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INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES EXCAVATION METHOD, AND MUCK CHARACTERISTICS

H. F. Haller, et al

Holmes and Narver, Incorporated

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Final Technical Report

INTERRELATIONSHIP OF IN-SITU ROCK PROPERTIES, EXCAVATION METHOD, AND MUCK CHARACTERISTICS

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13. ABSTRACT

Reports results of research to correlate the properties of in-situ rocks with materials handling properties of muck and parameters of excavation systems. Goals are to develop methods for predicting muck characteristics from collected data and for selection of transport equipment through the Muck Designation Number concept. Muck sample, rock, and operating data collection, testing methods, data processing, development of MDN, regression analyses, and equipment selection are described. Data for 52 samples from 23 mine and tunnel sites are presented in raw data printout and narrative-graphic summary form, showing lithology, rock properties, operating data, muck properties, and equipment applications. MDN are described by composite size and distribution curves, with regression analyses of 47 data sets and prediction accuracies of over 80 percent. Applications to equipment selection and design illustrate input to formulas used in design of belt and hydraulic conveying systems. DoD implications include more rational transport equipment selection and design, with resultant speed and cost benefits. Recommended additional research includes sampling operations and formations not previously available, resampling to improve the confidence level of the data, testing for abrasiveness in addition to tests previously performed, and predictor refinements. Development of computerized methods for defining hardware, computer simulation of tunnel systems, and field verification of the concepts are also recommended.

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FOREWORD

This report presents the results of a research program, completed in 1973, into the interrelationships of in-situ rock properties and the characteristics of muck produced by various excavation methods. The authors wish to express their appreciation and that of Holmes & Narver, Inc., for the assistance provided by the many U. S. Bureau of Mines and Holmes & Narver staff members, as well as those individuals and organizations listed below who also participated in the program.

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PURPOSE

The purpose of the program is to develop a method for predicting the materials handling properties of muck from the engineering properties of rock and the parameters of excavation systems, and means of selecting the most suitable transportation equipment for the muck through the concept of Muck Designation Numbers (MDN).

MDN range in whole numbers from 1 through 7. MDN 1 describes muck with a large maximum piece size, more than 20 percent plus 6-inch material, and a predominant distribution in the plus 1/2-inch size range. The maximum size of MDN 7 is relatively small; the predominant distribution is minus 1/2 inch, and more than 5 percent is minus 100 mesh in size. Intermediate numbers range in size and size distribution between end points. The concept recognizes that muck characteristics vary with excavation methods as well as rock properties.

SCOPE

This report describes results of research performed under an eighteen-month contract initiated on February 16, 1972. The work is a continuation of a previous 1-year contract the results of which also are summarized to present the total accomplished and the current status of the program.

CONCLUSIONS

Program activities have included sample and data collection, physical testing, data storage and processing, development of MDN, correlation with rock properties, establishing the parameters of muck handling systems, and illustrations of MDN applications to subsystem and hardware selection.

Regression analysis of 27 sets of rock property, Raise Boring Machine (RBM), and Tunnel Boring Machine (TBM) data produced a predictor equation with an apparent accuracy over 80 percent. Analysis of 20 sets of rock data with conventional excavation parameters produced an equation with an apparent accuracy of more than 90 percent.

An expected drop in apparent predictor accuracy to below preliminary levels did occur, and appropriate parameters remain to be developed for shield and drag cutter TBMs. However, it is concluded that MDN are predictable within the limits of reasonable accuracy for the majority of rocks and methods sampled under the program.

The examples show that MDN can be used to eliminate some transport subsystems from consideration, and to define the hardware required for use in the subsystems which are applicable. They also support a conclusion that computerized procedures for hardware definition should be developed. Areas which appear to require clarification prior to this development, and means of developing systems simulation as a construction planning tool are discussed.

REFERENCE TO DETAILS

Details of the topics summarized below are arranged under the same headings in the report.

SUMMARY

1. Technical Problems

Inadequate subsurface information on new tunnels limits the effectiveness of construction planning and forces contractors to base bids on methods and equipment which may not suit the job. Loss of time, lives, and money has often resulted.

Estimates of the volume of tunnel construction made several years ago focused attention on the importance of a more logical approach to methods and equipment selection. The advisability of increasing excavation speed while reducing costs has been reemphasized by recent studies which show that prior tunneling forecasts were conservative.

Muck transportation obviously is a major factor in tunnel cost; improvements would reduce tunnel costs significantly. Knowledge of the basic properties of a material is fundamental to improvement of handling techniques. Prior to the inception of the MDN program, however, practically no information had been collected on muck characteristics; and correlations between muck properties, the properties of the in-situ rock, and the components of rapid excavation systems had not been established.

These data are essential as a basis for optimum selection from the transportation systems in current use and for development of the high speed systems required in the future. A need also exists for fast, accurate means of defining the hardware required for some subsystems, and for comparing the performance of different total systems or of systems with varied arrangements of components.

2. General Methodology

The research plan was to collect muck samples, lithologic and operating data, and rock specimens where necessary from operating tunnels; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through MDN; and correlate rock and muck characteristics, MDN, and the components of rapid excavation systems with muck transport system capabilities.

Lithologic data consists of descriptions of rocks, their classification by probable origin and subsequent alteration, and Rock Quality Designations (RQDs) which indicate the frequency of discontinuities. Operating data includes descriptions of the equipment and methods used in the total excavation system. Rock test data includes unconfined uniaxial compressive strength, dry unit weight, hardness, and stress-strain relationships known as Young's modulus and Poisson's ratio. Commercial muck test data includes size distribution, shape, moisture content, dry loose unit weight, and abrasiveness. Additional muck tests by the Pittsburgh Mining and Safety Research Center (PMSRC) determine Atterberg limits, potential volume change, specific gravity, angles of repose, slide, and internal friction, apparent cohesion, and bulk density.

3. Technical Results

3.1 Site Selection

A list of current and scheduled tunnels, originally compiled to assure that program objectives could be met, was revised periodically. Excerpts from the last revision are included in Appendix A. Sites for data and sample collection were selected with emphasis on mechanical operations in hard rock. In the first year, some soft rock and conventional tunnels were included as examples of unusual advance rates and systems. In the second year, conventional operations in hard rock at deep mine sites were sampled at client request. Information peculiar to such sites is summarized in Appendix A.

3.2 Sample and Data Collection

In the current program, operating data and 18 muck samples were collected from eight sites. Totals for the program are 52 samples from 23 sites. Resampling at four sites confirmed the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

Rock specimens for engineering property tests have been collected from 41 formations at 22 sites. Twenty-one of the specimens, some of which represent formations sampled in 1971, were collected from ten sites in 1972.

Two shield, two RBM, 19 conventional, and 29 TBM operations have been sampled to date. Rock types sampled include four classified as Very High Strength, 27 High Strength, nine Medium, six Low, and six Very Low Strength. The basis for these classifications follows in the body of the report.

3.3 Physical Testing

Standard tests, approved by the American Society for Testing Materials and/or the U. S. Bureau of Mines, were selected for use by commercial laboratories to ensure consistency of results.

Contracts to perform muck tests were negotiated with 18 commercial laboratories. Samples were delivered for testing and shipment of fractions to the U. S. Bureau of Mines, PMSRC, for additional tests. Under the current contract, the volume of these fractions was increased from 2 to 4 cubic feet. One set of samples tested commercially was lost in transit to the PMSRC.

Contracts to perform rock tests were negotiated with five commercial laboratories. Forty-one sets of rock specimens were collected and tested. Stress-strain data from testing initiated in 1972 were obtained on 24 rocks including six collected in 1971. Schmidt hardness tests, also initiated in 1972, were completed on 33 cores and rock specimens by test methods modified to produce acceptable results. No abrasiveness tests were possible because equipment which was planned for use was not available.

3.4 Data Processing

Formats were developed for storage and printout of lithologic rock, muck, tunnel and transport capability data; all data have been stored on punch cards and printouts, "Raw Data Sheets" are presented in Appendix B. A form was developed for narrative and graphic presentation of data in the "System Data Sheets", included as Appendix C.

3.5 Development of MDN

3.6 Data Analysis

Size distribution curves from initial sampling varied distinctly, generally as had been expected; an algorithm to correlate MDN, in-situ rock properties, and excavation methods was developed as described in Appendix D. Continued sample testing produced some curves which fit well with the initial curves, and others which suggested establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and preliminary MDN were assigned.

Initial regression analyses produced predictor equations indicating accuracies over 90 percent for RBM/TBM and for conventional operations. MDN assignments were modified and consolidated, and additional iterations were performed when all data collected were in final form. Values for Young's modulus, Poisson's ratio, and Schmidt hardness resulting from second year tests were substituted for the less important parameters and inferred values used in the preliminary analyses. Indicated accuracies of prediction were over 80 percent for machine operations and 90 percent for conventional. Composite curves for each MDN, computer input data, and output tabulations are shown in Section 3 of the text.

3.7 Transport System Selection

A list of equipment capabilities, system constraints, and MDN applications has been included in Appendix E. Belt and hydraulic conveying system design parameters and available parametric mathematical models of these systems were studied under the current program. Collected muck property data were used as input to design formulas in examples of MDN data use for design of belt and hydraulic conveying systems. Examples of MDN applications to other systems are shown. Detailed calculations supporting the examples are shown in Appendix E.

4. DoD Implications

The advantages of underground siting for many DoD installations, and the necessity of such sites for some facilities are well known. The impact of one or many joint-use underground installations on national defense capability, and the importance of tunneling to weapons test programs require no evidence in this report. It is obvious that any action to improve the efficiency of muck handling will affect significant parts of DoD and national budgets in the future.

Data accumulated under the program, nonexistent elsewhere in rapid excavation technology, can provide a more rational basis for selection of materials handling systems for excavation methods in current use. These data will also be invaluable to the design of the equipment required to match the improved advance rates resulting from current excavation research. As alternatives to design of systems to handle a specific type of muck, MDN data can be used to select process equipment to change muck characteristics to suit a system, or to select separation and supplementary haulage equipment for the oversize fraction of muck which cannot be handled by a continuous system which is otherwise well adapted to a site.

MDN provide basic data required for a rational engineering approach to problem solutions in a most important subsystem of the rapid excavation process. The examples illustrate data application and identify areas in which improvement is possible. Further use of MDN data should be made to indicate the areas in which research and development of modifications or new methods would be most productive.

5. Implications for Further Research

5.1 Sample and Data Collection

Recommendations for further research are based in part on the following tabulation of formations and excavation systems for which data are available at the end of the current contract.

Excavation Method	Rock Strength					
	Very High	High	Medium	Low	Very Low	Total
Conventional	3	9	5	1	1	19
Shield	0	0	0	0	2	2
Machine						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	3	1	0	0	4
Combination Cutters	0	3	1	1	2	7

To be consistent with good sampling and testing practices, data reliability should be confirmed by repetition of all single samples. Statistically, the number of samples used in development of a predictor equation should be greater than the number of variables in the analysis. To improve prediction reliability additional samples, detailed in the body of the report, should be collected from all types of TBMs in selected formations.

To demonstrate variations in muck characteristics with rock properties, conventional and selected TBM samples should be collected from the Medium and Low Strength rocks. To provide data on the full range of rock types, stratified volcanic and fine-grained igneous rocks should be sampled. Sampling muck from tests of unusual rock breaking techniques which may become the standards of the future should be initiated to provide data on the muck for which transport systems may be required.

Within the scope of the program, useful operating parameters could not be developed for Atlas-Copco and Alpine machines or for the effective torque applied by other TBMs. Since the two named machines may become important types of equipment for special use, and torque data have been approximated in analysis of other machine operations, future research to develop these parameters is recommended.

5.2 Physical Testing

Continued testing is recommended for the physical property data collected in the past since all commercial test results appear to be important to one of the predictor equations, and the PMSRC test data remains to be evaluated.

Abrasiveness testing should be initiated as soon as possible to provide data for cost analyses. Investigation of the Protodyakonov test for resistance to fragmentation is recommended to determine the effect of a second dynamic property on prediction accuracy.

5.3 Data Analysis

Additional regression analyses should be run to test the effect of using other data and data combinations than those which were possible under the current program, and to review the data input to determine what modifications would be valid.

5.4 Methods Development

Computer methods should be developed in the public domain to define rapidly and accurately the hardware required for those systems for which manual procedures are time-consuming and expensive. Systems simulation data and programs should also be developed to provide a fast means of comparing the performance of different systems or of varying the components of a single system. Wide publicity in lay terms should be given to such developments to accelerate their acceptance by industry.

5.5 Concept Validation

The validity of the MDN concept should be tested in practice by predicting muck characteristics and selecting equipment for proposed tunnels, and comparing the predictions and the selected transport systems with the muck produced and the systems actually used.

6. Special Comments

A Schmidt impact rock test hammer and two self-rescuers were purchased during the reporting period for use in the program No invention has been made in the course of the work performed under this contract.

1. TECHNICAL PROBLEMS

The effectiveness of planning for new tunnels has been limited by the subsurface information which has been available. Owners and owner-agencies often have been reluctant to collect data on the properties of materials to be excavated, or to publish information which has been collected. Interested contractors are forced to base proposals on inadequate data and cost estimates on methods and equipment which may not be best for conditions as they exist. Generally, significant allowances are made for contingencies.

The importance of a more logical approach to selection of methods and equipment for tunneling was reemphasized by recent studies which indicate that prior estimates of demand were conservative. Wider application of tunnel boring machines, which require rock property data for design, and of an engineering approach to ground support have influenced owner and agency policies to collect and disseminate more and better quality exploratory information.

Progress has been made in research to determine relationships between rock properties, drillability, excavation, and ground support. Prior to the current program practically no information had been collected on the characteristics of muck; and correlations between rock and muck characteristics and the components of excavation systems had not been established.

In the absence of muck characteristic data, an adequate basis for selection of transportation subsystems and equipment does not exist, and tunneling progress and cost have been affected adversely. Muck data are also basic requirements for engineering the improvements to existing transport systems and the development of the new systems which will be necessary to keep pace with future excavation rates.

When a concept such as the MDN becomes a reliable predictor for muck characteristics, work remains to be done to provide rapid, accurate methods of defining the hardware required by several possible transport methods, and determining their relative capabilities. Studies of design methods used for belt and hydraulic conveying systems show that as manual procedures, they are tedious, repetitive, and mathematical; faster and less expensive methods would encourage greater use of results. Production and cost comparisons between subsystems, and between different arrangements of a single system are also time-consuming, and become more complicated as injuries and other unscheduled delays are incorporated in an analysis. A more rapid and economical means of comparing alternates would facilitate selection of optimum systems and components.

2. GENERAL METHODOLOGY

The objectives of the program are to develop a method for predicting the materials handling properties of muck from the in-situ properties of rock and the characteristics of excavation systems; and a means of selecting the most suitable transportation systems and equipment for the muck produced. The major emphasis is on mechanical excavation of hard rock. However, some soft rock and conventional operations are included as examples of unusual advance rates, equipment, and operating methods; and to provide comparators to demonstrate those differences which exist.

The program plan is to collect muck samples and operating data from tunnels and mining projects in rock of known properties; collect specimens from sites where the in-situ properties are unknown; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through the concept of Muck Designation Numbers (MDN); and to establish correlations between rock and muck characteristics, MDN, rapid excavation systems, and muck transport equipment.

3. TECHNICAL RESULTS

3.1 SITE SELECTION

A list of operating and scheduled tunnels, prepared originally to assure that program objectives could be met, has been revised periodically to reflect new starts and completions. Anticipating completion of the program, the last revision was made in September, 1972. Excerpts from that list are reproduced in Appendix A to illustrate the form and content. No other listing of this information is known. Letter inquiries inviting program participation by off-continent tunnel operators met with no response.

Tunnel contractors, although under no obligation to participate in the program, have been most cooperative. Operating mine cooperation has been equally good, although access usually requires more operator support, and the impact of economic conditions has reduced emphasis on research. Sample and data collection on a strictly noninterference basis, and full observance of safety requirements have been important in gaining operator acceptance.

Early planning assumed that one basis for site selection would be the availability of rock property data at specific sites. Experience proved that collection of these data is necessary from the majority of locations, and the program was modified to reflect this requirement.

In the first half of 1971, it became apparent that sampling tunnel operations in a wide range of rock strengths and excavation techniques would be necessary to demonstrate that muck characteristics vary distinctively with rock characteristics and operating methods. The program plan was modified to provide for data collection in the variety possible within the limits of time and availability, and additional funds were provided by contract modification to enlarge the scope of field sampling.

In the first year of the program, sites were selected to provide one-third of the samples from conventional excavation. In the second year eight conventional and ten mechanical operations were sampled. In response to a client request to obtain samples and data from conventional operations in strong rocks at maximum depth during 1972, sites were selected for field work in two quartzites at 7,094 feet and 6,100 feet, a phyllite at 6,200 feet, a conglomerate at 3,960 feet, and a graywacke at 3,480 feet below the surface. At some sites, planned sampling of stronger rocks and/or at greater depths could not be accomplished because of site conditions.

3.2 SAMPLE AND DATA COLLECTION

Muck samples and operating data were collected from 23 mine and tunnel sites. Of 52 samples, 11 were collected from sites visited only once. Resampling was done in similar formations at four sites to confirm the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment. The scope of collecting in-situ rock data has been greater than was anticipated originally, because formations encountered in most locations could not be correlated with the existing rock data. Rock specimens or cores have been collected for engineering property tests from 41 formations at 22 sites.

Two shield operations, two RBM, 19 conventional, and 29 TBM operations have been sampled to date. Rock types classified include four Very High, 27 High Strength, nine Medium, six Low, and six Very Low Strength. Early in 1972 a request was received from the Project Officer to increase the volume of samples provided for testing at the Pittsburgh Mining and Safety Research Center (PMSRC) from 2 to 4 cubic feet of minus 2-inch material. Sampling and laboratory procedures were modified to comply with this request.

Muck samples collected are representative of the material as it reaches the transportation system. Muck produced mechanically normally is sampled as it leaves the conveyor which is integral with the machine. Conventional muck is sampled by channeling. Pieces which are too large for practical delivery to a laboratory are measured, and calculated weights in the various size ranges are added to adjust the screen test results. Rock specimens, or rock cores when available, are collected in sizes large enough to permit the preparation of six test specimens approximately 2-1/8 inches in diameter by 4-1/4 inches long.

In the first year of the program, operating data was collected in the detail believed necessary for inclusion of all system components in analysis and selection of transportation subsystems. Preliminary data analysis indicated a need for more precise thrust, torque, and cutter data than was expected for mechanical tunneling. With the exception of two types of drag cutter machines, reliable data were collected in the second year on thrust and cutter spacing for all of the TBMs sampled under the program. Net torque could not be determined within the scope of the contract for most of the TBMs observed. To approximate these data, rotation and penetration rates were collected with the same exceptions.

3.3 PHYSICAL TESTING

Published test methods were reviewed in detail to ensure that tests performed by commercial laboratories would yield consistent results. The following American Society for Testing and Materials (ASTM) standard methods were selected as specifications in the first year of the program.

C566-67: Total Moisture Content by Drying

C136-67: Sieve or Screen Analysis of Fine and Coarse Aggregates

C117-69: Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

C29-69: Unit Weight of Aggregate, Loose Weight Determination

C170-50: Compressive Strength of Natural Building Stone

Specifications for the last test procedure were modified to provide for greater accuracy in specimen preparation so that results will be comparable to those reported by other rock property research programs.

Review of the data collected in the first year led to a decision to test rock specimens for deformation moduli in the second year to provide additional data for regression analyses. Following a review of test methods, ASTM Standard C170-50 was replaced by the following procedure, and additional standards were developed to conform with the practices following by U. S. Bureau of Mines research centers in measuring strain.

D2938-71: Unconfined Compressive Strength of Rock Core Specimens

Results of hardness tests by the Shore scleroscope, a laboratory instrument which tests hardness by rebound, were available for only a few of the rock formations sampled. Additional tests by this method were found to be beyond the financial scope of the study. Hardness testing by the Schmidt hammer, a portable device which also tests rebound hardness, is nondestructive and relatively inexpensive and was included in the 1972 program. A hammer was purchased for use in testing tunnel walls and rock specimens.

Standard methods of testing abrasiveness were reviewed to determine the feasibility of collecting these data from tests on muck samples.

The standard ASTM tests were found to measure the resistance of the sample to abrasion, rather than the abrasive effect on other materials. The latter is the property of greater interest in materials handling. A machine designed for such testing was located by the Project Officer at the PMSRC. Tests of retained muck samples were planned for the second half of 1972, but necessary renovation of the equipment could not be completed, and no tests were run.

Modification of the standard screen test procedure was found necessary in testing muck from some low strength rocks. Because the presence of moisture in muck samples affects test results by blinding screens, standard tests require drying prior to screening. Since fine particles adhere to others, washing prior to dry screening is necessary for accurate determination of the percentage of particles finer than 200 mesh. The percentage of fines is an important parameter in hydraulic conveying, and the ASTM test originally selected provided for dry screening following washing. This test was satisfactory for most formations, but not for those which disintegrate when washed. For these an additional screen test at natural moisture content was specified to show the properties of the muck which would be handled by systems other than hydraulic. Natural screen test results are identified and shown as dotted lines on the size distribution curves shown on the individual data sheets. and elsewhere by the notation (N) following the observation number.

Contracts to perform muck tests were negotiated with 18 commercial testing laboratories. Collected samples were delivered for testing and shipment of minus 2-inch fractions to the U. S. Bureau of Mines, PMSRC, for additional tests to be performed at this facility. One set of samples tested commercially was lost in transit to the PMSRC. Tests performed by the PMSRC include a standard suite to determine Atterberg limits, and tests for specific gravity, potential volume change, angles of repose for 1-inch and 10-inch drops, angles of slide and internal friction, apparent cohesion, and bulk density. These tests were run in accordance with procedures described in a paper, "Physical Properties of Bulk Materials," prepared by D. E. Frisque and L. C. Marracini, PMSRC, for a seminar and workshop in December 1970.

Contracts to perform tests on rock specimens were negotiated with five commercial laboratories. Two sets of specimens destroyed in preparation for testing in 1971 were replaced in 1972. Forty-one sets of rock specimens were collected and tested. Stress-strain data were obtained for 24 rocks, including 6 collected in 1971. Stress-strain data for one set of specimens were provided by the Twin Cities Mining

Research Center. All other modulus tests were run by commercial laboratories.

Initial Schmidt hardness tests on walls of tunnels gave results which correlated well with those reported by other researchers on similar rocks. Initial tests on 11 core specimens showed little correlation with field tests or with values obtained from the hardness-compressive strength relationships established by other investigations. Further trials on hand lapped core specimens and a modified cradle indicated that lapping raised test values somewhat nearer those observed in tunnel wall tests. Some variation in values appeared to be associated with core straightness. An inexpensive method of grinding opposite flat planes on cores and rock specimens, developed by the American Standards Testing Laboratories, Los Angeles, California, was found to produce acceptable results with specimens tested on the bed of a hydraulic press. Tests on 33 cores and specimens, averaging 31 readings per formation, were performed by this laboratory and project personnel.

3.4 DATA PROCESSING

A format was developed for computer printout of lithologic, rock, muck, operating, and transport system data. All data have been stored on punch cards and printouts are included as Appendix B. Blank spaces on the printout indicate that data is not available or is not applicable to the section.

Narrative and graphic summaries were prepared to combine these data with descriptions of the excavation systems from which rock and muck samples were taken, and are included as Appendix C. Rock strength classifications are based on uniaxial compressive strength, and conform with those proposed by D. U. Deere, et al, in the "Engineering Classification and Index Properties for Intact Rock," University of Illinois, 1966. These classifications are:

Very High Strength - Greater than 32,000 psi
High Strength - 16,000 to 32,000 psi
Medium Strength - 8,000 to 16,000 psi
Low Strength - 4,000 to 8,000 psi
Very Low Strength - Less than 4,000 psi

Grain size classifications of igneous rocks, from A. Johannsen's "A Descriptive Petrology of Igneous Rocks," 1931, are used as follows:

Very Coarse - Above 3 cm
Coarse - 1 to 3 cm
Medium - 1 to 10 mm
Fine - Below 1 mm

From J. F. Kemp's "A Handbook of Rocks," 1950, sedimentary rocks of fragmental grain size 2 mm and above are classified as conglomerates, while those below 2 mm in size are classified as sandstones or siltstones.

Symbols used to describe the shape of particles in the sample fractions between screen sizes are the following:

A - Angular
P - Platy
E - Elongated
I - Irregular
S - Subangular
R - Rounded
C - Cubic
Sp - Spheroid

The curves show the percentage of the total sample weight passing one screen size and retained on the next. Screen sizes below 1/2 inch were selected to provide openings which become progressively smaller by approximately 50 percent as shown below:

Screen Size	#4	#8	#16	#30	#50	#100	#200
Nominal Square Openings, Inches	0.187	0.094	0.047	0.023	0.012	0.006	0.003

3.5 DEVELOPMENT OF MDN

In accordance with the program plan, analysis of data and development of MDN were preliminary during the first year. As data was collected, test results were reviewed to confirm the validity of the concept. Based on classification by materials handling characteristics, the system as proposed employed seven numbered categories in which to group excavation products by size and size distribution. Numbers were to be assigned in a progression from No. 1 for muck with a relatively large maximum piece size and a predominant distribution in the 1 inch to 200 mesh range, to No. 7, of which the maximum size was relatively small with the predominant distribution minus 50 mesh in size. The concept also recognized that muck characteristics would vary with excavation methods and contemplated modifying the MDN to distinguish between excavation techniques.

Initial field work was scheduled at sites where rock strengths varied over a wide range and which provided examples of shield, machine, and conventional operations. The size distribution curves of the muck from these sites varied distinctly, in general agreement with the criteria, except that the size range of the predominant distribution was somewhat higher than had been inferred.

Resampling at four of the original sites confirmed the distinctive shape of the size distribution curves. Sampling at other sites produced some curves which fit well into the original categories and others which were distinctive enough to suggest establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and tentative MDN were assigned. Separate composite curves were prepared for muck produced by conventional and machine operations, and assignments were from No. 1 through No. 7 in each broad category, differentiated by the terms "Conventional," "Machine," or "Machine and Shield," and shown as tentative by a "T" prefix.

Refinements of the MDN were considered when additional data had been collected in the second year of the program. Attempts to gather data which would permit subdividing the machine classifications by cutter type had been unsuccessful. Eventually, the concept of a series of MDN for each excavation method was abandoned because of its complexity, the similarity between curves assigned different numbers, and acceptance of the concept that muck samples should be grouped with others of similar characteristics regardless of the excavation method, since the excavation parameters would be introduced in the regression analysis.

When all test data had been received, similar size distribution curves from commercial laboratory muck tests were plotted together in the composite curves shown on Figures 3-1 through 3-7. As discussed under Physical Testing, two sets of distribution curves were obtained for each of nine samples expected to break down during wash screening. Four sets of these curves showed no significant differences and were assigned the same MDN. As shown by the illustrations, the MDN of the others varied with the test method by three or four numbers. For those samples tested by both screening methods, the suffix "W" is used with the observation number to indicate that the sample was washed, and "N" to indicate screening with natural moisture. As shown on the data sheets, all MDN are based on dry screen analysis after washing unless noted by (N) to indicate analysis with natural moisture.

It was planned originally to modify the assigned MDN by point numbers to indicate such bulk material properties as abrasiveness and bulk density. The nature of the regression analysis output, consisting of predicted whole numbers and decimals (residuals) indicating the error of estimate, led to the conclusion that such modifications would be misleading, and this point concept was not developed further. Some consideration was given to assigning point numbers in an order of the percent in one or two predominant size ranges, but time did not permit evaluation of this concept.

As assigned, MDN indicate materials handling properties as shown by the range of sizes in the summaries which follow. For MDN 1 through 4, the ranges summarized are those of greatest interest to transportation by rail cars, free vehicles, and belt conveyors. For MDN 5 through 7, the ranges are those which may be of interest to any system, but are particularly significant in consideration of hydraulic and pneumatic systems. The maximum and minimum values shown for minus 1/2 inch, minus #8 plus #100, and minus #100 are derived from individual sample analyses and do not represent the sums of high and low values shown on the composite curves in all cases.

Reference to the summaries and the individual size distribution curves will show the relationship between MDN assignments and commercial screen test results. MDN 1 through 4 are differentiated by the percent in the maximum size range. MDN 1 contains more than 20% + 6", MDN 2 more than 0% and less than 20% + 6", MDN 3 contains 0% + 6" and more than 0% + 3", and MDN 4 contains 0% + 3" and more than 0% + 2". MDN 5 and 6 both contain 0% + 2", and differ by the concentrations in the -1" + 1/2" and the -1/2" + No. 4 fractions. MDN 6 samples contain 0% + 2" and, with one exception, more than 0% + 1". MDN 7 samples, again with one exception, contain 0% + 1". The exceptions, Samples CL-1 and Nast 2, could have been classified differently by one number to meet "nonexception" criteria, but were retained as shown because of the difference in slope of the last curve segment.

SIZE CHARACTERISTIC SUMMARIES

RANGE OF SIZE CHARACTERISTICS, MDN 1 THROUGH 4

MUCK, SIZE DISTRIBUTION BY WEIGHT AND PERCENT

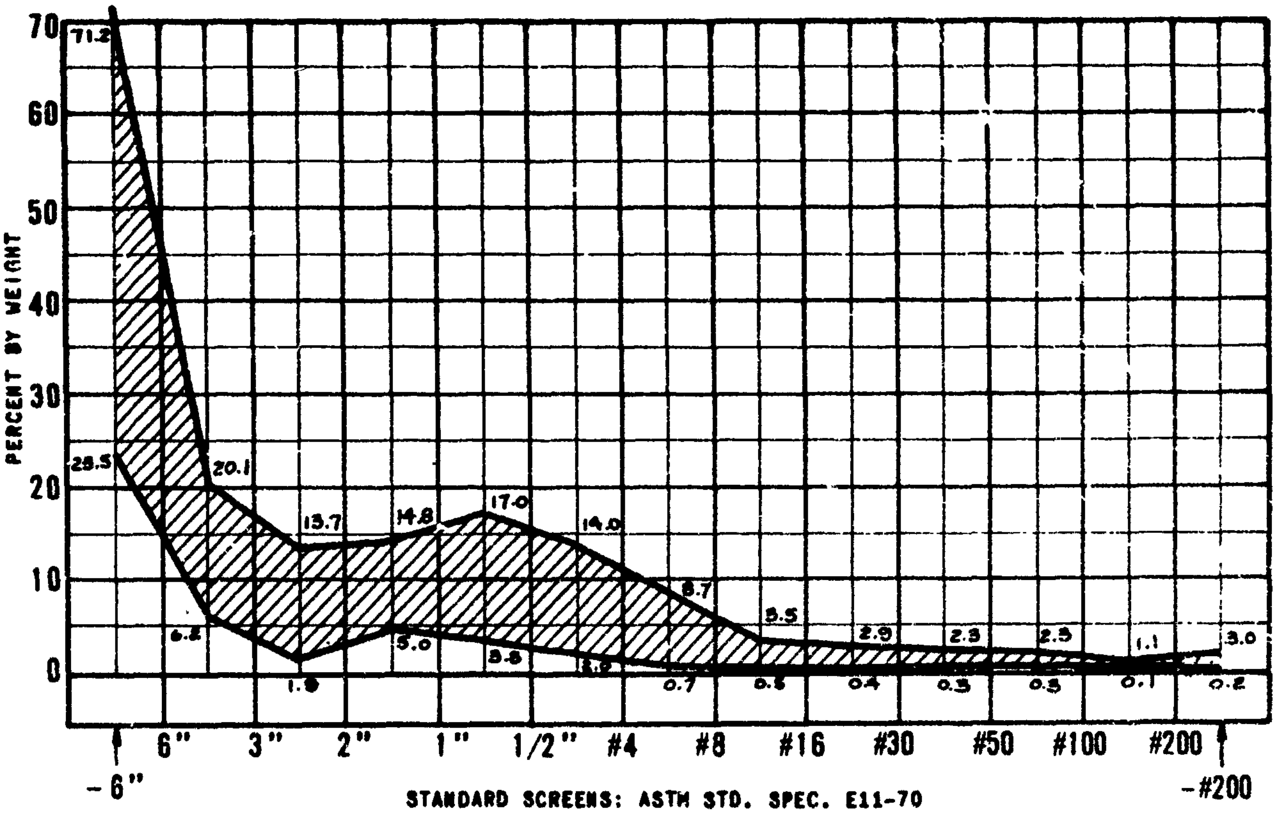
MDN	+6"	-6" +3"	-3" +2"	-2" +1"	-1" +1/2"	-1/2"	-#100*	Maximum Size Observed
1.	71.2-23.5	20.1-6.2	13.7-1.9	14.8-5.0	17.0-3.8	30.2-4.7	3.7-0.5	4'x3'x2'-18"x12"x10"
2.	19.1-4.7	28.9-6.8	18.2-1.4	19.3-6.8	15.7-10.4	61.6-8.4	17.4-0.7	2-1/2'x2-1/2'x12"-8"x8"x4"
3.	0.0	19.1-1.5	19.2-0.9	33.1-5.8	22.6-5.9	70.7-24.9	53.8-2.0	4'x1-1/2'x4"-4"x4"x1/2"
4.	0.0	0.0	8.0-0.4	26.6-1.9	31.0-5.2	87.0-45.0	42.1-6.5	3'x14"x8"-4"x1-1/2"x3/4"

* Included with -1/2" fraction

RANGE OF SIZE CHARACTERISTICS, MDN 5 THROUGH 7

MDN	+2"	-2" +1"	-1" +1/2"	-1/2" +#4	-#4 +#8	-#8 +#100	-#100	Maximum Size Observed
5.	0.0	33.8-2.2	32.7-13.3	24.0-10.6	11.5-4.3	39.8-6.9	28.6-8.1	8"x6"x6"-2"x1"x1/2"
6.	0.0	13.0-0.0	16.0-4.8	37.8-19.0	18.1-0.5	37.0-12.4	29.5-6.0	3'x2'x8"-1-1/2"x2-1/2"x3/4"
7.	0.0	0.8-0.0	11.5-1.0	25.0-2.0	13.8-2.3	61.0-36.1	49.2-11.7	18"x10"x4"-1"x1"x1/2"

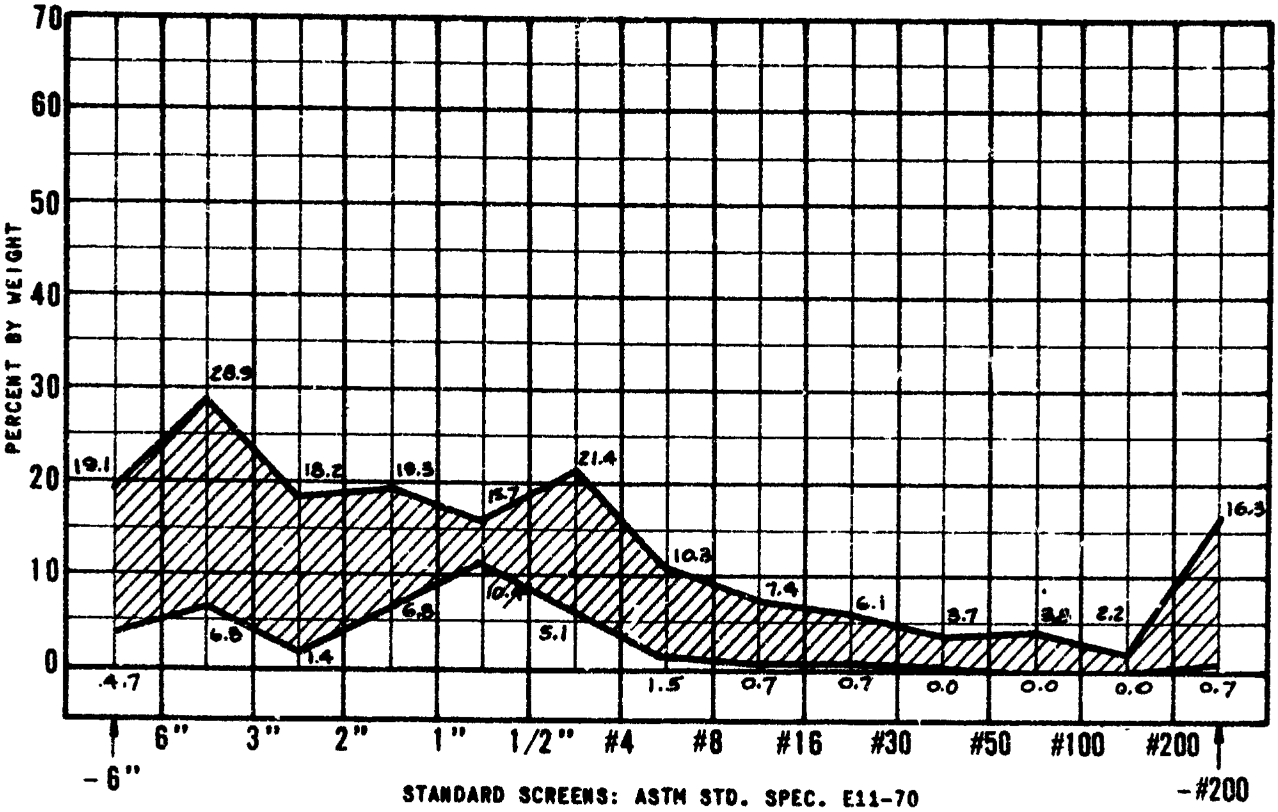
To explain the observation of a large boulder in a pile which produced no +6", +3", or +2" material in the screen analysis, these are nonrepresentative because none were found in the sample population. Observations were noted because maximum size is important in the design of handling systems.



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+6"	-6"+3"	-3"+2"	-2"+1"	-1"+½"	-½"	-#100	Observed
ST-1	39	C	1	71.2	8.1	1.9	5.4	4.5	8.9	0.5	4'x1'x1½'
LK-1	17	C	1	66.8	13.8	5.9	5.0	3.8	4.7	0.5	4'x3'x2'
LK-3	31	C	1	34.1	17.4	9.1	10.2	10.6	18.6	2.7	2½'x1'x6"
LK-4	33	C	1	26.3	19.3	13.7	13.9	9.8	17.0	3.7	27"x18"x12"
LK-2	19	C	1	49.1	16.9	8.7	5.8	5.5	14.0	1.8	3½'x2'x2'
H-3	15	C	1	32.5	11.4	12.0	9.9	9.9	24.3	2.9	28"x18"x12"
CR-1	41	C	1	44.7	6.2	8.5	14.1	10.2	16.3	1.9	30"x14"x12"
SM-1	27	C	1	23.5	10.8	3.7	14.8	17.0	30.2	2.9	18"x12"x10"
KM-1	103N	M	2	46.7	20.1	8.4	11.0	6.4	7.4	NA	36"x14"x8"
HS-1	43	C	1	26.3	17.5	9.2	13.2	13.3	20.5	3.5	22"x18"x18"
Summary			Max. Pct.	71.2	20.1	13.7	14.8	17.0	30.2	3.7	
			Min. Pct.	23.5	6.2	1.9	5.0	3.8	4.7	0.5	

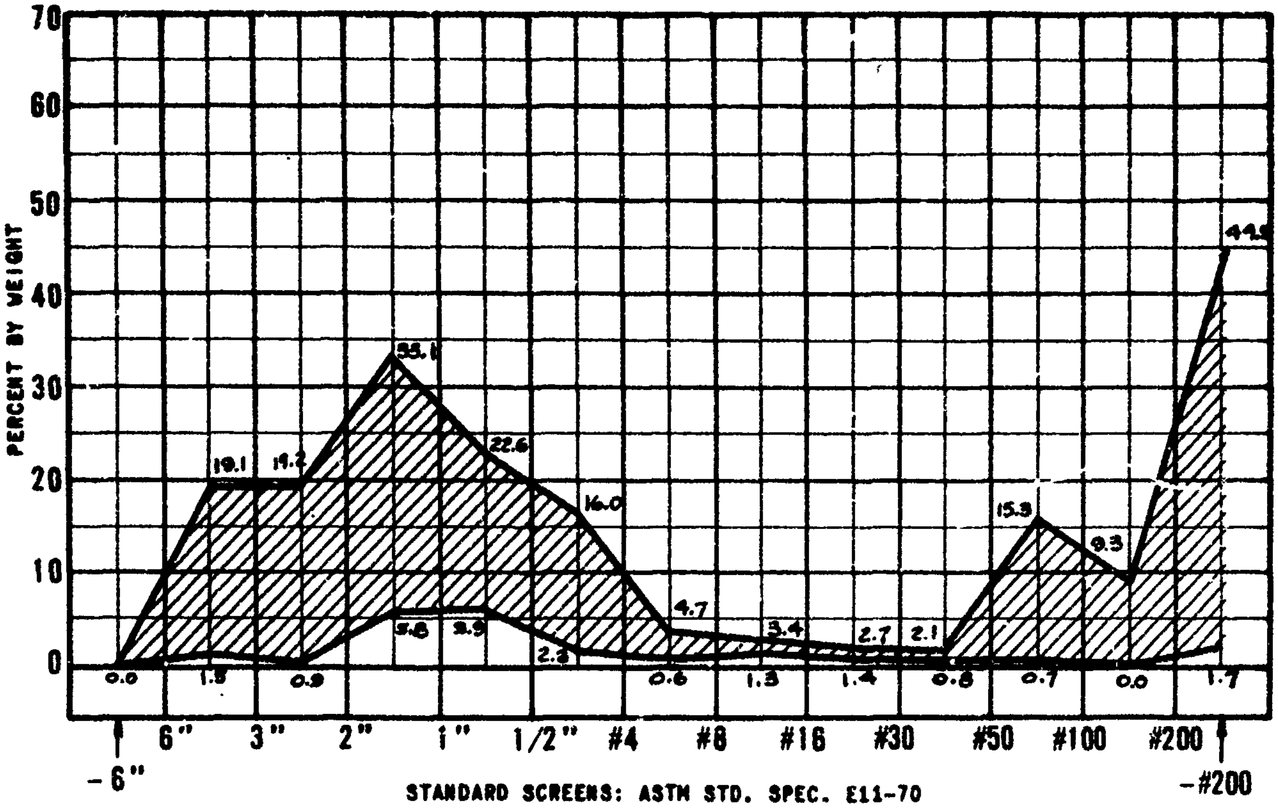
FIGURE 3-1
MDN DEVELOPMENT (MDN-1)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+6"	-6"+3"	-3"+2"	-2"+1"	-1"+½"	-½"	-#100	Observed
GA-1	9	C	1	4.7	17.9	12.2	10.3	11.7	43.2	3.7	2½'x2'x12"
11-3	57	C	1	7.8	12.6	11.3	14.4	14.9	39.0	8.9	18"x18"x4"
H-1	11	C	1	14.3	6.8	12.7	13.2	13.6	39.4	5.6	3'x2'x12"
NAST-3	5	C	1	14.5	16.2	6.2	12.6	13.7	36.8	5.3	2½'x1½'x12"
H-2	13	C	1	7.3	11.7	18.2	19.3	11.6	31.9	4.4	2'x1½'x12"
11-4	59	M	1	8.2	17.7	17.0	19.3	15.7	22.1	1.5	8"x8"x4"
MSU-2	65	C	1	19.1	28.9	17.2	16.0	10.4	8.4	0.7	21"x13"x10"
MB-3	37W	M	1	16.1	17.3	2.7	6.8	10.4	46.7	6.9	24"x12"x10"
MB-3	37N	M	2	15.9	18.2	2.7	7.0	12.8	43.4	1.7	24"x12"x10"
LK-7	25	C	1	13.1	14.0	11.2	12.3	15.5	33.9	5.5	2½'x2½'x12"
MB-1	35	M	1	7.2	9.7	1.4	8.7	11.4	61.6	17.4	2'x1½'x8"
SF-2	101N	S	2	10.0	10.0	NA	NA	NA	NA	NA	3'x2'x8"
Summary			Max. Pct.	19.1	28.9	18.2	19.3	15.7	61.6	17.4	
			Min. Pct.	4.7	6.8	1.4	6.8	10.4	8.4	0.7	

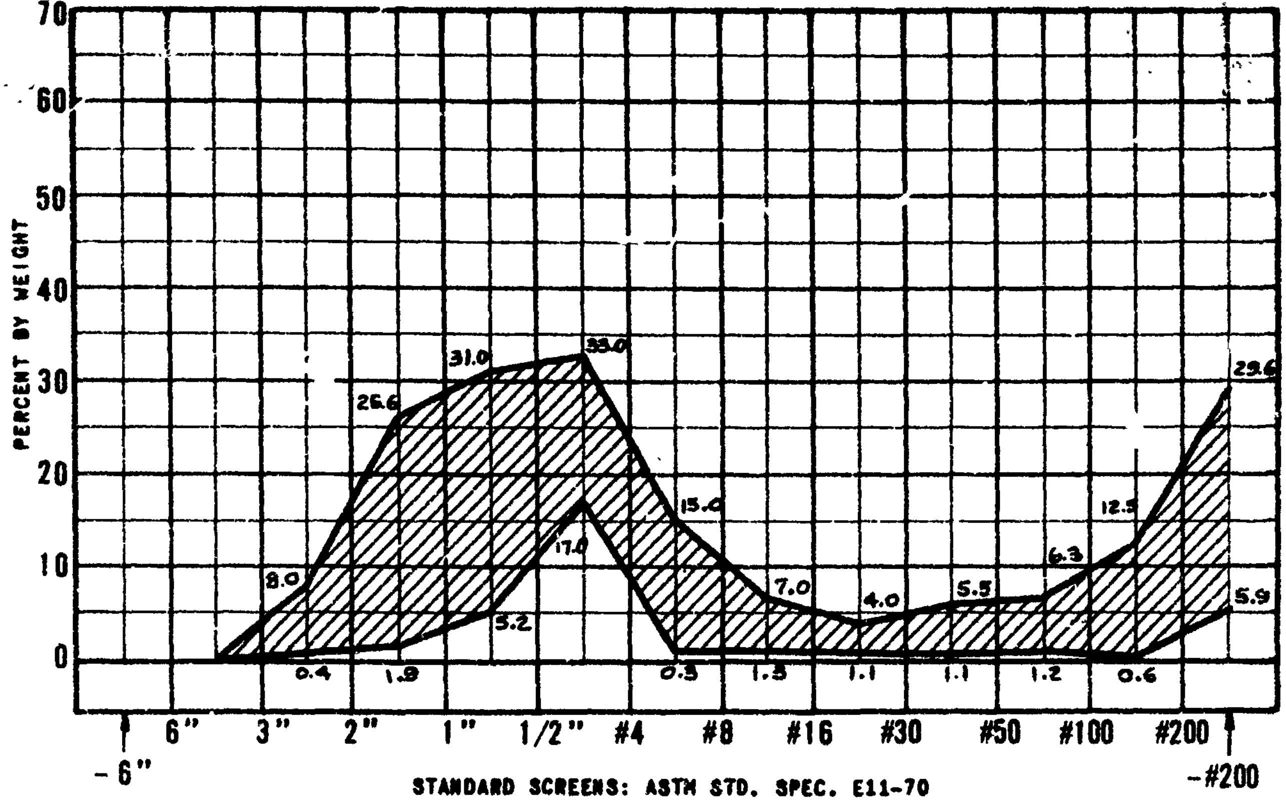
FIGURE 3-2
MDN DEVELOPMENT (MDN-2)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+6"	-6"+3"	-3"+2"	-2"+1"	-1"+½"	-½"	-#100	Observed
NAV-1	89W	M	1	0	12.1	7.4	6.9	5.9	67.7	53.8	6"x5"x2"
NAV-1	89N	M	2	0	19.1	6.8	23.0	19.0	32.1	NA	6"x5"x2"
MSU-1	63	C	1	0	17.0	12.0	24.0	18.0	29.0	2.0	6"x10"x8"
MB-2	51	C	1	0	12.5	19.2	24.5	18.9	24.9	2.1	4'x1½'x4"
LAY-1	83	M	1	0	7.6	7.5	5.8	12.6	66.5	26.6	4"x4"x½"
7-2	55	M	1	0	1.5	0.9	33.1	22.6	41.9	14.5	3"x9"x1"
WNG-2	97N	C	2	0	8.7	5.4	7.9	7.3	70.7	NA	18"x10"x4"
WNG-1	95N	M	2	0	6.9	3.3	15.7	11.7	62.4	NA	14"x4"x4"
Summary			Max. Pct.	0	19.1	19.2	33.1	22.6	70.7	53.8	
			Min. Pct.	0	1.5	0.9	5.8	5.9	24.9	2.0	

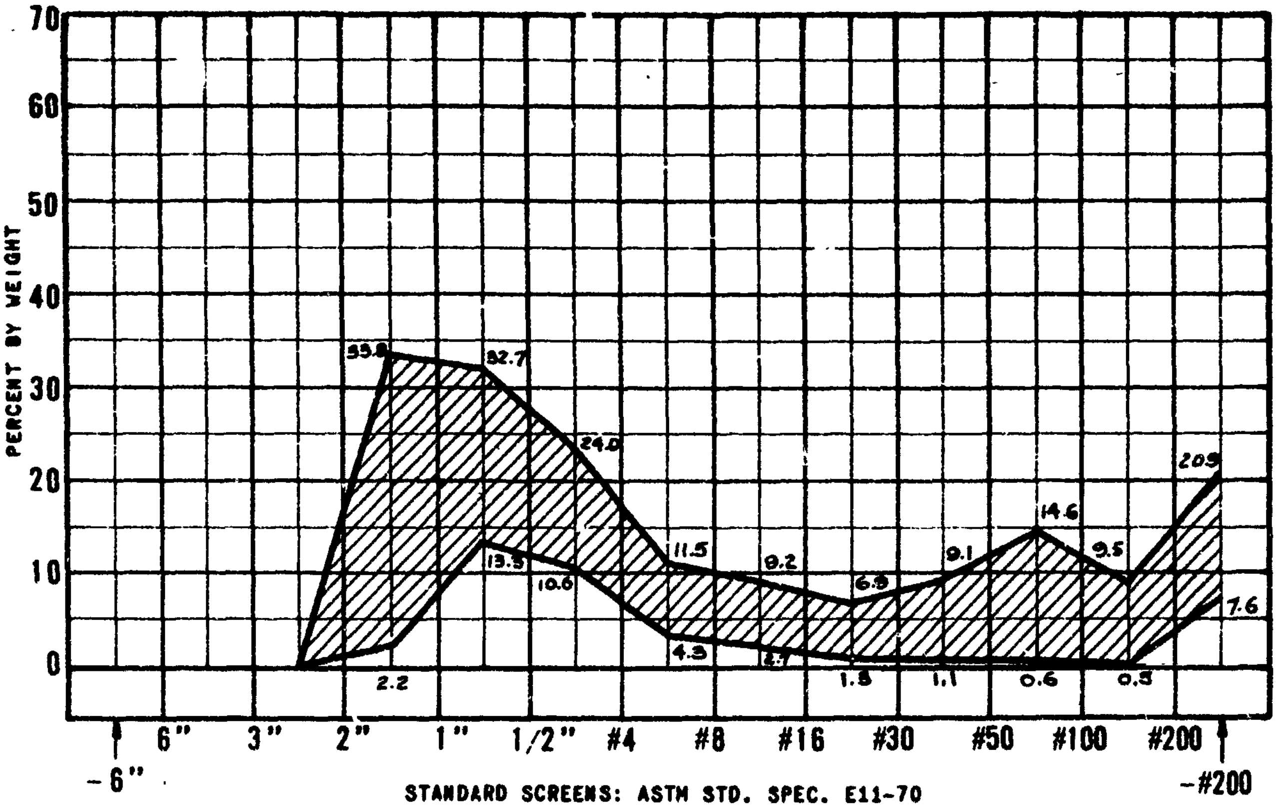
FIGURE 3-3
MDN DEVELOPMENT (MDN-3)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident. Symb.	Obs. No.	Exc. *	Test **	Percent by Weight							Max. Size Observed
				+6"	-6"+3"	-3"+2"	-2"+1"	-1"+½"	-½"	-#100	
LAW-2	67	M	1	0	0	3.0	25.0	18.0	54.0	8.7	3"x2"x½"
LAW-3	69	M	1	0	0	4.3	25.9	19.6	50.2	11.0	3"x2½"x½"
LAW-4	71	M	1	0	0	5.0	18.3	18.3	58.4	16.3	3½"x2½"x3/4"
RO-1	93	M	1	0	0	2.0	9.0	12.0	77.0	14.0	4"x1½"x3/4"
KM-1	103W	M	1	0	0	5.9	1.9	5.2	87.0	42.1	3'x14"x8"
72-1	61W	M	1	0	0	4.0	18.8	31.0	45.2	6.5	12"x7"x1½"
72-1	61N	M	2	0	0	8.0	24.0	23.0	45.0	NA	12"x7"x1½"
EVG-1	79	M	1	0	0	3.2	26.6	22.1	48.1	11.1	3"x6"x3/4"
EVG-2	81	M	1	0	0	2.2	24.4	26.7	46.7	12.4	4½"x2½"x1½"
NAV-2	91N	M	2	0	0	0.4	12.6	19.6	67.4	NA	5"x2"x1"
Summary		Max. Pct.		0	0	8.0	26.6	31.0	87.0	42.1	
		Min. Pct.		0	0	0.4	1.9	5.2	45.0	6.5	

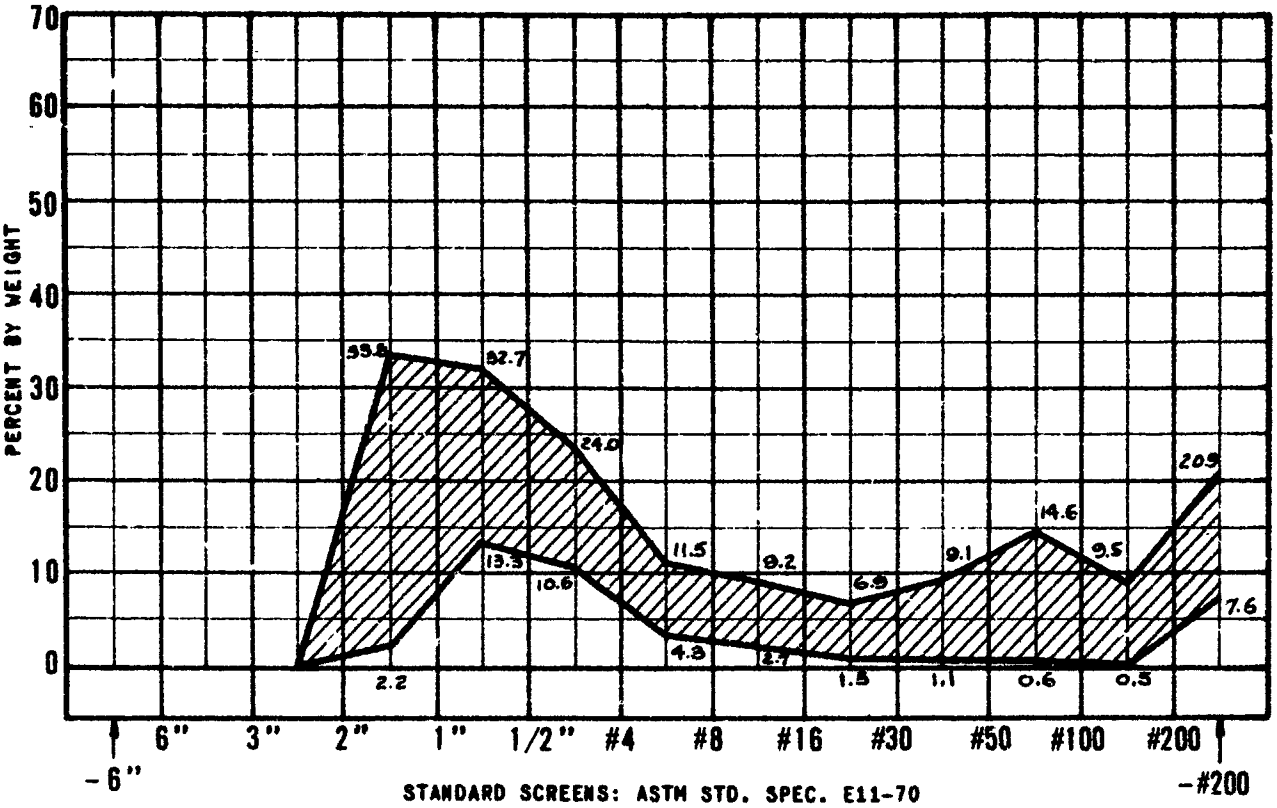
FIGURE 3-4
MDN DEVELOPMENT (MDN-4)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+2"	-2"+1"	-1"+½"	-½"+4#	-#4+#8	-#8+#100	-#100	Observed
5-1	53	M	1	0	33.8	20.9	15.5	4.4	8.6	16.8	2½"x8"x3/4"
MIL-1	73	M	1	0	14.5	28.0	24.0	8.2	17.2	8.1	2"x1"x½"
MIL-2	75	M	1	0	9.2	24.7	22.8	11.5	15.6	16.2	3"x2"x½"
QL-1	49	M	1	0	7.6	17.0	13.4	4.5	28.9	28.6	2"x1"x½"
MIL-3	77	M	1	0	25.4	32.7	17.4	4.3	6.9	13.3	4"x1-3/4"x½"
LAY-2	85	M	1	0	6.0	30.0	23.0	8.0	16.0	17.0	8"x6"x6"
NY-1	45	M	1	0	3.5	21.9	12.3	6.6	32.0	23.7	2"x2½"x3/4"
NY-2	47	M	1	0	2.2	13.3	10.6	5.6	39.8	28.5	2"x1-3/4"x½"
Summary			Max. Pct.	0	33.8	32.7	24.0	11.5	39.8	28.6	
			Min. Pct.	0	2.2	13.3	10.6	4.3	6.9	8.1	

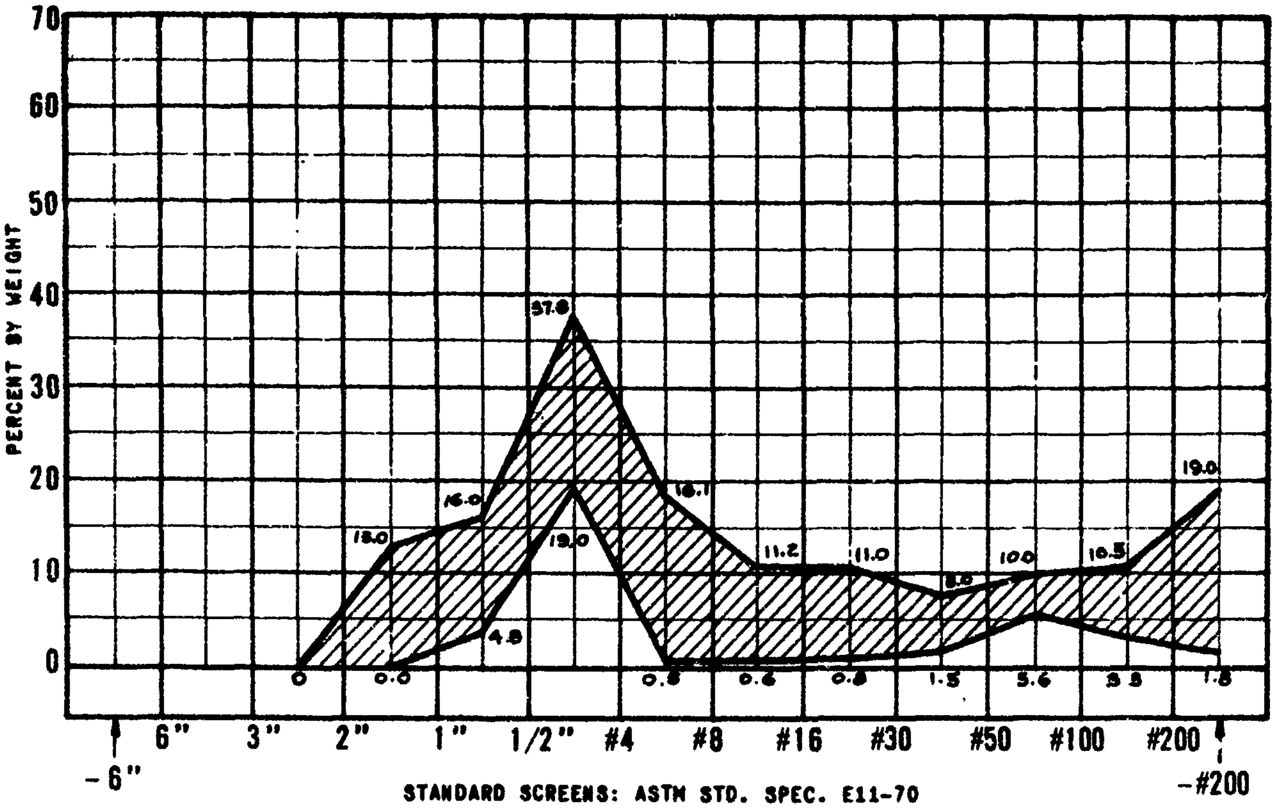
FIGURE 3-5
MDN DEVELOPMENT (MDN-5)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+2"	-2"+1"	-1"+½"	-½"+4#	-#4+#8	-#8+#100	-#100	Observed
5-1	53	M	1	0	33.8	20.9	15.5	4.4	8.6	16.8	2½"x8"x3/4"
MIL-1	73	M	1	0	14.5	28.0	24.0	8.2	17.2	8.1	2"x1"x½"
MIL-2	75	M	1	0	9.2	24.7	22.8	11.5	15.6	16.2	3"x2"x½"
QL-1	49	M	1	0	7.6	17.0	13.4	4.5	28.9	28.6	2"x1"x½"
MIL-3	77	M	1	0	25.4	32.7	17.4	4.3	6.9	13.3	4"x1-3/4"x½"
LAY-2	85	M	1	0	6.0	30.0	23.0	8.0	16.0	17.0	8"x6"x6"
NY-1	45	M	1	0	3.5	21.9	12.3	6.6	32.0	23.7	2"x2½"x3/4"
NY-2	47	M	1	0	2.2	13.3	10.6	5.6	39.8	28.5	2"x1-3/4"x½"
Summary		Max. Pct.		0	33.8	32.7	24.0	11.5	39.8	28.6	
		Min. Pct.		0	2.2	13.3	10.6	4.3	6.9	8.1	

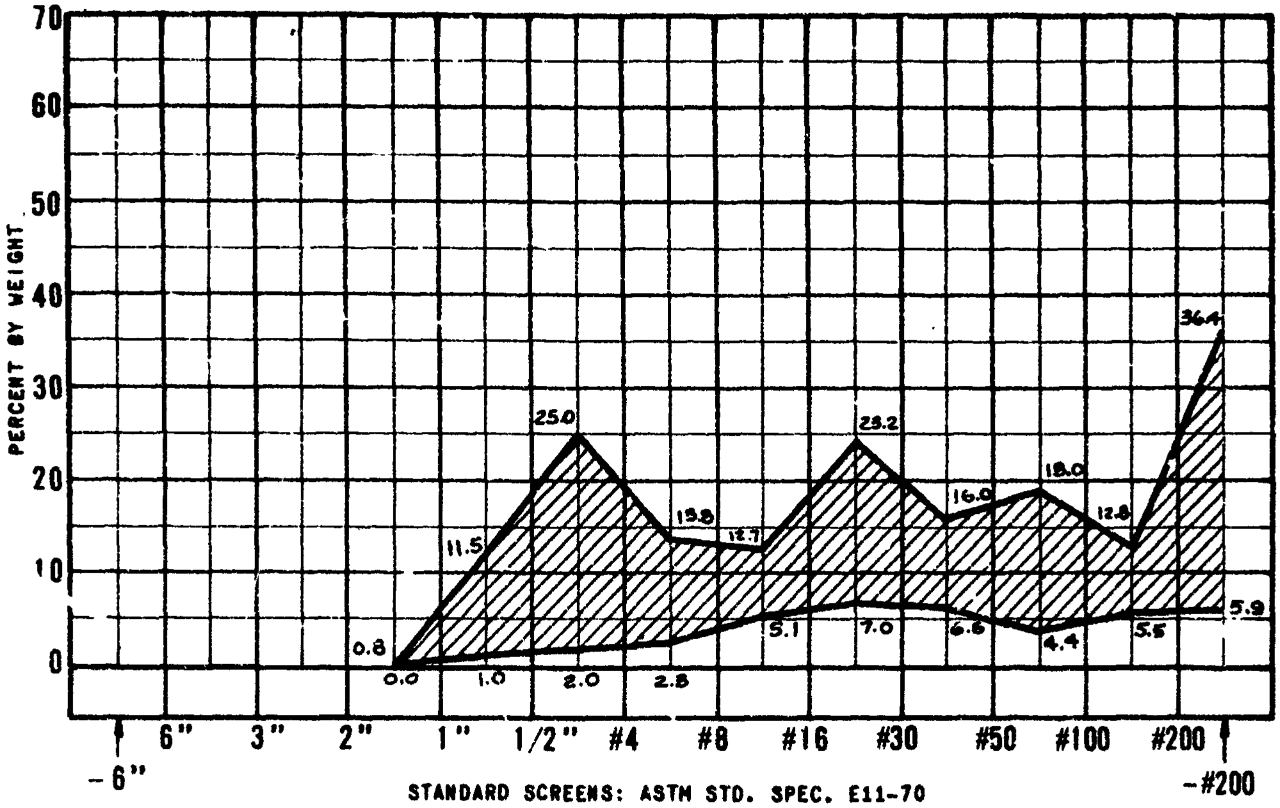
FIGURE 3-5
MDN DEVELOPMENT (MDN-5)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+2"	-2"+1"	-1"+½"	-½"+#4	-#4 +#8	-#8+#100	-#100	Observed
CL-1	29	M	1	0	0.0	4.8	37.8	18.1	32.1	7.2	1½"x2½"x3/4"
SF-2	101W	S	1	0	8.6	14.4	34.6	0.5	12.4	29.5	3'x2'x8"
LK-5	21	M	1	0	13.0	14.0	20.0	7.0	30.0	16.0	2½"x4"x3/4"
LK-6	23	M	1	0	1.0	9.0	19.0	12.0	37.0	22.0	2"x3½"x1¼"
CNT-1	87N	M	2	0	7.0	16.0	28.0	11.0	32.0	6.0	3"x2"x1¼"
CNT-1	87W	M	1	0	4.0	15.0	25.0	10.0	21.0	25.0	3"x2"x1¼"
Summary			Max. Pct.	0	13.0	16.0	37.8	18.1	37.0	29.5	
			Min. Pct.	0	0.0	4.8	19.0	0.5	12.4	6.0	

FIGURE 3-6
MDN DEVELOPMENT (MDN-6)



MUCK: PCT. BY WT. BETWEEN SCREENS

Ident.	Obs.	Exc.	Test	Percent by Weight							Max. Size
Symb.	No.	*	**	+2"	-2"+1"	-1"+$\frac{1}{2}$"	-$\frac{1}{2}$"+ #4	-#4+#8	-#8+#100	-#100	Observed
NAV-2	91W	M	1	0	0	1.3	2.5	2.3	57.7	36.2	5"x2"x1"
WNG-1	95W	M	1	0	0	1.0	2.0	5.0	59.0	33.0	14"x4"x4"
SF-1	99	S	1	0	0	2.2	4.5	6.1	38.0	49.2	5"x4"x3"
WNG-2	97W	C	1	0	0	2.0	4.0	5.0	61.0	28.0	18"x10"x4"
NAST-4	7	M	1	0	0	11.5	20.6	13.6	42.6	11.7	1$\frac{1}{2}$"x1"x$\frac{1}{2}$"
NAST-1	1	M	1	0	0	2.2	14.9	12.5	45.1	25.3	1"x3/4"x$\frac{1}{2}$"
NAST-2	3	M	1	0	0.8	8.0	25.0	13.8	36.1	16.3	1"x1"x$\frac{1}{2}$"
Summary			Max. Pct.	0	0.8	11.5	25.0	13.8	61.0	49.2	
			Min. Pct.	0	0	1.0	2.0	2.3	36.1	11.7	

FIGURE 3-7
MDN DEVELOPMENT (MDN-7)

3.6 DATA ANALYSIS

During the first year of the program, an algorithm was developed to correlate those bulk properties of the fragmented material represented by MDN with parameters representing rock properties and excavation methods. The quantitative relationship sought was a predictor equation, obtained by multiple regression of the physical property and operating data from tests and observations. A discussion of this technique is included in Appendix D.

