(LO,2711) NSSEG,NSHAFT 031540 0000
GO TO 4000 031550 0000
C ----- 031560 0000
C ***** 031570 0000
C SOFT GROUND TUNNELS AND SHAFTS 031580 0000
C ***** 031590 0000
C 1000 BE=BF 031600 0000
N=0 031610 0000
I2=0 031620 0000
TANPHI=TAN(PHI*PI/180.) 031630 0000
----- 031640 0000
C MINIMUM SUPPORT SIZE 031650 0000
----- 031660 0000
C ----- 031670 0000

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(Continued)

## COSTUN Listing (Continued)

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```

C GO TO(1001,1002,1003,1005) ISUPPT          031680 0000
C CAST IRON SEGMENTED SUPPORT                 031690 0000
1001 TSEGMM=0.6666                            031700 0000
TPLMIN=0.05                                     031710 0000
FF=4                                           031720 0000
GO TO 1004                                     031730 0000
C PRECAST CONCRETE SEGMENTED SUPPORT          031740 0000
1002 TSEGMN=1                                 031750 0000
TPLMIN=0.125                                  031760 0000
FF=2                                           031770 0000
GO TO 1004                                     031780 0000
C STEEL SEGMENTED SUPPORT                     031790 0000
1003 TSEGMN=0.583                            031800 0000
TPLMIN=0.03                                     031810 0000
FF=4                                           031820 0000
1004 IF(TLIN.GT.0. .AND. TLIN.LT.TPLMIN) GO TO 1008 031830 0000
IF(TLIN.GT.TPLMIN) GO TO 1025                031840 0000
GO TO 1009                                     031850 0000
1025 IF(ELWATR.LT.ELAUG .OR. LINWT.EQ.0) GO TO 1026 031860 0000
GO TO 1009                                     031870 0000
C WHEN WATER PRESSURE=0, INPUT LINER THICKNESS GREATER THAN MINIMUM 031880 0000
C VALUE WILL BE ACCEPTED                      031890 0000
1026 I2=1                                     031900 0000
TPLATE=TLIN                                    031910 0000
GO TO 2354                                     031920 0000
C STEEL SEGMENTED SUPPORT                     031930 0000
1005 IF(LINING.EQ.2) GO TO 1006                031940 0000
TLMIN=0.6666                                   031950 0000
IF(TLIN.GT.0. .AND. TLIN.LT.TLMIN) GO TO 1008 031960 0000
GO TO 1009                                     031970 0000
1006 TLMIN=0.333                             031980 0000
IF(TLIN.GT.0.) TLMIN=0                         031990 0000
GO TO 1009                                     032000 0000
C INPUT LINER OR LINING THICKNESS LESS THAN MINIMUM VALUE 032010 0000
1008 MSTAKE=1                                032020 0000
C -----
C UNIT WEIGHT OF SOIL                         032030 0000
C -----
1009 BBEE=BE                                 032040 0000
N=N+1                                         032050 0000
SEGDEP=ELSURF-EAUG                           032060 0000
C CHECK FOR GWT ABOVE GROUND SURFACE        032070 0000
IF(ELWATR.GT.ELSURF) GO TO 1045              032080 0000
C CHECK FOR SEGMENT BELOW GWT               032090 0000
IF(EAUG.LT.ELWATR) GO TO 1015                032100 0000
C GWT IS BELOW SEGMENT                      032110 0000
SIGGAH=SEGDEP*GAMMA                          032120 0000
IF(SEGDEP.LE.2.*BE) GO TO 1012                032130 0000
GAMMAA=GAMMA                                 032140 0000
GAMMAB=GAMMA                                 032150 0000
GO TO 1050                                     032160 0000
1012 GAMMAC=GAMMA                           032170 0000
GO TO 1050                                     032180 0000
C SEGMENT IS BELOW GWT                      032190 0000
1015 SIGGAH=DWATER*GAMMA+(ELWATR-EAUG)*(GAMMA-62.4) 032200 0000
IF(SEGDEP.LE.2.*BE) GO TO 1030                032210 0000
IF(DWATER.GT.2.*BE) GO TO 1020                032220 0000
C SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE 032230 0000
                                                032240 0000
                                                032250 0000

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(Continued)

## COSTUN Listing (Continued)

```

GAMMAAA=(GAMMA*DWATER+(GAMMA-62.4)*(2.*BE-DWATER))/(2.*BE)      032260 0000
GAMMAB=(GAMMA-62.4)                                                 032270 0000
GO TO 1050                                                       032280 0000
C SEGMENT AND GUT ARE BOTH DEEPER THAN 2BE                         032290 0000
1020 GAMMAA=GAMMA                                                 032300 0000
GAMMAC=(GAMMA*(DWATER-2.*BE)+(GAMMA-62.4)*(ELWATR-ELAUG))/SEGDEP 032310 0000
1/(SEGDEP-2.*BE)                                                 032320 0000
GO TO 1050                                                       032330 0000
C SEGMENT IS WITHIN 2BE OF GROUND SURFACE                         032340 0000
1030 GAMMAC=(GAMMA*DWATER+(GAMMA-62.4)*(ELWATR-ELAUG))/SEGDEP 032350 0000
GO TO 1050                                                       032360 0000
C GUT IS ABOVE GROUND SURFACE                                     032370 0000
1045 GAMMAAA=GAMMA-62.4                                         032380 0000
GAMMAB=GAMMA-62.4                                                 032390 0000
GAMMAC=GAMMA-62.4                                                 032400 0000
SIGGAH=SEGDEP*(GAMMA-62.4)                                         032410 0000
C ADJUST UNIT WEIGHTS OF SOIL FOR DRAINED SEGMENT                 032420 0000
1050 IF(LINWT.EQ.1) GO TO 1100                                     032430 0000
GAMMAAA=GAMMA                                                 032440 0000
GAMMAB=GAMMA                                                 032450 0000
GAMMAC=GAMMA                                                 032460 0000
C -----
C EXPRESS SOIL STRENGTH IN TERMS OF EQUIVALENT PHI               032470 0000
C -----
1100 PHIEQR=ATAN(COHESN/SIGGAH+TANPHI)                           032480 0000
PHIEQ=PHIEQR*180./PI                                              032490 0000
IF(PHIEQ.GT.45.) PHIEQ=45.                                         032500 0000
C -----
C TUNNEL AND SHAFT LOADS                                         032510 0000
C -----
C ESTABLISH SEGMENT TYPE AND SHAPE FACTORS                         032520 0000
IF(SEGDEP.LE.2.*BE) GO TO 1300                                     032530 0000
F=1.0                                                               032540 0000
FSHAPE=1.0                                                       032550 0000
IF(ITYPE.EQ.1) GO TO 1110                                         032560 0000
C SHAFT SEGMENT                                                 032570 0000
F=0.5                                                               032580 0000
FSHAPE=0.5                                                       032590 0000
IF(ISHAPS.EQ.2) F=0.6                                             032600 0000
IF(ISHAPS.EQ.2) FSHAPE=0.6                                         032610 0000
GO TO 1200                                                       032620 0000
C TUNNEL SEGMENT                                                 032630 0000
1110 IF(ISHAPE.EQ.3) FSHAPE=1.25                                 032640 0000
C -----
1200 PSOIL=2.*BE*GAMMAAA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)* 032650 0000
1 GAMMAB*FSHAPE                                                 032660 0000
GO TO 1310                                                       032670 0000
1300 F=1.0                                                       032680 0000
IF(ITYPE.EQ.1) GO TO 1301                                         032690 0000
C SHAFT SEGMENT                                                 032700 0000
F=0.5                                                               032710 0000
IF(ISHAPS.EQ.2) F=0.6                                             032720 0000
1301 PSOIL=SEGDEP*GAMMAC*F                                         032730 0000
C -----
1310 IF(LINWT.EQ.1) GO TO 1320                                     032740 0000
C DRAINED                                                       032750 0000
PWATER=0                                                       032760 0000
GO TO 1330                                                       032770 0000
C -----
032780 0000
032790 0000
032800 0000
032810 0000
032820 0000
032830 0000

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## COSTUN Listing (Continued)

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C   WATER TIGHT          032840 0000
1320 PWATER=68.4*(ELWATR-ELAUG) 032850 0000
C   QUT BELOW SEGMENT    032860 0000
C   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
GO TO 2000 032890 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   -----
C   SUPPORT SIZE          032990 0000
C   -----
C   GO TO(2100,2200,2300,2400) ISUPPT 033000 0000
C   CAST IRON SEGMENTED SUPPORT 033010 0000
2100 TPLATE=7.E-6*BF**0.68*PTOTAL**0.78 033020 0000
GO TO 2350 033030 0000
C   PRECAST CONCRETE LINER 033040 0000
2200 IF(ITYPE.EQ.2) GO TO 2235 033050 0000
C   TUNNEL SEGMENT          033060 0000
IF(ISSHAPE-2) 2210,2220,2230 033070 0000
2210 TPLATE=1.55E-8*(0.1+0.046*BF)*PTOTAL**1.6*EXP(SQRT((6.6-0.56*ALOG
1(PTOTAL))**2+0.016)) 033080 0000
GO TO 2350 033090 0000
2220 TPLATE=2.6E-7*(0.1+0.044*BF)*PTOTAL**1.38*EXP(SQRT((9.25-0.775*
1ALOG(PTOTAL))**2+0.048)) 033100 0000
GO TO 2350 033110 0000
2230 TPLATE=6.5E-8*(0.1+0.044*BF)*PTOTAL**1.48*EXP(SQRT((11.3-0.94*
1ALOG(PTOTAL))**2+0.21)) 033120 0000
GO TO 2350 033130 0000
C   SHAFT SEGMENT          033140 0000
2235 IF(ISSHAPS.EQ.1) GO TO 2210 033150 0000
TPLATE=6.8E-7*(5.+4.7*BF)*PTOTAL**0.93*EXP(SQRT((5.22-0.45*ALOG
1(PTOTAL))**2+0.08)) 033160 0000
GO TO 2350 033170 0000
C   STEEL SEGMENTED SUPPORT 033180 0000
2300 IF(ITYPE.EQ.2) GO TO 2335 033190 0000
C   TUNNEL SEGMENT          033200 0000
IF(ISSHAPE-2) 2310,2320,2330 033210 0000
2310 TPLATE=6.95E-7*BF**0.8*PTOTAL**0.88 033220 0000
GO TO 2350 033230 0000
2320 TPLATE=6.6E-4*BF**0.74*PTOTAL**0.39 033240 0000
GO TO 2350 033250 0000
2330 TPLATE=8.5E-4*BF**0.71*PTOTAL**0.38 033260 0000
GO TO 2350 033270 0000
C   SHAFT SEGMENT          033280 0000
2335 IF(ISSHAPS.EQ.1) GO TO 2310 033290 0000
TPLATE=0.001*BF**0.75*PTOTAL**0.38 033300 0000
2350 IF(TPLATE.LT.TPLMIN) TPLATE=TPLMIN 033310 0000
C   INPUT LINER THICKNESS GREATER THAN COMPUTED VALUE WILL BE USED 033320 0000
IF(TPLATE.LT.TLIN) TPLATE=TLIN 033330 0000
IF(TLIN.GE.TPLMIN .AND. TLIN.LT.TPLATE) MSTAKE=3 033340 0000
2354 TSEG=FF*TPLATE 033350 0000
033360 0000
033370 0000
033380 0000
033390 0000
033400 0000
033410 0000

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(Continued)

## COSTUN Listing (Continued)

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IF(TSEG.LT.TSEGMM) TSEG=TSEGMM          033420 0000
BE=BF+2.*TSEG                           033430 0000
IF(I TYPE.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(I TYPE.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(I TYPE.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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## COSTUN Listing (Continued)

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C SHAFT SEGMENT                                034000 0000
2535 IF(I$SHAPE.EQ.1) GO TO 2510                034010 0000
      WEB=0.1*B1**0.7*(PSOIL/1000.)**(.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
C
C
C ***** ***** ***** ***** ***** ***** ***** ***** ***** ***** 034300 0000
C CUT AND COVER ONLY                     034310 0000
C ***** ***** ***** ***** ***** ***** ***** ***** ***** ***** 034320 0000
C ***** ***** ***** ***** ***** ***** ***** ***** ***** ***** 034330 0000
C -----
C DATA                                     034340 0000
C -----                               034350 0000
C -----                               034360 0000
C -----                               034370 0000
C -----
C 2900 IF(ITYPE.EQ.2) GO TO 3300          034380 0000
ELROCK=A(I,27)                         034390 0000
ELIMP=A(I,24)                          034400 0000
D10=A(I,19)                            034410 0000
PERM=A(I,25)                           034420 0000
DROCK=ELSURF-ELROCK                   034430 0000
NBOX=TRDATA(NREACH,10)                 034440 0000
BFBUDT=TRDATA(NREACH,11)               034450 0000
BFBHT=TRDATA(NREACH,12)                034460 0000
IBOX2=TRDATA(NREACH,13)                034470 0000
IDECK=A(I,29)                           034480 0000
IBRACE=A(I,28)                          034490 0000
DTUN=ELSURF-ELAUG                      034500 0000
IF(IBOX2.EQ.1) GO TO 3000              034510 0000
BOXWDT=BFBUDT/NBOX                    034520 0000
BOXHT=BFBHT                           034530 0000
GO TO 3001                           034540 0000
                                         034550 0000
                                         034560 0000
                                         034570 0000

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## COSTUN Listing (Continued)

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3000 BOXWDT=BFBUDT/2.  

BOXHT=BFBHT/2.  

NBOX=2  

3001 SURGE=400.  

TROOF=0.0  

TINUT=0.0  

TINSB=0.0  

TINUL=0.0  

TEXUL=0.0  

UTROOF=0.0  

UTINSB=0.0  

K=0  

C-----  

3002 DTRNCH=DTUN+BFBHT/2+TINUT+TINSB/2.  

DSOIL=DTRNCH  

IF(DROCK.LT.DTRNCH) DSOIL=DROCK  

TOTBOX=BFBHT+TINUT+TROOF+TINSB  

DROOF=DTRNCH-TOTBOX  

WATPRI=0  

WATPRR=0  

IF(DWATER.GE.DTRNCH) GO TO 3005  

WATPRI=62.4*(DTRNCH-DWATER)  

IF(DWATER.LT.DROOF) WATPRR=WATPRI-62.4*TOTBOX  

C-----  

CC TRENCH PRESSURE FOR SUPPORTS  

C-----  

3005 SIGMAT=GAMMAX*DSOIL  

SIGMA1=GAMMAX*DSOIL  

IWATER=A(I,23)  

STABNO=A(I,30)  

IF(DWATER.LT.DSOIL.AND.IWATER.EQ.0) SIGMA1=GAMMAX*D WATER+(GAMMA-  

162.4)*(DSOIL-DWATER)  

IF(STABNO.LT.0.01) STABNO=(SIGMAT+SURGE)/(COHESN+(SIGMA1+SURGE)/2.  

1*(1-SIN(PHI*PI/180.))*TAN(PHI*PI/180.))  

IF(ISUPPT.EQ.5.OR.MEX.EQ.7) GO TO 3010  

C SLURRY WALL TRENCH SUPPORT  

TRENPR=0.3*SIGMAT  

IF(IWATER.EQ.1.AND.D10.GT.0.005) GO TO 3025  

IF(DWATER.LT.DSOIL) TRENPR=0.3*(GAMMAX*D WATER)**2.+(GAMMA-62.4)*  

1*(DSOIL-DWATER)**2.+2.*GAMMA*D WATER*(DSOIL-DWATER)+2.*62.4*(DSOIL-  

2DWATER)**2.)/DSOIL  

GO TO 3025  

C SOLDIER PILE / LAGGING TRENCH SUPPORT  

3010 TEMP1=0.6*GAMMA*DSOIL*(TAN(PI/180.)*(45.-PHI/2.))**2.  

TEMP2=2.4*COHESN*TAN(PI/180.)*(45.-PHI/2.)  

IF(STABNO.LE.4) GO TO 3015  

TM=1.1-0.1*STABNO  

IF(TM.LT.0.4) TM=0.4  

TRENPR=TEMP1*(PHI+0.83)/(PHI+0.62)-TEMP2*(PHI+0.83)/(PHI+0.62)*TM  

GO TO 3020  

3015 TRENPR=TEMP1*(PHI+0.14)/(PHI+0.35)-TEMP2*PHI/(PHI+0.2)  

3020 IF(TRENPR.LT.0.0) TRENPR=0.0  

C-----  

CC EARTH PRESSURE FOR BOX MEMBERS  

3025 ERTHPR=0.5*GAMMA*DTUN  

C-----  

CC THICKNESS OF BOX MEMBERS  

C-----
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(Continued)

## COSTUN Listing (Continued)

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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
C   IF(TLIN.GT.0.0) WRITE(LO,3500) NTSEG,NREACH 035240 0000
C   -----
C   AXIAL LOAD AND UNIFORM LOADS        035250 0000
3030 J=J+1                   035260 0000
      GO TO (3040,3050,3060,3070,3080),J 035270 0000
C   ROOF SLAB                 035280 0000
3040 PTOTAL=GAMMA*DROOF/1.1+WTROOF+SURGE 035290 0000
      GO TO 3052                 035300 0000
3050 TROOF=THICK/12.            035310 0000
      WTROOF=150.*TROOF           035320 0000
C   INVERT SLAB               035330 0000
      PWATER=WATPRI-WATPRR       035340 0000
      PTOTAL=PTOTAL+PWATER       035350 0000
3052 IF(WATPRI.EQ.0.0) GO TO 3055 035360 0000
      IF(WATPRR.GT.0.0) AXIALW=0.25*BOXHT*(WATPRI+WATPRR) 035370 0000
      IF(WATPRR.EQ.0.0) AXIALW=0.25*BOXHT*WATPRI*(DTRNCH-DWATER)/TOTBOX 035380 0000
3055 IF(DROCK.GE.DTRNCH) GO TO 3057 035390 0000
      IF(DROCK.LE.DROOF) GO TO 3058 035400 0000
      PSOIL=PSOIL*(DROCK-DROOF)/TOTBOX 035410 0000
3057 AXIALS=0.5*PSOIL*BOXHT 035420 0000
3058 AXIAL=AXIALW+AXIALS 035430 0000
      SPANL=BOXWDT              035440 0000
      GO TO 3100                035450 0000
3060 TINUT=THICK/12.            035460 0000
C   INTERIOR SLAB             035470 0000
      IF(IBOX2.EQ.1) GO TO 3062 035480 0000
      THICK=0.0                  035490 0000
      GO TO 3030                035500 0000
3062 PTOTAL=400.+WTINSB      035510 0000
      IF(WATPRI.EQ.0.0) GO TO 3065 035520 0000
      AXIALW=2.0*AXIALW          035530 0000
3065 IF(DROCK.LE.DROOF) GO TO 3067 035540 0000
      AXIALS=2.0*AXIALS          035550 0000
3067 AXIAL=AXIALS+AXIALW      035560 0000
      SPANL=BOXWDT              035570 0000
      GO TO 3100                035580 0000
3070 TINSB=THICK/12.            035590 0000
      WTINSB=150.*TINSB          035600 0000
      K=K+1                      035610 0000
      IF(K.EQ.1) GO TO 3002      035620 0000
C   INTERIOR WALL              035630 0000
      AXIAL=(GAMMA*DROOF/1.1+SURGE+WTROOF+WTINSB+400.)*BOXWDT 035640 0000
      SPANL=BOXHT                035650 0000
      IF(NBOX.GT.1) GO TO 3105      035660 0000
      THICK=0.0                  035670 0000
      GO TO 3030                035680 0000
3080 TINWL=THICK/12.            035690 0000
C   EXTERIOR WALL              035700 0000
      AXIAL=AXIAL/2.              035710 0000
      SPANL=BOXHT                035720 0000
                                035730 0000

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## COSTUN Listing (Continued)

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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
----- 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
----- 035940 0000
C FINAL OVERALL BOX DIMENSIONS                      035950 0000
    TOTBOX=BFBHT+TROOF+TINUT+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.+TINUT+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
    UTWALE=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
----- 036200 0000
C SLURRY WALL SUPPORT SYSTEM                      036210 0000
----- 036220 0000
C COMPUTE LENGTH OF SLURRY WALL                  036230 0000
    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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## COSTUN Listing (Continued)

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C WEIGHTED CREEP RATIO DETERMINES SLURRY WALL PENETRATION      036320 0000
CREPMN=(340.+1.55*COHESN)/COHESN                           036330 0000
GO TO 3113                                                 036340 0000
3112 CREPMN=4.3-1.8*ALOG10(SQRT(10.*ABS(PERM)))           036350 0000
3113 DSLURY=DTRNCH+10.                                     036360 0000
CREEP=(2.*DSLURY-DWATER-DTRNCH)/(DTRNCH-DWATER)          036370 0000
IF(CREEP.GT.CREPMN) GO TO 3120                           036380 0000
DSLURY=(CREPMN*(DTRNCH-DWATER)+DWATER+DTRNCH)/2.        036390 0000
DTIMP=ELSURF-ELIMP                                         036400 0000
IF(DTIMP.GE.DSLURY.OR.D10.LE.0.005) GO TO 3114            036410 0000
C SLURRY WALL PENETRATES IMPERVIOUS LAYER                  036420 0000
H1=DTIMP-DWATER                                           036430 0000
IF(H1.LT.0.) H1=0.                                         036440 0000
H2=DTIMP-DTRNCH                                         036450 0000
H2DN=H2                                                 036460 0000
H2UP=DTRNCH-DTIMP                                         036470 0000
IF(DTIMP.GE.DTRNCH) H2UP=0.                                036480 0000
IF(DTIMP.LT.DTRNCH) H2DN=0.                                036490 0000
AA=4.                                                       036500 0000
BB=4.*ABS(H2)+4*H2                                         036510 0000
CC=H1**2.+H2**2.+2.*H1*ABS(H2)+2.*H2UP*(H2-H1)+CREPMN*(H2-H1)*
1(H2DN+H1)                                              036520 0000
PENIMP=(-BB+SQRT(BB**2.-4.*AA*CC))/2./AA                036530 0000
IF(DTIMP.GE.DTRNCH) DSLURY=DTIMP+PENIMP                 036540 0000
IF(DTIMP.LT.DTRNCH) DSLURY=DTRNCH+PENIMP               036550 0000
C MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL          036560 0000
IF(DSLURY.LT.DTRNCH+10.) DSLURY=DTRNCH+10.              036570 0000
3114 IF(DSLURY.GT.DROCK+2.) DSLURY=DROCK+2.             036580 0000
GO TO 3120                                               036590 0000
C MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL          036600 0000
3115 DSLURY=DTRNCH+10.                                    036610 0000
GO TO 3120                                               036620 0000
C MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN ROCK           036630 0000
3116 DSLURY=DROCK+2.                                     036640 0000
GO TO 3120                                               036650 0000
C IS ROCK LINE AT LEAST 2 FT ABOVE ROOF OF BOX            036660 0000
3117 IF(DROCK+2..LT.DROOF) GO TO 3118                   036670 0000
DSLURY=DTRNCH+2.                                         036680 0000
GO TO 3120                                               036690 0000
3118 DSLURY=DROCK+2.                                     036700 0000
C -----
C SOLDIER PILE/LAGGING SUPPORT SYSTEM                     036710 0000
C -----
C 3120 TRENPR=TRENPR+SURGE                               036720 0000
C ANCHORS AND/OR STRUTS                                 036730 0000
WTSTRT=0.0225*TRENPR+0.8*BE                            036740 0000
ANCHDI=0.94*SQRT(TRENPR/1000.)                          036750 0000
IF(ANCHDI.LT.0.5) ANCHDI=0.5                           036760 0000
WTANCH=PI*(ANCHDI/2.)*2.*0.283*12.                      036770 0000
IF(IBRACE.EQ.1) WTANCH=0.                                036780 0000
IF(IBRACE.EQ.2) WTSTRT=0.                                036790 0000
IF(ISUPPT.EQ.6) GO TO 3190                           036800 0000
C WALES
WTWALE=SQRT(5.6*TRENPR)                                036810 0000
IF(WTWALE.LT.13.) WTWALE=13.                            036820 0000
DWALE=SQRT(6.*WTWALE)-5.0                                036830 0000
C SOLDIER PILES                                         036840 0000
C NOM DECKED SOLDIER PILES                            036850 0000
C                                         036860 0000
C                                         036870 0000
C                                         036880 0000
C                                         036890 0000

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(Continued)

## COSTUN Listing (Continued)

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WTSP = SQRT(TRENPR)
IF(WTSP.LT.13.) WTSP=13.
DSP=SQRT(6.*WTSP)-5.0
IF(IDECK.EQ.0) GO TO 3125
C DECKED SOLDIER PILES
SPAXAL=15.*BE/2.*400.
WTSPD=SQRT(TRENPR)+0.222*SPAXAL/1000.*(1.0-0.25*(TRENPR/1000.))
1***0.333)
IF(WTSPD.LT.13.) WTSPD=13.
DSPD=SQRT(6.*WTSPD)-5.0
C IS ROCK LINE ABOVE TRENCH BOTTOM
IF(DROCK.LE.DTRNCH) GO TO 3124
DPILEH=1./6.*SQRT(1.5*WTSPD)
IF(PHI.GT.0.) GO TO 3122
SPDLT=DTRNCH+(1.75*SPAXAL/(0.5*PI*DPILEH)-6.7*COHESN*DPILEH/2.)/
1(2.*COHESN+DPILEH/2.*GAMMA)
GO TO 3123
3122 CNQ=EXP(PI*TAN(PHI*PI/180.))*(TAN(PI/4.+PHI*PI/360.))**2
CNC=(CNQ-1.)/TAN(PHI*PI/180.)
IF(PHI.GT.0.) CNGAM=0.
IF(PHI.GT.10.) CNGAM=0.3*(PHI-10.)
IF(PHI.GT.20.) CNGAM=(PHI**2-335.)/22.3
IF(PHI.GT.35.) CNGAM=8.*((PHI-35.)*40.
IF(PHI.GT.40.) CNGAM=32.*((PHI-40.)*80.
AA=GAMMA*TAN(PHI*PI/180.)
BB=2.*COHESN+DPILEH/2.*GAMMA*CNC
CC=1.3*COHESN*DPILEH/2.*CNC+0.6*GAMMA*(0.5*DPILEH)**2*CNGAM
1-1.75*SPAXAL/(0.5*PI*DPILEH)
SPDLT=DTRNCH+(-BB+SQRT(BB**2-4.*AA*CC))/(2.*AA)
3123 IF(SPDLT.LT.DTRNCH+10.) SPDLT=DTRNCH+10.
IF(SPDLT.GT.DROCK+2.) SPDLT=DROCK+2.
GO TO 3125
3124 SPDLT=DTRNCH+2.
C -----
C FOR ROCK DESIGN, CHECK IF EXTERIOR BOX WALL IS SMALLER THAN DEPTH
C OF SOLDIER PILE EMBEDDED IN WALL
3125 IF(DROCK.GT.DROOF) GO TO 3130
IF(DROCK+10..GT.DROOF.AND.TEXUL.LT.DSP/12.) TEXUL=DSP/12.
IF(TEXUL.LT.DSPD/12.) TEXUL=DSPD/12.
C -----
C IN ROCK, EXCAVATED TRENCH WIDTH EQUALS BOX WIDTH
WDTBOX=BFBWDT+2*TEXUL+(NBOX-1)*TINWL
BE=WDTBOX
GO TO 3190
C -----
C COMPUTE FINAL EXCAVATED TRENCH WIDTH FOR BOX IN SOIL
3130 IF(IDECK.EQ.0) BE=BE+(2.*DWALE+2.*DSP)/12.
IF(IDECK.EQ.1) BE=BE+(2.*DWALE+2.*DSPD)/12.
GO TO 3190
C -----
C SIDE SLOPE FOR OPEN CUTS IN SOIL
C -----
C ALL SLOPING CUTS EXCEPT CLAYS (D10.LE.0.005) WILL BE Dewatered
3140 IF(COHESN.GT.0.0) GO TO 3150
C MATERIALS CHARACTERIZED BY PHI ONLY
SIDESL=1.25/TAN(PHI*PI/180.)
GO TO 3190
C MATERIALS CHARACTERIZED BY COHESION ONLY OR BY PHI AND COHESION

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## COSTUN Listing (Continued)

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3150 SIGGAH=GAMMAX*DSOIL          037480 0000
    IF(DWATER.LT.DSOIL.AND.D10.LE.0.005) SIGGAH=GAMMA*D WATER+(GAMMA-
162.4)*(DSOIL-DWATER)           037490 0000
    PHIDEU=ATAN(ATAN(PHI*PI/180.)/1.25) 037500 0000
    SIDESL=0.577                  037510 0000
    TEMP1=(1.0-COS(ATAN(1./SIDESL)-PHIDEU))/(4.*SIN(ATAN(1./SIDESL))) 037520 0000
1*COS(PHIDEU))                 037530 0000
    TEMP2=COHESN/(1.25*SIGGAH)      037540 0000
    IF(TEMP1.LE.TEMP2) GO TO 3190 037550 0000
037560 0000
C----- 037570 0000
C SLOPE ANGLE IS BETWEEN PHIDEU AND 60 DEGREES 037580 0000
C IF(PHI.EQ.0.0) MAX=11.0 037590 0000
C IF(PHI.GT.0.0) MAX=1/TAN(PHIDEU) 037600 0000
C 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)-PHIDEU))/(4.*SIN(ATAN(1./SIDESL))* 037640 0000
1*COS(PHIDEU))                 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 UBOX=TOTBOX*WDTBOX/27.       037780 0000
C----- 037790 0000
C TOTAL VOLUME OF CONCRETE PER FOOT OF BOX 037800 0000
UL=(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)+BFBUDT 037860 0000
    IF(ISUPPT.EQ.5.AND.DROCK.GT.DROOF) FORMAR=FORMAR+2.*TOTBOX 037870 0000
    IF(IBOX2.EQ.1) FORMAR=FORMAR+BFBUDT 037880 0000
C----- 037890 0000
C STORE TRANSFERRED 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)=UBOX                 038010 0000
    A(I,55)=UL                   038020 0000
    A(I,56)=FORMAR               038030 0000
    A(I,63)=UTWALE               038040 0000
    A(I,64)=UTSTRT               038050 0000

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(Continued)

## COSTUN Listing (Continued)

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A(I,65)=UTANCH          038060 0000
A(I,66)=UTSP            038070 0000
A(I,67)=UTSPD           038080 0000
GO TO 4000              038090 0000
C -----
C CUT AND COVER SHAFTS 038100 0000
C -----
3300 ICUTNC=1            038110 0000
ISUPPT=4                038120 0000
LINING=1                038130 0000
C REDUCE UNIT WEIGHT OF SOIL DUE TO BULKING DURING BACKFILLING 038140 0000
GAMMA=GAMMA/1.1         038150 0000
GO TO 1000              038160 0000
4000 CONTINUE             038170 0000
IF(NSSTYP.EQ.3.OR.NTSTYP.EQ.3) RETURN 038180 0000
C CHECK IF FACE INFLOW INPUT WHEN GROUND WATER TABLE BELOW SEGMENT 038190 0000
GI=A(I,9)               038200 0000
ELAUG=(ELNPL+ELNPR)/2. 038210 0000
BE=A(I,39)               038220 0000
ELBOTM=ELAUG-BE/2.      038230 0000
IF(ISHAPE.EQ.3) ELBOTM=ELAUG-BE/4. 038240 0000
IF(ITYPE.EQ.1.AND.GI.GT.0.0.AND.ELBOTM.GE.ELWATR) WRITE(LO,3600) 038250 0000
1NTSEG,NREACH           038260 0000
C -----
C CHECK IF SHAFT SEGMENT IS WET WHEN WATER TABLE IS BELOW SEGMENT 038270 0000
GI=B(I,9)               038280 0000
IF(ITYPE.EQ.2.AND.GI.GT.0.0.AND.ELNPB.GT.ELWATR) WRITE(LO,3605) 038290 0000
1NSSEG,NSHAFT           038300 0000
RETURN                  038310 0000
038320 0000
038330 0000
038340 0000
038350 0000
C
5000 PWATER=62.4*(ELWATR-ELAUG)
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 *****
1010 FORMAT(/, ' **** WARNING *** ---THICKNESS INPUTED FOR SEGMENT', I4, ' IN REACH', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN 038370 0000
1, I4, ' IN REACH', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN 038380 0000
20RED')
1011 FORMAT(/, ' **** WARNING *** ---THICKNESS INPUTED FOR SEGMENT', I4, ' IN SHAFT', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN 038400 0000
1, I4, ' IN SHAFT', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN 038410 0000
20RED')
2710 FORMAT(/, ' **** WARNING *** ---THICKNESS INPUTED FOR SEGMENT ', I4, ' IN REACH', I4, ' APPEARS TO BE INADEQUATE FOR WATER PRESSURE.', I4, ' COMPUTED THICK. FOR WATER PRESSURE USED') 038420 0000
2711 FORMAT(/, ' **** WARNING *** ---THICKNESS INPUTED FOR SEGMENT ', I4, ' IN REACH', I4, ' APPEARS TO BE INADEQUATE FOR WATER PRESSURE USED') 038430 0000
038440 0000
038450 0000
038460 0000
038470 0000

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## COSTUN Listing (Continued)

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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
***** 038590 0000
038600 0000
038610 0000
038615 0000
038620 0000
038630 0000
038635 0000
038640 0000
038650 0000
038660 0000
038670 0000
038680 0000
038690 0000
038700 0000
038710 0000
038720 0000
038730 0000
038740 0000
038750 0000
038760 0000
038770 0000
038780 0000
038790 0000
038800 0000
038810 0000
038820 0000
038830 0000
038840 0000
038850 0000
038860 0000
038870 0000
038880 0000
038890 0000
038900 0000
038910 0000
038920 0000
038930 0000
038940 0000
038950 0000
038960 0000
038970 0000
038980 0000
038990 0000
039000 0000
039010 0000
039020 0000
039030 0000

C
C
C RETURN
END
SUBROUTINE STABIL(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX
1,NTRMAX)
-----
C
C THIS SUBROUTINE SELECTS THE STABILITY NUMBER, STABILIZATION METHOD,
C AND EXCAVATION METHOD TO BE USED IN SOFT GROUND TUNNEL AND SHAFT
C SEGMENTS
-----
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 DO NOT COMPUTE A STABILITY NUMBER IF ONE WAS INPUT. ALSO, DO NOT
C COMPUTE ONE FOR PORTALS, DUMMY SHAFTS, AND CUT-AND-COVER SEGMENTS.
IF(ITYPE.EQ.1) GO TO 1000
-----
C
C THIS IS A SHAFT SEGMENT
CHECK FOR ROCK OR CUT AND COVER SEGMENTS AND FOR A PORTAL OR
A DUMMY SHAFT
NSSTYP=B(I,15)
IF(NSSTYP.EQ.1) GO TO 500
IF(NSSTYP.EQ.3) RETURN
NSHAFT=B(I,1)
NPORT=SHAFT(NSHAFT,23)
IF(NPORT.EQ.1) RETURN
ISHAPS=SHAFT(NSHAFT,16)
IF(ISSHAPS.LT.1) RETURN
BE =B(I,29)
STABNO=B(I,24)
IF(STABNO.GT.0.01) GO TO 1830
NSSEG =B(I,2)
MEX =B(I,7)
ELWATR=B(I,13)
D10 =B(I,16)
COHESM=B(I,17)
GAMMA =B(I,18)
PHI =B(I,19)
IWATER=B(I,21)

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## COSTUN Listing (Continued)

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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
ELAUG =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 -----
C THIS IS A TUNNEL SEGMENT 039190 0000
1000 NTSTYP=A(I,16) 039200 0000
IF(NTSTYP.EQ.1) GO TO 1002 039210 0000
IF(NTSTYP.EQ.3) RETURN 039220 0000
BE =A(I,39) 039230 0000
STABNO=A(I,30) 039240 0000
IF(STABNO.GT.0.01) GO TO 1830 039250 0000
NTSEG =A(I,1) 039260 0000
NPL =A(I,2) 039270 0000
NPR =A(I,3) 039280 0000
NREACH=A(I,4) 039290 0000
MEX =A(I,7) 039300 0000
ELWATR=A(I,14) 039310 0000
NPLS =A(I,17) 039320 0000
NPRS =A(I,18) 039330 0000
D10 =A(I,19) 039340 0000
PHI =A(I,20) 039350 0000
COHESN=A(I,21) 039360 0000
GAMMA =A(I,22) 039370 0000
IWATER=A(I,23) 039380 0000
ELIMP=A(I,24) 039390 0000
PERM =A(I,25) 039400 0000
MSTAB =A(I,31) 039410 0000
MUST =A(I,32) 039420 0000
MSTAC =A(I,34) 039430 0000
ISHAPE=TRDATA(NREACH,3) 039440 0000
ELNPL =CNP(NPL,2) 039450 0000
ELNPR =CNP(NPR,2) 039460 0000
ELNPLS=CNP(NPLS,2) 039470 0000
ELNPRS=CNP(NPRS,2) 039480 0000
ELSURF=(ELNPLS+ELNPRS)/2. 039490 0000
ELAUG =(ELNPL+ELNPR)/2. 039500 0000
SEGDEP=ELSURF-ELAUG 039510 0000
GO TO 1003 039520 0000
C ROCK TUNNEL 039530 0000
1002 AIRPR=0 039540 0000
A(I,33)=AIRPR 039550 0000
MSTAB=0 039560 0000
A(I,31)=MSTAB 039570 0000
RETURN 039580 0000
1003 AIRPR=0. 039590 0000
C COMPUTE STABILITY NUMBER BASED ON INPUT PARAMETERS 039600 0000
039610 0000

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COSTUN Listing (Continued)

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MSTABT=0          039620 0000
CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 039630 0000
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAC,F,FSHAPF, 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
C 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,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 040140 0000
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAC,F,FSHAPF, 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,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 040190 0000
1 STABNM,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 -----
C SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION       040390 0000
C IF USER WILL ALLOW A STABILIZATION METHOD AND STABILITY NUMBER IS 040400 0000
C HIGH, CHECK WHETHER USE OF STABILIZATION WILL DECREASE STABILITY 040410 0000
C NUMBER BY AT LEAST 1.0                                         040420 0000
C -----
C -----
1200 IF(STABNO.LE.4.) GO TO 1300                               040430 0000
IF(MUST.GT.1) GO TO 1300                                     040440 0000
C USER WILL ALLOW STABILIZATION TO BE USED                      040450 0000
IF(D10.LE. .005) GO TO 1215                                 040460 0000
AIRPR=0             040470 0000
IF(ELAUG.GE.ELWATR .OR.IWATER.EQ.0) GO TO 1205               040480 0000
IF(PERM.LT.0. .AND.ABS(PERM).GT.0.0006) GO TO 1209           040490 0000
IF(PERM.GT.0. .AND. D10.GT.0.08) GO TO 1209               040500 0000
C THE FIRST CHOICE METHOD IS GROUND INJECTIONS                 040510 0000
1205 MSTAB=3           040520 0000
COHSGI=20000.*SQRT(10.*ABS(PERM))                           040530 0000
STABNM=SIGMAT/(SHRSTR+COHSGI)                                040540 0000
IF(STABNO-STABNM.GE.1.) GO TO 1235                           040550 0000
C DECREASE IN STABILITY NUMBER CAUSED BY USE OF GROUND INJECTIONS IS 040560 0000
040570 0000
040580 0000

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## COSTUN Listing (Continued)

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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(ELAUG.GE.ELWATR) GO TO 1207                         040630 0000
IF(ELWATR-ELAUG.GT.115.) GO TO 1235                         040640 0000
C      COMPRESSED AIR IS AN ACCEPTABLE METHOD.                         040650 0000
1207 CALL AIRPRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT,    040660 0000
1 STABNM,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,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,    040800 0000
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPÉ,    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,ELAUG,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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## COSTUN Listing (Continued)

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STABNO=STABNM          041170 0000
GO TO 1800             041180 0000
1300 IF(ITYPE.EQ.1) A(I,38)=STABNO 041190 0000
IF(ITYPE.EQ.2) B(I,24)=STABNO 041200 0000
GO TO 1800             041210 0000
C *****XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX 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 -----
C CHECK IF USER WILL ALLOW SOME METHOD TO BE USED. 041280 0000
IF(MSTAB.GT.0) GO TO 1502 041290 0000
IERROR=1               041300 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 -----
C SEGMENT CANNOT BE EXCAVATED WITHOUT STABILIZATION. CHECK WHETHER 041350 0000
C USERS PREFERRED METHOD IS ACCEPTABLE 041360 0000
1502 IF(ITYPE.EQ.2) GO TO 1505 041370 0000
IF(MSTAC.EQ.1) GO TO 1510 041380 0000
C METHOD IS UNACCEPTABLE 041390 0000
IERROR=1               041400 0000
WRITE(LO,3030) NSSEG,NSHAFT 041410 0000
RETURN                 041420 0000
1505 IF(MSTAC.EQ.1) GO TO 1510 041430 0000
C METHOD IS UNACCEPTABLE 041440 0000
IERROR=1               041450 0000
WRITE(LO,2030) NTSEG,NREACH 041460 0000
RETURN                 041470 0000
C -----
C STABILIZATION METHOD INPUT IS ACCEPTABLE 041480 0000
C CHECK FOR PREFERRED METHOD 041490 0000
1510 IF(MSTAB.EQ.1) GO TO 1520 041500 0000
IF(MSTAB.EQ.3) GO TO 1518 041510 0000
C THE PREFERRED METHOD IS DEWATERING 041520 0000
MSTABT=2               041530 0000
CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 041540 0000
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPÉ, 041550 0000
2 SEGDEP)              041560 0000
GO TO 1525             041570 0000
C THE PREFERRED METHOD IS GROUND INJECTIONS 041580 0000
1518 COHSGI=20000.*SQRT(10.*ABS(PERM)) 041590 0000
STABNM=SIGMAT/(SHRSTR+COHSGI) 041600 0000
GO TO 1525             041610 0000
C THE PREFERRED METHOD IS COMPRESSED AIR 041620 0000
1520 IF(ITYPE.EQ.1) AIRPR=A(I,33) 041630 0000
IF(ITYPE.EQ.2) AIRPR=B(I,27) 041640 0000
C IF AIR PRESSURE IS INPUT, USE IT AND COMPUTE STABILITY NUMBER. IF 041650 0000
C NONE IS INPUT, COMPUTE AIR PRESSURE 041660 0000
IF(AIRPR.GT.0.) GO TO 1522 041670 0000
CALL AIRPRRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 041680 0000
1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG) 041690 0000
GO TO 1525             041700 0000
1522 STABNM=(SIGMAT-AIRPR*144.)/SHRSTR 041710 0000
C CHECK WHETHER SEGMENT CAN BE EXCAVATED AFTER STABILIZATION 041720 0000
041730 0000
041740 0000

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(Continued)

## COSTUN Listing (Continued)

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1585 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 -----
C SEGMENT CAN NOW BE EXCAVATED 041860 0000
1530 IF(ITYPE.EQ.1) GO TO 1535 041870 0000
B(I,24)=STABNM 041880 0000
B(I,27)=AIRPR 041890 0000
STABNO=STABNM 041900 0000
GO TO 1800 041910 0000
1535 A(I,30)=STABNM 041920 0000
A(I,33)=AIRPR 041930 0000
STABNO=STABNM 041940 0000
GO TO 1800 041950 0000
C -----
C SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION METHOD 041960 0000
C -----
C CHECK IF NO METHOD IS TO BE USED 041970 0000
1600 IF(MSTAB.EQ.0) GO TO 1640 041980 0000
C CHECK WHETHER USER REQUIRES STABILIZATION METHOD TO BE USED 041990 0000
IF(MUST.EQ.4) GO TO 1610 042000 0000
C STABILIZATION IS NOT REQUIRED.FORGET STABILIZATION AND EXCAVATE 042020 0000
C USING THE ORIGINAL GROUND CONDITIONS. 042040 0000
IF(ITYPE.EQ.1) GO TO 1605 042050 0000
WRITE(LO,3015) NSSEG,NSHAFT 042060 0000
MSTAB=0 042070 0000
B(I,24)=STABNO 042080 0000
B(I,25)=MSTAB 042090 0000
GO TO 1800 042100 0000
1605 WRITE(LO,2015) NTSEG,NREACH 042110 0000
MSTAB=0 042120 0000
A(I,30)=STABNO 042130 0000
A(I,31)=MSTAB 042140 0000
GO TO 1800 042150 0000
C -----
C USER REQUIRES USE OF A STABILIZATION METHOD. CHECK IF SPECIFIED 042160 0000
C METHOD IS ACCEPTABLE. IF METHOD IS UNACCEPTABLE, BASE COSTS ON 042170 0000
C UNSTABILIZED GROUND 042180 0000
1610 IF(ITYPE.EQ.1) GO TO 1615 042190 0000
IF(MSTAC.EQ.1) GO TO 1620 042200 0000
WRITE(LO,3020) NSSEG,NSHAFT 042210 0000
GO TO 1800 042220 0000
1615 IF(MSTAC.EQ.1) GO TO 1620 042230 0000
WRITE(LO,2020) NTSEG,NREACH 042240 0000
GO TO 1800 042250 0000
C -----
C STABILIZATION METHOD INPUT IS ACCEPTABLE 042260 0000
C CHECK FOR PREFERRED METHOD 042270 0000
1620 IF(MSTAB.EQ.1) GO TO 1630 042280 0000
IF(MSTAB.EQ.3) GO TO 1625 042290 0000
042300 0000
042310 0000
042320 0000

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## COSTUN Listing (Continued)

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C THE PREFERRED METHOD IS DEWATERING 042330 0000
MSTABT=2 042340 0000
CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 042350 0000
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPÉ, 042360 0000
2 SEQDEP) 042370 0000
GO TO 1635 042380 0000
C THE PREFERRED METHOD IS GROUND INJECTIONS 042390 0000
1625 COHSGI=20000.*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 AIRPRRS(AIRPR,D10,ELAUG,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 -----
C CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0 042530 0000
1635 IF(STABNO-STABNM.GE.1.) GO TO 1640 042540 0000
C STABILITY NUMBER DID NOT DECREASE BY AT LEAST 1.0 INFORM USER 042550 0000
IF(ITYPE.EQ.1) WRITE(LO,2025) NTSEG,NREACH 042560 0000
IF(ITYPE.EQ.2) WRITE(LO,3025) NSSEG,NSHAFT 042570 0000
1640 IF(ITYPE.EQ.1) A(I,30)=STABNM 042580 0000
IF(ITYPE.EQ.1) A(I,33)=AIRPR 042590 0000
IF(ITYPE.EQ.2) B(I,24)=STABNM 042600 0000
IF(ITYPE.EQ.2) B(I,27)=AIRPR 042610 0000
STABNO=STABNM 042620 0000
042630 0000
C *****
C CHECK FOR ACCEPTABLE EXCAVATION METHOD FOR THE STABILITY NUMBER 042640 0000
C TO BE USED. THE CHECK FOR COMPATIBILITY WITH SHAPE IS IN SUB INPUT 042650 0000
1800 IF(ITYPE.EQ.1) GO TO 1805 042660 0000
IF(MEX.EQ.4) GO TO 1830 042670 0000
IF(MEX.EQ.3 .AND. STABNO.LE.6.) GO TO 1830 042680 0000
C METHOD IS UNACCEPTABLE, SELECT HAND METHODS INSTEAD 042690 0000
MEX=4 042700 0000
B(I,7)=MEX 042710 0000
WRITE(LO,3040) NSSEG,NSHAFT 042720 0000
GO TO 1830 042730 0000
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 *****
C IF STABILITY NUMBER IS LOW, SHIELD IS VERY THIN AND LEAVES LITTLE 042850 0000
C SPACE FOR BACKFILL BEHIND THE LINING OR SUPPORT 042860 0000
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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## COSTUN Listing (Continued)

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IF(ITYPE.EQ.2) B(I,32)=BOB          042910 0000
RETURN                               042920 0000
C   ***** FATAL ERROR, STABILITY NUMBER IN SEGMENT',I5,' IN RE 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
----- 043420 0000
C      043430 0000
C      043440 0000
C      043450 0000
C      043455
RETURN

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## COSTUN Listing (Continued)

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END 043460 0000
SUBROUTINE STABNU(COHESN,ELAUG,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
----- 043500 0000
----- 043510 0000
----- 043520 0000
----- 043530 0000
----- 043540 0000
----- 043550 0000
----- 043560 0000
----- 043570 0000
----- 043580 0000
----- 043590 0000
----- 043600 0000
C CHECK WHETHER THIS IS THE SECOND COMPUTATION FOR THIS SEGMENT. IF 043610 0000
C SO, CAN BYPASS MOST OF THIS SUBROUTINE. 043620 0000
C IF(MSTABT.EQ.2) GO TO 1150 043630 0000
C COMPUTE STABILITY NUMBER FOR UNSTABILIZED GROUND 043640 0000
C CHECK FOR GWT ABOVE GROUND SURFACE 043650 0000
C IF(ELWATR.GT.ELSURF) GO TO 1050 043660 0000
C CHECK FOR SEGMENT BELOW GWT 043670 0000
C IF(ELAUG.LT.ELWATR) GO TO 1010 043680 0000
C GWT IS BELOW SEGMENT 043690 0000
C SIGGAH=SEGDEP*GAMMA 043700 0000
C IF(SEGDEP.LE.2.*BE) GO TO 1000 043710 0000
C GAMMAA=GAMMA 043720 0000
C GAMMAB=GAMMA 043730 0000
C GO TO 1100 043740 0000
1000 GAMMAC=GAMMA 043750 0000
C GO TO 1100 043760 0000
C SEGMENT IS BELOW GWT 043770 0000
1010 DWATER-ELSURF-ELWATR 043780 0000
C SIGGAH=DWATER*GAMMA+(ELWATR-ELAUG)*(GAMMA-62.4) 043790 0000
C IF(SEGDEP.LE.2.*BE) GO TO 1030 043800 0000
C IF(DWATER.GT.2.*BE) GO TO 1020 043810 0000
C SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE 043820 0000
C GAMMAA=(GAMMA*DWATER+(GAMMA-62.4)*(2.*BE-DWATER))/(2.*BE) 043830 0000
C GAMMAB=(GAMMA-62.4) 043840 0000
C GO TO 1100 043850 0000
C SEGMENT AND GWT ARE BOTH DEEPER THAN 2BE 043860 0000
1020 GAMMAA=GAMMA 043870 0000
C GAMMAB=(GAMMA*(DWATER-2.*BE)+(GAMMA-62.4)*(ELWATR-ELAUG))/(SEGDEP- 043880 0000
1 2.*BE) 043890 0000
C GO TO 1100 043900 0000
C SEGMENT IS WITHIN 2BE OF GROUND SURFACE 043910 0000
1030 GAMMAC=(GAMMA*DWATER+(GAMMA-62.4)*(ELWATR-ELAUG))/SEGDEP 043920 0000
C GO TO 1100 043930 0000
C GWT IS ABOVE GROUND SURFACE 043940 0000
1050 GAMMAA=GAMMA-62.4 043950 0000
C GAMMAB=GAMMA-62.4 043960 0000
C GAMMAC=GAMMA-62.4 043970 0000
C SIGGAH=SEGDEP*(GAMMA-62.4)

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## COSTUN Listing (Continued)

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C -----
1100 PHIEQR=ATAN(COHESN/SIGGAH+TANPHI) 043980 0000
      PHIEQ=PHIEQR*180./PI 043990 0000
      IF(PHIEQ.GT.45.) PHIEQ=45. 044000 0000
C ESTABLISH SEGMENT TYPE AND SHAPE FACTORS 044010 0000
      IF(SEGDEP.LE.2.*BE) GO TO 1300 044020 0000
      F=1.0 044030 0000
      FSHPAE=1.0 044040 0000
      IF(ITYPE.EQ.1) GO TO 1110 044050 0000
C SHAFT SEGMENT 044060 0000
      F=0.5 044070 0000
      FSHPAE=0.5 044080 0000
      IF(ISSHAPS.EQ.2) F=0.6 044090 0000
      IF(ISSHAPS.EQ.2) FSHPAE=0.6 044100 0000
      GO TO 1200 044110 0000
C TUNNEL SEGMENT 044120 0000
1110 IF(ISSHAP.EQ.3) FSHPAE=1.25 044130 0000
      GO TO 1200 044140 0000
C -----
C THE FOLLOWING UNIT WEIGHTS ARE FOR STABILIZATION BY DEWATERING 044150 0000
1150 IF(SEGDEP.LE.2.*BE) GO TO 1160 044160 0000
      GAMMAAA=GAMMA 044170 0000
      GAMMAB=GAMMA 044180 0000
      GO TO 1200 044190 0000
1160 GAMMAC=GAMMA 044200 0000
      GO TO 1350 044210 0000
C -----
C SEGMENT IS DEEPER THAN 2BE 044220 0000
1200 SIGMAT=2.*BE*GAMMAX*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)* 044230 0000
      1 GAMMAX*FSHPAE 044240 0000
C INCREASE SIGMAT IF GWT IS ABOVE GROUND AND SEGMENT NOT DEWATERED 044250 0000
      IF(MSTABT.EQ.2) GO TO 1250 044260 0000
      IF(ELWATR.GT.ELSURF) SIGMAT=SIGMAT+(ELWATR-ELSURF)*62.4 044270 0000
1250 SIGMA1=2.*BE*GAMMAA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)* 044280 0000
      1 GAMMAB*FSHPAE 044290 0000
      GO TO 1400 044300 0000
C SEGMENT IS NO DEEPER THAN 2BE 044310 0000
1300 F=1.0 044320 0000
      IF(ITYPE.EQ.1) GO TO 1350 044330 0000
C SHAFT SEGMENT 044340 0000
      F=0.5 044350 0000
      IF(ISSHAPS.EQ.2) F=0.6 044360 0000
1350 SIGMAT=SEGDEP*GAMMAX*F 044370 0000
C INCREASE SIGMAT IF GWT IS ABOVE GROUND AND SEGMENT NOT DEWATERED 044380 0000
      IF(MSTABT.EQ.2) GO TO 1375 044390 0000
      IF(ELWATR.GT.ELSURF) SIGMAT=SIGMAT+(ELWATR-ELSURF)*62.4 044400 0000
1375 SIGMA1=SEGDEP*GAMMAC*F 044410 0000
C -----

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## COSTUN Listing (Continued)

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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 -----
C RETURN 044500 0000
END 044510 0000
SUBROUTINE AIRPRS(AIRPR, D10, ELAUG, ELWATR, IERROR, ITYPE, PHI, SHRSTR, 044530 0000
1SIGMAT, STABNM, STABNO, LO, NREACH, NSHAFT, NSSEG, NTSEG) 044540 0000
C -----
C -----
C THIS SUBROUTINE DETERMINES THE AIR PRESSURE TO BE USED FOR SOFT 044550 0000
GROUND CONSTRUCTION IN COMPRESSED AIR 044560 0000
C -----
C CHECK FOR GRANULAR MATERIAL BELOW GWT. IF SO, AIR PRESSURE IS 044620 0000
CONTROLLED BY WATER HEAD 044630 0000
IF(D10.GT. .005 .AND.ELAUG.LT.ELWATR) AIRPR=.433*(ELWATR-ELAUG) 044640 0000
IF(D10.GT. .005 .AND.ELAUG.LT.ELWATR) RETURN 044650 0000
C -----
C AIR PRESSURE IS NOT CONTROLLED BY WATER HEAD. START BY COMPUTING 044660 0000
STABILITY NUMBER USING MINIMUM AIR PRESSURE OF 7 PSI. 044670 0000
AIRPR=7.0 044680 0000
STABNM=(SIGMAT-AIRPR*144.)/SHRSTR 044690 0000
C CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0 044700 0000
IF(STABNO-STABNM.GE.1.) GO TO 1100 044720 0000
C DECREASE LESS THAN 1.0 COMPUTE AIR PRESSURE FOR DECREASE= 1.0 044730 0000
AIRPR=(SIGMAT-(STABNO-1.)*SHRSTR)/144. 044740 0000
C CHECK FOR AIR PRESSURE GREATER THAN 50 PSI 044750 0000
IF(AIRPR.GT.50.) GO TO 1000 044760 0000
C AIR PRESSURE IS LESS THAN 50 PSI. CAN SEGMENT BE EXCAVATED 044770 0000
IF(STABNO-1. .LE.9. .AND.PHI.LT.29. .OR.STABNO-1. .LE.7. .AND.PHI 044780 0000
1 .GE.29.) GO TO 1050 044790 0000
C SEGMENT CANNOT BE EXCAVATED FOR STABILITY NUMBER DECREASE OF 1.0 044800 0000
CAUSED BY APPLICATION OF AIR PRESSURE,OR DECREASE OF 1.0 REQUIRES 044810 0000
AIR PRESSURE GREATER THAN 50 PSI. TRY 50 PSI 044820 0000
1000 AIRPR=50. 044830 0000
STABNM=(SIGMAT-AIRPR*144.)/SHRSTR 044840 0000
044850 0000

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COSTUN Listing (Continued)

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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   -----
C   STABILITY NUMBER DECREASE BY AT LEAST 1.0 FOR 7 PSI AIR PRESSURE. 044970 0000
C   CAN SEGMENT BE EXCAVATED 044980 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   -----
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   -----
RETURN 045220 0000
END 045225 0000
045230 0000

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(Continued)

## COSTUN Listing (Continued)