Parameters available for preliminary analysis with the first year's data included uniaxial compressive strength (CSTR), rock quality designation (RQD), dry unit weight (DUW), and water occurrence. To avoid reducing data derivatives to extremely small values, rocks with compressive strengths of less than 1K psi were assigned arbitrary strengths of 1. Rock classifications (CLASS) were quantified as Igneous = 1, Metamorphic = 2, and Sedimentary = 3. Water occurrence was considered a rock property, and was quantified as 1. = Dry, 2. = Minor to Moderate, and 3. = Wet. The construction of the dummy variable used for water occurrence is justified by the relative volumes represented. A physical property justification for the order and magnitude of the number assignment to the CLASS variable is indicated by the 1 to 1.17 ratio of the differences between average compressive strength values as listed in Table 5.1, page 57, of I. W. Farmer's "Engineering Properties of Rocks," 1968.

Schmidt hardness values (H) were converted Shore values, where available, or inferred from data published by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock" referenced above. Kerf spacing appeared to be an important TBM characteristic. Average dimensions were available for disc cutter and some drag cutter machines. For roller cutters for which no kerf pattern was apparent, values were obtained by dividing the body spacing by the number of buttons on or adjacent to a line along the face of the cutter and parallel to the axis of rotation. No kerf spacing was available for Alpine and Atlas-Copco TBMs. Net thrust values per square foot of face area (T) were available for TBMs with the same exceptions. No appropriate operating parameters were available for the Alpine and Atlas-Copco machines or for the shield operations sampled. Parameters peculiar to conventional operations, face area per drill hole (A/H), and explosives per cubic yard excavated (PF) were calculated from collected data.

An initial analysis using rock properties alone led to a predictor equation for which the accuracy, described by the multiple correlation coefficient, was 72 percent. This was expected since operating parameters were not included. Seventeen sets of data, combining rock properties with machine operating parameters, were analyzed by stepwise regression which indicated a prediction accuracy of slightly more than 90 percent. Ten sets of rock and conventional operating data were analyzed, with an indicated accuracy of over 99 percent. Since the number of observations was nearly equal to the number of variables, it was noted that this level of accuracy probably would not be maintained when more data became available.

The contract for the second year's program provided for collecting the same data on new samples as well as some additional data. One proposed parameter, abrasiveness, could not be determined because the test equipment required renovation which could not be completed in time for use. Schmidt hardness (H) was determined by laboratory tests on specimens from the twenty formations sampled during the year, and on nine specimens from sites previously sampled. Values used for others were inferred from tests of similar rocks, from data published by D. U. Deere, et al., in the "Engineering Classification and Index Properties for Intact Rock," or were assigned minimum values for rocks so weak that no test data could be obtained. Young's Modulus (ET) and Poisson's Ratio (P. Ratio) were determined by commercial laboratory tests on 22 sets of specimens, and for 1 set by tests performed by the Twin Cities Mining Research Laboratory of the U. S. Bureau of Mines. Other values were inferred or assigned as those for Schmidt hardness.

Since water occurrence in a tunnel can be controlled to a degree, it was considered more reasonable to treat this factor as a characteristic of the tunnel system, rather than a rock property. In the final analyses, water occurrence was quantified as in the preliminary, but described the condition in the tunnel at the time of sampling rather than that in a drill hole during exploration. In the regression matrix, the test methods which produced different MDN from the same sample were quantified as 1 = Dry screened after washing, and 2 = Screened with natural moisture; the suffix "W" was used with the observation number to indicate that the sample was washed, and "N" to indicate screening with natural moisture.

Values used for TBM kerf spacing and net thrust were derived as for the preliminary analysis, and rotation speeds (RPM) and penetration rates in feet per machine operating hour were collected during field observations or from tunnel records. No appropriate operating parameters could be developed for the Alpine and Atlas-Copco machines or for the shield operations sampled. Parameters peculiar to conventional operations, face area per drill hole (A/H), and explosives per cubic yard excavated (PF) were calculated from collected data.

As independent variables for prediction of muck materials handling properties, compressive strength, hardness, and the modulus of elasticity alone are believed inappropriate because they can be determined only by tests on intact specimens. These normally do not represent rock formations, which seldom exist without some discontinuity which affects the characteristics of excavated muck. The RQD, a function of the fractures, joints, and other planes of weakness in the rock mass, when used in the preliminary analysis as one independent variable, was among the less important. In the final analysis, RQD was used in combination with rock strength, hardness, and the elastic modulus modified by the factor 1×10^{-5} to produce a usable number (HCERQD). Other rock properties, water occurrence, and the test method were used as individual variables.

It has been suggested that better results might be developed by using an alternate method of dummy variable construction for rock classification (CLASS). Instead of assigning the three numbers 1, 2, and 3, the variable description could indicate merely class membership or nonmembership as in the following example:

Variable 1	Variable 2	Interpretation
1	0	Igneous
0	1	Metamorphic
0	0	Sedimentary

Testing the effectiveness of this construction is beyond the scope of the program, but is recommended for inclusion in future research.

Reliable data was collected on the cutter head rotation speed of the TBMs and on the thrust, kerf spacing, and penetration rates of all TBMs except the Alpine and Atlas-Copco. Thrust values were modified to thrust per square foot of face area in the TBM analyses. Net torque could be developed for only a few of the TBMs within the project scope. It appeared logical to combine the rotation speed with an area or volume dimension to equalize the effect of excavation size. Since volume per hour as a measurement of energy expended is related to energy input, and rotation speed is a (reciprocal) factor in the basic torque equation, a combination variable of cubic feet of excavation per hour and RPM (CF/RPM) was used in the final regression.

The preliminary analysis used the program known as STEPWISE which is available from the IBM/367 time-sharing system. It had the disadvantage of having a limit of ten variables, and with more extensive analysis, the output features were limited. With more data and more analysis, the program BMD02R was used. This program is one of the Biomedical Computer programs, available in a batch processing mode from the CDC 6600 Cybernet System. Variable significance testing is integral with these programs, as shown by the order in which the variables were entered and by the regression coefficients (Multiple R) on Figures 3-10 and 3-11 and the tabulation on page 3-22. Further discussion of both programs is included in Appendix D.

Twenty-seven sets of data were analyzed for machine operations using the values tabulated in Figure 3-8. Seven sets of data were not included because operating data was not complete. Results of the analysis shown in Figure 3-9 indicate an accuracy of about 82 percent with a standard error of 0.8106. A review of the data sets which resulted in residuals (errors in prediction) of more than one might reveal valid reasons for modification, but is beyond the scope of the current program.

Twenty sets of data with the values shown in Figure 3-10 were analyzed for conventional operations, with the output shown in Figure 3-11. The indicated accuracy is a little over 95 percent with a standard error of 0.5189. The residuals are generally smaller than those from the machine analysis; the number of variables is large in relation to the number of observations, and the indicated accuracy of prediction may be reduced by the inclusion of more data sets.

All of the data in each category was correlated to indicate the relative importance of the individual variables and eight additional correlations were run with each matrix to test the significance of various combinations of variables. The final correlations illustrated were run with the individual and combined variables which had the greatest effect on the regression coefficient in the trial runs.

The data sets shown in Figure 3-12 represent seven samples from machine and shield operations for which no operating parameters have been developed. Correlation using all variables showed an accuracy (nearly 100 percent) which is meaningless because of the small number of observations. For this reason a summarized computer output of the coefficients for the individual variables and of the residuals is not shown. However, the order of importance of the variables is indicated by the following table, which summarizes results of the regression:

Step No.	Variable No.	Variabie	Multiple R
1	9	Water	0.6345
2	10	Test	0.9013
3	3	Hardness	0.9475
4	2	DUW	0.9830
5	6	P. Ratio	0.9913
6	5	ET	0.9918
7	8	Class	0.9964

MACHINE EXCAVATION PARAMETERS

1 IDENT	2 ORS (PAGE) NO	3 EXC SYST	4 MDN	5 DUW PCF	6 H SCHMIDT	7 CSTR	8 ET PSI*10**6	9 P RATIO	10 RQD PCT	11 ROCK CLASS	12 WATER	13 TEST	14 XS AREA SF	15 THRST K LB/ SF	16 KERF SP FT	17 RPM	18 FT ADV PER HR
NAST1	1	M	7	167	51D	18	8.50B	.30B	90	1	2	1	75	3.89	.09	8.50	2.6
NAST2	3	M	7	167	51D	18	8.50B	.30B	90	1	2	1	75	3.89	.09	8.50	2.3
NAST4	7	M	7	160	54B	24	8.30B	.33B	90	1	2	1	76	8.45	.09	8.50	1.7
LK 5	21	M	6	165	54	32	9.00B	.32B	92	1	2	1	112	3.64	.25	6.00	2.7
LK 6	23	M	6	137	20C	3	1.50B	.20B	86	1	2	1	12	17.20	.13	6.00	4.8
CL 1	29	M	6	174	30C	9	9.70	.35B	10	2	2	1	130	5.09	.09	12.00	2.0
NY 1	45	M	5	179	48	15	12.26	.17	80	2	2	1	95	10.00	.17	10.75	3.6
NY 2	47	M	5	177	45	13	8.50	.20	90	2	2	1	57	8.49	.09	12.50	3.1
QL 1	49	M	5	165	30	11	4.50B	.25B	30	2	2	1	95	3.53	.18	10.75	2.9
5-1	53	M	5	166	37	22	5.38	.25	92	3	2	1	257	3.56	.20	4.50	5.0
7-2	55	M	3	166	37D	22D	5.38D	.25D	92	3	2	1	257	2.91	.20	4.50	4.4
72-1	61	M	4	168	46	22	8.37	.35	65	3	2	1	257	2.99	.20	4.50	5.5
LAW 2	67	M	4	161	42	29	8.70	.41	100	3	2	1	143	4.28	.20	9.00	7.7F
LAW 3	69	M	4	161	42	29	8.70D	.41D	100	3	2	1	143	4.28	.20	9.00	7.7F
LAW 4	71	M	4	157	52B	20	4.61	.50	100	3	2	1	143	3.76	.20	9.00	6.3
MIL 1	73	M	5	166	59B	36	10.00B	.30B	85	3	2	1	98	6.09	.16	9.30	5.0
MIL 2	75	M	5	166	59B	36	10.00B	.30B	85	3	2	1	98	6.09	.18	9.30	4.5
MIL 3	77	M	5	164	40	22	7.84	.46	81	3	2	1	98	6.52	.16	9.30	4.7
EVG 1	79	M	4	168	44	26	10.63	.50	100	3	3	1	84	2.74	.24	6.00	9.2
EVG 2	81	M	4	170	45	30	10.82	.30	100	3	3	1	84	3.18	.24	6.00	11.5
LAY 1	83	M	3	150	18	10	1.80B	.10E	84	3	2	1	131	2.73	.21	5.20	20.0
LAY 2	85	M	5	153	38*	22*	10.80A	.18A	85	3	2	1	131	4.47	.21	5.20	10.6
CNT 1	87	M	6	165	38*	28*	6.00AB	.18B	80	3	2	1	131	4.47	.21	5.20	8.8
NAV 1	89	M	3	142	7B	2	0.20B	.10E	70	3	2	1	330	1.31	.30	5.00	9.0
NAV 2	91N	M	4	117	5E	1	0.10E	.10E	60	3	2	2	330	0.37	.30	5.00	4.5
NAV 2	91W	M	7	117	5E	1	0.10E	.10E	60	3	2	1	330	0.37	.30	5.00	4.5
RO 1	93	M	4	166	36	11	4.47	.24	60	3	2	1	264	1.86	.28	11.00	9.3

* -WEIGHTED AVERAGE ** - 2.75 UPPER HEADS 1.38 LOWER HEADS A - 80 PERCENT OF FORMATION
B - INFFRRED FROM D. U. DEERE AD 646610-66 C - UNPOLISHED SPECIMEN D - INFERRED FROM TESTS OF SIMILAR SPECIMEN
E - ASSIGNED MINIMUM VALUE F - FROM CSM ANN. REPORT, H0210043-72

FIGURE 3-8

MACHINE ANALYSIS MATRIX

```
MACHINE EXCAVATION


 STEP NUMBER     7
 VARIABLE ENTERED     3

 MULTIPLE R                    .8287
 STD. ERROR OF EST.            .8106

 ANALYSIS OF VARIANCE
                           DF      SUM OF SQUARES      MEAN SQUARE
          REGRESSION        7             27.366             3.909
          RESIDUAL         19             12.485              .657
                                                                       .
                    VARIABLES IN EQUATION                              .
                                                                       .
   VARIABLE        COEFFICIENT  STD. ERROR  F TO REMOVE                .
                                                                       .
                                                                       .
   (CONSTANT          13.31161 )                                       .
  DUW       2         -.04691       .01628       8.3019                .
  HCEROD    3          .01073       .03589        .0894                .
  CLASS     4         -.68752       .28333       5.8884                .
  TEST      5        -1.93369      1.05053       3.3881                .
  CF/RPM    6         -.00393       .00180       4.7510                .
  THRST     7         -.11876       .06517       3.3207                .
  KERF      8        -5.61296      4.39335       1.6323                .


F-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION
```

```
IDENT    OHS    EXC    MDN   RESIDUALS
       (PAGE)   SYST
         NO

NASTI     1      M      7       .12465
NAST2     3      M      7       .11426
NAST4     7      M      7       .27895
LK   5   21      M      6     -.07115
LK   6   23      M      6     -.45514
CL   1   29      M      6       .35055
NY   1   45      M      5       .58412
NY   2   47      M      5     -.17971
OL   1   49      M      5     -.73811
    5-1  53      M      5     1.09407
    7-2  55      M      3    -1.11764
   72-1  61      M      4       .21645
LAW  2   67      M      4     -.76611
LAW  3   69      M      4     -.76611
LAW  4   71      M      4    -1.04057
MIL  1   73      M      5       .10540
MIL  2   75      M      5       .19697
MIL  3   77      M      5       .18398
EVG  1   79      M      4     -.38759
FVG  2   81      M      4     -.14136
LAY  1   83      M      3     -.80162
LAY  2   85      M      5       .53671
CNT  1   87      M      6     1.94910
NAV  1   89      M      3     -.48352
NAV  2   91N     M      4       .00000
NAV  2   91W     M      7     1.06631
RO   1   93      M      4       .14711
```

```
  SUMMARY TABLE

    STEP              VARIABLE                    MULTIPLE                      INCREASE         F VALUE TO
   NUMBER         ENTERED   REMOVED          R                 RSQ              IN RSQ       ENTER OR REMOVE


     1           CLASS    4                .6983             .4876              .4876            23.7947
     2           CF/RPM   6                .7270             .5285              .0408             2.0787
     3           DUW      2                .7642             .5840              .0555             3.0693
     4           TEST     5                .7894             .6231              .0391             2.2846
     5           THRST    7                .8123             .6598              .0366             2.2621
     6           KERF     8                .8278             .6852              .0254             1.6168
     7           HCFROD   3                .8287             .6867              .0015              .0894
```

FIGURE 3-9

OUTPUT, MACHINE DATA ANALYSIS

CONVENTIONAL EXCAVATION PARAMETERS

1 IDENT	2 ORS (PAGE) NO	3 EXC SYST	4 MDN	5 DUW PCF	6 H SCHMIDT	7 CSTR	8 ET PSI*10**6	9 P RATIO	10 RQD PCT	11 ROCK CLASS	12 WATER	13 TEST	14 XS AREA SF	19 A/H SF PER HOLE	20 PF LBS EXPL/ CU YD
NAST3	5	C	2	164	54B	28	8.32	.35B	90	1	2	1	160	2.2	6.3
GA 1	9	C	2	161	42	35	6.40B	.30B	96	1	2	1	103	2.1	6.1
H 1	11	C	2	163	50	32	8.00B	.31B	80	1	2	1	99	2.6	5.5
H 2	13	C	2	164	60B	39	10.00B	.35B	80	1	2	1	99	2.6	5.5
H 3	15	C	1	162	46	29	8.89	.31	90	1	2	1	99	2.6	5.8
LK 1	17	C	1	162	53	25	8.80B	.30B	83	1	1	1	245	5.2	4.0
LK 2	19	C	1	165	56B	28	9.40B	.33B	83	1	1	1	245	5.2	4.0
LK 7	25	C	2	158	37	7	4.76	.10	35	1	1	1	199	4.7	4.7
SM 1	27	C	1	165	47	19	7.46	.20	50	1	1	1	144	2.8	3.8
LK 3	31	C	1	178	50	26	11.20B	.34B	80	2	1	1	221	5.3	4.2
LK 4	33	C	1	182	33	14	6.50B	.30B	70	2	1	1	199	4.7	4.6
ST 1	39	C	1	168	45	21	8.35	.13	75	2	1	1	95	2.2	5.5
CM 1	41	C	1	168	41	13	5.72	.18	50	2	1	1	100	2.1	9.5
HS 1	43	C	1	187	41	19	8.62	.20	70	2	2	1	54	1.6	7.0
MB 2	51	C	3	171	44	22	9.76	.20	35	3	1	1	95	2.6	7.5
11-3	57	C	2	165	46	23	9.52	.15	90	3	1	1	180	5.1	3.5
MSU 1	63	C	3	171	36	11	7.20B	.25D	65	3	1	1	90	2.0	8.2
MSU 2	65	C	2	169	45	25	8.70	.22	80	3	1	1	90	1.8	6.7
WNG 2	97N	C	3	125	5E	1E	0.10E	.10E	30	3	1	2	45	2.5	5.0
WNG 2	97W	C	7	125	5E	1E	0.10E	.10E	30	3	1	1	45	2.5	5.0

* -WEIGHTED AVERAGE   ** - 2.75 UPPER HEADS 1.38 LOWER HEADS   A - 80 PERCENT OF FORMATION

B - INFERRED FROM D. U. DEERE AD 646610-66   C - UNPOLISHED SPECIMEN   D - INFERRED FROM TESTS OF SIMILAR SPECIMEN

E - ASSIGNED MINIMUM VALUE   F - FROM CSM ANN. REPORT, H0210043-72

FIGURE 3-10

CONVENTIONAL ANALYSIS MATRIX

```
CONVENTIONAL EXCAVATION



STEP NUMBER     7
VARIABLE ENTERED     8

MULTIPLE R                  .9553
STD. ERROR OF EST.          .5189
                                                                     IDENT   OBS    EXC   HDN   RESIDUALS
ANALYSIS OF VARIANCE                                                        (PAGE)  SYST
                     DF     SUM OF SQUARES     MEAN SQUARE                   NO
       REGRESSION     7          33.719           4.817
       RESIDUAL      12           3.231            .269              NAS1 3    5     C     2      .10022
                                                                     GA   1    9     C     2    -.17788
                                                            .        M    1   11     C     2     .02929
                 VARIABLES IN EQUATION                      .        M    2   13     C     2     .75113
                                                            .        M    3   15     C     1    -.99801
  VARIABLE       COEFFICIENT  STD. ERROR  F TO REMOVE       .        LK   1   17     C     1    -.20677
                                                            .        LK   2   19     C     1     .17759
                                                            .        LK   7   25     C     2     .54913
 (CONSTANT           17.95833 )                             .        SM   1   27     C     1    -.07092
 DUW        2         -.09408      .01107      72.2598      .        LK   3   31     C     1     .19906
 HCFROD     3         -.09692      .04206       5.3108      .        LK   4   33     C     1    -.12263
 PRATIO     4         4.85267     2.43086       3.9851      .        ST   1   39     C     1    -.17063
 CLASS      5         1.11286      .19869      31.3708      .        CR   1   41     C     1    -.50858
 WATER      6          .98792      .37610       6.8999      .        MS   1   43     C     1     .29526
 TEST       7        -3.79832      .70391      29.1167               MB   2   51     C     3     .57124
 PF         8         -.08263      .09977        .6859      .         11-3   57     C     2    -.52705
                                                                     MSU  1   63     C     3     .24558
                                                                     MSU  2   65     C     2    -.34169
F-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION                         WNG  2   97N    C     3     .00000
                                                                     WNG  2   97W    C     7     .20168



SUMMARY TABLE

 STEP              VARIABLE                 MULTIPLE                     INCREASE        F VALUE TO
NUMBER         ENTERED  REMOVED           R             RSQ               IN RSQ      ENTER OR REMOVE


  1           DUW      2                .7058          .4981              .4981          17.8669
  2           CLASS    5                .8041          .6465              .1484           7.1356
  3           TEST     7                .9086          .8255              .1790          16.4125
  4           WATER    6                .9328          .8701              .0445           5.1416
  5           HCEROD   3                .9390          .8818              .0117           1.3855
  6           PRATIO   4                .9527          .9076              .0258           3.6297
  7           PF       8                .9553          .9126              .0050            .6859
```

FIGURE -11

OUTPUT, CONVENTIONAL DATA ANALYSIS

SHIELD AND MISC. MACHINE EXCAVATION PARAMETERS

1 IDENT	2 OBS (PAGE) NO	3 EXC SYST	4 MDN	5 DUW PCF	6 H SCHMIDT	7 CSTR	8 ET PSI*10**6	9 P RATIO	10 ROD PCT	11 ROCK CLASS	12 WATER	13 TEST	14 XS AREA SF
MB 1	35	M	2	207	20C	7	2.50D	.15D	10	2	1	1	78
MB 3	37	M	2	188	16	6	2.10	.15	10	2	1	1	95
11-4	59	M	2	166	46	23	9.50D	.15D	90	3	1	1	130
WNG 1	95N	M	3	125	5E	1E	0.10E	.10E	30	3	2	2	80
WNG 1	95W	M	7	125	5E	1E	0.10E	.10E	30	3	2	1	80
SF 1	99	S	7	113	5E	1E	0.10E	.10E	15	3	3	1	346
SF 2	101N	S	2	142	7B	2	0.10E	.10E	50	3	2	2	346
SF 2	101W	S	6	142	7B	2	0.10E	.10E	50	3	2	1	346
KM 1	103N	M	1	144	42B	11	5.00B	.10E	90	3	2	2	100
KM 1	103W	M	4	144	42B	11	5.00B	.10E	90	3	2	1	100

* -WEIGHTED AVERAGE ** - 2.75 UPPER HEADS 1.38 LOWER HEADS A - 80 PERCENT OF FORMATION
B - INFERRED FROM D. U. DEERE AD 646610-66 C - UNPOLISHED SPECIMEN D - INFERRED FROM TESTS OF SIMILAR SPECIMEN
E - ASSIGNED MINIMUM VALUE F - FROM CSM ANN. REPORT, H0210043-72

FIGURE 3-12

SHIELD AND MISCELLANEOUS MACHINE MATRIX

3.7 TRANSPORT SYSTEM AND EQUIPMENT SELECTION

3.7.1 MDN and Bulk Properties Prediction

In application, exploration and test results from the site of a future tunnel would be substituted for the rock variables in the predictor equation, with quantified input on expected water occurrence and the characteristics of the proposed excavation subsystem. When sampling shows that the formation will disintegrate substantially when washed, two data sets would be used, one with a value of 1 as the TEST parameter and one with a value of 2. When two MDN are derived from sets of data which differ only in the TEST parameter, the lower number predicted will apply to muck handled in the natural state, and the higher to muck which has been processed by washing, as in preparation for hydraulic conveying.

Within the ranges shown on the summaries in Section 3.5, the predicted MDN will indicate the gross bulk handling properties of the resultant muck. More detailed inferences can be drawn by reference to the data sheets corresponding to the individual observations listed on Figures 3-1 through 3-7, selecting the properties of the formation which matches most nearly the rock, tunnel, and operating characteristics used in the prediction.

3.7.2 Use of MDN

Obviously, from the (statistically) small volume of data available at this stage of the program, predictions can be made for only a small proportion of all the possible combinations of rock, tunnel, and operation variables. Caution in application of the data which is available is suggested to prevent overconfidence in the accuracy of prediction. The "correlation coefficient" at any level indicates only the probability of deriving an MDN closer to the correct number than to any other. Much more data is required, and many predictions must be verified before the MDN concept can become a reliable technique suitable for general application. Nevertheless, with large infusions of judgment, the data and methods so far developed can be valuable tools within their obvious limitations.

Having predicted an MDN, broad selections from the available systems may be made from the following table.

TRANSPORT SYSTEM CAPABILITY							
Transport System	**MDN**						
	1	2	3	4	5	6	7
Conventional Rail	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Side Rail	*	*	*	*	*	*	*
Free Vehicles	(3)	(3)	Yes	Yes	Yes	(4)	(4)
Belt Conveyors	(1)	(1)	(2)	(2)	(2)	(2)	(2)
Hydraulic Pipeline	No	No	(5)	(5)	Yes	Yes	Yes
Pneumatic Pipeline	No	No	No	*	*	*	*

* Possible, technology not fully developed.

(1) Excessive width, wear, and damage.

(2) Excessive fines buildup probable in some formations.

(3) Excessive tire wear probable.

(4) Excessive roadbed maintenance probable in some formations.

(5) Practical for muck with less than 10 percent plus 1 inch.

Those systems noted by an asterisk have potential capability which has not been demonstrated in practice. The basis of other notations is discussed in the following examples of MDN applications which are provided in the detail consistent with the scope of the program.

3.7.3 Example 1: Hydraulic Pipeline Feasibility

Hydraulic conveying is a proven method of long distance horizontal and/or vertical slurry transport. Most industrial applications handle material minus 6 mesh in size. Those systems which handle solids in the plus 1/2 inch minus 8 inch size operate in the plus 500 tph capacity range through centrifugal pumps which are so large (16 inches x 40-1/2 inches typical) that use in any but the larger tunnels would result in serious congestion in the near face area. Lock feeders have demonstrated capability to handle limestone, mine refuse, and coal, 90 to 95 percent plus 1/2 inch in size, with 19 to 25 percent in the minus 2 inch plus 1-1/2 inch range, but the feeder size limits their application also to relatively large tunnels. Centrifugal pumps which will handle minus 1 inch material in the volume produced by current TBM advances are readily available in sizes which can be used in tunnels over 9 feet in diameter, while leaving adequate space for supply and support activities. Classification of hydraulic conveying as a proven tunnel technique is based upon a trial in a Colorado tunnel in which the system was demonstrated to perform well within design capacity.

Tunneling history suggests that an assumption of completely uniform characteristics is unrealistic for most rock formations. The design of an hydraulic system, lacking concrete evidence that no loose ground will be encountered, must incorporate a means of scalping off any material larger than the maximum for which the system is designed, and a means of disposal of this oversize. Assuming that this provision has been made, the limit of hydraulic systems' capabilities used in this study has been set at 10 percent plus 1 inch as indicated by Note (5) in the Transport Capability Table, and by notations on the individual raw data sheets. The basis for this limitation is the judgment of the investigators of the amount of oversize which could be handled by a supplemental haulage system without serious interference with other activities.

The following is a generalized actual case history to illustrate a practical application of MDN and MDN study data. A contractor driving a 16,000-foot, hard rock, water tunnel is using a TBM and conventional rail haulage in the first 9,000-foot section, 9 feet 9 inches in diameter and +0.25 percent in grade. This section is roughly parallel to and on the same elevation as a side hill access road to the outlet portal and the muck disposal area. It will intersect a cross tunnel (adit) at the p/t of the second section. The adit, which is 800 feet long, will provide an outlet to a portal on the access road about 2 miles from the muck disposal area.

Job time can be reduced by lining the first tunnel section and completing concrete structures at the main tunnel portal while the second main tunnel section is being driven. Rail muck haulage would interfere with lining, and the rotary car dump must be removed before construction at the main portal can begin; alternates to rail haulage through the first section for muck from the second section are being considered.

Rock and muck samples are available from the TBM output at three locations in the main tunnel, and from a conventional round at the inby end of the adit. The machine samples have been classified as MDN 7, from the data shown for Nast 1, 2, and 4 on Figure 3-7. Rock properties of the conventional sample GA-1 are shown on Figure 3-10. No disintegration was noted after 24 hours of immersion; the TEST parameter is 1. An advance rate of 3 feet per hour is expected at 8.5 RPM, with a kerf spacing of 0.10 feet and a thrust of 6.0 K pounds/square foot. The predictor equation (Figure 3-9) is:

$$\begin{aligned} \text{MDN} = {} & 18.312 - \text{DUW} \times 0.047 + \text{HCERQD} \times 10^{-5} \times 0.011 \\ & - \text{CLASS} \times 0.688 - \text{TEST} \times 1.934 - \text{CF/RPM} \times 0.004 \\ & - \text{THRUST} \times 0.119 - \text{KERF} \times 5.613. \end{aligned}$$

Substituting the independent variables from Figure 3-10:

$$\begin{aligned} \text{MDN} = {} & 18.312 - 161 \times 0.047 + (42 \times 35 \times 6.40 \times 96 \times 10^{-5} \times 0.011) \\ & - 1 \times 0.688 - 1 \times 1.934 - (76 \times 3.0/8.5) \times 0.004 \\ & - 6.0 \times 0.119 - 0.10 \times 5.613 \\ = {} & 18.312 - 7.567 + 0.099 - 0.688 - 1.934 - 0.107 \\ & - 0.714 - 0.561 \end{aligned}$$

$= 6.84$ which closely approaches the assigned MDN of the three Nast samples.

Reference to the Capability Table indicates that a choice of an alternate to rail haulage is between free vehicles, belt conveyors, and hydraulic conveying. Free vehicles were believed impractical for an average round trip of 7,600 feet in a tunnel in which passing room is less than 9 feet. A belt conveyor design (by others) was considered too expensive, and investigation of an hydraulic pipeline was initiated.

Methods of calculating critical velocities, selecting pipe size and operating velocities, and calculating power requirements developed by many researchers, have been summarized by the Colorado School of Mines Research Foundation in a publication, "The Transportation of Solids in Steel Pipes," 1963 (Reference 1). These methods were used with MDN data in a feasibility study of an hydraulic system.

As shown in detail in Appendix B, the first data required for hydraulic design are the size and size distribution of the muck. In this case, the data are available in Figure 3-7. In preconstruction planning for another site, the same data would be inferred by reference to the individual data sheets for the samples from which MDN 7 was developed. Inspection shows that only Nast 1, 2, and 4 can be representative since the others are all low strength rocks of another class.

Although a method involving evaluation of the head loss produced by each size fraction is considered somewhat more precise, calculation of a single mean-particle size is appropriate for a preliminary calculation. This size was calculated using the size distribution curve for Nast 4 (as the worst case) by taking the average size of the openings in each consecutive pair of screens as a multiplier for the percent of the total retained on the smaller of each pair and dividing the total by 100. The result is 0.198 inch.

Critical velocity is a function of a constant (varying from 0.3 to 1.5 with particle size and solids concentration), the mixture concentration by volume (C_V), the pipe size (D), and the specific gravity (S) of the solid. An average S of 2.65 was calculated from MDN data for Nast 1, 2, and 4, and GA-1. Critical velocities were calculated for two pipe sizes, after determining the constant from the Durand function curves and calculating C_V from concentrations by weight (C_W) as described in Reference 1:

3-Inch Pipe, V_{CR}	7.03 ft/sec
4-Inch Pipe, V_{CR}	8.05 ft/sec

Operating velocity (V_T) is a function of flow rate and pipe cross section. These were calculated for both pipe sizes and concentrations:

Description	30 Percent C_W	40 Percent C_W
3-Inch Pipe, V_T	8.84 ft/sec	6.23 ft/sec
4-Inch Pipe, V_T	5.13 ft/sec	3.61 ft/sec

These calculations indicate that the 3-inch pipe carrying the 30 percent C_W slurry can be used, maintaining the operating velocity above the critical. The flow rate corresponds to 204 gpm.

To determine power requirements, the head loss of clear water is taken from standard tables, a Reynolds number is calculated, a drag coefficient is taken from the standard Reynolds number chart, and the slurry head loss (i_m) is calculated. For the 3-inch pipe at 30 percent C_W, the calculated head loss is 42.15 feet per 100 feet of pipe. This loss is partially compensated by the tunnel grade, 0.25 percent, for an effective head loss of 41.90 feet per 100 feet. For the average distance of 16,000 feet/2 = 8,000 feet plus 500 feet, (added for a distance from the portal to the settling sump), the average head loss becomes 85 x 41.9 = 3,562 feet, and the average hp, based on a 40 percent pump efficiency, 564. The maximum hp is 165/85 x 564 = 1,094, corresponding to a maximum head loss of 6,914 feet.

Although there was an existing pipeline in the tunnel which could have been used as a return waterline, the cost estimate for a system to advance with the TBM was on the order of $200,000, without provision for power transmission. In comparison with an estimated operating advantage of about $30,000, the concept was not attractive to the contractor.

3.7.4 Example 2: Free Vehicle Application

The 800-foot adit referenced in Example 1 will be driven at a 10 foot x 10 foot cross section at any time during the life of the contract. Selection of excavation and haulage systems and equipment is necessary for advance procurement.

Core samples and drill logs from a vertical hole at the intersection elevation provide the following data:

Lithology:	Igneous, Biotitic Granite, Fine Grained
Dry Unit Weight (DUW):	161
Schmidt Hardness (H):	42
Compressive Strength (CSTR):	35
Young's Modulus (ET)	6.40

Poisson Ratio (P Ratio): 0.30

RQD: 96 Percent

Rock Class: 1 (Igneous)

Water Occurrence: 1 (Minor)

Immersion of a sample resulted in no disintegration; the TEST variable is 1.

Conventional excavation has broken similar rock with 50 holes (A/H = 2.0) and a powder factor (PF) of 6.1 pounds per cubic yard. A basic decision has been made not to drive the cross tunnel with the TBM because the (side) gripper design makes collaring a branch from an existing tunnel impractical, and the rock at the side hill portal is weathered and unstable for an indeterminate distance, which might further complicate TBM operation.

The MDN of the muck from conventional excavation in this formation is calculated by substituting the variables in the predictor equation (Figure 3-11):

$$\begin{aligned} \mathrm{MDN} = {} & 17.958 - \mathrm{DUW} \times 0.094 - \mathrm{HCERQD} \times 10^{-5} \times 0.097 \\ & + \mathrm{P.\ RATIO} \times 4.853 + \mathrm{ROCK\ CLASS} \times 1.113 \\ & + \mathrm{WATER} \times 0\quad 38 - \mathrm{TEST} \times 3.798 - \mathrm{PF} \times 0.083. \end{aligned}$$

Substituting the rock and operating variables:

$$\begin{aligned} \mathrm{MDN} = {} & 17.958 - (161 \times 0.094) - (42 \times 35 \times 6.4 \times 96 \times 0.097 \times \\ & 10^{-5}) + (0.30 \times 4.853) + (1 \times 1.113) \\ & + (2 \times 0.988) - (1 \times 3.798) - (6.1 \times 0.083) \\ = {} & 17.958 - 15.134 - 0.875 + 1.456 + 1.113 \\ & + 1.976 - 3.798 - 0.506 \\ = {} & 2.19, \text{ for which the MDN is 2.} \end{aligned}$$

The Capability Table (page 3-28) shows that rail, free vehicles, or belt conveyors are suitable systems for MDN 2, and calls attention to the probability of excessive tire wear with free vehicles, and to the excessive width, wear, and damage probable with belt conveyors. Figure 3-2 shows test results of seven conventionally excavated samples with a maximum block size range from 21 inches to 3 feet, and a range of plus 3-inch material from 19 to 48 percent. Conveyor design standards, requiring a belt width of 3 to 4 times the maximum block size, indicate a minimum width of 63 inches to 84 inches. The nominal capacity range of a 60-inch belt is from 600 to 1,000 tons per hour, and the maximum tonnage from this heading will not be greater than 70 tph. This removes the conveyor concept from further consideration.

The estimated completion time of the 800-foot tunnel section is 120 shifts, which may be scheduled during any part of the contract period. The past history of TBMs in strong rock (the main tunnel) predicts several unscheduled delays of days' to weeks' duration. A sound strategy appears to provide for completing the portal and the weathered section of the adit early in the contract, and to drive the remainder during main tunnel downtime. A rubber-tired load-haul-dump unit is a logical choice for mucking and haulage to the portal. The haulage distance is well within the range of this equipment, such a unit will be necessary for muck removal from the main tunnel dumping point, and will not be in critical demand during TBM shutdowns.

The unit can move easily from portal to portal, while a locomotive would require a crane and a lowboy. No car dump would be necessary, and the muck from one round could be stocked at the portal for truck loading during the drilling cycle. Choice of the best equipment for this application can be made from any standard line which provides safe clearance from tunnel ribs and the back, and a diesel engine with an approved exhaust scrubber. Many rigs are available with these specifications in the 2 to 3 cy class, and the final choice would be made of one with a bucket adapted to mount 2 or 3 heavy drifters to serve as a jumbo during drilling cycles. Excessive tire wear can be avoided by minimal fly rock clean up with the LHD bucket, and by the use of chain protectors if this becomes necessary.

3.7.5 Example 3: Belt Conveyors

Note (1) concerning belt conveyor applications in the Transport System Capability Table is illustrated by the excessive width required for an MDN 2 considered in Example 2. Note (2) shown in the table for other MDN has been applied in the data sheets to muck with concentrations

of more than 12.5 percent in the minus 100 mesh size range, a limitation based on field observations by the investigators.

To illustrate an MDN application to the selection of a belt conveyor haulage system, data from one of the tunnel sites sampled has been generalized to a 5,000-foot TBM operation in a strong sandstone, diameter 18 feet, grade plus 17 percent. Physical property data includes:

DUW:	166
Hardness:	37
Compressive Strength:	22 K psi
Young's Modulus:	6.00
RQD:	80 Percent
Rock Class (Sedimentary):	3
Immersion Results:	No Disintegration
TEST Variable:	1

A machine penetration rate of 6 feet per hour is anticipated with 4.5 RPM, 3.7 K pounds per square foot thrust, and a 0.20-foot kerf spacing.

From Figure 3-9, the predictor equation is:

$$\begin{aligned} \mathrm{MDN} = {} & 18.312 - \mathrm{DUW} \times 0.047 + \mathrm{HCERQD} \times 10^{-5} \times 0.011 \\ & - \mathrm{CLASS} \times 0.688 - \mathrm{TEST} \times 1.934 - \mathrm{CF/RPM} \\ & \times 0.004 - \mathrm{THRUST} \times 0.119 - \mathrm{KERF} \times 5.613 \end{aligned}$$

Substituting the variables

$$\begin{aligned} \mathrm{MDN} = {} & 18.312 - 166 \times 0.047 + (37 \times 22 \times 6.0 \times 80 \times 10^{-5}) \\ & \times 0.011 - 3 \times 0.688 - 1 \times 1.934 - (257 \times 6/4.5) \\ & \times 0.004 - 3.7 \times 0.119 - 0.20 \times 5.613 \end{aligned}$$

$$= 18.312 - 7.802 + 0.043 - 2.064 - 1.934 - 1.371$$

$$- 0.440 - 1.123$$

$$= 3.62$$

With this result, reference to the data sheets is necessary. Figure 3-8 lists 11 samples with MDN 3 or 4 in Rock Class 3. Of these, four are dissimilar in rock properties and excavation parameters. The muck characteristics of the remaining seven are shown below, and are summarized in a "worst case."

MDN	Ident. No.	MUCK				Max. Block Size	DUW Loose	DUW Solid	Angle/ Repose 10" Drop	% Moist. Nat.
		Size and Distribution								
		-6"+3"	-3"+1"	-1+100	-100	(In.)	(Lbs.)	(Lbs.)		
3	7-2	1.5	34.0	50.0	14.5	9	90	166	31°	4.0
4	Law-2	0	28.0	63.3	8.7	3	92	161	38°	7.2
4	Law-3	0	30.2	58.8	11.0	3	93	161	40°	5.5
4	Law-4	0	23.3	60.4	16.3	3-1/2	80	157	34°	7.9
4	Evg-1	0	29.8	59.1	11.1	6	94	168	31°	3.8
4	Evg-2	0	26.6	61.0	12.4	4-1/2	94	170	34°	2.3
4	72-1(W)	0	22.8	70.7	6.5	12	86	168	32°	1.5
4	72-1(N)	0	32.0	NA	NA	12	86	168	32°	1.5
Worst Case		1.5	34.0	48.2	16.3	12	94	170	31°	7.9

Of the alternatives, conventional rail was eliminated because of the grade. The LHDs and FWD shuttle cars available, while able to operate at the tunnel grade, were too wide to permit safe passage in the normal drift diameter. A simulation by others showed that multiple vehicles and turnouts would be necessary to keep up with the expected TBM advance while downtime for cutter changes would leave a large equipment inventory idle.

References used in a belt conveyor study were the 1966 CEMA publication, "Belt Conveyors for Bulk Materials," (Reference 2), and "Catalog No. 66," Stephens-Adamson Mfg. Co. (Reference 3).

The first muck characteristic considered was the maximum block size. While the 12-inch maximum dimension would imply a belt width of 48 inches based on chute design, the small percentage of plus 3-inch material indicated that this would be relaxed to 42 inches or 36 inches. Using a surcharge angle of 15 degrees (16 degrees less than the "worst case" angle of repose), and considering a "lump" as plus 3 inches in size, the 36-inch choice is confirmed by Table 1-1, Reference 3, subject to capacity calculations.

Choice of a general arrangement considered the TBM design and the supply transport system as well as the muck characteristics. The discharge from the TBM conveyor would be at 5 feet 3 inches below the tunnel crown over a head pully assembly 1-foot 9-inches deep. A 425-foot feeder conveyor hung from a monorail and a trolley is designed to travel with the TBM. Support for this assembly will be provided by roof channels rock bolted to the back; clearance to the invert will be 9 feet. About 4 feet of fill above the invert would be required to provide a flat surface wide enough for supply vehicles and a conventional conveyor. The fill would leave only 5 feet of clearance to the bottom of the feeder belt, and would have to be removed on completion to maintain the ventilation area for which the tunnel was designed. For these reasons, a rope belt, supported from the roof channels, was selected. To maintain adequate clearance from the floor, a 20-degree end roll angle is indicated by the geometry.

Belt speed is a function of cross section capacity, muck characteristics, and production rate. Anticipated production is 6 x 257 = 1,542 cubic feet per hour, or 262,140 pounds, which is equal to 4,369 pounds per minute. The cross section area of the belt is 0.684 square feet and is corrected for inclination. The dry, loose unit weight of the load is 94 pounds per cubic foot, or 63.4 pounds per linear foot of belt. Because the belt will be suspended over personnel and supply traffic, the edge distance is increased to 0.20 b by applying a factor of 0.45, extrapolated from Table 3-9, Reference 2. This results in a load per linear foot of 63.4 x 0.45 = 28.53 pounds, and an indicated belt speed of 4,369/28.53 = 153 feet per minute.

Troughing idler spacing was selected at 5.0 feet from Table 4-1, Reference 2, with a return idler spacing of 10 feet. Service factors, A = 15 and B = 56, result in application factors of III for troughing and return idlers requiring 5-inch diameter rolls. Because of the high percentage of fines, self-cleaning return idlers are indicated. Anticipating heavier service in another application, a 6-inch diameter roll is selected.

The length of a flight is a function of the length of the feeder conveyor and the tunnel length; 1,200 feet is selected as compatible with both. Calculation of required power in the case of a declined belt does not include a friction allowance for grease and seal friction because these may approach zero under some conditions, and cannot be depended upon to retard the belt.

Reduced friction belt tension (T_e) becomes a function of the length (L), a temperature factor (K_t), the revolving idler resistance (K_x), the belt width (W_b), the moving resistance of the loaded belt (K_y), the weight of the belt load (W_m), the elevation change (H), a reduced friction factor (C_l), and the resistance of the nondriving pulleys and skirt boards. Substitution in the formula (Reference 2) gives a tension of minus 5,632 pounds. Use of this value and the velocity (V) with the power formula (Reference 2) results in a belt horsepower of minus 26.1.

Adding 6 percent for speed reduction losses, the motor shaft horsepower becomes 24.5. This is the power required to retard the conveyor velocity in normal operation, and is subject to review under empty and partial loading conditions. A brake would be necessary to decelerate and hold the belt under conditions of power failure and must be designed not to overstress the belt. Since the flights will operate as parts of a system, sequence starting and stopping will be necessary to prevent pile ups at transfer points. Belt cleaners and possibly water sprays would be required because of the fines. Choice of a belt will depend not only on tension and service factors, but also on fire retardant characteristics. Detailed definitions of these system components is beyond the scope of this program, but the foregoing discussion and the detailed calculations shown in Appendix B serve to demonstrate the use of MDN data and a manual method of determining equipment requirements.

3.7.6 Example 4: Conventional Rail Systems

The major application of MDN data to selection of a rail haulage system is in the elimination of other subsystems from consideration. Rail haulage is adaptable to any MDN, and final design usually is dictated by space, production, and safety considerations. Other MDN applications possible are the use of shape, size, and consistency data in the designs of cars, car dumps, and storage facilities. As examples, a rotary car dump used with MDN 7 muck characterized by a high fines content operated well with two men while a MDN 2 muck, with a relatively low percentage of fines from a similar formation, required three men to unload and clean side dump cars in about twice the time. Either dumping method could have been improved by rubber half-liners. Similarly, two rather elaborate bin and chute installations could have been predicted to rathole as they did with platy MDN 3, 4, and 5 muck, while alternate bin designs might have eliminated through dumping and extra manpower. In still another case, anticipation of the large slab size and the characteristics of material with high liquid and plastic limits could have resulted in a car-dump, pug-mill conveyor design which worked well in place of one which was able to handle only about ten percent of the muck from a 5-mile, soft ground tunnel, and was replaced by an expensive and relatively inefficient alternate.

3.7.7 Equipment Selection Methods

The manual procedures illustrated for belt and hydraulic conveyor subsystems are obviously time-consuming and subject to a high degree of human error. Requiring many manipulations of the same or variations of the same data, they are often bypassed by the expedient of specifying performance and accepting vendors' recommendations with only a cursory intuitive verification by the contractor.

As tedious, repetitive mathematical operations, both procedures are excellent subjects for computer programmed solutions. With the increasing familiarity of construction organizations with computer techniques, there is no question that proven computer programs would be valuable tools for job planning, and could prevent costly errors in equipment application. Considerable effort has been expended in resolving apparent conflicts in design philosophy. Areas which appear to require further study are described in the section of this report which deals with implications for further research.

The parametric mathematical models described in HN-8080, "Materials Handling for Tunnels," referenced in Appendix E, were reviewed for application in this study. It is apparent that muck size and size distribution, on which MDN are based, as well as other physical property characteristics determined in the program, can be used as input for the design formulas and the models. However, modification and refinement of the models, originally developed for the high advance rates of the future, will be necessary for direct application to current operations. Other computer programs investigated were held to be proprietary. Time and funding of this program are insufficient for further investigation, or for the development of in-house programs.

Differences of opinion exist concerning the adequacy of the conventional methods of muck transportation for tunnel advance rates which are not far in the future. These unresolved differences illustrate the fact that no rapid, economical method of evaluating system capability has been developed for tunnel operations. Our experience in computer simulation indicates that this technique could produce excellent results. A successful demonstration, however, would require factual information on operational times, and delay frequency and severity, in order to model real life performance. A demonstration should also include a lay term explanation of the technique, since any successful method of selecting the best methods and equipment for tunneling must compare possible alternates in a way which can be understood and accepted by the user.

4. DoD IMPLICATIONS

The advantages of siting many DoD installations underground and the virtual necessity of such sites for some installations have been discussed by many authors in such diverse publications as science fiction and U. S. Government reports and will not be repeated here. The potential value of underground sites for joint use has received somewhat less publicity, but is illustrated well by concepts such as the Manhattan Island Parking Garage and Blast Shelter, an evaluation of which was prepared by Holmes & Narver, Inc., for the Oak Ridge National Laboratory in 1967 (ORNL TM 1381). The study defined cross-town vehicular tunnels connecting the Lincoln and Queens-Midtown, and an underground complex which would provide subsurface parking for 30,000 cars, as well as emergency housing for nearly two million people. The impact of one or many such facilities on national defense capability could be enlarged upon at length. With current population and mobility growth rates, increased use of underground siting for many purposes is a certainty. The importance of tunneling to weapons test programs requires no evidence in a report to the DoD. Any action which will increase the speed and productivity of any part of the tunneling system will decrease the cost of an operation on which a significant part of the DoD and the national budgets will be expended in the future.

It is apparent that muck handling is a significant part of the cost of any tunnel operation. Current selection of tunnel transportation systems often is based on availability, intuition, and contractor familiarity with the equipment used at other sites. In some cases, the choice has been completely unsuitable for the muck produced. This has resulted in delays and additional expense which may be avoided by use of the information collected by the MDN study.

Other investigations have implied that major modifications of conventional equipment or design of completely new systems will be necessary to dispose of the muck from the high speed excavation systems predicted for the future. Muck characteristic data is a requisite as a basis for the engineering design of such system improvements or of innovative systems.

As an alternate to the design of a haulage system suitable for handling a particular muck, it may be practical to change muck characteristics at the face to provide a suitable feed for a handling system particularly well adapted to the tunnel site. MDN data will be invaluable to the selection of the necessary processing equipment.

Another alternate is to provide a continuous transport system such as hydraulic or pneumatic for the major volume of the muck, and temporary storage, as in a trailer or muck car, for a minor quantity of oversize which would be handled separately. Again, muck characteristic data is a necessity to design the separation equipment and the secondary system.

The data accumulated under the program are nonexistent in usable form elsewhere. While some TBM manufacturers and operators use muck size as an indicator of cutter efficiency, changes are noted during informal inspections at the machine and are seldom recorded except to show a need for cutter replacement. A few screen analyses have been run, but results normally are not made available outside of a manufacturer's or contractor's organization.

In use of MDN data, it is probable that potential improvements in transportation systems will appear. Where such improvements require the application of techniques which are technically sound but not developed to a point of practical application, they should be identified as attractive areas for research.

In summary, the MDN program has provided a part of the basic data required for a rational, engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It illustrates application of data, identifies areas in which improvements are possible, and should be used to identify other areas in which research and development of modifications or new methods would be most productive.

5. IMPLICATIONS FOR FURTHER RESEARCH

5.1 SAMPLE AND DATA COLLECTION

The following samples have been collected, including 18 in 1972 and one collected but not tested in the 1971 program.

Excavation Method	Rock Strength					
	Very High	High	Medium	Low	Very Low	Total
Conventional	3	9	5	1	1	19
Shield	0	0	0	0	2	2
Machine						
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	3	1	0	0	4
Combination Cutters	0	3	1	1	2	7

The program has produced samples from 11 operations and/or formations which were not sampled previously. To conform to good sampling and testing practice, the reliability of the data should be confirmed by repetition, preferably of all single tests.

While the major interest of the program is in strong rocks, variations in muck characteristics with strength can only be demonstrated by sampling the full range of rock strengths excavated by any one method. As they are available, additional sites should be sampled in formations of varied strength, including the fine-grained igneous and volcanic rocks, of which no examples have been available.

Statistically, the number of samples used in developing a predictor equation should be much greater than the number of the variables used in the analysis. Because the reliability of prediction is of major importance, samples should be obtained from the following operations.

1. Drag Cutter Machine excavation in High, Medium, and Low Strength rocks. These samples would provide a

confirming data set in each strength category, and a total number of samples larger than the number of variables.

2. Roller Cutter Machine tunneling to provide confirming data on this method.

3. Combination Cutter Machine excavation in Low Strength rock to confirm data from a single sample collected previously.

4. Conventional tunneling in Low and Very Low Strength rocks to confirm data from single samples collected previously.

5. Disc Cutter Machine tunneling in Low Strength formations to improve the spread of the data on this method.

6. Disc Cutter Machine tunneling with tungsten carbide button insert cutters as a promising development in machine excavation of strong rocks.

Samples and data should be collected from tests of the unusual rock breaking techniques under development, including the electron beam, the water cannon, the conical borer, and continuous application of explosives. Muck data will be necessary to define applicable transport systems, which must be considered in evaluation of any excavation method.

No appropriate operating parameters for Atlas-Copco and Alpine TBMs could be developed under the current program. Some progress was made in determining effective torque for TBMs, but to do so involved getting manufacturers' data on motors, gear reducers, and/or hydraulic pumps, and motors as well as ampere draw data under operating conditions. The time and cost of collecting these data were beyond the scope of the program, but should be budgeted in any future work.

5.2 PHYSICAL TESTING

Physical property testing should continue as in the past, since all commercial test data appears important to one of the predictor equations, and the PMSRC data remains to be evaluated.

Abrasiveness testing should be initiated as soon as possible and continued to provide data for the design and cost analysis phase of equipment selection.

The modified Protodyakonov test for resistance to fragmentation should be investigated for effectiveness and cost to evaluate development of data on this rock property for use in regression analysis and prediction of MDN.

5.3 DATA ANALYSIS

Although many iterations of the regression analysis were performed, many other combinations of variables are possible. Construction has been suggested of a dummy variable for rock classification which would indicate class membership instead of the progression used. A trial also should be made of a correlation using a combination of RQD with hardness and modulus of elasticity alone, but time and funding did not permit analysis using all of the variations which might have improved prediction accuracy. Similarly, since dry unit weight was an important variable in all regressions, it appeared reasonable to substitute specific gravity for values of DUW to evaluate the significance of the same property without the effect of porosity. No analysis of data provided by FMSRC testing was made, because commercial data appeared to be more significant in preliminary analysis, and later addition of variables was impractical. Correlation using all of the variables finally available should be tried as well as other combinations which may appear advisable. Generally, development of regression coefficients which result in large residuals for some observations, indicates that the input data should be reviewed in search of valid reasons for modification. This was done following the preliminary analysis, but not following the final, and should be included in any future work.

5.4 METHODS DEVELOPMENT

The original proposal included time and funds for a thorough review of transportation subsystem design procedures, and for the development of improved methods where possible. When a scope reduction to the fund level of the current contract became necessary, it was agreed that this activity would be confined to an example of MDN application to each of the subsystems in common use. The examples are provided in Section 3, and detailed supporting calculations are shown in Appendix E. They show clearly the time-consuming nature of manual calculations for even a preliminary study of belt and hydraulic conveying feasibility, and indicate the additional calculations necessary for final design.

Mathematical procedures which are tedious, repetitive, and subject to gross error when performed manually are excellent prospects for computer applications. Under these criteria, design practices for both types of conveyors qualify eminently. Some areas in which clarification appears necessary include a formula for clear water head loss which produces results varying by more than 60 percent from those tabulated in standard reference works, and published data correlating belt width and lump size which show data points so far separated that the validity of interpolation is questionable. Undoubtedly, these and other problem areas could be rationalized by further study. Proven proprietary subroutines are reported in use by specialists in both fields. The mathematical subsystem models referenced in Section 3, although requiring modification for application to current operations, indicate that computer programs can be developed which would produce hardware selections from a minimum of input rapidly and at a reasonable cost.

As discussed in Sections 1 and 3, existence of computer design programs in the public domain could reduce contractor dependence on specialists, and provide useful tools for selection of transport system components which meet the requirements of total systems. These tools should be developed by further research. Another such tool which should be developed is system simulation, which could provide a rapid and economical means of comparing the performance of available subsystems, or of variations within a single transport system.

Two factors combine to limit acceptance of computer simulation by industry. One is lack of confidence in an unfamiliar technique which normally is described in an equally unfamiliar language. The second is a lack of the performance, delay, and cost data required for reasonable correlation between model and real-life performance. Development of a data bank would solve the second problem. Description in lay terms of the technique as the simple system which it is, and demonstration of its effectiveness could go far towards solution of the first problem. Both are recommended as subjects for future investigations.

5.5 CONCEPT VALIDATION

The validity of the MDN concept could be demonstrated best by using the predictor equation to calculate MDN for proposed tunnels in advance of construction, using the data to select transportation subsystems and components, and comparing the predicted muck characteristics and the selected transport systems with the muck produced and the subsystems actually used. This approach is recommended.

6. SPECIAL COMMENTS

A Schmidt rebound hardness tester and two MSA self-rescuers were purchased for use in the current program. No invention has been made in the course of the work performed under this contract.

GLOSSARY

ASTM	American Society for Testing and Materials
BM	Beam
CFM	Cubic feet per minute
CNTR	Center
COMPR.	Compressed
CONTIN.	Continuous
CONV	Conveyor
CY	Cubic Yard
DEG.	Degrees
DIA.	Diameter
DUW	Dry Unit Weight
Est, (E)	Estimated
FWD	Four Wheel Drive
GPM	Gallons per Minute
HP	Horse Power
HRS.	Hours
IN.	Inch
INTEG	Integral
Inter.	Internal
K	Thousand
LBS, #	Pounds
LHD	Load Haul Dump
LT	Long Ton
MDN	Muck Designation Number
MAX	Maximum
Moist.	Moisture
MM	Millimeter
NA.	Not Available
NO.	Number
PCF	Pounds per Cubic Foot
PCT	Percent
PF	Powder Factor
PMSRC	Pittsburgh Mining and Safety Research Center
POT.	Potential
PSF	Pounds per square foot
PSI	Pounds per square inch
Rect.	Rectangular
REG.	Regular
RBM	Raise Boring Machine
RPM	Revolutions per Minute
RQD	Rock Quality Designation
SF	Square Foot
ST	Scoop Tram
SPECIF.	Specific
STRNTH.	Strength
TBM	Tunnel Boring Machine
TC	Tungsten Carbide
TCB	Tungsten Carbide Button
T	Tentative
T.	Ton
V	Volt
VOL	Volume
W/	With
WT.	Weight
'	Foot
"	Inch
#	Number
%	Percent
(+)	Plus
(-)	Minus

APPENDIX A

TUNNEL PROJECTS AND CONVENTIONAL DEEP MINE SITES

TUNNEL PROJECTS

A list of operating and scheduled tunnels, prepared originally to assure that program objectives could be met, was revised periodically; but has not been brought up to date because of the termination of the program. Excerpts from the last revision are reproduced below to illustrate the form and content.

OPERATING AND SCHEDULED TUNNELS

Compiled by Holmes & Narver, Inc., Anaheim, California, under U. S. Bureau of Mines Contract H0220023. Revised September 1, 1972

NORTH AMERICAN CONTINENT

Project and Location	Owner or Agency	Size	Length	Contractor
San Manuel Mine San Manuel, Arizona	Magma Copper Company	12'x12'	Various	Own Force

Main level drifting on two levels in quartz monzonite and monzonite porphyry, concurrent with shaft sinking to 3,700-foot depth. A 9,000-foot drift is planned to explore a new ore body from the bottom level of the new shaft.

Project and Location	Owner or Agency	Size	Length	Contractor
Tonner #1 and #2 Brea, Calif.	The Metropolitan Water District of Southern Calif.	11'6" Diameter	#1 - 4,589' #2 - 19,360'	Shea Construction Company

A Calweld machine is being assembled at the site to bore low strength sandstone and siltstone. Geologic data and cores are available from the owner agency.

Project and Location	Owner or Agency	Size	Length	Contractor
Nast Tunnel Fryingpan Project Merideth, Colorado	U. S. Bureau of Reclamation Denver, Colorado	10' Diameter	3 Miles	Peter Kiewit Sons Company

A Wirth boring machine has been replaced by conventional drifting in fault zones, and is scheduled to resume work in more competent rock in November, 1972. Formations are predominantly granite, granite gneiss, granite porphyry, and granodiorite with compressive strengths from 18 K to 24 K psi. Rock is highly sheared in zones from a few feet to 400 feet thick.

DEEP MINE SITES

In response to an expression of interest by an ARPA representative, the Project Officer requested the inclusion of deep mine sites with the conventional operations sampled in the second year of the program. It was agreed that additional data on operating practices peculiar to such sites would be collected. Six samples for the basic program were collected from five sites at depths of more than 3,400 feet below the surface. Data normally collected is presented in Appendices B and C. Other information, beyond the scope of the data formats, is provided in this appendix.

Magma Mine, Superior, Arizona

Rock and muck samples taken from the 3,400-foot level of this mine at a depth of 3,960 feet below the surface are identified as MSU-1 and MSU-2. Discovery of an ore body at this location in 1875 is reported in "Rock to Riches," Dunning and Peplow, 1966, which describes intermittent development until 1910 when the Magma Copper Company was organized. For the next 20 years, mining and development, including additional shafts, continued steadily in ore bodies which increased in size and value at greater depth. High rock temperatures were also encountered, and a cooling and ventilating system was installed in 1931. By 1957, the mine had reached 4,800 feet in depth, but operations at this level were suspended reportedly because of low productivity resulting from high rock temperatures. Development on higher levels continued principally to the east of the older workings. Although an unusually high grade of ore continued to be developed, increasing distance added to the cost of hoisting, haulage, supplies, and ventilation as well as personnel travel time.

Since 1969, a new 22-foot diameter, concrete-lined shaft and a surface plant have been under construction from a location about a mile east of the current major workings. The new shaft will provide access to lower levels down to the 4,200-foot level, which is over 500 feet below sea level, at a depth of nearly 4,300 feet below the shaft collar. Personnel and supplies, which formerly reached these levels by way of an adit, a shaft from the 500-foot level to the 2,500-foot level, a mile of horizontal rail travel, and a second shaft, will reach the working levels directly from the new shaft. Ore will be hoisted to the 500-foot level in the new shaft and hauled to the mill through a 12.5-foot diameter tunnel which was driven by a TBM in 1969 and 1970.

Two Marley cooling towers have been installed with the surface equipment. One 7,100 gpm tower is used to cool compressors and AC units. A 5,000 gpm tower is used with one 700-ton and three 770-ton mechanical units to provide a 6,500-ton capacity system for underground cooling where rock temperatures of 115° to 138° are encountered in current operations and 150° is expected at greater depth. Chilled water at 55° to 60° is fed to 16-inch shell and 5/8-inch tube heat exchangers located in a 280-foot x 16-foot x 13-foot high alcove on the 3,000-foot level by a 16-inch insulated shaft pipeline. Return water at 85° is pumped to the surface through a second 16-inch line. From the exchangers, five 600-gpm, 500-psi circuits feed chilled water through 4-inch lines to working place spot coolers which are portable units with 40-hp compressors and 20-hp fans. Booster fans totalling 25 to 250 hp are installed in ventilation lines.

Ground support is not a major problem in development. Rock-bolted development drifts normally parallel the ore bodies in a medium to high strength conglomerate. The powder factor is above average; the percentage of minus 3-inch material is average or below. The 18-inch gage, light rail system in use throughout the mine for many years is being replaced by a 36-inch gage system on the 3,500-foot level and below. Eimco 21 loaders are used with 35- to 50-cubic foot cars in upper level development. With the wider gage on the 3,500-foot level, an Eimco 22 loader is used with two self-unloading, 15-cubic yard Hagglund shuttle cars. In combination with a company designed hydraulic dump, swing, and slide drill jumbo, the 3,500-foot level equipment is reported to produce about 38 percent higher footage per man-shift than the smaller equipment used on other levels.

Bunker Hill Company, Crescent Mine, Osburn, Idaho, and Hecla Mining Co., Star Mine, Burke, Idaho

Rock and muck samples from these mines are identified as CR-1 and ST-1. Both are in the Coeur D'Alene mining district which is an area of strong relief where surface elevations may vary by 600 feet in a quarter mile. Mining of zinc, lead, and silver ores in the area started in the 1880's and has continued to depths of 6,000 feet to 7,000 feet below the surface in veins which cut the quartzite and the argillite country rock. Formations have been folded and faulted extensively, and the bedding normally dips at a steep angle.

Rock bursts, common throughout the district, are described in a 1970 technical paper by G. G. Waddell, Mining Engineer, U. S. Bureau of Mines, as "the sudden, violent release of stored strain energy in rock by some mechanism of rock failure, usually accompanied by expulsion of rock with considerable damage to the mine." Research into cause, occurrence, and control of bursts has been conducted by the mining companies and the Bureau of Mines over a considerable period. Prime locations for bursts in mine development work have been identified as areas in which a competent rock is in contact with a less competent one; areas in which the strike of the bedding is an an acute angle with the axis of the opening; and dead end openings with either or both of the contact/orientation factors present. An effective control measure in force is an interval of one or two hours between production shifts in which period most rock bursts occur. However, one district mine operator is reported by Waddell to estimate that the rock burst problem adds at least $1 per ton to the cost of ore production.

The CR-1 sample was taken from a development heading on the 4,100-foot level of the Crescent Mine at an elevation about 1,400 feet below sea level, or 6,100 feet below the surface. The face was about 600 feet south of the shaft through which muck, men, and supplies were hoisted to and from the portal adit on the 3,100-foot level. The formation is a medium strength quartzite with minor-filled veinlets dipping at 75° to 90°. Fractures in the face dip at 45° and 10°. The rock requires more drilling time than had been expected, and only one heading of the two available is being driven. The rock temperature is 97° to 100°. Cooling is provided by a 120-ton Carrier AC unit located on the 3,100-foot level about 1,000 feet above the 4,100-foot level to maintain a wet bulb/dry bulb temperature of 85° at the face. Chilled water is fed to the AC compressor through a 4-inch insulated line, and is not recirculated. Two 40-hp fans draw air through the heat exchanger coils of the AC unit to pressurize 24-inch fiberglass ventilation lines through the shaft and the drift. The bolt pattern in the top is not unusual; plates and rock bolts are installed on the ribs as a precaution against slabbing or bursts. The powder factor is comparatively high, but the percentage of minus 3-inch material is average. The LHD unit and the diesel-powered, rubber-tired jumbo are reportedly fully acceptable to the miners and mine management.

Sample ST-1 was taken from a development heading on the 7,500-foot level of the Star Mine at an elevation of 1,744 feet below sea level, or 7,094 feet below the surface. The face was about 600 feet (800 feet via the drift) south of No. 4 shaft. The shaft is operated from the 2,000-foot level and reached through a long adit from the portal. The formation is high strength argillaceous quartzite, moderately folded and fractured, and the rock temperature is about 115°. Cooling had been provided by a 200-ton Carrier AC unit on the 7,300-foot level with ventilation through a 24-inch shaft pipeline. As observed, the system was not operating; the air temperature equalled the rock temperature, and production had stopped. The rock-bolt pattern was normal for the district. One minor rock burst was said to have occurred about 400 feet from the shaft. The powder factor is normal, but the percentage of minus 3-inch material is the second lowest observed. Equipment appears well matched and adequate for the operation.

Homestake Mine, Lead, South Dakota

Described by Dunning and Sadler in "Gold," 1970, as "the longest lived and greatest producer" of all gold mines, Homestake is also one of the deepest in the United States, with level development at 150-foot intervals to 7,100 feet below the surface, and a shaft under construction to lower levels. First operated as an open pit in the late 1870's, ore is currently produced from steep dipping, nearly parallel veins. The development observed was reached via the Yates shaft to the 4,850-foot level, a rail transfer, and a subshaft which services levels down to the 6,800-foot level. Sample HS-1 was taken from a 6,200-foot level heading in phyllite, a high strength, highly metamorphosed sediment with quartz and chlorite stringers.

Normal drift size has been 7-1/2 feet x 7-1/2 feet; the size is being enlarged to provide less resistance to air flow. Primary ventilation is provided by three exhaust fans rated at 1,300 KCFM. Fan power is being increased by over 60 percent to provide more air. Place temperatures up to 121° are reduced to a 74° to 85° range by 30- and 60-ton mechanical cooling units. Development ventilation lines are 16 inches in diameter. Ground support in development is minimal; rock bolts are installed only "as required." The depth of drill rounds (10 feet) is unusual for headings this size and the equipment used. The powder factor is relatively high, and the area per hole is the smallest observed; the percent of minus 3-inch muck is average. Production sustains good contract rates and appears to be satisfactory to management.

Mather "B" Mine, Cleveland Cliffs Iron Co., Negaunee, Michigan

This mine, first developed in the early 1940's, is located in a very old iron mining district known as the Marquette Range in the northern peninsula of Michigan. The iron-ore bodies are extensive, and are developed for block caving by drifts in waste and cross cuts in waste and ore. Sample MB-3 was taken from the twelfth level, west drift extension in a high strength graywacke (known locally as dirty quartzite) at an elevation of 2,030 feet below sea level, or 3,480 feet below the surface. Formations have been highly folded and fractured; normal bedding dip is 30° to 45°.

Development drifts near the ore bodies are normally supported in anticipation of increased pressure as mining approaches the level. The drift observed will connect with workings of an adjacent mine, the Mather "A," and was being driven without support. All haulage is rail, preferred over extensive belt conveyor installations previously used because of greater reliability. Relatively low rock and surface air temperatures result in no major cooling problems; heat is provided for winter operation of downcast shafts in some locations. The powder factor, the area per hole, and the percentage of minus 3-inch muck are above average. Rail, locomotives, cars, drill jumbos, and muckers are large and well matched as a result of extensive tests of many kinds of equipment.

APPENDIX B

RAW DATA SHEETS

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KEY  IDENTIFICATION      ROCK PROPERTIES
 1    NAST               IGNEOUS: GRANITE, GRAY, MEDIUM         DRY       COMP     ROD    ....HARDNESS...   YOUNGS    POISSON
                         TO FINE GRAINED, MODERATELY TO         WT        STRNTH   PCT    SHORE    SCHMIDT  MOD.      RATIO
     SAMPLE NO           SLIGHTLY FRACTURED AND JOINTED         PCF       KPSI     EST                      PSIX10E6
     NAST-1              10 TO 20 PCT  QUARTZ, 50 TO 60
                         PCT FELDSPAR, BALANCE DARK             167       18       90     NA       51       8.50      0.30
                         MINERALS.                                                                 NOTE     NOTE      NOTE
                                                                                                    4        2         2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS.................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100  NO200        NO200

    83       9.4       0.0             0.0   0.0   0.0   2.2     14.9   12.5   12.4   12.3   8.6    11.8   6.8          18.5


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                                   PI     AI     AI     AI     AI     SI     S


     POT VOL CHANGE      *....................ATTERBERG LIMITS..SIZE(-) 0.185IN..................................*
     (-)0.065  IN.SIZE   LIQUID       PLASTIC      SHRINKAGE    PLASTICITY      FLOW        TOUGHNESS
                         LIMITS       LIMIT        LIMIT        INDEX           INDEX       INDEX
                         PCT          PCT          PCT          PCT

      0                  14.50        14.00        13.50        0.50            3.0         0.10


   (-) 0.50IN.SIZE *......................MATERIAL SIZE(-) 0.50   IN............................*        SIZE(-)0.185 IN.
     SPECIF        ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT       BULK                 ANGLE INTER
     GRAVITY       1 IN DROP        10 IN DROP       STEEL PLATE      COHESION       DENSITY              FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT       PSF AT         PCF AT               DEGREES AT
                   9.0 PCT MOIST    9.0 PCT MOIST    9.0 PCT MOIST       PCT MOIST   0.0 PCT MOIST        8.5 PCT MOIST


     2.69          37               36               41               NA             85.16                42


                                                                      NAST-1         CURRENT:  04/01/73
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KEY

  1A
TUNNEL DATA


TUNNEL                         VENTILATION                          WATER INFLOW    UTILITY LINES            POWER SYSTEM

SIZE     SHAPE     GRADE      CFM   PRESS EXHST  SIZE    HP        GPM             AIR  WATER  PUMP          PRIMARY  SECONDARY
9FT      ROUND     +0.22PCT   10K           X    22IN              5-20            6IN  2IN    6IN            4160V      480V
 9IN

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK               PERSONNEL          SUPPLY     BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE          SHOTCRETE
RAIL, 36IN         RAIL               RAIL       4-1IN X 7FT     13IN X 10FT     4IN RING AND HALF
GAGE, 70LB                                       GROUTED         16 GAGE         SETS 4FT, 3FT, AND
RAIL, 16 CY                                                                      2FT IN BAD GROUND
CARS
MOTOR 12 TON


MACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES             RPM          TORQUE,MAX/OPERATE       THRUST,MAX/OPERATE

  MAKE     MODEL       WT      CENTER           INTERIOR        GAGE            HEAD,CENTER  HEAD           CENTER
  WIRTH    HARDROCK    67      2 HUGHES/WIRTH   15 HUGHES/WIRTH 6 HUGHES/WIRTH  8.5   INTEG
  ERKFLENZ             TONS    TCB 11.5IN       TCB 11.5IN      TCB 11.5IN TCB               KFTLB 150  KFTLB               KLB
                               ROLLER 2-TCB     ROLLER          ROLLER                       KFTLB 110  KFTLB               KLB 290
                               11.5IN TCB CONE


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET FROM     HYDRAULIC,      LASER                       FEET         HOUR,FT.
 KLB           FACE, 22IN      POWERED BY                KLB 3.89          0.09           2.6
               CONVEYOR TO     3-200HP MOTORS
               REAR


CONVENTIONAL EXCAVATION


MACHINE                 ROUND,                 EXPLOSIVES,                           BLASTING        MUCKING        GUIDANCE
JUMBO                   NO. HOLES              POWDER FACTOR
MACHINES                DEPTH                  TOTAL LBS
                        DIAM.                  PRIMERS,
                        CUT.                   TRIM
FEED LENGTH                                    INTERIOR
                                               CUT
                                               LIFTERS

        BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
        *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.          NAST-1      CURRENT: 04/01/73
                                                                                                 MDN 7
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KEY  IDENTIFICATION       ROCK PROPERTIES
 2    NAST                IGNEOUS: GRANITE, GRAY, MEDIUM        DRY      COMP      RQD   ....HARDNESS...    YOUNGS   POISSON
                          TO FINE GRAINED, MODERATELY TO        WT       STRNTH    PCT   SHORE   SCHMIDT    MOD.     RATIO
     SAMPLE NO            SLIGHTLY FRACTURED AND JOINTED        PCF      KPSI      EST                      PSIX10E6
     NAST-2               10 TO 20 PCT QUARTZ 50 TO 60
                          PCT FELDSPAR, BALANCE DARK            167       18        90    NA       51        8.50     0.30
                          MINERALS.                                                              NOTE      NOTE     NOTE
                                                                                                  4         4        2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA                         *................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
   DRY UNIT  MOISTURE  PCT(+)6      6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100   NO200    NO200
   WT  PCF   PCT       IN.SIZE

    76        10.8      0.0          0.0   0.0   0.8   8.0   25.0   13.8    11.5   10.3    6.6     7.7     5.5             10.8



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                  PI    PI     PI     AI     AI    SI     SI     S



     POT VOL CHANGE            *..................ATTERBERG LIMITS..SIZE(-) 0.056IN..............................*
     (-)0.056  IN.SIZE         LIQUID       PLASTIC      SHRINKAGE     PLASTICITY     FLOW        TOUGHNESS
                               LIMITS       LIMIT        LIMIT         INDEX          INDEX       INDEX
                               PCT          PCT          PCT           PCT

        0                      19.5         18.2         17.9          1.3            4.6          0.28


    (-) 0.50IN.SIZE *......................MATERIAL SIZE(-) 1.0    IN............................*        SIZE(-)1.0   IN.
     SPECIF          ANGLE/REPOSE    ANGLE/REPOSE    ANGLE/SLIDE     APPARENT        BULK                ANGLE INTER
     GRAVITY         1 IN DROP       10 IN DROP      STEEL PLATE     COHESION        DENSITY             FRICTION
                     DEGREES AT      DEGREES AT      DEGREES AT      PSF AT          PCF AT              DEGREES AT
                     8.7 PCT MOIST   8.7 PCT MOIST   8.7 PCT MOIST   8.5 PCT MOIST   0.0 PCT MOIST       8.5  PCT MOIST


      2.66            38              38              49               0              84.53               31



                                                                    NAST-2        CURRENT:   04/01/73
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KEY

  2A
TUNNEL DATA

TUNNEL                           VENTILATION                          WATER INFLOW     UTILITY LINES          POWER SYSTEM

SIZE     SHAPE      GRADE      CFM    PRESS EXHST  SIZE    HP         GPM              AIR  WATER  PUMP        PRIMARY   SECONDARY
9FT      ROUND      +0.22PCT   10K          X      22IN               5-20             6IN  2IN    6IN          4160V       480V
 9IN

HAULAGE SYSTEM                                      SUPPORT SYSTEM

MUCK              PERSONNEL          SUPPLY         BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE          SHOTCRETE
RAIL. 36IN        RAIL               RAIL           4-1IN X 7FT     13IN X 10FT     4IN RING AND HALF
GAGE 70LB                                           GROUTED APPROX.  16 GAGE        SETS 4FT. 3FT. AND
RAIL. 16                                            1200FT                          2FT IN BAD GROUND
CY CARS                                                                             APPROX. 650FT
MOTOR 12 TON


MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                     RPM            TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE      MODEL       WT      CENTER             INTERIOR           GAGE               HEAD.CENTER   HEAD          CENTER
  WIRTH     HARDROCK    67      2 HUGHES/WIRTH     15 HUGHES/WIRTH    6 HUGHES/WIRTH     8.5  INTEG
  ERKELENZ              TONS    TCB 11.5IN         TCB 11.5IN         TCB 11.5IN TCB                   KFTLB 150     KFTLB              KLB
                                ROLLER. 2-TCB      ROLLER             ROLLER                           KFTLB 110     KFTLB              KLB 290
                                11.5IN CONE


  ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                 BUCKETS FROM    HYDRAULIC.      LASER                       FEET         HOUR.FT.
  KLB            FACE. 22IN      POWERED BY                KLB 3.89          0.09           2.3
                 CONVEYOR TO     3-200HP MOTORS
                 REAR


CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                     EXPLOSIVES.                        BLASTING       MUCKING        GUIDANCE
JUMBO                    NO. HOLES                  POWDER FACTOR
MACHINES                 DEPTH                      TOTAL LBS
                         DIAM.                      PRIMERS.
                         CUT.                       TRIM
FEED LENGTH                                         INTERIOR
                                                    CUT
                                                    LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.            NAST-2     CURRENT: 04/01/73
                                                                                                     MDN 7
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KEY  IDENTIFICATION       ROCK PROPERTIES
 3    NAST                IGNEOUS: BIOTITIC GRANITE FINE      DRY       COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                          GRAINED. MAJOR QUARTZ. MINOR        WT        STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            FELDSPAR AND DARK MINERAL           PCF       KPSI      EST                      PSIX10E6
     NAST-3               CONTENT.
                                                              164        28        90      99      54       8.32     0.35
                                                                                                   NOTE              NOTE
                                                                                                    2                 2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.-...............................*   PCT (-)
   WT  PCF  PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  N04    N08    N016   N030   N050   N0100   N0200       N0200

    1       3.4       14.5         16.2  6.2   12.6  13.7   8.9    5.8    5.3    6.1    2.6    2.8    1.5                 3.8


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                              AI        AI    AI    AI    AI     AI     AI     AI     AI     AI     AI


     POT VOL CHANGE            *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN...................................*
     (-)0.056  IN.SIZE         LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW          TOUGHNESS
                               LIMITS        LIMIT         LIMIT          INDEX            INDEX         INDEX
                               PCT           PCT           PCT            PCT

       0                       19.50         17.41         17.13          2.09             4.10          0.51


     (-) 0.75IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*         SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT        BULK               ANGLE INTER
     GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION        DENSITY            FRICTION
                     DEGREES AT         DEGREES AT         DEGREES AT         PSF AT          PCF AT             DEGREES AT
                     2.8 PCT MOIST      2.8  PCT MOIST     2.8  PCT MOIST     3.0  PCT MOIST 0.0  PCT MOIST      3.0  PCT MOIST


      2.65            39                 36                 31                 80              91.2               38


                                                                              NAST-3         CURRENT:   04/01/73
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KEY

  3A
TUNNEL DATA


TUNNEL                         VENTILATION                         WATER INFLOW      UTILITY LINES                  POWER SYSTEM

SIZE      SHAPE      GRADE     CFM   PRESS EXHST  SIZE    HP       GPM               AIR   WATER  PUMP              PRIMARY   SECONDARY
10FT X    ALCOVE       0.0     10K          X     22IN             5-10              6IN   2IN    6IN                NA
16FT X8FT

HAULAGE SYSTEM                                    SUPPORT SYSTEM

MUCK              PERSONNEL          SUPPLY       BOLT,TYPE SIZE   ROOF PLATE        SET,SIZE,SHAPE           SHOTCRETE
RAIL 36IN GAGE,   RAIL               RAIL         1IN X 7FT          13IN X 10FT      NA
70LB RAIL, 16                                     GROUTED            16 GAGE
CY CARS
MOTOR 12 TON



MACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES               RPM           TORQUE,MAX/OPERATE        THRUST,MAX/OPERATE

  MAKE      MODEL       WT     CENTER             INTERIOR          GAGE           HEAD,CENTER   HEAD             CENTER

                                                                                                KFTLB        KFTLB                 KLB
                                                                                                KFTLB        KFTLB                 KLB



ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM     GUIDANCE    THRUST/SQ FT   KERF SPACING    ADVANCE PER
                                                                               FEET           HOUR,FT.
KLB                                                          KLB



CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                      EXPLOSIVES,                               BLASTING         MUCKING          GUIDANCE
JUMBO                     NO. HOLES 72                POWDER FACTOR 6.3LB/CY                    ELECTRICAL       1/2CY DIESEL
MACHINES JACK LEG 2-553F  DEPTH 9FT                   TOTAL LBS 300 GELEX 2, 60PCT              0-7 REGULAR      FRONT END
                          DIAM. 1-3/4IN               PRIMERS,                                  DELAYS           LOADER
                          CUT.  DOUBLE V              TRIM
FEED LENGTH 4FT                                       INTERIOR
                          SF/HOLE 2.2                 CUT
                                                      LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.      NAST-3      CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                 MDN 2
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KEY  IDENTIFICATION       ROCK PROPERTIES
  *   NAST                IGNEOUS. GRANITE. FINE GRAINED     DRY      COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
                          MODERATELY FRACTURED. MAJOR        WT       STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
      SAMPLE NO           QUARTZ AND MINOR FELDSPAR          PCF      KPSI      EST                       PSIX10E6
      NAST-4              CONTENT.
                                                             160       24        90     NA       54        8.30      0.33
                                                                                                           NOTE      NOTE
                                                                                                            2         2

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
  WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200          NO200

    83      17.2      0.0             0.0   0.0   0.0   11.5    20.6   13.6   12.7   11.0   14.5   4.4     5.8            5.9



    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                      PI      PI     PI      AI     AI     A       A


    PCT VOL CHANGE        *...................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW          TOUGHNESS
                          LIMITS        LIMIT         LIMIT          INDEX            INDEX         INDEX
                          PCT           PCT           PCT            PCT

      0                   19.20          18.97         17.50          0.23             3.40          0.06


   (-) 0.75IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*      SIZE(-)2.0   IN.
    SPECIF          ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE         APPARENT       BULK             ANGLE INTER
    GRAVITY         1 IN DROP           10 IN DROP          STEEL PLATE         COHESION       DENSITY          FRICTION
                    DEGREES AT          DEGREES AT          DEGREES AT          PSF AT         PCF AT           DEGREES AT
                    6.9 PCT MOIST       6.9 PCT MOIST       6.9 PCT MOIST       7.1 PCT MOIST  0.0 PCT MOIST    7.1 PCT MOIST


     2.64              39                 34                  40                  0              91               33



                                                                                   NAST-4          CURRENT:   04/01/73
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KEY

  4A
TUNNEL DATA


TUNNEL                      VENTILATION                           WATER INFLOW     UTILITY LINES           POWER SYSTEM

SIZE     SHAPE     GRADE     CFM   PRESS EXHST  SIZE   HP         GPM              AIR  WATER  PUMP        PRIMARY  SECONDARY
9FT      ROUND     +0.22PCT  10K         X      22IN              5-20             6IN  2IN    6IN          4160V      480V
 10IN

HAULAGE SYSTEM                                 SUPPORT SYSTEM

MUCK            PERSONNEL       SUPPLY         BOLT,TYPE SIZE  ROOF PLATE       SET,SIZE,SHAPE           SHOTCRETE
RAIL, 36IN      RAIL            RAIL           4-1IN X 7FT     13IN X 10FT      4IN RING AND HALF
GAGE, 70LB                                     GROUTED         16 GAGE          SETS, 4FT, 3FT, AND
RAIL, 16 CY                                    APPROX. 1200FT                   2FT IN BAD GROUND
CARS                                                                            APPROX. 650FT
MOTOR 12 TONS


MACHINE EXCAVATION


MACHINE                      CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES            RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE      MODEL     WT     CENTER            INTERIOR          GAGE              HEAD,CENTER  HEAD           CENTER
  WIRTH     HARDROCK  67     7 HUGHES TCB      19 HUGHES TCB     6 HUGHES TCB      8.5  INTEG
  ERKELENZ            TONS   11.5IN ROLLER,    11.5IN ROLLER     11.5IN ROLLER                  KFTLB 150   KFTLB              KLB
  HUGHES                     2-11.5IN CONE                                                      KFTLB125    KFTLB              KLB 630
  HEAD


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET FROM     HYDRAULIC       LASER                       FEET        HOUR,FT.
 KLB           FACE, 22FT      POWERED BY                KLB 8.45          0.09          1.7
               CONVEYOR TO     3-200HP MOTORS
               REAR


CONVENTIONAL EXCAVATION


MACHINE                ROUND,                 EXPLOSIVES,                     BLASTING      MUCKING       GUIDANCE
JUMBO                  NO. HOLES              POWDER FACTOR
MACHINES               DEPTH                  TOTAL LBS
                       DIAM.                  PRIMERS,
                       CUT.                   TRIM
FEED LENGTH                                   INTERIOR
                                              CUT
                                              LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED.                                     NAST-4     CURRENT: 04/01/73
                                                                                        MDN 7
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KEY  IDENTIFICATION        ROCK PROPERTIES
 5    GRANITE              IGNEOUS: GRANITE. MASSIVE.                DRY      COMP     RQD   ....HARDNESS..    YOUNGS   POISSON
       ADIT                MAJOR QUARTZ AND FELDSPAR.                WT       STRNTH   PCT   SHORE   SCHMID.   MOD.     RATIO
     SAMPLE NO             MINOR DARK MINERAL CONTENT.               PCF      KPSI     EST                     PSIX10E6
     GA-1
                                                                     161      35       96    NA      42        6.40     0.35
                                                                                                               NOTE     NOTE
                                                                                                                2        2

NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
 WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200       NO200

  114       1.9       4.7           17.9  12.2  10.3  11.7    14.4   6.6    5.6    5.6    3.7    3.6    0.2                3.5


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                               AI         AI    AI    AI    AI     AI     AI     AI     AI     AI     AI


   POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...................................*
   (-)0.056  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW         TOUGHNESS
                           LIMITS        LIMIT         LIMIT           INDEX             INDEX        INDEX
                           PCT           PCT           PCT             PCT

     0                     16.2          15.78         13.67           0.42              3.00         0.14


  (-)0.75 IN.SIZE *........................MATERIAL SIZE(-)2.0      IN..............................*       SIZE(-)2.0   IN.
   SPECIF       ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT         BULK               ANGLE INTER
   GRAVITY      1 IN DROP          10 IN DROP         STEEL PLATE        COHESION         DENSITY            FRICTION
                DEGREES AT         DEGREES AT         DEGREES AT         PSF AT           PCF AT             DEGREES AT
               0.9  PCT MOIST     0.9  PCT MOIST     0.9  PCT MOIST     0.9  PCT MOIST 0.0  PCT MOIST      0.9  PCT MOIST

   2.59         39                 36                 34                 215              106                46


                                                                         GA-1          CURRENT:   04/01/73
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KEY

  5A
TUNNEL DATA


TUNNEL                      VENTILATION                       WATER INFLOW     UTILITY LINES               POWER SYSTEM

SIZE     SHAPE     GRADE    CFM   PRESS EXHST   SIZE   HP     GPM              AIR  WATER  PUMP            PRIMARY  SECONDARY
10FT X   HORSESHOE -0.22PCT AK              X   22IN                           6IN  2IN                                110V
  10FT

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK             PERSONNEL          SUPPLY      BOLT.TYPE SIZE  ROOF PLATE     SET.SIZE.SHAPE         SHOTCRETE
EIMCO 912 LHD    NONE               EIMCO 912   1IN X 7FT                      4IN WF STEEL SETS AT
DIESEL                              LHD DIESEL  GROUTED APPROX                 4FT. APPROX.
                                                35FT                           180FT



MACHINE EXCAVATION


MACHINE                     CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES               RPM           TORQUE.MAX/OPERATE         THRUST.MAX/OPERATE

  MAKE     MODEL      WT    CENTER            INTERIOR          GAGE           HEAD.CENTER   HEAD          CENTER

                                                                                             KFTLB        KFTLB                 KLB
                                                                                             KFTLB        KFTLB                 KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                          FEET          HOUR.FT.
 KLB                                                     KLB



CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                     EXPLOSIVES.                          BLASTING       MUCKING        GUIDANCE
JUMBO  CRAWLER           NO. HOLES 48               POWDER FACTOR 6.1LB/CY               ELECTRICAL     EIMCO 912 LHD  TRANSIT
MACHINES 2-D93 DRIFTER   DEPTH 8FT                  TOTAL LBS 175 GELEX 2, 70PCT         0-10 REGULAR   FRONT END
                         DIAM. 1-3/4IN              PRIMERS.                             DELAYS         LOADER
                         CUT.  DOUBLE V             TRIM
FEED LENGTH 10FT                                    INTERIOR
                         SF/HOLE 2.1                CUT
                                                    LIFTERS

           BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
           NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
           TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
           FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
           *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.       GA-1       CURRENT: 04/01/73
           (3) EXCESSIVE TIRE WEAR PROBABLE.                                                 MDN 2
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KEY  IDENTIFICATION        ROCK PROPERTIES
 6    HUNTER               IGNEOUS: GRANITE, GRAY, FINE           DRY        COMP       RQD    ....HARDNESS...    YOUNGS    POISSON
                           GRAINED, MODERATELY JOINTED,           WT         STRNTH     PCT    SHORE    SCHMIDT   MOD.      RATIO
     SAMPLE NO             WITH 1.5 TO 2 FT BANDS OF              PCF        KPSI       EST                       PSIX10E6
     H-1                   LIGHT TAN PEGMATITE AND
                           LAMINATED GRANITIC GNEISS.             163         32         80      NA       50        8.00      0.31
                                                                                                                    NOTE      NOTE
                                                                                                                     2         2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200    NO200

    107      3.4       14.3         6.8  12.7  13.2  13.6    12.9   5.7    4.3    4.1    3.0    3.8     2.2              3.4


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                               AI          AI    AI    AI    AI      AI     AI     AI     AI     AI     AI


     POT VOL CHANGE         *....................ATTERBERG LIMITS..SIZE(-) 0.056IN..............................*
     (-)0.056  IN.SIZE      LIQUID         PLASTIC        SHRINKAGE        PLASTICITY        FLOW          TOUGHNESS
                            LIMITS         LIMIT          LIMIT            INDEX             INDEX         INDEX
                            PCT            PCT            PCT              PCT

       0                    18.0           17.0           13.4             1.0               4.4            0.23


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN.............................*       SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE        APPARENT        BULK               ANGLE INTER
     GRAVITY         1 IN DROP           10 IN DROP          STEEL PLATE        COHESION        DENSITY            FRICTION
                     DEGREES AT          DEGREES AT          DEGREES AT         PSF AT          PCF AT             DEGREES AT
                     1.3 PCT MOIST       1.3 PCT MOIST       1.3 PCT MOIST      2.2 PCT MOIST   0.0 PCT MOIST      2.2  PCT MOIST


     2.70            40                  37                  32                 780             103.5              44


                                                                                  H-1            CURRENT:   04/01/73
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```
KEY

  6A
TUNNEL DATA


TUNNEL                         VENTILATION                        WATER INFLOW   UTILITY LINES           POWER SYSTEM

SIZE     SHAPE      GRADE     CFM    PRESS EXHST   SIZE   HP      GPM            AIR   WATER  PUMP       PRIMARY   SECONDARY
10FT X   HORSESHOE  +0.25PCT  15K              X   26IN   125     20-400         8IN   4IN    10IN        4160V       440V
  10FT   MODIFIED

HAULAGE SYSTEM                                        SUPPORT SYSTEM

MUCK                PERSONNEL           SUPPLY        BOLT,TYPE SIZE  ROOF PLATE     SET,SIZE,SHAPE          SHOTCRETE
RAIL, 36IN GAGE     RAIL                RAIL          1IN X 7FT                      4IN WF SETS, 4FT,       500PSI 18 HRS
75LB RAIL, 4.8                                        GROUTED 17PCT                  3FT, 2FT FOR 23PCT      3750PSI 28 DAYS
CY CARS, 15TON                                                                                               16 PCT OF 7200
LOCOMOTIVE                                                                                                   FT



MACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES               RPM           TORQUE,MAX/OPERATE         THRUST,MAX/OPERATE

  MAKE      MODEL       WT     CENTER           INTERIOR           GAGE           HEAD,CENTER   HEAD          CENTER

                                                                                                KFTLB       KFTLB                KLB
                                                                                                KFTLB       KFTLB                KLB



  ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                             FEET        HOUR,FT.
  KLB                                                      KLB



CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                   EXPLOSIVES,                            BLASTING       MUCKING         GUIDANCE
JUMBO  4 BOOM HYDROJIB    NO. HOLES 38             POWDER FACTOR 5.5LB/CY                 ELECTRICAL     EIMCO NO25      LASER
MACHINES 4-CF99           DEPTH 10.5FT             TOTAL LBS 200                          0-10 REGULAR   RAIL, AIR
         1-CF133          DIAM. 1-3/4IN            PRIMERS, GELEX 2-1 1/2 IN              DELAYS         OPERATED
                          CUT.   SPIRAL BURN       TRIM 20LB SMOOTHTEX 70PCT X 7/8IN
FEED LENGTH 12FT                 5IN CENTER HOLE   INTERIOR GELEX 2-1 1/2 IN
                          SF/HOLE 2.6              CUT GELEX 2-1 1/2 IN
                                                   LIFTERS GELEX 2-1 1/2 IN

           BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
           NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
           TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
           FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
           *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.    H-1       CURRENT: 04/01/73
           (3) EXCESSIVE TIRE WEAR PROBABLE.                                               MON 2
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KEY  IDENTIFICATION        ROCK PROPERTIES
 7    HUNTER               IGNEOUS: GRANITE GRAY,                   DRY        COMP       RQD    ....HARDNESS...    YOUNGS    POISSON
                           GNEISSIC, MODERATELY JOINTED.            WT         STRNTH     PCT    SHORE   SCHMIDT    MOD.      RATIO
      SAMPLE NO                                                     PCF        KPSI       EST                       PSIX10E6
      H-2
                                                                    164         39         80     NA       60       10.00      0.35
                                                                                                          NOTE       NOTE      NOTE
                                                                                                            2          2         2

   NOTES:
   1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
   4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

   MUCK DATA
    DRY UNIT   MOISTURE   PCT(+16    *.................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
    WT  PCF    PCT        IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200     NO200

     109       3.4        7.3             11.7  18.2  19.3  11.6   9.3    4.8     4.2     4.5     3.4     1.3     1.1               3.3


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                 AI          AI    AI    AI    AI      AI      AI      AI      AI      AI      AI


     POT VOL CHANGE          *...................ATTERBERG LIMITS..SIZE(-) 0.056IN..............................*
     (-)0.056  IN.SIZE       LIQUID         PLASTIC        SHRINKAGE       PLASTICITY         FLOW         TOUGHNESS
                             LIMITS         LIMIT          LIMIT           INDEX              INDEX        INDEX
                             PCT            PCT            PCT             PCT

       0                     18.10          17.95          11.00           0.15               3.20         0.04


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN..............................*        SIZE(-)2.00  IN.
     SPECIF         ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE         APPARENT        BULK             ANGLE INTER
     GRAVITY        1 IN DROP           10 IN DROP          STEEL PLATE         COHESION        DENSITY          FRICTION
                    DEGREES AT          DEGREES AT          DEGREES AT          PSF AT          PCF AT           DEGREES AT
                    3.8 PCT MOIST       3.8  PCT MOIST      3.8  PCT MOIST      2.6  PCT MOIST 0.0  PCT MOIST    2.6  PCT MOIST


     2.60           38                  35                  38                  30              105              44



                                                                                H-2            CURRENT:   04/01/73
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KEY

  7A
TUNNEL DATA


TUNNEL                       VENTILATION                        WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST  SIZE    HP      GPM              AIR  WATER  PUMP         PRIMARY  SECONDARY
10FT      HORSESHOE +0.25PCT 8K              X      26IN    150     20-400           8IN  4IN    10IN          4160V      480V
 10FT     MODIFIED

HAULAGE SYSTEM                                        SUPPORT SYSTEM

MUCK                PERSONNEL          SUPPLY         BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE          SHOTCRETE
RAIL, 36IN GAGE     RAIL               RAIL           MINOR ROCK BOLT
75LB RAIL, 4.8                                        1IN X 7FT
CY CARS, 15TON                                        GROUTED
LOCOMOTIVE



HACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES             RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE      MODEL        WT    CENTER            INTERIOR          GAGE           HEAD,CENTER  HEAD             CENTER

                                                                                             KFTLB        KFTLB               KLB
                                                                                             KFTLB        KFTLB               KLB



 ANCHOR PRESS  MUCK SYSTEM      POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                             FEET        HOUR,FT.
 KLB                                                       KLB



CONVENTIONAL EXCAVATION


MACHINE                 ROUND,                     EXPLOSIVES,                           BLASTING       MUCKING        GUIDANCE
JUMBO  4 BOOM HYDROJIB  NO. HOLES 36-40            POWDER FACTOR 5.5LC/CY                ELECTRICAL     EIMCO NO25     LASER
MACHINES 4-CF99         DEPTH 11FT                 TOTAL LBS 225                         0-10 REGULAR   RAIL, AIR
         1-CF133        DIAM, 1-3/4IN              PRIMERS, GELEX 2                      DELAYS         OPERATED
                        CUT,  SPIRAL BURN          TRIM 25LB 30PCT DUPONT 7/8IN X 24IN
FEED LENGTH 12FT              5IN CENTER HOLE      INTERIOR GELEX 2
                        SF/HOLE 2.6                CUT GELEX 2
                                                   LIFTERS GELEX 2

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.          H-2        CURRENT: 04/01/73
          (3) EXCESSIVE TIRE WEAR PROBABLE.                                                     MDN 2
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KEY  IDENTIFICA;ION        ROCK PROPERTIES
 51   HUNTER               IGNEOUS: GRANITE GNEISS,             DRY      COMP      RQD   ....HARDNESS...   YOUNGS   POISSON
                           MODERATELY JOINTED, THREE            WT       STRNTH    PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO             INTERSECTING SETS OF                 PCF      KPSI                              PSIX10E6
     H-3                   FRACTURES DIPPING
                           45 DEG. TO VERTICAL                  162        29       90    NA       46       8.89     0.31
                           AT 4 IN. TO 2 FT.

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  N04    N08    N016   N030   N050   N0100   N0200      N0200

     104      2.9       32.5        11.4  12.0   9.9   9.9    7.5    3.5    2.9    2.9    2.3    2.3    1.1         1.8



    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR C=ELONGATED SP=SPHEROID


                         AI         AI   AI   AI   AI    AI    AI    AI    AI    AI    AI


    POT VOL CHANGE             *...................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
    (-)0.056  IN.SIZE          LIQUID       PLASTIC      SHRINKAGE     PLASTICITY       FLOW         TOUGHNESS
                               LIMITS       LIMIT        LIMIT         INDEX            INDEX        INDEX
                               PCT          PCT          FCT           PCT

    0                          17.20         16.80        16.65         0.40             3.80          0.11


   (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN..............................*      SIZE(-)2.0   IN.
    SPECIF      ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT     BULK              ANGLE INTER
    GRAVITY     1 IN DROP          10 IN DROP        STEEL PLATE       COHESION     DENSITY           FRICTION
                DEGREES AT         DEGREES AT        DEGREES AT        PSF AT       PCF AT            DEGREES AT
               4.46 PCT MOIST     4.46 PCT MOIST    4.46 PCT MOIST    4.46 PCT MOIST 4.46 PCT MOIST  4.46 PCT MOIST


    2.497         38.50             35.35             31.50                0            98.9            43.50



                                                                   H-3           CURRENT:   04/01/73
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```
KEY

 51A
TUNNEL DATA


TUNNEL                      VENTILATION                       WATER INFLOW     UTILITY LINES               POWER SYSTEM

SIZE     SHAPE     GRADE    CFM   PRESS EXHST  SIZE   HP      GPM              AIR  WATER  PUMP            PRIMARY  SECONDARY
10FT     HORSESHOE +0.25PCT 6K             X   26IN   220     20               10IN 4IN    12IN             4160V      480V
X10FT    MODIFIED

HAULAGE SYSTEM                               SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY     BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE          SHOTCRETE
RAIL, 36IN GAGE  RAIL             RAIL       1 IN X 7 FT                     4 IN WF 10 PCT          3 IN TO 4 IN TH
75LB RAIL, 4.8                               GROUTED                         X 22K FT.               36 PCT X 22K FT
CY CARS, 15TON                               9PCT X 22KFT
MOTOR



MACHINE EXCAVATION


MACHINE                     CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES              RPM          TORQUE,MAX/OPERATE       THRUST,MAX/OPERATE

  MAKE     MODEL      WT    CENTER           INTERIOR         GAGE            HEAD,CENTER  HEAD           CENTER

                                                                                           KFTLB       KFTLB                KLB
                                                                                           KFTLB       KFTLB                KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                          FEET          HOUR,FT.
 KLB                                                     KLB



CONVENTIONAL EXCAVATION


MACHINE                  ROUND,                    EXPLOSIVES,                           BLASTING       MUCKING        GUIDANCE
JUMBO  4 BOOM HYDRO      NO. HOLES 40              POWDER FACTOR 5.8LB/CY                ELECTRICAL     EIMCO NO25     LASER
MACHINES 4-CF93          DEPTH 11FT                TOTAL LBS 225                         0-10 REGULAR   AIR OPER.
           1-PR123       DIAM. 1.75 IN.            PRIMERS, GELEX 2.75PCT                DELAYS
                         CUT.  SPIRAL BURN         TRIM 30 PCT. 7/8 X 24 IN.
FEED LENGTH 12FT               5IN CENTER HOLE     INTERIOR GELEX 2. 75 PCT
                         SF/HOLE 2.6               CUT GELEX 2, 75 PCT
                                                   LIFTERS GELEX 2. 75 PCT

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.         H-3        CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                   MDN 1
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KEY  IDENTIFICATION       ROCK PROPERTIES
 8    LK                  IGNEOUS, BIOTITIC QUARTZ                     DRY       COMP      ROD    ....HARDNESS...    YOUNGS    POISSON
                          MONZONITE, FINE TO MEDIUM                    WT        STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO            GRAINED PORPHYRY.                            PCF       KPSI      ESI                     PSIX10E6
     LK-1
                                                                       162        25        83     NA       53       8.80      0.20
                                                                                                                     NOTE      NOTE
                                                                                                                       2         2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200     NO200

    102      0.4       66.8          13.8  5.9   5.0   3.8     2.0    0.7     0.5     0.4     0.3     0.3     0.1               0.4



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                              AI          AI    AI    AI    AI      AI      AI      AI      AI      AI      AI


     POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN................................*
     (-)0.056  IN.SIZE        LIQUID        PLASTIC       SHRINKAGE      PLASTICITY        FLOW          TOUGHNESS
                              LIMITS        LIMIT         LIMIT          INDEX             INDEX         INDEX
                              PCT           PCT           PCT            PCT

      0                       18.10         17.98         17.69          0.12              3.90          0.30


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN...............................*         SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE        APPARENT        BULK                 ANGLE INTER
     GRAVITY         1 IN DROP           10 IN DROP          STEEL PLATE        COHESION        DENSITY              FRICTION
                     DEGREES AT          DEGREES AT          DEGREES AT         PSF AT          PCF AT               DEGREES AT
                     0.8 PCT MOIST       0.8  PCT MOIST      0.8  PCT MOIST     0.4  PCT MOIST  0.0  PCT MOIST       0.4  PCT MOIST


      2.85            33                  30                  29                 435             97.3                 43



                                                                                   LK-1          CURRENT:   04/01/73
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KEY

  8A
TUNNEL DATA


TUNNEL                      VENTILATION                       WATER INFLOW     UTILITY LINES               POWER SYSTEM

SIZE     SHAPE     GRADE    CFM   PRESS EXHST  SIZE   HP      GPM              AIR  WATER  PUMP            PRIMARY  SECONDARY
18FT X   ARCHED    <5.5PCT  76K   HEAD  SURF   48IN   150     NONE             6IN  2IN                     4160V       220V
  16FT   BACK

HAULAGE SYSTEM                                SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY      BOLT.TYPE SIZE   ROOF PLATE       SET.SIZE.SHAPE          SHOTCRETE
WAGNER ST-8      DIESEL           DIESEL      3/4IN X 6FT.     13.5IN X 9FT
SCOOPTRAM,       TRUCK            TRUCK       AT 4FT
RAIL SKIP



MACHINE EXCAVATION


MACHINE                     CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES               RPM         TORQUE.MAX/OPERATE       THRUST.MAX/OPERATE

  MAKE     MODEL      WT    CENTER           INTERIOR         GAGE             HEAD.CENTER HEAD           CENTER

                                                                                           KFTLB       KFTLB              KLB
                                                                                           KFTLB       KFTLB              KLB


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                          FEET          HOUR.FT.
 KLB                                                     KLB



CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                     EXPLOSIVES.                           BLASTING       MUCKING        GUIDANCE
JUMBO  3 BOOM            NO. HOLES 47               POWDER FACTOR 4.0 LB/CY               ELECTRICAL     SCOOPTRAM      LASER
MACHINES GARDNER DENVER  DEPTH 10.5FT               TOTAL LBS 365                         0-15 REGULAR
          1-PR123        DIAM. 1-3/4IN              PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT   DELAYS
        2-CH123 DRIFTER  CUT.  6 HOLE BURN          TRIM 25LB 7/8IN X 16IN, 30PCT
FEED LENGTH 12FT               1-4IN CNTR HOLE      INTERIOR ANFO
                         SF/HOLE 5.2                CUT 40LB 1.5IN X 16IN, 45PCT
                                                    LIFTERS ANFO

            BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.         LK-1       CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                    MON 1
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KEY  IDENTIFICATION       ROCK PROPERTIES
 9    LK                  IGNEOUS: BIOTITIC QUARTZ           DRY      COMP      ROD   ....HARDNESS...    YOUNGS    POISSON
                          MONZONITE, FINE TO MEDIUM          WT       STRNTH    PCT   SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO            GRAINED PORPHYRY, WITH MINOR       PCF      KPSI      EST                      PSIX10E6
     LK-2                 STEEPLY INCLINED JOINTS.
                                                            165        28        83     NA       56        9.40      0.33
                                                                                                 NOTE      NOTE      NOTE
                                                                                                  2         2         2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)16   *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  N04     N08     N016    N030    N050    N0100   N0200       N0200

    103       1.6       49.1          16.9  8.7   5.8   5.5     5.3     2.0     1.8     1.3     1.0     0.8     0.5             1.3


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                            AI           AI    AI    AI    AI      AI      AI      AI      AI      AI      AI


     POT VOL CHANGE            *...................ATTERBERG LIMITS..SIZE(-) 0.056IN..................................*
     (-)0.056  IN.SIZE         LIQUID        PLASTIC        SHRINKAGE       PLASTICITY        FLOW         TOUGHNESS
                               LIMITS        LIMIT          LIMIT           INDEX             INDEX        INDEX
                               PCT           PCT            PCT             PCT

     0                         20.50          19.14          17.29           0.36              6.2          0.058


    (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN..............................*          SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT       BULK               ANGLE INTER
     GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION       DENSITY            FRICTION
                     DEGREES AT         DEGREES AT         DEGREES AT         PSF AT         PCF AT             DEGREES AT
                   4.7  PCT MOIST     4.7  PCT MOIST     4.7  PCT MOIST     4.9  PCT MOIST 0.0  PCT MOIST     4.9  PCT MOIST


     2.73            43                 42                 33                 210            97.6               39


                                                                          LK-2          CURRENT:   04/01/73
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KEY

  9A
TUNNEL DATA


TUNNEL                      VENTILATION                        WATER INFLOW     UTILITY LINES               POWER SYSTEM

SIZE     SHAPE     GRADE     CFM   PRESS EXHST  SIZE    HP      GPM              AIR  WATER  PUMP            PRIMARY  SECONDARY
18FT X   ARCHED    +2.0PCT   22K   HEAD  SURF   48IN    150     NONE             6IN  2IN                      4160V      220V
  16FT   BACK

HAULAGE SYSTEM                                SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY      BOLT,TYPE SIZE   ROOF PLATE       SET,SIZE,SHAPE          SHOTCRETE
WAGNER ST-8      DIESEL           DIESEL      3/4IN X 6FT      13.5IN X 9FT
SCOOPTRAM,       TRUCK            TRUCK       AT 4FT
RAIL SKIP



MACHINE EXCAVATION


MACHINE                     CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL      WT    CENTER           INTERIOR         GAGE              HEAD,CENTER  HEAD           CENTER

                                                                                             KFTLB       KFTLB              KLB
                                                                                             KFTLB       KFTLB              KLB


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                           FEET        HOUR,FT.
 KLB                                                     KLB



CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                     EXPLOSIVES.                            BLASTING        MUCKING        GUIDANCE
JUMBO  3 BOOM            NO. HOLES 47               POWDER FACTOR 4LB/CY                   ELECTRICAL      SCOOPTRAM      LASER
MACHINES GARDNER DENVER  DEPTH 10.5FT               TOTAL LBS 365                          0-15 REGULAR
         3-PR123 DRIFTER DIAM. 1-3/4IN              PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT    DELAYS
                         CUT,  6 HOLE BURN          TRIM 25LB 7/8IN X 16IN, 30PCT
FEED LENGTH 12FT               1-4IN CNTR HOLE      INTERIOR ANFO
                         SF/HOLE 5.2                CUT 40LB 1.5IN X 16IN, 45PCT
                                                    LIFTERS ANFO

            BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.        LK-2       CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                  MON 1
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KEY  IDENTIFICATION       ROCK PROPERTIES
 ID   LK                  IGNEOUS: BIOTITIC QUARTZ               DRY      COMP     ROD   ....HARDNESS...   YOUNGS   POISSON
                          MONZONITE, FINE TO MEDIUM              WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            GRAINED PORPHYPY                       PCF      KPSI     EST                     PSIX10E6
     LK-5
                                                                 165       32      92     NA      54       9.00     0.32
                                                                                                           NOTE     NOTE
                                                                                                            2        2

NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS..................................*  PCT (-)
 WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200        NO200

   94      16.8      0.0            0.0   0.0   13.0  14.0   20.0   7.0    8.0    8.0    8.0    6.0    5.0                  11.0


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                             PE    PI     PI     A      A      A      A      A


    POT VOL CHANGE          *......................ATTERBERG LIMITS..SIZE(-) 0.056IN..................................*
    (-)0.056  IN.SIZE       LIQUID       PLASTIC      SHRINKAGE     PLASTICITY     FLOW        TOUGHNESS
                            LIMITS       LIMIT        LIMIT         INDEX          INDEX       INDEX
                            PCT          PCT          PCT           PCT

      0                     25.00        20.95        19.68         4.05           5.50        0.73


   (-)0.056IN.SIZE *........................MATERIAL SIZE(-)2.0     IN..............................*        SIZE(-)2.0   IN.
   SPECIF          ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT       BULK                 ANGLE INTER
   GRAVITY         1 IN DROP        10 IN DROP       STEEL PLATE      COHESION       DENSITY              FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT       PSF AT         PCF AT               DEGREES AT
                   3.4 PCT MOIST    3.4  PCT MOIST   3.4  PCT MOIST   3.0  PCT MOIST 0.0  PCT MOIST       3.0  PCT MOIST


    2.67             33               32               38               75             100                 37


                                                                            LK-5          CURRENT:    04/01/73
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KEY

 10A
TUNNEL DATA


TUNNEL                       VENTILATION                       WATER INFLOW   UTILITY LINES            POWER SYSTEM

SIZE     SHAPE     GRADE     CFM    PRESS EXHST  SIZE    HP    GPM            AIR  WATER  PUMP         PRIMARY  SECONDARY
12FT     ROUND     VERT      NONE         NONE                 NONE                 NA                           440V
13-7/8IN PILOTHOLE

HAULAGE SYSTEM                                       SUPPORT SYSTEM

MUCK            PERSONNEL         SUPPLY             BOLT.TYPE SIZE  ROOF PLATE    SET.SIZE.SHAPE         SHO..ETE
WAGNER ST-8     DIESEL            DIESEL             NONE                           NONE
SCOOPTRAM       TRUCK             TRUCK
RAIL SKIP



MACHINE EXCAVATION


MACHINE                      CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES              RPM          TORQUE.MAX/OPERATE       THRUST.MAX/OPERATE

  MAKE     MODEL       WT    CENTER            INTERIOR          GAGE             HEAD.CENTER  HEAD           CENTER
  ROBBINS  H81R RAISE  49    1 ROBBINS. 11IN   19 ROBBINS 12IN   3 ROBBINS. 12IN    6    INTEG
           DRILL      TONS   STL DISC.2-11IN   STEEL DISC.2-11   STEEL DISC                      KFTLB 583   KFTLB            KLB 814
                                               IN TWIN STEEL                                      KFTLB 260   KFTLB            KLB 490-
                                               DISC                                                                                510


 ANCHOR PRESS  MUCK SYSTEM    POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               GRAVITY        ELECTRIC        SURVEY                      FEET        HOUR.FT.
 KLB                          MOTORS          IN PILOT  KLB 3.64          0.25           2.7
                              3-100 HP        HOLES



CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                  EXPLOSIVES.                   BLASTING      MUCKING      GUIDANCE
JUMBO                    NO. HOLES               POWDER FACTOR
MACHINES                 DEPTH                   TOTAL LBS
                         DIAM.                   PRIMERS.
                         CUT.                    TRIM
FEED LENGTH                                      INTERIOR
                                                 CUT
                                                 LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.      LK-5       CURRENT: 04/01/73
                                                                                                MDN 6
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KEY  IDENTIFICATION       ROCK PROPERTIES
 11   LK                  IGNEOUS: BIOTITIC QUARTZ            DRY     COMP      RQD   ....HARDNESS...   YOUNGS   POISSON
                          MONZONITE, FINE TO MEDIUM           WT      STRNTH    PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            GRAINED PORPHYRY, FREQUENT          PCF     KPSI      EST                     PSIX10E6
     LK-6                 FLAT ANGLED JOINTS.                 137       3        86    NA       20       1.50     0.20
                                                                      SINGLE                    NOTE     NOTE     NOTE
                                                                      SPECIMEN                   3        2        2
                                                                      L/R = 1.3

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

    90       16.8      0.0        0.0   0.0   1.0   9.0    19.0   12.0   11.0   11.0    8.0    7.0    6.0              16.0


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                         AI   A     A     A     A     A     A     A


     POT VOL CHANGE         *..................ATTERBERG LIMITS..SIZE(-) 0.056IN.............................*
     (-)0.056  IN.SIZE      LIQUID       PLASTIC      SHRINKAGE     PLASTICITY      FLOW       TOUGHNESS
                            LIMITS       LIMIT        LIMIT         INDEX           INDEX      INDEX
                            PCT          PCT          PCT           PCT

      0                     19.40        18.16        17.27         1.24            4.00       0.31


    (-) 0.75IN.SIZE *......................MATERIAL SIZE(-) 2.0    IN............................*       SIZE(-) 2.0  IN.
     SPECIF         ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT        BULK            ANGLE INTER
     GRAVITY        1 IN DROP         10 IN DROP        STEEL PLATE       COHESION        DENSITY         FRICTION
                    DEGREES AT        DEGREES AT        DEGREES AT        PSF AT          PCF AT          DEGREES AT
                    3.7 PCT MOIST    3.7  PCT MOIST    3.7  PCT MOIST    0.2  PCT MOIST 0.0  PCT MOIST   0.2  PCT MOIST


      2.53           30                29                32                0               101             40


                                                                          LK-6          CURRENT:   04/01/73
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KEY

 11A
TUNNEL DATA

TUNNEL                          VENTILATION                         WATER INFLOW    UTILITY LINES           POWER SYSTEM

SIZE      SHAPE     GRADE     CFM    PRESS EXHST   SIZE    HP       GPM             AIR   WATER   PUMP      PRIMARY   SECONDARY
4FT       ROUND     VERT                   NONE                     NONE                   NA                            440V
13 7/8IN PILOTHOLE

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK                PERSONNEL         SUPPLY       BOLT,TYPE SIZE   ROOF PLATE      SET,SIZE,SHAPE        SHOTCRETE
WAGNER ST-8         DIESEL            DIESEL       NONE
SCOOPTRAM           TRUCK             TRUCK
RAIL SKIP



MACHINE EXCAVATION

MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES          RPM          TORQUE,MAX/OPERATE        THRUST,MAX/OPERATE

  MAKE      MODEL       WT     CENTER             INTERIOR          GAGE              HEAD,CENTER  HEAD              CENTER
  ROBBINS   481R RAISE  49     1 ROBBINS 12IN     4 ROBBINS 12IN    1 ROBBINS 12IN      6  INTEG
            DRILL       TONS   STEEL DISC         TWIN STEEL        TWIN STEEL                     KFTLB 583    KFTLB             KLB
                                                  DISCS             DISCS                          KFTLB 200    KFTLB             KLB 220


 ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                GRAVITY          ELECTRIC         SURVEY                        FEET         HOUR,FT.
 KLB                             MOTORS           IN PILOT   KLB 17.2           0.13           4.8
                                 3-100 HP         HOLE



CONVENTIONAL EXCAVATION

MACHINE                     ROUND,                 EXPLOSIVES,                            BLASTING        MUCKING        GUIDANCE
JUMBO                       NO. HOLES              POWDER FACTOR
MACHINES                    DEPTH                  TOTAL LBS
                            DIAM.                  PRIMERS,
                            CUT,                   TRIM
FEED LENGTH                                        INTERIOR
                                                   CUT
                                                   LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.         LK-6        CURRENT: 04/01/73
                                                                                                  MDN 6
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KEY  IDENTIFICATION       ROCK PROPERTIES
 12   LK                  IGNEOUS: QUARTZ MONZONITE              DRY      COMP      RQD   ....HARDNESS...   YOUNGS   POISSON
                          PORPHYRY, INTENSELY ALTERED            WT       STRNTH    PCT   SHORE   SCHMIDT   MOD.     RATIO
    SAMPLE NO             COARSE GRAINED                         PCF      KPSI      EST                     PSIX10E6
     LK-7
                                                                 158        7        39     NA      37       4.76     0.10

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS....................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100    NO200      NO200

    107      8.7       13.1          14.0  11.2  12.3  15.5    14.2   4.3     3.7     3.1     1.0     1.2      1.2                 4.3



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                         A           A     A     A     A       A     A       A       A       A       A


     POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
     (-)0.056  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE       PLASTICITY         FLOW          TOUGHNESS
                             LIMITS        LIMIT         LIMIT           INDEX              INDEX         INDEX
                             PCT           PCT           PCT             PCT

       0                     18.00         17.12         17.04           0.88               5.00           0.18


    (-)0.75 IN.SIZE *...........................MATERIAL SIZE(-)2.0    IN ..............................*      SIZE(-) 2.0  IN.
     SPECIF          ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE          APPARENT       BULK                ANGLE INTER
     GRAVITY         1 IN DROP           10 IN DROP          STEEL PLATE          COHESION       DENSITY             FRICTION
                     DEGREES AT          DEGREES AT          DEGREES AT           PSF AT         PCF AT              DEGREES AT
                    1.7  PCT MOIST      1.7  PCT MOIST      1.7  PCT MOIST       0.2  PCT MOIST 0.0  PCT MOIST      0.2  PCT MOIST


     2.68              29                  26                  28                   70             114                45




                                                                     LK-7            CURRENT:   04/01/73
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KEY

 12A
TUNNEL DATA

                                       VENTILATION                       WATER INFLOW      UTILITY LINES                 POWER SYSTEM
TUNNEL
                                                                                                                         PRIMARY   SECONDARY
SIZE       SHAPE      GRADE      CFM    PRESS EXHST  SIZE    HP         GPM               AIR   WATER  PUMP               4160        220
15FT X     ARCHED     -26PCT     22K    X            48IN    150        MINOR             6IN   2IN    4IN
 14 FT     BACK
                                                             SUPPORT SYSTEM
HAULAGE SYSTEM
                                                             BOLT,TYPE SIZE  ROOF PLATE     SET,SIZE,SHAPE           SHOTCRETE
MUCK               PERSONNEL            SUPPLY               6FTX3/4IN#4FT   13.5INX9FT
WAGNER ST-8        DIESEL               DIESEL
SCOOP TRAM         TRUCK                TRUCK
RAIL SKIP


MACHINE EXCAVATION

MACHINE                           CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                 RPM           TORQUE,MAX/OPERATE          THRUST,MAX/OPERATE

  MAKE      MODEL       WT        CENTER             INTERIOR           GAGE           HEAD,CENTER   HEAD           CENTER

                                                                                                     KFTLB          KFTLB                 KLB
                                                                                                     KFTLB          KFTLB                 KLB


ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                                                                             FEET        HOUR,FT.
KLB                                                       KLB



CONVENTIONAL EXCAVATION

MACHINE                        ROUND,                       EXPLOSIVES,                      BLASTING          MUCKING       GUIDANCE
JUMBO  3 BOOM                  NO. HOLES   42               POWDER FACTOR 4.7 LB/CY          ELECTRICAL        SCOOPTRAM     LASER
MACHINES PR-123                DEPTH 10.5                   TOTAL LBS 350                    0-15 REGULAR
                               DIAM. 1.75                   PRIMERS, 25LB, 1.5X8IN, 60PCT    DELAYS
                               CUT,  BURN                   TRIM 25LB,7/8X16IN, 30PCT
FEED LENGTH 12FT                     4 IN CENTER            INTERIOR
                               SF/HOLE 4.7                  CUT
                                                            LIFTERS

            BASIS FOR MC  IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.        LK-7        CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                   MDN 2
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KEY  IDENTIFICATION       ROCK PROPERTIES
 13   SM                  IGNEOUS: QUARTZ                   DRY      COMP      RQD    ....HARDNESS...   YOUNGS    POISSON
                          MONZONITE COARSE GRAINED          WT       STRNTH    PCT    SHORE   SCHMIDT   MOD.      RATIO
     SAMPLE NO            WITH MANY SULFIDE VEINLETS.       PCF      KPSI      FST                      PSIX10E6
     SM-1                 HIGHLY FRACTURED.PRONOUNCED
                          ORTHOGONAL FAULTING               165      19        50     NA      47        7.44      0.20

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
  WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

   97       1.1       23.5          10.8  3.7   14.8  17.0   14.0   5.9    3.0    2.2    1.5    0.7    0.7              2.2


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                      A          A    A    A    A     A    A     A    A     A     A


    POT VOL CHANGE          *...................ATTERBERG LIMITS..SIZE(-) 0.056IN..............................*
    (-)0.056  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW         TOUGHNESS
                            LIMITS        LIMIT         LIMIT          INDEX            INDEX        INDEX
                            PCT           PCT           PC.            PCT

      0                     12.50         11.02         10.52          1.48             5.1          0.29


   (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0      IN............................*          SIZE(-) 2.0  IN.
    SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT       BULK              ANGLE INTER
    GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION       DENSITY           FRICTION
                    DEGREES AT         DEGREES AT         DEGREES AT         PSF AT         PCF AT            DEGREES AT
                   0.2  PCT MOIST     0.2  PCT MOIST     0.2  PCT MOIST     0.2  PCT MOIST 0.0  PCT MOIST    0.2  PCT MOIST


    2.72            36                 31                 28                 90             112               44


                                                                            SM-1          CURRENT:   04/01/73
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KEY

 13A
TUNNEL DATA


TUNNEL                          VENTILATION                             WATER INFLOW   UTILITY LINES              POWER SYSTEM

SIZE     SHAPE      GRADE      CFM   PRESS EXHST  SIZE   HP       GPM            AIR  WATER  PUMP             PRIMARY  SECONDARY
12FT X   RECT       +0.4PCT    14K   X            24IN   60       NONE           4IN  2IN    8IN               2400       480
17FT

HAULAGE SYSTEM                                    SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY          BOLT.TYPE SIZE  ROOF PLATE    SET.SIZE.SHAPE          SHOTCRETE
RAIL 10 TON      RAIL             RAIL                                          12IN H BEAM
BOTTOM DUMP                                                                     10FTX12INX12IN
36 IN GAGE                                                                      POSTS # 5FT
45 LB



MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES            RPM          TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE      MODEL      WT       CENTER            INTERIOR          GAGE        HEAD.CENTER  HEAD          CENTER

                                                                                             KFTLB         KFTLB               KLB
                                                                                             KFTLB         KFTLB               KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING  ADVANCE PER
                                                                              FEET         HOUR.FT.
 KLB                                                      KLB



CONVENTIONAL EXCAVATION

MACHINE                      ROUND.                    EXPLOSIVES.                          BLASTING       MUCKING       GUIDANCE
JUMBO  3 BOOM                NO. HOLES   52            POWDER FACTOR 3.8LB/CY               IGNITER CORD   EIMCO 40      TRANSIT
MACHINES CF79                DEPTH 5 FT                TOTAL LBS 100                        FUSE. NO 6     LOADER
         OR D 89             DIAM. 1 5/8 IN            PRIMERS. PRIMACORD                   CAPS
                             CUT.  WEDGE               TRIM AMOGEL
FEED LENGTH 6 FT                                       INTERIOR AMOGEL
                             SF/HOLE 2.8               CUT AMOGEL
                                                       LIFTERS AMOGEL

           BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
           NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
           TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
           FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
           *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.      SM-1        CURRENT: 04/01/73
           (3) EXCESSIVE TIRE WEAR PROBABLE.                                                 MDN 1
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NO.  IDENTIFICATION         ROCK PROPERTIES
 14   CLIMAX                METAMORPHIC: GRANITIC GNEISS,      DRY      COMP     RQD    ....HARDNESS...   YOUNGS    POISSON
                            HIGHLY METAMORPHOSED.              WT       STRNTH   PCT    SHORE   SCHMIDT   MOD.      RATIO
     SAMPLE NO              MODERATELY TO HIGHLY               PCF      KPSI     EST                      PSIX10E6
     CL-1                   FRACTURED. HIGHLY SILICIFIED.
                                                               174         9      10      NA      30      9.70      0.35
                                                                                                  NOTE              NOTE
                                                                                                   3                 2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
  WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16     NO30     NO50     NO100     NO200      NO200

    87       8.8       0.0          0.0   0.0   0.0   4.8     37.8   18.1    11.2   8.5      6.8      5.6      5.4                  1.8



    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                 AI     AI     AI     AI     AI     AI     AI



    POT VOL  CHANGE           *...................ATTERBERG LIMITS..SIZE(-)       IN...........................*
    (-)         IN.SIZE        LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW          TOUGHNESS
                               LIMITS        LIMIT         LIMIT          INDEX            INDEX         INDEX
                               PCT           PCT           PCT            PCT

    NA                         NA            NA            NA             NA               NA            NA


   (-)      IN.SIZE *.......................MATERIAL SIZE(-)         IN..............................*         SIZE(-)        IN.
    SPECIF          ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT       BULK                 ANGLE INTER
    GRAVITY         1 IN DROP          10 IN DROP        STEEL PLATE       COHESION       DENSITY              FRICTION
                    DEGREES AT         DEGREES AT        DEGREES AT        PSF AT         PCF AT               DEGREES AT
                        PCT MOIST          PCT MOIST         PCT MOIST         PCT MOIST      PCT MOIST            PCT MOIST


    NA              NA                 NA                NA                NA             NA                   NA



                                                                          CL-1         CURRENT:   04/01/73
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KEY

 14A
TUNNEL DATA

TUNNEL                          VENTILATION                         WATER INFLOW    UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE      CFM   PRESS EXHST  SIZE    HP       GPM             AIR  WATER  PUMP           PRIMARY  SECONDARY
13FT      ROUND      +0.25PCT   10K            X   24IN             5-10            4IN  2IN                    4160V     480V

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK            PERSONNEL       SUPPLY           BOLT.TYPE SIZE  ROOF PLATE     SET.SIZE.SHAPE         SHOTCRETE
RAIL            RAIL            RAIL             NONE




MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                 RPM          TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE     MODEL      WT        CENTER           INTERIOR          GAGE              HEAD.CENTER  HEAD          CENTER
  CALWELD  HARDROCK.  200       1 SMITH TCB      12 SMITH TCB      6 SMITH TCB        12    26
           40         TONS      TRICONE. 24IN    GTMH8 ROLLER      GTSH8 ROLLER                   KFTLB 347  KFTLB              KLB 133
                                                                                                  KFTLB      KFTLB              KLB 130


 ANCHOR PRESS  MUCK SYSTEM    POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET FROM    ELECTRO-       LASER                       FEET         HOUR.FT.
 KLB           FACE.          HYDRAULIC                KLB 5.09          0.09           2.0
               CONVEYOR TO    825 HP
               REAR 24IN


CONVENTIONAL EXCAVATION

MACHINE                  ROUND.                   EXPLOSIVES.                      BLASTING      MUCKING       GUIDANCE
JUMBO                    NO. HOLES                POWDER FACTOR
MACHINES                 DEPTH                    TOTAL LBS
                         DIAM.                    PRIMERS.
                         CUT.                     TRIM
FEED LENGTH                                       INTERIOR
                                                  CUT
                                                  LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED.                                        CL-1      CURRENT: 04/01/73
                                                                                           MDN 6
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KEY  IDENTIFICATION        ROCK PROPERTIES
 15   LK                   METAMORPHIC: INTERLAYERED            DPY        COMP      RQD   ....HARDNESS...   YOUNGS    POISSON
                           TRANSITION BETWEEN QUARTZITE         WT         STRNTH    PCT   SHORE    SCHMIDT  MOD.      RATIO
     SAMPLE NO             AND TACTITE. MODERATELY TO           PCF        KPSI      EST                     PSIX10E6
     LK-3                  STRONGLY ALTERED METASEDIMENTS
                           WITH REPLACEMENT PYRITE.             178          26       80     NA       50     11.20      0.34
                           CHALCOPYRITE AND MAGNETITE AND                                                     NOTE      NOTE
                           A HIGH PERCENTAGE OF SILICATES                                                      2         2
                           VERY FINE TO MEDIUM
                           GRAINED.