```

SUBROUTINE REACHD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX) 045240 0000
----- 045245 0000
----- 045250 0000
----- 045260 0000
----- 045270 0000
----- 045280 0000
----- 045290 0000
----- 045300 0000
----- 045310 0000
----- 045320 0000
----- 045330 0000
----- 045340 0000
----- 045350 0000
----- 045360 0000
----- 045370 0000
----- 045380 0000
----- 045390 0000
----- 045400 0000
----- 045410 0000
----- 045420 0000
----- 045430 0000
----- 045440 0000
----- 045450 0000
----- 045460 0000
----- 045470 0000
----- 045480 0000
----- 045490 0000
----- 045500 0000
----- 045510 0000
----- 045520 0000
----- 045530 0000
----- 045540 0000
----- 045550 0000
----- 045560 0000
----- 045570 0000
----- 045580 0000
----- 045590 0000
----- 045600 0000
----- 045610 0000
----- 045620 0000
----- 045630 0000
----- 045640 0000
----- 045650 0000
----- 045660 0000
----- 045670 0000
----- 045680 0000
----- 045690 0000
----- 045700 0000
----- 045710 0000
----- 045720 0000
----- 045730 0000
----- 045740 0000
----- 045750 0000
----- 045760 0000
----- 045770 0000

C THIS SUBROUTINE DETERMINES THE BEGINNING SEGMENT AND TOTAL
C NUMBER OF SEGMENTS IN THE REACHES.
C N1 ..... LOCATION IN (A) ARRAY OF LEFT SEGMENT IN A REACH 045300 0000
C N2 ..... LOCATION IN (A) ARRAY OF RIGHT SEGMENT IN A REACH 045310 0000
C I ..... TUNNEL SEGMENT SEQUENCE NUMBER 045320 0000
C
C COMMON /BASIC/ NSS NTS 045330 0000
C DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 045340 0000
1 TRDATA(NTRMAX,23) 045350 0000
C
C N1=1 045360 0000
I=0 045370 0000
IPR=A(1,4) 045380 0000
NREACH=IPR 045390 0000
NPL=A(1,2) 045400 0000
NPR=A(1,3) 045410 0000
STANPL=CNP(NPL,1) 045420 0000
STANPR=CNP(NPR,1) 045430 0000
STAMLS=(STANPL+STANPR)/2. 045440 0000
NSHAFT=TRDATA(NREACH,1) 045450 0000
NPBS=SHAFT(NSHAFT,3) 045460 0000
STANPB=CNP(NPBS,1) 045470 0000
C
100 I=I+1 045480 0000
NREACH=A(I,4) 045490 0000
IF(I.EQ.NTS+1) GO TO 200 045500 0000
IF(NREACH.NE.IPR) GO TO 200 045510 0000
N2=I 045520 0000
GO TO 500 045530 0000
C
200 IF(STAMLS.LT.STANPB) GO TO 250 045540 0000
NRSEG1=N1 045550 0000
NSEGS=N2-N1+1 045560 0000
GO TO 300 045570 0000
250 NRSEG1=N2 045580 0000
NSEGS=-(N2-N1+1) 045590 0000
300 TRDATA(IPR,5)=NRSEG1 045600 0000
TRDATA(IPR,6)=NSEGS 045610 0000
IF(I.EQ.NTS+1) GO TO 600 045620 0000
C
NPL=A(I,2) 045630 0000
NPR=A(I,3) 045640 0000
STANPL=CNP(NPL,1) 045650 0000
STANPR=CNP(NPR,1) 045660 0000
STAMLS=(STANPL+STANPR)/2. 045670 0000
NSHAFT=TRDATA(NREACH,1) 045680 0000
NPBS=SHAFT(NSHAFT,3) 045690 0000
STANPB=CNP(NPBS,1) 045700 0000
IPR=NREACH 045710 0000

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(Continued)

## COSTUN Listing (Continued)

```

N1=I          045780 0000
N2=I          045790 0000
C
500 IF(I.NE.NTS+1) GO TO 100 045800 0000
500 CONTINUE 045810 0000
C
----- 045820 0000
RETURN      045830 0000
END         045840 0000
SUBROUTINE ADRATE (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1 NTRMAX) 045850 0000
----- 045860 0000
----- 045865 0000
----- 045870 0000
----- 045880 0000
----- 045890 0000
THIS SUBROUTINE COMPUTES THE ULTIMATE HEADING ADVANCE RATE FOR 045900 0000
SEGMENTS IN WHICH NONE WAS USER SPECIFIED AND COMPUTES THE AVERAGE 045910 0000
ADVANCE RATE IN ALL SEGMENTS 045920 0000
----- 045930 0000
----- 045940 0000
----- 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
----- 045990 0000
----- 046000 0000
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
NRSEQ1=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=NRSEQ1+I-1 046120 0000
IF(NSEGS.LT.0) N=NRSEQ1-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
IF EXCAVATION IS DOWNHILL, ULTIMATE ADVANCE RATE IS ONLY 90 PERCENT 046210 0000
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
QI=A(N,9) 046340 0000

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## COSTUN Listing (Continued)

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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 -----
C AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED, MUST COMPUTE ONE 046480 0000
C COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS 046490 0000
C CHECK FOR METHOD OF EXCAVATION 046500 0000
1020 IF(MEX.GT.5) GO TO 1160 046510 0000
C THIS IS NOT CUT AND COVER 046520 0000
ISHAPE=TRDATA(NREACH,3) 046530 0000
IF(MEX.NE.2.AND.MEX.NE.3) GO TO 50 046540 0000
IF(MEX.EQ.2) GO TO 150 046550 0000
C -----
C MOLE IN SOFT GROUND 046560 0000
ARTULT=(2.*(STABNO-7.)*2 +1.)/100000.* (80.-BE)**3.*SLARF 046570 0000
GO TO 1100 046580 0000
C MOLE IN ROCK 046590 0000
C ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI 046600 0000
150 IF(RS.LT.3000.) RS=3000. 046610 0000
ARTULT=(10000000./((BE*RS))*.6+.4*SIN(3.14159*(RQD/75.+1.167))) 046620 0000
1*(GI+1500.)/(5.*GI+1500.)*SLARF 046630 0000
GO TO 1100 046640 0000
C -----
C CONVENTIONAL EXCAVATION IN ROCK OR HAND OR RIPPER EXC IN SOFT GRND 046650 0000
50 IF(ISSHAPE.EQ.1) SFA=0.785 046660 0000
IF(ISSHAPE.EQ.2) SFA=0.893 046670 0000
IF(ISSHAPE.EQ.3) SFA=0.425 046680 0000
IF(MEX.EQ.1) ARTULT=((.08*BE**2.25)*RQD+1000.)*((GI+1500.)/ 046690 0000
1 (5.*GI+1500.))/(SFA*BE**1.5*E**(.035*BE)*(1.+.0025*RS/1000.)* 046700 0000
2 SLARF*(1.-RQD*(BE-10.)/6000.)) 046710 0000
IF(MEX.EQ.1) GO TO 1200 046720 0000
IF(MEX.EQ.4) ARTULT=(0.3*(STABNO-10.)*2 +1.)/100000.* 046730 0000
1 (80.-BE)**3.*SLARF*0.785/SFA 046740 0000
IF(MEX.EQ.5) ARTULT=(1.4*(STABNO-7.5)*2 +1.)/100000.* 046750 0000
1 (80.-BE)**3.*SLARF*0.785/SFA 046760 0000
IF(ISSHAPE.NE.3) GO TO 1100 046770 0000
C -----
C SHAPE IS BASKETHANDLE. CHECK FOR COMPUTED ADVANCE RATE GREATER 046780 0000
C THAN FOR CIRCLE OF SAME BE FOR STABILITY NUMBER = 0. IF GREATER, 046790 0000
SET ARTULT FOR BASKETHANDLE EQUAL TO MAXIMUM RATE FOR CIRCLE. 046800 0000
IF(MEX.EQ.4) ART=0.00031*(80.-BE)**3.*SLARF 046810 0000
IF(MEX.EQ.5) ART=0.0007975*(80.-BE)**3.*SLARF 046820 0000
IF(ARTULT.GT.ART) ARTULT=ART 046830 0000
C -----
C CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS 046840 0000
1100 IF(MSTAB.NE.3) GO TO 1200 046850 0000
C GROUND INJECTIONS ARE USED. CHECK FOR APPLICATION FROM INSIDE SEQ. 046860 0000
NPLS=A(N,17) 046870 0000
046880 0000
046890 0000
046900 0000
046910 0000
046920 0000

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(Continued)

## COSTUN Listing (Continued)

```

NPRS=A(N,18) 046930 0000
ELNPLS=CNP(NPLS,2) 046940 0000
ELNPRS=CNP(NPRS,2) 046950 0000
ELSURF=(ELNPLS+ELNPRS)/2. 046960 0000
ELAUG=(ELNPL+ELNPR)/2. 046970 0000
SEGDEP=ELSURF-ELAUG 046980 0000
IF(ISSHAP.EQ.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 -----
C CUT AND COVER 047070 0000
1160 SIDESL=A(N,53) 047080 0000
IF(SIDESL.GT.0.) GO TO 1180 047090 0000
C VERTICAL CUT 047100 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 -----
C 100 IF(TSEGL.LE.25.*((1.-BINSAR**2.)*ARTULT)) GO TO 120 047270 0000
C ULTIMATE ADVANCE RATE IS ATTAINED 047280 0000
ARFAC=TSEGL/(25.*((1.-BINSAR)**2.*ARTULT+TSEGL)) 047290 0000
PINSAR=1.0 047300 0000
GO TO 240 047310 0000
C ULTIMATE ADVANCE RATE NEVER ATTAINED, SEGMENT TOO SHORT 047320 0000
120 ARFAC=.5*((BINSAR+SQRT(BINSAR**2.+.04*TSEGL/ARTULT))) 047330 0000
PINSAR=SQRT(BINSAR**2.+.04*TSEGL/ARTULT) 047340 0000
240 MEXP=MEX 047350 0000
C COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT 047360 0000
A(N,49)=ARTULT 047370 0000
300 A(N,8)=ARTULT*ARFAC 047380 0000
400 CONTINUE 047390 0000
C -----
C COMPUTE ADVANCE RATES IN SHAFT SEGMENTS 047400 0000
DO 800 NSHAFT=1,NSMAX 047410 0000
IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800 047420 0000
C IF THE SHAFT IS A PORTAL, SKIP ADVANCE RATE COMPUTATIONS 047430 0000
NPORT=SHAFT(NSHAFT,23) 047440 0000
IF(NPORT.EQ.1) GO TO 800 047450 0000
NSSEG1=SHAFT(NSHAFT,1) 047460 0000
NSEGS=SHAFT(NSHAFT,4) 047470 0000
047480 0000
047490 0000
047500 0000

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(Continued)

## COSTUN Listing (Continued)

```

C INITIALIZE VALUES 047510 0000
PINSAR=0. 047520 0000
MEXP=0. 047530 0000
DO 700 I=1,NSEQS 047540 0000
C N-SEQUENCE NUMBER OF SHAFT SEGMENT 047550 0000
N=I-1+NSSEG1 047560 0000
MEX=B(N,7) 047570 0000
SSEQL=B(N,35) 047580 0000
C CHECK FOR SHAFT CONSTRUCTED IN CUT AND COVER 047590 0000
IF(MEX.EQ.0) ARSULT=0. 047600 0000
IF(MEX.EQ.0) GO TO 700 047610 0000
STABNO=B(N,24) 047620 0000
C D-DEPTH TO MIDPOINT OF SHAFT SEGMENT 047630 0000
D=B(N,36) 047640 0000
AR=B(N,8) 047650 0000
RQD=B(N,6) 047660 0000
GI=B(N,9) 047670 0000
C FW IS AN INFLOW ADVANCE RATE FACTOR=1.0 IN DRY SHAFTS,.5 IN WET 047680 0000
IF(GI.LT.1.) GO TO 440 047690 0000
C SHAFT IS WET 047700 0000
FW=0.5 047710 0000
GO TO 450 047720 0000
C SHAFT IS DRY 047730 0000
440 FW=1.0 047740 0000
450 BE=B(N,29) 047750 0000
RS=B(N,5) 047760 0000
IF(MEX.EQ.MEXP) GO TO 410 047770 0000
C THIS IS FIRST SEGMENT IN SHAFT OR EXCAVATION METHOD HAS CHANGED 047780 0000
BINSAR=0. 047790 0000
GO TO 420 047800 0000
C EXCAVATION IS SAME AS IN PREVIOUS SEGMENT 047810 0000
410 BINSAR=PINSAR-.05 047820 0000
IF(BINSAR.LT.0.) BINSAR=0. 047830 0000
420 IF(AR.GT.0.) ARSULT=AR 047840 0000
IF(AR.GT.0.) GO TO 500 047850 0000
C -----
C AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED,MUST COMPUTE ONE 047860 0000
C COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS 047870 0000
C CHECK FOR METHOD OF EXCAVATION 047880 0000
IF(MEX.EQ.1 .OR. MEX.EQ.4) GO TO 1610 047890 0000
IF(MEX.EQ.3) GO TO 1600 047900 0000
C -----
C MOLE IN ROCK 047910 0000
C ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI 047920 0000
IF(RS.LT.3000.) RS=3000. 047930 0000
ARSULT=(5000000/(BE*RS))*(.5+RQD/200.)*FW 047940 0000
GO TO 1650 047950 0000
C MOLE IN SOFT GROUND 047960 0000
C -----
1600 ARSULT=(25.-4.*STABNO)*(1.-D/6000.) 047970 0000
GO TO 1650 047980 0000
C CONVENTIONAL EXCAVATION IN ROCK OR HAND EXCAVATION IN SOFT GROUND 047990 0000
1610 IF(MEX.EQ.4) GO TO 1620 048000 0000
C CONVENTIONAL EXCAVATION IN ROCK 048010 0000
ARSULT=.05*FW*(RQD+100.)*(1.-D/6000.) 048020 0000
GO TO 1650 048030 0000
C HAND EXCAVATION IN SOFT GROUND 048040 0000
1620 ISHAPS=SHAFT(NSHAFT,16) 048050 0000
048060 0000
048070 0000
048080 0000

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(Continued)

## COSTUN Listing (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
048120 0000
048130 0000
048140 0000
048150 0000
048160 0000
048170 0000
048180 0000
048190 0000
048200 0000
048210 0000
048220 0000
048230 0000
048240 0000
048250 0000
048260 0000
048270 0000
048280 0000
048290 0000
048300 0000
048310 0000
048320 0000
048330 0000
048340 0000
048350 0000
048360 0000
048370 0000
048380 0000
048390 0000
048400 0000
048410 0000
048415 0000
048420 0000
048430 0000
048440 0000
048450 0000
048460 0000
048470 0000
048480 0000
048490 0000
048500 0000
048510 0000
048520 0000
048530 0000
048540 0000
048550 0000
048560 0000
048570 0000
048580 0000
048590 0000
048600 0000
048610 0000
048620 0000
048630 0000

C   CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS
1650 IF(MSTAB.EQ.3) GO TO 1660          048130 0000
GO TO 1700
C   GROUND INJECTIONS ARE USED.CHECK FOR APPLICATION FROM INSIDE SEG.
1660 IF(D.LE.200.) GO TO 1700          048140 0000
C   GROUND INJECTIONS ARE MADE FROM WITHIN SEGMENT AND SLOWS ADVANCE
ARSULT=100./(100.+ARSULT)*ARSULT      048150 0000
048160 0000
048170 0000
048180 0000
048190 0000
048200 0000
048210 0000
048220 0000
048230 0000
048240 0000
048250 0000
048260 0000
048270 0000
048280 0000
048290 0000
048300 0000
048310 0000
048320 0000
048330 0000
048340 0000
048350 0000
048360 0000
048370 0000
048380 0000
048390 0000
048400 0000
048410 0000
048415 0000
048420 0000
048430 0000
048440 0000
048450 0000
048460 0000
048470 0000
048480 0000
048490 0000
048500 0000
048510 0000
048520 0000
048530 0000
048540 0000
048550 0000
048560 0000
048570 0000
048580 0000
048590 0000
048600 0000
048610 0000
048620 0000
048630 0000

C   -----
500 IF(SSEGL.LE.25.*(1.-BINSAR**2.)*ARSULT) GO TO 520
C   ULTIMATE ADVANCE RATE IS ATTAINED
ARFAC=SSEGL/(25.*(1.-BINSAR)**2 *ARSULT+SSEGL)
PINSAR=1.0
GO TO 640
C   ULTIMATE ADVANCE RATE NEVER ATTAINED,SEGMENT TOO SHORT
520 ARFAC=.5*(BINSAR+SQRT(BINSAR**2.+.04*SSEGL/ARSULT))
PINSAR=SQRT(BINSAR**2.+.04*SSEGL/ARSULT)
640 MEXP=MEX
C   COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT
B(N,39)=ARSULT
700 B(N,8)=ARSULT*ARFAC
800 CONTINUE
C   -----
RETURN
END
SUBROUTINE CONSTM (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX)
C   -----
C   THIS SUBROUTINE CALCULATES SEGMENT CONSTRUCTION TIMES INCLUDING
TIME FOR LINING
C   -----
COMMON /BASIC/ NSS,NTS
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23)
C   -----
CALCULATE CONSTRUCTION TIME FOR TUNNEL SEGMENTS
DO 50 I=1,NTS
NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND
SHOTCRETED TUNNEL SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO
CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO
BECAUSE IT IS PLACED IMMEDIATELY AFTER EXCAVATION
AL=10.E30
NTSTYP=A(I,16)
NREACH=A(I,4)
HOURS=TRDATA(NREACH,8)
DAYS=TRDATA(NREACH,9)

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## COSTUN Listing (Continued)

```

IF (NTSTYP.GT.1) GO TO 40          048640 0000
LINING=A(I,10)
IF(LINING.EQ.1) AL=3*HOURS       048650 0000
40 AR=A(I,8)                      048660 0000
TSEGL=A(I,45)                    048670 0000
50 A(I,50)=(TSEGL/AR+TSEGL/AL)*7./DAYS 048680 0000
50 A(I,50)=(TSEGL/AR+TSEGL/AL)*7./DAYS 048690 0000
50 A(I,50)=(TSEGL/AR+TSEGL/AL)*7./DAYS 048700 0000
C CALCULATE CONSTRUCTION TIME FOR SHAFT SEGMENTS 048710 0000
DO 100 I=1,NSS                   048720 0000
NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND 048730 0000
SHOTCRETED SHAFT SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO 048740 0000
CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO 048750 0000
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 COUVER 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 RETURN                           048910 0000
END                               048920 0000
SUBROUTINE PUMPHT (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX)                          048930 0000
048940 0000
048945 0000
C THIS SUBROUTINE COMPUTES PUMPING HEIGHTS FOR TUNNEL SEGMENTS 048950 0000
048960 0000
048970 0000
048980 0000
048990 0000
COMMON /BASIC/ NSS,NTS           049000 0000
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23)                049010 0000
049020 0000
C DO 200 I=1,NTS                  049030 0000
NREACH=A(I,4)                     049040 0000
NTSTYP=A(I,16)                    049050 0000
IF(NTSTYP.EQ.3) GO TO 100          049060 0000
C ROCK OR SOFT GROUND             049070 0000
COMPUTE PUMPING HEIGHTS. PUMPING HEIGHT EQUALS SHAFT DEPTH OR 049080 0000
DIFFERENCE IN ELEVATION FROM TOP OF SHAFT TO MIDPOINT OF TUNNEL 049090 0000
SEGMENT, WHICHEVER IS GREATER    049100 0000
NSHAFT=TRDATA(NREACH,1)            049110 0000
NPTS=SHAFT(NSHAFT,2)              049120 0000
ELTS=CNP(NPTS,2)                  049130 0000
NPL=A(I,2)                        049140 0000
NPR=A(I,3)                        049150 0000
ELNPL=CNP(NPL,2)                  049160 0000
ELNPR=CNP(NPR,2)                  049170 0000
C ELEVATION AT MIDPOINT OF TUNNEL SEGMENT 049180 0000
ELAVG=(ELNPL+ELNPR)/2.            049190 0000
049200 0000

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(Continued)

## COSTUN Listing (Continued)

```

PH=ELTS-ELAUG 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 -----
RETURN 049540 0000
END 049550 0000
SUBROUTINE PUMPRT (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, 049560 0000
1NTRMAX) 049570 0000
C -----
049575 0000
C C FLOW RATE TO BE PUMPED FROM TUNNEL AND DEWATERING FOR TUNNELS 049580 0000
C C AND SHAFTS. 049590 0000
C C -----
049600 0000
C C -----
049610 0000
C C -----
049620 0000
C C -----
049630 0000
C C -----
049640 0000
C 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 C ****
049680 0000
C C ****
049690 0000
TUNNELS 049700 0000
C C ****
049710 0000
C 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,6) 049760 0000
NSEGSA=IABS(NSEGS) 049770 0000

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## COSTUN Listing (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(NSEGSA.GT.0) N=NRSEQ1+I-1          049850 0000
IF(NSEGSA.LT.0) N=NRSEQ1-I+1          049860 0000
NTSTYP=A(N,16)          049870 0000
PERM=A(N,25)           049880 0000
D10=A(N,19)            049890 0000
IWATER=A(N,23)          049900 0000
MSTAB=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
ELAUG=(ELNPL+ELNPR)/2.      050000 0000
IF(NTSTYP.EQ.3) GO TO 200          050010 0000
-----
C   ROCK OR SOFT GROUND TUNNELS          050020 0000
C   -----
C   HEADING INFLOW AND RESIDUAL FLOW IN TUNNELS          050030 0000
GI=A(N,9)              050040 0000
ELBOTM=ELAUG-BE/2.          050050 0000
ISHAPE=TRDATA(NREACH,3)      050060 0000
IF(ISSHAPE.EQ.3) ELBOTM=ELAUG-BE/4.      050070 0000
C   IF GROUNDWATER BELOW TUNNEL, GI = 0          050080 0000
IF(ELWATR.LT.ELBOTM) GI=0.          050090 0000
IF(NTSTYP.EQ.2) GO TO 140          050100 0000
C   ROCK TUNNELS          050110 0000
C   ESTABLISH RESIDUAL INFLOW(GPM/FT) AND INFLOW AT FACE FOR PUMPING          050120 0000
C   IN GPM          050130 0000
IF(GI.GE.100.) GO TO 135          050140 0000
GIR=0.001*GI          050150 0000
GIF=GI          050160 0000
GO TO 155          050170 0000
135 GIR=0.1          050180 0000
GIF=100.          050190 0000
GO TO 155          050200 0000
C   SOFT GROUND TUNNELS          050210 0000
140 GIF=GI          050220 0000
GIR=0.          050230 0000
155 A(N,60)=GIR          050240 0000
R=FLRT          050250 0000
TSEGL=A(N,45)          050260 0000
FLRT=0.5*GIR*TSEGL          050270 0000
C   AVERAGE FLOW TO BE PUMPED AND CHARGED TO NTH SEGMENT          050280 0000
FLOW=Z+R+FLRT+GIF          050290 0000
A(N,59)=FLOW          050300 0000
Z=FLOW-GIF          050310 0000
C   THE FOLLOWING WILL DETERMINE THE LENGTH OF PIPE REQUIRED          050320 0000
FOR THE SEGMENT WHEN PUMPING UPHILL. IT IS ASSUMED THAT NO PIPE          050330 0000
C   050340 0000
C   050350 0000

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(Continued)

COSTUN Listing (Continued)

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C IS REQUIRED WHEN THE WATER MAY RUN DOWN THE SEGMENT IN THE      050360 0000
C DIRECTION OF THE EXIT SHAFT.                                     050370 0000
NPL=A(N,2)                                                       050380 0000
NPR=A(N,3)                                                       050390 0000
ELEUD=CNP(NPR,2)-CNP(NPL,2)                                     050400 0000
C SLOPE IS POSITIVE WHEN UPHILL IN THE DIRECTION OF HEADING ADVANCE 050410 0000
C   SS= SIGN OF THE SLOPE (ACTUAL VALUE IS IMMATERIAL)             050420 0000
SS=ELEUD*MSEGL                                                    050430 0000
C ESTABLISH THE PIPE LENGTH REQUIRED                           050440 0000
PIPE=0.0                                                       050450 0000
C IF(SS.LT.0) PIPE=0.5*TSEG1                                     050460 0000
DETERMINE THE CUMULATIVE PIPE LENGTHS REQUIRED                 050470 0000
A(N,58)=ZZ+TUBE+PIPE                                         050480 0000
TUBE=PIPE                                                       050490 0000
ZZ=A(N,58)                                                       050500 0000
IF(NTSTYP.EQ.2) GO TO 160                                      050510 0000
C ROCK TUNNELS                                                 050520 0000
GO TO 300                                                       050530 0000
C                                                               050540 0000
C                                                               050550 0000
C DEWATERING FOR SOFT GROUND TUNNELS                            050560 0000
160 IF(MSTAB.NE.2 .OR.ABS(PERM).LE. 0.0006) GO TO 250          050570 0000
HEADU=0                                                       050580 0000
ELIMP=A(N,24)                                                    050590 0000
C IF DEWATERING METHOD USED, WATER TABLE ABOVE IMPERVIOUS LAYER, AND 050600 0000
C WATER TABLE ABOVE ELAUG, THEN SET FOLLOWING VALUES            050610 0000
IF(ELIMP.GE.ELBOTM) DRAWDN=ELWATR-ELIMP                      050620 0000
IF(ELIMP.LT.ELBOTM) DRAWDN=ELWATR-ELBOTM                     050630 0000
DIMP=ELBOTM-ELIMP                                              050640 0000
GO TO 210                                                       050650 0000
C -----
C CUT AND COVER DEWATERING                                     050660 0000
C -----
C 200 NPLS=A(N,17)                                               050680 0000
NPRS=A(N,18)                                                       050690 0000
ELNPLS=CNP(NPLS,2)                                              050700 0000
ELNPRS=CNP(NPRS,2)                                              050710 0000
ELSURF=(ELNPLS+ELNPRS)/2.                                       050720 0000
IF(D10.LE.0.005) GO TO 250                                      050730 0000
ELIMP=A(N,24)                                                    050740 0000
DTRNCH=A(N,52)                                                   050750 0000
ISUPPT=A(N,26)                                                   050760 0000
PERM=ABS(PERM)                                                 050770 0000
IF(ISUPPT.NE.6 .OR. IWATER.EQ.1) GO TO 205                    050780 0000
C CHECK FOR SLURRY WALL PENETRATING IMPERVIOUS LAYER           050790 0000
DSLURY=A(N,38)                                                   050800 0000
IF(DSLURY.GE.ELSURF-ELIMP.OR.DSLURY.GE.ELSURF-ELROCK) GO TO 250 050810 0000
205 HEADU=-7.* ALOG10(PERM)+1.)                                 050820 0000
IF(HEADU.GT.21.) HEADU=21.                                       050830 0000
IF(HEADU.LT.0.0) HEADU=0.                                       050840 0000
C HEADU=0 FOR SUMP PUMPING                                     050850 0000
IF(IWATER.EQ.0.OR. ISUPPT.EQ.5.AND.ELROCK.GT.ELSURF-DTRNCH)HEADU=0 050860 0000
DRAWDN=DTRNCH-(ELSURF-ELWATR)                                    050870 0000
DIMP=ELSURF-ELIMP-DTRNCH                                       050880 0000
IF(DIMP.LT.0.0) DRAWDN=ELWATR-ELIMP                            050890 0000
C 210 IF(DIMP.LT.0.) DIMP=0                                     050900 0000
DEWATERING IS NOT NEEDED IF GROUNDWATER BELOW BOTTOM OF EXC.    050910 0000
IF(DRAWDN.LE.0.) GO TO 250                                      050920 0000
                                                050930 0000

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## COSTUN Listing (Continued)

```

HEAD=DRAWDN+DIMP+HEADU 050940 0000
PERM=ABS(PERM) 050950 0000
FLOWDW=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(FLOWDW.LE.0.7) GO TO 220 051030 0000
IF(FLOWDW.GT.400.) GO TO 230 051040 0000
FLOWL=15.*FLOWDW**1.2 051050 0000
WELLSP=15.*FLOWDW**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/FLOWDW 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)=FLOWDW*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 SHAFTS-- DEWATERING ONLY 051280 0000
C **** 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(NSSSTYP.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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COSTUN Listing (Continued)

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ELSURF=CNP(NPTS,2)
ISHAPS=SHAFT(NSHAFT,16)
ELIMP=B(N,20)
DRAWDN=ELWATR-ELNPB
DIMP=ELNPB-ELIMP
HEAD=DRAUDN+DIMP
PERM=ABS(PERM)
FLOWDW=0.75*(0.73+0.27*(HEAD-DIMP)/HEAD)*(HEAD**2-DIMP**2)
1/(HEAD-SQRT(HEAD*DIMP))*PERM
WELLS=3
SFP=3.14
IF(ISHAPS.EQ.2) SFP=4
WELLSP=SFP*(BE+20.)/3.
FLOWL=FLOWDW*WELLSP
GO TO 560
C ROCK OR CUT AND COVER SHAFTS
550 FLOWL=0
C STORE WELL CAPACITY
560 B(N,42)=FLOWL
600 CONTINUE
700 CONTINUE
RETURN
END
SUBROUTINE VOLUME (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX)
-----
C THIS SUBROUTINE COMPUTES THE EXCAVATED VOLUME PER LINEAR FOOT OF
C TUNNEL AND SHAFT
-----
COMMON /BASIC/ NSS,NTS
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23)
-----
C TUNNEL VOLUME INCLUDING OVERBREAK IN SOLID CUBIC YARDS/FOOT
DO 10 I=1,NTS
NTSTYP=A(I,16)
C CHECK IF SEGMENT EXCAVATED BY CUT AND COVER
IF(NTSTYP.EQ.3) GO TO 55
TUNNEL
BOB=A(I,42)
NREACH=A(I,4)
ISHAPE=TRDATA(NREACH,3)
C CHECK THE SHAPE OF TUNNEL
IF(ISHAPE.EQ.1) SFA=0.785
IF(ISHAPE.EQ.2) SFA=0.893
IF(ISHAPE.EQ.3) SFA=0.425
U=BOB**2*SFA/27.
GO TO 10
C CUT AND COVER
55 BE=A(I,39)
DTRNCH=A(I,52)
NPLS=A(I,17)
NPRS=A(I,18)
SIDESL=A(I,53)
C COMPUTE THE DEPTH OF ROCK

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## COSTUN Listing (Continued)

```

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
UROCK=. 052130 0000
USOIL=(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
UROCK=BE*(DTRNCH-DROCK)/27. 052170 0000
USOIL=(BE+DROCK*SIDESL)*DROCK/27. 052180 0000
88 U=UROCK+USOIL 052190 0000
10 A(I,51)=U 052200 0000
C -----
C SHAFT 052210 0000
DO 20 I=1,NSS 052220 0000
BOB=B(I,32) 052230 0000
SFA=0.785 052240 0000
NSHAFT=B(I,1) 052250 0000
ISHAPS-SHAFT(NSHAFT,16) 052260 0000
NSTTYP=B(I,15) 052270 0000
IF(ISHAPS.EQ.2) SFA=1. 052280 0000
U=0. 052290 0000
IF(ISHAPS.EQ.0) GO TO 20 052300 0000
IF(NSTTYP.NE.3) U=BOB**2*SFA/27. 052310 0000
20 B(I,38)=U 052320 0000
RETURN 052330 0000
END 052340 0000
SUBROUTINE EXCVOI (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX) 052350 0000
052360 0000
052365 0000
C -----
C CALCULATES THE EXCAVATED VOLUME TO EXIT FROM EACH SHAFT AND 052370 0000
LENGTH OF TRENCH TEMPORARILY LEFT OPEN IN CUT-AND-COVER EXCAVATION 052380 0000
052390 0000
052400 0000
052410 0000
052420 0000
052430 0000
052440 0000
052450 0000
052460 0000
052470 0000
052480 0000
052490 0000
052500 0000
052510 0000
052520 0000
052530 0000
052540 0000
052550 0000
052560 0000
052570 0000
052580 0000
052590 0000
052600 0000
052610 0000
052620 0000
052630 0000
052640 0000
052650 0000
C -----
C INITIALIZE TOTAL EXCAVATED VOLUME 052400 0000
DO 100 N=1,NSMAX 052410 0000
100 SHAFT(N,9)=0.0 052420 0000
C CALCULATE VOLUME FROM CUT AND COVER REACH 052430 0000
052440 0000
052450 0000
052460 0000
052470 0000
052480 0000
052490 0000
052500 0000
052510 0000
052520 0000
052530 0000
052540 0000
052550 0000
052560 0000
052570 0000
052580 0000
052590 0000
052600 0000
052610 0000
052620 0000
052630 0000
052640 0000
052650 0000
M=NRSEG1

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## COSTUN Listing (Continued)

```

L=0
UTDSD=0.
1100 T1=0.
L=L+1
TSEGL =A(M,45)
U =A(M,51)
UBOX =A(M,54)
AR =A(M, 8)
ARTULT=A(M,49)
LINING=A(M,10)
CTTS1 =TSEGL/AR
C ADVANCE RATE FACTOR AT END POINTS OF SEGMENT
BINSAR=PINSAR-0.05
IF(BINSAR.LT.0.) BINSAR=0.
TMULT=(1.-BINSAR)/0.02
PINSAR=BINSAR+0.02*CTTS1
IF(PINSAR.GT.1.)PINSAR=1.
C TIME REQUIRED FOR TRENCH TO BE LEFT OPEN
IF(LINING.EQ.1) TIMEOP=30.*DAYS/7.+10.
IF(LINING.EQ.3) TIMEOP=10.
UTEXC=UTEXC+U*TSEGL
UTBOX=UTBOX+UBOX*TSEGL
IF(CTTS1.GT.TIMEOP) T1=CTTS1-TIMEOP
C COMPUTE THE LENGTH OF OPEN WITHOUT BACKFILL
1200 IF(CTTS1.LE.TMULT) OPENT=ARTULT*(CTTS1-T1)*(BINSAR+0.01*(CTTS1+T1))
1 )
IF(CTTS1.GT.TMULT) OPENT=ARTULT*(BINSAR*(TMULT-T1)+0.01*(TMULT**2
1 -T1**2)+CTTS1-TMULT)
IF(T1.GT.TMULT) OPENT=ARTULT*(CTTS1-T1)
C CALCULATE VOLUME OF DISPOSAL AND BACKFILL
UTDST=(0.1*UTEXC+UTBOX+(U-UBOX)*OPENT)/1.1
UBFT=(U-UBOX)*OPENT
T2=TIMEOP-CTTS1+T1
PIN2=PINSAR
N=M+NSEGSA/NSEGSA
LL=L+1
C CHECK IF THE NEXT SEGMENT IS INVOLVED
IF(T2.LE.0.) GO TO 1500
C CHECK FOR END OF REACH
1300 IF(LL.GT.NSEGSA) GO TO 1500
TSEGL =A(N,45)
U2 =A(N,51)
UBOX2 =A(N,54)
AR =A(N, 8)
ARTU2 =A(N,49)
CTTS2 =TSEGL/AR
BIN2=PIN2-0.05
IF(BIN2.LT.0.) BIN2=0.
C CHECK IF MORE SEGMENTS INVOLVED
IF(T2.LE.CTTS2) GO TO 1400
LL=LL+1
T2=T2-CTTS2
N=N+NSEGSA/NSEGSA
UTDST=UTDST+U2*TSEGL
UBFT=UBFT+(U2-UBOX2)*TSEGL
PIN2=BIN2+0.02*CTTS2
IF(PIN2.GT.1.) PIN2=1.
OPENT=OPENT+TSEGL
052660 0000
052670 0000
052680 0000
052690 0000
052700 0000
052710 0000
052720 0000
052730 0000
052740 0000
052750 0000
052760 0000
052770 0000
052780 0000
052790 0000
052800 0000
052810 0000
052820 0000
052830 0000
052840 0000
052850 0000
052860 0000
052870 0000
052880 0000
052890 0000
052900 0000
052910 0000
052920 0000
052930 0000
052940 0000
052950 0000
052960 0000
052970 0000
052980 0000
052990 0000
053000 0000
053010 0000
053020 0000
053030 0000
053040 0000
053050 0000
053060 0000
053070 0000
053080 0000
053090 0000
053100 0000
053110 0000
053120 0000
053130 0000
053140 0000
053150 0000
053160 0000
053170 0000
053180 0000
053190 0000
053200 0000
053210 0000
053220 0000
053230 0000

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## COSTUN Listing (Continued)