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.NO.10043-72.

 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
  WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

   105      0.1       34.1        17.4  9.1   10.2  10.6   8.7    2.8    1.6    1.2    0.8    0.8    0.4                2.3


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                     AI          AI    AI    AI    AI     AI     AI     AI     AI     AI     AI


   POT VOL CHANGE         *.......................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
   (-)0.056  IN.SIZE      LIQUID       PLASTIC       SHRINKAGE      PLASTICITY        FLOW        TOUGHNESS
                          LIMITS       LIMIT         LIMIT          INDEX             INDEX       INDEX
                          PCT          PCT           PCT            PCT

   0                      18.25         17.92         17.80         0.33              5.50         0.06


  (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0     IN..............................*      SIZE(-)2.0   IN.
   SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT        BULK               ANGLE INTER
   GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION        DENSITY            FRICTION
                   DEGREES AT         DEGREES AT         DEGREES AT         PSF AT          PCF AT             DEGREES AT
                  1.5  PCT MOIST     1.5  PCT MOIST     1.5  PCT MOIST     0.4  PCT MOIST  0.0  PCT MOIST    0.4  PCT MOIST


   3.21            30                 29                 29                 175             117.8              41



                                                                              LK-3          CURRENT:   04/01/73
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KEY

 15A
TUNNEL DATA


TUNNEL                        VENTILATION                         WATER INFLOW    UTILITY LINES               POWER SYSTEM

SIZE      SHAPE      GRADE    CFM   PRESS EXHST  SIZE    HP       GPM             AIR  WATER  PUMP            PRIMARY  SECONDARY
16FT X    ARCHED     +2.0PCT  52K   HEAD  SURF   48IN    150      NONE            5IN  2IN                     4160V      220V
14-1/2FTTBACK

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK              PERSONNEL           SUPPLY       BOLT.TYPE SIZE  ROOF PLATE       SET.SIZE.SHAPE         SHOTCRETE
WAGNER ST-8       DIESEL              DIESEL       3/4IN X 6FT     13.5IN X 9FT
SCOOPTRAM         TRUCK               TRUCK        AT 4FT
RAIL. SKIP



MACHINE EXCAVATION


MACHINE                       CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES              RPM          TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE     MODEL      WT      CENTER          INTERIOR          GAGE            HEAD.CENTER  HEAD          CENTER

                                                                                             KFTLB         KFTLB          KLB
                                                                                             KFTLB         KFTLB          KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                            FEET         HOUR.FT.
 KLB                                                      KLB



CONVENTIONAL EXCAVATION


MACHINE                  ROUND.                  EXPLOSIVES.                               BLASTING       MUCKING         GUIDANCE
JUMBO  3 BOOM            NO. HOLES 42            POWDER FACTOR 4.2LB/CY                    ELECTRICAL     SCOOPTRAM       LASER
MACHINES 3-PR123         DEPTH 6FT               TOTAL LBS 205                             0-15 REGULAR
          DRIFTERS       DIAM. 1-3/4IN           PRIMERS. 15LB 1.5IN X 8IN. 60-75PCT       DELAYS
                         CUT.  6 HOLE BURN       TRIM 15LB 7/8IN X 16IN. 30PCT
FEED LENGTH 12FT               1-4IN CNTR HOLE   INTERIOR ANFO
                                                 CUT 25LB 1.5IN X 16IN. 45PCT
                               SF/HOLE 5.3       LIFTERS ANFO

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.        LK-3      CURRENT: 04/01/73
          (3) EXCESSIVE TIRE WEAR PROBABLE.                                                   MON 1
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KEY  IDENTIFICATION         ROCK PROPERTIES                           DRY       COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
 16   LK                    METAMORPHIC: TACTITE STRONGLY             WT        STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
                            ALTERED CALCAREOUS META-                  PCF       KPSI      EST                       PSIX10E6
      SAMPLE NO             SEDIMENTS. WITH REPLACEMENT               182         14       70      NA      33        6.50      0.30
      LK-4                  PYRITE. CHALCOPYRITE AND                                                                NOTE      NOTE
                            MAGNETITE AND A HIGH PER-                           SINGLE                                2         2
                            CENTAGE OF SILICATES. FINE TO                       SPECIMEN
                            VERY FINE GRAINED.                                  L/R = 1.3


NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


MUCK DATA
 DRY UNIT   MOISTURE   PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS................................*   PCT (-)
 WT  PCF    PCT        IN.SIZE     6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200    NO200

  124       2.1        26.3            19.3  13.7  13.9  9.8    7.3    1.6     1.6     1.2     0.8     0.8     0.8              2.9


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                               AI          AI    AI    AI    AI     AI     AI      AI      AI      AI      AI


   POT VOL CHANGE        *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...................................*
   (-)0.056  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE      PLASTICITY        FLOW          TOUGHNESS
                         LIMITS        LIMIT         LIMIT          INDEX             INDEX         INDEX
                         PCT           PCT           PCT            PCT

    0                    19.00         17.95         16.43          1.05              5.40          0.19


  (-) 0.75IN.SIZE *.....................MATERIAL SIZE(-) 2.0     IN...........................*     SIZE(-) 2.0  IN.
   SPECIF         ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT          BULK             ANGLE INTER
   GRAVITY        1 IN DROP          10 IN DROP        STEEL PLATE       COHESION          DENSITY          FRICTION
                  DEGREES AT         DEGREES AT        DEGREES AT        PSF AT            PCF AT           DEGREES AT
                  2.0 PCT MOIST      2.0  PCT MOIST    2.0  PCT MOIST    0.2  PCT MOIST 0.0  PCT MOIST     0.2  PCT MOIST

   3.36           37                 35                30                165               115              43


                                                                     LK-4          CURRENT:   04/01/73
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KEY

 16A
TUNNEL DATA

TUNNEL                        VENTILATION                      WATER INFLOW    UTILITY LINES          POWER SYSTEM

SIZE     SHAPE      GRADE     CFM   PRESS EXHST  SIZE   HP     GPM             AIR  WATER  PUMP       PRIMARY  SECONDARY
15FT X   ARCHED     +2.0PCT   50K   HEAD  SURF   48IN   150    NONE            6IN  2IN                4160V      220V
  14FT   BACK
                                             SUPPORT SYSTEM
HAULAGE SYSTEM
                                             BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE        SHOTCRETE
MUCK             PERSONNEL        SUPPLY                                     6IN WF STEEL SETS
WAGNER ST-8      DIESEL           DIESEL                                     AT 5FT
SCOOPTRAM        TRUCK            TRUCK      NONE
R, IL, SKIP



MACHINE EXCAVATION

MACHINE                       CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES          RPM           TORQUE,MAX/OPERATE       THRUST,MAX/OPERATE

  MAKE     MODEL      WT      CENTER          INTERIOR         GAGE         HEAD,CENTER   HEAD           CENTER

                                                                                          KFTLB          KFTLB            KLB
                                                                                          KFTLB          KFTLB            KLB



 ANCHOR PRESS  MUCK SYSTEM    POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                           FEET        HOUR,FT.
 KLB                                                    KLB



CONVENTIONAL EXCAVATION

MACHINE                   ROUND,               EXPLOSIVES,                           BLASTING       MUCKING      GUIDANCE
JUMBO  3 BOOM             NO. HOLES 42         POWDER FACTOR 4.6LB/CY                ELECTRICAL     SCOOPTRAM    LASER
MACHINES GARDNER DENVER   DEPTH 6 FT           TOTAL LBS 205                         0-15 REGULAR
         3-PR123          DIAM, 1-3/4IN        PRIMERS, 15LB 1.5IN X 8IN, 60-75PCT   DELAYS
             DRIFTERS     CUT,  6 HOLE BURN    TRIM 15LB 7/8IN X 16IN, 30PCT
FEED LENGTH 12FT                1-4IN CENTER   INTERIOR ANFO
                                HOLE           CUT 25LB 1.5IN X 16IN, 45PCT
                                SF/HOLE 4.7    LIFTERS ANFO

           BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
           NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
           TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES,
           FREE VEHICLES (3) BELT CONV, (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
           *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.    LK-4      CURRENT: 04/01/73
           (3) EXCESSIVE TIRE WEAR PROBABLE.                                              MON 1
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KEY  IDENTIFICATION       ROCK PROPERTIES
 17   MATHER B            METAMORPHIC: INTER LAYERED           DRY        COMP       RQD    ....HARDNESS...    YOUNGS    POISSON
                          BANDS HEMATITE AND MARTITE           WT         STRNTH     PCT    SHORE    SCHMIDT   MOD.      RATIO
     SAMPLE NO            HIGHLY JOINTED NORMALLY FLAT         PCF        KPSI       EST                       PSIX10E6
     MB-1                 LYING. OFTEN HIGHLY FOLDED.          207          7         10      NA        20      2.50      0.15
                          NATURAL IRON OVER 60 PCT                                                    NOTE      NOTE      NOTE
                          MOISTURE 9 PCT. SILICA 5 PCT.                                                 3         4         4

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEFRE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE   PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
   WT  PCF   PCT        IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100   NO200     NO200

    128       7.2        7.2           9.7   1.4   8.7   11.4    20.1   10.3    7.4    3.3     1.8     1.3     1.1              15.3



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                 AI          AI    AI    AI    AI      AI     AI     AI     AI     AI     AI


     POT VOL CHANGE             *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
     (-)0.056  IN.SIZE          LIQUID          PLASTIC        SHRINKAGE       PLASTICITY        FLOW          TOUGHNESS
                                LIMITS          LIMIT          LIMIT           INDEX             INDEX         INDEX
                                PCT             PCT            PCT             PCT

     0                          17.8            15.1           13.9            2.7               4.1           0.66


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN..............................*        SIZE(-)2.0    IN.
     SPECIF           ANGLE/REPOSE          ANGLE/REPOSE         ANGLE/SLIDE          APPARENT        BULK           ANGLE INTER
     GRAVITY          1 IN DROP             10 IN DROP           STEEL PLATE          COHESION        DENSITY        FRICTION
                      DEGREES AT            DEGREES AT           DEGREES AT           PSF AT          PCF AT         DEGREES AT
                    6.2  PCT MOIST        6.2  PCT MOIST       6.2  PCT MOIST       6.9  PCT MOIST 0.0  PCT MOIST   6.9  PCT MOIST


     4.34             37                    35                   31                    235             141            35


                                                                                  MB-1          CURRENT:   04/01/73
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KEY

 17A
TUNNEL DATA


TUNNEL                          VENTILATION                        WATER INFLOW    UTILITY LINES           POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST  SIZE     HP    GPM             AIR  WATER  PUMP        PRIMARY  SECONDARY
9FT       ROUND       0.0       3K         X        8IN      5     NONE            2IN  1IN                            440V
11.5IN

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK            PERSONNEL       SUPPLY           BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE       SHOTCRETE
42IN SCRAPER    RAIL            RAIL                                             9FT 6IN DIA. X
RAIL            HOIST           HOIST                                            4IN WF AT 45IN




MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES             RPM          TORQUE.MAX/OPERATE    THRUST.MAX/OPERATE

  MAKE     MODEL         WT     CENTER         INTERIOR       GAGE               HEAD.CENTER  HEAD         CENTER
  CALWELD  OCCILLATOR 69                       258 CARBOLOY   20 CARBC.           8
                         TONS                  DRAG BITS      RIPPERS                         KFTLB 1200  KFTLB                KLB 300
                                                                                              KFTLB       KFTLR      *         KLB 285
                                                                                                                     *


 ANCHOR PRESS  MUCK SYSTEM   POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               FLIGHT        REMOTE HYDRAUL. SURVEY                      FEET         HOUR.FT.
 KLB 285       CONVEYOR      PUMPS. 2-90GPM.           KLB 3.66           NA            NA
               TO REAR OF    2500 PSI. 2-125
               MACHINE       HP MOTORS


CONVENTIONAL EXCAVATION


MACHINE                ROUND.                  EXPLOSIVES.                         BLASTING      MUCKING       GUIDANCE
JUMBO                  NO. HOLES               POWDER FACTOR
MACHINES               DEPTH                   TOTAL LBS
                       DIAM.                   PRIMERS.
                       CUT.                    TRIM
FEED LENGTH                                    INTERIOR
                                               CUT
                                               LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.         MB-1        CURRENT: 04/01/73
                                                                                               MDN 2
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KEY  IDENTIFICATION       ROCK PROPERTIES
 18   MB                  METAMORPHIC: INTERLAYERED         DRY     COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
                          HEMATITE AND MARTITE              WT      STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            HIGHLY JOINTED. NORMALLY          PCF     KPSI     EST                     PSIX10E6
     MB-3                 FLAT LYING. OFTEN HIGHLY          188       6       10     NA      16       2.10     0.15
                          FOLDED. NATURAL IRON
                          60 PCT. SILICA 5 PCT

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
  WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100  NO200        NO200

    140      14.5     16.1        17.3  2.7   6.8   10.4   16.8   8.0    5.5    5.6    2.2    1.7    1.2                5.7
                      15.9        18.2  2.7   7.0   12.8   21.4   7.3    7.0    3.1    1.3    1.6    1.0                0.7

   SCREEN ANALYSIS:  UPPER LINE. DRY SCREENED (ASTM C136). AFTER WASHING (ASTM C117).  LOWER LINE. SCREENED BEFORE DRYING

    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                      AI-P        AI-P  AI-P  AI-P  AI     AI     AI     AI     AI     AI     AI


   POT VOL CHANGE      *.....................ATTERBERG LIMITS.SIZE(-) 0.056IN.................................*
   (-)0.056  IN.SIZE    LIQUID        PLASTIC       SHRINKAGE     PLASTICITY       FLOW         TOUGHNESS
                        LIMITS        LIMIT         LIMIT         INDEX            INDEX        INDEX
                        PCT           PCT           PCT           PCT

                        21.50          20.86         19.0          0.64            5.7           0.11


  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*      SIZE(-)2.0   IN.
   SPECIF         ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT      BULK                ANGLE INTER
   GRAVITY        1 IN DROP         10 IN DROP        STEEL PLATE       COHESION      DENSITY             FRICTION
                  DEGREES AT        DEGREES AT        DEGREES AT        PSF AT        PCF AT              DEGREES AT
                 11.56PCT MOIST    11.56PCT MOIST    11.56PCT MOIST    11.56PCT MOIST 11.56PCT MOIST     11.56PCT MOIST


    4.31          35.5              30.5              30.17                 120         119.6               37



                                                                  MB-3          CURRENT:   04/01/73
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```
KEY

 18A
TUNNEL DATA


TUNNEL                          VENTILATION                        WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE     SHAPE      GRADE       CFM    PRESS EXHST  SIZE   HP      GPM              AIR  WATER  PUMP           PRIMARY  SECONDARY
10FTX    RECT       0           4K     X            8IN    15      NONE             2IN  1IN                    2300      440
9FT 6 IN

HAULAGE SYSTEM                                      SUPPORT SYSTEM

MUCK               PERSONNEL          SUPPLY        BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE           SHOTCRETE
48IN SCRAPER       RAIL               RAIL                                          8IN-58LB WF SETS
160 CF CARS                                                                         7FT CAP. 8FT POSTS
2-30T MOTORS                                                                        WOOD LAGGING
30 IN GAGE                                                                          PIPE SPILING
80 LB RAIL



MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES               RPM          TORQUE.MAX/OPERATE        THRUST.MAX/OPERATE

  MAKE      MODEL       WT      CENTER            INTERIOR          GAGE            HEAD CENTER  HEAD          CENTER
ALPINE      F-6A        11T      68 KENNAMETAL.NO. 43KH TCB                          60
                                 ON TWIN RIPPER   HEADS                                          KFTLB49 HP    KFTLB            KLB 2-10
                                                                                                 KFTLB         KFTLB            KLB


  ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                 GATHERING        440V            TRANSIT                     FEET        HOUR.FT.
  KLB            ARMS.FLIGHT                              KLB NA              NA            NA
                 CONVEYORS



CONVENTIONAL EXCAVATION


MACHINE                   ROUND.                 EXPLOSIVES.                     BLASTING       MUCKING        GUIDANCE
JUMBO                     NO. HOLES              POWDER FACTOR
MACHINES                  DEPTH                  TOTAL LBS
                          DIAM.                  PRIMERS.
                          CUT.                   TRIM
FEED LENGTH                                      INTERIOR
                                                 CUT
                                                 LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO     MB-3        CURRENT: 04/01/73
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.      MDN 2
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KEY  IDENTIFICATION        ROCK PROPERTIES
 19   ST                   METAMORPHIC: ARGILLIACEOUS          DRY       COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
                           QUARTZITE. MEDIUM TO THIN           WT        STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO             BEDDED.MODERATELY TO HIGHLY         PCF       KPSI      EST                      PSIX10E6
     ST-1                  FOLDED. MODERATE FRACTURING         168        21        75     NA       45       8.35       0.13

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS ................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100  NO200     NO200

    94       1.0       71.2          8.1   1.9   5.4   4.5     4.4    1.3    1.1    0.7    0.5    0.4    0.3          0.2



    SH.PE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                     APE         APE   APE   APE   APE     AIE    AI     AI     AI     AI     AI


    POT VOL CHANGE        *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
    (-)0.056  IN.SIZE      LIQUID       PLASTIC      SHRINKAGE     PLASTICITY       FLOW        TOUGHNESS
                           LIMITS       LIMIT        LIMIT         INDEX            INDEX       INDEX
                           PCT          PCT          PCT           PCT

    0                      18.10        15.57        10.91         2.53             5.10        0.50


   (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN............... ............*      SIZE(-)2.0   IN.
    SPECIF          ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE      APPARENT         BULK            ANGLE INTER
    GRAVITY         1 IN DROP         10 IN DROP        STEEL PLATE      COHESION         DENSITY         FRICTION
                    DEGREES AT        DEGREES AT        DEGREES AT       PSF AT           PCF AT          DEGREES AT
                    0.26PCT MOIST     0.26PCT MOIST     0.26PCT MOIST    0.26PCT MOIST    0.26PCT MOIST   0.26PCT MOIST


    2.689           37.15             33.60             31.17            740              91              32.7


                                                              ST-1           CURRENT:   04/01/73
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```
KEY

 19A
TUNNEL DATA


TUNNEL                            VENTILATION                           WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE        CFM    PRESS EXHST  SIZE    HP        GPM              AIR  WATER  PUMP           PRIMARY  SECONDARY
9FTX      ARCH BACK +0.5PCT       7      X            24 IN   40        NONE             4 IN 2 IN                   2300      480
 10.7FT

HAULAGE SYSTEM                                        SUPPORT SYSTEM

MUCK                PERSONNEL            SUPPLY       BOLT,TYPE SIZE   ROOF PLATE       SET,SIZE,SHAPE          SHOTCRETE
60 CF SIDE DUMP     RAIL                 RAIL         6FTX.75IN        9FTX13IN MATS
40 LB RAIL                                            4/ MAT
24 IN GAGE
6 T MOTOR



MACHINE EXCAVATION


MACHINE                           CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES              RPM            TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE      MODEL      WT         CENTER           INTERIOR         GAGE            HEAD,CENTER    HEAD           CENTER

                                                                                                   KFTLB          KFTLB              KLB
                                                                                                   KFTLB          KFTLR              KLB



 ANCHOR PRESS  MUCK SYSTEM       POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                                                                                 FEET          HOUR,FT.
 KLB                                                        KLB




CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                     EXPLOSIVES,                           BLASTING        MUCKING        GUIDANCE
JUMBO  3 BOOM             NO. HOLES 44               POWDER FACTOR 5.5LB/CY                ELECTRICAL      ATLAS-COPCO    TRANSIT
MACHINES                  DEPTH 7 FT                 TOTAL LBS 125                         0-14 REGULAR    LM56
       2-583F             DIAM. 1 5/8 IN             PRIMERS, 25LBS 60WR 1X16 IN           DELAYS
       1-D99              CUT,  BURN2-4 IN           TRIM NILITE
FEED LENGTH 8FT                                      INTERIOR NILITE
                          SF/HOLE 2.2                CUT NILITE
                                                     LIFTERS NILITE

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.          ST-1        CURRENT: 04/01/73
          (3) EXCESSIVE TIRE WEAR PROBABLE.                                                       MDN 1
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KEY   IDENTIFICATION       ROCK PROPERTIES
 20    CR                  METAMORPHIC: QUARTZITE                    DRY       COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                           MODERATLEY FOLDED                         WT        STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
      SAMPLE NO            MODERATELY TO HIGHLY FRACTURED            PCF       KPSI      EST                      PSIX10E6
      CR-1                 /JOINTED WITH MINOR FILLED                168        13        50      NA      41      5.72      0.18
                           VEINLETS. DIPPING 75-90
                           DEGREES

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)16    *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*   PCT (-)
  WT PCF    PCT       IN.SIZE     6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

    97       1.7       44.7         6.2   8.5   14.1  10.2    8.3   1.9    1.9    1.0    0.9    0.4     1.6              0.3



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                              AI          AI    AI    AI    AI     AI     AI     AI     AI     AI     AI


     POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN..................................*
     (-)0.056  IN.SIZE        LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW        TOUGHNESS
                              LIMITS        LIMIT         LIMIT          INDEX            INDEX       INDEX
                              PCT           PCT           PCT            PCT

     0                        16.50         14.83         11.76          1.67             4.90        0.34


    (-)0.75 IN.SIZE  *.......................MATERIAL SIZE(-)2.0     IN...............................*        SIZE(-)2.0   IN.
     SPECIF         ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT       BULK              ANGLE INTER
     GRAVITY        1 IN DROP          10 IN DROP        STEEL PLATE       COHESION       DENSITY           FRICTION
                    DEGREES AT         DEGREES AT        DEGREES AT        PSF AT         PCF AT            DEGREES AT
                   0.28 PCT MOIST     0.28 PCT MOIST    0.28 PCT MOIST    0.28 PCT MOIST 0.28 PCT MOIST    0.28 PCT MOIST


     2.714          37.6               34.3              31.75              400            90               42.1



                                                                         CR-1          CURRENT:   04/01/73
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```
KEY

 20A
TUNNEL DATA


TUNNEL                           VENTILATION                            WATER INFLOW   UTILITY LINES           POWER SYSTEM

SIZE     SHAPE      GRADE      CFM   PRESS EXHST  SIZE    HP      GPM            AIR  WATER  PUMP          PRIMARY  SECONDARY
10 FT    ROUNDED    +0.5PCT    14K   X            24 IN   30      MINOR          4 IN 2 IN   2 IN           2300      480
10 FT    CORNERS

HAULAGE SYSTEM                                    SUPPORT SYSTEM

MUCK             PERSONNEL      SUPPLY            BOLT+TYPE SIZE  ROOF PLATE      SET+SIZE+SHAPE        SHOTCRETE
EIMCO 912B       LHD            LHD               5 FT X 5/8 IN   9 FTX 13 IN
L.H.D.
SKIP




MACHINE EXCAVATION


MACHINE                    CUTTERS+MAKE+TYPE+DIAM+CUTTING EDGES                RPM          TORQUE+MAX/OPERATE      THRUST+MAX/OPERATE

  MAKE     MODEL     WT     CENTER           INTERIOR           GAGE         HEAD+CENTER  HEAD          CENTER

                                                                                          KFTLB         KFTLB            KLB
                                                                                          KFTLB         KFTLB            KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                            FEET        HOUR+FT.
 KLB                                                      KLB




CONVENTIONAL EXCAVATION


MACHINE                  ROUND+                    EXPLOSIVES+                         BLASTING         MUCKING         GUIDANCE
JUMBO  2 BOOM            NO. HOLES 48              POWDER FACTOR 9.5 LB/CY             ELECTRICAL       EIMCO           LASER
MACHINES D-93            DEPTH 8 FT                TOTAL LBS 265                       DUPONT ACUDET    912B
                         DIAM. 1 INX5/8 IN         PRIMERS+ 15LB TROJAN 60 WR.         0-14             LHD
                         CUT.  V                   TRIM NILITE
FEED LENGTH 8FT                                    INTERIOR NILITE
                         SF/HOLE 2.1               CUT NILITE
                                                   LIFTERS NILITE

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
          *POSSIBLE+TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH+ WEAR+ DAMAGE.     CR-1        CURRENT: 04/01/73
          (3) EXCESSIVE TIRE WEAR PROBABLE.                                                MDN 1
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KEY  IDENTIFICATION      ROCK PROPERTIES
 21   HOMESTAKE          METAMORPHIC. PHYLLITE WITH           DRY      COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
                         VEINQUARTZ. CHLORITE SCHIST          WT       STRNTH   PCT   SHORE   SCHMIDT  MOD.     RATIO
     SAMPLE NO           HIGHLY METAMORPHOSED AND             PCF      KPSI     EST                    PSIX10E6
     HS-1                FOLDED. WITH MINOR FAULTING
                                                              187       19      70     NA      41      8.62     0.20

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS....................................*  PCT (-)
  WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  N04    N08    N016   N030   N050   N0100   N0200      N0200

   136       2.2       25.3          17.5   9.2   13.2  13.3    10.4   3.2    2.0    1.2    0.7    0.5    0.5                3.0



   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                       PA        PA    PA    PA    PA     PA     PA     PA     PA     A      A


   POT VOL CHANGE          *...................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
   (-)0.056  IN.SIZE        LIQUID       PLASTIC      SHRINKAGE     PLASTICITY      FLOW      TOUGHNESS
                            LIMITS       LIMIT        LIMIT         INDEX           INDEX     INDEX
                            PCT          PCT          PCT           PCT

   0                        18.80        16.06        15.12         2.74            2.70      1.01


  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*        SIZE(-)2.0   IN.
   SPECIF        ANGLE/REPOSE      ANGLE/REPOSE     ANGLE/SLIDE       APPARENT        BULK              ANGLE INTER
   GRAVITY       1 IN DROP         10 IN DROP       STEEL PLATE       COHESION        DENSITY           FRICTION
                 DEGREES AT        DEGREES AT       DEGREES AT        PSF AT          PCF AT            DEGREES AT
                3.1  PCT MOIST    3.1  PCT MOIST   3.1  PCT MOIST    2.0  PCT MOIST 0.0  PCT MOIST     2.0  PCT MOIST


   2.84          40                34               31                160             99                39



                                                                       HS-1          CURRENT:   04/01/73
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KEY

 21A
TUNNEL DATA

TUNNEL                          VENTILATION                                 WATER INFLOW    UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST  SIZE    HP              GPM             AIR  WATER  PUMP           PRIMARY  SECONDARY
7FT6IN    ARCH   BACK           7K     X            16 IN 30                MINOR           2 IN 2 IN                   2400       440
 7FT6IN
                                                    SUPPORT SYSTEM
HAULAGE SYSTEM
                                                    BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE           SHOTCRETE
MUCK            PERSONNEL          SUPPLY           6 FT X 5/8 IN
RAIL            RAIL               RAIL
1.5T ROCKER
CARS 40LB RAIL
18 IN GAGE
6 OR 8 T MOTORS


MACHINE EXCAVATION

MACHINE                         CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                   RPM           TORQUE,MAX/OPERATE         THRUST,MAX/OPERATE

  MAKE      MODEL      WT       CENTER             INTERIOR            GAGE            HEAD,CENTER   HEAD            CENTER

                                                                                                     KFTLB         KFTLB                 KLB
                                                                                                     KFTLB         KFTLB                 KLB


 ANCHOR PRESS  MUCK SYSTEM      POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                                                                                FEET         HOUR,FT.
 KLB                                                         KLB



CONVENTIONAL EXCAVATION

MACHINE                      ROUND,                       EXPLOSIVES,                                  BLASTING           MUCKING         GUIDANCE
JUMBO   AIR LEG              NO. HOLES 34                 POWDER FACTOR 7.0 LB/CY                      ELECTRICAL         EIMCO           TRANSIT
MACHINES 3IN JACK HAMMER     DEPTH 10 FT                  TOTAL LBS 140                                7-MILLESECOND      21
                             DIAM. 1.5 IN                 PRIMERS, 9LB, 60 PCT 1X6 IN                  10-REGULAR
                             CUT,   BURNS-2 IN            TRIM ANFO
FEED LENGTH 6FT                                           INTERIOR ANFO
                             SF/HOLE 1.6                  CUT ANFO
                                                          LIFTERS ANFO

           BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
           NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
           TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
           FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
           *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH, WEAR, DAMAGE.
           (3) EXCESSIVE TIRE WEAR PROBABLE.                                                 HS-1        CURRENT: 04/01/73
                                                                                             MDN 1
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KEY  IDENTIFICATION       ROCK PROPERTIES
 22   NEW YORK            METAMORPHIC: MICA SCHIST                    DRY      COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
                          OCCASIONAL QUARTZ                           WT       STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO            LAMINATIONS                                 PCF      KPSI      EST                       PSIX10E6
      NY-1
                                                                      179       15        80     NA       48       12.26     0.17

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200      NO200

     101     12.4      0              0     0     3.5   21.9    12.3   6.6     7.5     5.3     7.5     11.7    7.7         16.0



     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                PAI   PA     PA     PA     AI     A-P    A-P    A


     POT VOL CHANGE          *...................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
     (-)0.056  IN.SIZE        LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW        TOUGHNESS
                              LIMITS        LIMIT         LIMIT           INDEX             INDEX       INDEX
                              PCT           PCT           PCT             PCT

     0                        24.90         23.60         22.92           1.30               5.3         0.25


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN.............................*         SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE        ANGLE/REPOSE      ANGLE/SLIDE        APPARENT       BULK                ANGLE INTER
     GRAVITY         1 IN DROP           10 IN DROP        STEEL PLATE        COHESION       DENSITY             FRICTION
                     DEGREES AT          DEGREES AT        DEGREES AT         PSF AT         PCF AT              DEGREES AT
                    5.56 PCT MOIST      5.56 PCT MOIST    5.56 PCT MOIST     5.56 PCT MOIST 5.56 PCT MOIST      5.56 PCT MOIST


     2.614           39.80               37.45             38.75               0              84.76              26.2



                                                                               NY-1         CURRENT:   04/01/73
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KEY

 22A
TUNNEL DATA


TUNNEL                         VENTILATION                       WATER INFLOW   UTILITY LINES             POWER SYSTEM

SIZE    SHAPE    GRADE     CFM   PRESS EXHST  SIZE   HP          GPM            AIR  WATER  PUMP          PRIMARY  SECONDARY
11 FT   ROUND    -0.30PCT  36K          X     20 IN  40          40             4 IN 4 IN   6 IN           6600      440


HAULAGE SYSTEM                                SUPPORT SYSTEM

MUCK             PERSONNEL       SUPPLY       BOLT,TYPE SIZE  ROOF PLATE    SET,SIZE,SHAPE          SHOTCRETE
RAIL             RAIL            RAIL                                       HALF CIRCLE
17CY CARS                                                                   BOLTED STEEL
10T MOTORS                                                                  LAGGING IN
70LB RAIL                                                                   FAULT ZONES
36 IN GAGE


MACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES         RPM          TORQUE,MAX/OPERATE       THRUST,MAX/OPERATE

  MAKE     MODEL     WT        CENTER        INTERIOR        GAGE           HEAD,CENTER  HEAD         CENTER
  JARVA    12-1100   NA        2 REED        28 REED,3 DISC  6 JARVA TCB    10.75
                               5 DISC        OK-3            DISC,OKC-3W                 KFTLB 244    KFTLB               KLB
                               OK-1                                                      KFTLB        KFTLB               KLB  953


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS TO      NA             LASER                       FEET        HOUR,FT.
 KLB           BELT                                     KL3 10.0          0.17           3.6



CONVENTIONAL EXCAVATION


MACHINE                  ROUND,                EXPLOSIVES,                         BLASTING     MUCKING      GUIDANCE
JUMBO                    NO. HOLES             POWDER FACTOR
MACHINES                 DEPTH                 TOTAL LBS
                         DIAM.                 PRIMERS,
                         CUT,                  TRIM
FEED LENGTH                                    INTERIOR
                                               CUT
                                               LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.        NY-1         CURRENT: 04/01/73
                                                                                                  MDN 5
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KEY  IDENTIFICATION        ROCK PROPERTIES
 23   NEW YORK             METAMORPHIC: MICA SCHIST          DRY      COMP     RQD   ... HARDNESS...   YOUNGS   POISSON
                           OCCASIONAL QUARTZ                 WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO             LAMINATIONS                       PCF      KPSI     EST                     PSIX10E6
     NY-2
                                                             177      13       90    NA      45        8.50     0.20

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS..................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100  NO200     NO200

    97       7.2       0              0     0     2.2   13.3    10.6   5.6    9.2    6.9    9.1    14.6   9.5               19.0


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                 PAI   PA     PA     AI     AI     A-P    A-P    A


    POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN..................................*
    (-)0.056  IN.SIZE       LIQUID          PLASTIC        SHRINKAGE       PLASTICITY         FLOW          TOUGHNESS
                            LIMITS          LIMIT          LIMIT           INDEX              INDEX         INDEX
                            PCT             PCT            PCT             PCT

    0                       24.00           23.32          22.00           0.68               6.70          0.10


  (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)2.0      IN..............................*    SIZE(-)2.0   IN.
   SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT          BULK              ANGLE INTER
   GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION          DENSITY           FRICTION
                   DEGREES AT         DEGREES AT         DEGREES AT         PSF AT            PCF AT            DEGREES AT
                 4.22 PCT MOIST     4.22 PCT MOIST     4.22 PCT MOIST     4.22 PCT MOIST 4.22 PCT MOIST     4.22 PCT MOIST


   2.878           42.00              37.95              40.17              0                 80.92             29.2



                                                                              NY-2          CURRENT:   04/01/73
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KEY

 23A
TUNNEL DATA

TUNNEL                        VENTILATION                         WATER INFLOW     UTILITY LINES          POWER SYSTEM

SIZE     SHAPE     GRADE      CFM   PRESS EXHST  SIZE    HP       GPM              AIR  WATER  PUMP       PRIMARY  SECONDARY
8 FT     ROUND     +0.30PCT 18K            X     12 IN  40        20               4 IN 4 IN   4 IN        6600       440
6 IN

HAULAGE SYSTEM                                       SUPPORT SYSTEM

MUCK              PERSONNEL        SUPPLY            BOLT,TYPE SIZE  ROOF PLATE    SET,SIZE,SHAPE         SHOTCRETE
RAIL              RAIL             RAIL                                            HALF CIRCLE BOLTED
13 CY CARS                                                                         STEEL LAGGING
10 T MOTORS                                                                        IN FAULT ZONES
70 LB RAIL
36 IN GAGE


MACHINE EXCAVATION

MACHINE                       CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES              RPM            TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL     WT       CENTER           INTERIOR         GAGE            HEAD,CENTER    HEAD          CENTER
JARVA      8-806     NA       2 REED           12 REED QC-3     3 JARVA DISC    12.5
                              TOOTH TYPE       TCB BUTTON       GKC-3W, TCB                    KFTLB 158   KFTLB               KLB
                                                                                               KFTLB       KFTLB               KLB  482


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS         NA             LASER                       FEET        HOUR,FT.
 KLB           TO BELT                                  KLB 8.49          0.09           3.1


CONVENTIONAL EXCAVATION

MACHINE                  ROUND,                   EXPLOSIVES,                      BLASTING      MUCKING      GUIDANCE
JUMBO                    NO. HOLES                POWDER FACTOR
MACHINES                 DEPTH                    TOTAL LBS
                         DIAM.                    PRIMERS,
                         CUT,                     TRIM
FEED LENGTH                                       INTERIOR
                                                  CUT
                                                  LIFTERS

        BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
        *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.    NY-2      CURRENT: 04/01/73
                                                                                           MDN 5
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KEY  IDENTIFICATION       ROCK PROPERTIES
 24   QUEEN               METAMORPHIC: GRAY MICA SCHIST         DRY       COMP       RQD   ....HARDNESS...   YOUNGS   POISSON
       LANE               OCCASIONAL QUARTZ SEAMS. MICA          WT       STRNTH     PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            VARIES FROM DENSE. FINE               PCF       KPSI       EST                     PSIX10E6
     QL-1                 GRAINED TO EXTREMELY COARSE.
                                                                 165        11        30     NA      30       4.50     0.25
                                                                                                              NOTE     NOTE
                                                                                                               2        2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*  PCT (-)
   WT  PCF   PCT       .N.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100    NO200      NO200

    108      9.0       0.0             0.0   0.0   7.6   17.0    13.4   4.5     4.9    5.4     8.4     10.2     7.7               20.9



    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                PE   PE     PI     PI     PI     PI     PI     PI


    POT VOL CHANGE        *...................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE      LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW          TOUGHNESS
                           LIMITS        LIMIT         LIMIT           INDEX             INDEX         INDEX
                           PCT           PCT           PCT             PCT

    0                      24.0          23.3          22.7            0.7               4.0           0.17


   (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN..............................*      SIZE(-)2.0   IN.
    SPECIF           ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE         APPARENT      BULK              ANGLE INTER
    GRAVITY          1 IN DROP           10 IN DROP          STEEL PLATE         COHESION      DENSITY           FRICTION
                     DEGREES AT          DEGREES AT          DEGREES AT          PSF AT        PCF AT            DEGREES AT
                     9.8  PCT MOIST      9.8  PCT MOIST      8.4  PCT MOIST      9.3  PCT MOIST 0.0  PCT MOIST   9.3  PCT MOIST


    2.57             39                  37                  40                  125           75                30


                                                                                 QL-1          CURRENT:   04/01/73
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KEY

 24A
TUNNEL DATA

                                                                  WATER INFLOW    UTILITY LINES              POWER SYSTEM
TUNNEL                             VENTILATION
                                                                                                             PRIMARY  SECONDARY
SIZE      SHAPE      GRADE      CFH    PRESS EXHST   SIZE    HP     GPM           AIR   WATER   PUMP          4160V      480V
11FT      ROUND      .1-3PCT    4K              X    14IN                                4IN

                                                    SUPPORT SYSTEM
HAULAGE SYSTEM
                                                    BOLT.TYPE SIZE   ROOF PLATE   SET.SIZE.SHAPE             SHOTCRETE
MUCK             PERSONNEL          SUPPLY                                        OCCASIONAL SEMI-
RAIL             RAIL               RAIL                                          CIRCULAR PLATES
                                                                                  PINNED AT SPING LINE
                                                                                  AT FAULTS



MACHINE EXCAVATION

                                                                                  RPM          TORQUE.MAX/OPERATE        THRUST.MAX/OPERATE
MACHINE                            CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES

  MAKE     MODEL      WT     CENTER           INTERIOR         GAGE               HEAD.CENTEP  HEAD         CENTER
  JARVA    MARK       70     2 REED STEEL     26 REED STEEL    6 REED STEEL       10.75INTEG
           11-1100    TONS   TRIPLE DISC      TRIPLE DISC      TRIPLE DISC                     KFTLB        KFTLB                 KLB
                                                                                               KFTLB 244    KFTLB                 KLB 377


 ANCHOR PRESS  MUCK SYSTEM   POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET FROM   4-125HP ELECT.   LASER                       FEET        HOUR.FT.
 KLB 3402      FACE.         MOTORS. 40HP               KLB 3.53          0.18          2.9
               CONVEYOR      MOTORS.
               BELT TO REAR  HYDRAULIC


CONVENTIONAL EXCAVATION

                                                                                     BLASTING     MUCKING       GUIDAN:E
MACHINE                   ROUND.                   EXPLOSIVES.
JUMBO                     NO. HOLES                POWDER FACTOR
MACHINES                  DEPTH                    TOTAL LBS
                          DIAM.                    PRIMERS.
                          CUT.                     TRIM
FEED LENGTH                                        INTERIOR
                                                   CUT
                                                   LIFTERS

                BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
                NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
                TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
                FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
                *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.      QL-1       CURRENT: 04/01/73
                                                                                                     MDN 5
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KEY  IDENTIFICATION       ROCK PROPERTIES
 25   MB                  SEDIMENTARY. GRAYWACKE                 DRY       COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                          (ARGILLACEOUS QUARTZITE)               WT        STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            MASSIVE TO MEDIUM BEDDED.              PCF       KPSI                               PSIX10E6
     MB-2                 HIGHLY FOLDED AND FRACTURED
                          NORMAL DIP OF BEDDING                  171         22       35     NA       44        9.76     0.20
                          30 DEGREES TO 45 DEGREES

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS..................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

     102      2.1       0.0          12.5  19.2  24.5  18.9   13.2   3.8    2.7    1.6    0.8    0.7     0.4         1.7


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                   APE   APE   API   APE    APIE   APIE   AIE    AI     AI     AI


    POT VOL CHANGE          *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
    (-)0.056  IN.SIZE        LIQUID         PLASTIC        SHRINKAGE       PLASTICITY        FLOW       TOUGHNESS
                             LIMITS         LIMIT          LIMIT           INDEX             INDEX      INDEX
                             PCT            PCT            PCT             PCT

    0                        17.70          17.48          16.73           0.22              7.2        0.0


   (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)2.0     IN...............................*      SIZE(-)2.0   IN.
    SPECIF         ANGLE/REPOSE        ANGLE/REPOSE       ANGLE/SLIDE          APPARENT        BULK              ANGLE INTER
    GRAVITY        1 IN DROP           10 IN DROP         STEEL PLATE          COHESION        DENSITY           FRICTION
                   DEGREES AT          DEGREES AT         DEGREES AT           PSF AT          PCF AT            DEGREES AT
                  1.58 PCT MOIST      1.58 PCT MOIST     1.58 PCT MOIST       1.58 PCT MOIST  1.58 PCT MOIST    1.58 PCT MOIST


    2.678          35.75               33.25              31.42                 250             99.36             42.5



                                                                              MB-2           CURRENT:   04/01/73
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KEY

 25A
TUNNEL DATA

TUNNEL                         VENTILATION                        WATER INFLOW    UTILITY LINES             POWER SYSTEM

SIZE      SHAPE      GRADE     CFM    PRESS EXHST  SIZE    HP     GPM             AIR  WATER  PUMP          PRIMARY   SECONDARY
10 FT     RECT       +2.0 PCT  8K             X    16 IN   30     NONE            6 IN 4 IN                  2300       480
 10.8 FT

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY           BOLT,TYPE SIZE  ROOF PLATE      SE1.SIZE.SHAPE           SHOTCRETE
RAIL 140-200CF   RAIL             RAIL             5 FT X .75 IN   AS REQUIRED
BOTTOM DUMPCARS
60-80LB RAIL
10T MOTOR
30 IN GAGE



MACHINE EXCAVATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES            RPM          TORQUE,MAX/OPERATE        THRUST,MAX/OPERATE

  MAKE      MODEL       WT     CENTER           INTERIOR          GAGE         HEAD,CENTER  HEAD            CENTER

                                                                                            KFTLB           KFTLB               KLB
                                                                                            KFTLB           KFTLB               KLB



 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM     GUIDANCE   THRUST/SQ FT  KERF SPACING   ADVANCE PER
                                                                             FEET          HOUR,FT.
 KLB                                                       KLB




CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                   EXPLOSIVES,                        BLASTING        MUCKING       GUIDANCE
JUMBO  2 BOOM             NO. HOLES 36             POWDER FACTOR 7.5LB/CY             IGNITER CORD    EIMCO         TRANSIT
MACHINES D-93             DEPTH 8 FT               TOTAL LBS 210                      FUSE, CAPS      40

       1 1/4 STEEL        CUT,  V                  TRIM ANFO
FEED LENGTH 10FT                                   INTERIOR ANFO
                          SF/HOLE 2.6              CUT ANFO
                                                   LIFTERS ANFO

        BASIS FOR MCN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
        *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED.                                             MB-2       CURRENT: 04/01/73
                                                                                              MDN 3
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KEY  IDENTIFICATION       ROCK PROPERTIES
 26   5-1                 SEDIMENTARY: SANDSTONE FINE       DRY      COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
                          GRAINED. WELL COMPACTED.          WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
      SAMPLE NO           LIGHT BROWN OVER 50 PCT           PCF      KPSI                             PSIX10E6
      5-1                 QUARTZ.
                                                            166      22       92    61      37        3.38     0.25

   NOTES:
   1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
   4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

   MUCK DATA
    DRY UNIT  MOISTURE  PCT(+)6   *..................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
    WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

     83       5.4       0.0          0.0   0.0   33.8  20.9   15.5   4.4    2.7    1.3    1.1    3.5    5.0               11.8


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                               PI    PI    PI    PI    PI    A     A     A

    POT VOL CHANGE         *...................ATTERBERG LIMITS..SIZE(-) 0.185IN................................*
    (-)0.065  IN.SIZE      LIQUID       PLASTIC       SHRINKAGE      PLASTICITY     FLOW       TOUGHNESS
                           LIMITS       LIMIT         LIMIT          INDEX          INDEX      INDEX
                           PCT          PCT           PCT            PCT

    0                      16.90        15.50         15.18          1.40           5.0        0.28

   (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN................................*   SIZE(-)2.0   IN.
    SPECIF         ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT        BULK              ANGLE INTER
    GRAVITY        1 IN DROP        10 IN DROP       STEEL PLATE      COHESION        DENSITY            FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT       PSF AT          PCF AT             DEGREES AT
                   6.3 PCT MOIST    6.3 PCT MOIST    6.3 PCT MOIST    4.8 PCT MOIST   0.0 PCT MOIST      4.8 PCT MOIST

    2.73           35               29               28               280             85.23              29


                                                                     5-1            CURRENT:   04/01/73
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```
KEY

 26A
TUNNEL DATA


TUNNEL                        VENTILATION                            WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE     SHAPE      GRADE     CFM   PRESS EXHST  SIZE    HP          GPM              AIR  WATER  PUMP           PRIMARY  SECONDARY
18 FT    ROUND      -7.0PCT   17K            X   36IN    75          5-10                  2IN    4IN            4160V      480V
 1 IN

HAULAGE SYSTEM                                        SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY              BOLT,TYPE SIZE  ROOF PLATE       SET,SIZE,SHAPE          SHOTCRETE
30IN PIGGYBACK   DIESEL           DIESEL              4-5/8IN X 4FT   8.2LB CHANNEL,
CONVEYORS, 36IN  TRUCKS,          TRUCKS,                             6IN X 9.5FT OR
SUSPENDED        JEEPS            JEEPS                               13.5FT AT 4FT
CONVEYOR                                                              OR 2FT



MACHINE EXCAVATION


MACHINE                           CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                  RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL      WT          CENTER             INTERIOR          GAGE              HEAD,CENTER  HEAD           CENTER
  ROBBINS  181-122    260         1 ROBBINS,         43 ROBBINS,       3 ROBBINS,        4.5  INTEG
                      TONS        7.5IN TRIPLE       12IN STEEL        12IN STEEL                     KFTLB1720   KFTLB                KLB 1580
                                  STEEL DISC         DISC              DISC                           KFTLB       KFTLB                KLB 914


 ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                BUCKETS FROM    6-200HP MOTORS   LASER                       FEET        HOUR,FT.
 KLB            FACE, 30IN      FOR HEAD                   KLB 3.56          0.20           5.0
                CONVEYOR TO
                REAR


CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                   EXPLOSIVES,                          BLASTING      MUCKING      GUIDANCE
JUMBO                     NO. HOLES                POWDER FACTOR
MACHINES                  DEPTH                    TOTAL LBS
                          DIAM.                    PRIMERS,
                          CUT.                     TRIM
FEED LENGTH                                        INTERIOR
                                                   CUT
                                                   LIFTERS

          BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.         S-1        CURRENT: 04/01/73
                                                                                                 MON 5
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KEY  IDENTIFICATION     ROCK PROPERTIES
 27   7-2               SEDIMENTARY: SANDSTONE FINE            DRY      COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
                        GRAINED. WELL COMPACTED.               WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
      SAMPLE NO         LIGHT BROWN. OVER 50 PCT               PCF      KPSI                             PSIX10E6
      7-2               QUARTZ.
                                                               166       22      92     61       37      5.38     0.25

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*  PCT (-)
  WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200     NO200

   90       4.0       0.0       1.5   0.9   33.1  22.6  15.4    4.3    2.6    1.4    1.2    2.5    3.8               10.7


  SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                PI    PI    PI    PI    PI      PI     PI     A      A      A


  POT VOL CHANGE     *....................ATTERBERG LIMITS..SIZE(-) 0.056IN................................*
  (-)0.056  IN.SIZE   LIQUID        PLASTIC       SHRINKAGE     PLASTICITY     FLOW      TOUGHNESS
                      LIMITS        LIMIT         LIMIT         INDEX          INDEX     INDEX
                      PCT           PCT           PCT           PCT

  0                   23.0          17.63         17.58         5.37           6.90      0.78


 (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN............................*      SIZE(-)2.0   IN.
  SPECIF         ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT       BULK                ANGLE INTER
  GRAVITY        1 IN DROP         10 IN DROP        STEEL PLATE       COHESION       DENSITY             FRICTION
                 DEGREES AT        DEGREES AT        DEGREES AT        PSF AT         PCF AT              DEGREES AT
                 2.6  PCT MOIST    2.6  PCT MOIST    2.6  PCT MOIST    2.8  PCT MOIST 0.0  PCT MOIST      2.8  PCT MOIST


  2.63           32                31                29                0              92.8                44


                                                                       7-2            CURRENT:  04/01/73
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KEY

 27A
TUNNEL DATA


TUNNEL                           VENTILATION                        WATER INFLOW    UTILITY LINES           POWER SYSTEM

SIZE     SHAPE     GRADE     CFM    PRESS EXHST    SIZE    HP      GPM             AIR   WATER  PUMP        PRIMARY  SECONDARY
18FT     ROUND     +2.0PCT   17K              X    36IN    75      5-10                   2IN    4IN         4160V      480V
 1IN

HAULAGE SYSTEM                                       SUPPORT SYSTEM

MUCK               PERSONNEL          SUPPLY         BOLT.TYPE SIZE  ROOF PLATE       SET.SIZE.SHAPE        SHOTCRETE
30IN PIGGYBACK     DIESEL             DIESEL         4-5/8IN X 4FT   8.2LB CHANNEL
CONVEYOR. 36IN     TRUCKS             TRUCKS.                        6IN X 9.5FT OR
SUSPENDED          JEEPS              JEEPS                          13.5FT AT 4FT
CONVEYOR                                                             OR 2FT



MACHINE EXCAVATION


MACHINE                          CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                  RPM           TORQUE.MAX/OPERATE       THRUST.MAX/OPERATE

  MAKE      MODEL      WT     CENTER             INTERIOR          GAGE              HEAD.CENTER   HEAD          CENTER
  ROBBINS   181-122    260    1 ROBBINS 7.5IN    41 ROBBINS12IN    ROBBINS 12 IN     4.5   INTEG
                       TONS   TRIPLE STEEL       STEEL DISC        STEEL DISC                      KFTLB1720     KFTLB              KLB 1580
                              DISC                                                                 KFTLB         KFTLB              KLB 747


 ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                BUCKETS FROM    4-200HP MOTORS   LASER                         FEET         HOUR.FT.
 KLB            FACE. 30IN      FOR HEAD                    KLB 2.91           0.20           4.4
                CONVEYOR TO
                REAR


CONVENTIONAL EXCAVATION


MACHINE                       ROUND.                    EXPLOSIVES.                        BLASTING        MUCKING        GUIDANCE
JUMBO                         NO. HOLES                 POWDER FACTOR
MACHINES                      DEPTH                     TOTAL LBS
                              DIAM.                     PRIMERS.
                              CUT.                      TRIM
FEED LENGTH                                             INTERIOR
                                                        CUT
                                                        LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
            *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.         7-2         CURRENT: 04/01/73
                                                                                                  MDN 3
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KEY  IDENTIFICATION       ROCK PROPERTIES
 28  11-3                 SEDIMENTARY: SHALE, MASSIVE TO        DRY       COMP       RQD   ....HARDNESS...     YOUNGS    POISSON
                          THINLY LAMINATED, INTERBEDDED         WT        STRNTH     PCT   SHORE    SCHMIDT    MOD.      RATIO
     SAMPLE NO            SILTSTONE AND SHALE, WITH             PCF       KPSI       EST                       PSIX10E6
     11-3                 MINOR SANDSTONE AND LIMESTONE
                          LAYERS. GRAIN SIZE FINE TO            165                  90              AV        9.52      0.15
                          COARSE. QUARTZ 24 TO 33 PCT.                  4 MAJ BEDS         PARALLEL  46
                                                                         22 TO 29          41-55.
                                                                        3 MIN BEDS         NORMAL
                                                                         12 TO 17          41-54.
                                                                        WT. AV. 23         WT. AV. 48

NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...............................*  PCT (-)
  WT  PCF  PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200    NO200

  99       1.1       7.8          12.6  11.3  14.4  14.9    16.4   5.7    3.5    2.0    1.4    1.1    0.9              8.0


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                         PA         PA    FA    PA    PA     A      A      A      A      A


   POT VOL CHANGE          *..................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
   (-)0.056  IN.SIZE       LIQUID       PLASTIC      SHRINKAGE    PLASTICITY     FLOW         TOUGHNESS
                           LIMITS       LIMIT        LIMIT        INDEX          INDEX        INDEX
                           PCT          PCT          PCT          PCT

   0                       15.60        14.81        14.51        0.79           3.00          0.26


   (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0     IN..............................*         SIZE(-)2.0    IN.
   SPECIF          ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT         BULK                 ANGLE INTER
   GRAVITY         1 IN DROP        10 IN DROP       STEEL PLATE      COHESION         DENSITY              FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT       PSF AT           PCF AT               DEGREES AT
                   1.0  PCT MOIST   1.0  PCT MOIST   1.0  PCT MOIST   0.2  PCT MOIST 0.0  PCT MOIST         0.2  PCT MOIST

   2.65            25               25               29               550              100                  46


                                                                           11-3         CURRENT:  04/01/77
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KEY

 28A
TUNNEL DATA

TUNNEL                        VENTILATION                         WATER INFLOW      UTILITY LINES                POWER SYSTEM

SIZE      SHAPE     GRADE     CFM   PRESS EXHST   SIZE   HP       GPM               AIR  WATER  PUMP             PRIMARY   SECONDARY
24FTX7    RECT      VARIES    90-100K  X                          NONE              4IN  4IN    4IN                          '10V
.5FT5FT

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK              PERSONNEL         SUPPLY       BOLT.TYPE SIZE   ROOF PLATE        SET.SIZE.SHAPE           SHOTCRETE
WAGNER ST-5       DIESEL            DIESEL       5/8IN X 6FT      11IN X 10FT
SCOOPTRAM.        TRUCKS.           TRUCKS.      4FT X 4FT
16TON SHUTTLE     JEEPS             JEEPS        PATTERN
CARS



MACHINE EXCAVATION


MACHINE                       CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                  RPM           TORQUE.MAX/OPERATE         THRUST.MAX/OPERATE

  MAKE      MODEL       WT    CENTER            INTERIOR          GAGE              HEAD.CENTER   HEAD            CENTER

                                                                                                  KFTLB        KFTLB                KLB
                                                                                                  KFTLB        KFTLB                KLB



 ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                                                                               FEET          HOUR.FT.
 KLB                                                         KLB



CONVENTIONAL EXCAVATION


MACHINE                    ROUND.                      EXPLOSIVES.                              BLASTING         MUCKING          GUIDANCE
JUMBO  2 BOOM HYDROJIB     NO. HOLES 35                POWDER FACTOR 3.5LB/CY                   ELECTRICAL       SCOOPTRAM        TRANSIT
MACHINES 2-AR93            DEPTH 10.5FT - 11FT         TOTAL LBS 234                            M.S. DELAYS                       LASER
             DRIFTERS      DIAM. 1-3/4IN               PRIMERS. 16LB 1.25IN X 8IN. 75PCT
                           CUT.  V                     TRIM 11LB 1.25IN X 12IN. COALITE 5Y
FEED LENGTH 14FT                 1-6FT BUSTER          INTERIOR ANFO
                                 HOLE                  CUT
                                 SF./HOLE 5.1          LIFTERS 32LB 1.25IN X 12IN. RXL 60PCT

             BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
             NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
             TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
             FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO      11-3        CURRENT: 04/01/73
             *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.        MDN 2
             (3) EXCESSIVE TIRE WEAR PROBABLE.
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KEY  IDENTIFICATION      ROCK PROPERTIES
 29  11-4                SEDIMENTARY: SHALE. MASSIVE TO        DRY       COMP      RQD   ....HARDNESS...   YOUNGS   POISSON
                         THINLY LAMINATED. INTERBEDDED         WT        STRNTH    PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO           SILTSTONE AND SHALE WITH MINOR        PCF       KPSI      EST                     PSIX10E6
     11-4                SANDSTONE AND LIMESTONE LAYERS
                         GRAIN SIZE FINE TO COARSE.           166                  90            46        9.50     0.15
                         QUARTZ 24 TO 33 PCT.                          4 MAJ BEDS        PARALLEL AV        NOTE     NOTE
                                                                        22 TO 29         41-55.              4        4
                                                                       3 MIN BEDS        NORMAL
                                                                        12 TO 17         41-54.
                                                                       WT. AV. 23        WT. AV. 48

NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS..................................*   PCT (-)
 WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100    NO200      NO200

   96      1.1       8.2           17.7  17.0  19.3  15.7     12.7  3.4     2.5     1.2     0.6     0.2     0.2               1.3


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                     PA            PA    PA    PA    PA       PA    PA      PA      A       A       A


   POT VOL CHANGE         *.......................ATTERBERG LIMITS..SIZE(-) 0.056IN...................................*
   (-)0.056  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW         TOUGHNESS
                           LIMITS        LIMIT         LIMIT          INDEX            INDEX        INDEX
                           PCT           PCT           PCT            PCT

   0.                      15.80         15.60         13.26          0.20             4.00          0.05


  (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)2.0      IN................................*       SIZE(-)2.0    IN.
   SPECIF         ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE        APPARENT        BULK            ANGLE INTER
   GRAVITY        1 IN DROP           10 IN DROP          STEEL PLATE        COHESION        DENSITY         FRICTION
                  DEGREES AT          DEGREES AT          DEGREES AT         PSF AT          PCF AT          DEGREES AT
                 0.9  PCT MOIST      0.9  PCT MOIST      0.9  PCT MOIST     0.2  PCT MOIST 0.0  PCT MOIST   0.2  PCT MOIST


   2.78           28                  29                  28                 282             100             54
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KEY

 29A
TUNNEL DATA

                                     VENTILATION                         WATER INFLOW     UTILITY LINES              POWER SYSTEM
TUNNEL
                                                                                                                     PRIMARY  SECONDARY
SIZE      SHAPE      GRADE      CFM   PRESS EXHST  SIZE    HP            GPM              AIR  WATER  PUMP            4160V      600V
18FTX8    RECT       0.0        20K   ENTRY FACE           40            NONE             2IN
.5FT
                                                         SUPPORT SYSTEM
HAULAGE SYSTEM
                                                         BOLT.TYPE SIZE  ROOF PLATE       SET.SIZE.SHAPE           SHOTCRETE
MUCK               PEPSONNEL           SUPPLY            5/8IN X 6FT AT
DIESEL SHUTTLE     DIESEL              DIESEL            4FT X 4FT
CAR. CONVEYOR      TRUCK               TRUCK



MACHINE EXCAVATION

MACHINE                             CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                  RPM          TORQUE.MAX/OPERATE       THRUST.MAX/OPERATE

  MAKE     MODEL       WT        CENTER             INTERIOR          GAGE                HEAD.CENTER  HEAD          CENTER
  ATLAS -  4-HEAD      180          48 T.C. DRAG    CUTTERS MOUNTED   ON 4 ROTATING       3 1/4UPPER
  COPCO                L.T.         HEADS                                                 1 5-8LOWER   KFTLB         KFTLB              KLB 1.093
                                                                                                       KFTLB         KFTLB              KLB


  ANCHOR PRESS  MUCK SYSTEM       POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                FLIGHT CONVEYOR   4-80KW MOTORS    TRANSIT                     FEET        HOUR.FT.
  KLB 1000      STAR WHEEL.       HEAD ROTATION    LASER     KLB NA            NA            NA
                25IN CONVEYOR     2-78KW MOTORS
                                  HYDRAULICS


CONVENTIONAL EXCAVATION

                                                                                          BLASTING        MUCKING         GUIDANCE
MACHINE                    ROUND.                       EXPLOSIVES.
JUMBO                      NO. HOLES                    POWDER FACTOR
MACHINES                   DEPTH                        TOTAL LBS
                           DIAM.                        PRIMERS.
                           CUT.                         TRIM
                                                        INTERIOR
FEED LENGTH                                             CUT
                                                        LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.        11-4       CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                   MDN 2
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KEY  IDENTIFICATION     ROCK PROPERTIES
 30   72-1              SEDIMENTARY: SHALE              DRY       COMP     RQD    ....HARDNESS...   YOUNGS   POISSON
                        INTERBEDED SILTSTONE            WT        STRNTH   PCT    SHORE   SCHMIDT   MOD.     RATIO
      SAMPLE NO         + SHALE MINOR SANDSTONE         PCF       KPSI     EST                      PSIX10E6
      72-1              + LIMESTONE. FINE TO
                        COURSE GRAINED                  168        22      65     41-55    46       8.37     0.35

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS.............................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

    86        1.5      0          0    4.0   18.8  31.0   24.1   7.3    4.5    1.1    1.5    1.2    0.6                5.9
                       0.0        0.0  8.0   24.0  28.0   20.0

    SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117).  LOWER LINE, SCREENED BEFORE DRYING

     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                          PE    P    P     P     P     P     P-A   P-A   A

     POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...................................*
     (-)0.056  IN.SIZE        LIQUID        PLASTIC      SHRINKAGE     PLASTICITY      FLOW        TOUGHNESS
                              LIMITS        LIMIT        LIMIT         INDCX           INDEX       INDEX
                              PCT           PCT          PCT           PCT

     0                        18.00         17.10        15.58         0.90            4.40        0.20

    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN...........................*     SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT        BULK           ANGLE INTER
     GRAVITY         1 IN DROP        10 IN DROP       STEEL PLATE      COHESION        DENSITY        FRICTION
                     DEGREES AT       DEGREES AT       DEGREES AT       PSF AT          PCF AT         DEGREES AT
                    1.3  PCT MOIST   1.3  PCT MOIST   1.3  PCT MOIST   1.0  PCT MOIST 0.0  PCT MOIST  1.0  PCT MOIST

     2.72            36               32               30               170             100            41

                                                                        72-1         CURRENT:   04/01/73
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```
KEY

 30A
TUNNEL DATA

TUNNEL                      VENTILATION                        WATER INFLOW    UTILITY LINES         POWER SYSTEM

SIZE     SHAPE     GRADE     CFM   PRESS EXHST  SIZE   HP     GPM             AIR  WATE'  PUMP      PRIMARY  SECONDARY
18 FT    ROUND     +10.0PCT  18K         X      36 IN 120     5-10            2 IN        4IN        4160       480
 1 IN

HAULAGE SY.TEM                                  SUPPORT SYSTEM

MUCK               PERSONNEL         SUPPLY     BOLT.TYPE SIZE  ROOF PLATE        SET.SIZE.SHAPE       SHOTCRETE
30 IN PIGGYBACK    DIESEL            DIESEL     6-6FTX5/8 IN    8.2 LB CHANNEL
CONVEYOR 36 IN     TRUCKS            TRUCKS                     6 IN X9.5FT OR
SUSPENDED          JEEPS             JEEPS                      13.5 FT AT 2 FT
CONVEYOR


MACHINE EXCAVATION

MACHINE                     CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                  RPM         TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE     MODEL     WT     CENTER            INTERIOR          GAGE              HEAD.CENTER HEAD         CENTER
ROBBINS    181-122   260    1ROBBINS DISC     43 ROBBINS DISC   3 ROBBINS DISC     4.5
                            7.5IN TRIPLE W/   12IN. ESCO RING   12IN W/ESCO RNG               KFTLB1147    KFTLB           KLB
                                                    ESCO RING                                 KFTLB        KFTLB           KLB 769


 ANCHOR PRESS  MUCK SYSTEM      POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS          4-200 HP       LASER                       FEET         HOUR.FT.
 KLB 1000      TO BELT          FOR HEAD                 KLB 2.99          0.20           5.5



CONVENTIONAL EXCAVATION

MACHINE                 ROUND.                 EXPLOSIVES.                    BLASTING     MUCKING      GUIDANCE
JUMBO                   NO. HOLES              POWDER FACTOR
MACHINES                DEPTH                  TOTAL LBS
                        DIAM.                  PRIMERS.
                        CUT.                   TRIM
FEED LENGTH                                    INTERIOR
                                               CUT
                                               LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED.                                    72-1        CURRENT: 04/01/73
                                                                                       MDN 4
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KEY  IDENTIFICATION     ROCK PROPERTIES
 31   MSU               SEDIMENTARY: CONGLOMERATE          DRY      COMP    RQD   ....HARDNESS...   YOUNGS   POISSON
                        (BRECCIA) .25 IN TO 10 IN          WT       STRNTH  PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO          ROUNDED TO ANGULAR BOULDERS        PCF      KPSI    EST                     PSIX10E6
     MSU-1              COBBLES, PEBBLES,
                        PREDOMINATELY LIMESTONE            171      11      65     NA      36       7.20     0.25
                        MATRIX, W/CHERT, SCHIST,                                                    NOTE     NOTE
                        DIBASE FRAGMENTS                                                             2        2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
  WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200     NO200

   104      5.6       0            17.0  12.0  24.0  18.0  16.0   4.0    3.0    2.0    1.0    1.0    0.0                 2.0


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID

                                 A     A     A     A      A      A      A      A      A      A


    POT VOL CHANGE         *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE      LIQUID         PLASTIC        SHRINKAGE        PLASTICITY        FLOW          TOUGHNESS
                           LIMITS         LIMIT          LIMIT            INDEX             INDEX         INDEX
                           PCT            PCT            PCT              PCT

    0                      13.80          12.77          10.78            1.03              3.20          0.32


  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)12.0      IN............................*      SIZE(-)12.0   IN.
    SPECIF          ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT        BULK             ANGLE INTER
    GRAVITY         1 IN DROP        10 IN DROP       STEEL PLATE      COHESION        DENSITY          FRICTION
                    DEGREES AT       DEGREES AT       DEGREES AT       PSF AT          PCF AT           DEGREES AT
                   0.4  PCT MOIST   0.4  PCT MOIST   0.4  PCT MOIST   0.3  PCT MOIST 0.0  PCT MOIST    0.3  PCT MOIST


    2.74            35               29               27               410             111              46


                                                                       MSU-1          CURRENT:   04/01/73
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KEY

 31A
TUNNEL DATA


TUNNEL                          VENTILATION                          WATER INFLOW    UTILITY LINES           POWER SYSTEM

SIZE    SHAPE    GRADE    CFM   PRESS EXHST  SIZE   HP           GPM             AIR  WATER  PUMP          PRIMARY  SECONDARY
9 FT    RECT     0.0      10K   X            24 IN  50           NONE            6 IN 2 IN                      4168      480
10 FT

HAULAGE SYSTEM                                       SUPPORT SYSTEM

MUCK              PERSONNEL        SUPPLY      BOLT.TYPE SIZE   ROOF PLATE       SET.SIZE.SHAPE        SHOTCRETE
RAIL              RAIL             RAIL        6 FT X 5/8 IN     3FT-4FT-5FT
44CF ROCKERCARS                                21 BOLTS/5 FT     6 PLATES/5FT
4-6T MOTORS                                    SPAN              SPAN
30 LB RAIL
18 IN GAGE


MACHINE FXCAVATION


MACHINE                      CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES            RPM          TORQUE.MAX/OPERATE        THRUST.MAX/OPERATE

  MAKE      MODEL      WT    CENTER          INTERIOR          GAGE           HEAD.CENTER  HEAD           CENTER

                                                                                         KFTLB          KFTLB              KLB
                                                                                         KFTLB          KFTLB              KLB


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT   KERF SPACING  ADVANCE PER
                                                                            FEET         HOUR.FT.
 KLB                                                      KLB


CONVENTIONAL EXCAVATION

MACHINE                   ROUND.                    EXPLOSIVES.                         BLASTING        MUCKING        GUIDANCE
JUMBO  3 BOOM             NO. HOLES 42-50           POWDER FACTOR 8.2 LB/CY             ELECTRICAL      EIMCO          LASER
MACHINES 3IN DIA          DEPTH 5.5 FT              TOTAL LBS 150                       IGNITER CORD    21
        DRIFTER           DIAM. 1 3/8 IN            PRIMERS. 25 LB AMOGEL NO. 4         NO. 6 CAPS.FUSE
                          CUT.  V                   TRIM CARBAMITE
FEED LENGTH 7FT                                     INTERIOR CARBAMITE
                          SF/HOLE 2.0               CUT CARBAMITE
                                                    LIFTERS CARBAMITE

        BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
        *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED.
                                                                                MSU-1      CURRENT: 04/01/73
                                                                                MDN 3
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KEY  IDENTIFICATION      ROCK PROPERTIES
 32   MSU                SEDIMENTARY: CONGLOMERATE             DRY       COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                         1/4 - 10 IN ROUNDED TO ANGULAR        WT        STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO           BOULDERS, COBBLES, PEBBLES            PCF       KPSI                               PSIX10E6
     MSU-2               IN PREDOMINATELY LIMESTONE
                         MATRIX, W/CHERT, SCHIST               169         25       80      NA       45      8.70     0.22
                         DIAMASE FRAGMENTS WELL
                         TO MODERATELY CONSOLODATED

   NOTES:
   1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
   4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


   MUCK DATA
    DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS......................................*  PCT (-)
    WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  N04    N08    N016   N030   N050   N0100   N0200          N0200

     107      1.9       19.1        28.9  17.2  16.0  10.4    5.1    1.5    0.7    0.7    0      0       0                  0.7



      SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                           A             A     A     A     A      A      A      A      A      A      A



      POT VOL CHANGE            *....................ATTERBERG LIMITS..SIZE(-) 0.056IN................................*
      (-)0.056  IN.SIZE         LIQUID          PLASTIC        SHRINKAGE        PLASTICITY         FLOW         TOUGHNESS
                                LIMITS          LIMIT          LIMIT            INDEX              INDEX        INDEX
                                PCT             PCT            PCT              PCT

      0                         20.00            13.99          10.67           6.01                4.50         1.40


     (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN..............................*        SIZE(-)2.0   IN.
      SPECIF         ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT          BULK             ANGLE INTER
      GRAVITY        1 IN DROP          10 IN DROP         STEEL PLATE        COHESION          DENSITY          FRICTION
                     DEGREES AT         DEGREES AT         DEGREES AT         PSF AT            PCF AT           DEGREES AT
                     0.83 PCT MOIST     0.83 PCT MOIST     0.83 PCT MOIST     0.83 PCT MOIST    0.0 PCT MOIST    0.83 PCT MOIST


       2.65            34.2               29.75              33.75                 790             96.15            43.45



                                                                               MSU-2          CURRENT:   04/01/73
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KEY

 32A
TUNNEL DATA

TUNNEL                       VENTILATION                        WATER INFLOW     UTILITY LINES            POWER SYSTEM

SIZE     SHAPE      GRADE    CFM    PRESS EXHST  SIZE    HP     GPM              AIR  WATER  PUMP         PRIMARY  SECONDARY
9FT X    RECT       0.0      9K     X            24 IN   50     NONE             6 IN 2 IN                 4160       480
 10FT

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK               PERSONNEL         SUPPLY      BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE        SHOTCRETE
RAIL               RAIL              RAIL        6 FT X 5/8 IN   3.4 1/2. 6 FT
44CF ROCKER                                      21 BOLTS/5 FT   7 PLATES 1
DUMP 4-6T MOTOR                                  SPAN            SPAN
30LB RAIL
18 IN GAGE


MACHINE EXCAVATION

MACHINE                      CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES          RPM          TORQUE.MAX/OPERATE        THRUST.MAX/OPERATE

  MAKE      MODEL       WT   CENTER          INTERIOR         GAGE         HEAD.CENTER  HEAD          CENTER
                                                                                        KFTLB         KFTLB           KLB
                                                                                        KFTLB         KFTLB           KLB


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT  KERF SPACING  ADVANCE PER
                                                                            FEET        HOUR.FT.
 KLB                                                      KLB



CONVENTIONAL EXCAVATION

MACHINE                  ROUND.                    EXPLOSIVES.                         BLASTING         MUCKING         GUIDANCE
JUMBO  2 BOOM            NO. HOLES 50              POWDER FACTOR 6.7                   ELECTRICAL       EIMCO           LASER
MACHINES 3IN DIA         DEPTH 5.5 FT              TOTAL LBS 122                       IGNITER CORD     21
         DRIFTER         DIAM. 1 3/8 IN            PRIMERS. AMOGEL                     FUSE NO. 6 CAPS
                         CUT.  V                   TRIM
FEED LENGTH 6FT                                    INTERIOR AMOGEL OR CARBAMITE
                         SF/HOLE 1.8               CUT
                                                   LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (3) BELT CONV. (1) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (1) EXCESSIVE WIDTH. WEAR. DAMAGE.      MSU-2      CURRENT: 04/01/73
            (3) EXCESSIVE TIRE WEAR PROBABLE.                                                 MDN 2
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KEY  IDENTIFICATION        ROCK PROPERTIES
 33   LAWRENCE             SEDIMENTARY: LIMESTONE LIGHT        DRY      COMP     RQD   ....HARDNESS...   YOUNGS     POISSON
                           TO MEDIUM GRAY FINE GRAINED.        WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.       RATIO
     SAMPLE NO             SOME CHERT NODULES. TRACES TO       PCF      KPSI     EST                     PSIX10E6
     LAW-2                 OCCASIONAL CLAY PARTINGS
                                                               161        29     100     46       42       8.70      0.41

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
   WT  PCF   PCT      IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100    NO200     NO200

    92       7.2      0.0            0.0   3.0   25.0  18.0    22.1   9.4     6.5    3.5     2.0     1.8      0.8              7.9


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                                      PAI   PI    PI      PI     I      I      AI     A      I


    POT VOL CHANGE          *..................ATTERBERG LIMITS..SIZE(-) 0.185IN..............................*
    (-)0.065  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE      PLASTICITY          FLOW        TOUGHNESS
                            LIMITS        LIMIT         LIMIT          INDEX               INDEX       INDEX
                            PCT           PCT           PCT            PCT

    0                       12.5          12.3          9.6            0.2                 4.0         0.05


   (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0      IN.............................*      SIZE(-)2.0   IN.
    SPECIF          ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT        BULK               ANGLE INTER
    GRAVITY         1 IN DROP          10 IN DROP        STEEL PLATE       COHESION        DENSITY            FRICTION
                    DEGREES AT         DEGREES AT        DEGREES AT        PSF AT          PCF AT             DEGREES AT
                    5.4 PCT MOIST      5.4 PCT MOIST     5.4 PCT MOIST       7 PCT MOIST   0.0 PCT MOIST        7 PCT MOIST


    2.83              39                 38                31                  0                83.97          30



                                                                            LAW-2           CURRENT:   04/01/73
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KEY

 33A
TUNNEL DATA

TUNNEL                       VENTILATION                         WATER INFLOW    UTILITY LINES             POWER SYSTEM

SIZE    SHAPE     GRADE     CFM    PRESS EXHST  SIZE    HP       GPM             AIR  WATER  PUMP          PRIMARY  SECONDARY
13FT    ROUND     +0.25PCT  21K             X   28IN             40-12           6IN  21N    6IN            4160V      480V
 8IN

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK              PERSONNEL        SUPPLY       BOLT,TYPE SIZE  ROOF PLATE       SET,SIZE,SHAPE            SHOTCRETE
RAIL              RAIL             RAIL         NONE



MACHINE EXCAVATION

MACHINE                      CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL     WT      CENTER           INTERIOR         GAGE              HEAD,CENTER  HEAD         CENTER
  ALKIRK   HARDROCK  400     1 LAWRENCE TCB   11 LAWRENCE TCB  5 LAWRENCE TCB     9    30
                     TONS    24IN TRICONE     15IN DISC,       15IN ROLLER                    KFTLB        KFTLB              KLB
                                              11-TCB 15IN                                     KFTLB206     KFTLB              KLB 614


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS FROM    ELECTRO-       LASER                       FEET         HOUR,FT.
 KLB           FACE, 24IN      HYDRAULIC                KLB 4.28          0.20           7.7
               CONVEYOR TO     600HP HEAD
               REAR            150 CENTER


CONVENTIONAL EXCAVATION

MACHINE                ROUND,                 EXPLOSIVES,                           BLASTING     MUCKING      GUIDANCE
JUMBO                  NO. HOLES              POWDER FACTOR
MACHINES               DEPTH                  TOTAL LBS
                       DIAM.                  PRIMERS,
                       CUT.                   TRIM
FEED LENGTH                                   INTERIOR
                                              CUT
                                              LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED.                          LAW-2      CURRENT: 04/01/73
                                                                             MDN 4
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KEY  IDENTIFICATION     ROCK PROPERTIES
 34   LAWRENCE          SEDIMENTARY: LIMESTONE LIGHT          DRY      COMP     RQD   ....HARDNESS...   YOUNGS    POISSON
                        TO MEDIUM GRAY. FINE GRAINED.         WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.      RATIO
     SAMPLE NO          SOME CHERT NODULES. TRACES TO         PCF      KPSI     EST                     PSIX10E6
     LAW-3              OCCASIONAL CLAY PARTINGS.                        3
                                                             161        29      100    46       42       8.70     0.41
                                                                                                         NOTE     NOTE
                                                                                                          4        4

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS..................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200    NO200

    93       5.5       0.0          0.0   4.3   25.9  19.6   20.2   7.4    5.0    3.5    1.8    1.3    1.1               9.9


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID

                                             PAI   PAI   PI     PAI    I      I      I      I      I


    POT VOL CHANGE        *......................ATTERBERG LIMITS..SIZE(-) 0.185IN..................................*
    (-)0.065  IN.SIZE     LIQUID        PLASTIC        SHRINKAGE      PLASTICITY       FLOW        TOUGHNESS
                          LIMITS        LIMIT          LIMIT          INDEX            INDEX       INDEX
                          PCT           PCT            PCT            PCT

    0.                    11.8          10.6           10.0           1.2              2.9         0.41


  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*       SIZE(-)2.0   IN.
    SPECIF         ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT        BULK              ANGLE INTER
    GRAVITY        1 IN DROP         10 IN DROP        STEEL PLATE       COHESION        DENSITY           FRICTION
                   DEGREES AT        DEGREES AT        DEGREES AT        PSF AT          PCF AT            DEGREES AT
                   6.1 PCT MOIST     6.1 PCT MOIST     8.4 PCT MOIST       7 PCT MOIST   0.0 PCT MOIST       7 PCT MOIST

    2.80           41                40                38                0               84.04             32


                                                                          LAW-3          CURRENT:   04/01/73
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KEY

 34A
TUNNEL DATA


TUNNEL                        VENTILATION                             WATER INFLOW     UTILITY LINES           POWER SYSTEM

SIZE     SHAPE     GRADE      CFM    PRESS EXHST  SIZE    HP          GPM              AIR   WATER  PUMP       PRIMARY   SECONDARY
13FT     ROUND     +0.25PCT   20K            X    28IN                40-120           6IN   2IN    6IN         4160V      480V
 8IN

HAULAGE SYSTEM                                    SUPPORT SYSTEM

MUCK              PERSONNEL       SUPPLY          BOLT,TYPE SIZE   ROOF PLATE          SET,SIZE,SHAPE        SHOTCRETE
RAIL              RAIL            RAIL            NONE




MACHINE EXCAVATION


MACHINE                       CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                 RPM           TORQUE,MAX/OPERATE          THRUST,MAX/OPERATE

  MAKE      MODEL      WT     CENTER               INTERIOR            GAGE              HEAD,CENTER   HEAD              CENTER
  LKIRK     HARDROCK   400    1 LAWRENCE TCB       11 LAWRENCE TCB     5 LAWRENCE TCB      9    30
                       TONS   24IN TRICONE         15IN DISC, 11       15IN ROLLER                     KFTLB        KFTLB                   KLB
                                                   TCB 15IN ROLLER                                     KFTLB206     KFTLB                   KLB 514


 ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                BUCKETS FROM     ELECTRO-         LASER                         FEET          HOUR,FT.
 KLB            FACE, 24IN       HYDRAULIC                   KLB 4.28           0.20            7.7
                CONVEYOR TO      600HP HEAD
                REAR             150 CENTER


CONVENTIONAL EXCAVATION


MACHINE                    ROUND,                    EXPLOSIVES,                              BLASTING      MUCKING       GUIDANCE
JUMBO                      NO. HOLES                 POWDER FACTOR
MACHINES                   DEPTH                     TOTAL LBS
                           DIAM.                     PRIMERS,
                           CUT.                      TRIM
FEED LENGTH                                          INTERIOR
                                                     CUT
                                                     LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED.                                            LAW-3      CURRENT: 04/01/73
                                                                                                 MDN 4
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KEY  IDENTIFICATION      ROCK PROPERTIES
 35   LAWRENCE           SEDIMENTARY: LIMESTONE LIGHT           DRY        COMP       RQD    ....HARDNESS...    YOUNGS    POISSON
                         TO MEDIUM GRAY FINE GRAINED.           WT         STRNTH     PCT    SHORE    SCHMIDT   MOD.      RATIO
     SAMPLE NO           SOME CHERT NODULES. TRACES TO          PCF        KPSI       EST                       PSIX10E6
     LAW-4               OCCASIONAL CLAY PARTINGS.
                                                                157         20        100     46        52       4.61      0.50
                                                                                                       NOTE
                                                                                                        2

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6    *.................PER CENT BY WEIGHT BETWEEN SCREENS.................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200       NO200

    80       7.9       0.0           0.0   5.0   18.3  18.3   17.0   7.3    5.1    3.4    5.5    3.8     2.0              14.3


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                            PI    PI    PI     PI     PI     PI     PA     PA     A


     POT VOL CHANGE       *...................ATTERBERG LIMITS..SIZE(-) 0.056IN................................*
     (-)0.056  IN.SIZE    LIQUID       PLASTIC       SHRINKAGE     PLASTICITY       FLOW        TOUGHNESS
                          LIMITS       LIMIT         LIMIT         INDEX            INDEX       INDEX
                          PCT          PCT           PCT           PCT

     0                    20.2         20.0          13.5          0.2              4.7         0.05


    (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0     IN............................*       SIZE(-)2.0   IN.
     SPECIF      ANGLE/REPOSE      ANGLE/REPOSE     ANGLE/SLIDE      APPARENT       BULK             ANGLE INTER
     GRAVITY     1 IN DROP         10 IN DROP       STEEL PLATE      COHESION       DENSITY          FRICTION
                 DEGREES AT        DEGREES AT       DEGREES AT       PSF AT         PCF AT           DEGREES AT
                 8.9 PCT MOIST     8.9 PCT MOIST    8.9 PCT MOIST    8.8 PCT MOIST  0.0 PCT MOIST    8.8 PCT MOIST

     2.73         42                34                37               210            84.57          28


                                                                     LAW-4         CURRENT:   04/01/73
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KEY

 35A
TUNNEL DATA

TUNNEL                       VENTILATION                        WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE     SHAPE      GRADE    CFM   PRESS EXHST   SIZE   HP      GPM              AIR  WATER  PUMP           PRIMARY   SECONDARY
13FT     ROUND      +0.25PCT 21K             X   29IN           40-120           6IN  2IN    6IN             4160V      480V
 8IN

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK             PERSONNEL         SUPPLY        BOLT.TYPE SIZE  ROOF PLATE       SET.SIZE.SHAPE          SHOTCRETE
RAIL             RAIL              RAIL          NONE




MACHINE EXCAVATION


MACHINE                      CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES                   RPM          TORQUE.MAX/OPERATE         THRUST.MAX/OPERATE

  MAKE      MODEL      WT    CENTER             INTERIOR           GAGE             HEAD.CENTER  HEAD            CENTER
  ALKIRK    HARDROCK   400   1 LAWRENCE TCB     11 LAWRENCE TCB    5 LAWRENCE         9    30
                       TONS  24IN TRICONE       15IN DISC. 11      15IN ROLLER                   KFTLB           KFTLB                 KLB
                                                TCB 15IN ROLLER                                  KFTLB206        KFTLB                 KLB 540



 ANCHOR PRESS  MUCK SYSTEM       POWER SYSTEM      GUIDANCE   THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS FROM      ELECTRO-          LASER                        FEET        HOUR.FT.
 KLB           FACE. 24IN        HYDRAULIC                    KLB 3.76          0.20          6.3
               CONVEYOR TO       600HP
               REAR              150 HEAD



CONVENTIONAL EXCAVATION


MACHINE                    ROUND.                    EXPLOSIVES.                        BLASTING        MUCKING         GUIDANCE
JUMBO                      NO. HOLES                 POWDER FACTOR
MACHINES                   DEPTH                     TOTAL LBS
                           DIAM.                     PRIMERS.
                           CUT.                      TRIM
FEED LENGTH                                          INTERIOR
                                                     CUT
                                                     LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
            *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.        LAW-4      CURRENT: 04/01/73
                                                                                                  MDN 4
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KEY  IDENTIFICATION      ROCK PROPERTIES
 36   MILWAUKEE          SEDIMENTARY: LIMESTONE, GRAY          DRY      COMP      RQD   ....HARDNESS...    YOUNGS    POISSON
                         FINE GRAINED, HORIZONTAL              WT       STRNTH    PCT   SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO           JOINT SPACING 6 IN. TO 1 FOOT.        PCF      KPSI      EST                      PSIX10E6
     MIL-1

                                                               166      36        85    NA       59        10.00      0.30
                                                                                                 NOTE      NOTE       NOTE
                                                                                                  2         2          2

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS..................................*   PCT (-)
  WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200       NO200

    89      5.5       0.0          0.0   0.0   14.5  28.0   24.0   8.2    6.2    4.8    4.2    2.0    0.5                7.6


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID

                                               PE    PI     PI     PI     PA     S      S    S


   POT VOL CHANGE        *....................ATTERBERG LIMITS..SIZE(-) 0.056IN..............................*
   (-)0.056  IN.SIZE     LIQUID        PLASTIC      SHRINKAGE     PLASTICITY    FLOW        TOUGHNESS
                         LIMITS        LIMIT        LIMIT         INDEX         INDEX       INDEX
                         PCT           PCT          PCT           PCT

   0                     16.90         15.69        15.46         1.21          5.00        0.24

  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN...........................*        SIZE(-)2.0   IN.
   SPECIF        ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT       BULK               ANGLE INTER
   GRAVITY       1 IN DROP        10 IN DROP       STEEL PLATE      COHESION       DENSITY            FRICTION
                 DEGREES AT       DEGREES AT       DEGREES AT       PSF AT         PCF AT             DEGREES AT
                2.5  PCT MOIST   2.5  PCT MOIST   2.5  PCT MOIST   4.1  PCT MOIST 0.0  PCT MOIST     3.5  PCT MOIST

   2.89          36               35               30               95             86                 35


                                                                    MIL-1        CURRENT:   04/01/73
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KEY

 36A
TUNNEL DATA


TUNNEL                         VENTILATION                             WATER INFLOW    UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE     CFM    PRESS EXHST  SIZE   HP          GPM             AIR   WATER  PUMP          PRIMARY   SECONDARY
11FT      ROUND      +6.2PCT   4K              X   19IN   25          5.              6IN   1IN    6IN             4680V      440V
 2IN

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK               PERSONNEL         SUPPLY        BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE           SHOTCRETE
RAIL, 24IN GAGE    RAIL              RAIL                          OCCASIONAL      4IN H RING SETS IN
5TON MOTORS                                                        PINNED STEEL    FAULT ZONES
                                                                   LAGGING



MACHINF EXC*VATION


MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                    RPM           TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE      MODEL      WT      CENTER           INTERIOR          GAGE                 HEAD,CENTER   HEAD           CENTER
  JARVA     11-1100    65      1 REED STEEL     22 REED STEEL     4 REED STEEL         9.3  INTEG
                       TONS    CONE, 5 DISC     TRIPLE DISC       TRIPLE DISC                        KFTLB 170    KFTLB                 KLB 1104
                                                                                                     KFTLB        KFTLB                 KLB  596


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
               BUCKET FROM     6-50HP MOTORS   LASER                         FEET          HOUR,FT.
 KLB 1650      FACE, 18IN      FOR HEAD                   KLB 6.09           0.16            5.0
               CONVEYOR TO     1-40HP MOTOR
               REAR            HYDRAULIC


CONVENTIONAL EXCAVATION

MACHINE                  ROUND,                        EXPLOSIVES,                        BLASTING       MUCKING        GUIDANCE
JUMBO                    NO. HOLES                     POWDER FACTOR
MACHINES                 DEPTH                         TOTAL LBS
                         DIAM.                         PRIMERS,
                         CUT.                          TRIM
FEED LENGTH                                            INTERIOR
                                                       CUT
                                                       LIFTERS

        BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
        *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED.                                          MIL-1       CURRENT: 04/01/73
                                                                                           MDN 5
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KEY  IDENTIFICATION        ROCK PROPERTIES
 37   MILWAUKEE            SEDIMENTARY: LIMESTONE, GRAY,                DRY        COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                           FINE GRAINED, HORIZONTAL JOINT               WT         STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO             SPACING 6 IN. TO 1 FOOT.                     PCF        KPSI      EST                      PSIX10E6
     MIL-2
                                                                        166         36        85     NA       59      10.00     0.30
                                                                                                                     NOTE     NOTE      NOTE
                                                                                                                      2        2         2

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *...............PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
  WT  PCF  PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200    NO200

   89      6.1       0.0           0.0   0.0   9.2   24.7  22.8   11.5   6.8    4.9    2.7    1.2    7.6              8.6


   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                                  PE    PI     PI     PI     PR     S      S      S


   POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
   (-)0.056  IN.SIZE       LIQUID        PLASTIC       SHRINKAGE      PLASTICITY      FLOW          TOUGHNESS
                           LIMITS        LIMIT         LIMIT          INDEX           INDEX         INDEX
                           PCT           PCT           PCT            PCT

     0                     20.10         16.68         16.37          3.42            6.10          0.56


  (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN............................*      SIZE(-)2.0    IN.
   SPECIF         ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT       BULK              ANGLE INTER
   GRAVITY        1 IN DROP          10 IN DROP         STEEL PLATE        COHESION       DENSITY           FRICTION
                  DEGREES AT         DEGREES AT         DEGREES AT         PSF AT         PCF AT            DEGREES AT
                 5.8  PCT MOIST     5.8  PCT MOIST     5.8  PCT MOIST     5.0  PCT MOIST 0.0  PCT MOIST    5.0  PCT MOIST

   2.93           32                 30                 30                 110            90                33


                                                                           MIL-2         CURRENT:   04/01/73
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KEY

 37A
TUNNEL DATA

TUNNEL                          VENTILATION                                WATER INFLOW     UTILITY LINES                POWER SYSTEM

SIZE      SHAPE      GRADE      CFM     PRESS EXHST   SIZE    HP        GPM              AIR   WATER  PUMP             PRIMARY   SECONDARY
11FT      ROUND      +0.25PCT 4K                X     18IN    25         10              6IN   1IN    6IN               4680V      440V
 2IN

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK                PERSONNEL         SUPPLY       BOLT,TYPE SIZE  ROOF PLATE        SET,SIZE,SHAPE          SHOTCRETE
RAIL, 24IN GAGE     RAIL              RAIL                         OCCASIONAL        4IN H RING SETS IN
5TON MOTORS                                                        PINNED STEEL      FAULT ZONES
                                                                   LAGGING



MACHINE EXCAVATION


MACHINE                          CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                 RPM             TORQUE,MAX/OPERATE        THRUST,MAX/OPERATE

  MAKE      MODEL        WT      CENTER              INTERIOR            GAGE                HEAD,CENTER     HEAD              CENTER
  JARVA     11-1100      65      1 REED STEEL        22 REED STEEL       4 REED STEEL        9.3  INTEG
                         TONS    CONE, 5 DISC        TRIPLE DISC         TRIPLE DISC                         KFTLB 170    KFTLB                      KLB 1104
                                                                                                             KFTLB        KFTLB                      KLB  596


 ANCHOR PRESS  MUCK SYSTEM       POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
               BUCKET FROM       6-50HP MOTORS    LASER                         FEET         HOUR,FT.
 KLB 1650      FACE, 18IN        FOR HEAD.                   KLB 6.09           0.18            4.5
               CONVEYOR TO       1-40HP MOTOR
               REAR              HYDRAULICS


CONVENTIONAL EXCAVATION


MACHINE                  ROUND,                      EXPLOSIVES,                          BLASTING        MUCKING         GUIDANCE
JUMBO                    NO. HOLES                   POWDER FACTOR
MACHINES                 DEPTH                       TOTAL LBS
                         DIAM.                       PRIMERS,
                         CUT.                        TRIM
FEED LENGTH                                          INTERIOR
                                                     CUT
                                                     LIFTERS

         BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
         NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
         TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
         FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
         *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.          MIL-2      CURRENT: 04/01/73
                                                                                                   MDN 5
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KEY  IDENTIFICATION       ROCK PROPERTIES
 38   MILWAUKEE           SEDIMENTARY: LIMESTONE                      DRY      COMP      RQD   ....HARDNESS...   YO''NGS   POISSON
                          FINE GRAINED, GREY                          WT       STRNTH    PCT   SHORE   SCHMIDT   MC .      RATIO
     SAMPLE NO                                                        PCF      KPSI                            PSIX10E6
     MIL-3
                                                                      164        22      81      NA      40      7.84      0.46

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUN VALUE.  6. FROM CSM A.R.H0210043-72.


  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *...................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200      NO200

     79      5.1       0           0     0    25.4  32.7   17.4   4.3     3.1     2.0     1.2     0.6     0.5                12.8



    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                                PE    PI     PI     PI     PA     S      S      S


    POT VOL CHANGE          *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN.....................................*
    (-)0.056  IN.SIZE        LIQUID         PLASTIC        SHRINKAGE      PLASTICITY          FLOW         TOUGHNESS
                             LIMITS         LIMIT          LIMIT          INDEX               INDEX        INDEX
                             PCT            PCT            PCT            PCT

    0                        15.20          14.40          12.96          0.80                3.50         0.22


  (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)2.0      IN..................................*      SIZE(-)2.0   IN.
   SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT       BULK              ANGLE INTER
   GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION       DENSITY           FRICTION
                   DEGREES AT         DEGREES AT         DEGREES AT         PSF AT         PCF AT            DEGREES AT
                  2.5  PCT MOIST     2.5  PCT MOIST     2.5  PCT MOIST     2.3  PCT MOIST 0.0  PCT MOIST     2.3  PCT MOIST


   2[illegible]             36                 32                 32                 60             95                36



                                                                          MIL-3          CURRENT:    04/01/73
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KEY

 38A
TUNNEL DATA


TUNNEL                          VENTILATION                            WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST  SIZE   HP          GPM              AIR  WATER  PUMP           PRIMARY  SECONDARY
11FT      ROUND      +0.2PCT    4            X      18IN  25           MINOR            6IN 1IN 6I  N               4680      440
2 IN

HAULAGE SYSTEM                                      SUPPORT SYSTEM

MUCK                PERSONNEL            SUPPLY     BOLT.TYPE SIZE  ROOF PLATE       SET.SIZE.SHAPE           SHOTCRETE
RAIL                RAIL                 RAIL       NONE
24IN GAGE
5T MOTOR



MACHINE EXCAVATION


MACHINE                         CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES              RPM          TORQUE.MAX/OPERATE        THRUST.MAX/OPERATE

  MAKE      MODEL       WT      CENTER             INTERIOR         GAGE          HEAD.CENTER  HEAD          CENTER
JARVA       11-1100     65      1 REED             22 REED          4 REED          9.3
                                OK-1               2K3              OK-5                       KFTLB         KFTLB                 KLB
                                                                                               KFTLB119      KFTLB                 KLB 639


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS         6-50HP MOTORS   LASER                       FEET        HOUR.FT.
 KLB           TO BELT         DRIVE HEAD                KLB 6.52          0.16           4.7



CONVENTIONAL EXCAVATION


MACHINE                 ROUND.                  EXPLOSIVES.                           BLASTING      MUCKING      GUIDANCE
JUMBO                   NO. HOLES               POWDER FACTOR
MACHINES                DEPTH                   TOTAL LBS
                        DIAM.                   PRIMERS.
                        CUT.                    TRIM
FEED LENGTH                                     INTERIOR
                                                CUT
                                                LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.              4IL-3      CURRENT: 04/01/73
                                                                                                       MDN 5
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KEY  IDENTIFICATION       ROCK PROPERTIES
 39  MT GREEN             SEDIMENTARY: LIMESTONE                 DRY       COMP      RQD   ....HARDNESS...    YOUNGS    POISSON
                          FINE GRAINED, LIGHT                    WT        STRNTH    PCT   SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO            GREY                                   PCF       KPSI                               PSIX10E6
     EVG-1
                                                                 168         26      100     NA       44      10.63     0.50

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS..................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100  NO200   NO200

    94       3.8       0            0    3.2   26.6  22.1   21.5   4.3    3.7    3.3    2.0    2.2    2.4             8.7


     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                                              P     P     P      P      P      PA     A      A      A


     POT VOL CHANGE         *....................ATTERBERG LIMITS..SIZE(-) 0.056IN.....................................*
     (-)0.056  IN.SIZE       LIQUID       PLASTIC       SHRINKAGE      PLASTICITY       FLOW        TOUGHNESS
                             LIMITS       LIMIT         LIMIT          INDEX            INDEX       INDEX
                             PCT          PCT           PCT            PCT

     0                       15.10        13.69         11.57          1.41             3.0         0.47


    (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0     IN.............................*     SIZE(-)2.0   IN.
     SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT         BULK           ANGLE INTER
     GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION         DENSITY        FRICTION
                     DEGREES AT         DEGREES AT         DEGREES AT         PSF AT           PCF AT         DEGREES AT
                    3.1  PCT MOIST     3.1  PCT MOIST     3.1  PCT MOIST     3.0  PCT MOIST 0.0  PCT MOIST   3.0  PCT MOIST


     2.81            37                 31                 31                 70               104            42


                                                                              EVG-1          CURRENT:   04/01/73
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KEY

 39A
TUNNEL DATA


TUNNEL                         VENTILATION                        WATER INFLOW   UTILITY LINES          POWER SYSTEM

SIZE   SHAPE    GRADE    CFM   PRESS EXHST  SIZE  HP          GPM            AIR  WATER  PUMP       PRIMARY  SECONDARY
10FT   ROUND    +0.2PCT  18          X      30IN  90          400                  3 IN               7200      480
4 IN

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK           PERSONNEL      SUPPLY      BOLT,TYPE SIZE  ROOF PLATE    SET,SIZE,SHAPE       SHOTCRETE
RAIL           RAIL           RAIL        NONE
4CY CARS
5T MOTOR
24IN GAGE
54 LB RAIL


MACHINE EXCAVATION


MACHINE                   CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES            RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL     WT   CENTER          INTERIOR         GAGE             HEAD,CENTER  HEAD         CENTER
ROBBINS   105-144    75   3 ROBBINS       2 ROBBINS        6 ROBBINS          6
                   TONS   11 IN DIA       12 IN DIA        12 IN DIA                     KFTLB       KFTLB           KLB
                          DISC            DISC             DISC                          KFTLB230    KFTLB           KLB 230


 ANCHOR PRESS  MUCK SYSTEM   POWER SYSTEM   GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET        4-100 HP       LASER                       FEET        HOUR,FT.
 KLB           TO BELT       MOTURS DRIVE             KLB   2.74        0.24          9.2
                             HEAD


CONVENTIONAL EXCAVATION


MACHINE              ROUND,                 EXPLOSIVES,                        BLASTING     MUCKING      GUIDANCE
JUMBO                NO. HOLES              POWDER FACTOR
MACHINES             DEPTH                  TOTAL LBS
                     DIAM.                  PRIMERS,
                     CUT.                   TRIM
FEED LENGTH                                 INTERIOR
                                            CUT
                                            LIFTERS

        BASIS FOR MON IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
        *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED.
                                                                              EVG-1        CURRENT: 04/01/73
                                                                              MON 4
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KEY  IDENTIFICATION      ROCK PROPERTIES
 40   MT GREEN           SEDIMENTARY: LIMESTONE                      DRY      COMP    RQD   ....HARDNESS...   YOUNGS   POISSON
                         FINE GRAINED, LIGHT                         WT       STRNTH  PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO           GREY                                        PCF      KPSI                            PSIX10E6
     EVG-2
                                                                     170       30     100    NA       45      10.82     0.30

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210843-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200      NO200

    94       2.5       0.0         0.0   2.2   24.4  26.7   17.8   4.8    3.0    3.0    2.3    3.4    2.9                9.5



    SHAPE OF FRAC,IONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                       PA    PA    PI     PA     PA     P      A      A      A


    POT VOL CHANGE          *...................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE        LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW       TOUGHNESS
                             LIMITS        LIMIT         LIMIT          INDEX            INDEX      INDEX
                             PCT           PCT           PCT            PCT

    0                        15.50         12.80         12.06          2.70             2.70       1.00


   (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN............................*        SIZE(-)2.0    IN.
    SPECIF          ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT        BULK              ANGLE INTER
    GRAVITY          1 IN DROP         10 IN DROP        STEEL PLATE       COHESION        DENSITY           FRICTION
                    DEGREES AT        DEGREES AT        DEGREES AT        PSF AT          PCF AT            DEGREES AT
                   3.15 PCT MOIST    3.15 PCT MOIST    3.15 PCT MOIST    3.15 PCT MOIST  3.15 PCT MOIST    3.15 PCT MOIST


    2.473           40.1              34.4              31.92              470             97.78             36.1



                                                                             EVG-2         CURRENT:   04/01/73
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```
KEY

 40A
TUNNEL DATA


TUNNEL                    VENTILATION                         WATER INFLOW    UTILITY LINES          POWER SYSTEM

SIZE     SHAPE     GRADE     CFM   PRESS EXHST  SIZE   HP     GPM             AIR  WATER  PUMP       PRIMARY  SECONDARY
10 FT    ROUND     +0.2PCT   18          X      30 IN 90      400                   3IN                7200      480
 4 IN

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK            PERSONNEL        SUPPLY         BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE       SHOTCRETE
RAIL            RAIL             RAIL           NONE
4CY CARS
5T MOTOR
24 IN GAGE
54 LB RAIL



MACHINE EXCAVATION


MACHINE                   CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES           RPM          TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE      MODEL      WT  CENTER        INTERIOR       GAGE             HEAD.CENTER  HEAD        CENTER
ROBBINS     105-144    75  3 ROBBINS     21 ROBBINS     2 ROBBINS         6
                     TONS  11 IN DIA     12 IN DIA      12 IN DIA                     KFTLB       KFTLB               KLB
                           DISC          DISC           DISC                          KFTLB246    KFTLB               KLB 267


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKET          4-100 HP        LASER                       FEET        HOUR.FT.
 KLB           TO BELT         MOTORS DRIVE              KLB 3.18          0.24          11.5
                               HEAD



CONVENTIONAL EXCAVATION


MACHINE               ROUND.                   EXPLOSIVES.                    BLASTING      MUCKING       GUIDANCE
JUMBO                 NO. HOLES                POWDER FACTOR
MACHINES              DEPTH                    TOTAL LBS
                      DIAM.                    PRIMERS.
                      CUT.                     TRIM
FEED LENGTH                                    INTERIOR
                                               CUT
                                               LIFTERS

         BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
         NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
         TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
         FREE VEHICLES YES BELT CONV. YES HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
         *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED.                                          EVO-2      CURRENT: 04/01/73
                                                                                            MDN 4
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KEY  IDENTIFICATION       ROCK PROPERTIES                DRY     COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
 41   LAYOUT              SEDIMENTARY: SANDSTONE MEDIUM  WT      STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
                          GRAINED. LIGHT BROWN TO RED.   PCF     KPSI     EST                     PSIX10E6
     SAMPLE NO            MASSIVE. POROUS. POORLY
     LAY-1                CEMENTED.
                                                         150     10       84    NA      18        1.80     0.10
                                                                                                  NOTE     NOTE
                                                                                                   2        2

NOTES:
1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6    *...............PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
 WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200       NO200

  105      4.1       0.0             7.6   7.5   5.7   12.0    12.6   4.6    3.4    2.7    1.8    15.4   1.0            25.7

   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                     PI    PI    PI    PI      A      A      A      A      A      A

   POT VOL CHANGE          *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN...........................*
   (-)0.056  IN.SIZE       LIQUID       PLASTIC      SHRINKAGE     PLASTICITY      FLOW        TOUGHNESS
                           LIMITS       LIMIT        LIMIT         INDEX           INDEX       INDEX
                           PCT          PCT          PCT           PCT

   0                       21.20        17.06        15.17         3.14            6.00        0.52

  (-)0.75 IN.SIZE  *......................MATERIAL SIZE(-)2.0     IN............................*     SIZE(-)2.0    IN.
   SPECIF          ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE     APPARENT         BULK              ANGLE INTER
   GRAVITY         1 IN DROP        10 IN DROP       STEEL PLATE     COHESION         DENSITY           FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT      PSF AT           PCF AT            DEGREES AT
                 3.6  PCT MOIST   3.6  PCT MOIST   3.6  PCT MOIST  3.6  PCT MOIST 0.0  PCT MOIST      3.6  PCT MOIST

   2.66            37               35               27              210              97.4              38

                                                                     LAY-1           CURRENT:   04/01/73
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```
KEY

 41A
TUNNEL DATA

TUNNEL                      VENTILATION                       WATER INFLOW     UTILITY LINES               POWER SYSTEM

SIZE     SHAPE     GRADE    CFM   PRESS EXHST  SIZE   HP      GPM              AIR  WATER  PUMP            PRIMARY  SECONDARY
12FT     ROUND     +0.125PCT15K           X    36IN   100     20-100           6IN  3.5IN  8IN              7300V      480V
 11IN

HAULAGE SYSTEM                                SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY      BOLT,TYPE SIZE  ROOF PLATE       SET,SIZE,SHAPE          SHOTCRETE
RAIL, 24IN GAGE  RAIL             RAIL        3/4IN X 7FT,    13IN X 9FT       4IN H RINGS AT
65LB RAIL,                                    10PCT                            4FT
10TON MOTORS
10 CY CARS


MACHINE EXCAVATION

MACHINE                     CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES               RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL      WT    CENTER           INTERIOR         GAGE             HEAD,CENTER  HEAD           CENTER
  ROBBINS  141-127-1  125   1 ROBBINS 11IN   23 ROBBINS 11IN  6 ROBBINS 12IN   5.2  INTEG
                      TONS  STEEL TRIPLE     STEEL DISC       STEEL DISC                    KFTLB NA    KFTLB             KLB 900
                            DISC                                                            KFTLB498AV  KFTLB             KLB 357AV

 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS FROM    6-100HP MOTORS  LASER                      FEET         HOUR,FT.
 KLB 1000      FACE, 30IN      FOR HEAD                  KLB 2.73        0.21           20.0
               CONVEYOR TO
               REAR


CONVENTIONAL EXCAVATION

MACHINE                  ROUND,                   EXPLOSIVES,                          BLASTING       MUCKING        GUIDANCE
JUMBO                    NO. HOLES                POWDER FACTOR
MACHINES                 DEPTH                    TOTAL LBS
                         DIAM.                    PRIMERS,
                         CUT,                     TRIM
FEED LENGTH                                       INTERIOR
                                                  CUT
                                                  LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES YES BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.     LAY-1      CURRENT: 04/01/73
                                                                                                MDN 3
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KEY  IDENTIFICATION        ROCK PROPERTIES
 42   LAY                  SEDIMENTARY: CONGLOMERATE        DRY      COMP     ROD   ....HARDNESS...   YOUNGS    POISSON
                           WELL GRADED COBBLES TO           WT       STRNTH   PCT   SHORE   SCHMIDT   MOD.      RATIO
      SAMPLE NO            PEBBLES OF QUARTZITE             PCF      KPSI                             PSIX10E6
      LAY-2                POORLY CEMENTED WITH
                           REDDISH BROWN SANDSTONE          153        22     85      NA       38     10.80     0.18
                                                                      WTD                     WTD     NOTE      NOTE
                                                                      AV.                     AV.       1         1

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100   NO200        NO200

    104      3.3       0           0     0    6.0   30.0   23.0   8.0    6.0    4.0    2.0    4.0    4.5                12.5


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                                P    P-A    A     A     A     A     A     A


    POT VOL CHANGE       *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE    LIQUID       PLASTIC      SHRINKAGE     PLASTICITY      FLOW        TOUGHNESS
                         LIMITS       LIMIT        LIMIT         INDEX           INDEX       INDEX
                         PCT          PCT          PCT           PCT

    0                    15.00        14.18        13.80         0.82            4.00        0.21


   (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.0      IN..............................*   SIZE(-)2.0    IN.
    SPECIF          ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE         APPARENT        BULK              ANGLE INTER
    GRAVITY         1 IN DROP         10 IN DROP        STEEL PLATE         COHESION        DENSITY           FRICTION
                    DEGREES AT        DEGREES AT        DEGREES AT          PSF AT          PCF AT            DEGREES AT
                   3.4  PCT MOIST    3.4  PCT MOIST    3.4  PCT MOIST     3.0  PCT MOIST 0.0  PCT MOIST     3.0  PCT MOIST


    2.65            38                32                32                  15              86                39


                                                                 LAY-2          CURRENT:   04/01/73
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KEY

 42A
TUNNEL DATA


TUNNEL                          VENTILATION                       WATER INFLOW    UTILITY LINES             POWER SYSTEM

SIZE     SHAPE     GRADE     CFM    PRESS EXHST  SIZE   HP        GPM             AIR  WATER  PUMP          PRIMARY  SECONDARY
12 FT    ROUND     +0.125PCT15K           X      36IN  100        20-100          6IN  3.5IN  8IN            7300      480
 11 IN

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK              PERSONNEL         SUPPLY       BOLT+TYPE SIZE  ROOF PLATE       SET+SIZE+SHAPE          SHOTCRETE
RAIL              RAIL              RAIL                                          4 IN H FULL
10 CY CARS                                                                        RINGS IN BAD
10T MOTOR                                                                         GROUND
24 IN GAGE
65 LB RAIL



MACHINE EXCAVATION


MACHINE                         CUTTERS+MAKE+TYPE+DIAM+CUTTING EDGES            RPM          TORQUE+MAX/OPERATE      THRUST+MAX/CPERATE

  MAKE     MODEL       WT       CENTER           INTERIOR         GAGE          HEAD+CENTER  HEAD          CENTER
ROBBINS    141-127-1  125       1 ROBBINS        23 ROBBINS       6 ROBBINS      5.2
                      TON       11IN TRIPLE      11 IN DIA        12 IN DIA                  KFTLB         KFTLB                   KLB
                                DISC             DISC             DISC                       KFTLB491      KFTLB                   KLB 585


 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS         6-100 HP MOTORS LASER                       FEET         HOUR+FT.
 KLB           TO BELT         DRIVE HEAD                KLB 4.47          0.21           10.6



CONVENTIONAL EXCAVATION


MACHINE                 ROUND+                   EXPLOSIVES+                          BLASTING      MUCKING      GUIDANCE
JUMBO                   NO. HOLES                POWDER FACTOR
MACHINES                DEPTH                    TOTAL LBS
                        DIAM.                    PRIMERS+
                        CUT+                     TRIM
FEED LENGTH                                      INTERIOR
                                                 CUT
                                                 LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE+TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.        LAY-2      CURRENT: 04/01/73
          (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                            MDN 5
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KEY  IDENTIFICATION       ROCK PROPERTIES
 52   CNT                 SEDIMENTARY, CONGLOMERATE          DRY      COMP      RQD    ....HARDNESS...   YOUNGS   POISSON
                          80 PCT QUARTZITE PEBBLES           WT       STRNTH    PCT    SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO            TO COBBLES, 40 PCT MORE            PCF      KPSI                               PSIX10E6
     CNT-1                THAN 12 IN. DIAMETER
                          TO 30 IN. 20PCT CALCAR-           165        28       80      NA       38      6.00     0.18
                          EOUSLY CEMENTED SAND-                       WTD                        WTD     NOTE     NOTE
                          STONE MATRIX.                               AV.                        AV.      1-2       2

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.P.H0210043-72.


 MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS..................................*   PCT (-)
  WT  PCF  PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100    NO200     NO200


    96      7.0      0.0             0.0   0.0   4.0  15.0    25.0   10.0    7.0    4.0    4.0    6.0      7.1       17.9
                     0.0             0.0   0.0   7.0  16.0    28.0   11.0    8.0    6.0    8.0   10.0      3.3        2.7

   SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117),  LOWER LINE, SCREENED BEFORE DRYING

   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                                                   PE-R  PE-R   AP-R   AI-R    AI S   AI-S    S-AI    S-AI


   POT VOL CHANGE        *....................ATTERBERG LIMITS..SIZE(-) 0.056IN................................*
   (-)0.056  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE       PLASTICITY       FLOW       TOUGHNESS
                         LIMITS        LIMIT         LIMIT           INDEX            INDEX      INDEX
                         PCT           PCT           PCT             PCT

   0                      18.0          16.89         15.66           1.1              3.1        0.36


  (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*        SIZE(-)2.0   IN.
  SPECIF          ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT         BULK              ANGLE INTER
  GRAVITY         1 IN DROP         10 IN DROP        STEEL PLATE       COHESION         DENSITY           FRICTION
                  DEGREES AT        DEGREES AT        DEGREES AT        PSF AT           PCF AT            DEGREES AT
                 6.57 PCT MOIST    6.57 PCT MOIST    6.57 PCT MOIST    6.57 PCT MOIST   0.0 PCT MOIST     6.57 PCT MOIST


  2.721            39.65             34.55             31.67                  0             113                39


                                                                          CNT-1          CURRENT:   04/01/73
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KEY

 52A
TUNNEL DATA

TUNNEL                     VENTILATION                      WATER INFLOW    UTILITY LINES        POWER SYSTEM

SIZE     SHAPE      GRADE     CFM   PRESS EXHST  SIZE   HP     GPM             AIR  WATER  PUMP      PRIMARY  SECONDARY
12 FT    ROUND      +0.125PCT15K          X      36IN  100     20-200          6IN  3.5IN  8IN        7300      480
 11 IN

HAULAGE SYSTEM                                   SUPPORT SYSTEM

MUCK             PERSONNEL        SUPPLY         BOLT.TYPE SIZE  ROOF PLATE      SET.SIZE.SHAPE       SHOTCRETE
RAIL             RAIL             RAIL           3/4 IN X 7FT    13IN X 9FT
10 CY CARS
10T MOTOR
24 IN GAGE
65 LB RAIL


MACHINE EXCAVATION

MACHINE                          CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES          RPM         TORQUE.MAX/OPERATE      THRUST.MAX/OPERATE

  MAKE      MODEL        WT      CENTER          INTERIOR        GAGE          HEAD.CENTER  HEAD        CENTER
ROBBINS    141-127-1 125         1 ROBBINS       23 ROBBINS      6 ROBBINS      5.2
                     TON         11IN TRIPLE     11 IN DIA       12 IN DIA                  KFTLB       KFTLB              KLB
                                 DISC            DISC            DISC                       KFTLB 515   KFTLB 515          KLB 585


 ANCHOR PRESS  MUCK SYSTEM      POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               BUCKETS          6-100 HP MOTORS LASER                        FEET         HOUR.FT.
 KLB   NA      TO BELT          DRIVE HEAD                 KLB 4.47          0.21            8.8



CONVENTIONAL EXCAVATION

MACHINE                  ROUND.                    EXPLOSIVES.                      BLASTING       MUCKING       GUIDANCE
JUMBO                    NO. HOLES                 POWDER FACTOR
MACHINES                 DEPTH                     TOTAL LBS
                         DIAM.                     PRIMERS.
                         CUT.                      TRIM
FEED LENGTH                                        INTERIOR
                                                   CUT
                                                   LIFTERS

        BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
        NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISIURE.
        TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
        FREE VEHICLES (4) BELT CONV. YES HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
        *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.      CNT-1      CURRENT: 04/01/73
                                                                                                   MDN 6
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KEY  IDENTIFICATION      ROCK PROPERTIES
 43  NAVAJO              SEDIMENTARY:  SILTSTONE, FINE          DRY        COMP       RQD     ....HARDNESS...    YOUNGS   POISSON
                         GRAINED, GRAY, MORE THAN 33            WT         STRNTH     PCT     SHORE   SCHMIDT    MOD.     RATIO
     SAMPLE NO           PCT QUARTZ, 30 PCT CLAY, 10            PCF        KPSI       EST                        PSIX10E6
     NAV-1               PCT FELDSPAR, 15 PCT MICA,
                         CHLORITE AND GYPSUM.                  142          2         70       NA       7        0.20     0.10
                                                                                                       NOTE      NOTE     NOTE
                                                                                                        2         2        5

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
 DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*   PCT (-)
 WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200     NO200

   86       8.1      0.0           12.1  7.4   6.9   5.9     2.2     0.6     1.3     1.8     2.1     5.9     9.3              44.5
                     0.0           19.1  6.8  23.0  19.0

   SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117).  LOWER LINE, SCREENED BEFORE DRYING

    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                                   PI    PI    PI    PI      AI      SI      S       S       A       A


    POT VOL CHANGE             *...................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
    (-)0.056  IN.SIZE          LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW         TOUGHNESS
                               LIMITS        LIMIT         LIMIT           INDEX             INDEX        INDEX
                               PCT           PCT           PCT             PCT

    1.3                        36.80         23.61         21.04           13.19             7.00         1.88


   (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN.............................*        SIZE(-)2.0   IN.
    SPECIF         ANGLE/REPOSE        ANGLE/REPOSE        ANGLE/SLIDE        APPARENT       BULK               ANGLE INTER
    GRAVITY        1 IN DROP           10 IN DROP          STEEL PLATE        COHESION       DENSITY            FRICTION
                   DEGREES AT          DEGREES AT          DEGREES AT         PSF AT         PCF AT             DEGREES AT
                  7.7  PCT MOIST      7.7  PCT MOIST      7.7  PCT MOIST     7.5  PCT MOIST 0.0  PCT MOIST     7.5  PCT MOIST


    3.13           30                  30                  30                 340            98                 36


                                                                              NAV-1          CURRENT:  04/01/73
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KEY

 43A
TUNNEL DATA

TUNNEL                        VENTILATION                           WATER INFLOW    UTILITY LINES              POWER SYSTEM

SIZE     SHAPE     GRADE     CFM   PRESS EXHST  SIZE  HP      GPM             AIR  WATER  PUMP           PRIMARY   SECONDARY
20FT     ROUND     +0.05PCT  18K            X   30IN  60      1               6IN         4IN             4160V      440V
 6IN

HAULAGE SYSTEM                                    SUPPORT SYSTEM

MUCK               PERSONNEL          SUPPLY      BOLT+TYPE SIZE  ROOF PLATE     SET+SIZE+SHAPE           SHOTCRETE
RAIL+ 24IN GAGE    RAIL               RAIL        3/4IN X 8FT OR  5FT OR 13FT                             TO PREVENT AIR
70LB+ 16CY CARS                                   10FT SET IN     16 GAGE                                 SLACKING
15TON MOTOR                                       EPOXY



MACHINE EXCAVATION

MACHINE                   CUTTERS+MAKE+TYPE+DIAM+CUTTING EDGES                  RPM           TORQUE+MAX/OPERATE        THRUST+MAX/OPERATE

  MAKE     MODEL      WT    CENTER            INTERIOR           GAGE           HEAD+CENTER   HEAD          CENTER
  DRESSER  TB-205     200   4IN CHISEL        30 DRESSER         6 DRESSER        5   INTEG
                      TONS    KENNAMETAL      STEEL DISC+ 26     TC DISCS                     KFTLB 879    KFTLB                 KLB 1583
                            TC PICK BITS      KENNAMETAL TCB                                  KFTLB 586    KFTLB                 KLB 431
                                              PICK BITS

 ANCHOR PRESS  MUCK SYSTEM     POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
               BUCKETS FROM    4-180HP DC       LASER                         FEET         HOUR+FT+
 KLB 6616      FACE+ 36IN      MOTORS FOR HEAD             KLB 1.31           0.30           9.0
               CONVEYOR TO     1-75HP MOTOR+
               REAR            HYDRAULICS


CONVENTIONAL EXCAVATION

                                                                               BLASTING       MUCKING        GUIDANCE
MACHINE                  ROUND+                   EXPLOSIVES+
JUMBO                    NO. HOLES                POWDER FACTOR
MACHINES                 DEPTH                    TOTAL LBS
                         DIAM+                    PRIMERS+
                         CUT+                     TRIM
FEED LENGTH                                       INTERIOR
                                                  CUT
                                                  LIFTERS

         BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
         NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
         TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
         FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE NO
         *POSSIBLE+TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.     NAV-1       CURRENT: 04/01/73
         (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                         MDN 3
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KEY  IDENTIFICATION       ROCK PROPERTIES
 44   NAVAJO              SEDIMENTARY: SANDSTONE GRAY          DRY        COMP     RQD    ....HARDNESS...    YOUNGS    POISSON
                          MEDIUM GRAINED, MASSIVE,             WT         STRNTH   PCT    SHORE   SCHMIDT    MOD.      RATIO
     SAMPLE NO            FRIABLE AND POROUS, GRAINS           PCF        KPSI     EST                       PSIX10E6
     NAV-2                ANGULAR TO SUBROUNDED,
                          PRIMARILY QUARTZ, POORLY             117        LESS     60      NA       5         0.10      0.10
                          CEMENTED.                                       THAN                      NOTE      NOTE      NOTE
                                                                          1                         5         5         5

 NOTES:
 1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

 MUCK DATA
  DRY UNIT  MOISTURE  PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
  WT  PCF   PCT       IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200     NO200

   87        8.2      0.0          0.0   0.0   0.0   1.3    2.5     2.3     11.8    23.2    12.7    10.0    7.1             29.1
                      0.0          0.0   0.4   12.6  19.6

   SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117).  LOWER LINE, SCREENED BEFORE DRYING

   SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                                   AI    AI    A      AI     AI      RE      AI      A       A


   POT VOL CHANGE              *..................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
   (-)0.056  IN.SIZE           LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW          TOUGHNESS
                               LIMITS        LIMIT         LIMIT           INDEX             INDEX         INDEX
                               PCT           PCT           PCT             PCT

   0                           18.20         16.91         16.60           1.29              4.50          0.28


 (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN..............................*     SIZE(-)2.0   IN.
  SPECIF         ANGLE/REPOSE      ANGLE/REPOSE      ANGLE/SLIDE       APPARENT          BULK              ANGLE INTER
  GRAVITY        1 IN DROP         10 IN DROP        STEEL PLATE       COHESION          DENSITY           FRICTION
                 DEGREES AT        DEGREES AT        DEGREES AT        PSF AT            PCF AT            DEGREES AT
                 8.6  PCT MOIST    8.6  PCT MOIST    8.6  PCT MOIST    8.1  PCT MOIST 0.0  PCT MOIST     8.1  PCT MOIST


  2.72           31                28                32                45                99                28



                                                                       NAV-2          CURRENT:   04/01/73
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KEY

 44A
TUNNEL DATA


TUNNEL                        VENTILATION                          WATER INFLOW    UTILITY LINES                POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST  SIZE    HP      GPM             AIR  WATER  PUMP             PRIMARY  SECONDARY
20FT      ROUND      +0.05PCT 18K              X    30IN    60      1               6IN         4IN               4160V      440V
 6IN

HAULAGE SYSTEM                                        SUPPORT SYSTEM

MUCK              PERSONNEL         SUPPLY            BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE            SHOTCRETE
RAIL, 24IN GAGE   RAIL              RAIL              3/4IN X 8FT OR  5FT OR 13FT                               TO PREVENT
70LB RAIL, 16                                         10FT SET IN     16 GAGE                                   AIR SLACKING
CY CARS                                               EPOXY
15TON MOTOR



MACHINE EXCAVATION


MACHINE                     CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES            RPM            TORQUE,MAX/OPERATE        THRUST,MAX/OPERATE

  MAKE     MODEL       WT    CENTER           INTERIOR          GAGE            HEAD,CENTER    HEAD           CENTER
  DRESSER  TB-205      200   4IN CHISEL       30 DRESSER        6 DRESSER         5  INTEG
                       TONS  6 KENNAMETAL     STEEL DISC,       TC DISC                        KFTLB 879   KFTLB              KLB 1583
                             TC PICK BITS     26 KENNAMETAL                                    KFTLB 586   KFTLB              KLB 123
                                              TC PICK BITS

 ANCHOR PRESS  MUCK SYSTEM    POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               UCKETS FROM  4 -180HP DC        LASER                       FEET        HOUR,FT.
 KLB 616 R     FACE, 36IN     MOTORS FOR HEAD            KLB 0.37          0.30           4.5
               CONVEYOR TO    1-75HP MOTOR,
               REAR           HYDRAULICS


CONVENTIONAL EXCAVATION


MACHINE                 ROUND,                EXPLOSIVES,                            BLASTING        MUCKING        GUIDANCE
JUMBO                   NO. HOLES             POWDER FACTOR
MACHINES                DEPTH                 TOTAL LBS
                        DIAM.                 PRIMERS,
                        CUT,                  TRIM
FEED LENGTH                                   INTERIOR
                                              CUT
                                              LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.     NAV-2     CURRENT: 04/01/73
          (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                         MDN 7 OR 4(N)
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KEY IDENTIFICATION      ROCK PROPERTIES
 45  ROCHESTER          SEDIMENTARY: SANDSTONE                ORY       COMP     RQD   ....HARDNESS...   YOUNGS   POISSON
                        FINE GRAINED, BROWN                   WT        STRNTH   PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO          TO DARK RED, MASSIVE                  PCF       KPSI                             PSIX10E6
     RO-1
                                                              166       11       60     NA       36      4.47     0.24

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8   NO16   NO30   NO50   NO100   NO200        NO200

    89       4.3       0          0    2.0   9.0   12.0   33.0   15.0   7.0   4.0    2.0    2.0    3.0                  11.0


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                         PE    PE    PE     P      A      A     A      A      A


    POT VOL CHANGE        *....................ATTERBERG LIMITS..SIZE(-) 0.056IN.................................*
    (-)0.056  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW        TOUGHNESS
                          LIMITS        LIMIT         LIMIT          INDEX            INDEX       INDEX
                          PCT           PCT           PCT            PCT

    0                     19.70         17.35         16.52          2.35             7.20        0.33


   (-)0.75 IN.SIZE *......................MATERIAL SIZE(-)2.0     IN...............................*       SIZE(-)2.0   IN.
    SPECIF        ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE       APPARENT       BULK              ANGLE INTER
    GRAVITY       1 IN DROP        10 IN DROP       STEEL PLATE       COHESIO        DENSITY           FRICTION
                  DEGREES AT       DEGREES AT       DEGREES AT        PSF AT         PCF AT            DEGREES AT
                 8.48 PCT MOIST   8.48 PCT MOIST   8.48 PCT MOIST    8.48 PCT MOIST 8.48 PCT MOIST    8.48 PCT MOIST

     2.77         42.30            41.20            38.33                550            93.1              30.5


                                                                       RO-1          CURRENT:  04/01/73
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KEY

 45A
TUNNEL DATA


TUNNEL                        VENTILATION                           WATER INFLOW     UTILITY LINES             POWER SYSTEM

SIZE     SHAPE      GRADE     CFM     PRESS EXHST  SIZE    HP       GPM              AIR  WATER  PUMP          PRIMARY   SECONDARY
18 FT    ROUND      +0.045PCT22K            X      48 IN 300        40               8IN  4IN    8IN            13200       440
 4 IN

HAULAGE SYSTEM                                     SUPPORT SYSTEM

MUCK              PERSONNEL       SUPPLY           BOLT,TYPE SIZE   ROOF PLATE       SET,SIZE,SHAPE            SHOTCRETE
RAIL              RAIL            RAIL             5FT, 6FT, 8FTX   12FT 6IN OR
10CY CARS                                          5/8 IN 24 IN.    8FT 6 IN X
36 IN GAGE
15T MOTOR                                          CENTERS          8 IN, 14 GAGUE
50 LB RAIL


MACHINE EXCAVATION


MACHINE                      CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                       RPM           TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE      MODEL      WT    CENTER        INTERIOR          GAGE                       HEAD,CENTER   HEAD         CENTER
LAWRENCE    HR1        NA    1-24IN TCB    24 DISC AND       5 TCB                       11    30
  1-R                        TRI CONE      2 TCB ROLLER      ROLLER                                   KFTLB        KFTLB                KLB
                                                                                                      KFTLB364     KFTLB                KLB 492


 ANCHOR PRESS  MUCK SYSTEM    POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
               BUCKET         ELECTRO-        LASER                         FEET         HOUR,FT.
 KLB           TO BELT        HYDRAULIC                  KLB  1.86          0.28           9.5
                              960 HP


CONVENTIONAL EXCAVATION


MACHINE                    ROUND,                       EXPLOSIVES,                          BLASTING       MUCKING        GUIDANCE
JUMBO                      NO. HOLES                    POWDER FACTOR
MACHINES                   DEPTH                        TOTAL LBS
                           DIAM.                        PRIMERS,
                           CUT.                         TRIM
FEED LENGTH                                             INTERIOR
                                                        CUT
                                                        LIFTERS

         BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
         NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
         TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
         FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE NO  PNEUMATIC PIPELINE YES*
         *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.      RO-1       CURRENT: 04/01/73
         (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                          MDN 4
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KEY  IDENTIFICATION      ROCK PROPERTIES
 46   WESTERN            SEDIMENTARY: SANDSTONE COARSE      DRY       COMP       RQD    ....HARDNESS...    YOUNGS    POISSON
      NUCLEAR            GRAINED, POORLY CONSOLIDATED,      WT        STRNTH     PCT    SHORE    SCHMIDT   MOD.      RATIO
      SAMPLE NO          ARKOSIC, WITH MINOR LAYERS OF      PCF       KPSI       EST                       PSIX10E6
      WNG-1              THIN SEAMED SILTSTONE.
                                                            125       LESS       30      NA         5      0.10      0.10
                                                                      THAN                       NOTE      NOTE      NOTE
                                                                       1                           5         5         5

   NOTES:
   1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
   4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.