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GO TO 1300 053240 0000
1400 TMULT2=(1.-BIN2)/0.02 053250 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
UTDST=UTDST+U2*OPENT2 053310 0000
UBFT=UBFT+(U2-UBOX2)*OPENT2 053320 0000
OPENT=OPENT+OPENT2 053330 0000
C MAXIMUM VOLUME IN LENGTH 'OPEN' 053340 0000
1500 IF(UTDS.GT.UTDST) GO TO 1600 053350 0000
UTDS=UTDST 053360 0000
UBF=UBFT 053370 0000
OPEN=OPEN 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 -----
C COMPUTE THE TOTAL VOLUME OF EXCAVATION AND BOX IN A REACH 053460 0000
1700 MM=M+1 053470 0000
DO 2000 J=MM,N 053480 0000
TSEGL=A(J,45) 053490 0000
U=A(J,51) 053500 0000
UBOX=A(J,54) 053510 0000
UTEXC=UTEXC+U*TSEGL 053520 0000
2000 UTBOX=UTBOX+UBOX*TSEGL 053530 0000
2100 UDS=UTDS/UTEXC 053540 0000
SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+UTDS 053550 0000
C BACKFILL VOLUME 053560 0000
UBACDS=UBF/1.1/(UTEXC-UTBOX) 053570 0000
UBACEX=0.909-UBACDS 053580 0000
C STORE VALUES IN ARRAY 053590 0000
TRDATA(I,16)=OPEN 053600 0000
TRDATA(I,21)=UDS 053610 0000
TRDATA(I,22)=UBACEX 053620 0000
TRDATA(I,23)=UBACDS 053630 0000
1000 CONTINUE 053640 0000
C -----
C CALCULATE VOLUME FROM TUNNEL SEGMENT 053650 0000
DO 200 N=1,NTS 053660 0000
NREACH=A(N,4) 053670 0000
NSHAFT=TRDATA(NREACH,1) 053680 0000
NTSTYP=A(N,16) 053690 0000
IF(NTSTYP.EQ.3) GO TO 200 053700 0000
U=A(N,51) 053710 0000
TSEGL=A(N,45) 053720 0000
SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+U*TSEGL 053730 0000
200 CONTINUE 053740 0000
C -----
C CALCULATE VOLUME FROM SHAFT SEGMENT 053750 0000
DO 300 N=1,NSS 053760 0000
NSHAFT=B(N,1) 053770 0000
NSSTYP=B(N,15) 053780 0000
053790 0000
053800 0000
053810 0000

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(Continued)

## COSTUN Listing (Continued)

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IF(NSTYP.EQ.3) GO TO 300
U=B(N,38)
SSEG1=B(N,35)
SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+U*SSEG1
300 CONTINUE
C -----
RETURN
END
SUBROUTINE MUCKLD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX)
C -----
C C C C C
CALCULATES REQUIRED MUCK LOADING RATES IN EACH SEGMENT AND
MAXIMUM RATE IN EACH REACH OR SHAFT BASED ON ULTIMATE ADVANCE RATE
C -----
COMMON /BASIC/ NSS NTS
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23)
C -----
MUCK LOADING RATE IN TUNNEL SEGMENTS AND MAXIMUM RATE IN REACH
DO 400 NREACH=1,NTRMAX
IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400
C
HOURS=TRDATA(NREACH,8)
NRSEG1=TRDATA(NREACH,5)
NSEGS=TRDATA(NREACH,6)
NSEGSA=IABS(NSEGS)
C
RMLMAX=0
C
DO 300 I=1,NSEGSA
N=SEQUENCE NUMBER OF TUNNEL SEGMENT
IF(NSEGS.GT.0) N=NRSEG1+I-1
IF(NSEGS.LT.0) N=NRSEG1-I+1
NSTYP=A(N,16)
IF (NSTYP.EQ.3) GO TO 300
MEX=A(N,7)
U=A(N,51)
ARTULT=A(N,49)
C
CALCULATE MUCK LOADING RATE
IF(MEX.EQ.1) GO TO 200
RML=3.*U*ARTULT/HOURS
GO TO 250
200 IF(5.*HOURS/ARTULT.GE.2) RML=5.*U
IF(5.*HOURS/ARTULT.LT.2.) RML=2.*U*ARTULT/HOURS
250 IF(RMLMAX.LT.RML) RMLMAX=RML
A(N,48)=RML
300 CONTINUE
C
350 TRDATA(NREACH,7)=RMLMAX
400 CONTINUE
C -----
MUCK LOADING RATE IN SHAFT SEGMENTS AND MAXIMUM RATE IN SHAFTS
DO 800 NSHAFT=1,NSMAX
IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800
C
HOURS=SHAFT(NSHAFT,17)

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## COSTUN Listing (Continued)

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NSEQ1=SHAFT(NSHAFT,1)          054380 0000
NSEGS=SHAFT(NSHAFT,4)          054400 0000
C
RMLMAX=0                         054410 0000
C
DO 700 I=1,NSEGS                054420 0000
N=I-1+NSEQ1                      054430 0000
C
SEQUENCE NUMBER OF SHAFT SEGMENT 054440 0000
C
CHECK FOR CUT AND COVER OR DUMMY SHAFT - NO RML COMPUTED 054450 0000
MEX=B(N,7)                        054460 0000
IF(MEX.EQ.0) GO TO 700           054470 0000
U=B(N,38)                         054480 0000
ARSULT=B(N,39)                   054490 0000
IF(MEX.EQ.1) GO TO 600           054500 0000
RML=3.*U*ARSULT/HOURS          054510 0000
GO TO 650                         054520 0000
600 IF(5.*HOURS/ARSULT.GE.12.) RML=5.*U/6.      054530 0000
IF(5.*HOURS/ARSULT.LT.12.) RML=2.*U*ARSULT/HOURS 054540 0000
650 IF(RMLMAX.LT.RML) RMLMAX=RML               054550 0000
B(N,37)=RML                      054560 0000
700 CONTINUE                       054570 0000
C
750 SHAFT(NSHAFT,10)=RMLMAX        054580 0000
800 CONTINUE                       054590 0000
C
----- 054600 0000
RETURN                            054610 0000
END                               054620 0000
SUBROUTINE AIRLOK(A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,NPMAX,
1NSMAX,NTRMAX)                  054630 0000
----- 054640 0000
----- 054650 0000
----- 054660 0000
----- 054665 0000
----- 054670 0000
----- 054680 0000
CCC THIS SUBROUTINE DETERMINES THE LOCATIONS OF AIR LOCKS AND COOLING 054690 0000
CC PLANT IN A REACH AND COMPUTES THE COOLING AND VENTILATION       054700 0000
CC REQUIREMENTS OF TUNNEL SEGMENTS AND MAXIMUM REQUIREMENT IN A REACH 054710 0000
CCC ----- 054720 0000
CCC ----- 054730 0000
COMMON /BASIC/ NSS,NTS           054740 0000
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23),CUMSL(NPMAX) 054750 0000
C
----- 054760 0000
----- 054770 0000
DO 200 J=1,NTRMAX                054780 0000
IF(TRDATA(J,1).LT.0) GO TO 200    054790 0000
ISHAPE=TRDATA(J,3)                054800 0000
IF(ISSHAP.EQ.0) GO TO 200         054810 0000
C
INITIALIZATION                    054820 0000
NRSEG1=TRDATA(J,5)                054830 0000
NSEGS=TRDATA(J,6)                 054840 0000
NSHAFT=TRDATA(J,1)                054850 0000
DTC=0.                             054860 0000
GT=0.                             054870 0000
AIRTEM=SHAFT(NSHAFT,11)           054880 0000
NSEGSA=IABS(NSEGS)                054890 0000
KOOL=0                            054900 0000
DTCA=0.                           054910 0000
CAUT=0.                           054920 0000
M=0                                054930 0000
N1=1                                054940 0000
NPBS=SHAFT(NSHAFT,3)              054950 0000

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(Continued)

## COSTUN Listing (Continued)

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HH-SHAFT(NSHAFT,8)          054960 0000
NPLOCK=0                     054970 0000
IF(I$SHAPE.EQ.1) SFA=0.785  054980 0000
IF(I$SHAPE.EQ.2) SFA=0.893  054990 0000
IF(I$SHAPE.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(NSEGSA.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 -----
C DETERMINE THE LOCATION OF AIR LOCK FOR A SEGMENT IN COMPRESSED AIR 055170 0000
DO 100 N=1 NSEGSA                                           055180 0000
IF(NSEGSA.LT.0) GO TO 60                                     055190 0000
I=NRSEG1+N-1                                                 055200 0000
NPFEND=A(I,3)                                                 055210 0000
NPREND=A(I,2)                                                 055220 0000
NPS=A(I,17)                                                   055230 0000
GO TO 65                                                     055240 0000
60 I=NRSEG1-N+1                                             055250 0000
NPFEND=A(I,2)                                                 055260 0000
NPREND=A(I,3)                                                 055270 0000
NPS=A(I,18)                                                   055280 0000
65 BE=A(I,39)                                                 055290 0000
PH=A(I,57)                                                   055300 0000
TSEGL=A(I,45)                                                 055310 0000
DM=A(I,46)                                                   055320 0000
RTEMP=A(I,12)                                                 055330 0000
MSTAB=A(I,31)                                                 055340 0000
IF(MSTAB.NE.1) GO TO 85                                     055350 0000
PERM=A(I,25)                                                 055360 0000
D10=SQRT(10.*ABS(PERM))                                    055370 0000
IF(D10.LE.0.005) D10=0.005                                 055380 0000
C -----
M=M+1                                                       055390 0000
C COMPUTE VENTILATION QUANTITY FOR THE SEGMENT IN COMPRESSED AIR 055400 0000
CAU=(28.5+10.*ALOG10(D10))*SFA*BE**2                      055410 0000
C CHECK THE FIRST COMPRESSED AIR SEGMENT                   055420 0000
IF(M.NE.1) GO TO 70                                         055430 0000
C CHECK IF COOLING PLANT FOR FIRST AIR LOCK TO BE MOVED FROM 055440 0000
C SHAFT TO ABOVE THE LOCK                                   055450 0000
IF(ABS(CUMFCA-CUMSL(NPBS))+HH.LE.12000..AND.DTC.GT.0.) GO TO 75 055460 0000
GO TO 71                                                     055470 0000
C CHECK SEPARATION BETWEEN TWO COMPRESSED AIR SEGMENTS    055480 0000
70 IF(ABS(CUMSL(M-1)-CUMSL(NPREND)).GT.5000..AND. 055490 0000
1 ABS(CUMFCA-CUMSL(NPREND)).GT.2000.) GO TO 71           055500 0000
C CHECK THE STATIONING OF THE SEGMENT END POINT TO DETERMINE THE 055510 0000
055520 0000
055530 0000

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## COSTUN Listing (Continued)

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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
COMPRESSED AIR SEGMENTS.      055590 0000
C                                         055600 0000
71 N2=N-1                         055610 0000
DO 72 NN=N1,N2                   055620 0000
II=NRSEG1+(NN-1)*NSEGS/NSEGSA 055630 0000
A(II,35)=CAUT                  055640 0000
72 A(II,37)=QT                  055650 0000
N1=N                           055660 0000
CAUT=0.                         055670 0000
KOOL=1                          055680 0000
C KOOL = INDICATOR FOR THE LOCATION OF COOLING PLANT        055690 0000
QT=0.                           055700 0000
C SET UP THE LOCK               055710 0000
75 NPLOCK=NPREND                055720 0000
DTHLOK=CNP(NPS,2)-CNP(NPLOCK,2) 055730 0000
DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPBS)) 055740 0000
C COMPUTE THE LENGTH OF PIPE FOR COOLING IN COMPRESSED AIR SEGMENT 055750 0000
80 IF(KOOL.EQ.0) PUMPLT=5280.*DM+HH 055760 0000
IF(KOOL.EQ.1) PUMPLT=5280.*DM-DLOCK+DTHLOK 055770 0000
C NPLOCK = NEGATIVE IF COOLING PLANT OF FIRST AIR LOCK MOVED FROM 055780 0000
SHAFT TO TOP OF LOCK          055790 0000
IF (KOOL.EQ.1.AND.M.EQ.1.AND.DTC.GT.0.) NPLOCK=-NPLOCK 055800 0000
C COMPUTE THE QUANTITY OF COOLED AIR REQUIRED IN COMPRESSED AIR 055810 0000
SEGMENT                         055820 0000
Q=CAU*(74.00+0.031*PUMPLT)+SQRT(CAU)*PUMPLT 055830 0000
1 *(0.23+0.0454*(RTEMP-85.))+239.*PUMPLT 055840 0000
IF(CAU.GT.CAUT) CAUT=CAU      055850 0000
M=NPFEND                        055860 0000
GO TO 90                         055870 0000
C -----
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
1INTRMAX)                      056105 0000

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(Continued)

## COSTUN Listing (Continued)

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C----- THIS SUBROUTINE OUTPUTS CALCULATED TUNNEL AND SHAFT DATA ----- 056110 0000
C----- 056120 0000
C----- 056130 0000
C----- 056140 0000
C----- 056150 0000
C----- 056160 0000
C----- 056170 0000
C----- 056180 0000
C----- 056190 0000
C----- 056200 0000
C----- 056210 0000
C----- REFER TO COMMENT ON DOUBLE PRECISION LITERALS IN SUBROUTINE 4.
C----- DOUBLE PRECISION TNONE,AIRPRS,DEWATR,GRDINJ,SUMP,STABIL
C----- 056230 0000
C----- 056240 0000
C----- 056250 0000
C----- 056260 0000
C----- 056270 0000
C----- 056280 0000
C----- 056290 0000
C----- 056300 0000
C----- 056310 0000
C----- 056320 0000
C----- N-SEGMENT SEQUENCE NUMBER 056330 0000
C----- DO 100 N=1,NTS 056340 0000
C----- NLINES=NLINES+1 056350 0000
C----- IF(LIST(4).EQ.1) GO TO 10 056360 0000
C----- IF(NLINES.LT.40) GO TO 10 056370 0000
C----- NLINES=0 056380 0000
C----- WRITE(LO,3000) 056390 0000
C----- WRITE(LO,3010) 056400 0000
C----- 10 NREACH=A(N,4) 056410 0000
C----- NPL=A(N,2) 056420 0000
C----- MPR=A(N,3) 056430 0000
C----- NTSEG=A(N,1) 056440 0000
C----- BE= A(N,39) 056450 0000
C----- NTSTYP=A(N,16) 056460 0000
C----- IF(NTSTYP.EQ.3) GO TO 40 056470 0000
C----- 056480 0000
C----- ISHAPE=TRDATA(NREACH,3) 056490 0000
C----- MTM=TRDATA(NREACH,4) 056500 0000
C----- HSLOPE=A(N,47) 056510 0000
C----- IF(MTM.NE.3) GO TO 20 056520 0000
C----- CHECK FOR MAXIMUM SLOPE FOR TRAIN 056530 0000
C----- IF(ABS(HSLOPE).LE.0.05) GO TO 30 056540 0000
C----- WRITE(LO,1020) NTSEG,NREACH 056550 0000
C----- NLINES=NLINES +1 056560 0000
C----- IERROR=1 056570 0000
C----- GO TO 30 056580 0000
C----- 20 IF(MTM.NE.1) GO TO 30 056590 0000
C----- 056600 0000
C----- CHECK FOR TUNNEL CROWN HIGH ENOUGH TO HANDLE A TRUCK 056610 0000
C----- IF(ISHAPE.LE.2.AND.BE.LT.16.) GO TO 25 056620 0000
C----- IF(ISHAPE.EQ.3.AND.BE.LT.30.) GO TO 25 056630 0000
C----- GO TO 30 056640 0000
C----- 25 WRITE(LO,1021) NTSEG,NREACH 056650 0000
C----- NLINES=NLINES +1 056660 0000
C----- IERROR=1 056670 0000
C----- 30 CONTINUE 056680 0000

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(Continued)

## COSTUN Listing (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(HSLOPE).LE.0.26) GO TO 32 056710 0000
WRITE(LO,1023) NTSEG,NREACH 056720 0000
NLINES=N\INES+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(MTSTYP.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=N\INES+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
ITEMS=ISTA2/10. 056960 0000
IHUNS=ISTA2-ITEMS*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 USOIL=0.0 057110 0000
UROCK=0.0 057120 0000
U=A(N,51) 057130 0000
IF(NTSTYP.EQ.1) UROCK=U 057140 0000
IF(NTSTYP.EQ.2) USOIL=U 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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## COSTUN Listing (Continued)

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UROCK=0.
USOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.          057270 0000
IF(DROCK.GE.DTRNCH) GO TO 60                  057280 0000
C COMPUTE THE EXCAVATED VOLUME IF CUT IS IN PART SOIL-PART ROCK 057290 0000
UROCK=BE*(DTRNCH-DROCK)/27.                   057300 0000
USOIL=(BE+DROCK*SIDESL)*DROCK/27.            057310 0000
057320 0000
60 IUTR-UROCK                                057330 0000
IUTS-USOIL                                 057340 0000
C -----
IF(NTSTYP.EQ.1) GO TO 70                      057350 0000
ISUPPT=A(N,26)                               057360 0000
GAMMA=A(N,22)                                057370 0000
PERM=ABS(A(N,25))                            057380 0000
IFLOWL=A(N,61)                                057390 0000
STABNO=A(N,30)                                057400 0000
IF(NTSTYP.EQ.3) GO TO 65                      057410 0000
057420 0000
C -----
C SOFT GROUND TUNNEL                         057430 0000
AIRPR=A(N,33)                                057440 0000
MSTAB=A(N,31)                                057450 0000
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 -----
C CUT AND COVER
65 UL =A(N,55)                                057520 0000
SIDESL=A(N,53)                               057530 0000
WELLS=A(N,68)                                057540 0000
DSLURY=0.0                                    057550 0000
057560 0000
SPDLT=0.0                                    057570 0000
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
UBACEX=TRDATA(NREACH,22)                       057630 0000
UBACDS=TRDATA(NREACH,23)                       057640 0000
U=A(N,51)                                    057650 0000
UBOX=A(N,54)                                 057660 0000
057670 0000
BACKFL=(UBACEX+UBACDS)*(U-UBOX)*1.1        057680 0000
C CHECK IF SEGMENT IN SAME REACH             057690 0000
C 70 IF(IPR.EQ.NREACH) GO TO 85              057700 0000
C -----
C CALCULATE CONSTRUCTION TIME FOR THE REACH (CTR)
NSEGS=TRDATA(NREACH,6)                         057710 0000
NSEGSA=IABS(NSEGS)                            057720 0000
057730 0000
HOURS=TRDATA(NREACH,8)                          057740 0000
057750 0000
DAYS=TRDATA(NREACH,9)                           057760 0000
CTR=0.0                                       057770 0000
ALOCK=0.0                                     057780 0000
ICTR=0                                         057790 0000
MEXP=0                                         057800 0000
SETUSH=0.0                                    057810 0000
SETUPM=0.0                                    057820 0000
SETUPR=0.0

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(Continued)

## COSTUN Listing (Continued)

```

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,?)         057890 0000
C 702 IF(MEX.GE.6) GO TO 705 057900 0000
    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 -----
C CUT AND COUER 058030 0000
C 705 ELWATR =A(NN,14) 058040 0000
    D10=A(NN,19) 058050 0000
    IWATER=A(NN,23) 058060 0000
    ELIMP=A(NN,24) 058070 0000
    PERM=A(NN,25) 058080 0000
    FLOWL=A(NN,61) 058090 0000
    NPLS=A(NN,17) 058100 0000
    NPRS=A(NN,18) 058110 0000
    DTRNCH=A(NN,52) 058120 0000
    ELROCK=A(NN,27) 058130 0000
    ELNPLS=CNP(NPLS,2) 058140 0000
    ELNPRS=CNP(NPRS,2) 058150 0000
C CALCULATE THE EXTRA CURING TIME FOR CIP CONCRETE 058160 0000
    IF(L.LT.0) GO TO 708 058170 0000
    MM>NN 058180 0000
    IF(NSEGS.GT.0) MM=N+NSEGSA-I 058190 0000
    LINING=A(MM,10) 058200 0000
    IF(LINING.EQ.1) GO TO 707 058210 0000
    CTR=CTR+CTTS 058220 0000
    GO TO 708 058230 0000
    707 TIMECR=30.-CTR 058240 0000
    IF(TIMECR.LT.0.) TIMECR=0. 058250 0000
    L=-1 058260 0000
    708 IF(D10.LE.0.005.OR.IWATER.EQ.0) GO TO 730 058270 0000
    IF(PERM.GT.0.0.AND.D10.GT.0.08) GO TO 709 058280 0000
    IF(PERM.LT.0.0.AND.ABS(PERM).GT.0.0006) GO TO 709 058290 0000
    TIMEDW=30. 058300 0000
    GO TO 730 058310 0000
    709 ELSURF=0.5*(ELNPLS+ELNPRS) 058320 0000
    DWATER=ELSURF-ELWATR 058330 0000
    DRAWDN=DTRNCH-DWATER 058340 0000
    DROCK=ELSURF-ELROCK 058350 0000
    PERM=ABS(PERM) 058360 0000
    IF(DROCK.LT.DTRNCH.AND.ISUPPT.EQ.5) GO TO 730 058370 0000
C CHECK IF WATER TABLE BELOW BASE OF CUT 058380 0000
    IF(DRAWDN.LE.0.) GO TO 730 058390 0000
                                                058400 0000

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(Continued)

COSTUN Listing (Continued)

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C      DIMP=ELSURF-ELIMP-DTRNCH          058410 0000
C      CHECK IF IMPERVIOUS LAYER ABOVE BASE OF CUT    058420 0000
C      IF(DIMP.GE.0.0) GO TO 710          058430 0000
C      DRAWDN=ELWATR-ELIMP          058440 0000
C      DIMP=0.0          058450 0000
C      710 HEADU=-7.* ALOG10(PERM)+1. )          058460 0000
C      CHECK IF VACUUM HEAD GREATER THAN 21 FEET    058470 0000
C      IF(HEADU.GT.21.) HEADU=21.0          058480 0000
C      CHECK IF VACUUM HEAD LESS THAN 0 FEET        058490 0000
C      IF(HEADU.LT.0.0) HEADU=0.0          058500 0000
C      HEAD=DRAWDN+HEADU+DIMP          058510 0000
C      PIPED=0.5*FLOWL**0.4          058520 0000
C      MINIMUM PIPE SIZE          058530 0000
C      IF(PIPED.LT.1.) PIPED=1.          058540 0000
C      DRAWDOWN TIME          058550 0000
C      EXPT=2.5*DRAWDN*ALOG10(240.* (HEAD-SQRT(HEAD*DIMP))/PIPED)/(DRAWDN 058560 0000
C      1+HEADU)/(0.73+0.27*(DRAWDN+HEADU)/HEAD)-5.0 058570 0000
C      TIMET=0.00267*PIPED**2*10.**EXPT/PERM/DRAWDN 058580 0000
C      CHECK FOR MAXIMUM SEGMENT DEWATERING TIME IN REACH 058590 0000
C      IF(TIMEDW.LT.TIMET) TIMEDW=TIMET          058600 0000
C      730 ICTR=ICTR+CTTS          058610 0000
C      ICTR=ICTR+14.*SETUSH+28.*SETUPM+7.*SETUPR+14.*ALOCK 058620 0000
C      -----
C      CHECK FOR CUT AND COVER REACH          058630 0000
NTSTYP=A(N,16)          058640 0000
IF(NTSTYP.EQ.3) GO TO 740          058650 0000
TRDATA(NREACH,10)=SETUSH          058660 0000
TRDATA(NREACH,11)=SETUPM          058670 0000
TRDATA(NREACH,12)=SETUPR          058680 0000
GO TO 750          058690 0000
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
058810 0000
C      -----
C      IF(NTSTYP.EQ.3) GO TO 80          058820 0000
C      ROCK OR SOFT GROUND TUNNEL          058830 0000
C      WRITE(LO,3001) NREACH,NTSEG,ISTA,ITENS,IHUNS,LSEGL,BFT,BE,BOB,AR, 058840 0000
C      1ARTULT,TL,IUTS,IUTR,IFL,IPH,ICTTS,ICTR,IPRML,HOURS,DAYS 058850 0000
C      IF(NTSTYP.EQ.1) GO TO 100          058860 0000

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(Continued)

## COSTUN Listing (Continued)

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C ----- 058870 0000
C SOFT GROUND TUNNEL 058880 0000
C IF(MSTAB.NE.1) GO TO 75 058890 0000
C AIR LOCK NODAL POINTS 058900 0000
C NPLOCK=A(N,36) 058910 0000
C STA=CNP(NPLOCK,1) 058920 0000
C ISTA=STA/100. 058930 0000
C ISTA2=STA-ISTA*100 058940 0000
C ITENS=ISTA2/10. 058950 0000
C IHUNS=ISTA2-ITENS*10 058960 0000
C IHUNS=IABS(IHUNS) 058970 0000
C WRITE(LO,3002) ISTA,ITENS,IHUNS,STABNO,STABIL,AIRPR,IFLOWL,GAMMA, 058980 0000
C 1PERM 058990 0000
C NLINES=NLINES+1 059000 0000
C GO TO 100 059010 0000
C AIR PRESSURE NOT USED 059020 0000
C 75 WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM 059030 0000
C NLINES=NLINES+1 059040 0000
C GO TO 100 059050 0000
C ----- 059060 0000
C CUT AND COVER 059070 0000
C 80 WRITE(LO,3004) NREACH,NTSEG,ISTA,ITENS,IHUNS,LSEGL,AR,ARTULT,IUTS, 059080 0000
C 1 IVTR,IPH,ICCTS,ICTR HOURS,DAYS 059090 0000
C IF(ISUPPT.EQ.5) SPDLT=A(N,38) 059100 0000
C IF(ISUPPT.EQ.6) DSLURY=A(N,38) 059110 0000
C WRITE(LO,3005) STABNO,STABIL,IFLOWL,GAMMA,PERM,UL,BE,SIDESL, 059120 0000
C 1DSLURY,SPDLT,BACKFL,OPEN 059130 0000
C NLINES=NLINES+1 059140 0000
C GO TO 100 059150 0000
C ----- 059160 0000
C THIS SEGMENT IN SAME REACH AS PREVIOUS SEGMENT 059170 0000
C 85 IF(LIST(4).EQ.1) GO TO 100 059180 0000
C WRITE(LO,2150) 059190 0000
C NLINES=NLINES+1 059200 0000
C ----- 059210 0000
C IF(NTSTYP.EQ.3) GO TO 95 059220 0000
C ROCK OR SOFT GROUND TUNNEL 059230 0000
C WRITE(LO,3011) NTSEG,ISTA,ITENS,IHUNS,LSEGL,BFT,BE,BOB,AR,ARTULT, 059240 0000
C 1TL,IUTS,IVTR,IFL,IPH,ICCTS 059250 0000
C IF(NTSTYP.EQ.1) GO TO 100 059260 0000
C ----- 059270 0000
C SOFT GROUND TUNNEL 059280 0000
C IF(MSTAB.NE.1) GO TO 90 059290 0000
C AIR LOCK NODAL POINTS 059300 0000
C NPLOCK=A(N,36) 059310 0000
C STA=CNP(NPLOCK,1) 059320 0000
C ISTA=STA/100. 059330 0000
C ISTA2=STA-ISTA*100 059340 0000
C ITENS=ISTA2/10. 059350 0000
C IHUNS=ISTA2-ITENS*10 059360 0000

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## COSTUN Listing (Continued)

```

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 -----
C CUT AND COVER 059460 0000
95 WRITE(LO,3014) NTSEG,ISTA,ITENS,IHUNS,LSEGL,AR,ARTULT,IUTS,IUTR, 059470 0000
1IPH,ICTTS 059480 0000
IF(ISUPPT.EQ.5) SPDLT=A(N,38) 059490 0000
IF(ISUPPT.EQ.6) DSLURY=A(N,38) 059500 0000
WRITE(LO,3015) STABNO,STABIL,IFLOWL,GAMMA,PERM,UL,BE,SIDESL, 059510 0000
1DSLURY,SPDLT,BACKFL 059520 0000
NLINES=NLINES+1 059530 0000
100 IPR=NREACH 059540 0000
IF(LIST(4).EQ.0) WRITE(LO,2222) 059550 0000
----- 059560 0000
C C OUTPUT CALCULATED SHAFT DATA 059570 0000
C
IF(LIST(5).EQ.1) GO TO 300 059580 0000
IPS=0 059590 0000
ITYPE=2 059600 0000
NLINES=40 059610 0000
DO 200 N=1,NSS 059620 0000
NLINES=NLINES+1 059630 0000
IF(NLINES.LT.40) GO TO 102 059640 0000
NLINES=0 059650 0000
NLINES=0 059660 0000
WRITE(LO,2000) 059670 0000
WRITE(LO,2010) 059680 0000
102 NSHAFT=B(N,1) 059690 0000
NSSEG=B(N,2) 059700 0000
BE=B(N,29) 059710 0000
BOB=B(N,32) 059720 0000
ARSULT=B(N,39) 059730 0000
IPRML=SHAFT(NSHAFT,10) 059740 0000
ICTSS=B(N,40) 059750 0000
IAADS=SHAFT(NSHAFT,9)*0.00003 059760 0000
LSEGL=B(N,35) 059770 0000
NPB=B(N,4) 059780 0000
IELNPB=CNP(NPB,2) 059790 0000
TL=B(N,11)*12. 059800 0000
AR=B(N,8) 059810 0000
NPORT=SHAFT(NSHAFT,23) 059820 0000
NSSTYP=B(N,15) 059830 0000
----- 059840 0000
C EXCAVATED VOLUMES 059850 0000
UROCK=0.0 059860 0000
USOIL=0.0 059870 0000
U=B(N,38) 059880 0000
IF(NSSTYP.EQ.1) UROCK=U 059890 0000
IF(NSSTYP.EQ.2) USOIL=U 059900 0000
IUSR=UROCK 059910 0000
IUSG=USOIL 059920 0000
----- 059930 0000
----- 059940 0000

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(Continued)

## COSTUN Listing (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,?) 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(ISSHAPS.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,?) 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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(Continued)

## COSTUN Listing (Continued)

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HOURS=SHAFT(NSHAFT,17)                               060530 0000
DAYS=SHAFT(NSHAFT,18)                               060540 0000
IF(NSTYP.EQ.3) GO TO 150                           060550 0000
WRITE(LO,2001) NSHAFT,NSSEG,ISTA,ITENS,IHUNS,IELNPB,LSEGL,BFS,BE,
1BOB,AR,ARSULT,TL,IUSS,IUSR,IADS,ICTSS,ICTS,IPRML,HOURS,DAYS 060560 0000
IF(NSTYP.EQ.1) GO TO 200                           060570 0000
060580 0000
----- 060590 0000
C   SOFT GROUND SHAFT                            060600 0000
C   IF(MSTAB.NE.1) GO TO 140                      060610 0000
C   COMPRESSED AIR USED                         060620 0000
C   WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM 060630 0000
NLINES=NLINE+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=NLINE+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,
1IADS,HOURS,DAYS                                060720 0000
WRITE(LO,2005) GAMMA,PERM                         060730 0000
NLINES=NLINE+1                                     060740 0000
GO TO 200                                         060750 0000
060760 0000
C   ----- 060770 0000
C   THIS SEGMENT IN SAME SHAFT AS PREVIOUS SEGMENT 060780 0000
160  WRITE(LO,2100)                               060790 0000
NLINES=NLINE+1                                     060800 0000
IF(NSTYP.EQ.3) GO TO 170                         060810 0000
WRITE(LO,2011) NSSEG,IELNPB,LSEGL,BFS,BE,BOB,AR,ARSULT,TL,IUSS,
1IUSR,ICTSS                                       060820 0000
IF(NSTYP.EQ.1) GO TO 200                         060830 0000
060840 0000
C   ----- 060850 0000
C   SOFT GROUND SHAFT                            060860 0000
C   IF(MSTAB.NE.1) GO TO 165                      060870 0000
C   COMPRESSED AIR USED                         060880 0000
C   WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM 060890 0000
NLINES=NLINE+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=NLINE+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=NLINE+1                                     061000 0000
200  IPS=MSHAFT                                 061010 0000
WRITE(LO,2222)                                    061020 0000
C   ----- 061030 0000
C   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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## COSTUN Listing (Continued)

C  
 \*\*\*\*\*  
 1020 FORMAT(/, 35H FATAL ERROR, HAUL SLOPE IN SEGMENT', I5, 9H IN REACH,  
 1 15, 42H EXCEEDS 5 PERCENT --TOO STEEP FOR A TRAIN) 061110 0000  
 061120 0000  
 061130 0000  
 061140 0000  
 1021 FORMAT(/, ' FATAL ERROR, EXCAVATED DIMENSION IN SEGMENT', I5, ' IN  
 1REACH', I5, ' IS TOO SMALL FOR A TRUCK, USE TRAIN OR CONVEYOR') 061150 0000  
 061160 0000  
 1022 FORMAT(//, 1X, 100(1H\*), /, 10X, ' EXECUTION HALTED AFTER SUBROUTINE  
 1 CALCS DUE TO ERRORS', /, 1X, 100(1H\*)) 061170 0000  
 061180 0000  
 1023 FORMAT(/, ' FATAL ERROR, SLOPE OF SEGMENT', I5, ' IN REACH', I5,  
 1 ' EXCEEDS 26 PERCENT --TOO STEEP FOR MUCK TRANSPORT METHODS CON  
 2SIDERED') 061190 0000  
 061200 0000  
 061210 0000  
 1025 FORMAT(/, ' FATAL ERROR, ALL TRUCK MUCK TRANSPORT IS SPECIFIED IN  
 1 SEGMENT', I5, ' IN REACH', I5, ' IN WHICH COMPRESSED AIR IS USED') 061220 0000  
 061230 0000  
 1030 FORMAT(/, \*\*\* REMINDER \*\*\* USE OF COMPRESSED AIR IN SEGMENT'  
 1I5, ' IN REACH', I5, ' REQUIRES USE OF CONVEYOR-TRUCK TRANSPORT MÉT  
 2HOD RATHER', /20X, ' THAN INPUT METHOD') 061240 0000  
 061250 0000  
 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 ',  
 146(1H\*)//, ' SHAFT SEG STATION ELEV AT LENGTH \*SHAFT DIMENSIONS\* \*  
 2\*ADVANCE RATES\*\* LINING \*EXCAV VOLUME\* SIZE OF CONSTRUCTION RML-  
 3 HOURS DAYS', /12X, 'ALONG BOTTOM (FT) FINISH EXCAV EXCAV AVER  
 4AGE UNIFORM THICK SOIL ROCK DISPOSAL TIME (DAYS) MAX PER  
 5 PER', /12X, 'TUNNEL OF SEG (FT) (FT) W/O.B. USED  
 6 (IN) (CY/FT)(CY/FT) AREA SEG SHAFT (CY/ DAY WEEK  
 7', /12X, 'ALIGN.', 36X, '(FT/DAY) (FT/DAY)', 24X, '(ACRES)', 16X, '(HR)') 061270 0000  
 061280 0000  
 061290 0000  
 061300 0000  
 061310 0000  
 061320 0000  
 061330 0000  
 061340 0000  
 2001 FORMAT(1X, I4, I5, I6, 1H+, 2I1, I7, I8, F7.2, 2F6.2, 2F8.1, F9.2, 2I7, 2I8,  
 12I6, 2F6.1) 061350 0000  
 061360 0000  
 2002 FORMAT(2I1, F5.1, 2X, A6, 6X, I9, 1X, F11.1, E9.2) 061370 0000  
 2003 FORMAT(2I1, 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 )/2I1, '\*\*\*STABILIZATION\*\*\* DEWATERING \*SOIL  
 1 PROPERTIES\*', /2I1, 'NUMBER MÉTHOD AIRPR (GPM/WELL) UNIT WT PER  
 2M', /35X, '(PSI)', 16X, '(PCF) (CM/SEC)') 061410 0000  
 061420 0000  
 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  
 1DUMMY', 22X, I8) 061470 0000  
 061480 0000  
 2200 FORMAT(1X, 131(1H-)/1X, I4, 5X, I6, 1H+, 2I1, I7, 22X, ' THIS SHAFT IS A  
 1PORTAL', 21X, I8) 061490 0000  
 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  
 2CE RATES\*\* LINING \*EXCAV VOLUME\* PUMP PUMP CONSTRUCTION RML-  
 3HOURS DAYS', /12X, 'AT LEFT LENGTH FINISH EXCAV EXCAV AVERAGE UNIF  
 4ORM THICK SOIL ROCK FLOW HEIGHT TIME (DAYS) MAX PER P 061530 0000  
 5ER', /12X, 'OF SEG (FT) (FT) W/O.B. USED (I 061540 0000  
 6N) (CY/FT)(CY/FT) RATE (FT) SEG REACH (CY/ DAY WEEK', /40X 061550 0000  
 7, '(FT) (FT/DAY) (FT/DAY)', 25X, '(GPM)', 22X, '(HR)') 061560 0000  
 061570 0000  
 061580 0000  
 061590 0000  
 3001 FORMAT(1X, I4, I5, I6, 1H+, 2I1, I6, 2F7.2, F6.2, F8.1, F9.1, F9.2, 2I7, I8, I7,  
 13I6, 2F6.1) 061600 0000  
 061610 0000  
 3002 FORMAT(1I1X, 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,  
 12F6.1) 061630 0000  
 061640 0000  
 3005 FORMAT(2I1X, F5.1, 2X, A6, 6X, I9, 1X, F11.1, E9.2, F8.1, F8.2, F6.2, 2F7.1,  
 1F8.0, T114, ' F8.0, T122, ') 061650 0000  
 061660 0000  
 3010 FORMAT( 33(2H--, 2H )/12X, 'AIRLOCK \*\*\*STABILIZATION\*\*\* DEWATER  
 1ING \*SOIL PROPERTIES\* CONCRETE \*CUT AND COVER SEGMENT PROPERTIES\* 061670 0000  
 061680 0000

(Continued)

## COSTUN Listing (Continued)

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2 REACH'/12X,'STATION NUMBER METHOD AIRPR (GPM/WELL) UNIT WT 061690 0000
3 PERM BOX BASE SIDE & SUPPORT LENGTH* BACKFL OPEN'/12X, 061700 0000
4'6Q 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
3811 FORMAT(5X,I5,I6,1H+,2I1,I6,2F7.2,F6.2,F8.1,F9.1,F9.2,2I7,I8,I7,I6) 061740 0000
3814 FORMAT(5X,I5,I6,1H+,2I1,I6,20X,F8.1,F9.1,9X,2I7,8X,I7,I6) 061750 0000
3815 FORMAT(21X,F6.1,2X,A6,6X,I9,1X,F11.1,E9.2,F8.1,F9.2,F6.2,2F7.1,
1F8.0,T14,'') 061760 0000
1 061770 0000
C *****XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX***** 061780 0000
C 061790 0000
C 061800 0000
C RETURN 061805
C END 061810 0000
C SUBROUTINE SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE) 061820 0000
C ----- 061830 0000
C THIS SUBROUTINE COMPUTES THE NUMBER OF SETUP FOR SHIELD, MOLE,
C AND RIPPER EXCAVATION 061840 0000
C ----- 061850 0000
C ----- 061860 0000
C IF(ITYPE.EQ.2) GO TO 500 061870 0000
C TUNNEL 061880 0000
C IF(MEX.LE.1.OR.MEX.GE.>1`~/~E10 600 061890 0000
C IF(MEX.LT.3) GO TO 100 061900 0000
C SHIELD SETUP 061910 0000
C IF(SETUSH.GE.1..AND.(MEXP.LT.3.OR.MEXP.GE.6)) SETUSH=SETUSH+0.25 061920 0000
C 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
C IF (SETUPM.GE.1.) GO TO 150 061970 0000
C FIRST MOLE SETUP 061980 0000
C SETUPM=1. 061990 0000
C GO TO 600 062000 0000
150 IF(MEXP.EQ.2.OR.MEXP.EQ.3) GO TO 200 062010 0000
C RESETUP 062020 0000
C SETUPM=SETUPM+0.25 062030 0000
C GO TO 600 062040 0000
C CHANGE CUTTER 062050 0000
200 IF(MEXP.NE.MEX) SETUPM=SETUPM+0.125 062060 0000
C GO TO 600 062070 0000
C RIPPER SETUP 062080 0000
400 IF(MEX.EQ.4) GO TO 600 062090 0000
C RESETUP 062100 0000
C IF(MEXP.NE.5.AND.SETUPR.GE.1.) SETUPR=SETUPR+0.25 062110 0000
C IF(SETUPR.LT.1.) SETUPR=1. 062120 0000
C 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
C IF(MEX.GE.3.AND.SETUSH.LT.1.) SETUSH=1. 062180 0000
C IF(MEX.EQ.4) GO TO 600 062190 0000
C IF(SETUPM.LT.1.) GO TO 550 062200 0000
C CHANGE CUTTER 062210 0000
C IF(MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+0.125 062220 0000
C GO TO 600 062230 0000
C FIRST SETUP 062240 0000
550 SETUPM=1. 062250 0000

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(Continued)

## COSTUN Listing (Continued)

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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,
1NTRMAX,MSSMAX)        062290 0000
                                         062295
C   COSTTU COLLECTS ALL OF THE TUNNEL COSTS AND OUTPUTS THEM      062300 0000
----- 062310 0000
COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE           062330 0000
COMMON/G/ TUNLC,TUNECC,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
                                         062380 0000
C   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,TSCP,TSCE                                     062410 0000
INTEGER RCL,RCE,RCM,RCT                                     062420 0000
INTEGER TUNLC,TUNECC,TUNMC,TUNTC                           062430 0000
                                         062440 0000
C   CALCULATE TUNNEL COSTS A REACH AT A TIME                  062450 0000
ITYPE=1                                                 062460 0000
C   062470 0000
TUNLC=0                                                 062480 0000
TUNECC=0                                              062490 0000
TUNMC=0                                              062500 0000
TUNTC=0                                              062510 0000
                                         062520 0000
C   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
MTM=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(ISSHAPE.EQ.1) SFA=0.785                                062690 0000
IF(ISSHAPE.EQ.1) SFP=3.14                                 062700 0000
IF(ISSHAPE.EQ.2) SFA=0.893                                062710 0000
IF(ISSHAPE.EQ.2) SFP=3.57                                062720 0000
IF(ISSHAPE.EQ.3) SFA=0.425                                062730 0000
IF(ISSHAPE.EQ.3) SFP=2.66                                062740 0000
                                         062750 0000
C   NBOX =TRDATA(NREACH,10)                                    062760 0000
BFBWDT =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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(Continued)

## COSTUN Listing (Continued)

```

UDS =TRDATA(NREACH,21)          062820 0000
UBACEX=TRDATA(NREACH,22)          062830 0000
UBACDS=TRDATA(NREACH,23)          062840 0000
C
NPBS=SHAFT(NSHAFT,3)            062850 0000
DDS=SHAFT(NSHAFT,5)              062860 0000
CDS=SHAFT(NSHAFT,6)              062870 0000
HH=SHAFT(NSHAFT,8)              062880 0000
NSEGSA=IABS(NSEGS)               062890 0000
C
----- 062900 0000
NPBS=SHAFT(NSHAFT,3)            062910 0000
DDS=SHAFT(NSHAFT,5)              062920 0000
CDS=SHAFT(NSHAFT,6)              062930 0000
HH=SHAFT(NSHAFT,8)              062940 0000
NSEGSA=IABS(NSEGS)               062950 0000
C
----- 062960 0000
DETERMINE NUMBER OF SHIFTS IN A WORK DAY
SHIFTS=1.                         062970 0000
IF(HOURS.GE.12.) SHIFTS=2.          062980 0000
IF(HOURS.GE.21.) SHIFTS=3.          062990 0000
C
CALCULATE COST FACTORS FOR LENGTH OF WORK WEEK
IF(HOURS/SHIFTS.LE.8.) CFLUWK=(6.08+0.192*(DAYS-4.))**2 063000 0000
1 +0.384*SHIFTS)*SHIFTS/HOURS   063010 0000
IF(HOURS/SHIFTS.GT.8.) CFLUWK=(0.76+0.024*(DAYS-4.))**2 063020 0000
1 +0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS)                   063030 0000
CFEWWK=(3.75+30./HOURS)/DAYS      063040 0000
C
----- 063050 0000
ALOCK=1.0                          063060 0000
CLIND=0.                            063070 0000
UCMCP=0.                            063080 0000
IF(Ishape.EQ.0.OR.DTCA.EQ.0.) GO TO 5 063090 0000
C
CALCULATE COST OF INSTALLATION OF CONVEYOR IN FREE AIR FOR
CONVEYOR+TRUCK TRANSPORT, AND COST OF COMPRESSED AIR PIPING
CALL CUINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1, 063100 0000
1 CLIND,UCMCP,NTSMAX,NPMMAX)        063110 0000
C
----- 063120 0000
CALCULATE NUMBER OF AIR LOCK LOCATIONS AND LENGTH OF LOCK
CALL LOCKLT(A,NSEGS,RMLMAX,MTM,ALOCK,ALOCKL,NTSMAX,NRSEG1) 063130 0000
C
----- 063140 0000
5 RL=0.0
DO 10 IJ=1,NSEGSA                 063150 0000
IF(NSEGSA.GT.0) I=NRSEG1+IJ-1       063160 0000
IF(NSEGSA.LT.0) I=NRSEG1-IJ+1       063170 0000
TSEGL=A(I,45)                      063180 0000
10 RL=RL+TSEGL                     063190 0000
C
----- 063200 0000
RCL=0.                             063210 0000
RCE=0.                             063220 0000
RCM=0.                             063230 0000
RCT=0.                             063240 0000
NLINES=60                           063250 0000
063260 0000
C
----- 063270 0000
CALCULATE TUNNEL COSTS FOR EACH SEGMENT
063280 0000
C
----- 063290 0000
063300 0000
DO 900 IS=1,NSEGSA                 063310 0000
I=SEQUENCE NUMBER OF TUNNEL SEGMENT
I=NRSEG1+IS-1                      063320 0000
NPS=A(I,17)                         063330 0000
IF(NSEGSA.GT.0) GO TO 110           063340 0000
I=NRSEG1-IS+1                      063350 0000
NPS=A(I,18)                         063360 0000
110 NPL =A(I,2)                      063370 0000
NPR =A(I,3)                         063380 0000
063390 0000

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(Continued)

**COSTUN Listing (Continued)**

```

C   ELNPL =CNP(NPL,2)          0E3400 0000
C   ELNPR =CNP(NPR,2)          0E3410 0000
C   ELAUG =0.5*(ELNPL+ELNPR)  0E3420 0000
C   RS=A(I,5)                  0E3430 0000
C   RQD=A(I,6)                  0E3440 0000
C   MEX=A(I,7)                  0E3450 0000
C   AR=A(I,8)                  0E3460 0000
C   GI=A(I,9)                  0E3470 0000
C   THE VARIABLE FOR LINING TYPE IS CALLED L1(ONE)M1(ONE)NG IN THIS
C   SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING
C   WHICH COMPUTES LINING COSTS
C   LINING=A(I,10)              0E3500 0000
C   TL =A(I,11)                  0E3510 0000
C   TSEG =A(I,11)                0E3520 0000
C   NOFORM=A(I,13)              0E3530 0000
C   ELWATR=A(I,14)              0E3540 0000
C   LINUT =A(I,15)              0E3550 0000
C   NTSTYP=A(I,16)              0E3560 0000
C   IF(NTSTYP.EQ.1) GO TO 115   0E3570 0000
C   NPLS =A(I,17)              0E3580 0000
C   NPRS =A(I,18)              0E3590 0000
C   CALCULATE AVERAGE SURFACE ELEVATION
C   ELNPLS=CNP(NPLS,2)          0E3600 0000
C   ELNPRS=CNP(NPRS,2)          0E3610 0000
C   ELSURF=0.5*(ELNPLS+ELNPRS)  0E3620 0000
C   DEPTH OF TUNNEL
C   DTUN=ELSURF-ELAUG          0E3630 0000
C   CALCULATE DEPTH OF ROCK SURFACE
C   ELROCK=A(I,27)              0E3640 0000
C   DROCK=ELSURF-ELROCK        0E3650 0000
C
C   115 ELBOTM=ELAUG-0.5*BE
C   IF(IISHAPE.EQ.3) ELBOTM=ELAUG-0.25*BE
C
C   D10 =A(I,19)                0E3660 0000
C   PHI =A(I,20)                0E3670 0000
C   PERM=A(I,25)                0E3680 0000
C   ISUPPT=A(I,26)              0E3690 0000
C   IBRACE=A(I,28)              0E3700 0000
C   IDECK=A(I,29)              0E3710 0000
C   STABNO=A(I,30)              0E3720 0000
C   MSTAB=A(I,31)              0E3730 0000
C   AIRPR=A(I,33)              0E3740 0000
C   CAUT =A(I,35)              0E3750 0000
C   GT =A(I,37)                 0E3760 0000
C   Q =A(I,38)                  0E3770 0000
C   BE =A(I,39)                  0E3780 0000
C   BE40 =A(I,40)                0E3790 0000
C   BE60 =A(I,41)                0E3800 0000

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(Continued)