   MUCK DATA
    DRY UNIT   MOISTURE   PCT(+)6    *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
    WT  PCF    PCT        IN.SIZE    6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200       NO200

     82        10.5       0.0              0.0   0.0   1.0   1.0     2.0     5.0     12.0    17.0    16.0    14.0    8.1         24.9
                          0.0              6.9   3.3   15.7  11.7

     SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117).  LOWER LINE, SCREENED BEFORE DRYING

      SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID


                                   AE    AE    AE    S      A       A       A       A       A       A


      POT VOL CHANGE        *...................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
      (-)0.056  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE       PLASTICITY        FLOW        TOUGHNESS
                            LIMITS        LIMIT         LIMIT           INDEX             INDEX       INDEX
                            PCT           PCT           PCT             PCT

      0                     24.90         19.97         19.94           4.93              7.40        0.66


     (-)0.75 IN.SIZE *.....................MATERIAL SIZE(-)2.0     IN.............................*      SIZE(-)2.0   IN.
      SPECIF       ANGLE/REPOSE     ANGLE/REPOSE     ANGLE/SLIDE      APPARENT         BULK              ANGLE INTER
      GRAVITY      1 IN DROP        10 IN DROP       STEEL PLATE      COHESION         DENSITY           FRICTION
                   DEGREES AT       DEGREES AT       DEGREES AT       PSF AT           PCF AT            DEGREES AT
                   10.1 PCT MOIST   10.1 PCT MOIST   10.0 PCT MOIST   10.6 PCT MOIST 0.0  PCT MOIST     10.6 PCT MOIST


      2.71         34               31               32               0                85                27



                                                                      WNG-1         CURRENT:   04/01/73
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```
KEY

 46A
TUNNEL DATA


TUNNEL                    VENTILATION                         WATER INFLOW     UTILITY LINES              POWER SYSTEM

SIZE     SHAPE     GRADE    CFM   PRESS EXHST  SIZE    HP     GPM              AIR  WATER  PUMP           PRIMARY  SECONDARY
10FT X   RECT     +0.5PCT  5-7K     X          18IN           20-25            4IN                          440V      110V
 8FT

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK               PERSONNEL          SUPPLY    BOLT,TYPE SIZE  ROOF PLATE      SET,SIZE,SHAPE          SHOTCRETE
RAIL, 24IN GAGE    RAIL               RAIL      NONE                                                    IN BAD
40LB RAIL                                                                                               GROUND




MACHINE EXCAVATION


MACHINE                   CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES                RPM          TORQUE,MAX/OPERATE      THRUST,MAX/OPERATE

  MAKE     MODEL      WT   CENTER            INTERIOR            GAGE         HEAD,CENTER  HEAD            CENTER
  ALPINE    F6-A      11   72 KENNAMETAL U   43 K PICK BITS                    60
  MINER               TONS MOUNTED ON TWIN   RIPPER HEADS                                   KFTLB       KFTLB             KLB
                                                                                            KFTLB       KFTLB             KLB


 ANCHOR PRESS  MUCK SYSTEM       POWER SYSTEM     GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
               GATHERING ARMS    440V ELECTRIC    TRANSIT                     FEET        HOUR,FT.
 KLB           14IN CHAIN CONV   MOTORS           LASER     KLB NA             NA            2.0
               18IN BELT CONV.   50.4HP HEAD
               TO REAR           2-20.2HP THRUST


CONVENTIONAL EXCAVATION


MACHINE                   ROUND,                   EXPLOSIVES,                         BLASTING        MUCKING        GUIDANCE
JUMBO                     NO. HOLES                POWDER FACTOR
MACHINES                  DEPTH                    TOTAL LBS
                          DIAM.                    PRIMERS,
                          CUT.                     TRIM
FEED LENGTH                                        INTERIOR
                                                   CUT
                                                   LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.    WNG-1      CURRENT: 04/01/73
            (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                       MDN 7 OR 3(N)
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KEY  IDENTIFICATION       ROCK PROPERTIES
 47  WESTERN              SEDIMENTARY: SANDSTONE COARSE        DRY      COMP      RQD   ....HARDNESS...   YOUNGS    POISSON
      NUCLEAR             GRAINED, POORLY CONSOLIDATED,        WT       STRNTH    PCT   SHORE   SCHMIDT   MOD.      RATIO
     SAMPLE NO            ARKOSIC, WITH MINOR LAYERS           PCF      KPSI      EST                     PSIX10E6
     WNG-2                OF THIN SEAMED SILTSTONE,
                          VARYING CONCENTRATIONS OF            125      LESS      30     NA      5        0.10      0.10
                          CARBONIFEROUS MATERIAL                        THAN                     NOTE     NOTE      NOTE
                          REPLACED BY SILICA.                           1                        5        5         5

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS.................................*  PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4     NO8     NO16    NO30    NO50    NO100   NO200   NO200

    83       8.3       0.0         0.0   0.0   0.0   2.0    4.0    5.0     11.0    16.0    16.0    18.0    7.9             28.1
                       0.0         8.7   5.4   7.9   7.3

    SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117),  LOWER LINE, SCREENED BEFORE DRYING

     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGUL/R R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID

                                   AE    AE    AE    S      A      A       A       A       A       A

     POT VOL CHANGE          *....................ATTERBERG LIMITS..SIZE(-) 0.056IN..................................*
     (-)0.056  IN.SIZE       LIQUID        PLASTIC      SHRINKAGE     PLASTICITY      FLOW         TOUGHNESS
                             LIMITS        LIMIT        LIMIT         INDEX           INDEX        INDEX
                             PCT           PCT          PCT           PCT

     0                       25.25         24.74        23.37         0.51            4.00         0.13

    (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)2.0      IN..............................*       SIZE(-)2.0   IN.
     SPECIF         ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE         APPARENT         BULK               ANGLE INTER
     GRAVITY        1 IN DROP          10 IN DROP         STEEL PLATE         COHESION         DENSITY            FRICTION
                    DEGREES AT         DEGREES AT         DEGREES AT          PSF AT           PCF AT             DEGREES AT
                   9.0  PCT MOIST     9.0  PCT MOIST     9.0  PCT MOIST      9.0  PCT MOIST 0.0  PCT MOIST       9.0  PCT MOIST

     2.72           32                 31                 40                  0                86                 28

                                                                         WNG-2           CURRENT:   04/01/73
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```
KEY

 47A
TUNNEL DATA


TUNNEL                        VENTILATION                           WATER INFLOW     UTILITY LINES                POWER SYSTEM

SIZE      SHAPE      GRADE      CFM    PRESS EXHST   SIZE    HP       GPM              AIR   WATER   PUMP           PRIMARY   SECONDARY
5FT X     RECT       VARIES     5-7K      X          18IN             DRY              2IN   1IN                     440V        110V
  9FT

HAULAGE SYSTEM                                             SUPPORT SYSTEM

MUCK              PERSONNEL          SUPPLY        BOLT,TYPE SIZE   ROOF PLATE       SET,SIZE,SHAPE              SHOTCRETE
42IN SCRAPER      RAIL               RAIL
RAIL                                 AIR HOIST




MACHINE EXCAVATION


MACHINE                              CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES             RPM           TORQUE,MAX/OPERATE          THRUST,MAX/OPERATE

  MAKE      MODEL       WT       CENTER            INTERIOR           GAGE             HEAD,CENTER   HEAD           CENTER

                                                                                                     KFTLB          KFTLB                 KLB
                                                                                                     KFTLB          KFTLB                 KLB


 ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM    GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                                                                               FEET          HOUR,FT.
 KLB                                                          KLB



CONVENTIONAL EXCAVATION


MACHINE                    ROUND,                        EXPLOSIVES,                                BLASTING        MUCKING         GUIDANCE
JUMBO                      NO. HOLES 18                  POWDER FACTOR 5.0LB/CY                     SAFETY FUSE,    SCRAPER         TRANSIT
MACHINES LE ROI            DEPTH 6FT                     TOTAL LBS 59, 40PCT GELEX 2                CAPS
         MOD35-AIRLEG      DIAM. 1.5IN                   PRIMERS,
                           CUT,  BURN 5 HOLE             TRIM
FEED LENGTH 6FT                                          INTERIOR
                                                         CUT
                                 SF/HOLE 2.5             LIFTERS

            BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE,
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.           WNG-2        CURRENT: 04/01/73
            (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                               MDN 7 OR 3(N)
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KEY  IDENTIFICATION      ROCK PROPERTIES
 48   SAN                SEDIMENTARY: SANDSTONE ARKOSIC     DRY      COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
       FERNANDO          IRREGULARLY BEDDED, LOOSELY        WT       STRNTH    PCT    SHORE    SCHMIDT   MOD.      RATIO
     SAMPLE NO           CONSOLIDATED WITH LAYERS AND       PCF      KPSI      EST                       PSIX10E6
     SF-1                LENSES OF SILTY MUDSTONE.
                                                            113      LESS      15      NA        5       0.10      0.10
                                                                     THAN                       NOTE     NOTE      NOTE
                                                                      1                           5        5         5

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *.................PER CENT BY WEIGHT BETWEEN SCREENS...............................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3/4.  2IN.  1IN.  1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100   NO200      NO200

     91      10.5      0.0          0.0   0.0   0.0   2.2     4.5     6.1     5.1     7.0    11.5    14.4    12.8       36.4


    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

                                                    RE      SE      AI      AI      AI      AI      A


    POT VOL CHANGE       *....................ATTERBERG LIMITS..SIZE(-) 0.185IN..................................*
    (-)0.065  IN.SIZE     LIQUID        PLASTIC       SHRINKAGE        PLASTICITY        FLOW          TOUGHNESS
                          LIMITS        LIMIT         LIMIT            INDEX             INDEX         INDEX
                          PCT           PCT           PCT              PCT

    0                     17.75         16.19         13.94            1.56              5.8           0.27


   (-)0.185IN.SIZE *......................MATERIAL SIZE(-)0.185   IN............................*        SIZE(-)0.185 IN.
    SPECIF          ANGLE/REPOSE       ANGLE/REPOSE      ANGLE/SLIDE       APPARENT       BULK               ANGLE INTER
    GRAVITY         1 IN DROP          10 IN DROP        STEEL PLATE       COHESION       DENSITY            FRICTION
                    DEGREES AT         DEGREES AT        DEGREES AT        PSF AT         PCF AT             DEGREES AT
                   14.3 PCT MOIST     14.3 PCT MOIST    12.5 PCT MOIST          PCT MOIST 0.0 PCT MOIST     13.0 PCT MOIST

    2.86            38                 33                36                  NA             84.3             42


                                                                   SF-1           CURRENT:   04/01/73
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KEY

 48A
TUNNEL DATA

TUNNEL                        VENTILATION                      WATER INFLOW    UTILITY LINES          POWER SYSTEM

SIZE    SHAPE      GRADE     CFM   PRESS EXHST  SIZE   HP      GPM             AIR  WATER  PUMP       PRIMARY   SECONDARY
21FT    ROUND      +0.25PCT  20K   FACE    X    36IN           200             6IN         6IN         4160V       480V

HAULAGE SYSTEM                                  SUPPORT SYSTEM

MUCK             PERSONNEL         SUPPLY       BOLT,TYPE SIZE  ROOF PLATE     SET,SIZE,SHAPE         SHOTCRETE
RAIL             RAIL              RAIL                                        CONTINUOUS PRECAST
                                                                               CONCRETE 8IN OR
                                                                               10IN THICK X
                                                                               4FT - 4 SEGMENT


MACHINE EXCAVATION

MACHINE                        CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES            RPM          TORQUE,MAX/OPERATE     THRUST,MAX/OPERATE

  MAKE     MODEL      WT       CENTER          INTERIOR         GAGE           HEAD,CENTER  HEAD          CENTER
  ROBBINS   2215      285           HYDRAULIC  OPERATED RIPPER  TOOTH          DNA
            RIPPER    TONS                                                                  KFTLB         KFTLB           KLB 7000
            SHIELD                                                                          KFTLB DNA     KFTLB DNA       KLB


 ANCHOR PRESS   MUCK SYSTEM     POWER SYSTEM    GUIDANCE  THRUST/SQ FT  KERF SPACING  ADVANCE PER
                BUCKET TO 6FT   HYDRAULIC       LASER                       FEET         HOUR,FT.
 KLB            CONVEYOR TO                               KLB NA            DNA            24
                REAR


CONVENTIONAL EXCAVATION

MACHINE                  ROUND,                       EXPLOSIVES,                          BLASTING       MUCKING       GUIDANCE
JUMBO                    NO. HOLES                    POWDER FACTOR
MACHINES                 DEPTH                        TOTAL LBS
                         DIAM.                        PRIMERS,
                         CUT.                         TRIM
FEED LENGTH                                           INTERIOR
                                                      CUT
                                                      LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.      SF-1      CURRENT: 04/01/73
          (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                          MON 7
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KEY  IDENTIFICATION      ROCK PROPERTIES
 49   SAN                SEDIMENTARY: SANDSTONE AND          DRY       COMP      RQD    ....HARDNESS...    YOUNGS    POISSON
       FERNANDO          BIOTITE   RICH SILTSTONE.           WT        STRNTH    PCT    SHORE   SCHMIDT    MOD.      RATIO
      SAMPLE NO          POORLY TO WELL CONSOLIDATED.        PCF       KPSI      EST                       PSIX10E6
      SF-2               POORLY TO WELL SORTED.
                                                             142       2         50     NA       7         0.10      0.10
                                                                                                 NOTE      NOTE      NOTE
                                                                                                 2         5         5

 NOTE :
 1. 50 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
 4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6, FROM CSM A.R.H0210043-72.

 MUCK DATA
  DRY UNIT   MOISTURE   PCT(+)6    *....................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
  WT   PCF   PCT        IN.SIZE    6IN.   3IN.   2IN.   1IN.   1/2IN.  NO4     NO8    NO16    NO30    NO50    NO100    NO200     NO200

    80        17.5      0.0               0.0    0.0    8.6    14.4    34.6    0.5     0.6     0.8     1.5     9.5      10.5      19.0
                        10                10

   SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117),  LOWER LINE, SCREENED BEFORE DRYING

    SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SF=SPHEROID

                        PE                PE    NA     RS     RS     SI     SI      SI      SI      SI      SI

   POT VOL CHANGE          *.....................ATTERBERG LIMITS..SIZE(-) 0.056IN.....................................*
   (-)0.056   IN.SIZE      LIQUID         PLASTIC        SHRINKAGE       PLASTICITY         FLOW          TOUGHNESS
                           LIMITS         LIMIT          LIMIT           INDEX              INDEX         INDEX
                           PCT            PCT            PCT             PCT

   0                       31.5           26.8           21.5            4.7                7.6           0.61

 (-)0.75 IN.SIZE *.........................MATERIAL SIZE(-)1.0      IN...............................*       SIZE(-)1.0   IN.
   SPECIF           ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE         APPARENT          BULK                ANGLE INTER
   GRAVITY          1 IN DROP          10 IN DROP         STEEL PLATE         COHESION          DENSITY             FRICTION
                    DEGREES AT         DEGREES AT         DEGREES AT          PSF AT            PCF AT              DEGREES AT
                   15.1 PCT MOIST     15.1 PCT MOIST     15.1 PCT MOIST        15 PCT MOIST      0 PCT MOIST       15    PCT MOIST

   3.02             38                 36                 30                  80                75.36              27

                                                                  SF-2            CURRENT:   04/01/73
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KEY

 49A
TUNNEL DATA


TUNNEL                  VENTILATION                 WATER INFLOW  UTILITY LINES           POWER SYSTEM

SIZE    SHAPE   GRADE   CFM  PRESS EXHST SIZE  HP   GPM           AIR WATER  PUMP         PRIMARY SECONDARY
21FT    ROUND   +0.25PCT 20K FACE   X    36IN       20            6IN        6IN           4160V    480V


HAULAGE SYSTEM                         SUPPORT SYSTEM

MUCK          PERSONNEL      SUPPLY    BOLT.TYPE SIZE ROOF PLATE  SET.SIZE.SHAPE          SHOTCRETE
RAIL          RAIL           RAIL                                 CONTINUOUS PRECAST
                                                                  CONCRETE 8IN OR
                                                                  10IN THICK X
                                                                  4FT - 4 SEGMENT



MACHINE EXCAVATION


MACHINE                 CUTTERS.MAKE.TYPE.DIAM.CUTTING EDGES      RPM        TORQUE.MAX/OPERATE   THRUST.MAX/OPERATE

  MAKE   MODEL     WT   CENTER        INTERIOR      GAGE          HEAD.CENTER HEAD       CENTER
  ROBBINS 221S     285       HYDRAULIC OPERATED RIPPER TOOTH      DNA
          RIPPER   TONS                                                      KFTLB      KFTLB          KLB 7000
          SHIELD                                                             KFTLB DNA  KFTLB DNA      KLB


 ANCHOR PRESS MUCK SYSTEM  POWER SYSTEM GUIDANCE THRUST/SQ FT KERF SPACING ADVANCE PER
              BUCKET TO 6FT HYDRAULIC   LASER                   FEET        HOUR.FT.
 KLB          CONVEYOR TO                        KLB DNA        DNA           24
              REAR



CONVENTIONAL EXCAVATION


MACHINE              ROUND.            EXPLOSIVES.                  BLASTING     MUCKING      GUIDANCE
JUMBO                NO. HOLES         POWDER FACTOR
MACHINES             DEPTH             TOTAL LBS
                     DIAM.             PRIMERS.
                     CUT.              TRIM
FEED LENGTH                            INTERIOR
                                       CUT
                                       LIFTERS

          BASIS FOR MDN IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
          NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
          TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
          FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
          *POSSIBLE.TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.   SF-2     CURRENT: 04/01/73
          (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                        MDN 6 OR 2(N)
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KEY  IDENTIFICATION      ROCK PROPERTIES
 50   KERR-              SEDIMENTARY: MUDSTONE, DARK                     DRY       COMP      RQD   ....HARDNESS...   YOUNGS   POISSON
       MCGEE             GRAY, FINE GRAINED, MASSIVE.                    WT        STRNTH    PCT   SHORE   SCHMIDT   MOD.     RATIO
     SAMPLE NO                                                           PCF       KPSI      EST                     PSIX10E6
     KM-1
                                                                         144       11        90     NA       42       5.0      0.10
                                                                                                            NOTE     NOTE     NOTE
                                                                                                             2        2        5

  NOTES:
  1. 80 PCT. OF FORMATION.  2. INFERRED FROM D.U.DEERE AD 646610-66.  3. UNPOLISHED SPECIMEN.
  4. INFERRED FROM TESTS/SIMILAR ROCK.  5. ASSIGNED MINIMUM VALUE.  6. FROM CSM A.R.H0210043-72.

  MUCK DATA
   DRY UNIT  MOISTURE  PCT(+)6   *................PER CENT BY WEIGHT BETWEEN SCREENS...................................*   PCT (-)
   WT  PCF   PCT       IN.SIZE   6IN.  3IN.  2IN.  1IN.  1/2IN.  NO4    NO8    NO16   NO30   NO50   NO100    NO200        NO200

    81       9.4       0.0             0.0   5.9   1.9   5.2     28.9   0.3    1.3    2.7    5.4    6.3      12.5         29.6
                       46.7            20.1  8.4   11.0  6.4     3.3

    SCREEN ANALYSIS:  UPPER LINE, DRY SCREENED (ASTM C136), AFTER WASHING (ASTM C117).  LOWER LINE, SCREENED BEFORE DRYING

     SHAPE OF FRACTIONS BETWEEN SCREEN SIZES  A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR F=ELONGATED SP=SPHEROID


                       PE              PE    PI    PI    PI      A      A      A      A      A      A


    POT VOL CHANGE        *..................ATTERBERG LIMITS..SIZE(-) 0.056IN...............................*
    (-)0.056  IN.SIZE      LIQUID        PLASTIC       SHRINKAGE      PLASTICITY       FLOW        TOUGHNESS
                           LIMITS        LIMIT         LIMIT          INDEX            INDEX       INDEX
                           PCT           PCT           PCT            PCT

    0                      28.30         24.97         19.12          3.33             3.60         0.92


   (-)0.75 IN.SIZE *.......................MATERIAL SIZE(-)2.00    IN.................................*        SIZE(-)2.0   IN.
    SPECIF          ANGLE/REPOSE       ANGLE/REPOSE       ANGLE/SLIDE        APPARENT        BULK                 ANGLE INTER
    GRAVITY         1 IN DROP          10 IN DROP         STEEL PLATE        COHESION        DENSITY              FRICTION
                    DEGREES AT         DEGREES AT         DEGREES AT         PSF AT          PCF AT               DEGREES AT
                   12.7 PCT MOIST     12.7 PCT MOIST     12.7 PCT MOIST     10.9 PCT MOIST 0.0  PCT MOIST      10.9 PCT MOIST


    2.87            29                 28                 31                 37              79                   35



                                                                               KM-1            CURRENT:   04/01/73
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KEY

 50A
TUNNEL DATA


TUNNEL                            VENTILATION                        WATER INFLOW     UTILITY LINES                POWER SYSTEM

SIZE      SHAPE      GRADE     CFM    PRESS EXHST  SIZE    HP        GPM              AIR  WATER  PUMP             PRIMARY  SECONDARY
10FT X    RECT       +0.5PCT   5K     FACE  VENT   24IN    25        DRY
 9FT

HAULAGE SYSTEM                                         SUPPORT SYSTEM

MUCK              PERSONNEL         SUPPLY            BOLT,TYPE SIZE  ROOF PLATE       SET,SIZE,SHAPE           SHOTCRETE
RAIL, 36IN GAGE   RAIL              RAIL                                               4IN WF STEEL
45LB RAIL                                                                              SETS AT 3FT OR
                                                                                       6FT



MACHINE EXCAVATION


MACHINE                           CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES             RPM           TORQUE,MAX/OPERATE       THRUST,MAX/OPERATE

  MAKE      MODEL      WT       CENTER           INTERIOR         GAGE             HEAD,CENTER   HEAD           CENTER
  ALPINE     F6-A      11       40 KENNAMETAL U  43 KM PICK BITS   MOUNTED          78
  MINER                TONS     ON TWIN RIPPER   HEADS                                           KFTLB       KFTLB              KLB
                                                                                                 KFTLB NA    KFTLB NA           KLB NA


 ANCHOR PRESS   MUCK SYSTEM      POWER SYSTEM     GUIDANCE   THRUST/SQ FT   KERF SPACING   ADVANCE PER
                GATHERING ARMS   ELECTRIC MOTORS  TRANSIT                        FEET          HOUR,FT.
 KLB            14IN FLIGHT      50.4HP HEAD      LASER      KLB NA              NA               NA
                CONVEYOR         2-20.4HP THRUST


CONVENTIONAL EXCAVATION


MACHINE                    ROUND,                     EXPLOSIVES,                            BLASTING        MUCKING         GUIDANCE
JUMBO                      NO. HOLES                  POWDER FACTOR
MACHINES                   DEPTH                      TOTAL LBS
                           DIAM.                      PRIMERS,
                           CUT.                       TRIM
FEED LENGTH                                           INTERIOR
                                                      CUT
                                                      LIFTERS

            BASIS FOR MDA IS DRY SCREEN ANALYSIS AFTER WASHING UNLESS
            NOTED BY (N) FOR SCREEN ANALYSIS WITH NATURAL MOISTURE.
            TRANSPORT SYSTEM CAPABILITY:CONVENTIONAL RAIL YES SIDE RAIL YES*
            FREE VEHICLES (4) BELT CONV. (2) HYDRAULIC PIPELINE YES PNEUMATIC PIPELINE YES*
            *POSSIBLE,TECHNOLOGY NOT FULLY DEVELOPED. (2) EXCESSIVE FINES BUILDUP PROBABLE.      KN-1        CURRENT: 04/01/73
            (4) EXCESSIVE ROADBED MAINTENANCE PROBABLE.                                          MDV 4 OR 1(N)
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APPENDIX C

SYSTEM DATA SHEETS

Identification	Page	Identification	Page
NAST-1	C-1-C-2	5-1	C-53-C-54
NAST-2	C-3-C-4	7-2	C-55-C-56
NAST-3	C-5-C-6	11-3	C-57-C-58
NAST-4	C-7-C-8	11-4	C-59-C-60
GA-1	C-9-C-10	72-1	C-61-C-62
H-1	C-11-C-12	MSU-1	C-63-C-64
H-2	C-13-C-14	MSU-2	C-65-C-66
H-3	C-15-C-16	LAW-2	C-67-C-68
LK-1	C-17-C-18	LAW-3	C-69-C-70
LK-2	C-19-C-20	LAW-4	C-71-C-72
LK-5	C-21-C-22	MIL-1	C-73-C-74
LK-6	C-23-C-24	MIL-2	C-75-C-76
LK-7	C-25-C-26	MIL-3	C-77-C-78
SM-1	C-27-C-28	EVG-1	C-79-C-80
CL-1	C-29-C-30	EVG-2	C-81-C-82
LK-3	C-31-C-32	LAY-1	C-83-C-84
LK-4	C-33-C-34	LAY-2	C-85-C-86
MB-1	C-35-C-36	CNT-1	C-87-C-88
MB-3	C-37-C-38	NAV-1	C-89-C-90
ST-1	C-39-C-40	NAV-2	C-91-C-92
CR-1	C-41-C-42	RO-1	C-93-C-94
HS-1	C-43-C-44	WNG-1	C-95-C-96
NY-1	C-45-C-46	WNG-2	C-97-C-98
NY-2	C-47-C-48	SF-1	C-99-C-100
QL-1	C-49-C-50	SF-2	C-101-C-102
MB-2	C-51-C-52	KM-1	C-103-C-104

ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10 to 20% quartz, 50 to 60% feldspar, balance dark minerals.
Uniaxial Compressive Strength: 18 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 167 PCF.
Ground Water: Minor, primarily from fault zones.
Hardness: Schmidt 51 (Note 4).
Youngs Mod.: 8.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 9' 9" diameter. Grade: (+) 0.22%.
Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 5 to 20 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 70# rail.
Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground, 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required.

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight: 67 tons.
Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB Cone.
Rotation: Head, 8 1/2 RPM
Torque: 150 K ft. # max., 110 K ft. # operating
Thrust: 290 K lbs.
Muck System: Bucket from face, 22" belt conveyor to rear.
Power System: 3-200 HP electric motor driven hydraulic pumps driving four hydraulic head motors and the thrust and anchor cylinders.
Guidance System: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

Abrasiveness N. A.

Pot. Vol. Change, Material Size (-) 0.065" : 0

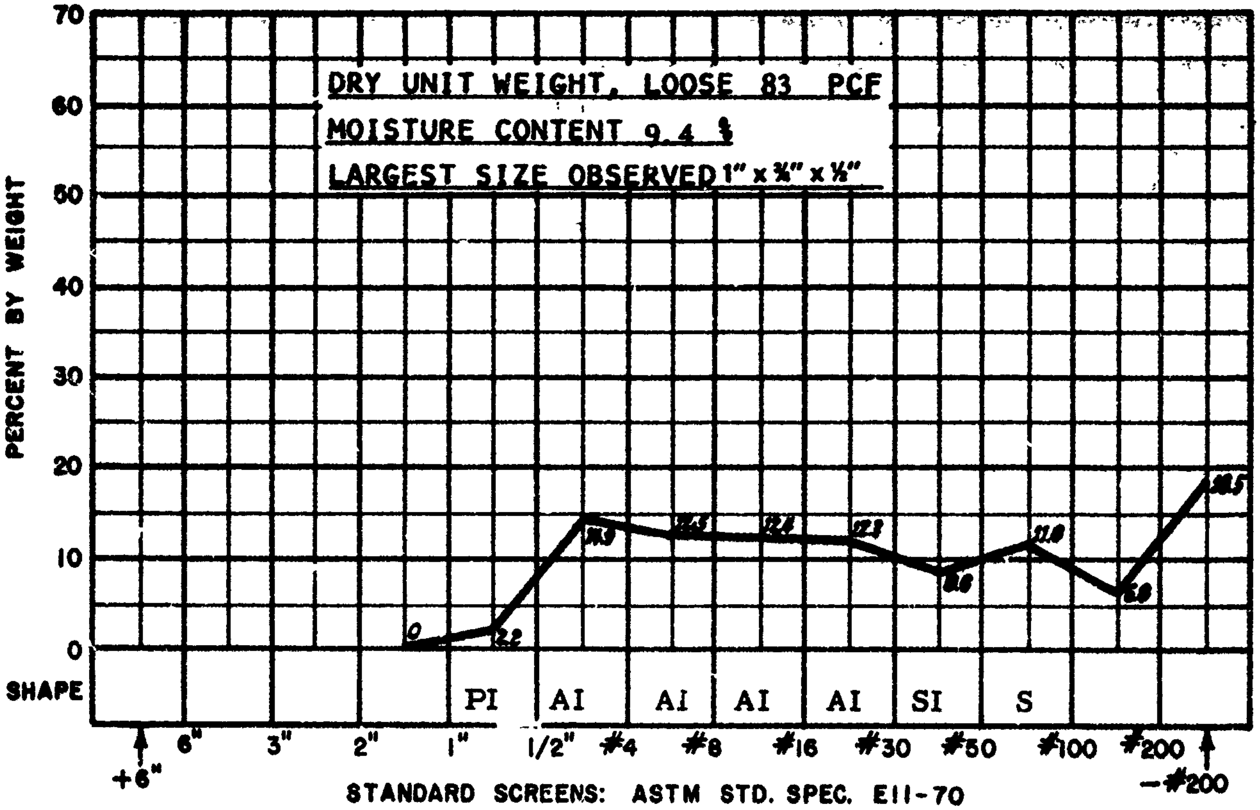
Spec. Gravity, Material Size (-) 0.50" : 2.69

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 14.50 %
Plastic Limit 14.00 %
Shrinkage Limit 13.50 %
Plasticity Index 0.50 %
Toughness Index 0.16
Flow Index 3.0

MATERIAL SIZE (-) 0.50 IN.

Angle/Repose 1" Drop @ 9.0 % **Moisture,** 37°
Apparent Cohesion PSF @ % **Moisture,** NA
Angle/Repose 10" Drop @ 9.0 % **Moisture,** 36°
Angle Slide Steel Plate @ 9.0 % **Moisture,** 41°
Bulk Density PCF @ 0.0% **Moisture,** 85.16
Angle Internal Friction @ 8.5 % **Moisture,** 42°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, moderately to slightly fractured and jointed. Medium to fine grained. High strength. RQD (Est.) 90%. DUW: 167 PCF. Ground water: Minor. Hardness: Schmidt 51.

System Class: TBM, Wirth Erkelenz, Hardrock, 9'9" dia. 25 Hughes Tool/ Wirth TCB roller and cone cutters. RPM: 8-1/2, 110 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Steel ring and half sets, roofplates and rock bolts.

ROCK DATA:

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10% to 20% quartz, 50% to 60% feldspar, balance dark minerals.
Uniaxial Compressive Strength: 18 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 167 PCF.
Ground Water: Minor, primarily from fault zones.
Hardness: Schmidt 51 (Note 4).
Youngs Mod.: 8.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 9'9" diameter. Grade: (+) 0.22%.
Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 5 to 20 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.
Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight 67 tons.
Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.
Rotation: 8 1/2 RPM
Torque: 150 K ft # max., 100 K ft. # operating.
Thrust: 290 K lbs
Muck System: Bucket from face, 22" belt conveyor to rear.
Power System: 3-200 HP electric motor driven hydraulic pumps driving four hydraulic head motors and the thrust and anchor cylinders.
Guidance System: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

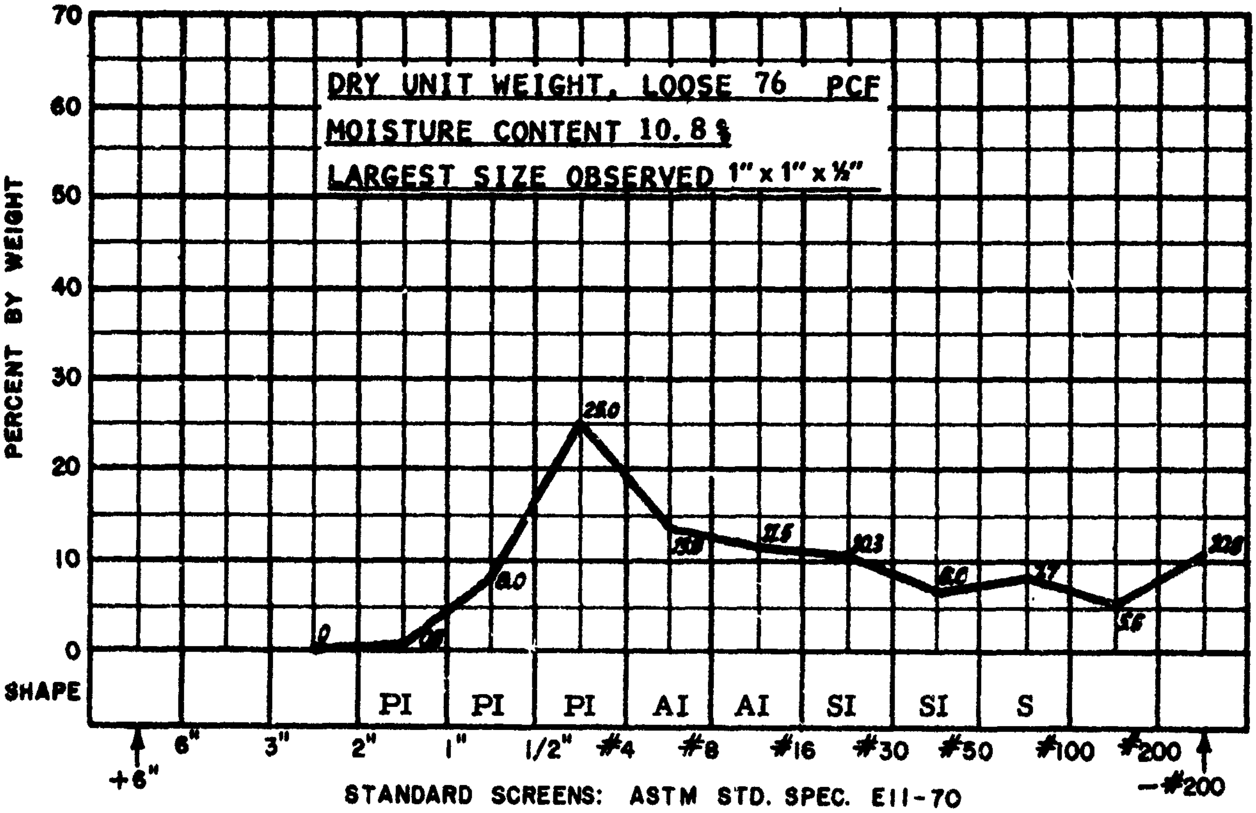
Abrasiveness	**Pot. Vol. Change, Material**	**Spec. Gravity, Material**
N. A.	**Size (-)0.056" : 0**	**Size (-) 0.50" : 2.66**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.5 %	**Plastic Limit 18.2 %**	**Shrinkage Limit 17.9 %**
Plasticity Index 1.3 %	**Toughness Index 0.28**	**Flow Index 4.6**

MATERIAL SIZE (-) 1.0 IN.

Angle/Repose 1" Drop	**Apparent Cohesion PSF**	**Angle/Repose 10" Drop**
@ 8.7 % Moisture, 38°	**@ 8.5% Moisture, 0**	**@ 8.7 % Moisture, 38°**
Angle Slide Steel Plate	**Bulk Density PCF**	**Angle Internal Friction**
@ 8.7 % Moisture, 49°	**@ 0.0% Moisture, 84.53**	**@ 8.5 % Moisture, 31°**



DRY UNIT WEIGHT, LOOSE 76 PCF
MOISTURE CONTENT 10.8 %
LARGEST SIZE OBSERVED 1" x 1" x ½"

STANDARD SCREENS: ASTM STD. SPEC. E11-70

MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, medium to fine grained, moderately to slightly fractured and jointed. High strength. RQD: (Est.) 90%. DUW: 167 PCF. Ground water: Minor. Hardness: Schmidt 51.

System Class: TBM, Wirth Erkelenz, Hardrock. 9' 9" dia. 25 Hughes Tool/ Wirth TCB roller and tricone cutters. RPM: 8-1/2, 100 K ft # Torque, 290 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. NAST-2
4/1/73	MDN	Sheet 2
	7	

ROCK DATA:

Lithology: Igneous, biotitic granite, fine grained, with major quartz and minor feldspar and dark mineral contents.
Uniaxial Compressive Strength: 28 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 164 PCF.
Ground Water: Minor, from fault zones.
Hardness: Shore 99.2, Schmidt 54 (Note 2).
Youngs Mod.: 8.3210 PSI x 10^6
Poisson Ratio: 0.35 (Note 2).

TUNNEL DATA:

Size: 10' high x 16' wide x 8', alcove from 9'-9" diameter tunnel.
Ventilation System: 10 KCFM, exhaust, 22" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 5-10 GPM.
Power System: Not applicable.
Haulage System: Muck, personnel, supplies by rail cars, 36" Gage, 70# rail.
Support System: 1" x 7' grouted rock bolts and 13" x 10'-16 gage roof plates.

EXCAVATION DATA:

Conventional Rail Haulage System.
Drilling: 2-S53F, 4' feed, jack legs.
Drill Round: 72 holes, 1 3/4" diameter, 9' av. depth, double V-cut.
Explosives: 300# Gelex #2-60%. Powder Factor, 6.3#/CY.
Blasting: Electrical, zero and 7 regular delays.
Mucking: Diesel front end loader, 1/2 CY.
Guidance: Not applicable.

NOTE 2: Inferred from D.U. Deere AD646610-1966.

MUCK DATA

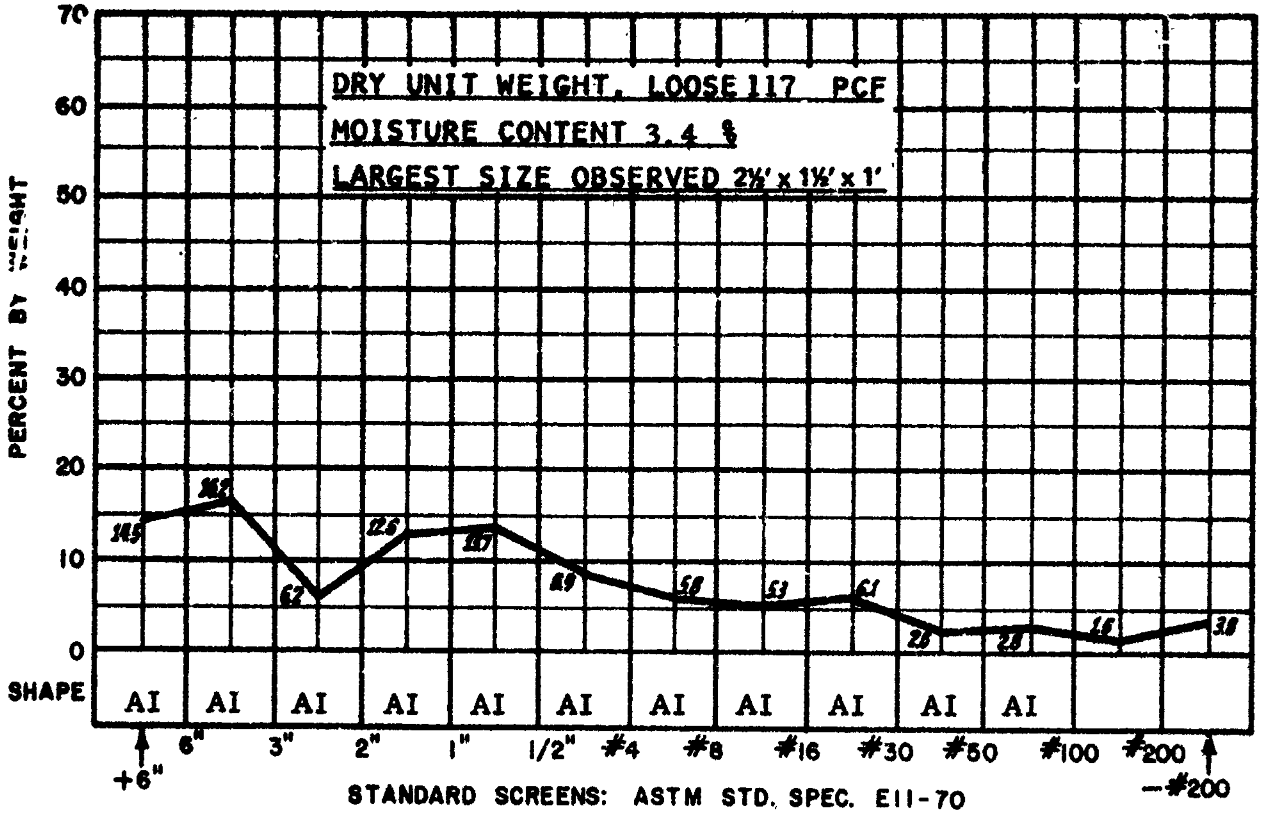
Abrasiveness	**Pot. Vol. Change, Material**	**Spec. Gravity, Material**
N. A.	**Size(-)0.056" : 0**	**Size(-)0.75" : 2.65**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.50%	**Plastic Limit 17.41 %**	**Shrinkage Limit 17.13 %**
Plasticity Index 2.09 %	**Toughness Index 0.51**	**Flow Index 4.10**

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop	**Apparent Cohesion PSF**	**Angle/Repose 10" Drop**
@ 2.8 % Moisture, 39°	**@ 3.0 % Moisture, 80**	**@ 2.8 % Moisture, 36°**
Angle Slide Steel Plate	**Bulk Density PCF**	**Angle Internal Friction**
@ 2.8 % Moisture, 31°	**@ 0.0 % Moisture, 91.2**	**@ 3.0 % Moisture, 38°**



DRY UNIT WEIGHT, LOOSE 117 PCF
MOISTURE CONTENT 3.4 %
LARGEST SIZE OBSERVED 2½' x 1½' x 1'

MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, biotitic, fine grained. High strength. RQD (Est.) 90%. DUW: 164 PCF. Ground water: Minor. Hardness: Shore 99.2, Schmidt 54.

System Class: Conventional Rail. 10' high x 16' wide x 8' alcove. Two jack leg drills, 72-9' holes, double V-cut. PF 6.3#/CY. Mucking: Diesel front end loader, 1/2 CY. Haulage: Rail. Support: Grouted rock bolts and roof plates.

ROCK DATA:

Lithology: Igneous, granite, fine grained, moderately fractured, major quartz and minor feldspar and dark mineral contents.
Uniaxial Compressive Strength: 24 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 160 PCF.
Ground Water: Minor, primarily from fault zones.
Hardness: Schmidt 54 (Note 2).
Youngs Mod.: 8.30 PSI x 10^6 (Note 2).
Poisson Ratio: 0.33 (Note 2).

TUNNEL DATA:

Size: 9-'10" diameter. **Grade:** (+) 0.22%.
Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 5 to 20 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.
Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model (Modified)*. Weight 67 tons.
Cutters: 29 Hughes Tool Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 19-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.
Rotation: 8 1/2 RPM.
Torque: 150 K ft. # max , 125 K ft # operating.
Thrust: 630 K lbs.
Muck System: Bucket from face, 22" belt conveyor to rear.
Power System: 3-200 HP electric motor driven hydraulic pumps driving four hydraulic motors and the thrust and anchor cylinders.
Guidance System: Laser

*Modified by replacement of original by a Hughes Tool Co. cutting head and cutters.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

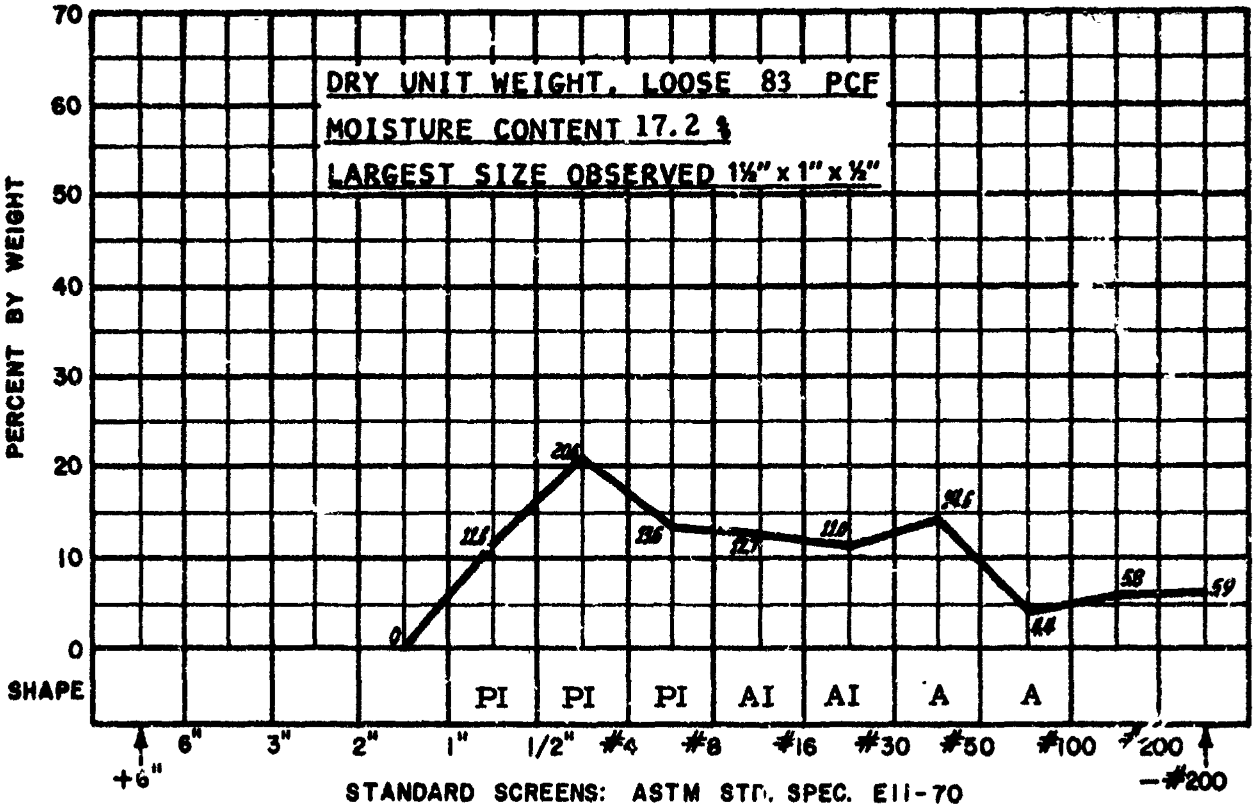
Abrasiveness N. A.	**Pot. Vol. Change, Material** **Size (-)0.056 : 0**	**Spec. Gravity, Material** **Size (-) 0.75 : 2.64**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.20%	Plastic Limit 18.97%	Shrinkage Limit 17.50%
Plasticity Index 0.23 %	Toughness Index 0.06	Flow Index 3.40

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 6.9 % Moisture, 39°	Apparent Cohesion PSF @ 7.1 % Moisture, 0	Angle/Repose 10" Drop @ 6.9 % Moisture, 34°
Angle Slide Steel Plate @ 6.9 % Moisture, 40°	Bulk Density PCF @ 0.0 % Moisture, 91	Angle Internal Friction @ 7.1 % Moisture, 33°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, fine grained, moderately fractured. High strength. RQD (Est.) 90%. DUW: 160 PCF. Ground water: Minor. Hardness: Schmidt 54.

System Class: TBM, Wirth Erkelenz, Hardrock, with Hughes Tool head, 9' 10" dia. 29 Hughes Tool TCB roller and cone cutters. RPM: 1/2. 125 K ft # torque, 630 K# thrust. Mucking: Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts.

ROCK DATA:

Lithology: Igneous, granite, massive, major feldspar and quartz, minor dark mineral content.
Uniaxial Compressive Strength: 35 KPSI
RQD: (Estimated) 96%
Dry Unit Weight: 161 PCF
Ground Water: Minor, through fractures.
Hardness: Schmidt 42.
Youngs Mod.: 6.40 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 10' x 10' Horse shoe. Grade (-) 0.22%
Ventilation System: 8 KCFM, exhaust, 22" pipe.
Utility System: 6" air line, 2" water line
Water Inflow: 5-10 gpm.
Power System: 110V. lighting
Haulage System: Muck and supplies: Eimco 912 diesel.
Support System: 4" WF steel sets @ 4' in 180' approx. at portal end; 1" x 7' grouted rock bolts for approx. 35'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Crawler Jumbo, 2-D93 Drifters, 10' feeds.
Drill Round: 48-1 3/4" holes, double V cut, 8' depth.
Explosives: 175# Gelex #2-70%. Powder factor, 6.1#/CY.
Blasting: Electrical, regular delays, zero through #10.
Mucking System: Eimco 912 diesel, front end loader.
Guidance: Transit lines.

NOTE 2: Inferred from D. U. Deere AD646610-1966.

MUCK DATA

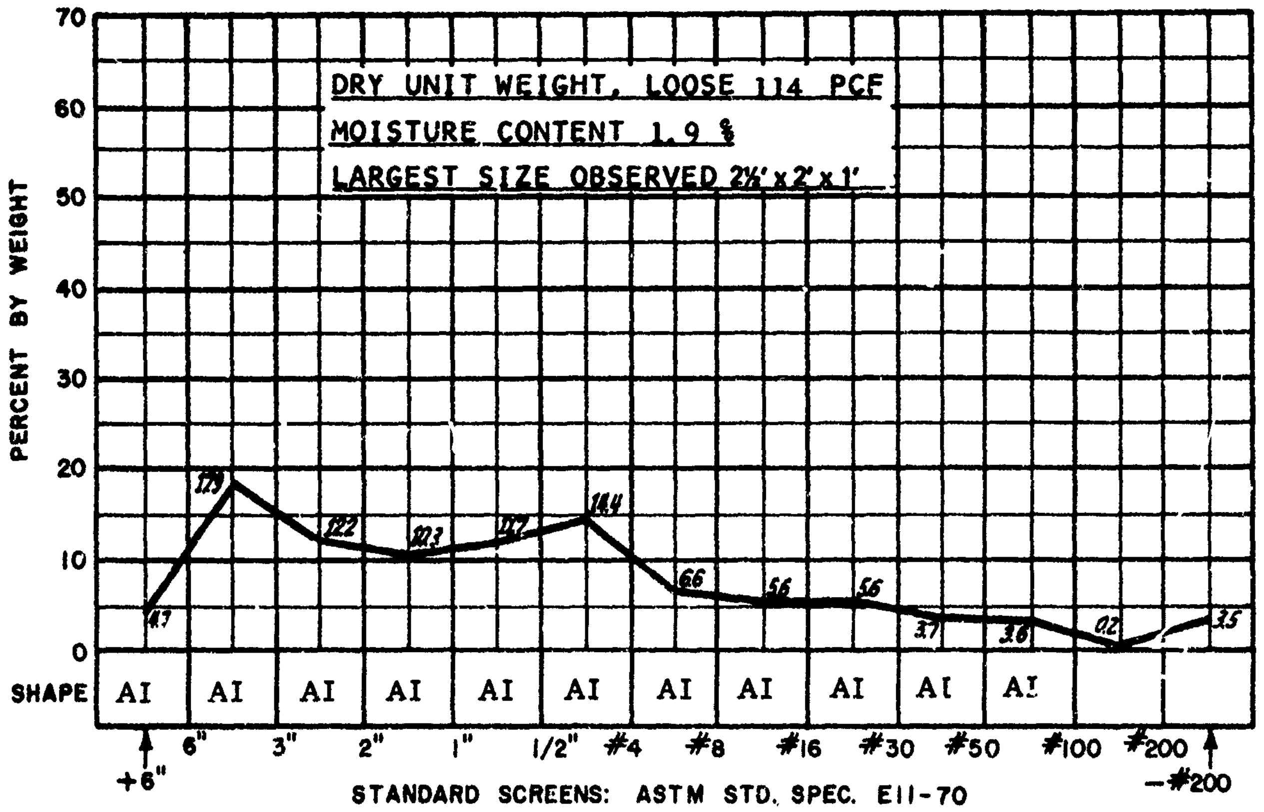
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056": 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.59**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 16.20 %	Plastic Limit 15.78 %	Shrinkage Limit 13.67 %
Plasticity Index 0.42 %	Toughness Index 0.14	Flow Index 3.00

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 0.9 % Moisture, 39°	Apparent Cohesion PSF @ 0.9 % Moisture, 215	Angle/Repose 10" Drop @ 0.9 % Moisture, 36°
Angle Slide Steel Plate @ 0.9 % Moisture, 34°	Bulk Density PCF @ 0.0 % Moisture, 106	Angle Internal Friction @ 0.9 % Moisture, 46°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, massive, minor dark minerals. Very high strength. RQD (Est.) 96%. DUW: 161 PCF. Ground water: Minor. Hardness: Schmidt 42.

System Class: Conventional Trackless. 10' x 10' arch. Two machine jumbo, 48-8' holes, V-cut. PF 6.1 #/CY. Front end loader mucking and haulage. Support: Steel sets at 4', 25%, occasional rock bolts in 730'.

ROCK DATA:

Lithology: Igneous, granite, gray, fine grained, moderately jointed with 1.5' to 2' bands of light tan pegmatite and laminated granite gneiss.
Uniaxial Compressive Strength: 32 KPSI.
RQD: (Estimated) 80%.
Dry Unit Weight: 162 PCF.
Ground Water: Formations generally dry.
Hardness: Schmidt 50.
Youngs Mod.: 8.00 PSI x 10^6 (Note 2).
Poisson Ratio: 0.31 (Note 2).

TUNNEL DATA:

Size: 10' x 10', Modified Horseshoe. Grade: (+) 1/4%
Ventilation: 15 KCFM, exhaust, 26" dia. pipe, 125 HP at 7200' from portal.
Utility System: 8" air line, 4" water line, 10" pump line.
Water Inflow: 20 GPM. (As much as 400 GPM in occasional pockets)
Power System: 4160/440V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail. Three-15T. Goodman locomotives; 2 trains of 11 to 13 cars @ 4.8 CY. Canton car transfer at 50' to 250' from face, passing tracks @1500'.
Support System: 4" WF sets @ 4', 3' and 2' for 23%, 1" x 7' grouted bolts for 17%, Shotcrete: 500 psi @ 18 hrs., 3750 psi @ 28 days, for 16% of 7200'.

EXCAVATION DATA:

Conventional Rail System.
Drilling: Rail mounted hydrojib jumbo, 4-CF99, & 1-CF133 drifters, 12' feed.
Drill Round: 38 holes, 1-5" center hole and 37 at 1 3/4" dia. Spiral Burn Cut, 10 1/2' depth.
Explosives: 183 lbs. Gelex #2-75% x 1-1/2" dia., and 20 lbs. Smoothtex 70% x 7/8" dia. in upper perimeter holes. Powder factor: 5 1/2#/CY.
Blasting: Electrical, regular delays zero through 10.
Mucking: EIMCO #25, rail, air operated.
Guidance: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056" : 0

Spec. Gravity, Material
Size(-)0.75" : 2.70

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.0%
Plasticity Index 1.0 %

Plastic Limit 17.0 %
Toughness Index 0.23

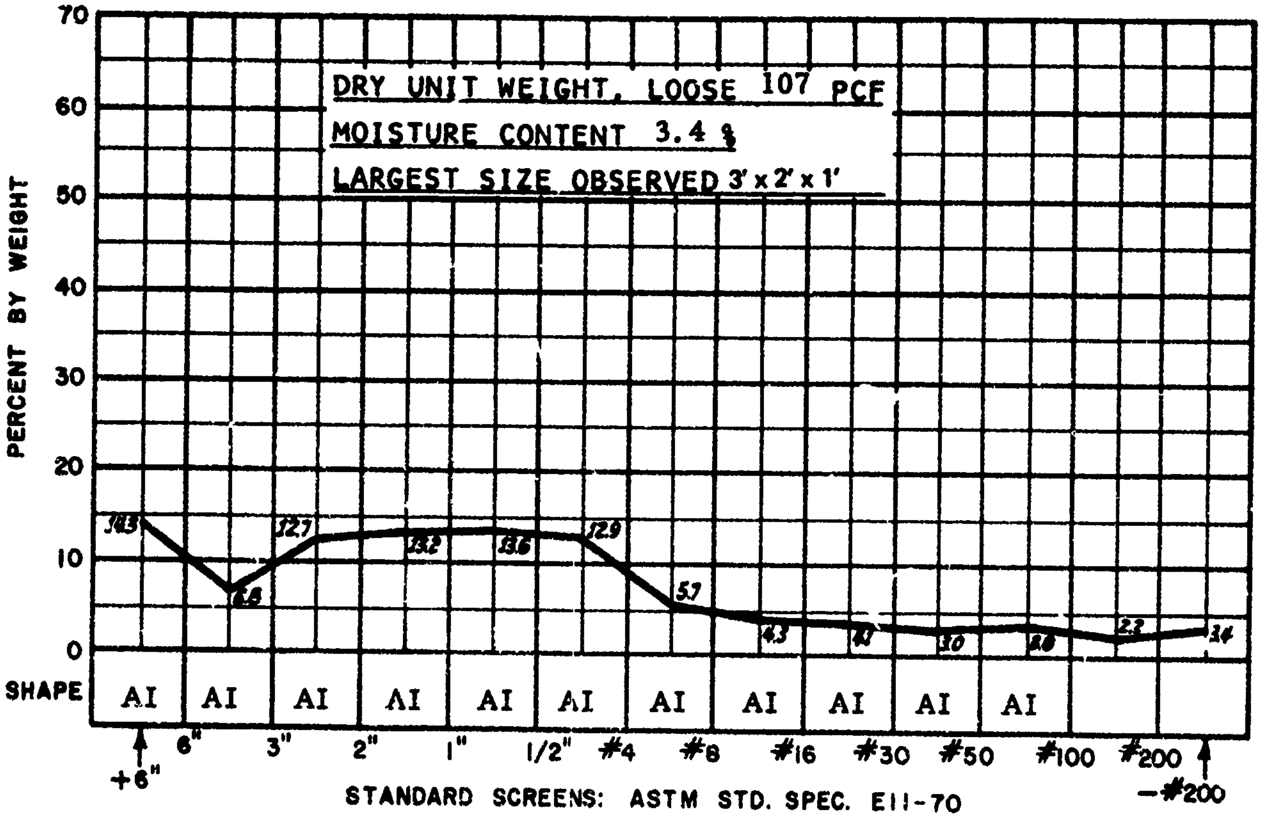
Shrinkage Limit 13.4 %
Flow Index 4.4

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 1.3 % Moisture, 40°
Angle Slide Steel Plate
@ 1.3 % Moisture, 32°

Apparent Cohesion PSF
@ 2.2% Moisture, 780
Bulk Density PCF
@ 0.0% Moisture, 103.48

Angle/Repose 10" Drop
@ 1.3 % Moisture, 37°
Angle Internal Friction
@ 2.2 % Moisture, 44°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, fine grained, with 1.5' to 2' bands of pegmatite and laminated granite gneiss. High strength. RQD (Est.) 80%. DUW: 162 PCF. Ground water: Minor. Hardness: Schmidt 50.

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 38 10-1/2' holes, burn cut. PF 5.5#/CY. Overhead loader mucking, rail haulage. Support: Steel sets at 2' to 4', 23%, rock bolts 17%, shotcrete 16%, in 7200'.

ROCK DATA:

Lithology: Igneous, granite, gray, gneissic, moderately jointed.
Uniaxial Compressive Strength: 39 KPSI
RQD: (Estimated) 80%
Dry Unit Weight: 164 PCF
Ground Water: Generally dry - occasional flows through fractures
Hardness: Schmidt 57 (Note 2).
Youngs Mod.: 7.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.32 (Note 2)

TUNNEL DATA:

Size: 10' x 10' modified horseshoe. Grade: (+) 1/4%
Ventilation System: 8 KCFM exhaust, 26" pipe, 150 HP at 10,000 from portal.
Utility System: 8" air line, 4" water line, 10" pump line
Water Inflow: 20-400 GPM, normal 135 GPM
Power System: 4160/480/240V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail. Three-10T. Goodman locomotives, 3 trains of 5 to 7 cars @ 4.8 cy. Canton car transfers at 50' to 250' from face, passing tracks @ 1500' to 2500'.
Support System: Minor rock bolt support for last 2500'.