## COSTUN Listing (Continued)

```

BOB =A(I,42) 063900 0000
BOB40 =A(I,43) 063910 0000
BOB60 =A(I,44) 063920 0000
C 063930 0000
TSEQL =A(I,45) 063940 0000
DM =A(I,46) 063950 0000
HSLOPE=A(I,47) 063960 0000
RML =A(I,48) 063970 0000
U =A(I,51) 063980 0000
C 063990 0000
TOTBOX=A(I,43) 064000 0000
DTRNCH=A(I,52) 064010 0000
SIDESL=A(I,53) 064020 0000
UBOX =A(I,54) 064030 0000
UL =A(I,55) 064040 0000
FORMAR=A(I,56) 064050 0000
C 064060 0000
PH =A(I,57) 064070 0000
PIPL =A(I,58) 064080 0000
FLOW =A(I,59) 064090 0000
GIR =A(I,60) 064100 0000
FLOWL =A(I,61) 064110 0000
C 064120 0000
WEB =A(I,62) 064130 0000
TPLATE=A(I,62) 064140 0000
WTWALE=A(I,63) 064150 0000
WTSTRT=A(I,64) 064160 0000
WTANCH=A(I,65) 064170 0000
WTSP =A(I,66) 064180 0000
WTSPD =A(I,67) 064190 0000
C 064200 0000
WELLS =A(I,68) 064210 0000
SPDLT =A(I,38) 064220 0000
DSLURY=A(I,38) 064230 0000
PSOIL =A(I,63) 064240 0000
PWATER=A(I,64) 064250 0000
PTOTAL=A(I,65) 064260 0000
IWATER=A(I,23) 064270 0000
C 064280 0000
----- LABOR COST FACTOR IN COMPRESSED AIR 064290 0000
CFLCA=AIRPR**2/400.+1.5 064300 0000
C IF(NTSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1. 064310 0000
C COST FACTOR FOR TRAVEL TIME TO THE FACE 064320 0000
Y=0.3*SHIFTS*(0.76+0.024*(DAYS-4.)*2+0.048*SHIFTS) 064330 0000
IF(HOURS/SHIFTS.LT.8.) Y=Y*5.*((HOURS/SHIFTS+0.2*DM-8.)/DM 064340 0000
IF(Y.LT.0.) Y=0. 064350 0000
IF(NTSTYP.EQ.3) Y=0. 064360 0000
C 064370 0000
CLES=0. 064380 0000
CEES=0. 064390 0000
CMES=0. 064400 0000
CLAC=0. 064410 0000
CEAC=0. 064420 0000
CMAC=0. 064430 0000
IF(NTSTYP.EQ.3) GO TO 750 064440 0000
IF(MSTAB.NE.1) GO TO 750 064450 0000
IF(IS.NE.1) GO TO 700 064460 0000
DLOCK=0. 064470 0000

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(Continued)

## COSTUN Listing (Continued)

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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)-ELAUG)/(DM*5280.-DLOCK) 064590 0000
C   -----
C   CALCULATE SETUP COST FOR TUNNEL SEGMENT I          064600 0000
  750 CALL CSETPU(A,B,NSEGS,MRSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,SETUPR, 064610 0000
    1 CLES,CEES,CMES,CFLWWK,CFEWWK,NTSTYP,DSES,DMES,NTSMAX,NSSMAX) 064620 0000
C   -----
C   CALCULATE COST OF EXCAVATION IN TUNNEL SEGMENT I    064630 0000
    CALL COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPE,SFA,SFP, 064640 0000
    1 PSOIL,STABNO,DTRNCH,DRACK,SIDESL,UBOX,UZOIL,UROCK,PHI, 064650 0000
    2 DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLWWK,CFEWWK,NTSTYP) 064660 0000
C   -----
C   CALCULATE COST OF MUCK LOADING IN TUNNEL SEGMENT I  064670 0000
    CALL CMUKLD(CLML,CEML,CMMML,ITYPE,MEX,AR,DM,U,Y,RML,RMLMAX, 064680 0000
    1 MSTAB,CFLCA,CFLWWK,CFEWWK,HOURS) 064690 0000
C   -----
C   CALCULATE MUCK TRANSPORTATION AND HOISTING COSTS FOR 064700 0000
TUNNEL SEGMENT I                      064710 0000
    CALL CMTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR, 064720 0000
    1 HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPE,RL,UCLT,UCET,Y,UCLMH, 064730 0000
    2 HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,UBACEX,UBACDS,UBOX, 064740 0000
    3 UZOIL,UROCK,TOTBOX,CFLWWK,CFEWWK,CFLCA,DDS,NTSTYP,DTRNCH,DRACK) 064750 0000
C   -----
C   CALCULATE MUCK DISPOSAL COST FOR TUNNEL SEGMENT I    064760 0000
    CALL CMUKDP(CLMD,CEMD,CMMMD,AR,U,CDS,DDS,UDS,NTSTYP,HOURS, 064770 0000
    1 CFLWWK,CFEWWK,ITYPE) 064780 0000
C   -----
C   CALCULATE COST OF TUNNEL SUPPORTS FOR TUNNEL SEGMENT I 064790 0000
    IF(LINING.EQ.4.AND.NTSTYP.EQ.1)GO TO 1900          064800 0000
    IF(LINING.NE.4.OR.NTSTYP.NE.1)GO TO 2000          064810 0000
  1900 CALL ROCK(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60, 064820 0000
    1 ITYPE,Y,NTSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL, 064830 0000
    2 BOB,LINUT,MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,SFA,LINING,DM, 064840 0000
    3 CLL,CEL,CML,CLFW,CEFV,CMFW) 064850 0000
    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,LINUT, 064870 0000
    2 MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,DSLURY,DTRNCH,IDECK,DRACK, 064880 0000
    3 WTSTRF,WTWALE,SPDLT,WTSPD,WTSP,WTANCH,TOTBOX,IBRACE,SFA) 064890 0000
C   -----
C   CALCULATE COST OF LINING AND FORMWORK IN TUNNEL SEGMENT I 064900 0000
    CALL LINING1(CLL,CEL,CML,CLFW,CEFV,CMFW,ITYPE,LINING,RQD,MEX, 064910 0000
    1 WEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPE,BE,UCLT,UCET,MTM, 064920 0000
    2 UCLMH,UCEMH,SFA,NOFORM,AR,NTSTYP,PSOIL,PWATER,UL,SFP, 064930 0000
    3 FORMAR,HOURS,CFLCA,CFLWWK,CFEWWK) 064940 0000
  2500 CONTINUE
C   ----- 064950 0000
C   ----- 064960 0000

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(Continued)

## COSTUN Listing (Continued)

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C   CALCULATE GROUTING COSTS FOR TUNNEL SEGMENT I          064970 0000
C   CALL CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPE,BE,AR,RS,NTSTYP,MSTAB,    064980 0000
C   1      DTUN,HH,HOURS,CFLWWK,CFEWWK,SSEG1,PERM,SFP,DTG,TIMEG)    064990 0000
C   -----
C   CALCULATE COST OF PUMPING FOR TUNNEL SEGMENT I          065000 0000
C   CALL CPUMP(CLIP,CEP,CMP,NTSTYP,FLOW,PH,PIPL,AR,ITYPE,    065010 0000
C   1      ELSURF,ELBOTM,DAYS,LIN1NG,PUMPTM,MEX,DTRNCH,DRCK,FLOWL,    065020 0000
C   2      WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPB,IWATER,CFLWWK,CFEWWK)    065030 0000
C   -----
C   CALCULATE COST OF AIR CONDITIONING AND COMPRESSED AIR FOR TUNNEL 065040 0000
C   SEGMENT I                                              065050 0000
C   CALL CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NTSTYP,MSTAB,ITYPE,    065060 0000
C   1      AIRPR,SFA,ISHAPE,HH,CAUT,ALOCK,DTC,DTCA,PUMPLT,DM,    065070 0000
C   2      ALOCKL,UCMCP,CFLWWK,CFEWWK,DAYS,Y,PERM)    065080 0000
C   -----
C   IF(ILIST(6).EQ.1) GO TO 810                           065090 0000
C   IF(NLINES+10.LT.60) GO TO 810                           065100 0000
C   WRITE(LO,1000)                                         065110 0000
C   NLINES=6                                              065120 0000
C   -----
C   CALCULATE COST FACTORS                               065130 0000
C   810 POP=(1.+0.01*OM)*(1.+0.01*PM)                  065140 0000
C   CF(1),CF(2) AND CF(3) ARE COMPOSITE COST FACTORS FOR L, E, AND M. 065150 0000
C   CFL-SHAFT(NSHAFT,12)                                065160 0000
C   CFE-SHAFT(NSHAFT,13)                                065170 0000
C   CFM-SHAFT(NSHAFT,14)                                065180 0000
C   RCF-SHAFT(NSHAFT,15)                                065190 0000
C   CF(1)=POP*CFL*RCF                                 065200 0000
C   CF(2)=POP*CFE*RCF                                 065210 0000
C   CF(3)=POP*CFM*RCF                                 065220 0000
C   -----
C   MULTIPLY BY COMPOSITE COST FACTORS AND THEN OBTAIN SEGMENT 065230 0000
C   COSTS PER FOOT TO THE NEAREST DOLLAR                065240 0000
C   IL( 1)=CLES*CF(1)+.5                                065250 0000
C   IE( 1)=CEES*CF(2)+.5                                065260 0000
C   IM( 1)=CMES*CF(3)+.5                                065270 0000
C   IL( 2)=CLE *CF(1)+.5                                065280 0000
C   IE( 2)=CEE *CF(2)+.5                                065290 0000
C   IM( 2)=CME *CF(3)+.5                                065300 0000
C   IL( 3)=CLML*CF(1)+.5                                065310 0000
C   IE( 3)=CEML*CF(2)+.5                                065320 0000
C   IM( 3)=CMML*CF(3)+.5                                065330 0000
C   IL( 4)=CLMT*CF(1)+.5                                065340 0000
C   IE( 4)=CEMT*CF(2)+.5                                065350 0000
C   IM( 4)=CMMT*CF(3)+.5                                065360 0000
C   IL( 5)=CLMH*CF(1)+.5                                065370 0000
C   IE( 5)=CEMH*CF(2)+.5                                065380 0000
C   IM( 5)=CMMH*CF(3)+.5                                065390 0000
C   IL( 6)=CLMD*CF(1)+.5                                065400 0000
C   IE( 6)=CEMD*CF(2)+.5                                065410 0000
C   IM( 6)=CMMD*CF(3)+.5                                065420 0000
C   IL( 7)=CLTS*CF(1)+.5                                065430 0000
C   IE( 7)=CETS*CF(2)+.5                                065440 0000
C   IM( 7)=CMTS*CF(3)+.5                                065450 0000
C   IL( 8)=CLL *CF(1)+.5                                065460 0000
C   -----

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(Continued)

## COSTUN Listing (Continued)

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IE( 8)=CEL *CF(2)+.5          065550 0000
IM( 8)=CML *CF(3)+.5          065560 0000
IL( 8)=CLFW*CF(1)+.5          065570 0000
IE( 9)=CEFUX*CF(2)+.5         065580 0000
IM( 9)=CMFW*CF(3)+.5          065590 0000
IL(10)=CLG *CF(1)+.5          065600 0000
IE(10)=CEQ *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
----- 065690 0000
C 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
----- 065790 0000
C 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
----- 065930 0000
C C CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS 065940 0000
TLC = SLCPF*TSEG/1000.          065950 0000
TEC = SECPF*TSEG/1000.          065960 0000
TMC = SMCPF*TSEG/1000.          065970 0000
TSC = TLC+TEC+TMC              065980 0000
----- 065990 0000
C IF(LIST(6).EQ.1) GO TO 840   066000 0000
C WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL 066010 0000
ITSEG=1
NTSEG=A(I,1)                   066020 0000
WRITE(LO,1001) NREACH,NTSEG,(IL(JJJ),JJJ=1,12),SLCPF,TLC 066030 0000
WRITE(LO,1002)                 (IE(JJJ),JJJ=1,12),SECPF,TEC 066040 0000
WRITE(LO,1003)                 (IM(JJJ),JJJ=1,12),SMCPF,TMC 066050 0000
WRITE(LO,1004) TCES,TCE,TCML,TCMT,TCMH,TCMD,TCTS,TCL,TCFW, 066060 0000
1TCG,TCP,TCAC,TSCPF,ITSEG,L TSC 066070 0000
C NLINES=NLINES+5               066080 0000
C ACCUMULATE TUNNEL SEGMENT COSTS INTO COST OF REACH 066090 0000
----- 066100 0000
C                                         066110 0000
----- 066120 0000

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(Continued)

## COSTUN Listing (Continued)

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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 -----
C LIST OUT REACH COSTS      066190 0000
850 IF(LIST(6).EQ.1) GO TO 860      066200 0000
  WRITE(LO,1007) SHAFT(NSHAFT,12),RCL, SHAFT(NSHAFT,15),
  1 SHAFT(NSHAFT,13),RCE,SHAFT(NSHAFT,14),RCM,CFLWK,RCT,CFEWK      066210 0000
  NLLINES=NLLINES+7      066220 0000
C -----
C ACCUMULATE COSTS OF ALL REACHES      066230 0000
860 TUNLC=TUNLC+RCL      066240 0000
TUNECC=TUNECC+RCE      066250 0000
TUNMC=TUNMC+RCM      066260 0000
TUNTC=TUNTC+RCT      066270 0000
C -----
C TRDATA(NREACH,17)=RCL      066280 0000
TRDATA(NREACH,18)=RCE      066290 0000
TRDATA(NREACH,19)=RCM      066300 0000
TRDATA(NREACH,20)=RCT      066310 0000
C END OF COSTS ON A REACH BASIS      066320 0000
950 CONTINUE           066330 0000
RETURN                066340 0000
C -----
C -----
1000 FORMAT(1H1,47(1H*),27H T U N N E L C O S T S ,46(1H*)//,
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
60RM 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,
  1 10H -- LABOR ,F5.2,5X,31HTOTAL REACH LABOR COST .....,I9/      066550 0000
  2 9X,9HFACTOR ,F5.2,26X,10HEQUIPMENT ,F5.2,5X,
  3 31HTOTAL REACH EQUIPMENT COST .....,I9/      066560 0000
  4 49X,10HMATERIALS ,F5.2,5X,31HTOTAL REACH MATERIALS COST .....,I9/      066570 0000
  5 43X,16HLABOR WORK WEEK ,F5.2,5X,
  6 31HTOTAL REACH COST .....,I9/      066580 0000
  7 43X,16HEQUIP WORK WEEK ,F5.2)      066590 0000
C -----
C END
SUBROUTINE COSTSF(B,CNP,SHAFT,TRDATA,NSSMAX,NPMAX,NSMAX,NTRMAX,
1NTSMAX)      066600 0000
C ----- 066610 0000
C ----- 066620 0000
C ----- 066630 0000
C ----- 066640 0000
C ----- 066650 0000
C ----- 066660 0000
C ----- 066670 0000

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(Continued)

## COSTUN Listing (Continued)

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C-----066580 0000
CC COSTSF COLLECTS ALL OF THE SHAFT COSTS AND OUTPUTS THEM 066590 0000
CC-----066700 0000
C-----066710 0000
C-----066720 0000
C-----066740 0000
C-----066750 0000
C-----066760 0000
1 23) 066770 0000
C-----066780 0000
C-----066790 0000
1 INTEGER SLCPF, SECpf, SMCPF, TLC, TEC, TMC 066800 0000
1 INTEGER TCES, TCE, TCML, TCMM, TCMD, TCts, TCL, TCFW, TCP, TCAC, 066810 0000
1 TCG, TSCPf, TSC 066820 0000
1 INTEGER SCL, SCE, SCM, SCT 066830 0000
1 INTEGER TUNLC, TUNEc, TUNMC, TUNTC 066840 0000
1 INTEGER SFTTLC, SFTTEC, SFTTMC, SFTTC 066850 0000
1 INTEGER TLABOR, TEQUIP, TMATER, TCOST 066860 0000
1 INTEGER RCL, RCe, RCM, RCT 066870 0000
C-----066880 0000
C-----066890 0000
1 Y=0.0 066900 0000
1 ITYPE=2 066910 0000
C-----066920 0000
C-----066930 0000
SFTTLC=0 066940 0000
SFTTEC=0 066950 0000
SFTTMC=0 066960 0000
SFTTC=0 066970 0000
DO 950 NSHAFT=1,NSMAX 066980 0000
IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 950 066990 0000
BF=SHAFT(NSHAFT,7) 067000 0000
NSEG1=SHAFT(NSHAFT,1) 067010 0000
NSEGS=SHAFT(NSHAFT,4) 067020 0000
RMLMAX=SHAFT(NSHAFT,10) 067030 0000
DDS=SHAFT(NSHAFT,5) 067040 0000
CDS=SHAFT(NSHAFT,6) 067050 0000
C-----067060 0000
ISHAPS=SHAFT(NSHAFT,16) 067070 0000
HOURS =SHAFT(NSHAFT,17) 067080 0000
DAYS =SHAFT(NSHAFT,18) 067090 0000
NPORT =SHAFT(NSHAFT,23) 067100 0000
SFA=0.785 067110 0000
SFP=3.14 067120 0000
IF(ISHAPS.EQ.2) SFA=1.0 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-----067180 0000
C-----067190 0000
1 CALCULATE COST FACTOR FOR LENGTH OF WORK WEEK 067200 0000
1 IF(HOURS/SHIFTS.LE.8.) CFLWWK=(6.08+0.192*(DAYS-4.))**2 067210 0000
1 +0.384*SHIFTS)*SHIFTS/HOURS 067220 0000
1 IF(HOURS/SHIFTS.GT.8.) CFLWWK=(0.76+0.024*(DAYS-4.))**2 067230 0000
1 +0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS) 067240 0000
1 CFEWK=(3.75+30./HOURS)/DAYS 067250 0000
C-----067260 0000
C-----067250 0000
C-----067260 0000
C-----067250 0000
C-----067260 0000

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(Continued)

## COSTUN Listing (Continued)

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DTP=0.
DO 10 MN=1,NSEGS
II=NSSEG1+NN-1
MSTAB=B(II,25)
SSEGL =B(II,35)
HH   =B(II,36)
FLOUL=B(II,42)
IF(FLOUL.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.
NLINE5=60
C CALCULATE SHAFT COSTS FOR EACH SEGMENT
C
DO 900 ISS=1,NSEGS
C I=SEQUENCE NUMBER OF SHAFT SEGMENT
C I=NSSEG1+ISS-1
C CHECK FOR A PORTAL OR A DUMMY SHAFT
C IF(NPORT.EQ.0.AND.ISHAPS.NE.0) GO TO 67
C THIS SHAFT IS A PORTAL OR A DUMMY SHAFT
C IF(LIST(7).EQ.0) WRITE(LO,3005) NSHAFT
C GO TO 860
67 NPB=B(I,4)
ELNPB=CMP(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 SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING
C WHICH COMPUTES LINING COSTS
LINING=B(I,10)
TL=B(I,11)
TSEG =B(I,11)
NOFORM=B(I,12)
ELWATR=B(I,13)
LINUT =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)

## COSTUN Listing (Continued)

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C          067850 0000
RE      =B(I,29) 067860 0000
BE48    =B(I,30) 067870 0000
BE60    =B(I,31) 067880 0000
BOB     =B(I,32) 067890 0000
BOB48   =B(I,33) 067900 0000
BOB60   =B(I,34) 067910 0000
C          067920 0000
SSEQL   =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
PUATER=B(I,43) 068040 0000
C          068050 0000
LABOR COST FACTOR IN COMPRESSED AIR
CFLCA=AIRPR**2/400.+1.5 068060 0000
IF(NSSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1. 068070 0000
C          068080 0000
C          -----
C          068090 0000
CALCULATE SETUP COST FOR SHAFT SEGMENT I
CALL CSETUP(A,B,NSEGS,NSSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,SETUPR,
1 CLES,CEES,CMES,CFLUWK,CFEWWK,NSSTYP,DSES,DMES,DRES,NTSMAX,NSSMAX) 068100 0000
C          068110 0000
C          068120 0000
C          068130 0000
C          068140 0000
C          068150 0000
C          068160 0000
C          068170 0000
C          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
1           IF(LINING.EQ.2) PUMPTM=PUMPTM+30./DTP 068220 0000
700        CONTINUE 068230 0000
C          068240 0000
C          068250 0000
C          068260 0000
1           PSOIL,STABNO,DTRNCH,DROCK,SIDESL,UBOX,UZOIL,UROCK,PHI, 068270 0000
2           DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLUWK,CFEWWK,NSSTYP) 068280 0000
C          068290 0000
C          068300 0000
C          068310 0000
1           MSTAB,CFLCA,CFLUWK,CFEWWK,HOURS) 068320 0000
C          068330 0000
C          068340 0000
C          068350 0000
1           HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPS,RL,UCLT,UCET,Y,UCLMH, 068360 0000
2           HSCA,UCEMH,MSTAB,DLOCK,CLIMB,HOURS,OPEN,DCENT,UBACEX,UBACDS,UBOX, 068370 0000
3           UZOIL,UROCK,TOTBOX,CFLUWK,CFEWWK,CFLCA,DDS,NSSTYP,DTRNCH,DROCK) 068380 0000
C          068390 0000
C          068400 0000
C          068410 0000
1           CFLUWK,CFEWWK,ITYPE) 068420 0000

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(Continued)

## COSTUN Listing (Continued)

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C   ----- 068430 0000
C   CALCULATE COST OF SHAFT SUPPORTS FOR SHAFT SEGMENT I 068440 0000
C   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,POTAL,BOB,LINUT, 068460 0000
2     MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,DSLURY,DTRNCH,IDECK,DRCK, 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
C   CALL LINING1(CL1,CEL,CML,CLFU,CEFU,CMFW,ITYPE,LINING,RQD,MEX, 068510 0000
1     WEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPS,BE,UCLT,UCET,MTM, 068520 0000
2     UCMLH,UCEMH,SFA,NOFORH,AR,NSSTYP,PSOIL,PWATER,UL,SFP, 068530 0000
3     3FORMAR,HOURS,CFLCA,CFLWWK,CFEWWK) 068540 0000
C   ----- 068550 0000
C   CALCULATE GROUTING COSTS FOR SHAFT SEGMENT I 068560 0000
C   CALL CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPS,BE,AR,RS,NSSTYP,MSTAB, 068570 0000
1     DTUN,HH,HOURS,CFLWWK,CFEWWK,SSEG1,PERM,SFP,DTG,TIMEG) 068580 0000
C   ----- 068590 0000
C   CALCULATE COST OF PUMPING FOR SHAFT SEGMENT I 068600 0000
C   CALL CPUMP(CL1,CEP,CMP,NSSTYP,FLOW,PH,PIPL,AR,ITYPE, 068610 0000
1     ELSURF,ELBOTM,DAYS,LINING,PUMPTM,MEX,DTRNCH,DRCK,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
C   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
C   IF(LIST(7).EQ.1) GO TO 810 068740 0000
C   IF(NLINES+11.LT.60) GO TO 810 068750 0000
C   WRITE(LO,2000) 068760 0000
C   NLINES=6 068770 0000
C   ----- 068780 0000
C   CALCULATE COST FACTORS 068790 0000
C   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
C   CFL-SHAFT(NSHAFT,12) 068820 0000
C   CFE-SHAFT(NSHAFT,13) 068830 0000
C   CFM-SHAFT(NSHAFT,14) 068840 0000
C   RCF-SHAFT(NSHAFT,15) 068850 0000
C   CF(1)=POP*CFL*RCF 068860 0000
C   CF(2)=POP*CFE*RCF 068870 0000
C   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
C   IL(1)=CLES*CF(1)+.5 068920 0000
C   IE(1)=CEES*CF(2)+.5 068930 0000
C   IM(1)=CMES*CF(3)+.5 068940 0000
C   IL(2)=CLE*CF(1)+.5 068950 0000
C   IE(2)=CEE*CF(2)+.5 068960 0000
C   IM(2)=CME*CF(3)+.5 068970 0000
C   IL(3)=CLML*CF(1)+.5 068980 0000
C   IE(3)=CEML*CF(2)+.5 068990 0000
C   IM(3)=CMML*CF(3)+.5 069000 0000

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COSTUN Listing (Continued)

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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)=CMMMD*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)=CEF W*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
----- 069250 0000		
C 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
----- 069350 0000		
C 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
----- 069480 0000		
C C CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS	069490	0000
TLC = SLCpf*SSEG1/1000.	069500	0000
TEC = SECPF*SSEG1/1000.	069510	0000
TMC = SMCPF*SSEG1/1000.	069520	0000
TSC = TLC+TEC+TMC	069530	0000
----- 069540 0000		
C IF(LIST(7).EQ.1) GO TO 840	069550	0000
C WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL	069560	0000
ISSEG1=SSEG1	069570	0000
NSSEG=B(I,2)	069580	0000

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(Continued)

## COSTUN Listing (Continued)

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        WRITE(LO,2001) NSHAFT,NSSEG,(IL(JJJ),JJJ=1,11),SLOPF,TLC      069590 0000
        WRITE(LO,2002)          (IE(JJJ),JJJ=1,11),SECPF,TEC      069600 0000
        WRITE(LO,2003)          (IM(JJJ),JJJ=1,11),SMCPF,TMC      069610 0000
        WRITE(LO,2004) TCES,TCE,TCML,TCMH,TCMD,TCTS,TCL,TCFW,      069620 0000
1 TCG,TCP,TCAC,TSCP,ISSÉGL,TSC      069630 0000
C   NLINES=NLINES+5      069640 0000
C
C   ACCUMULATE SHAFT SEGMENT COSTS INTO COST OF SHAFT      069650 0000
840 SCL=SCL+TLC      069660 0000
SCE=SCE+TEC      069670 0000
SCM=SCM+TMC      069680 0000
SCT=SCL+SCE+SCM      069690 0000
C   END OF COSTS ON A SEGMENT BASIS      069700 0000
900 CONTINUE      069710 0000
C -----
C   LIST OUT TOTAL COST OF SHAFT      069720 0000
850 IF(LIST(7).EQ.1) GO TO 860      069730 0000
        WRITE(LO,1004) SHAFT(NSHAFT,12),SCL,SHAFT(NSHAFT,15),      069740 0000
1 SHAFT(NSHAFT,13),SCE,SHAFT(NSHAFT,14),SCM,CFLWWK,SCT,CFEWWK      069750 0000
NLINES=NLINES+7      069760 0000
C
C -----
C   ACCUMULATE COSTS OF ALL SHAFTS      069770 0000
860 SFTTLC=SFTTLC+SCL      069780 0000
SFTTEC=SFTTEC+SCE      069790 0000
SFTTMC=SFTTMC+SCM      069800 0000
SFTTC=SFTTLC+SFTTEC+SFTTMC      069810 0000
C
SHAFT(NSHAFT,19)=SCL      069820 0000
SHAFT(NSHAFT,20)=SCE      069830 0000
SHAFT(NSHAFT,21)=SCM      069840 0000
SHAFT(NSHAFT,22)=SCT      069850 0000
C   END OF COSTS ON A SHAFT BASIS      069860 0000
950 CONTINUE      069870 0000
C
C   PRINT REACH COST SUMMARIES      069880 0000
IF(LIST(8).EQ.1) GO TO 965      069890 0000
        WRITE(LO,1500)      069900 0000
NLINES=5      069910 0000
DO 960 NREACH=1,NTRMAX      069920 0000
IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 960      069930 0000
NSHAFT=TRDATA(NREACH,1)      069940 0000
RCL=TRDATA(NREACH,17)      069950 0000
RCE=TRDATA(NREACH,18)      069960 0000
RCM=TRDATA(NREACH,19)      069970 0000
RCT=TRDATA(NREACH,20)      069980 0000
        WRITE(LO,1501) NREACH,NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),      069990 0000
1 JJ=12,14),RCL,RCE,RCM,RCT      070000 0000
NLINES=NLINES+2      070010 0000
IF(NLINES.LT.58) GO TO 960      070020 0000
        WRITE(LO,1500)      070030 0000
NLINES=5      070040 0000
960 CONTINUE      070050 0000
965 CONTINUE      070060 0000
C
C   PRINT SHAFT COST SUMMARIES      070070 0000
IF(LIST(9).EQ.1) GO TO 975      070080 0000
1      070090 0000
      070100 0000
NLINES=5      070110 0000
      070120 0000
      070130 0000
      070140 0000
      070150 0000
      070160 0000

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(Continued)

COSTUN Listing (Continued)

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        WRITE(LO,1600)
NLINES=5
DO 970 NSHAFT=1,NSMAX
IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 970
SCL-SHAFT(NSHAFT,19)
SCE-SHAFT(NSHAFT,20)
SCM-SHAFT(NSHAFT,21)
SCT-SHAFT(NSHAFT,22)
WRITE(LO,1601) NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),JJ=12,14) 070170 0000
1 SCL, SCE, SCM, SCT 070180 0000
NLINES=NLINES+2 070190 0000
IF(NLINES.LT.58) GO TO 970 070200 0000
WRITE(LO,1600) 070210 0000
NLINES=5 070220 0000
970 CONTINUE 070230 0000
975 CONTINUE 070240 0000
C -----
C TOTAL PROJECT CONSTRUCTION COSTS 070250 0000
TLABOR=TUNLC+SFTTLC 070260 0000
TEQUIP=TUNECC+SFTTEC 070270 0000
TMATER=TUNMC+SFTTMC 070280 0000
TCOST=TUNTC+SFTTC 070290 0000
070300 0000
C -----
C PRINT PROJECT SUMMARY SHEET 070310 0000
WRITE(LO,2) TITLE 070320 0000
WRITE(LO,1005) PM,TUNLC,OM,TUNECC,TUNMC,TUNTC 070330 0000
070340 0000
WRITE(LO,1006) SFTTLC,SFTTEC,SFTTMC,SFTTC 070350 0000
070360 0000
WRITE(LO,1007) TLABOR,TEQUIP,TMATER,TCOST 070370 0000
070380 0000
C -----
C RETURN 070390 0000
C -----
C -----
2 FORMAT(1H1,10(/),50X,70(1H*),/,50X,1H*,68X,1H*, 070400 0000
110(/,50X,1H*,2X,16A4.2X,1H*), 070410 0000
3 /,50X,1H*,68X,1H*,/,50X,70(1H*),///) 070420 0000
1004 FORMAT(1X,119(1H-),//, 7X, 14HREGIONAL COST,6X,10HCOST INDEX,10X 070430 0000
110H -- LABOR ,F5.2, 5X,25HSHAFT LABOR COST ..... ,I9/ 070440 0000
2 7X,9HFACTOR ,F5.2,26X,10HEQUIPMENT ,F5.2,5X, 070450 0000
3 25HSHAFT EQUIPMENT COST .... ,I9/ 070460 0000
4 47X,10HMATERIALS ,F5.2, 5X,25HSHAFT MATERIALS COST .... ,I9/ 070470 0000
5 41X,16HLABOR WORK WEEK ,F5.2,5X,25HSHAFT COST ..... ,I9/ 070480 0000
6 41X,16HEQUIP WORK WEEK ,F5.2) 070490 0000
1005 FORMAT(50X,17HPROFIT MARGIN ,F5.2,3X, 070500 0000
1 36HTOTAL TUNNEL LABOR COST.....($1000),I9/, 070510 0000
2 50X,17HOVERHEAD MARGIN ,F5.2,3X, 070520 0000
3 36HTOTAL TUNNEL EQUIPMENT COST.....,I9/, 070530 0000
4 75X,36HTOTAL TUNNEL MATERIAL COST.....,I9/, 070540 0000
5 75X,36HTOTAL TUNNEL COST.....,I9/) 070550 0000
1006 FORMAT(//,75X,36HTOTAL SHAFT LABOR COST.....,I9/ 070560 0000
1 75X,36HTOTAL SHAFT EQUIPMENT COST.....,I9/ 070570 0000
2 75X,36HTOTAL SHAFT MATERIAL COST.....,I9/ 070580 0000
3 75X,36HTOTAL SHAFT COST.....,I9/) 070590 0000
1007 FORMAT(//,75X,35HTOTAL PROJECT LABOR COST.....,I10/ 070600 0000
1 75X,35HTOTAL PROJECT EQUIPMENT COST.....,I10/ 070610 0000
2 75X,35HTOTAL PROJECT MATERIAL COST.....,I10/ 070620 0000
3 75X,35HTOTAL PROJECT COST.....,I10/) 070630 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 070640 0000
1M A R Y ,35(1H*)// 14X,19HEXIT REGIONAL ,6(1H*), 070650 0000
070660 0000
070670 0000
070680 0000
070690 0000
070700 0000
070710 0000
070720 0000
070730 0000
070740 0000

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## COSTUN Listing (Continued)

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2 12HCOST INDEXES,6(1H*),10X,17(1H*),15H COSTS ($1000) ,16(1H*)/, 070750 0000
3 3X,52HREACH 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,16)/) 070780 0000
1600 FORMAT(1H1,1X,41(1H*),37H SHAFT COST SUMMARY , 070790 0000
1 41(1H*)// 23X,10HRÉGIONAL ,6(1H*),12HCOST INDEXES,6(1H*), 070800 0000
2 10X,17(1H*),15H COSTS ($1000) ,16(1H*)/,3X,5HSHAFT,14X, 070810 0000
3 33HCOST FACTOR LABOR EQUIP MATL,16X, 070820 0000
4 41HLABOR EQUIPMENT MATERIAL TOTAL,/ 1X,119(1H-)/) 070830 0000
1601 FORMAT(4X,I3,18X,F4.2,2X,3(4X,F4.2),11X,4(3X,19)/) 070840 0000
2000 FORMAT(1H1,45(1H*),23H SHAFT COST 52(1H*)// 070850 0000
1120H SHAFT SEG ***** COST IN DOLLARS PER FOOT OF SHAFT 070860 0000
***** SEG SEGMENT SEGMENT 070870 0000
3120H NO NO EXC EXC MUCK MUCK MUCK SUP- LIN LIN GR 070880 0000
40UT PUMP- AIR- COST LENGTH COST 070890 0000
5120H SETUP LOAD HOIST DISP PORTS ING FORM 070900 0000
6 ING COND ($/FT) (FEET) ($1000) 070910 0000
? /,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,12I6,18,I10) 070960 0006
3005 FORMAT(1H1,6H SHAFT,14,' IS A PORTAL OR A DUMMY SHAFT ALL CO 070970 0000
1STS ARE ZERO') 070980 0000
----- 070990 0000
C C RETURN 071000 0000
END 071005 0000
SUBROUTINE CUINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1, 071020 0000
1CLIMD,UCMCP,NTSMAX,NPMAX) 071030 0000
DIMENSION A(NTSMAX,68), CNP(NPMAX,2),CUMSL(NPMAX) 071050 0000
----- 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
----- 071110 0000
C DTFACN=0. 071120 0000
UCMCP=0. 071130 0000
NSEGSA=IABS(NSEGS) 071140 0000
----- 071150 0000
C 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)

## COSTUN Listing (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
CAUT=A(N,35)
UCMCP=UCMCP+(26.+0.0018*CAUT-0.00000015*CAUT**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(ALOKLT.LT.ALOCKL) ALOCKL=ALOKLT

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## COSTUN Listing (Continued)

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100 CONTINUE                                071510 0000
C -----
C ALOCK = NEGATIVE FOR COOLING PLANT FOR FIRST LOCK MOVED FROM SHAFT 071920 0000
C TO GROUND SURFACE ABOVE SECOND LOCK POSITION 071930 0000
C IF(M.LT.0) ALOCK=-ALOCK 071940 0000
C RETURN 071950 0000
C END 071960 0000
C SUBROUTINE CSETUP(A,B,NSEGS,NSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM, 071980 0000
C 1SETUPR,CLES,CEES,CMES,CFLWUK,CFEWUK,NSTYP,DSES,DMES,DRS,NTSMAX, 071990 0000
C 2NSSMAX) 071995 0000
C -----
C CSETUP DETERMINES THE AVERAGE COSTS INVOLVED IN SETTING UP THE 072000 0000
C NECESSARY EQUIPMENT TO EXCAVATE EACH SEGMENT 072010 0000
C -----
C DIMENSION A(NTSMAX,68),B(NSSMAX,43) 072020 0000
C -----
C IF(NSTYP.EQ.3) GO TO 500 072030 0000
C INITIALIZE 072050 0000
C UCLSS=0. 072060 0000
C UCESS=0. 072070 0000
C UCMSS=0. 072080 0000
C UCLMS=0. 072090 0000
C UCEMS=0. 072100 0000
C UCMMMS=0. 072110 0000
C UCLR5=0. 072120 0000
C UCERS=0. 072130 0000
C UCMRS=0. 072140 0000
C -----
C IF(ITYPE.EQ.2) GO TO 200 072150 0000
C TUNNEL 072160 0000
C FIRST SEGMENT IN THE REACH 072170 0000
C IF(I.NE.NSEG1) GO TO 150 072180 0000
C DETERMINE THE TOTAL LENGTH OF SHIELD, MOLE AND RIPPER EXCAVATED 072190 0000
C SEGMENTS IN A REACH 072200 0000
C DSES=0.0000001 072210 0000
C DMES=0.0000001 072220 0000
C DRES=0.0000001 072230 0000
C NSEGSA=IABS(NSEGS) 072240 0000
C DO 100 NN=1,NSEGSA 072250 0000
C M=NSEG1+(NN-1)*NSEGS/NSEGSA 072260 0000
C MEX=A(M,?) 072270 0000
C TSEGL=A(M,45) 072280 0000
C IF(MEX.LE.1.OR.MEX.GE.6) GO TO 100 072290 0000
C SHIELD 072300 0000
C IF(MEX.GE.3) DSES=DSES+TSEGL 072310 0000
C MOLE 072320 0000
C IF(MEX.LE.3) DMES=DMES+TSEGL 072330 0000
C RIPPER 072340 0000
C IF(MEX.EQ.5) DRES=DRES+TSEGL 072350 0000
100 CONTINUE 072360 0000
150 MEX=A(I,7) 072370 0000
IF(MEX.LE.1.OR.MEX.GE.6) GO TO 400 072380 0000
C SHIELD SET UP COSTS 072390 0000
C IF(MEX.LT.3) GO TO 160 072400 0000
C UCLSS=(20000.+3.*HH+45.*BE**2)*SETUSH 072410 0000
C UCESS=(2000.+0.04*BE*HH+21.*BE**2)*SETUSH 072420 0000
C UCMSS=(700.+0.1*HH+2.5*(BE-6.)*2)*SETUSH 072430 0000
C MOLE SETUP COSTS 072440 0000
C 072450 0000
C 072460 0000
C 072470 0000
C 072480 0000

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(Continued)

## COSTUN Listing (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
UCLR=(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 -----
C SHAFT 072590 0000
200 IF(I.NE.NSEG1) GO TO 350 072600 0000
DSES=0.0000001 072610 0000
DMES=0.0000001 072620 0000
DRES=0.0000001 072630 0000
C DETERMINE THE TOTAL LENGTH OF SHIELD AND MOLE EXCAVATED 072640 0000
C SEGMENTS IN A SHAFT 072650 0000
SETUSH=0. 072660 0000
SETUPM=0. 072670 0000
DO 300 NN=1,NSEGS 072680 0000
M=NSEG1+NN-1 072690 0000
MEX=B(M,7) 072700 0000
SSEGL=B(M,35) 072710 0000
IF(MEX-2) 300,220,210 072720 0000
C SHIELD 072730 0000
210 DSES=DSES+SSEGL 072740 0000
IF(SETUSH.LT.1.) SETUSH=1. 072750 0000
IF(MEX.EQ.4) GO TO 300 072760 0000
C MOLE 072770 0000
220 DMES=DMES+SSEGL 072780 0000
IF(SETUPM.LT.1.) GO TO 250 072790 0000
IF(MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+0.125 072800 0000
GO TO 300 072810 0000
250 SETUPM=1. 072820 0000
300 MEXP=MEX 072830 0000
C -----
C 350 MEX=B(I,7) 072840 0000
C SHIELD SETUP COSTS 072850 0000
IF(MEX.LT.3) GO TO 360 072860 0000
UCLSS=(2000.+930.*BE)*SETUSH 072870 0000
UCESS=(500.+14.)*(BE-5.)*2)*SETUSH 072880 0000
UCMSS=(300.+(BE-3.)*2)*SETUSH 072890 0000
C MOLE SETUP COSTS 072900 0000
360 IF(.NOT.(MEX.EQ.2.OR.MEX.EQ.3)) GO TO 400 072910 0000
UCLMS=(130.*(BE+5.)*2+65000.)*SETUPM 072920 0000
UCEMS=(165.*(BE-10.)*2+20000.)*SETUPM 072930 0000
UCMMS=(30.*(BE-10.)*2+3200.)*SETUPM 072940 0000
C -----
C TOTAL SETUP COSTS 072950 0000
400 CLES=(UCLSS/DSES+UCLMS/DMES+UCLR/DRES)*CFLWUK 072960 0000
CEES=(UCESS/DSES+UCEMS/DMES+UCERS/DRES)*CFEWUK 072970 0000
CMES=UCMSS/DSES+UCMMS/DMES+UCMRS/DRES 072980 0000
RETURN 072990 0000
C
500 CLES=0. 073000 0000
CEES=0. 073010 0000
CMES=0. 073020 0000
C
500 CLES=0. 073030 0000
CEES=0. 073040 0000
CMES=0. 073050 0000
C
500 CLES=0. 073060 0000

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**COSTUN Listing (Continued)**

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RETURN
END
SUBROUTINE COEX(CLE, CEE, CME, ITYPE, MEX, AR, BE, RS, ISHAPE, SFA, SFP,
1                 PSOIL, STABNO, DTRNCH, DRCK, SIDESL, UBOX, USOIL, URCK, FHI,
2                 DCENT, HOURS, Y, DM, MSTAB, CFLCA, CFLWK, CFLUWK, NSTYP)
-----
C          COEX CALCULATES EXCAVATION COSTS IN TUNNELS AND SHAFTS
-----
C          IF(NSTYP.NE.2) GO TO 110
C          CALCULATE WEIGHT OF SHIELD
F=1.
IF(ISHAPE.EQ.3) F=1.56
IF(ITYPE.EQ.2.AND.ISHAPE.EQ.2) F=2.
WTSHLD=(0.037*SQRT(B1.+F*BE**2)-0.038)*PSOIL*STABNO**2*SFP
-----
110 IF(ITYPE.EQ.2) GO TO 100
C          CALCULATE UNIT COST OF TUNNEL EXCAVATION
C          CHECK TUNNEL EXCAVATION METHODS
GO TO (120,220,320,420,520,620,620),MEX
C          ROCK TUNNEL
CONVENTIONAL EXCAVATION
120 GO TO (121,122,123),ISHAPE
C          SHAPE IS CIRCLE
121 UCL=0.07*(BE+40.)**2-100.
UCE=0.046*(BE+15.)**2
UCM=SFA*SQRT(RS)*BE**2/2000.+(0.11*(BE+10.)**2-25.)/AR
GO TO 124
C          SHAPE IS HORSESHOE
122 UCL=0.08*(BE+40.)**2-110.
UCE=0.05*(BE+15.)**2+4.
UCM=SFA*SQRT(RS)*BE**2/2000.+(0.12*(BE+10.)**2-22.)/AR
GO TO 124
C          SHAPE IS BASKETHANDLE
123 UCL=0.1*BE**2+60.
UCE=0.04*(BE+5.)**2+17.
UCM=SFA*SQRT(RS)*BE**2/2000.+(0.13*(BE-5.)**2+14.)/AR
124 CONTINUE
GO TO 800
C          MOLE EXCAVATION
220 UCL=0.021*BE**2+55.
UCE=0.048*BE**2
UCM=(5000.+RS+120000./AR)*BE**2/220000.
GO TO 800
-----
C          SOFT GROUND TUNNEL
MOLED
320 UCL=(55.+0.021*BE**2)*CFLCA
UCE=0.048*BE**2+0.00035*WTSHLD
UCM=(0.045+0.02*HOURS/AR)*BE**2+(0.5+0.05*BE)*HOURS/AR
GO TO 800
C          HAND EXCAVATED
420 UCL=(0.1*(BE+5.)**2+30.)*CFLCA
UCE=0.02*(BE+7.)**2+0.00035*WTSHLD
UCM=(0.5+0.25*BE)*HOURS/AR
GO TO 800
C          RIPPER EXCAVATED

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(Continued)

COSTUN Listing (Continued)

520	UCL=(50.+0.01*(BE+4.))**2)*CFLCA UCE=12.+0.2*BE+0.000035*UTSHLD UCM=(2.0+0.09*BE)*HOURS/AR GO TO 800 ***** C CUT AND COVER	073650 0000 073660 0000 073670 0000 073680 0000 073690 0000 073700 0000 073710 0000 073720 0000 073730 0000 073740 0000 073750 0000 073760 0000 073770 0000 073780 0000 073790 0000 073800 0000 073810 0000 073820 0000 073830 0000 073840 0000 073850 0000 073860 0000 073870 0000 073880 0000 073890 0000 073900 0000 073910 0000 073920 0000 073930 0000 073940 0000 073950 0000 073960 0000 073970 0000 073980 0000 073990 0000 074000 0000 074010 0000 074020 0000 074030 0000 074040 0000 074050 0000 074060 0000 074070 0000 074080 0000 074090 0000 074100 0000 074110 0000 074120 0000 074130 0000 074140 0000 074150 0000 074160 0000 074170 0000 074180 0000 074190 0000 074200 0000 074210 0000 074220 0000
C	620 IF(DROCK.GE.DTRNCH) GO TO 700 OPEN CUT INVOLVING ROCK EXCAVATION UROCK=BE*(DTRNCH-DROCK)/27. UCLROK=71.+0.55*AR*UROCK/HOURS UCEROK=15.+(0.4+0.0035*DTRNCH)*AR*UROCK/HOURS UCMROK=(1.1+0.0006*(DTRNCH+DROCK))*UROCK IF(UCLROK.LT.84.75) UCLROK=84.75 IF(AR*UROCK/HOURS.LT.25.) UCEROK=15.+(0.4+0.0035*DTRNCH)*25. IF(DROCK.GT.0.) GO TO 650 ALL ROCK , NO SOIL EXCAVATION USOIL=0. DCENT=0. UCLSOL=0. UCESOL=0. UCMSOL=0. GO TO 750 SOME ROCK, SOME SOIL EXCAVATION ----- SOIL EXCAVATION	
C	650 USOIL=(BE+DROCK*SIDESL)*DROCK/27. DCENT=DROCK*(1.5*BE+DROCK*SIDESL)/(BE+DROCK*SIDESL)/3. IF(SIDESL.LT.1.) GO TO 670 IF(AR*USOIL/HOURS.LE.500.) GO TO 670 SOIL EXCAVATED BY SCRAPERS 660 SCRAPR=AR*USOIL/HOURS/(290.-0.9*DCENT) IF(SCRAPR.LT.1.) SCRAPR=1. PUSHER=SCRAPR/4. IF(PUSHER.LT.1.) PUSHER=1. UCLSOL=17.+8.0*(SCRAPR+PUSHER) UCESOL=19.*SCRAPR+10.*PUSHER UCMSOL=(5.5*SCRAPR+3.0*PUSHER)*HOURS/AR GO TO 750 SOIL EXCAVATED BY DRAGLINE 670 BUCMIN=10.-0.7*SQRT(160.-DROCK) 680 BUCKET=2.5*(AR*USOIL/HOURS/(1.05-0.00014*(PHI-50.))**2)-40. 1 / (170.-DCENT) IF(BUCKET.LT.BUCMIN) BUCKET=BUCMIN UCLSOL=19.0 UCESOL=13.0+0.85*BUCKET**2 UCMSOL=1.1*BUCKET*USOIL/(40.+0.4*(170.-DCENT)*BUCKET) 1 / (1.05-0.00014*(PHI-50.))**2 GO TO 750 ----- SOIL EXCAVATION ONLY, NO ROCK EXCAVATION	
C	700 UROCK=0. UCLROK=0. UCEROK=0. UCMROK=0. USOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27. DCENT=DTRNCH*(1.5*BE+DTRNCH*SIDESL)/(BE+DTRNCH*SIDESL)/3. IF(SIDESL.LT.1) GO TO 720 IF(AR*USOIL/HOURS.GT.500.) GO TO 660	

(Continued)

## COSTUN Listing (Continued)