EXCAVATION DATA:

Conventional Rail System
Drilling: 4 boom Hydojib jumbo, 4-CF99 + 1-CF133 drifters, 12' contin. feed.
Drill Round: 36-40 holes, 1 3/4" diameter, 11' deep, spiral burn cut with 5" center hole.
Explosives: 200 lbs. 75% Gelex #2, 25 lbs. 30% Dupont 7/8" x 24" in back holes.
Blasting: Electrical, regular delays 0-10, Powder factor 5.5#/CY.
Mucking: EIMCO #25, rail, air operated
Guidance: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

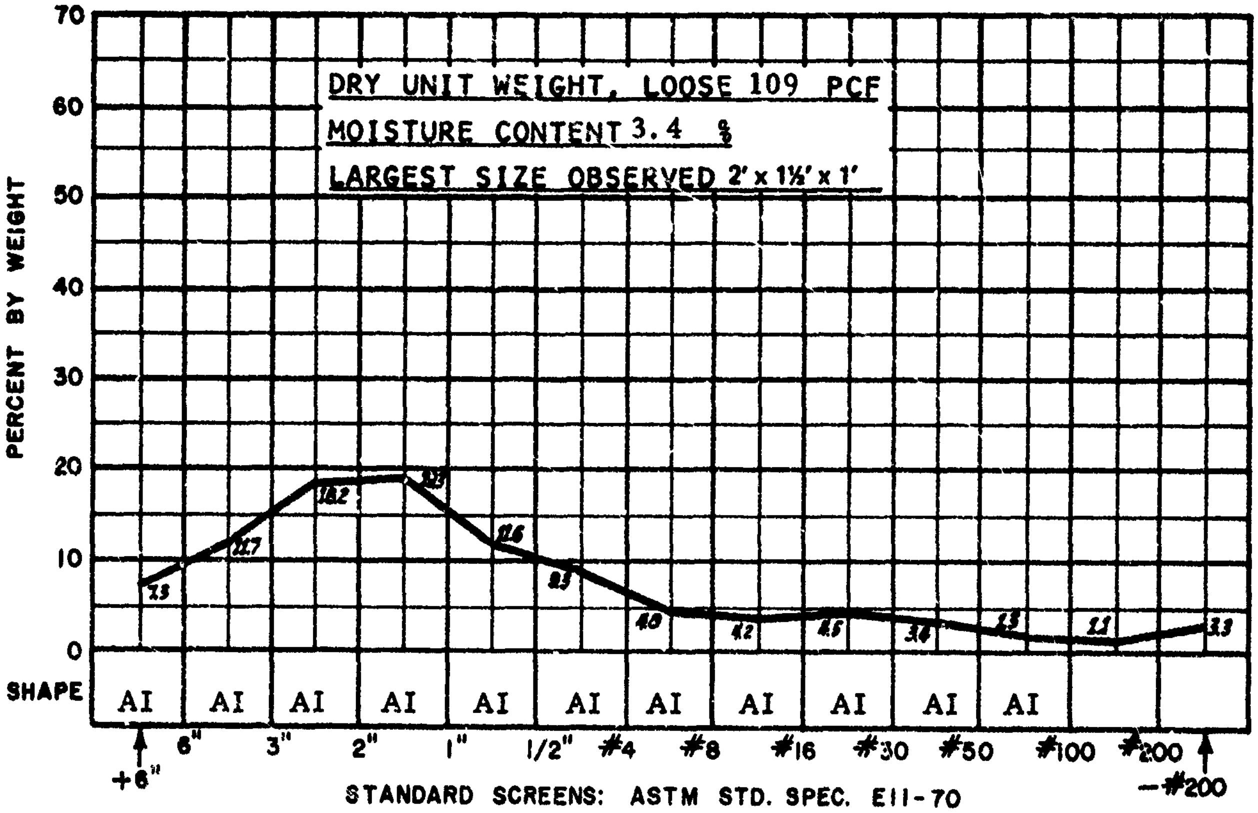
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.60

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.10%	Plastic Limit 17.95%	Shrinkage Limit 11.00 %
Plasticity Index 0.15 %	Toughness Index 0.04	Flow Index 3.20

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 3.8 % Moisture, 38°	Apparent Cohesion PSF @ 2.6 % Moisture, 30	Angle/Repose 10" Drop @ 3.8 % Moisture, 35°
Angle Slide Steel Plate @ 3.8 % Moisture, 38°	Bulk Density PCF @ 0.0 % Moisture, 105	Angle Internal Friction @ 2.6 % Moisture, 44°


DRY UNIT WEIGHT, LOOSE 109 PCF
MOISTURE CONTENT 3.4 %
LARGEST SIZE OBSERVED 2' x 1½' x 1'

MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, gneissic, moderately jointed. Very high strengt RQD (Est.) 80%. DUW: 164 PCF. Ground water: Minor. Hardness: Schmidt 57.

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 36 to 40 - 11' holes, burn cut. PF 5.5#/CY. Overhead loader mucking - rail haulage. Support: occasional rock bolts 7200' to 10,000'.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. H-2
4/1/73	MDN	Sheet 2
	2	

ROCK DATA:

Lithology: Igneous, granite gneiss, moderately jointed, with three intersecting sets of fractures dipping 45° to vertical at 4" to 2'.
Uniaxial Compressive Strength: 29 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 162 PCF.
Ground Water: Minor to moderate in fractures.
Hardness: Schmidt 46
Youngs Mod.: 6.89 PSI x 10^6
Poisson Ratio: 0.31

TUNNEL DATA:

Size: 10' x 10' modified horseshoe. Grade: ([illegible] 1/4%.
Ventilation System: 6 KCFM exhaust, 26" pipe, 220 HP at 22,000' from portal.
Utility System: 10" air line, 4" water line, 12" pump line.
Water Inflow: 400 GPM, total, 2-3 GPM from breast.
Power System: 4160/480/240V.
Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail. Three-15T. Goodman locomotives, 3 trains of 13 cars @ 4.8 cy. Canton car transfers at 50' to 250' from face, passing tracks @ 2700' to 3600'.
Support System: 1" x 7' grouted bolts in current use. Total: rock bolts 9%, 3" to 4" shotcrete 36%, 4" WF steel sets 10%.

EXCAVATION DATA:

Conventional Rail System
Drilling: 4 boom Hydojib jumbo, 4-CF93 + 1-PR123 drifters, 12' contin. feed.
Drill Round: 40 holes, 1 3/4" diameter, 11' deep, spiral burn cut with 5" center hole.
Explosives: 200 lbs. 75% Gelex #2, and 25 lbs., 30% 7/8" x 24" in back holes.
Blasting: Electrical, regular delays 0-10, Powder factor 5.8#/CY.
Mucking: EIMCO #25, rail, air operated.
Guidance: Laser.

MUCK DATA

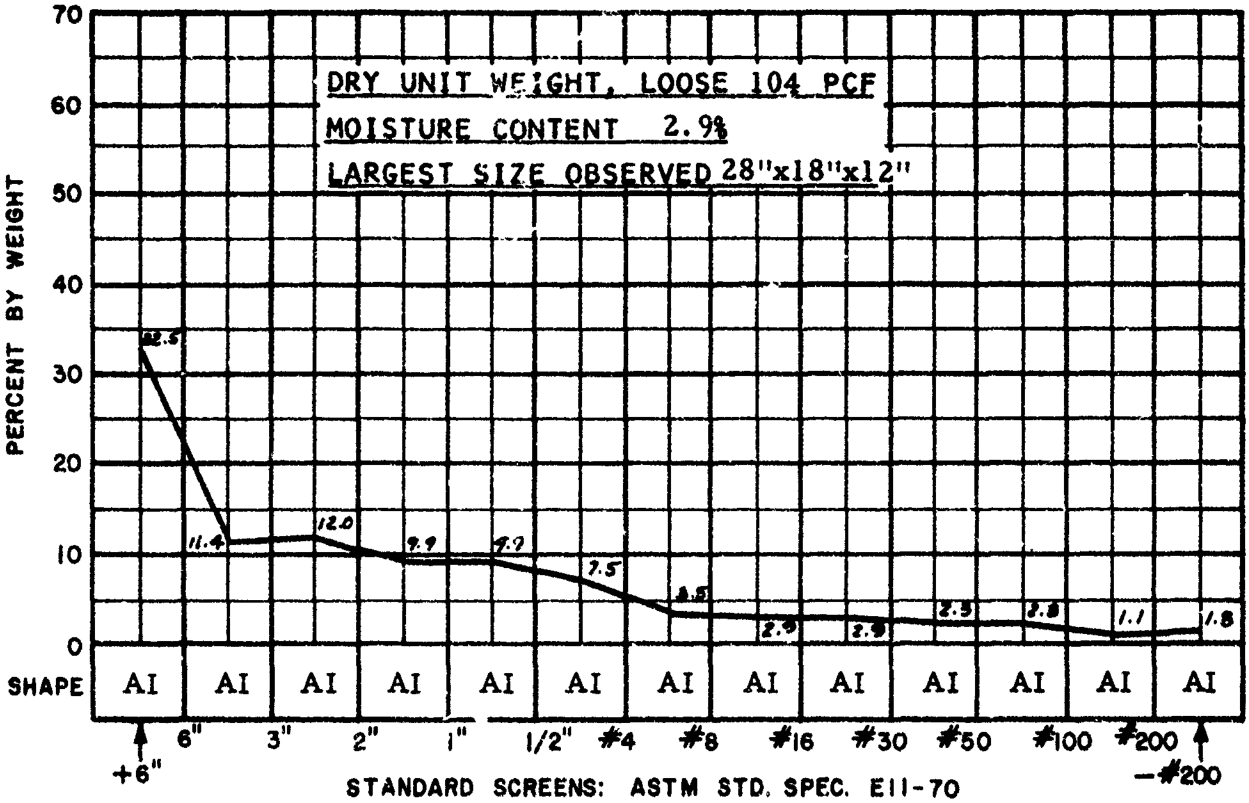
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.497

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 17.20%	Plastic Limit 16.80%	Shrinkage Limit 16.65%
Plasticity Index 0.40%	Toughness Index 0.11	Flow Index 3.80

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop @ 4.46% Moisture, 38.50°	Apparent Cohesion PSF @ 4.46% Moisture, 0	Angle/Repose 10" Drop @ 4.46% Moisture, 35.35°
Angle Slide Steel Plate @ 4.46% Moisture, 31.50°	Bulk Density PCF @ 4.46% Moisture, 98.9	Angle Internal Friction @ 4.46% Moisture, 43.50°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite gneiss, moderately jointed with intersecting fractures dipping 45° to vertical at 4" to 2', 1-1/2' average. High Strength. RQD (Est.) 90%. DUW: 162 PCF. Ground water: Minor to moderate. Hardness: Schmidt 46.

System Class: Conventional Rail. 10' x 10' arch. 5 machine jumbo, 40-11' holes, burn cut w/5" center hole. PF 4.75#/CY. Overhead loader mucking-rail haulage. Support: Grouted rock bolts as required.

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.
Uniaxial Compressive Strength: 25 KPSI
RQD: (Estimated) 83%
Dry Unit Weight: 162 PCF.
Ground Water: None apparent
Hardness: Schmidt 53.
Youngs Mod.: 8.80 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 5 1/2%.
Ventilation System: 76 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage, surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220V for fans, 110 volt lighting.
Haulage System: Wagner ST8 Scooptram to raise, chute loaded into rail mounted skip. Personnel and supplies by diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless System
Drilling: Gardner-Denver 3 boom jumbo, 1 PR123 and 2 DH 123 drifters, 12' feeds.
Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2' deep.
Explosives: 25# - 1 1/2" x 8", 60% or 75% primers, 25# - 7/8" x 16", 30% in trim holes, 40# - 1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/cy.
Blasting: Electrical, regular delays, 0 through 15.
Mucking: Scooptram.
Guidance: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

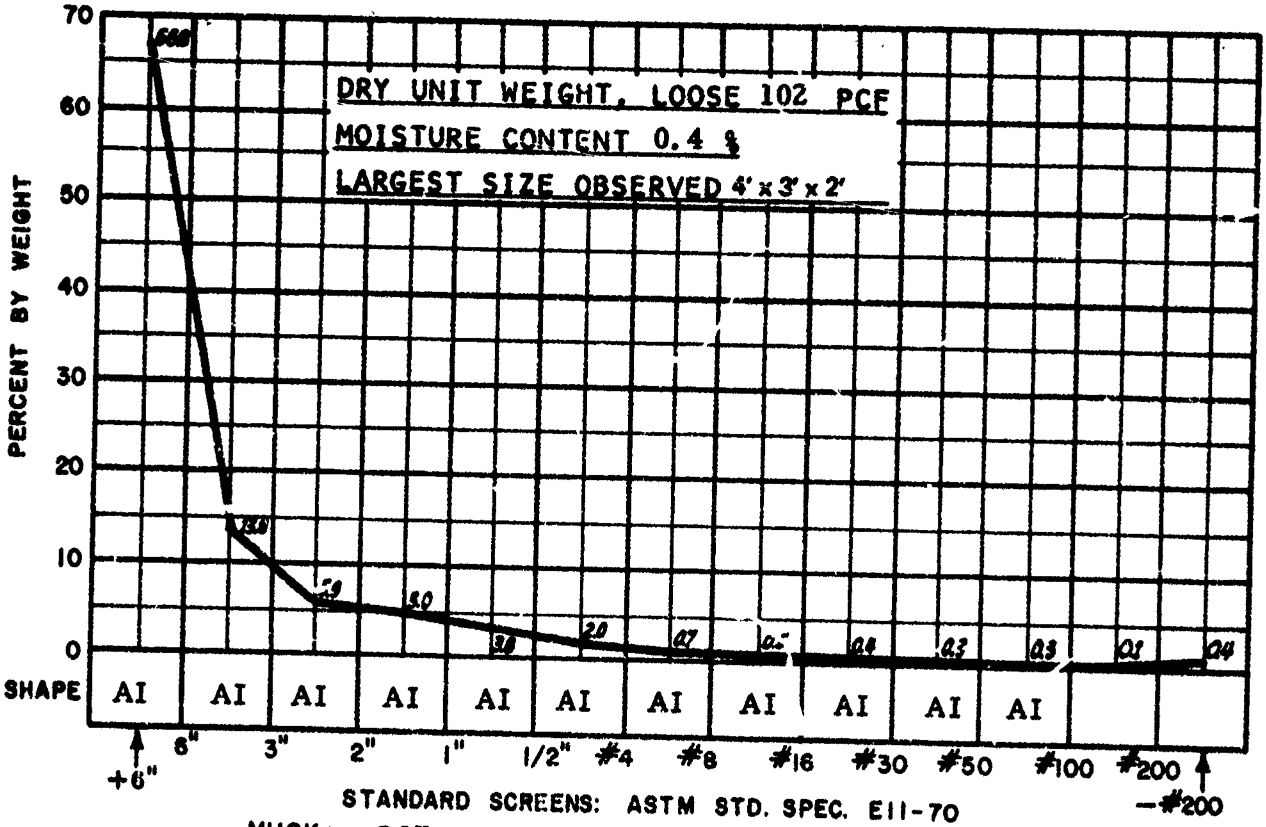
Abrasiveness **N. A.**	**Pot. Vol. Change, Material Size (-)0.056" : 0**	**Spec. Gravity, Material Size (-)0.75" : 2.85**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.10 %	**Plastic Limit 17.98 %**	**Shrinkage Limit 17.69 %**
Plasticity Index 0.12 %	**Toughness Index 0.30**	**Flow Index 3.90**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 0.8 % Moisture, 33°**	**Apparent Cohesion PSF** **@ 0.4 % Moisture, 435**	**Angle/Repose 10" Drop** **@ 0.8 % Moisture, 30°**
Angle Slide Steel Plate **@ 0.8 % Moisture, 29°**	**Bulk Density PCF** **@ 0.0 % Moisture, 97.3**	**Angle Internal Friction** **@ 0.4 % Moisture, 43°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 83%. DUW: 162 PCF. Ground Water: Dry. Hardness: Schmidt 53.

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47-10 1/2' holes, burn cut. PF 4#/CY. Scooptram mucking and haulage to raise-rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 1	Ident. No. LK-1 Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, with minor steeply inclined joints.
Uniaxial Compressive Strength: 28 KPSI
RQD: (Estimated) 83%
Dry Unit Weight: 165 PCF
Ground Water: None apparent
Hardness: Schmidt 56 (Note 2).
Youngs Mod.: 9.40 PSI x 10^6 (Note 2).
Poisson Ratio: 0.33 (Note 2).

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 2%.
Ventilation System: 22 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220 for pumps and fans, 110V lighting.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station, rail mounted skip to surface. Personnel and supplies by diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless system.
Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.
Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2' deep.
Explosives: 25#-1 1/2" x 8", 60% or 75% primers, 25#-7/8" x 16", 30% in trim holes, 40#-1 1/2" x 16", 45% in 6 hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/CY.
Blasting: Electrical, regular delays, 0 through 15.
Mucking: Scooptram.
Guidance: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

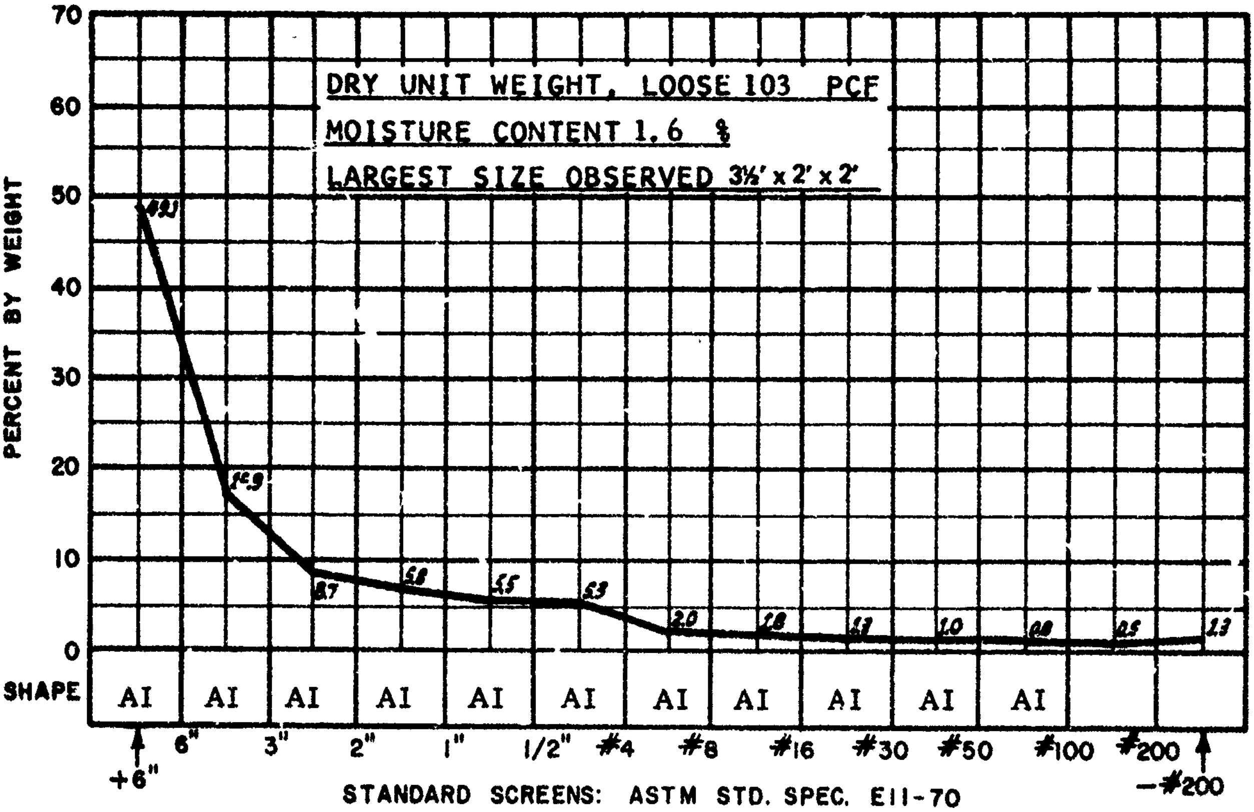
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.73**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.50%	**Plastic Limit 19.14%**	**Shrinkage Limit 17.29 %**
Plasticity Index 0.36 %	**Toughness Index 0.058**	**Flow Index 6.2**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 4.7 % Moisture, 43°**	**Apparent Cohesion PSF** **@ 4.9 % Moisture, 210**	**Angle/Repose 10" Drop** **@ 4.7 % Moisture, 42°**
Angle Slide Steel Plate **@ 4.7 % Moisture, 33°**	**Bulk Density PCF** **@ 0.0 % Moisture, 97.6**	**Angle Internal Friction** **@ 4.9 % Moisture, 39°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, minor steep angle joints. High strength. RQD (Est.) 83%. DUW: 165 PCF. Ground water: Dry. Hardness: Schmidt 56.

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47 - 10 1/2' holes, burn cut. PF 4#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 1	Ident. No. LK-2 Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.
Uniaxial Compressive Strength: 32 KPSI
RQD: (Estimated) 92%
Dry Unit Weight: 165 PCF
Ground Water: None apparent.
Hardness: Schmidt 54.
Youngs Mod.: 9.00 PSI x 10^6 (Note 2).
Poisson Ratio: 0.32 (Note 2).

TUNNEL DATA:

Size: 12' diameter vertical bore hole, reamed from 1312' to 1212' below collar, from a 13 7/8" diameter pilot hole.
Ventilation System: None in bore hole.
Utility System: 5 to 10 gpm. Water for dust suppression through pilot hole.
Water Inflow: None apparent
Power System: 440V to surface drive motors.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/ rail mounted skip to surface.
Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight 49 tons. Cutters: 27 Robbins, Steel Disc. Gage: 3-12". Center: 1-11". Interior: 19-12" single and 2-11" twin. Two sets of three 12" dia. TCB roller stabilizers are installed on third points below the cutter head.
Rotation, cutter head: 6 RPM.
Torque: 260 K Foot Lbs. Full Load.
Reaming Pull: Total 814K Lbs @ 2400 PSI, net 507 K#.
Muck Disposal: Scooptram, underground.
Power System: 3-440V, 100 HP motors, 1.667: 1 gathering box ratio.
Guidance System: Survey in pilot hole.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-)0.056" : 0

Spec. Gravity, Material
Size (-)0.056": 2.67

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.00 %
Plasticity Index 4.05 %

Plastic Limit 20.95 %
Toughness Index 0.73

Shrinkage Limit 19.68 %
Flow Index 5.50

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 3.4 % Moisture, 33°

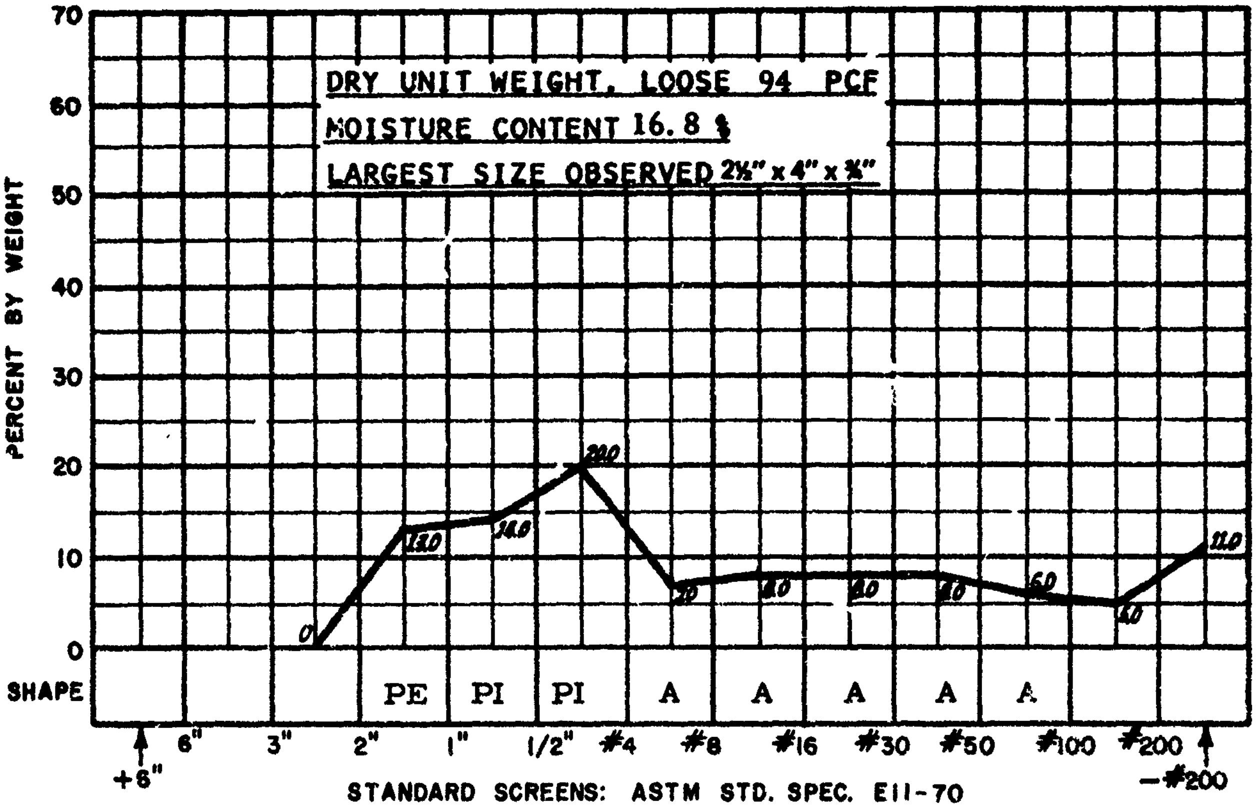
Apparent Cohesion PSF
@ 3.0 % Moisture, 75

Angle/Repose 10" Drop
@ 3.4 % Moisture, 32°

Angle Slide Steel Plate
@ 3.4 % Moisture, 38°

Bulk Density PCF
@ 0.0 % Moisture, 100

Angle Internal Friction
@ 3.0 % Moisture, 37°



DRY UNIT WEIGHT, LOOSE 94 PCF
MOISTURE CONTENT 16.8 %
LARGEST SIZE OBSERVED 2½" x 4" x ¾"

MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD (Est.) 92%, DUW: 165 PCF. Ground water: Dry. Hardness: Schmidt 54.

System Class: RBM, Robbins H81R, 12' dia. 27 Robbins disc cutters, 6 RPM, 383.5 Kft. # torque, 408 K# pull average. Mucking and haulage: Scooptram underground, rail skip to surface. Support: None.

ROCK DATA:

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, frequent flat angled joints.
Uniaxial Compressive Strength: 3 KPSI (One Spec., L/R = 1.3).
RQD: (Estimated) 86%.
Dry Unit Weight: 137 PCF.
Ground Water: None apparent.
Hardness: Schmidt 20 (Note 3).
Youngs Mod.: 1.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.20 (Note 2).

TUNNEL DATA:

Size: 4' diameter vertical bore hole reamed from 298' to 286' below collar from a 13 7/8" diameter pilot hole.
Ventilation System: Not applicable.
Utility System: 5 to 10 gpm water for dust suppression through pilot hole.
Water Inflow: None apparent.
Power System: 440V to surface drive motors.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/ rail mounted skip to surface. Personnel and supplies by diesel truck.
Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight: 49 tons.
Cutters: 11-Robbins, Steel Disc. Gage: 1-12" twin. Center 1-12" single. Interior: 4-12" twin. Three 12" TCB roller stabilizers are installed at third points below the cutter head.
Rotation, Cutter head: 6 RPM
Torque: 260 K Foot/lbs. Full Load
Reaming Pull: Net 207K#
Muck Disposal: Scooptram underground.
Power System: 3-440V, 100 HP motors, 1.667: 1 gathering box ratio.
Guidance System: Survey in pilot hole.

NOTE 2: Inferred from D. U. Deer; AD 646610-1966.
NOTE 3: Test of Unpolished Specimen.

MUCK DATA

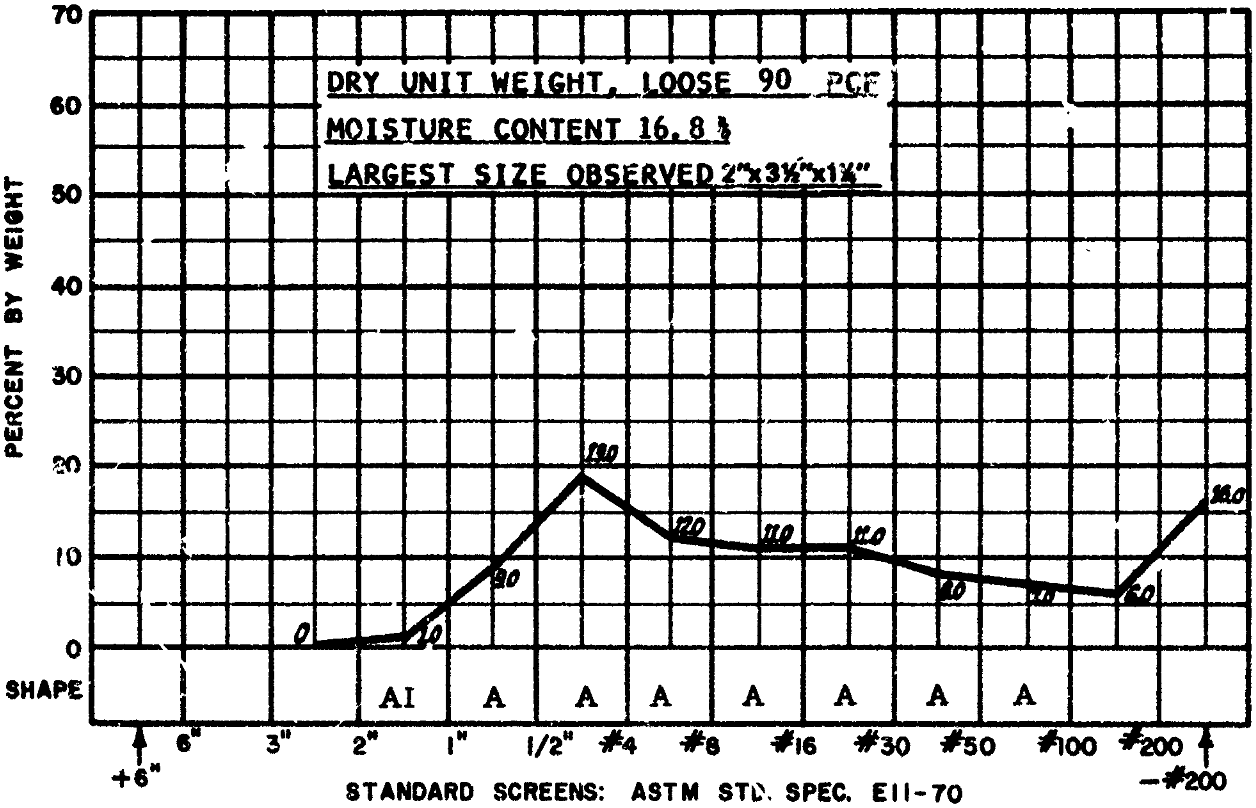
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-)0.75" : 2.53**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.40 %	**Plastic Limit 18.16 %**	**Shrinkage Limit 17.27 %**
Plasticity Index 1.24 %	**Toughness Index 0.31**	**Flow Index 4.00**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 3.7 % Moisture, 30°**	**Apparent Cohesion PSF** **@ 0.2 % Moisture, 0**	**Angle/Repose 10" Drop** **@ 3.7 % Moisture, 29°**
Angle Slide Steel Plate **@ 3.7 % Moisture, 32°**	**Bulk Density PCF** **@ 0.0 % Moisture, 101**	**Angle Internal Friction** **@ 0.2 % Moisture, 40°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, frequent flat angled joints. Very low strength. RQD (Est.) 86%. DUW: 137 PCF. Ground water: Dry. Hardness: Schmidt 20.

System Class: RBM, Robbins H81R, 4' dia. 11 Robbins disc cutters. 6 RPM, 260 K ft # torque, 198 K # pull (average). Mucking and Haulage: Scooptram underground, rail skip to surface. Support: None.

ROCK DATA:

Lithology: Igneous, quartz monzonite porphyry, intensely altered, coarse grained.
Uniaxial Compressive Strength: 7 KPSI.
RQD: (Estimated) 35%.
Dry Unit Weight: 158 PCF
Ground Water: None
Hardness: Schmidt 37.
Youngs Mod.: 4.76 PSI x 10^6.
Poisson Ratio: 0.10.

TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (-) 26%.
Ventilation System: 22 KCFM, pressure, 48" pipe and tubing, 150 HP @ 650'.
Utility System: 6" air, 2" water, 4" pump line.
Water Inflow: Minor
Power System: 4160/220, 110V lighting.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by Diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Three boom hydrojib jumbo, w/PR123 drifters on 12' feeds.
Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1-4" diameter center hole, all 10 1/2' deep.
Explosives: 25#-1 1/2" x 8", 60% as primers, 25#-7/8" x 16", 30% in trim holes, 300#-1 1/2" x 16" in remainder of round. Powder factor: 4.7#/CY.
Blasting: Electrical, regular delays 0 through 15.
Mucking System: Scooptram
Guidance: Laser.

MUCK DATA

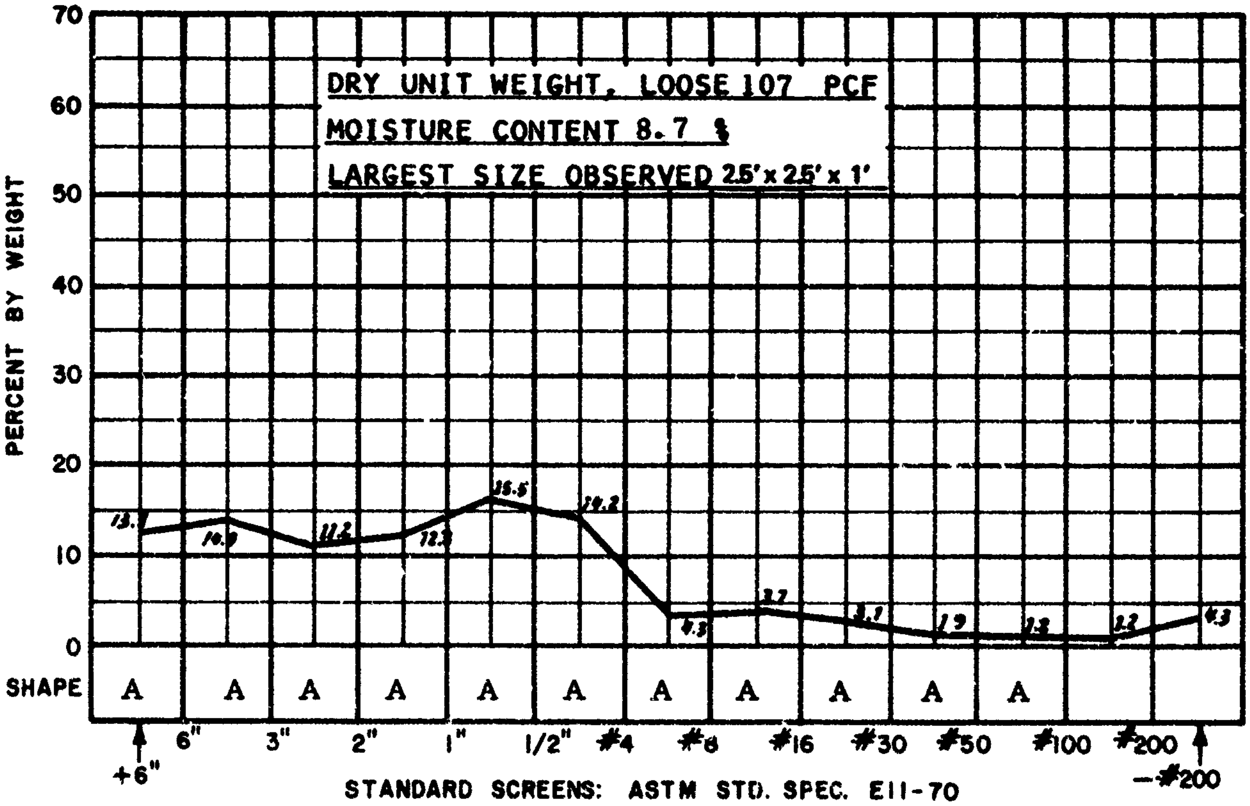
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size(-)0.056" : 0**	**Spec. Gravity, Material** **Size(-)0.75" : 2.68**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.00%	**Plastic Limit 17.12 %**	**Shrinkage Limit 17.04 %**
Plasticity Index 0.88 %	**Toughness Index 0.18**	**Flow Index 5.00**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 1.7 % Moisture, 29°**	**Apparent Cohesion PSF** **@ 0.2 % Moisture, 70**	**Angle/Repose 10" Drop** **@ 1.7 % Moisture, 26°**
Angle Slide Steel Plate **@ 1.7 % Moisture, 28°**	**Bulk Density PCF** **@ 0.0 % Moisture, 114**	**Angle Internal Friction** **@ 0.2 % Moisture. 45°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: igneous: Quartz monzonite porphyry, intensely altered, course grained. Low strength. RQD (Est.) 85%. DUW: 158 PCF. Ground water: None. Hardness: Schmidt 37.

System Class: Conventional Trackless, 15' wide x 14' arch. Three boom jumbo, 42-10 1/2' holes, burn cut. PF 4.7 #/CY. Scooptram mucking and haulage rail skip to surface. Support: Roof plates and rock bolts at 4'.

ROCK DATA:

Lithology: Igneous, quartz monzonite, coarse grained with many sulfide veinlets, highly fractured, pronounced orthogonal faulting.
Uniaxial Compressive Strength: 19K.
RQD: (Estimated) 50%.
Dry Unit Weight: 165 PCF
Ground Water: Saturated below working levels.
Hardness: Schmidt 47.
Youngs Mod.: 7.46 PSI x 10^6.
Poisson Ratio: 0.20.

TUNNEL DATA:

Size: 12' x 12' Grade: (+) 0.4%
Ventilation System: 14 KCFM, pressure, 24" diameter pipe, 60 HP @ 400' from airway.
Utility System: 2" water, 4" airline, 8" pump line.
Water Inflow: None upper levels, 20-200 gpm lower levels.
Power System: 2400/480/240/110.
Haulage System: Muck, supplies, personnel by railcars, 8 ton battery locomotives, 10 ton bottom dump devel. cars, 36" gage, 45# rail.
Support System: 10 1/2' x 12" x 12" wood posts, 12" H beam cap sets at 5' centers in normal ground.

EXCAVATION DATA:

Conventional Rail System.
Drilling: 3 boom hydrojib jumbo, CF79 drifters on 6' shells or D89 drifters on 6' chain feeds.
Drill Round: 52 holes, 1 5/8" diameter, including 2 hole wedge burn and 4 relievers, 5' depth.
Explosives: 100# Carbamite per round (Amogel in wet ground).
Blasting: #6 caps, 8' fuse, timed by order of connection to igniter cord. (Primacord used in place of primer powder) Powder factor 3.8#/CY.
Mucking System: Eimco 40 loader.
Guidance: Transit survey.

MUCK DATA

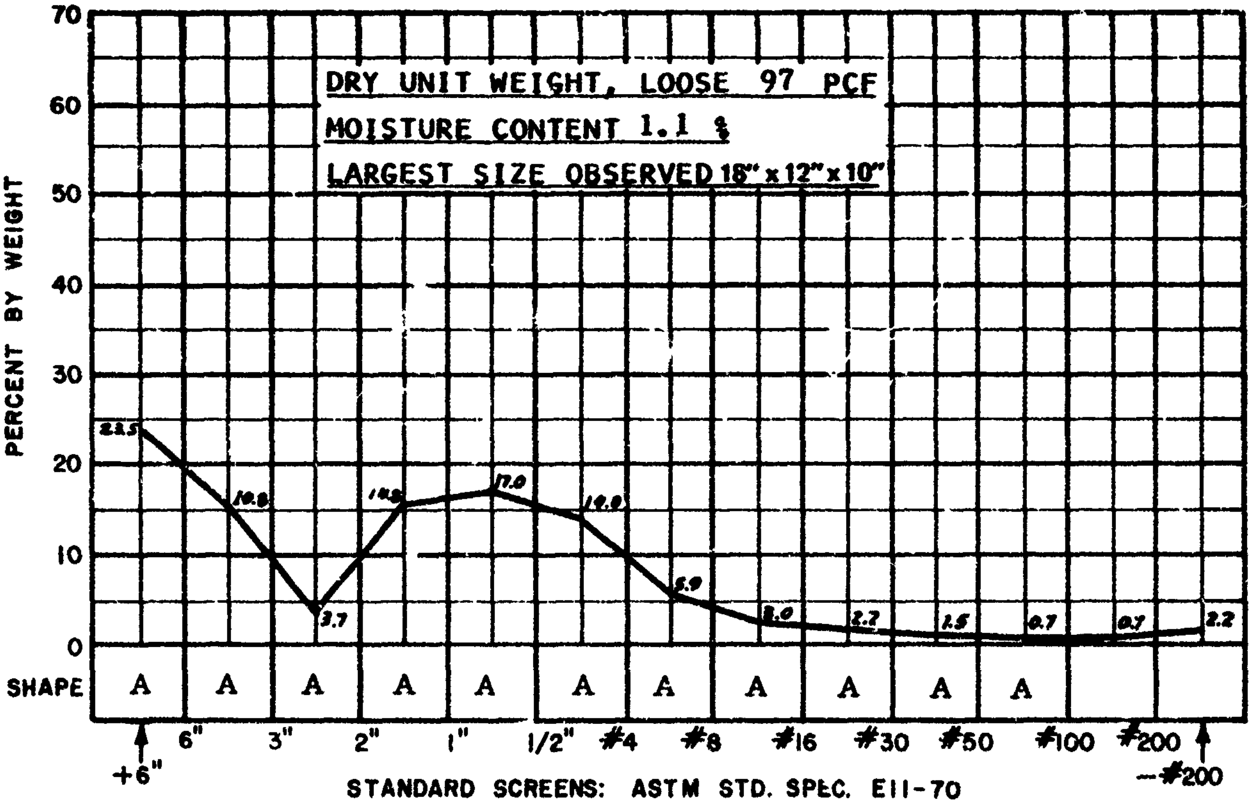
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size(-) 0.056" : 0**	**Spec. Gravity, Material** **Size(-)0.75" : 2.72**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 12.50%	**Plastic Limit 11.02%**	**Shrinkage Limit 10.52 %**
Plasticity Index 1.48 %	**Toughness Index 0.29**	**Flow Index 5.1**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 0.2 % Moisture, 36°**	**Apparent Cohesion PSF** **@ 0.2 % Moisture, 90**	**Angle/Repose 10" Drop** **@ 0.2 % Moisture, 31°**
Angle Slide Steel Plate **@ 0.2 % Moisture, 28°**	**Bulk Density PCF** **@ 0.0 % Moisture, 112**	**Angle Internal Friction** **@ 0.2 % Moisture, 44°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, course grained, many sulfide veinlets. Highly fractured, pronounced orthogonal faulting. High strength. RQD (Est.) 50%. DUW: 165 PCF. Ground water: Dry. Hardness: Schmidt 47.

System Class: Conventional Rail. 12' x 12'. Three boom jumbo, 52-5' holes, wedge cut. PF 3.8#/CY. Eimco 40 mucker. Haulage: Rail. Support: Wood posts and steel cap at 5'.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 1	Ident. No. SM-1 Sheet 2

ROCK DATA:

Lithology: Metamorphic, granitic gneiss, highly metamorphosed, moderately to highly fractured, highly silicified.
Uniaxial Compressive Strength: 9 KPSI.
RQD: (Estimated) 10%.
Dry Unit Weight: 174 PCF.
Ground Water: Minimal-drains to other workings.
Hardness: Schmidt 30 (Note 3).
Youngs Mod.: 9.70 PSI x 10^6.
Poisson Ratio: 0.35 (Note 2)

TUNNEL DATA:

Size: 13', round, Grade (+) 1/4 percent.
Ventilation System: 10 K CFM. exhaust, 24" pipe
Utility System: 4" air line, 2" water line.
Water Inflow: 5-10 gpm.
Power System: 4160/480V.
Haulage System: Personnel, muck, supplies by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Calweld, Hardrock model, #40.
Weight: 200 tons.
Cutters: 19-Smith Tool Tungsten Carbide Button, Gage: 6-GT-SH 8 roller.
Center: 1-TCB 24" tricone, interior: 12-GT-MH8 roller.
Rotation: Center cutter-26 RPM, Head-12 RPM.
Torque: 347 K # max.
Thrust: 1,128 K #. 677 K# operating
Muck Collection: Buckets from face, 24" conveyor to rear.
Power System: 480V Electro-Hydraulic, 825 HP.
Guidance System: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 3: Test of Unpolished Specimen.

MUCK DATA

Abrasiveness N. A.

Pot. Vol. Change, Material Size : NA

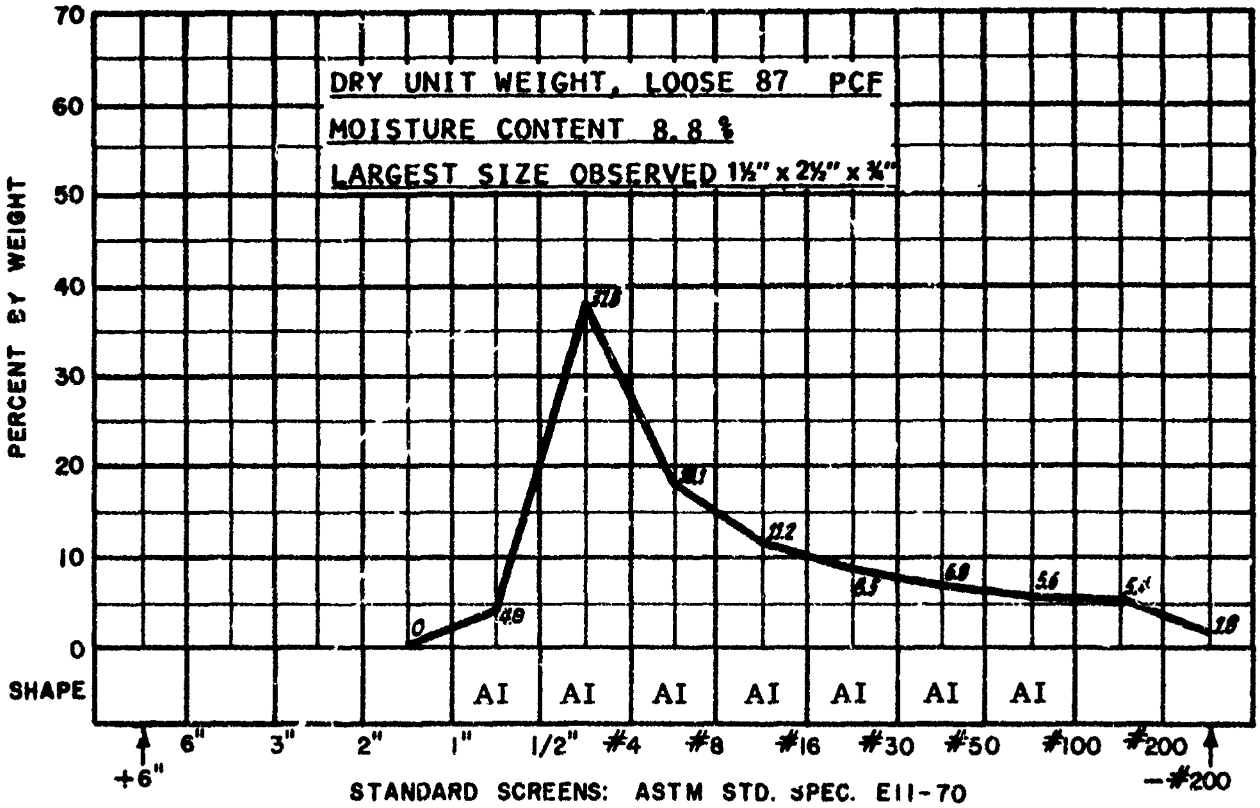
Spec. Gravity, Material Size : NA

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit NA %
Plastic Limit NA %
Shrinkage Limit NA %
Plasticity Index NA %
Toughness Index NA
Flow Index NA

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture, NA
Apparent Cohesion PSF @ % Moisture, NA
Angle/Repose 10" Drop @ % Moisture, NA
Angle Slide Steel Plate @ % Moisture, NA
Bulk Density PCF @ % Moisture, NA
Angle Internal Friction @ % Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Granitic gneiss, highly metamorphosed and silicified, moderately to highly fractured. RQD: (Est.) 10%. DUW: 174 PCF. Medium strength. Ground water: Dry. Hardness: Schmidt 30.

System Class: TBM, Calweld #40, 13' dia. 19 Smith Tool TCB roller and tricone cutters. RPM: Head 12, center 26. 347K ft # torque, 677 K# thrust.

Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Metamorphic, interlayered transition between quartzite and tactite. Moderately to strongly altered metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, very fine to medium grained.
Uniaxial Compressive Strength: 26 KPSI.
RQD: (Estimated) 80%
Dry Unit Weight: 178 PCF.
Ground Water: None apparent
Hardness: Schmidt 50.
Youngs Mod.: 11.20 PSI x 10^6 (Note 2).
Poisson Ratio: 0.34 (Note 2).

TUNNEL DATA:

Size: 16' wide x 14 1/2' high, arched back. Grade: (+) 2%.
Ventilation System: 52 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220V for pumps and fans, 110V lighting
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.
Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.
Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 6' deep.
Explosives: 15# - 1 1/2" x 8", 60% or 75% as pri[illegible] 15# - 7/8" x 16", 30% in trim holes, 25# - 1 1/2" x 16", 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5#/cy.
Blasting: Electrical, regular delays, 0 through 15.
Mucking: Scooptram.
Guidance: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

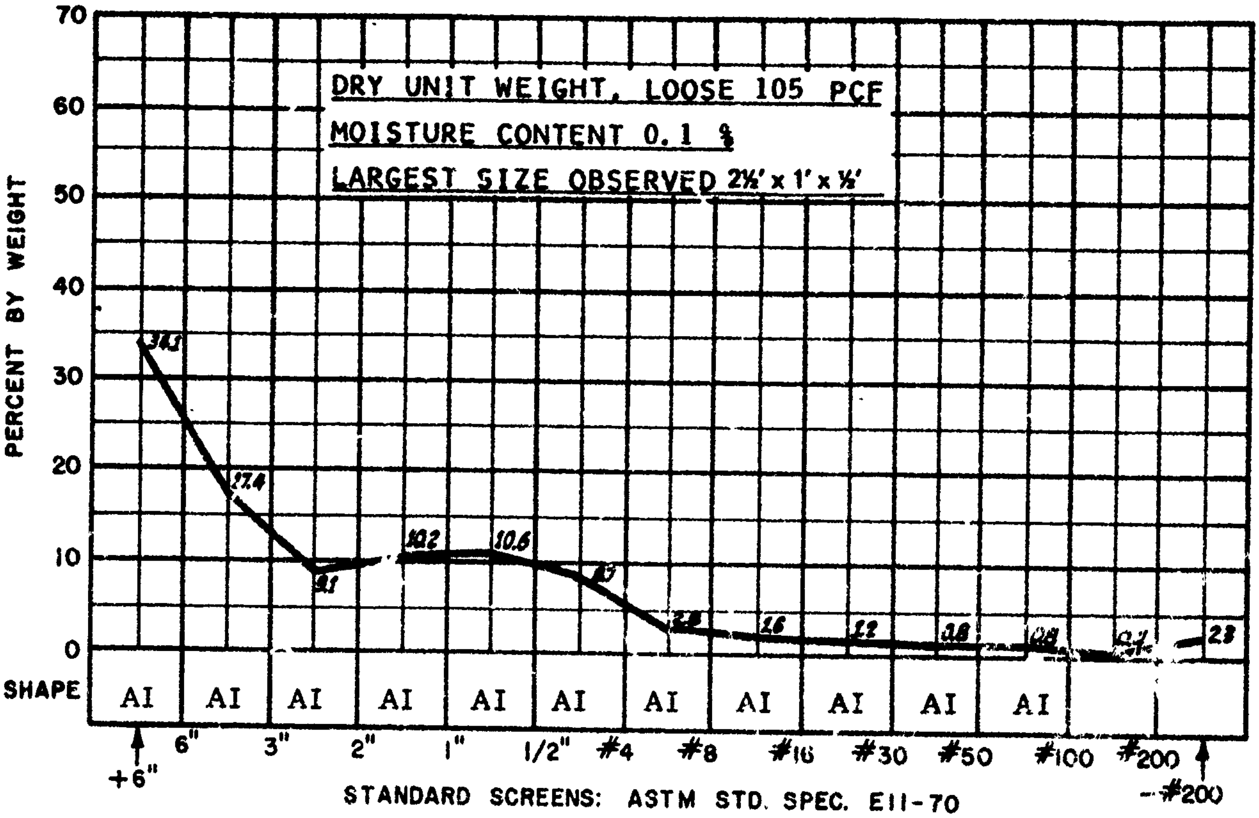
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-) 0.75" : 3.21**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.25%	**Plastic Limit 17.92 %**	**Shrinkage Limit 17.80 %**
Plasticity Index 0.33 %	**Toughness index 0.06**	**Flow Index 5.50**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 1.5 % Moisture, 30°**	**Apparent Cohesion PSF** **@ 0.4 % Moisture, 175**	**Angle/Repose 10" Drop** **@ 1.5 % Moisture, 29°**
Angle Slide Steel Plate **@ 1.5 % Moisture, 29°**	**Bulk Density PCF** **@ 0.0 % Moisture, 117.8**	**Angle Internal Friction** **@ 0.4 % Moisture, 41°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Quartzite-tactite transition, very fine to medium grained, with replacement sulphides and magnetite, high in silicates. High strength. RQD: (Est.) 80%. DUW: 178 PCF Ground water: Dry. Hardness: Schmidt 50.

System Class: Conventional Trackless. 16' wide x 14-1/2' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5#/CY. Scooptram mucking and haulage, rail skip to surface Support: Roof plates and rock bolts at 4'.

ROCK DATA:

Lithology: Metamorphic, tactite, strongly altered calcareous metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, fine to very fine grained.
Uniaxial Compressive Strength: 14 KPSI (One Spec., L/R = 1.3).
RQD: (Estimated) 70%
Dry Unit Weight: 182 PCF
Ground Water: None apparent.
Hardness: Schmidt 33.
Youngs Mod.: 6.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (+) 2%.
Ventilation System: 50 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.
Utility System: 6" compressed air, 2" water.
Water Inflow: None apparent.
Power System: 4160/220V for pumps and fans, 110V lighting.
Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail mounted skip to surface. Personnel and supplies by diesel truck.
Support System: 6" WF Steel Sets at 5'.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.
Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut and 1 center hole, 4" diameter; all 6' deep.
Explosives: 15#-1 1/2" x 8", 60% or 75% as primers, 15#-7/8" x 16' 30% in trim holes, 25#-1 1/2" x 16", 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5.5#/CY.
Blasting: Electrical, regular delays, 0 through 15
Mucking: Scooptram.
Guidance: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

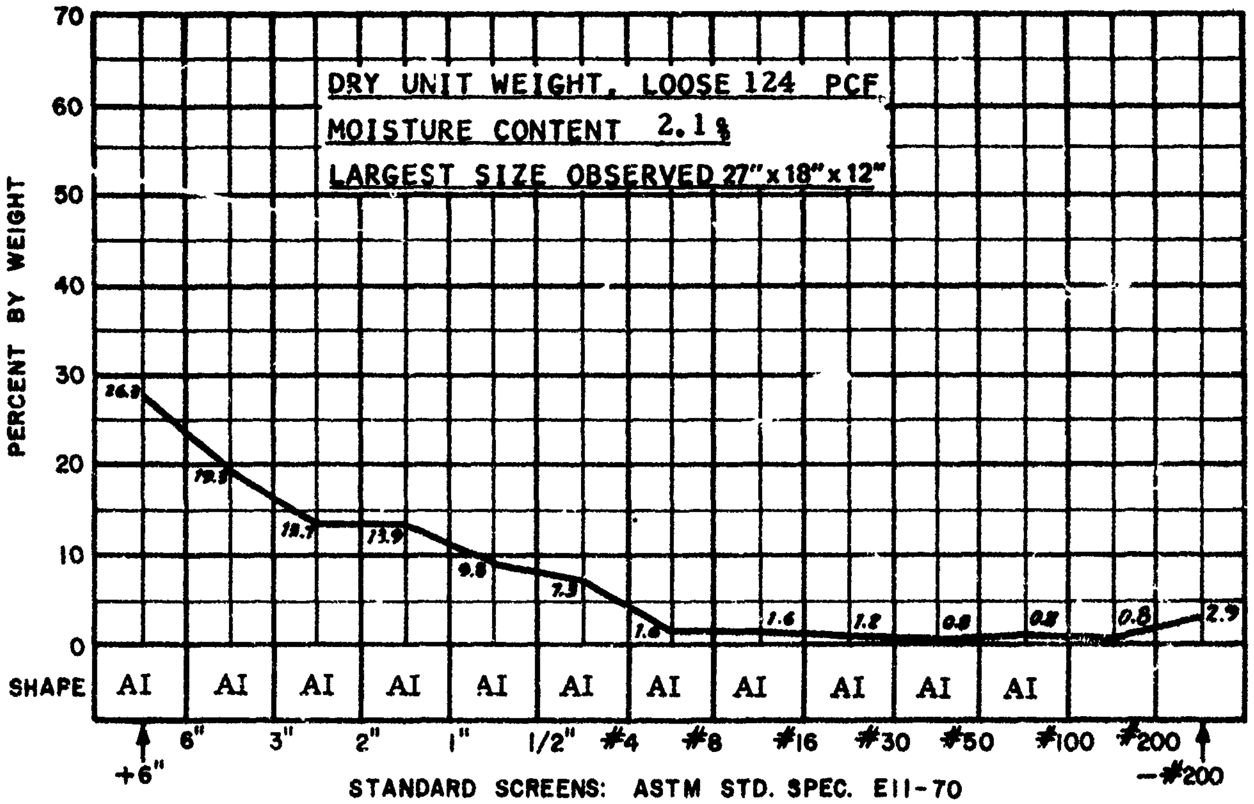
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056" : 0**	**Spec. Gravity, Material** **Size (-) 0.75" : 3.36**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 19.00%	**Plastic Limit 17.95 %**	**Shrinkage Limit 16.43 %**
Plasticity Index 1.05 %	**Toughness Index 0.19**	**Flow Index 5.40**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 2.0 % Moisture, 37°**	**Apparent Cohesion PSF** **@ 0.2 % Moisture, 165**	**Angle/Repose 10" Drop** **@ 2.0 % Moisture, 35°**
Angle Slide Steel Plate **@ 2.0 % Moisture, 30°**	**Bulk Density PCF** **@ 0.0 % Moisture, 115**	**Angle Internal Friction** **@ 0.2 % Moisture, 43°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Tactite, fine to very fine grained, with replacement sulphides and magnetite, high in silicates. Medium strength. RQD (Est.) 70%. DUW: 182 PCF. Ground water: Dry. Hardness: Schmidt 33.

System Class: Conventional Trackless. 15' wide x 14' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5.5#/CY. Scooptram mucking and haulage, rail skip to surface. Support. Steel sets at 5'.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 1	Ident. No. LK-4 Sheet 2

ROCK DATA:

Lithology: Metamorphic, interlayered bands of hematite and martite, highly jointed, normally flat lying, but often highly folded. Natural iron over 60%, silica 5%.
Uniaxial Compressive Strength: 7 KPSI.
RQD: (Estimated) 10%
Dry Unit Weight: 207 PCF
Ground Water: Formation generally dry.
Hardness: Schmidt 20 (Note 3).
Youngs Mod.: 2.50 PSI x 10^6 (Note 4).
Poisson Ratio: 0.15 (Note 4).

TUNNEL DATA:

9'-11 1/2" diameter; normal grade: 0%.
Ventilation System: 3 KCFM, pressure, 8" dia. tube, 5 HP @ 250' from main level.
Utilities: 2" air line, 1" water line, 2-1 1/2" pressure and 1-3" return hydraulic lines.
Water Inflow: None
Power System: 110V lighting, 440V to scraper hoist.
Muck Haulage: 30 HP hoist, and 42" scraper to raise, all rail on main level. Personnel, rail and ladders· supplies by rail cars and hoist.
Support: Continuous; 9'-6" dia. x 4" WF sets at 45".

EXCAVATION DATA:

Machine: Calweld Oscillator. Wt: 69 K#.
Cutters: 278 Carboloy drag bits. Gage: 20 rippers (experimental). Interior: 258 "J" tools.
Rotation: 8 RPM
Torque: 1200 K ft.#.
Thrust: 300 K# max., 285 K# operating.
Anchorage: Thrust on installed sets, 285K# operating.
Muck Collection: Flight conveyor to rear of machine, removal by scraper.
Power System: Remote power unit; 2-90 gpm, 2500 psi hydraulic pumps and 125 HP motors on main level; thrust and rotation through hydraulic cylinders.
Guidance System: Survey.

NOTE 3: Test of Unpolished Specimen.
NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material Size (-)0.056" : 0

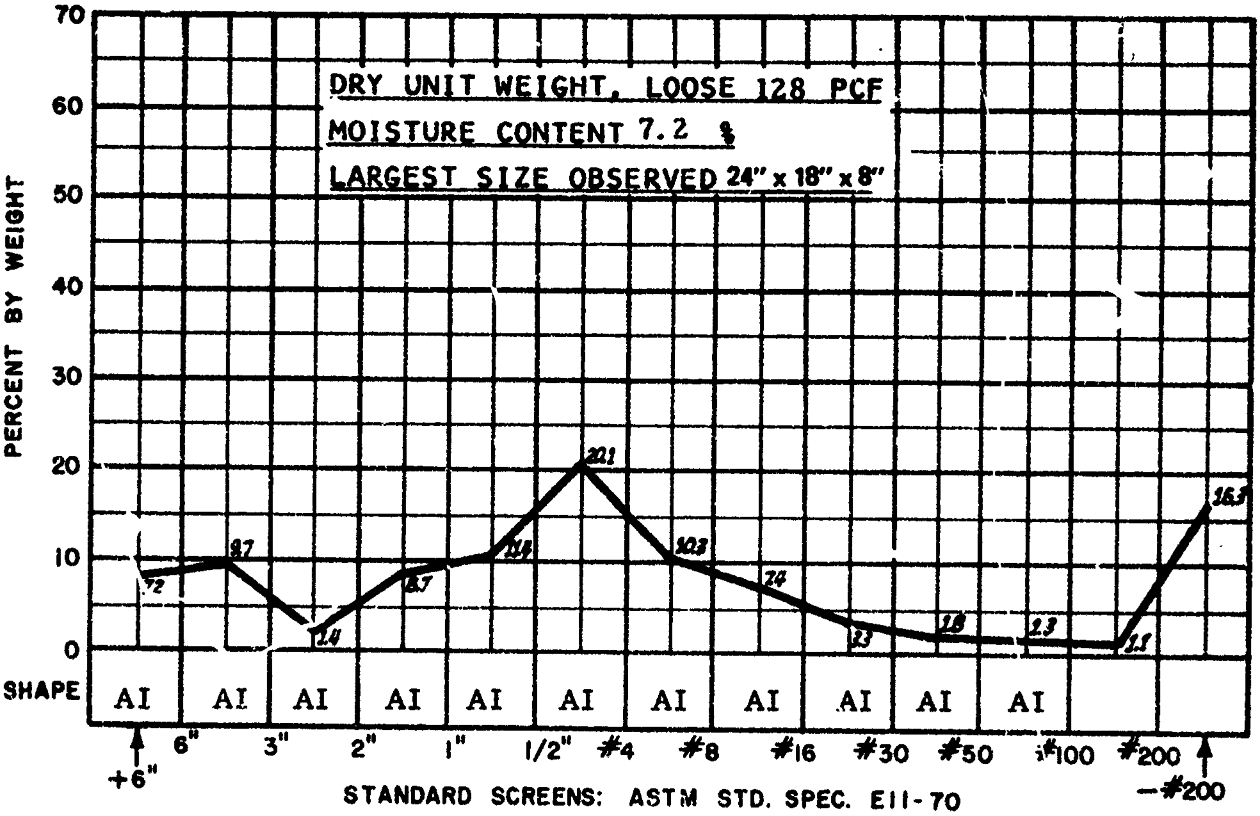
Spec. Gravity, Material Size (-) 0.75" : 4.34

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 17.8 %
Plastic Limit 15.1 %
Shrinkage Limit 13.9 %
Plasticity Index 2.7 %
Toughness Index 0.66
Flow Index 4.1

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 6.2 % Moisture, 37°
Apparent Cohesion PSF @ 6.9 % Moisture, 235
Angle/Repose 10" Drop @ 6.2 % Moisture, 35°
Angle Slide Steel Plate @ 6.2 % Moisture, 31°
Bulk Density PCF @ 0.0 % Moisture, 141
Angle Internal Friction @ 6.9 % Moisture, 35°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%. DUW: 207 PCF. Ground water: Dry. Hardness: Schmidt 20.

System Class: TBM, oscillator, Calweld #53, 9'11 1/2" dia. 278 Carboloy drag bits. 8 RPM, 1200 K ft# torque, 285 K# thrust. Mucking: Flight conveyor and scraper to raise. Haulage: Rail. Support: Continuous, 9'6" dia. x 4" H sets at 45".

ROCK DATA:

Lithology: Metamorphic, interlayered hematite and martite, highly jointed, normally flat lying, often highly folded. Natural iron over 60%, silica 5%.
Uniaxial Compressive Strength: 6 KPSI.
RQD: (Estimated) 10%.
Dry Unit Weight: 188 PCF
Ground Water: None
Hardness: Schmidt 16.
Youngs Mod.: 2.10 PSI x 10^6
Poisson Ratio: 0.15

TUNNEL DATA:

Size: 10' wide x 9'-6" (7' cap and 8' post). Grade: Level
Ventilation System: 4 KCFM pressure, 8" diameter pipe and tubing, 15 HP @ 600', and 8" exhaust, 5 HP @ 100'.
Utility System: 2" airline, 1" water line
Water Inflow: None
Power System: 2300/440V.
Haulage System Muck, 30 HP hoist and 48" scraper from surge pile at rear of miner to chute - 160 CF cars, 30 ton tandem locomotives on 30" gage 60# rail to shaft pocket, 14 ton skips to surface.
Support System: 8"-58# WF sets, 7' cap, 8' post, at 4'-5", wood lagging and pipe spiling, 8-1" diameter or 6-2" diameter in back.