```

720 BUCMIN=10.-0.7*SQRT(160.-DTRNCH) 074230 0000
GO TO 680 074240 0000
C -----
C COSTS OF BACKFILL 074250 0000
750 U=UROCK+USOIL 074260 0000
UCLBAK=82.0 074270 0000
UCEBAK=32.0 074280 0000
IF(AR*(U-UBOX)/HOURS.LE.1200.) GO TO 760 074290 0000
UCLBAK=82.*(U-UBOX)*AR/HOURS/1200. 074300 0000
UCEBAK=32.*(U-UBOX)*AR/HOURS/1200. 074310 0000
760 UCMBAK=6.81*(U-UBOX) 074320 0000
UCL=UCLR0K+UCLS0L+UCLBAK 074330 0000
UCE=UCEROK+UCESOL+UCEBAK 074340 0000
UCM=UCMR0K+UCMSOL+UCMBAK 074350 0000
GO TO 800 074360 0000
C **** 074370 0000
C CALCULATE UNIT COSTS OF SHAFT EXCAVATION 074380 0000
100 IF(NSTYP.EQ.3) GO TO 500 074390 0000
GO TO (140,240,340,440),MEX 074400 0000
C ROCK SHAFT 074410 0000
C CONVENTIONAL 074420 0000
140 UCL=30.+4.25*BE 074430 0000
UCE=8.+2.2*BE 074440 0000
UCM=(0.01+RS/2000000.)*BE**2 + (.8+RS/40000.+3.4/AR)*BE + 5. 074450 0000
GO TO 800 074460 0000
C MOLED 074470 0000
240 UCL=0.032*BE**2+84. 074480 0000
UCE=0.072*BE**2 074490 0000
UCM=(5000.+RS+120000./AR)*BE**2/150000. 074500 0000
GO TO 800 074510 0000
C ----- 074520 0000
C SOFT GROUND SHAFT 074530 0000
C MOLED 074540 0000
340 UCL=(0.032*BE**2+84.0)*CFLCA 074550 0000
UCE=0.072*BE**2+0.000035*WTSHLD 074560 0000
UCM=(0.045+0.03*HOURS)*BE**2+(0.5+0.05*BE)*HOURS/AR 074570 0000
GO TO 800 074580 0000
C HAND/SHIELD 074590 0000
440 IF(Ishape.EQ.1) UCL=63.0*CFLCA 074600 0000
IF(Ishape.EQ.2) UCL=70.0*CFLCA 074610 0000
UCE=7.40+0.000035*WTSHLD 074620 0000
UCM=(3.70+0.05*BE)*HOURS/AR 074630 0000
800 CLE=UCL*(HOURS*CFLWWK+Y*DM)/AR 074640 0000
CEE=UCE*HOURS*CFEWWK/AR 074650 0000
CME=UCM 074660 0000
GO TO 900 074670 0000
C 074680 0000
500 CLE=0. 074690 0000
CEE=0. 074700 0000
CME=0. 074710 0000
C 074720 0000
900 RETURN 074730 0000
END 074740 0000
SUBROUTINE CMUKLD(CLML,CEML,CMLL,I TYPE,MEX,AR,DM,U,Y,RMY,RMLMAX,
1 MSTAB,CFLCA,CFLWWK,CFEWWK,HOURS) 074750 0000
C ----- 074760 0000
C ----- 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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## COSTUN Listing (Continued)

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C ----- 074810 0000
C ----- 074820 0000
C 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*CFLWK+Y*DM)/AR 075100 0000
CEML=UCE*HOURS*CFEWK/AR 075110 0000
CMML=UCM*U 075120 0000
300 RETURN 075130 0000
END 075140 0000
SUBROUTINE CMTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR, 075150 0000
1HSFA,U,HH,LINING,RML,RMLMAX,HSLAPE,BE,ISHAPE,RL,UCLT,UCET,Y,UCLMH, 075160 0000
2HSFA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,UBACEX,UBACDS,VBOX, 075170 0000
3 USOIL,UROCK,TOTBOX,CFLWK,CFEWK,CFLCA,DD$,NSTYP,DTRNCH,DROCK) 075180 0000
C ----- 075190 0000
C CMTAH CALCULATES MUCK TRANSPORT COSTS IN TUNNELS AND MUCK HOISTING 075200 0000
C COSTS IN TUNNELS AND SHAFTS. IT ALSO CALCULATES COST OF TRANSPORT 075210 0000
C FOR BACKFILL IN CUT-AND-COVER TUNNEL. 075220 0000
C ----- 075230 0000
C SHAFT OR TUNNEL 075240 0000
IF(ITYPE.EQ.2) GO TO 600 075250 0000
C ----- 075260 0000
C ----- 075270 0000
IF(NSTYP.EQ.3) GO TO 2000 075280 0000
C COST OF MUCK TRANSPORT IN TUNNELS 075290 0000
GO TO (20,60,40,80),MTM 075300 0000
C ----- 075310 0000
C TRUCK TRANSPORT Z= TRUCK VOLUME/4 075320 0000
20 IF(ISHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2 075330 0000
IF(ISHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)*4/22000. 075340 0000
TRUCKS=0.06*RMLMAX/Z*DM**0.7 075350 0000
IF(TRUCKS.LT.1.) TRUCKS=1. 075360 0000
C ----- 075370 0000
C ----- 075380 0000

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## COSTUN Listing (Continued)

```

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

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(Continued)

## COSTUN Listing (Continued)

```

UCEMT=8.10
IF(RMLMAX.LE.100.) UCEMT=4.50
IF(RMLMAX.GT.300) UCEMT=14.90
UCMMT=0.02
1100 UCE=UCECON+UCEMT
UCM=UCMCON+UCMMT
C STORE COST VALUES FOR USE IN LINING COMPUTATIONS (SUB LINING)
UCLT=(0.6*SQRT(RMLMAX+40.)-1.1)*DM
UCET=UCE
GO TO 400
-----
CC CONVEYOR AND TRUCK (FOR COMPRESSED AIR SEGMENT ONLY)
80 IF(MSTAB.NE.1) GO TO 20
IF(DLOCK.LE.0.001) GO TO 60
DCA=DM-DLOCK/5280.
C TRUCKS IN FREE AIR
IF(ISSHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2
IF(ISSHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)**4/22000.
TRUCKS=0.06*RMLMAX/Z*(DLOCK/5280.)**0.7
IF(TRUCKS.LT.1.) TRUCKS=1.
UCETR=(1.5+3.1*Z)*TRUCKS
UCMTR=0.05*(1.+0.77*ABS(HSFA ))*DLOCK/5280.
C CONVEYOR IN COMPRESSED AIR
UCECON=DCA*((1.+4.*HSCA )*SQRT(RMLMAX+40.)-26.*HSCA -1.5)
UCMCON=DCA*(0.01+0.23*HSCA )
IF(HSCA .GE.0.) GO TO 1200
UCECON=DCA*(SQRT(RMLMAX+40.)+6.*HSCA -1.5)
UCMCON=0.01*DCA
C COST OF MUCK TRANSFER IN AIR LOCK
1200 UCEMT=8.10
IF(RMLMAX.LE.100.) UCEMT=4.50
IF(RMLMAX.GT.300.) UCEMT=14.9
UCMMT=0.02
UCL=((0.013*AR+0.6*DCA)*SQRT(RMLMAX+40.))+0.06*AR-1.1*DCA)*CFLCA
1 +7.7*(TRUCKS+CFLCA)+23.9+CLIND*AR/HOURS
UCE=UCECON+UCEMT+UCETR
UCM=UCMCON+UCMMT+UCMTR
-----
CC CALCULATE MUCK TRANSPORT COSTS
400 CLMT=UCL*HOURS*CFLWUK/AR
CEMT=UCE*HOURS/AR*CFEWUK
CMMT=UCM*
IF(HH.GT.0.) GO TO 500
C SHAFT IS A PORTAL, HOISTING COSTS ARE ZERO
300 UCL=0.
UCE=0.
UCM=0.
UCLIND=0.
GO TO 700
C COST OF BACKFILL TRANSPORT IN CUT AND COVER
2000 DCENT=(DCENT*USOIL-UBOX*(DTRNCH-TOTBOX/2.))/(U-UBOX)
IF(DROCK.LT.DTRNCH) DCENT=DCENT+UROCK*(DTRNCH+DROCK)/2.-(U-UBOX)
TRUCKS=(0.02+(OPEN+DCENT/0.1)/7500.)*UBACEX*(U-UBOX)*AR/HOURS
IF(TRUCKS.LT.1.) TRUCKS=1
UCL=(10.+(15.5+4.7*DDS)*UBACDS*(U-UBOX)*AR/1000.)*24./HOURS
1 +8.20+6.25*TRUCKS

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## COSTUN Listing (Continued)

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UCE=(6.+12.5+2.1*DDS)*UBACDS*(U-UBOX)*AR/1000.)*24./HOURS      076550 0000
1   +8.40+2.70*TRUCKS                                              076560 0000
UCM=0.055*DDS*UBACDS+0.00005*(OPEN+DCENT/0.1)*UBACEX              076570 0000
1   +8.2*HOURS/AR/(U-UBOX)                                           076580 0000
C   CALCULATE COST OF BACKFILL TRANSPORT PER FOOT OF TUNNEL          076590 0000
CLMT=UCL*HOURS/AR*CFLWWK                                         076600 0000
CEMT=UCE*HOURS/AR*CFEWWK                                         076610 0000
CMMT=UCM*(U-UBOX)                                                 076620 0000
C   RESET UNIT COSTS TO ZERO SO MUCK HOISTING COST WILL BE ZERO IN    076630 0000
CUT-AND-COVER                                                       076640 0000
GO TO 300                                                          076650 0000
C   *****
C   CALCULATE UNIT COST OF MUCK HOISTING IN TUNNELS                   076660 0000
500 UCL=35.+0.003*HH*(1.+0.002*RMLMAX)+0.016*RMLMAX                076670 0000
UCE=10. + 0.03*RMLMAX                                              076680 0000
UCM=0.05                                                       076690 0000
UCLIND=(50000.+0.04*(900.+HH)*RMLMAX)/RL                         076700 0000
GO TO 700                                                          076710 0000
076720 0000
C   -----
C   CALCULATE UNIT COST OF MUCK HOISTING IN SHAFTS                   076730 0000
600 UCL=0.                                                       076740 0000
UCE=0.                                                       076750 0000
UCM=0.                                                       076760 0000
UCLIND=0.                                                       076770 0000
IF(NSTYP.EQ.3) GO TO 800                                         076780 0000
UCL=29. + 0.002*HH*(1.+0.008*RMLMAX)                            076790 0000
UCE=3.+0.04*RMLMAX                                              076800 0000
UCM=0.05                                                       076810 0000
UCLIND=0.                                                       076820 0000
076830 0000
C   -----
C   CALCULATE MUCK HOISTING COSTS                                     076840 0000
700 CLMH=(HOURS*UCL/AR+UCLIND)*CFLWWK                           076850 0000
CEMH=HOURS*UCE/AR*CFEWWK                                         076870 0000
CMMH=UCM*U*HH/1000.                                               076880 0000
GO TO 750                                                          076890 0000
800 CLMH=0.                                                       076900 0000
CEMH=0.                                                       076910 0000
CMMH=0.                                                       076920 0000
750 CONTINUE                                                       076930 0000
C   STORE COST VALUES FOR USE IN LINING COMPUTATION                 076940 0000
UCLMH=UCL                                                       076950 0000
UCEMH=UCE                                                       076960 0000
076970 0000
C   RETURN                                                       076980 0000
END
SUBROUTINE CMUKDP(CLMD,CEMD,CMMD,AR,U,CDS,DDS,UDS,NSTYP,HOURS,
1   CFLWWK,CFEWWK,ITYPE)                                         076990 0000
077000 0000
C   -----
C   CMUKDP CALCULATES THE COST OF MUCK DISPOSAL FOR TUNNELS AND SHAFTS 077010 0000
077020 0000
077030 0000
077040 0000
077050 0000
077060 0000
077070 0000
077080 0000
077090 0000
077100 0000
077110 0000

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## COSTUN Listing (Continued)

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IF (NSTYP.EQ.3) UMKDP=UDSRU          077120 0000
UCL=(10.+(15.5+4.7*DDS)*UMKDP*AR/1000.)*24./HOURS 077130 0000
UCE=(6.+(12.5+2.10*DDS)*UMKDP*AR/1000.)*24./HOURS 077140 0000
UCM=0.055*DDS                         077150 0000
UCDS=CDS*UMKDP*0.00003                077160 0000
C   CALCULATE COST OF MUCK DISPOSAL    077170 0000
CLMD=UCL*HOURS/AR*CFLWK              077180 0000
CEMD=UCE*HOURS/AR*CFEWK               077190 0000
CMMD=UCDS+UCM*UMKDP                 077200 0000
GO TO 200                            077210 0000
077220 0000
C   100 CLMD=0.                         077230 0000
CEMD=0.                               077240 0000
CMMD=0.                               077250 0000
C   200 RETURN                          077260 0000
END
SUBROUTINE CTSUP(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60 077270 0000
1 ITYPE,Y DM,NSTYP,BF,ISUPPF,TPLATE,TSEG,PSOIL,WEB,PTOTAL 077280 0000
2 BOB,LINWF,MSTAB,CFLCA HOURS,CFLWK,CFEWK,DSLURY,DTRNCH,IDECK, 077290 0000
3 DROCK,WTSTRT,WTWALE,SPDLT,WTSPD,WTSP,WTANCH,TOTBOX,IBRACE,SFA) 077300 0000
077310 0000
077320 0000
077330 0000
077340 0000
077350 0000
077360 0000
077370 0000
077380 0000
077390 0000
077400 0000
077410 0000
077420 0000
077430 0000
077440 0000
077450 0000
077460 0000
077470 0000
077480 0000
077490 0000
077500 0000
077510 0000
077520 0000
077530 0000
077540 0000
077550 0000
077560 0000
077570 0000
077580 0000
077590 0000
077600 0000
077610 0000
077620 0000
077630 0000
077640 0000
077650 0000
077660 0000
077670 0000
077680 0000
077690 0000
-----
CTSUP CALCULATES THE COST OF SUPPORTS IN TUNNELS AND SHAFTS
-----
IS IT A ROCK TUNNEL OR SHAFT          077330 0000
IF(NSTYP.EQ.1) GO TO 5               077340 0000
II IS A FLOW INDICATOR               077350 0000
II=4                                 077360 0000
IS IT A SOFT GROUND TUNNEL OR SHAFT 077370 0000
IF(NSTYP.EQ.2) GO TO 1000            077380 0000
GO TO 1500                           077390 0000
077400 0000
077410 0000
077420 0000
077430 0000
077440 0000
077450 0000
077460 0000
077470 0000
077480 0000
077490 0000
077500 0000
077510 0000
077520 0000
077530 0000
077540 0000
077550 0000
077560 0000
077570 0000
077580 0000
077590 0000
077600 0000
077610 0000
077620 0000
077630 0000
077640 0000
077650 0000
077660 0000
077670 0000
077680 0000
077690 0000
-----
5 IF(ITYPE.EQ.2) ISHAP=1
E=2.71828
IF(RQD.GT.40..AND.RQD.LT.60.) GO TO 10
IF(RQD.LE.40.) GO TO 40
C   RQD .GE. 60   ROCK BOLTS USED
20 II=4
510 GO TO (200,210),MEX
C   CONVENTIONAL EXCAVATION
200 IF(ISSHAP.LE.3) GO TO 220
C   F IS A ROCK BOLT WEIGHT FACTOR, FF IS A WIRE MESH WEIGHT FACTOR
C   SHAPE IS BASKETHANDLE
F=1.6
FF=0.74
GO TO 230
C   SHAPE IS CIRCLE OR HORSESHOE
220 F=1.0
FF=1.0
GO TO 230
C   MOLE EXCAVATION

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COSTUN Listing (Continued)

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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*EX**(.0.026*BE)**(100-RQD)**2)/(152.-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 -----
C UNIT COSTS OF ROCK BOLT SUPPORTS IN TUNNELS 077770 0000
UCL=0.02*WRB*AR                         077780 0000
IF(BE.LE.16.) UCE=1.76                     077790 0000
IF(BE.GT.16..AND.WRB*AR.LE.1000.) UCE=9.35 077800 0000
IF(BE.GT.16..AND.WRB*AR.GT.1000.) UCE=9.35+0.0023*(WRB*AR-1000.) 077810 0000
UCM=0.32*WWM+(0.23+RS/530000.)*WRB        077820 0000
GO TO 300                                    077830 0000
C -----
C WEIGHT OF WIRE MESH IN SHAFTS           077840 0000
250 WWM=FF*4.*BE                          077850 0000
C -----
C UNIT COSTS OF ROCK BOLT SUPPORTS IN SHAFTS 077860 0000
UCL=0.0                         077870 0000
077880 0000
IF(MEX.EQ.1) UCE=0.0                     077890 0000
IF(MEX.EQ.2) UCE=1.76                   077900 0000
UCM=0.32*WWM+(0.23+RS/530000.)*URB       077910 0000
GO TO 300                                    077920 0000
C -----
C RQD IS BETWEEN 40 AND 60, INTERPOLATION OF COSTS IS NECESSARY. 077930 0000
C COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE 077940 0000
C INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD. 077950 0000
C -----
C STORE THE CORRECT VALUES OF RQD AND BE 077960 0000
10 RQDD=RQD                           077970 0000
BBE=BE                             077980 0000
C ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE 077990 0000
BE=BE40                            078000 0000
RQD=40                            078010 0000
II=1                               078020 0000
GO TO 410                           078030 0000
C RQD .LE. 40 STEEL SETS USED        078040 0000
40 II=4                           078050 0000
410 GO TO (420,430,440),ISHAPE      078060 0000
C SHAPE IS CIRCLE                   078070 0000
420 GO TO (450,460),MEX            078080 0000
C -----
C FACTOR FOR WEIGHT OF STEEL SUPPORTS=F 078090 0000
C CONVENTIONAL EXCAVATION          078100 0000
450 F=0.56*((RQD-20.)/100.)**2+1.22 078110 0000
C FBL= FACTOR FOR BLOCKING AND LAGGING 078120 0000
FBL=1.0                           078130 0000
GO TO 470                           078140 0000
C MOLE EXCAVATION                  078150 0000
460 F=1.0                           078160 0000
FBL=0.81                          078170 0000
C WEIGHT OF STEEL SUPPORTS        078180 0000
470 WST=F*EX**((SQRT(ABS(0.7*BE-6.))+3.7-2*((RQD+20.)/100.)**2)) 078190 0000
GO TO 480                           078200 0000
C SHAPE IS HORSESHOE               078210 0000
430 WST=EX**((SQRT(ABS(0.85*BE-7.))+0.8+0.3*SQRT(100.-RQD))) 078220 0000
C -----

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(Continued)

## COSTUN Listing (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   -----
C   UNIT COSTS OF STEEL SUPPORTS IN TUNNELS 078360 0000
490 IF(MEX.EQ.1) YY=1.1 078370 0000
IF(MEX.EQ.2) YY=1.0 078380 0000
UCL=YY*(0.001*WST*AR+0.4*BE) 078390 0000
UCE=YY*(6.+0.0002*WST*AR) 078400 0000
UCM=36.*YY/AR+0.095*WST+150.*BL 078410 0000
GO TO 300                078420 0000
C   -----
C   UNIT COSTS OF STEEL SUPPORTS IN SHAFT 078430 0000
500 UCL=1.1/3.*(0.001*WST*AR+0.4*BE) 078440 0000
UCE=1.1/3.*(6.+0.0002*WST*AR) 078450 0000
UCM=0.095*WST+150.*BL 078460 0000
C   -----
C   COST OF SUPPORTS 078470 0000
C   300 CLTS=(HOURS*CFLWWK+Y*DM)*UCL/AR 078480 0000
CETS=HOURS*CFEWWK*UCE/AR 078490 0000
CMTS=UCM 078500 0000
C   -----
IF(II.GE.3) GO TO 700 078510 0000
IF(II.GE.2) GO TO 600 078520 0000
C   STORE COSTS COMPUTED USING FICTITIOUS RQD=40 078530 0000
CL40=CLTS 078540 0000
CE40=CETS 078550 0000
CM40=CMTS 078560 0000
REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF 078570 0000
INTERPOLATION COMPUTATION 078580 0000
RQD=60 078590 0000
BE=BEGO 078600 0000
C   REDEFINE FLOW INDICATOR 078610 0000
II=II+1 078620 0000
GO TO 510 078630 0000
C   STORE COSTS COMPUTED USING FICTITIOUS RQD=60 078640 0000
600 CL60=CLTS 078650 0000
CE60=CETS 078660 0000
CM60=CMTS 078670 0000
C   -----
INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN SUPPORT COSTS 078680 0000
CLTS=CL40+((RQDD-40)/20)*(CL60-CL40) 078690 0000
CETS=CE40+((RQDD-40)/20)*(CE60-CE40) 078700 0000
CMTS=CM40+((RQDD-40)/20)*(CM60-CM40) 078710 0000
C   -----
REINSTATE ORIGINAL VALUES OF RQD AND BE 078720 0000
RQD=RQDD 078730 0000
BE=BEGO 078740 0000
700 RETURN 078750 0000
078760 0000
078770 0000
078780 0000
078790 0000
078800 0000
078810 0000
078820 0000

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(Continued)

## COSTUN Listing (Continued)

```

C   *****
C   SOFT GROUND TUNNELS OR SHAFTS
C   *****
C   ESTABLISH SHAPE FACTOR BASED ON PERIMETER
1000 IF(ITYPE.EQ.2) GO TO 1035
      GO TO(1010,1020,1030),ISHAPE
C   CIRCULAR
1010 SFP=3.14
      GO TO 1050
C   HORSESHOE
1020 SFP=3.57
      GO TO 1050
C   BASKETHANDLE
1030 SFP=2.66
      GO TO 1050
C   SHAFT SEGMENT
1035 IF(ISHAPE.EQ.1) GO TO 1010
C   SQUARE
      SFP=4
1050 PERMTR=0.5*(BE+BF)*SFP
      GO TO(1060,1070,1060,1300),ISUPPT
C   SEGMENTED CAST IRON OR STEEL SUPPORTS
1060 S=3
      GO TO 1080
C   SEGMENTED CONCRETE SUPPORTS
1070 S=4
1080 TWEB=TPLATE
      IF(TWEB.GT.1.) TWEB=1
      AREA=S*TPLATE+2.*TWEB*(TSEG-TPLATE)
C   CALCULATE SUPPORT QUANTITIES
      GO TO(1110,1120,1190),ISUPPT
C   -----
C   SEGMENTED CAST IRON SUPPORTS
1110 WCI=450.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR
      YY=0.13*WCI
      GO TO 1200
C   -----
C   SEGMENTED CONCRETE SUPPORTS
1120 UL=1./27.*((AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR
      IF(ITYPE.EQ.2) GO TO 1175
C   TUNNEL SEGMENT
      GO TO (1150,1160,1170),ISHAPE
C   CIRCULAR
1150 RST=0.01
      GO TO 1185
C   HORSESHOE
1160 RST=0.032-0.16E-6*PTOTAL
      PMINT=54000./BF**1.5
      RSTMNT=0.032-0.16E-6*PMINT
      GO TO 1180
C   BASKETHANDLE
1170 RST=0.032-0.16E-6*PTOTAL
      PMINT=60000./BF**1.7

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(Continued)

## COSTUN Listing (Continued)

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RSTMNT=0.032-0.16E-6*PMINT          079380 0000
GO TO 1180                          079390 0000
C SHAFT SEGMENT                      079400 0000
1175 IF(ISSHAP.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 -----
C SEGMENTED STEEL SUPPORTS          079510 0000
1190 WST=491.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR 079520 0000
YY=0.095*UST                        079530 0000
1200 IF(ITYPE.EQ.2) GO TO 1210      079540 0000
C TUNNEL SEGMENT                     079550 0000
Y3=1                                079560 0000
GO TO 1230                          079570 0000
C SHAFT SEGMENT                      079580 0000
C IS COMPRESSED AIR USED            079590 0000
1210 IF(MSTAB.EQ.1) GO TO 1220      079600 0000
Y3=0.333                            079610 0000
GO TO 1230                          079620 0000
1220 Y3=1.25                         079630 0000
1230 UCL=Y3*(50.+0.04*BE**2)*((CFLCA-1.)*2./3.+1.) 079640 0000
IF(ITYPE.EQ.2) UCL=Y3*(50.+0.04*BE**2)                  079650 0000
UCE=Y3*(5.5+0.003*(BE+10.))**2                         079660 0000
UCM=Y3*(2.1+0.001*BE**2)*HOURS/AR+YY                   079670 0000
C -----
C ADD COST FOR CAULKING SEGMENTED SUPPORTS IN WATERTIGHT TUNNELS 079680 0000
C AND SHAFTS                         079690 0000
IF(LINWT.EQ.1) GO TO 1240           079700 0000
GO TO 1350                          079710 0000
1240 IF(ITYPE.EQ.2) GO TO 1250      079720 0000
C TUNNEL SEGMENT                     079730 0000
IF(ISSHAP.EQ.1) GO TO 1260           079740 0000
C HORSESHOE OR BASKETHANDLE        079750 0000
SEGN=6                             079760 0000
GO TO 1270                          079770 0000
1250 IF(ISSHAP.EQ.1) GO TO 1260      079780 0000
C SQUARE                            079790 0000
SEGN=8                             079800 0000
GO TO 1270                          079810 0000
                                            079820 0000

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(Continued)

## COSTUN Listing (Continued)

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C   GO TO 1270
C   CIRCULAR
1260 SEGM=3
1270 CJOINT=BE*SFP/5+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))
      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 UBACKG=SFA*(BOB**2-BE**2)
      IF(ITYPE.EQ.1) UCL=UCL+1.3*UBACKG*AR*CFLCA/HOURS
      IF(ITYPE.EQ.2) UCL=UCL+1.3*UBACKG*AR/HOURS
      UCE=UCE+0.5*UBACKG*AR/HOURS
      UCM=UCM+1.2*UBACKG
      GO TO 300
C   *****
C   CUT AND COUVER
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.
      CETTS=0.

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## COSTUN Listing (Continued)

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CMTS=0. 080380 0000
RETURN 080390 0000
FOR SLOPING CUT, ONLY COST OF ROCK BOLTS WILL BE COMPUTED 080400 0000
C 1505 IF(MEX.EQ.7) GO TO 1750 080410 0000
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 C SLURRY WALL 080480 0000
C -----
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 C WALES AND STRUTS 080570 0000
C -----
WALERS AND STRUTS ARE SPACED 10 FEET VERTICALLY. 080580 0000
ACTUAL NUMBER OF STRUTS AND WALERS REQUIRED IS DSOIL/10 - 1 080590 0000
BECAUSE RESTRAINT AT BOTTOM OF SOLDIER PILE ACTS AS A STRUT. 080600 0000
IF ACTUAL NUMBER REQUIRED IS LESS THAN ONE, THEN USE ONE. 080610 0000
IS ROCK LINE ABOVE TRENCH BOTTOM 080620 0000
1515 IF(DROCK.LT.DTRNCH) GO TO 1520 080630 0000
STRUT=(DTRNCH/10.-1.)/15.*BE*WTSTRT 080640 0000
IF(IBRACE.EQ.3) STRUT=(DROOF/10.-1.)/15.*BE*WTSTRT 080650 0000
WALE=(DTRNCH/10.-1.)*2.*WTWALE 080660 0000
GO TO 1560 080670 0000
1520 STRUT=(DROCK/10.-1.)/15.*BE*WTSTRT 080680 0000
IF(IBRACE.EQ.3 .AND. DROOF.LT.DROCK) STRUT=(DROOF/10.-1.)/15.* 080690 0000
1BE*WTSTRT 080700 0000
C IS DECKING REQUIRED 080710 0000
IF(IDECK.EQ.1) GO TO 1540 080720 0000
WALE=(DROCK/10.-1.)*2.*WTWALE 080730 0000
GO TO 1560 080740 0000
1540 WALE=(DROCK/10.-1.)*2.*WTWALE+((DTRNCH-DROCK)/10.-1.)*2.*13. 080750 0000
C VERTICAL CUTS IN SOIL LESS THAN 20 FEET HAVE ONE STRUT 080760 0000
1560 IF(STRUT.LT.BE*WTSTRT/15.) STRUT=BE*WTSTRT/15. 080770 0000
C THERE ARE TWO WALES FOR EVERY STRUT AND A MINIMUM OF TWO WALES 080780 0000
C CONNECTING DECKED SOLDIER PILES IN ROCK 080790 0000
IF(IDECK.EQ.1.AND.DROCK.LT.DTRNCH.AND.WALE.LT.2.*WTWALE+26.) 080800 0000
1 WALE=2.*WTWALE+26. 080810 0000
IF(WALE.LT.2.*WTWALE) WALE=2.*WTWALE 080820 0000
080830 0000
080840 0000

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## COSTUN Listing (Continued)

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C NO STRUTS IF COMPLETELY SUPPORTED BY ANCHORS 080850 0000  
 IF(1BRACE.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. 1BRACE.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  
 CC 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 EMBEDDED 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  
 DWTAUG=SQRT(6. \*(2.\*WTSP\*SPLT+WTSPD\*SPDLT)/(2.\*SPLT+SPDLT)) 081110 0000  
 SPLTAU=(2.\*SPLT+SPDLT)/3. 081120 0000  
 UCL=UCL+(0.009\*(DWTAUG+7. )\*\*2-0.2)\*0.4\*SPLTAU\*AR/HOURS 081130 0000  
 UCE=UCE+0.02\*DWT AUG\*SPLTAU\*AR/HOURS 081140 0000  
 UCM=UCM+0.012\*DWT AUG\*SPLTAU+0.1\*PILE 081150 0000  
 C----- 081160 0000  
 CC ADD COST OF LAGGING 081170 0000  
 C----- 081180 0000  
 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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## COSTUN Listing (Continued)

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BL=DROCK*3.*2./1000.          081280 0000
GO TO 1700                     081290 0000
1680 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
----- 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(UTANCH/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
----- 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
UCLR=110.*ANCHLT*(DTRNCH-DROCK)*AR/HOURS/(1.2+130./(110.-RQD))**2 081690 0000
1/(50.-0.25*ANCHLT)             081700 0000
IF(UCLR.LT.54.) UCLR=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+UCLR                    081760 0000
UCE=UCE+UCERB                  081770 0000
UCM=UCM+UCMRB                  081780 0000
1800 IF(MEX.EQ.7) GO TO 300      081790 0000
----- 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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## COSTUN Listing (Continued)

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C   ADD COST OF TIMBER                               081860 0000
1820 UCL=UCL+0.072*BE*AR/HOURS                  081870 0000
      UCE=UCE+0.009*BE*AR/HOURS                  081880 0000
      UCM=UCM+0.18*BE                           081890 0000
C   ADD COST OF GIRDERS AND STRINGERS             081900 0000
      UCL=UCL+15.+(5.3*BE+580.)*2/40000.        081910 0000
      UCE=UCE+6.5+7.*((BE+100.)*2/10000.        081920 0000
      UCM=UCM+0.16*(5.3*BE+30.)                  081930 0000
      GO TO 300                                  081940 0000
      END                                         081950 0000
      SUBROUTINE LINING1(CL,L,CEL,CML,CLFU,CEFU,CMFU,ITYPE,LINING,RQD,MEX
1,WEB,TL,B0B,B0B40,BF,Y,DM,B0B60,ISHAPE,BE,UCLT,UCET,MTM,
2UCLMH,UCEMH,SFA,N0FORM,AR,NSTYP,PSOIL,PWATER,UL,SFP,
3FORMAR,HOURS,CFCA,CFLWWK,CFEWWK)            081960 0000
C   -----
C   LINING CALCULATES THE LINING COSTS AND THE FORMWORK COST FOR A    082000 0000
TUNNEL OR SHAFT SEGMENT                                         082010 0000
C   -----
C   IF(NSTYP.EQ.3) GO TO 910                                     082020 0000
C   ***** ROCK OR SOFT GROUND *****                                082030 0000
C   II IS A FLOW INDICATOR                                         082040 0000
C   -----
C   -----
C   IS SEGMENT LINED                                         082050 0000
C   IF(LINING.GT.0) GO TO 37                                    082060 0000
C   SEGMENT IS UNLINED --- SET ALL COSTS TO ZERO               082070 0000
      CLL=0.0                                         082080 0000
      CEL=0.0                                         082090 0000
      CML=0.0                                         082100 0000
2 CLFU=0.0                                         082110 0000
      CEFU=0.0                                         082120 0000
      CMFU=0.0                                         082130 0000
      RETURN                                         082140 0000
C   -----
C   -----
C   RATIO OF REINFORCEMENT TO CONCRETE BY VOLUME                082150 0000
C   -----
C   SET MINIMUM STEEL REQUIREMENTS                            082160 0000
37 IF(NSTYP.EQ.1) RSTMN=0.005                         082170 0000
      IF(NSTYP.EQ.2) RSTMN=0.01                         082180 0000
      IF(ITYPE.EQ.2) GO TO 49                         082190 0000
C   TUNNEL SEGMENT                                         082200 0000
      GO TO(41,42,45),ISHAPE                         082210 0000
C   CIRCLE                                         082220 0000
41 RST=RSTMN                                         082230 0000
      GO TO 4                                         082240 0000
C   HORSESHOE                                         082250 0000
42 RST=0.014-7.3E-8*PWATER                         082260 0000
      IF(LINING.EQ.1) PMINT=195000/BF**1.7          082270 0000
      IF(LINING.EQ.2) PMINT=36500/BF**1.6           082280 0000
44 RSTMNT=0.014-7.3E-8*PMINT                         082290 0000
      GO TO 48                                         082300 0000
C   BASKETHANDLE                                         082310 0000
45 RST=0.014-6.6E-8*PWATER                         082320 0000
      IF(LINING.EQ.1) PMINT=280000/BF**1.9          082330 0000
                                                082340 0000
                                                082350 0000
                                                082360 0000
                                                082370 0000
                                                082380 0000
                                                082390 0000
                                                082400 0000
                                                082410 0000
                                                082420 0000
                                                082430 0000

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(Continued)

## COSTUN Listing (Continued)

```

48 IF(LINING.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(ISSHAP.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=RSTMNT+(RSTMNT-RSTMNT)*PWATER/PMINT 082540 0000
IF(RST.LT.RSTMNT) RST=RSTMNT                 082550 0000
C      -----
C      IS IT A SOFT GROUND TUNNEL OR SHAFT    082560 0000
4 IF(NSTYP.EQ.2) GO TO 40                  082570 0000
C      ROCK TUNNELS OR SHAFTS                  082580 0000
C      CHECK RQD                                082590 0000
5 IF(RQD.LE.40.) GO TO 40                  082600 0000
IF(RQD.GE.60.) GO TO 20                  082610 0000
C      RQD IS BETWEEN 40 AND 60, INTERPOLATION OF COSTS IS NECESSARY. 082620 0000
C      COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE 082630 0000
C      INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD. 082640 0000
10 II=1                                    082650 0000
C      STORE THE CORRECT VALUES OF RQD AND BOB 082660 0000
RQDD=RQD                                 082670 0000
BBOB=BOB                                 082680 0000
C      ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE 082690 0000
RQD=40.                                 082700 0000
BOB=BOB40                               082710 0000
GO TO 55                                 082720 0000
C      RQD .GE. 60                            082730 0000
20 II=4                                    082740 0000
30 F=1.                                     082750 0000
      GO TO (200,300),LINING                082760 0000
C      RQD .LE. 40                            082770 0000
40 II=4.                                   082780 0000
55 IF(LINING.EQ.1) GO TO 200               082790 0000
C      IS THIS A SOFT GROUND TUNNEL OR SHAFT 082800 0000
IF(NSTYP.EQ.2) GO TO 300               082810 0000
S=0.05*RQD+1.25                         082820 0000
C      TL IS STORED IN FEET                082830 0000
C      59 IF( TL.LT.WEB) GO TO 70           082840 0000
C      F IS A FACTOR FOR INCREASING SHOTCRETE VOLUME OVER STEEL SETS 082850 0000
60 F=1.                                     082860 0000
      GO TO 300                            082870 0000
70 F=(S+WEB/4.)/S                         082880 0000
      GO TO 300                            082890 0000
C      **** CONCRETE LINING ****            082900 0000
C      -----
C      200 UL=SFA/27.*((BOB**2-BF**2))        082910 0000
ULREIM=SFA/27.*((BE**2-BF**2.))          082920 0000
IF(NSTYP.EQ.2) UL=4./27.*SFA*TL*(BF+TL)  082930 0000
IF(NSTYP.EQ.2) ULREIM=UL                  082940 0000
WREIM=491.*RST*ULREIM*27.                  082950 0000
      GO TO (220,260),ITYPE                082960 0000
220 IF(NSTYP.EQ.2) GO TO 230              082970 0000
                                082980 0000
                                082990 0000
                                083000 0000
                                083010 0000

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(Continued)

## COSTUN Listing (Continued)

```

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

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(Continued)

## COSTUN Listing (Continued)

```

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=UL*UCM 083650 0000
-----
C IF(II.GE.3) GO TO 525 083660 0000
C IF(II.GE.2) GO TO 500 083670 0000
C STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=40 083680 0000
CL40=CLL 083690 0000
CE40=CEL 083700 0000
CM40=CML 083710 0000
C REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF 083720 0000
INTERPOLATION COMPUTATION 083730 0000
RQD=60 083740 0000
BOB=BOB60 083750 0000
C REDEFINE FLOW INDICATOR 083760 0000
II=II+1 083770 0000
GO TO 30 083780 0000
-----
C C STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=60 083790 0000
500 CL60=CLL 083800 0000
CE60=CEL 083810 0000
CM60=CML 083820 0000
C INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN LINING COSTS 083830 0000
CLL=CL40+(RQDD-40.)/20.*(CL60-CL40) 083840 0000
CEL=CE40+(RQDD-40.)/20.*(CE60-CE40) 083850 0000
CML=CM40+(RQDD-40.)/20.*(CM60-CM40) 083860 0000
C REINSTATE ORIGINAL VALUES OF RQD AND BOB 083870 0000
RQD=RQDD 083880 0000
BOB=BBOB 083890 0000
-----
C C UNIT COST OF FORMWORK EQUALS ZERO FOR SHOTCRETE 083900 0000
525 IF(LINING.EQ.2) GO TO 2 083910 0000
C LINING IS CONCRETE. CHECK FOR SUPPRESSED FORMWORK COSTS 083920 0000
IF(NOFORM.GT.0) GO TO 2 083930 0000
C UNIT COST OF FORMWORK IN TUNNELS 083940 0000
UCL=9.*BF*CFLCA 083950 0000
IF(ISSHAP.EQ.1) X=2.2 083960 0000
IF(ISSHAP.EQ.2) X=2.0 083970 0000
IF(ISSHAP.EQ.3) X=1.6 083980 0000
UCE=15.+X*BF 083990 0000
UCM=0.18*BF 084000 0000
AL=3.*HOURS 084010 0000
IF(NSTYP.EQ.2) AL=AR 084020 0000
GO TO 700 084030 0000
C UNIT COST OF FORMWORK IN SHAFTS 084040 0000
550 IF(ISSHAP.EQ.1) SFP=3.14 084050 0000
IF(ISSHAP.EQ.2) SFP=4. 084060 0000
UCL=25.+4.*BF 084070 0000
UCE=(10.+1.5*BF)*SFP/3.14 084080 0000
UCM=0.7*BF 084090 0000
AL=2.*HOURS 084100 0000
GO TO 700 084110 0000
C

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## COSTUN Listing (Continued)

```

C COMPUTE FORMWORK COSTS
 700 CLFU=(HOURS*CFLWK+Y*DM)*UCL/AL          084180 0000
      CEFU=HOURS*CFEWK*UCE/AL                  084190 0000
      CMFW=UCM                                 084200 0000
      GO TO 1000                               084210 0000
C ***** CUT AND COVER *****                  084220 0000
 910 IF(ITYPE.EQ.2) GO TO 940                084230 0000
C TUNNEL                                     084240 0000
IF(LINING.EQ.3) GO TO 930                  084250 0000
C -----
C CIP BOX
UCL=480.-0.075*(70.-UL)**2                 084260 0000
UCE=55.-0.008*(65.-UL)**2                   084270 0000
UCM=26.*UL
HOURCR=UL *AR/(110.-0.03*(UL -60.))**2   084280 0000
IF(HOURCR.LT.8.) HOURCR=8                  084290 0000
CLL=UCL*HOURCR/AR*CFLWK                  084300 0000
CEL=UCE*HOURCR/AR*CFEWK                  084310 0000
CML=UCM                                 084320 0000
HOURCR=FORMAR*AR/(680.-0.004*(FORMAR-400.))**2 084330 0000
IF(HOURCR.LT.8) HOURCR=8                  084340 0000
CLFU=(100.+0.85*FORMAR)*HOURCR/AR*CFLWK  084350 0000
CEFW=(8.+(FORMAR+100.))**2/4500.)*HOURCR/AR*CFEWK 084360 0000
CMFW=0.35*FORMAR                         084370 0000
RETURN                                    084380 0000
C -----
C PRECAST CONCRETE BOX
 930 UCL=(0.07*(UL +10.))**2-7.)*50./UL    084390 0000
      UCE=(0.007*(UL +80.))**2-45.)*50./UL    084400 0000
      UCM=104.*UL                                084410 0000
      HOURCR=UL*AR/50.                           084420 0000
      IF(HOURCR.LT.8.) HOURCR=8                084430 0000
      CLL=UCL*HOURCR/AR*CFLWK                084440 0000
      CEL=UCE*HOURCR/AR*CFEWK                084450 0000
      CML=UCM                                 084460 0000
      GO TO 2                                  084470 0000
C -----
C SHAFT
 940 IF(ISSHAP.EQ.2) GO TO 945              084480 0000
      SFP=3.14                                084490 0000
      GO TO 950                                084500 0000
 945 SFP=4                                  084510 0000
 950 UL=(BF+TL)*TL*SFP/27.                  084520 0000
      UCL= 0.07*(UL +10.))**2-7.               084530 0000
      UCE= 0.007*(UL +80.))**2-45.             084540 0000
      UCM=104.*UL                                084550 0000
      CLL=UCL*CFLWK                            084560 0000
      CEL=UCE*CFEWK                            084570 0000
      CML=UCM                                 084580 0000
      GO TO 2                                  084590 0000
 1000 RETURN                                 084600 0000
      END                                     084610 0000
      SUBROUTINE CGROUT(CLG,CEG,CMG,ITYPE,GI,ISSHAP,BE,AR,RS,NSTYP, 084620 0000
      1MSTAB, DTUM,HH,HOURS,CFLWK,CFEWK,$SEG,PERM,SFP,DIG,TIMEG) 084630 0000
      -----
      -----
C CGROUT CALCULATES THE COST OF GROUTING IN A TUNNEL OR SHAFT 084640 0000
      ----- 084650 0000
      ----- 084660 0000
      ----- 084670 0000
      ----- 084680 0000
      ----- 084690 0000
      ----- 084700 0000
      ----- 084710 0000
      ----- 084720 0000
      ----- 084730 0000
      ----- 084740 0000
      ----- 084750 0000

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(Continued)

## COSTUN Listing (Continued)

```

C SEGMENT 084760 0000
C ----- 084770 0000
C ----- 084780 0000
C ----- 084790 0000
C IF(NSTYP.EQ.2) GO TO 500 084800 0000
C IF(NSTYP.EQ.3) GO TO 650 084810 0000
C ***** ROCK ***** 084820 0000
C IF(ITYPE.EQ.2) GO TO 300 084830 0000
C ----- 084840 0000
C TUNNEL 084850 0000
C 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(ISSHAPE.EQ.1) SFP=3.14 084920 0000
IF(ISSHAPE.EQ.2) SFP=3.57 084930 0000
IF(ISSHAPE.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(ISSHAPE.LE.2.AND.DTUN-BE/2..GT.50.) GO TO 600 085190 0000
IF(ISSHAPE.EQ.3.AND.DTUN-BE/4..GT.50.) GO TO 600 085200 0000
C GROUTING FROM GROUND SURFACE 085210 0000
TIMEG=0.6+DTUN/20.+BE/40. 085220 0000
IF(ISSHAPE.EQ.3) TIMEG=0.6+DTUN/20.+BE/80. 085230 0000
UCL=79.*(BE+10.)/25.*TIMEG*AR/HOURS 085240 0000
UCE=15.*(BE+10.)/25.*TIMEG*AR/HOURS 085250 0000
UCM=3.*TIMEG*(BE+10.)/25.+0.25*(BE+10.)**2*(0.55+0.15* ALOG10(SQRT
1(10.*ABS(PERM)))/(1.55+0.15* ALOG10(SQRT(10.*ABS(PERM)))) 085260 0000
IF(ISSHAPE.EQ.3) UCM=3.*TIMEG*(BE+10.)/25.+0.25*(BE+10.)*(0.5*BE+
110.)*(0.55+0.15* ALOG10(SQRT(10.*ABS(PERM)))/(1.55+0.15* ALOG10(SQ
2RT(10.*ABS(PERM))))) 085270 0000
GO TO 1000 085280 0000
C GROUTING FROM EXCAVATION FACE 085290 0000
600 UCL=0 085300 0000
085310 0000
085320 0000
085330 0000

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## COSTUN Listing (Continued)

```

UCE=3.4*BE          085340 0000
UCM=0.14*BE+0.8*(0.55+0.15* ALOG10(SQRT(10.*ABS(PERM))))/
1(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))*BE*SFP      085350 0000
GO TO 1000          085360 0000
085370 0000
085380 0000
085390 0000
085400 0000
085410 0000
085420 0000
085430 0000
085440 0000
085450 0000
085460 0000
085470 0000
085480 0000
085490 0000
085500 0000
085510 0000
085520 0000
085530 0000
085540 0000
085550 0000
085560 0000
085570 0000
085580 0000
085590 0000
085600 0000
085610 0000
085620 0000
085630 0000
085640 0000
085650 0000
085660 0000
085670 0000
085680 0000
085690 0000
085700 0000
085710 0000
085720 0000
085730 0000
085740 0000
085750 0000
-
```

(Continued)

## COSTUN Listing (Continued)

```

C   SET COSTS=0          085760 0000
C   UCL=0.                085770 0000
C   UCE=0.                085780 0000
C   UCM=0.                085790 0000
C   GO TO 800              085800 0000
C   -----
C   DEEP WELL PUMPING      085810 0000
C   -----
C   SOFT GROUND            085820 0000
C   100 IF(ITYPE.EQ.2) GO TO 250 085830 0000
C   -----
C   TUNNEL                 085840 0000
C   WELLIN=ELSURF-ELBOTM   085850 0000
C   PROVIDE 5 DAYS PUMPING AHEAD OF EXCAVATION TO REVERSE FLOW 085860 0000
C   PROVIDE 50 FT FINISHED LINING PAST PUMP BEFORE STOPPING ITEM 085880 0000
C   IF(ISUPPT.LE.3) GO TO 180 085890 0000
C   STEEL RIBS WITH LINING 085900 0000
C   PROVIDE THE GREATER OF TIME TO FINISH 50 FT LINING AHEAD OF PUMP, 085910 0000
C   OR 30 CALENDAR DAYS FOR CURING OF CONCRETE 085920 0000
C   SHOTCRETE IS PLACED UP TO THE FACE. CONCRETE IS KEPT 150 FT 085930 0000
C   BEHIND FACE.           085940 0000
C   IF(50./AR*7./DAYS.GE.30.) GO TO 150 085950 0000
C   -----
C   PUMPING TIME CONTROLLED BY CURING TIME 085960 0000
C   CONCRETE               085970 0000
C   IF(LINING.EQ.1) PUMPTM=35.+150./AR*7./DAYS 085980 0000
C   SHOTCRETE              085990 0000
C   IF(LINING.EQ.2) PUMPTM=35. 086000 0000
C   GO TO 450              086010 0000
C   -----
C   PUMPING TIME CONTROLLED BY PLACING RATE OF LINING 086020 0000
C   CONCRETE               086030 0000
C   150 IF(LINING.EQ.1) PUMPTM=5.+200./AR*7./DAYS 086040 0000
C   SHOTCRETE              086050 0000
C   IF(LINING.EQ.2) PUMPTM=5.+50./AR*7./DAYS 086060 0000
C   GO TO 450              086070 0000
C   -----
C   SEGMENTED SUPPORT       086080 0000
C   180 PUMPTM=5.+50./AR*7./DAYS 086090 0000
C   GO TO 450              086100 0000
C   -----
C   SHAFT                   086110 0000
C   250 IF(ELWATR.LT.ELNPB) GO TO 950 086120 0000
C   -----
C   -----
C   -----

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(Continued)

## COSTUN Listing (Continued)

```

C PUMPING TIME DETERMINED IN COSTSF          086180 0003
C WELLS=3                                     086190 0003
C NO WELLS IF FLOW=0                         086200 0000
C IF(FLOWL.LT.0.0001) WELLS=0                 086210 0000
C CONSIDER 1 FT LENGTH OF SHAFT             086220 0000
C WELLLN=1                                    086230 0000
C GO TO 450                                   086240 0000
C -----
C CUT-AND-COVER                             086250 0000
C 300 IF(ITYPE.EQ.2) GO TO 950              086260 0000
C TUNNEL                                     086270 0000
C IF(ELWATR.LT.ELSURF-DTRNCH) GO TO 950    086280 0000
C IF(IWATER.EQ.0) GO TO 900                  086290 0000
C IS IT SOLDIER PILE WITH LAGGING         086300 0000
C IF(ISUPPT.EQ.5) GO TO 350                 086310 0000
C IF(DROCK.LT.DTRNCH .AND. ELWATR.LT.ELSURF-DROCK) GO TO 950 086320 0000
C GO TO 400                                   086330 0000
C IS ROCK LINE ABOVE TRENCH BOTTOM        086340 0000
C 350 IF(DROCK.LT.DTRNCH) GO TO 900        086350 0000
C 400 PUMPTM=(1./AR+(TIMEDW+10.)/RL)*7./DAYS 086360 0000
C IF(LINING.EQ.1) PUMPTM=(1./AR+(TIMEDW+40.)/RL)*7./DAYS 086370 0000
C WELLN=DTRNCH                            086380 0000
C IF(WELLN.GT.DROCK) WELLN=DROCK          086390 0000
C 450 PIPED=0.5*FLOWL**0.4                 086400 0000
C IF(PIPED.LT.1.) PIPED=1                  086410 0000
C SETUP COST OF DEEP WELLS                086420 0000
C UCL=(0.4*PIPED+3.2)*WELLN*WELLS*AR/24.*DAYS/7.*CFLWK/1.12 086430 0000
C UCE=(0.15*PIPED+1.)*WELLN*WELLS*AR/24.*DAYS/7.*CFEWK/0.715 086440 0000
C UCM=(0.75*PIPED+3.)*WELLN*WELLS*AR/24.*DAYS/7. 086450 0000
C OPERATING COST OF DEEP WELLS           086460 0000
C UCL=UCL+0.85*WELLS*PUMPTM*AR*DAYS/7. 086470 0000
C UCE=UCE+0.000265*FLOWL*PH*(0.0026+7./(2000.+0.000265*FLOWL*PH))* 086480 0000
C 1WELLS*PUMPTM*AR*DAYS/7. 086490 0000
C UCM=UCM+5.*PH*FLOWL/1000000.*WELLS*PUMPTM*AR*DAYS/7. 086500 0000
C SETUP                                     086510 0000
C IS IT CUT-AND-COVER                     086520 0000
C IF(MSTYP.EQ.3) GO TO 1000               086530 0000
C SOFT GROUND                                086540 0000
C IF(ITYPE.EQ.2) GO TO 1000               086550 0000
C -----
C PUMPING FROM TUNNEL                      086560 0000
C -----
C                                         086570 0000
C                                         086580 0000
C                                         086590 0000

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(Continued)

## COSTUN Listing (Continued)

```

C----- 086590 0000
C 800 IF(FLOW.GT.0.) GO TO 850 086600 0000
C NO COST IF FLOW IS ZERO 086610 0000
C GO TO 1000 086620 0000
C----- 086630 0000
C 850 IF(PH.LE.0.) GO TO 1000 086640 0000
UCL=UCL+5.+11.*PH/3000.+0.003*PIPL 086650 0000
UCE=UCE+(0.25+PH/2000.)*FLOW/500. 086660 0000
UCM=UCM+5.*PH/1000.*FLOW/1000. 086670 0000
GO TO 1000 086680 0000
C----- 086690 0000
C SUMP PUMPING 086700 0000
C----- 086710 0000
C 900 PUMPTM=(1./AR+10./RL)*7./DAYS 086720 0000
IF(LINING.EQ.1) PUMPTM=(1./AR+40./RL)*7./DAYS 086730 0000
UCL=5.*PUMPTM/500.*AR*DAYS/7. 086740 0000
UCE=0.4*PUMPTM/500.*AR*DAYS/7. 086750 0000
UCM=(0.15+0.0000044*PH*FOWL)*PUMPTM/500.*AR*DAYS/7. 086760 0000
GO TO 1000 086770 0000
C SHAFT 086780 0000
C----- 086790 0000
C 950 CLP=0. 086800 0000
CEP=0. 086810 0000
CMP=0. 086820 0000
RETURN 086830 0000
C----- 086840 0000
C CALCULATE PUMPING COSTS 086850 0000
1000 CLP=UCL*24/AR*7./DAYS*1.12 086860 0000
CEP=UCE*24./AR*7./DAYS*0.715 086870 0000
CMP=UCM*24./AR*7./DAYS 086880 0000
RETURN 086890 0000
END 086900 0000
SUBROUTINE CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NSTYP,MSTAB,
1 ITYPE,AIRPR,SFA,ISHAPE,HH,CAUT,ALOCK,DTC,DTCA,PUMPLT,DM, 086910 0000
2 ALOCKL,UCMCP,CFLWUK,CFEWUK,DAYS,Y,PERM) 086920 0000
C----- 086930 0000
C CAIRC COMPUTES THE COSTS OF VENTILATION, AIR COOLING, 086940 0000
C COMPRESSED AIR, AND AIR LOCKS 086950 0000
C----- 086960 0000
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----- 086970 0000
C SHAFT OR TUNNEL 086980 0000
50 IF(ITYPE.EQ.2) GO TO 300 086990 0000
***** TUNNELS *****
C----- 087000 0000
C CHECK COOLING REQUIREMENT 087010 0000
IF(Q.GT.0.) GO TO 100 087020 0000
C----- 087030 0000
C NO COOLING 087040 0000
UCLC=0. 087050 0000
UCLMC=0. 087060 0000
UCEC=0. 087070 0000
UCMC=0. 087080 0000
GO TO 200 087090 0000
C----- 087100 0000
C COST OF SETUP AND OPERATION OF COOLING PLANT 087110 0000
100 IF(ALOCK.GT.0.) UCLMC=QT*ALOCK/48. 087120 0000
IF(ALOCK.LT.0.) UCLMC=QT*(1.-ALOCK)/48. 087130 0000
UCLC=8.20 087140 0000
UCEC=0.0000013*QT 087150 0000
UCMC=0.0000009*Q 087160 0000

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(Continued)

## COSTUN Listing (Continued)

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C -----
C 200 IF(MSTAB.NE.1) GO TO 60 087170 0000
C COMPRESSED AIR 087180 0000
C CAV=(28.5+10.*ALOG10(D10))*SFA*BEX**2 087190 0000
C ALOKA=ABS(ALOCK) 087200 0000
C UCLCA=16.4 087210 0000
C COSTS OF AIR LOCK AND SETUP 087220 0000
C UCLLKA=20.4 087230 0000
C UCLLOK=(38000.+3.*HH)*(1.+0.25*(ALOKA-1.)) 087240 0000
C UCELOK=(10000.+0.8*HH)*(1.+0.25*(ALOKA-1.)) 087250 0000
C ALOCKD=BF 087260 0000
C IF(ISSHAP.EQ.3) ALOCKD=0.5*BF 087270 0000
C IF(ALOCKD.GT.15.) ALOCKD=15. 087280 0000
C IF(ALOCKL.LT.30.) ALOCKL=30. 087290 0000
C WALOCK=16.*ALOCKD*(ALOCKL+ALOCKD) 087300 0000
C VBULK=5.*((SFA*BF**2-0.785*ALOCKD**2)/27. 087310 0000
C UCLMCA=(1200.+0.1*HH)*(1.+0.25*(ALOKA-1.))+140.*VBULK*ALOKA 087320 0000
C COST OF COMPRESSED AIR PLANT, SETUP AND OPERATION 087330 0000
C UCLMCA=0.075*(30000.+14.4*CAUT)*ALOKA 087340 0000
C UCECA=2.3+0.0011*CAUT 087350 0000
C UCMCA=0.003*CAU*((AIRPR+14.7)/14.7+0.000123*PUMPLT)**0.242-1.) 087360 0000
C CLAC=(UCLLKA*HOURS/AR+UCLMC/DTC+(UCLMCA+UCLLOK)/DTCA)*CFLWWK 087370 0000
1 +(UCLCA+UCLC)*24./AR*7./DAYS*1.12 087380 0000
CEAC=(UCEC+UCECA)*24./AR*7./DAYS*0.715+UCELOK/DTCA*CFEWWK 087390 0000
CMAC=(UCMC+UCMCA)*24./AR*7./DAYS+UCMCP+UCMLOK/DTCA 087400 0000
1 +0.000015*WALOCK*HOURS/AR 087410 0000
GO TO 500 087420 0000
C -----
C CALCULATE UNIT COSTS OF VENTILATION 087430 0000
C 60 UCLU=3.*DM 087440 0000
C UCEU=0.5+0.625*SFA*BEX**2/1000. 087450 0000
C UCMU=3.3*SFA*BEX**2*DM/1000. 087460 0000
C UCMDFU=3.+SFA*BEX**2/200. 087470 0000
C CLAC=UCLU*(HOURS*CFLWWK+0.5*Y*DM)/AR 087480 0000
C IF(DTC.GT.0.) CLAC=CLAC+(UCLMC/DTC+HOURS*UCLC/AR/4.)*CFLWWK 087490 0000
C CEAC=(UCEU+UCEC*HOURS/AR/4.)*CFEWWK 087500 0000
C CMAC=UCMDFU+HOURS*UCMU/AR+UCMC*HOURS/AR/4. 087510 0000
C GO TO 500 087520 0000
C ***** SHAFTS ***** 087530 0000
C COMPRESSED AIR AND COOLING COSTS 087540 0000
C 300 IF(NSTYP.EQ.1.OR.MSTAB.NE.1) GO TO 400 087550 0000
C CAV=(28.5+10.*ALOG10(D10))*SFA*BEX**2 087560 0000
C Q=75.*CAV+20.*SQRT(CAV)+5000. 087570 0000
C UCLCA=8.20 087580 0000
C UCEC=0.0000013*Q 087590 0000
C UCECA=2.3+0.0011*CAU 087600 0000
C UCMCA=0.0000009*Q 087610 0000
C UCMCA=0.003*CAU*((AIRPR+14.7)/14.7+0.0025)**0.242-1.) 087620 0000
C CLAC=UCLCA*24./AR*1.12 087630 0000
C CEAC=(UCEC+UCECA)*24./AR*0.715 087640 0000
C CMAC=(UCMC+UCMCA)*24./AR 087650 0000
C GO TO 500 087660 0000
C 400 CLAC=0. 087670 0000
C CEAC=0. 087680 0000
C CMAC=0. 087690 0000
C -----
C 500 RETURN 087700 0000
C END 087710 0000
C ----- 087720 0000
C 087730 0000
C 087740 0000

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(Continued)

## COSTUN Listing (Concluded)

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SUBROUTINE NEXSET(L0,L1)          087750 0000
DIMENSION A(4),B(4)              087760 0000
DATA A/4HEND,4HOF S,4HYSTE,4HM  087770 0000
WRITE(L0,1) A                   087780 0000
 5 READ(L1,2) 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,
1 ITYPE,Y,NSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTCTAL,BOB,LINUT,
2 MSTAB,CFLCA,HOURS,CFLWWK,CFEWWK,SFA,LINING,DM,CLL,CEL,CML,
3 CLFW,CEFWR,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
  UBACKG=SFA*(BE**2-(BE-.333)**2)
  UCL=UCL+1.3*UBACKG*AR/HOURS
  UCE=UCE+.5*UBACKG*AR/HOURS
  UCM=UCM+1.2*UBACKG
  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

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(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