EXCAVATION DATA:

Machine: Alpine, Model F-6A Total Weight: 11 tons.
Cutters: 68 Kennametal 43 KH carbide tipped "plumb bob" type, mounted on twin ripper heads at 90° to boom.
Rotation: 60 RPM about horizontal axis; boom moved vertically and horizontally by hydraulic cylinders.
Torque: 49.6 HP.
Thrust: Sumping thrust from 2-10 HP crawler motors.
Anchor Pressure: Crawlers only.
Muck Collection: Central 14" flight conveyor fed by two gathering arms on inclined apron, discharging to surge pile.
Power System: 440V.
Guidance: Transit lines.

MUCK DATA **Test Data**

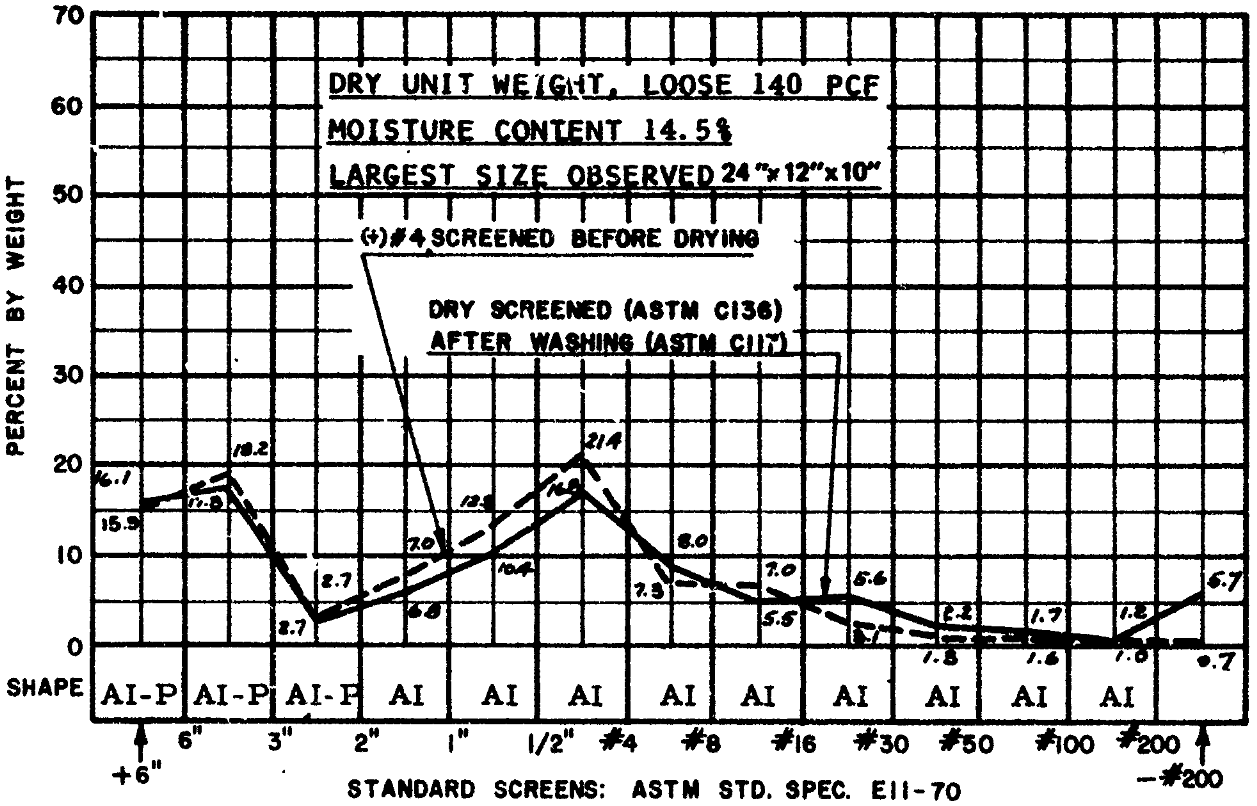
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056": 0	Size (-)0.75": 4.31

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 21.50%	Plastic Limit 20.86%	Shrinkage Limit 19.00%
Plasticity Index 0.64%	Toughness Index 0.11	Flow Index 5.7

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 11.56% Moisture, 35.5°	Apparent Cohesion PSF @ 11.56% Moisture, 120	Angle/Repose 10" Drop @ 11.56% Moisture, 30.5°
Angle Slide Steel Plate @ 11.56% Moisture, 30.17°	Bulk Density PCF @ 11.56% Moisture, 119.64	Angle Internal Friction @ 11.56% Moisture, 37.0°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%. DUW: 188 PCF: Ground water: Dry. Hardness: Schmidt 16.

System Class: TBM, Twin head, Alpine F-6A, 10' wide x 9'6" heading. 68 Kennametal T. C. tipped bits. 60 RPM, 49.6 HP head torque, 20 HP sumping thrust. Mucking: Gathering arms, flight conveyor. Haulage: Scraper to rail cars to skip. Support: Steel sets, pipe spiles.

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ROCK DATA:

Lithology: Metamorphic, argillaceous quartzite, medium to thin bedded, moderately to highly folded. Beds high angled to vertical, moderate fracturing sub-parallel to beds and vertical across beds.
Uniaxial Compressive Strength: 21 KPSI.
RQD: 75% (Estimated for vertical hole).
Dry Unit Weight: 168 PCF.
Ground Water: None
Hardness: Schmidt 45.
Youngs Mod.: 8.35 PSI x 10^6.
Poisson Ratio: 0.13.

TUNNEL DATA:

Size: 9' W x 10.7', 1 1/2' R. top corner arch. Grade: +1/2%
Ventilation System: 7 KCFM pressure, 24" pipe and tubing, 40 HP at 800'.
Utility System: 4" air line, 2" water line.
Water Inflow: None to minor.
Power System: 2300/480/120 (lighting).
Haulage System: Muck, personnel, supplies by rail cars, 24" gage, 40# rail, 6 ton battery locomotive, 60 CF side dump cars.
Support System: 9' x 13" mats, parallel to centerline, 2 in top and 2 each rib, 4 3/4" x 6' rock bolts per mat.

EXCAVATION DATA:

Conventional Rail System.
Drilling: 3 boom jumbo, 2-S83F and 1-D99 machines, 8' screw feeds.
Drill Round: 44 holes: 2-4" and 42-1 5/8" diameter, burn cut, 7' depth.
Explosives: 100# Nilite, 25#-60 WR 1" x 16" primers.
Blasting: Electrical, zero and 14 regular delays. Powder Factor: 5.5#/CY.
Mucking System: Atlas-Copco LM56 overhead.
Guidance: Transit lines.

MUCK DATA **Test Data**

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-) 0.75: 2.689

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.10%
Plasticity Index 2.53%

Plastic Limit 15.57%
Toughness Index 0.50

Shrinkage Limit 10.91%
Flow Index 5.10

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop
@ 0.26% Moisture, 37.15°

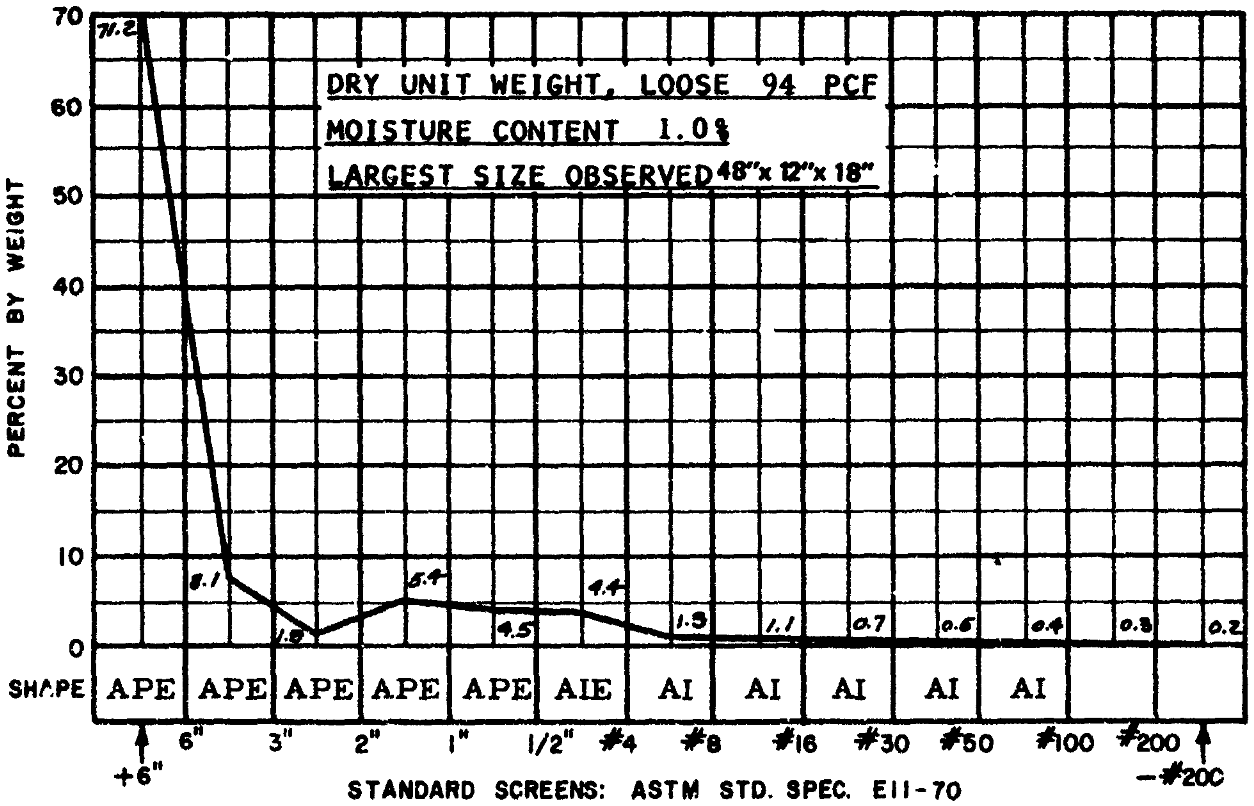
Apparent Cohesion PSF
@ 0.26% Moisture, 740

Angle/Repose 10" Drop
@ 0.26% Moisture, 33.60°

Angle Slide Steel Plate
@ 0.26% Moisture, 31.17°

Bulk Density PCF
@ 0.26% Moisture, 91

Angle Internal Friction
@ 0.26% Moisture, 32.7°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Argillaceous quartzite, moderately fractured, moderately to highly folded, medium to thin bedded. High strength.

RQD (Est.) 75%. DUW: 168 PCF. Ground water: None. Hardness: Schmidt 45.

System Class: Conventional Rail: 9' x 10'7", 3 boom jumbo, 44-7' holes, burn cut. PF 5.5 #/CY. Mucking: Atlas Copco LM56. Haulage: Rail. Support: Rockbolts and mats.

ROCK DATA:

Lithology: Metamorphic, quartzite, with minor filled veinlets, thin bedded to massive, moderately folded,moderately to highly fractured/jointed, beds dip 75°-90°.

Uniaxial Compressive Strength: 13 KPSI.

RQD: (Estimated) Vertical: 50%, horizontal 20-30%.

Dry Unit Weight: 168 PCF.

Ground Water: Minor

Hardness: Schmidt 41.

Youngs Mod.: 5.72 PSI x 10^6

Poisson Ratio: 0.18.

TUNNEL DATA:

Size: 10' x 10' with 1 1/2' top corner radius. Grade: (+) 0.5%.

Ventilation: 13.5 KCFM, pressure, 24" diameter pipe, 80 HP @ 1700' from cooling unit.

Utility System: 4" air line, 2" water line, 2" pumpline.

Power System: 2300/480/120.

Haulage System: Muck, Eimco 912B-LHD to skip pocket, skips and rail to surface.

Personnel, Supplies: Rail, cage to level, LHD or Jumbo on level.

Support System: 13" x 9' plates, 5' x 5/8" rock bolts at 3 1/2', plates and rock bolts on ribs where needed.

Water Inflow: Minor.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: 2 boom hydrojib jumbo, 8' feed, D-93 drifters.

Drill Round: 48 holes, 1 5/8" diameter x 8' V cut.

Explosives: 265#, 250# Nilite, 15# Trojan 60 WR. Powder factor, 9.5#/CY.

Blasting: Electrical, Dupont Acudet 0-14 delay caps.

Mucking: Eimco 912B-LHD.

Guidance: Laser

MUCK DATA **Test Data**

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056": 0

Spec. Gravity, Material
Size (-)0.75": 2.714

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 16.50% **Plastic Limit 14.83%** **Shrinkage Limit 11.76%**
Plasticity Index 1.67% **Toughness Index 0.34** **Flow Index 4.90**

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop
@ 0.28% Moisture, 37.6°

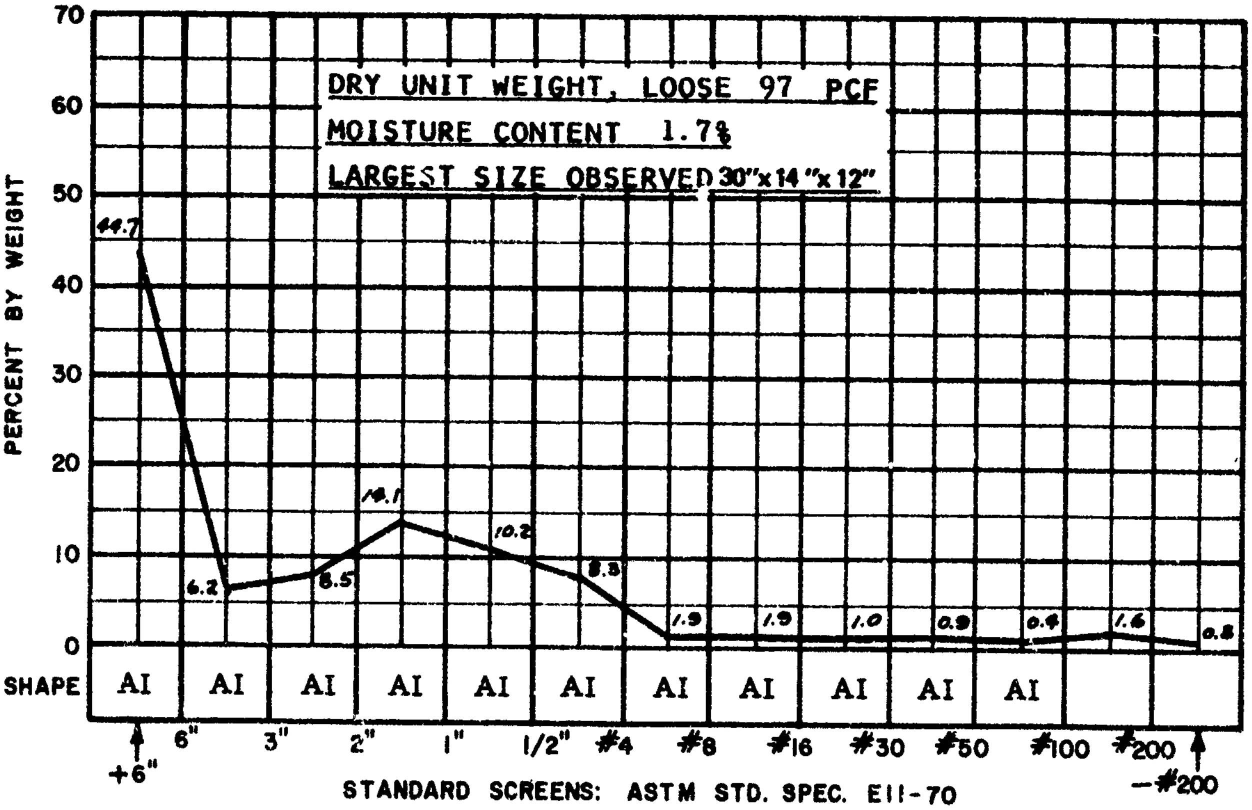
Apparent Cohesion PSF
@ 0.28% Moisture, 400

Angle/Repose 10" Drop
@ 0.28% Moisture, 34.3°

Angle Slide Steel Plate
@ 0.28% Moisture, 31.75°

Bulk Density PCF
@ 0.28% Moisture, 90

Angle Internal Friction
@ 0.28% Moisture, 42.1°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Quartzite minor filled veinlets, moderately to highly fractured/jointed, moderately folded, beds dip 75° to 90°. Medium strength. RQD (Est.) 50%. DUW: 168 PCF. Hardness: Schmidt 41.

Ground Water: Minor.

System Class: Conventional Trackless: 10' x 10', 2 boom jumbo, 48-8' holes, V cut. PF 9.5 #/CY. Mucking: Eimco 912B. Haulage: LHD. Support: Rock bolts and plates.

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Sheet 2

ROCK DATA:

Lithology: Metamorphic, phyllite, with vein quartz and chlorite schist, highly metamorphosed and folded, with minor faulting.
Uniaxial Compressive Strength: 19 KPSI
RQD: (Estimated) 70%
Dry Unit Weight: 187 PCF
Ground Water: Dry
Hardness: Schmidt 41.
Youngs Mod.: 8.62 PSI x 10^6.
Poisson Ratio: 0.20.

TUNNEL DATA:

Size: 7'-6" wide x 7'-6" arch.
Ventilation: 7 KCFM, 16" diameter pipe, 30 HP @ 300'. Fan integral with mechanical cooling unit.
Utility System: 2" water line, 2" airline, 4" water line to cooling unit.
Water Inflow: Minor
Power System: 2400/440/110V.
Haulage System: Muck, supplies, personnel by railcars, 6 and 8 ton locomotives 1 1/2 ton rocker dump cars, 18" gage, 40# rail car passes 80'-300' from face.
Support System: Normally none, 5/8" x 6' rock bolts as required.

EXCAVATION DATA:

Conventional Rail System
Drilling: 2-6' feed air legs, mounting 3" jackhammers.
Drill Round: 34 holes, 5-2" diameter burncut, circular or box relievers 29 x 1 1/4", average advance 10' per round.
Explosives: 140#. 131# AN/FO, 9#-1 x 6", 60% primers.
Blasting: Electrical, 7 millisecond delays, 10 regular delays. Powder factor , 7.0#/CY.
Mucking: Eimco, model 21.
Guidance: Transit survey.

MUCK DATA

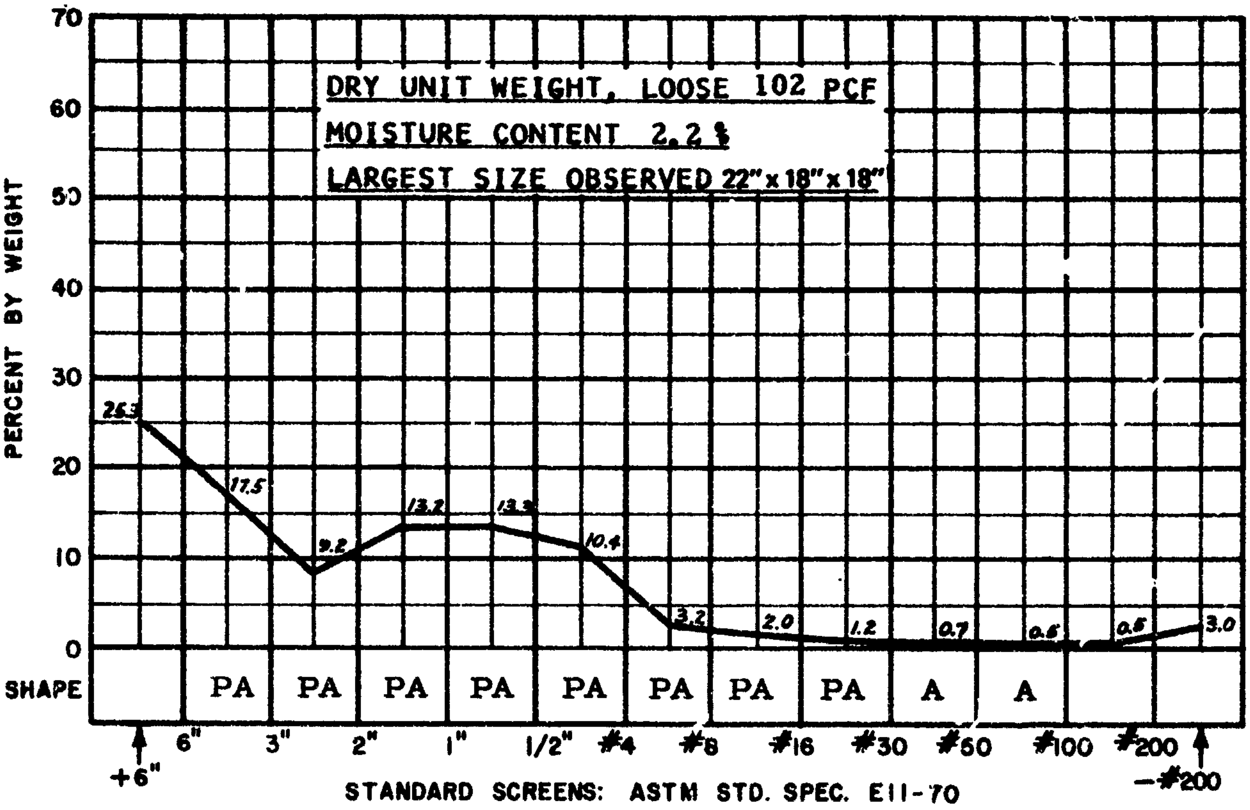
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-)0.75" : 2.84**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.80%	**Plastic Limit 16.06 %**	**Shrinkage Limit 15.12 %**
Plasticity Index 2.74 %	**Toughness Index 1.01**	**Flow Index 2.70**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 3.1 % Moisture, 40°**	**Apparent Cohesion PSF** **@ 2.0 % Moisture, 160**	**Angle/Repose 10" Drop** **@ 3.1 % Moisture, 34°**
Angle Slide Steel Plate **@ 3.1 % Moisture, 31°**	**Bulk Density PCF** **@ 0.0 % Moisture, 99**	**Angle Internal Friction** **@ 2.0 % Moisture, 39°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Phyllite with vein quartz and chlorite schist, highly metamorphosed and folded. High strength. RQD (Est.) 70%. DUW: 187 PCF. Ground water: Dry. Hardness: Schmidt 41.

System Class: Conventional Rail. 7' 6" wide x 7' 6" arch, two air leg drills, 34-10' holes, burn cut. PF 7.0 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: 15 KPSI.
RQD: (Estimated) 80%.
Dry Unit Weight: 179 PCF.
Ground Water: Dry
Hardness: Schmidt 48.
Youngs Mod.: 12.26 PSI x 10^6.
Poisson Ratio: 0.17.

TUNNEL DATA:

Size: 11' diameter. Grade: (-) 0.03%.
Ventilation: 3.6 KCFM, exhaust, @ 3475', 20" diameter pipe, 40 HP.
Utility System: 4" airline, 4" waterline, 6" pumpline.
Water Inflow: 40 GPM
Power System: 6600V/440V.
Haulage System: Muck, supplies, personnel by railcars, 10 ton locomotive 17 CY cars, 36" gage, 70# rail.
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva, 12-1100, Total Weight: NA.
Cutters: 30 Reed steel disc and 6 Jarva TCB disc. Gage: 6 TCB QKC-3W. 2 disc. Interior: 28 steel 3 disc QK3. Center: 2 steel 5 disc QK-1.
Rotation: 10.75 RPM.
Torque: 244K# Feet Max.
Thrust: 953K# Operating.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

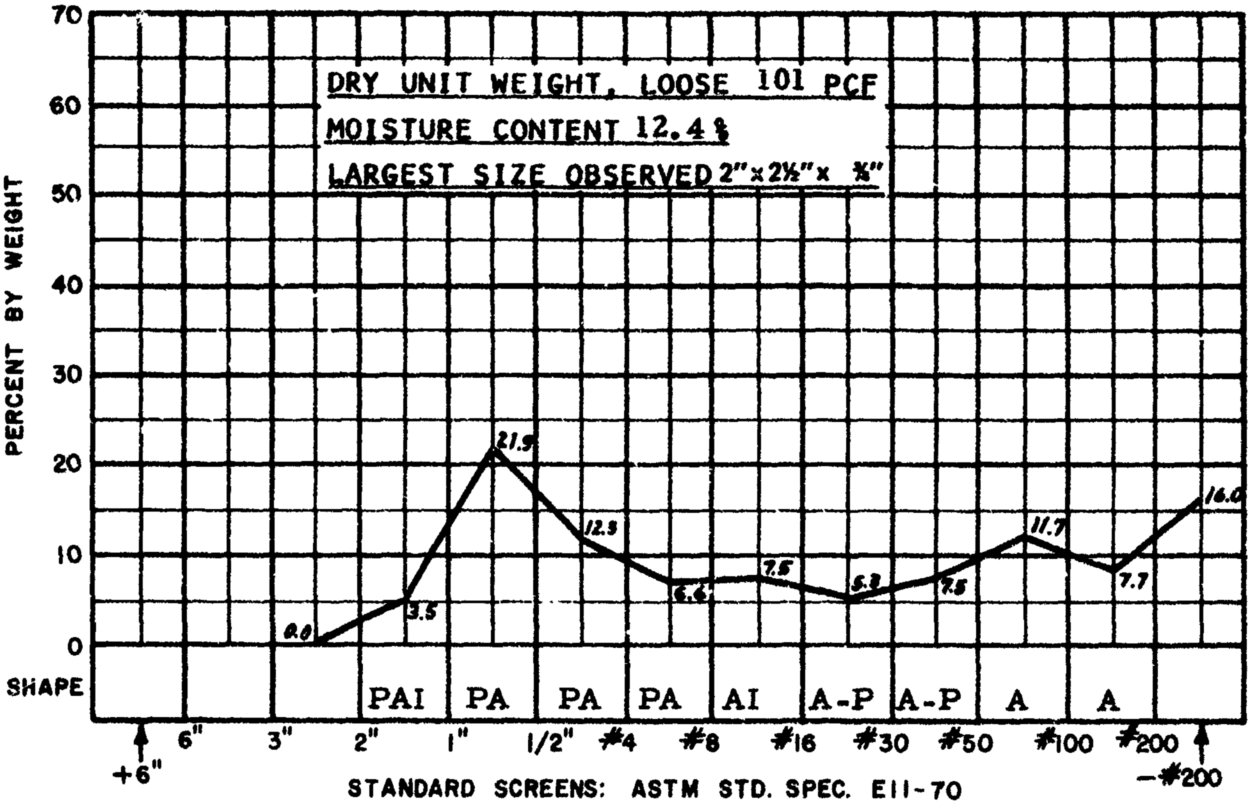
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.75": 2.614

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24.90%	Plastic Limit 23.60%	Shrinkage Limit 22.92%
Plasticity Index 1.30%	Toughness Index 0.25	Flow Index 5.3

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop @ 5.56% Moisture, 39.8°	Apparent Cohesion PSF @ 5.56% Moisture, 0	Angle/Repose 10" Drop @ 5.56% Moisture, 37.45°
Angle Slide Steel Plate @ 5.56% Moisture, 38.75°	Bulk Density PCF @ 5.56% Moisture, 84.76	Angle Internal Friction @ 5.56% Moisture, 26.2°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz lamination. Medium strength. RQD (Est.) 80%. DUW: 179 PCF. Ground water: Dry. Hardness: Schmidt 48.

System Class: TBM, Jarva 12-1100, 11' dia. 30 Reed and 6 Jarva discs. RPM: NA, Torque: NA, Thrust: NA. Mucking: Buckets to belt. Support: None.

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: 13 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 177 PCF.
Ground Water: Dry
Hardness: Schmidt 45.
Youngs Mod.: 8.50 PSI x 10^6.
Poisson Ratio: 0.20.

TUNNEL DATA:

Size: 8'-6" diameter. Grade: (+) 0.03%.
Ventilation: 18 KCFM, exhaust @ 1500', 12" diameter pipe, 40 HP
Utility System: 4" airline, 4" waterline, 4" pumpline.
Water Inflow: 20 GPM.
Power System: 6600/440V.
Haulage System: Muck, supplies, personnel by railcars 10 ton locomotive 13 CY cars, 36" gage, 70# rail.
Support System: Half circle bolted steel lagging in fault zones, pinned to ribs.

EXCAVATION DATA:

Machine: Jarva 8-806. Total Weight: NA.
Cutters: 14 Reed disc and 3 Jarva TCB disc. Gage 3 TCB disc QKC-3W Interior, 12 TCB disc QC-3, center 2 steel tooth type.
Rotation: 12.5 RPM.
Torque: 158K# feet max.
Thrust: 482K# operating.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

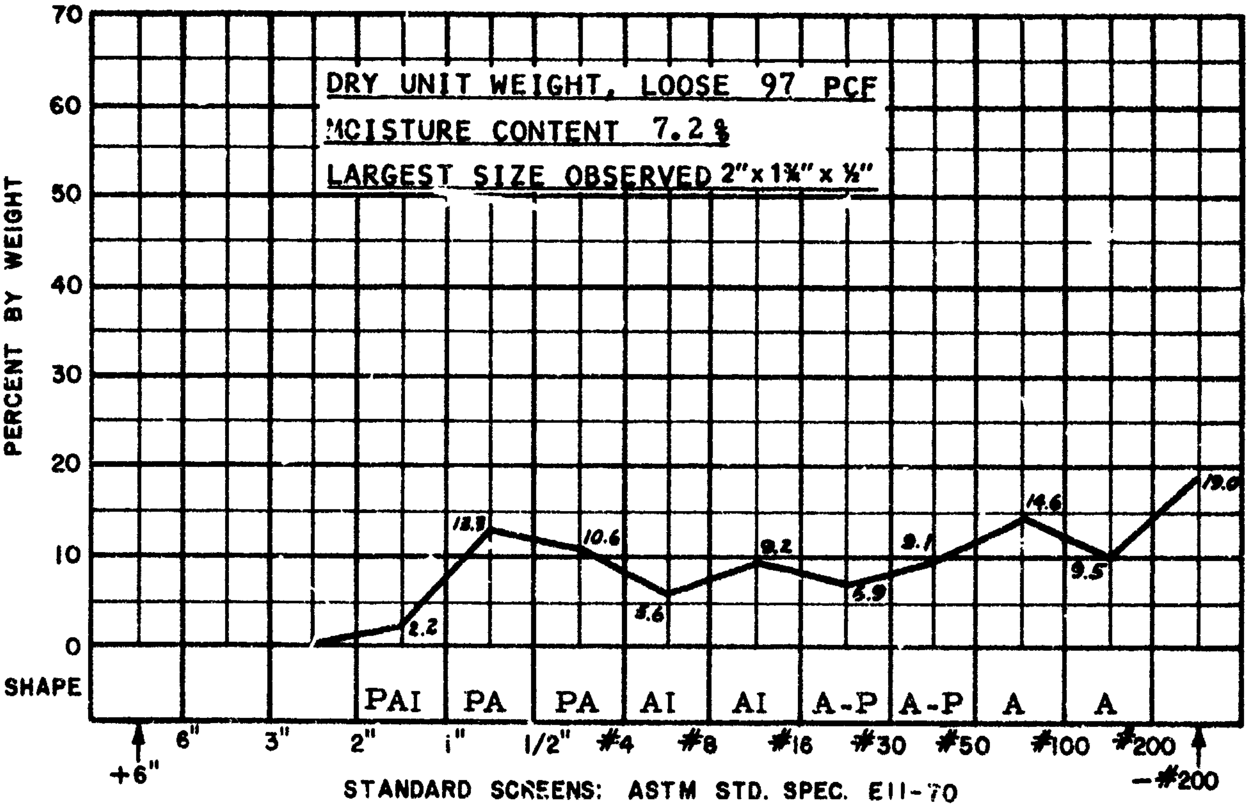
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.878

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24.00%	Plastic Limit 23.32%	Shrinkage Limit 22.00%
Plasticity Index 0.68%	Toughness Index 0.10	Flow Index 6.70

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop @ 4.22% Moisture, 42°	Apparent Cohesion PSF @ 4.22% Moisture, 0	Angle/Repose 10" Drop @ 4.22% Moisture, 37.95°
Angle Slide Steel Plate @ 4.22% Moisture, 40.17°	Bulk Density PCF @ 4.22% Moisture, 80.92	Angle Internal Friction @ 4.22% Moisture, 29.2°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Mica schist, occasional quartz laminations. Medium strength. RQD (Est.) 90%. DUW. 177 PCF. Ground water: Dry. Hardness: Schmidt 45.

System Class: TBM, Jarva 8-806, 8'6" dia. 14 Reed and 3 Jarva discs and rollers. RPM: NA. Torque: NA. Thrust: NA. Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Metamorphic, gray mica schist, occasional quartz seams, mica varies from dense fine grained to extremely coarse.
Uniaxial Compressive Strength: 11 KPSI.
RQD: (Estimated) 30%
Dry Unit Weight: 165 PCF
Ground Water: Major inflow occurs in faults and fault zones.
Hardness: Schmidt 30.
Youngs Mod.: 4.50 PSI x 10^6 (Note 2).
Poisson Ratio: 0.25 (Note 2).

TUNNEL DATA:

Size: 11', diameter. Grade: (+) 1 to 3%
Ventilation System: 4 KCFM exhaust 14" pipe.
Utility System: 4" waterpipe, no airline.
Water Inflow: 60 gpm, drains in ditch
Power System: 4160/480V
Haulage System: Muck, personnel, supplies by rail cars.
Support System: None, occasional semi-circular plates pinned at spring line in fault zones

EXCAVATION DATA:

Machine: Jarva, Mark 11-1100, Total Weight: 70 tons
Cutters: 34 Reed, type QK steel multiple disc. Gage: 6 triple disc. Center: 2-triple disc. Interior: 26 triple disc.
Rotation: Cutterhead, 10.75 RPM
Torque: 244 K ft. #
Anchor Pressure: Maximum 3,402 K#.
Thrust: 1,134 K#. operating
Muck System: Buckets from face, belt to rear.
Power System: Four 125 HP, 480V motors drive head, 40 HP 480V motor drive hydraulic system.
Guidance System: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

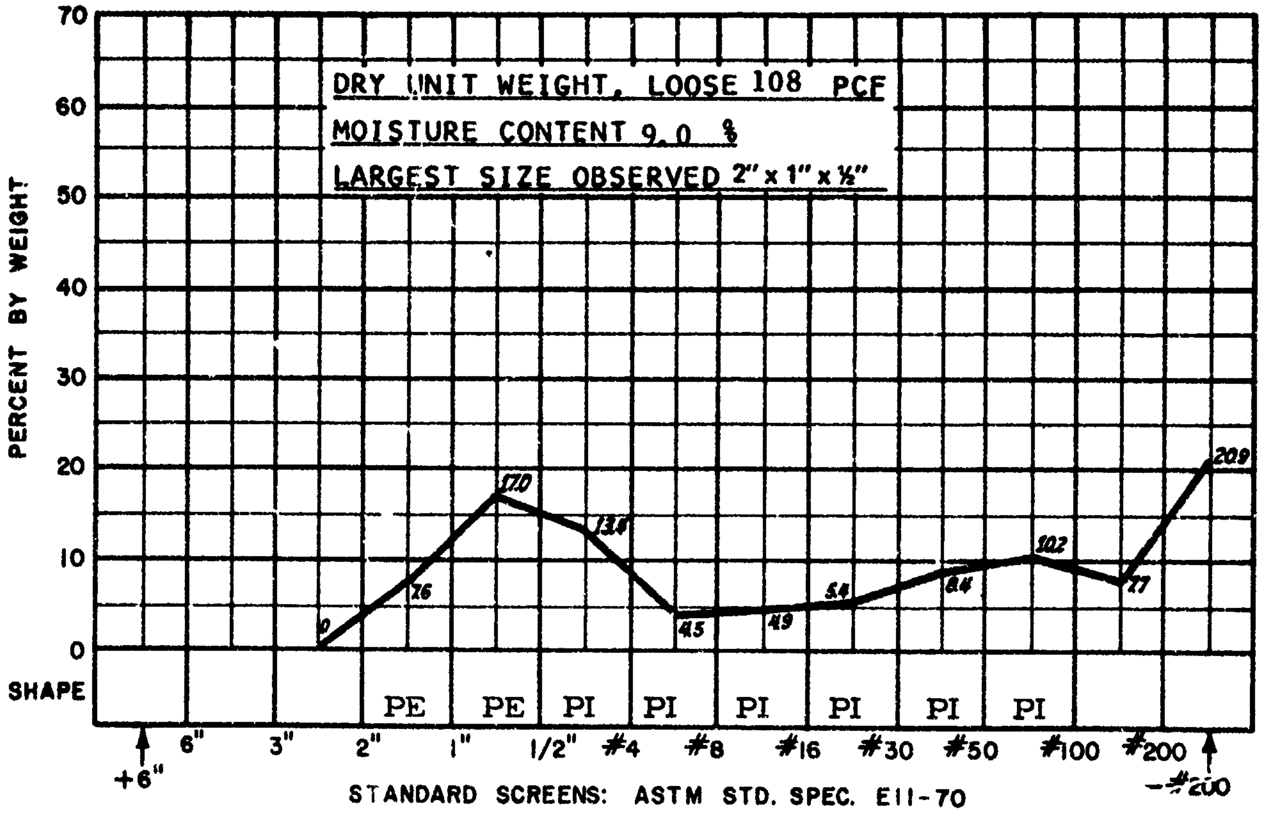
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056" : 0**	**Spec. Gravity, Material** **Size(-) 0.75" : 2.57**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24.0 %	**Plastic Limit 23.3 %**	**Shrinkage Limit 22.7 %**
Plasticity Index 0.7 %	**Toughness Index 0.17**	**Flow Index 4.0**

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop **@ 9.8 % Moisture, 39°**	**Apparent Cohesion PSF** **@ 9.3 % Moisture, 125**	**Angle/Repose 10" Drop** **@ 9.8 % Moisture, 37°**
Angle Slide Steel Plate **@ 8.4 % Moisture, 40°**	**Bulk Density PCF** **@ 0.0 % Moisture, 75**	**Angle Internal Friction** **@ 9.3 % Moisture, 30°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Mica schist, dense, fine grained to extremely coarse occasional quartz seams. Medium strength. RQD (Est.) 30%. DUW: 165 PCF. Ground water: Minor inflows at fault zones. Hardness: Schmidt 30.

System Class: TBM, Jarva Mark 11-1100, 11' dia. 36 Reed triple discs. RPM: 10.75. Torque: 244 K ft #. Thrust: 1,134 K #. Mucking: Buckets to belt. Haulage: Rail. Support: Minor, semicircular plates in fault zones.

ROCK DATA:

Lithology: Sedimentary, graywacke ("argillaceous quartzite"), massive to medium bedded, highly folded and fractured, normal dip of bedding 30° to 45°.
Uniaxial Compressive Strength: 22 KPSI.
RQD: (Estimated) 35%.
Dry Unit Weight: 171 PCF.
Ground Water: None.
Hardness: Schmidt 44.
Youngs Mod.: 9.76
Poisson Ratio: 0.20

TUNNEL DATA:

Size: 10' wide x 10.8'. Grade: (+) 2%.
Ventilation System: 8 KCFM, exhaust, 16" diameter pipe, 30 HP @ 1800' and pressure auxiliary, 8" pipe, 5 HP @ 100'.
Utility System: 6" air line, 4" water line.
Water Inflow: None.
Power System: 2300/480/120V.
Haulage System: Muck, personnel, supplies by railcars, 30" gage, 80# and 60# rail, 10 ton trolley locomotives, 200 and 140 CF bottom dump cars to skip pocket, 14 ton skips to surface.
Support System: Roof plates and 3/4" x 6' bolts as required.

EXCAVATION DATA:

Conventional Rail System.
Drilling: Hydrojib jumbo, 2 boom, D93 drifters, 1 1/4" round steel on 10' chain feeds.
Drill Round: 36 holes, 1 5/8" diameter, V cut, 8' depth.
Explosives: 210#, 200# Ammonium Nitrate, 10#-7/8" x 8", 70% in ribs and top. Powder factor, 7.0#/CY.
Blasting: Detaprime primers, caps, fuse and igniter cord.
Mucking System: Eimco Model 40 mucker.
Guidance: Transit Lines.

MUCK DATA **Test Data**

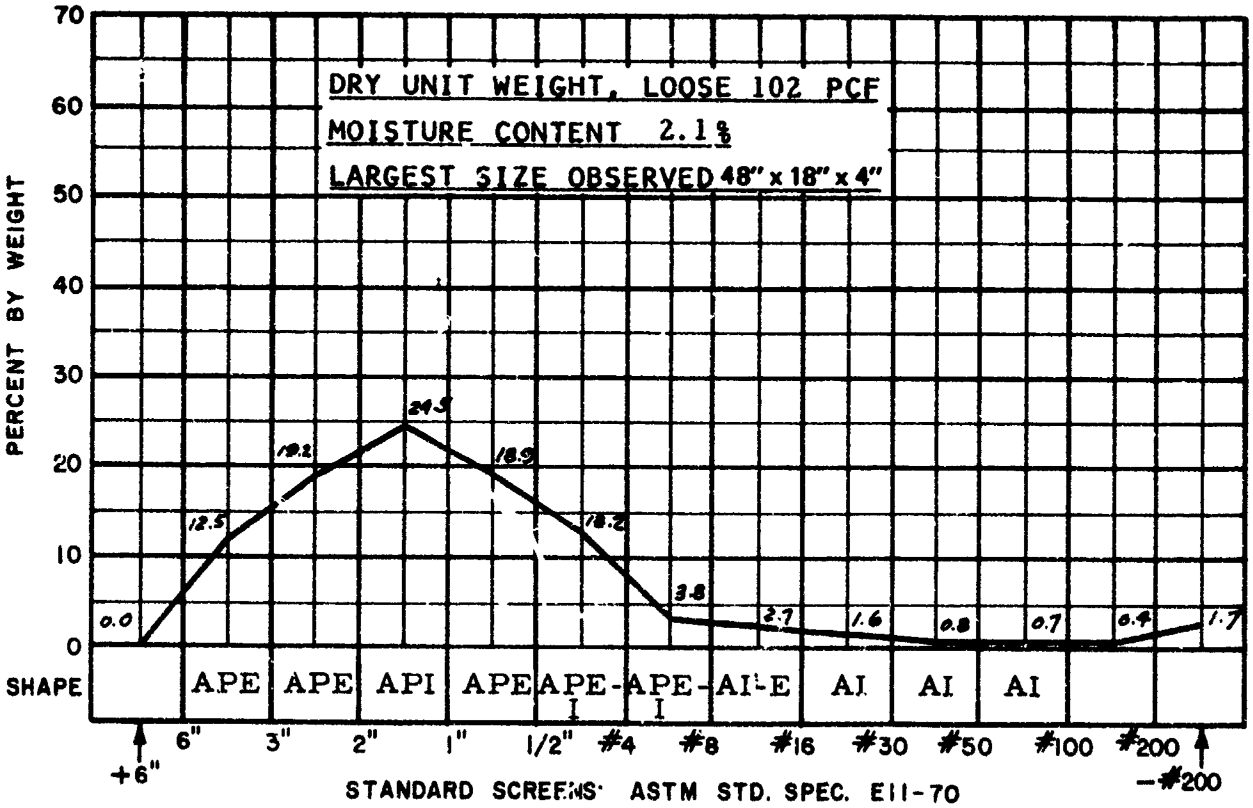
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056": 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.678**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 17.70%	**Plastic Limit 17.48%**	**Shrinkage Limit 16.73%**
Plasticity Index 0.22%	**Toughness Index 0.03**	**Flow Index 7.2**

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop **@ 1.58% Moisture, 35.75°**	**Apparent Cohesion PSF** **@ 1.58% Moisture, 250**	**Angle/Repose 10" Drop** **@ 1.58% Moisture, 33.25°**
Angle Slide Steel Plate **@ 1.58% Moisture, 31.42°**	**Bulk Density PCF** **@ 1.58% Moisture, 99.36**	**Angle Internal Friction** **@ 1.58% Moisture, 42.5°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Graywacke, massive to medium bedded, normal dip 30° to 45°, highly folded and fractured. High strength. RQD (Est.) 35%. DUW: 171 PCF. Ground water: None. Hardness: Schmidt 44.

System Class: Conventional rail, 10' wide x 10.8'. Two machine jumbo, 36 - 8' holes, V cut. PF 7.0 #/CY. Overhead loader mucking - rail haulage. Support: Rock bolts and plates as required.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. MB-2
4/1/73	MDN	Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.
Uniaxial Compressive Strength: 22 KPSI.
RQD: 92%.
Dry Unit Weight: 166 PCF
Ground Water: Dry.
Hardness: Shore 61, Schmidt 37.
Youngs Mod.: 5.38 PSI x 10^6.
Poisson Ratio: 0.25

TUNNEL DATA:

Size: 18'-1" dia. Grade (-) 7%
Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4100'.
Utility System: 2" water line, 4" pump line. No air line - compressor on machine.
Water Inflow: 5-10 gpm
Power System: 4160/480V
Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.
Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.
Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".
Rotation: 4 1/2 RPM (Center integral with head)
Torque: 1,720 K ft. #
Thrust: 1,580 K# max., 914 K# operating.
Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.
Power System: Six-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.
Guidance System: Laser.

MUCK DATA

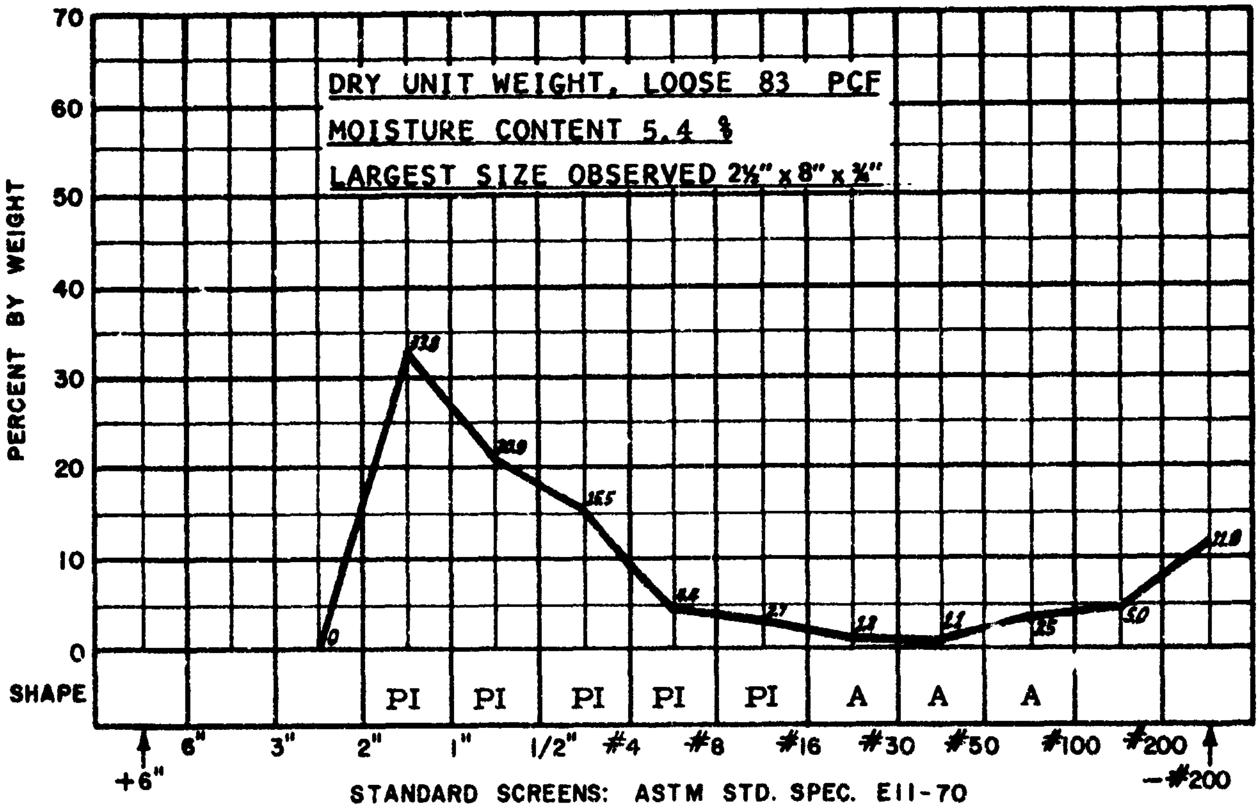
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.065" : 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.73**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 16.90%	**Plastic Limit 15.50 %**	**Shrinkage Limit 15.18%**
Plasticity Index 1.40 %	**Toughness Index 0.28**	**Flow Index 5.0**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 6.3 % Moisture, 35°**	**Apparent Cohesion PSF** **@ 4.8% Moisture, 280**	**Angle/Repose 10" Drop** **@ 6.3 % Moisture, 29°**
Angle Slide Steel Plate **@ 6.3 % Moisture, 28°**	**Bulk Density PCF** **@ 0.0% Moisture, 85.23**	**Angle Internal Friction** **@ 4.8 % Moisture, 29°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 166 PCF. Ground water: Dry. Hardness: Shore 61, Schmidt 37.

System Class: TBM, Robbins 181-122, 18' 1" dia. 47 Robbins disc cutters. RPM: 4-1/2, 1,720 K FT.# torque, 914 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.
Uniaxial Compressive Strength: 22 KPSI.
RQD: 92%.
Dry Unit Weight: 166 PCF.
Ground Water: Dry.
Hardness: Shore 61, Schmidt 37 (Note 4).
Youngs Mod.: 5.38 PSI x 10^6 (Note 4).
Poisson Ratio: 0.25 (Note 4).

TUNNEL DATA:

Size: 18'-1" dia. Grade (+) 2%.
Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4800'.
Utility System: 2" water line, 4" pump line. No air line - compressor on machine.
Water Inflow: 5-10 gpm.
Power System: 4160/480V.
Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.
Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.
Cutters: 47 Robbins, Steel Disc. Gage: 3-12". Center: 1-7 1/2" triple, Interior: 43-12".
Rotation: 4 1/2 RPM (Center integral with head)
Torque: 1,720 Kft #
Thrust 1,580 K# max., 747 K# operating.
Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.
Power System: Four-480V., 200 HP motors drive head. Hydraulic pumps power thrust and anchor cylinders.
Guidance System: Laser.

NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

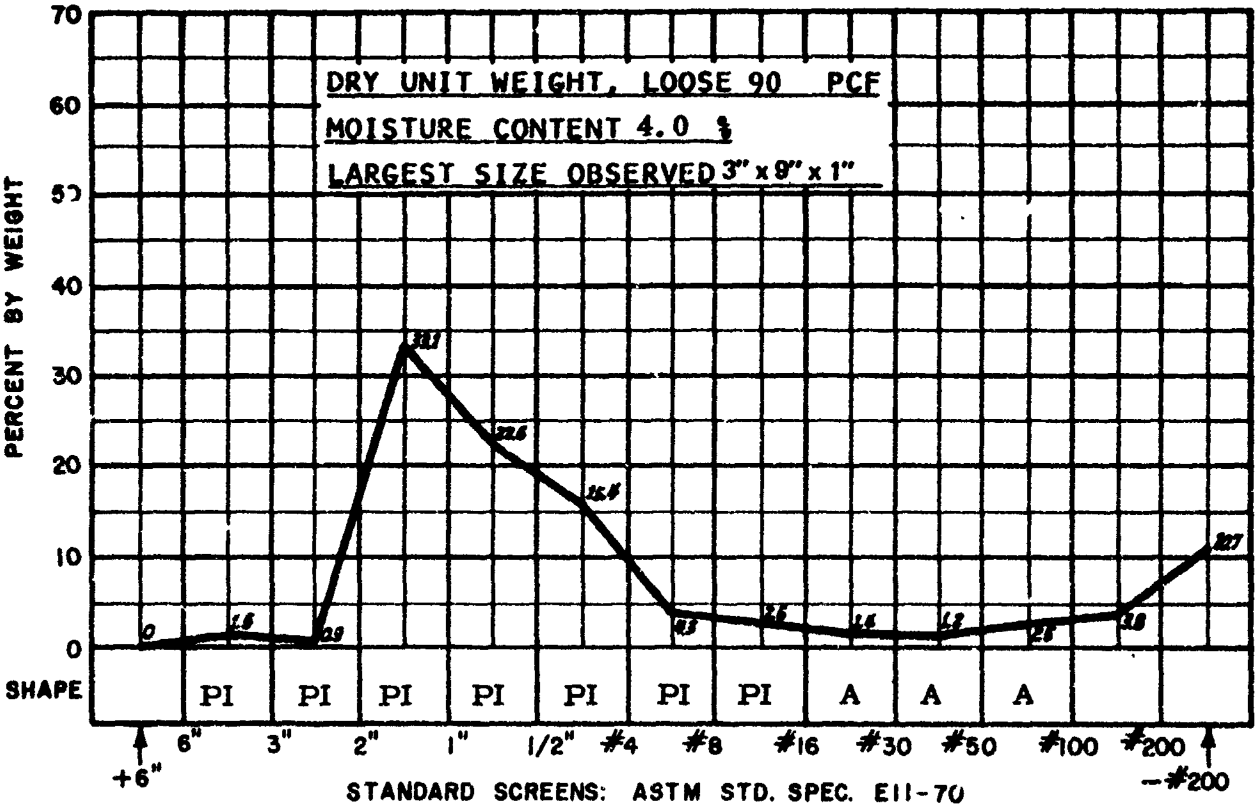
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-)0.75": 2.63**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 23.0 %	**Plastic Limit 17.63%**	**Shrinkage Limit 17.58 %**
Plasticity Index 5.37 %	**Toughness Index 0.78**	**Flow Index 6.90**

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop **@ 2.6 % Moisture, 32°**	**Apparent Cohesion PSF** **@ 2.8 % Moisture, 0**	**Angle/Repose 10" Drop** **@ 2.6 % Moisture, 31°**
Angle Slide Steel Plate **@ 2.6 % Moisture, 29°**	**Bulk Density PCF** **@ 0.0 % Moisture, 92.8**	**Angle Internal Friction** **@ 2.8 % Moisture, 44°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 166 PCF. Ground water: Dry. Hardness: Shore 61, Schmidt 37.

System Class: TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,720 K FT # torque, 747 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly-laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.
Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 23 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 165 PCF.
Ground Water: Dry
Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular. Schmidt (Av) 46.
Youngs Mod.: 9.52
Poisson Ratio: 0.15

TUNNEL DATA:

Size: 24' wide x 7 1/2' rectangular. Grade: Varies.
Ventilation System: 80-100K CFM, pressure.
Utility System: 4" air, 4" water, 4" pump, where required.
Water Inflow: Normally none.
Power System: 110V. Lighting-all equipment diesel or air powered.
Haulage System: Wagner ST-5 Scooptrams, 16 ton shuttle cars to conveyors, 1 1/2 CY loaders for cleanup. Personnel and supplies, diesel jeeps and trucks.
Support System: 5/8" x 6' rock bolts on 4' x 4' pattern, 11" wide x 10' roof plates where required.

EXCAVATION DATA:

Conventional Trackless System.
Drilling: Two boom hydrojib jumbos, AR93 drifters, 14'feed.
Drill Round: 35 holes, 1 3/4" diameter, 10 1/2 to 11' deep, and 1-6' buster hole, V-cut.
Explosives: 16#-1 1/4" x 8", 75% primers, 32#-1 1/4" x 12" RXL, 60% in lifters, 11# coalite 5Y, 1 1/4" x 12" in back holes, 175# AN/FO in remainder of round. Power factor: 3.5#/CY.
Blasting: Electrical, MS delays.
Mucking: Wagner ST-5 Scooptrams.
Guidance: Transit/Laser.

MUCK DATA

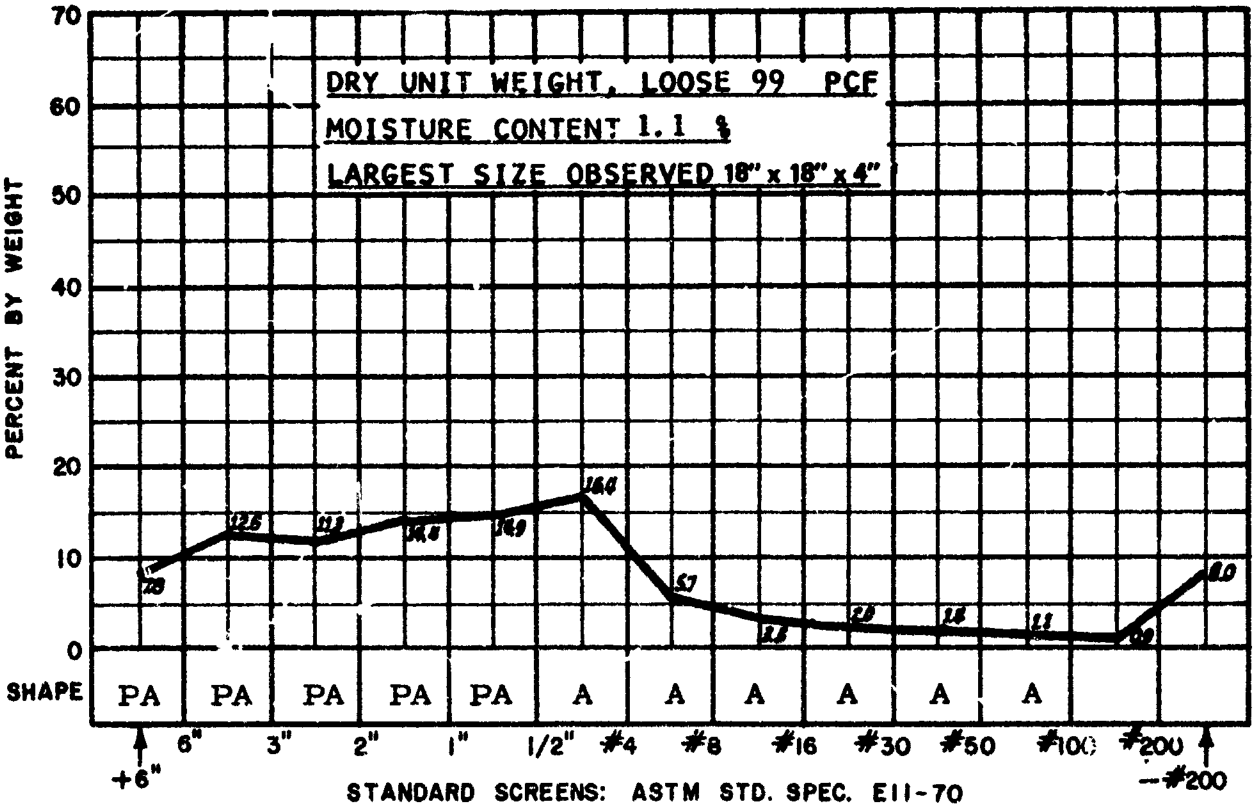
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-) 0.056" : 0	Spec. Gravity, Material Size (-) 0.75" : 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.60 %	Plastic Limit 14.81 %	Shrinkage Limit 14.51 %
Plasticity Index 0.79 %	Toughness Index 0.26	Flow Index 3.00

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 1 % Moisture, 25°	Apparent Cohesion PSF @ 0.2 % Moisture, 550	Angle/Repose 10' Drop @ 1 % Moisture, 25°
Angle Slide Steel Plate @ 1 % Moisture, 29°	Bulk Density PCF @ 0.0 % Moisture, 100	Angle Internal Friction @ 0.2 % Moisture, 46°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%. DUW: 165 PCF. Ground water: Dry. Hardness: Shore, 41-55, Schmidt 46.

System Class: Conventional trackless. 24' wide x 7-1/2', rectangular. Two boom jumbo, 35-1-3/4" holes, V-cut. PF 3.5#/CY. Mucking: Scooptram. Haulage: Scooptram and/or shuttle cars to conveyor. Support: Rock bolts, 4' x 4' pattern.

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 22 K to 29 KPSI, three minor beds: 12 K to 17 KPSI. Weighted Average: 22 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 41.0 to 55 parallel to bedding planes, 41 to 54 perpendicular. Schmidt (av) 46.

Youngs Mod.: 9.50 PSI x 10^6 (Note 4).

Poisson Ratio: 0.15 (Note 4).

TUNNEL DATA:

Size: 18' wide x 8 1/2' high, rectangular. Grade: Level.

Ventilation System: 20 KCFM exhaust from face, pressure to entry, 40 HP.

Utility System: 2" water line (250 cfm compressor on machine trailer).

Water Inflow: None.

Power System: Cable to trailer mounted transformer.

Haulage: Muck by diesel shuttle car to conveyor, personnel and supplies by diesel truck.

Support System: 5/8" rock bolts, normally 6' long on 4' x 4' spacing, as required.

EXCAVATION DATA:

Machine: Atlas-Copco 4 head prototype. Weight: 180 LT. Two 4' dia. heads are mounted on each side of center on horizontal booms rotated about vertical pivots. Heads are rotated around boom centerlines by motors and reducers integral with the booms; booms and heads rotate from side to forward positions.

Cutters: 48 Sandvik T.C., drag type, mounted on head peripheries. Leading cutters, 40mm wide, 8 per head; Finish cutters, 120mm wide, 4 per head.

Rotation: Upper heads: 3 1/4 RPM. Lower: 1 5/8 RPM.

Torque: Head rotation: 80 KW. Boom rotation: 100 LT per boom.

Thrust: 488 LT produced by 4 hydraulic cylinders between advanced and front units.

Anchorage: Two top and two side cylinders, approximately 1,000 K#.

Muck Collection: Flight conveyors move muck from sides to a central 26" flight conveyor, discharging on a 9 1/2' dia. star wheel. The wheel feeds a 25" belt conveyor, transferring muck to a Joy loader and shuttle cars.

Power System: 4160/600/120V, 60 Hz. Head rotation: 4-80 KW motors, hydraulics: 2-78 KW motors, 2300 psi.

Guidance: Transit/Laser.

NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

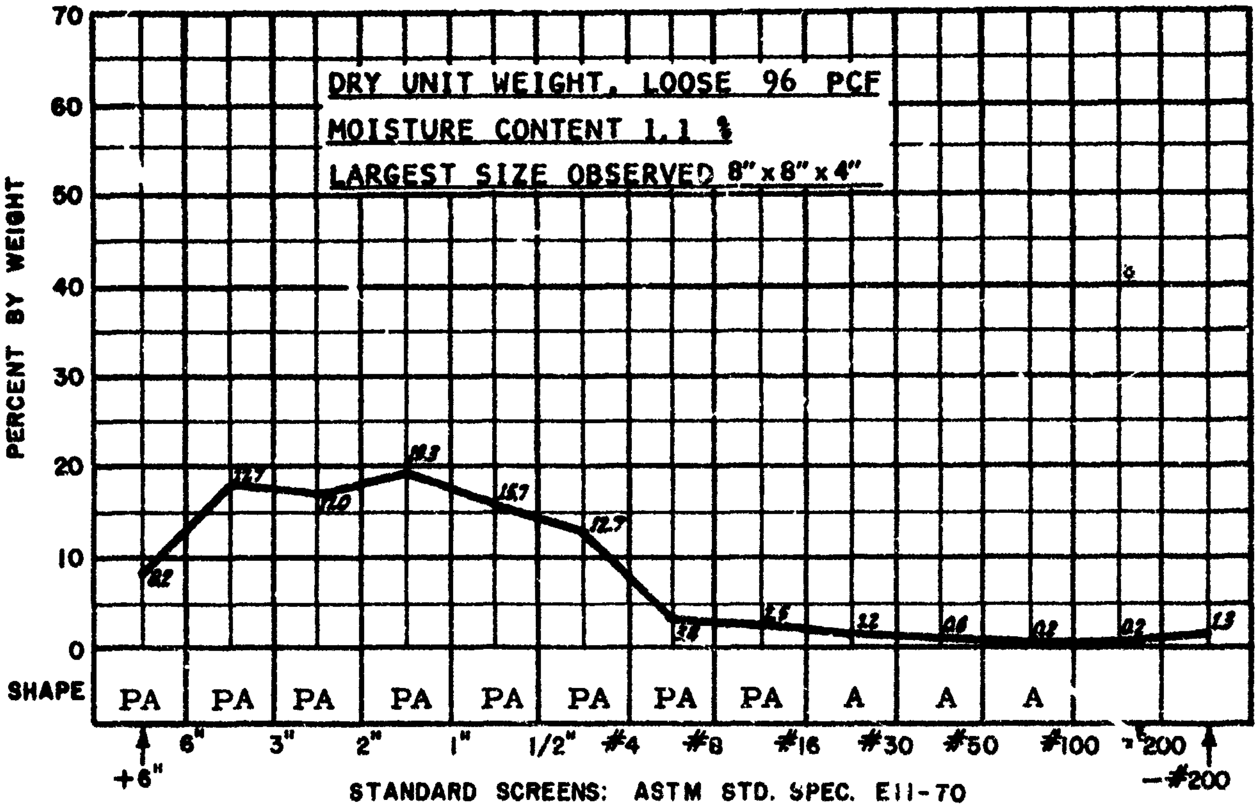
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056" : 0**	**Spec. Gravity, Material** **Size (-) 0.75" : 2.78**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.80 %	**Plastic Limit 15.60 %**	**Shrinkage Limit 13.26 %**
Plasticity Index 0.20 %	**Toughness Index 0.05**	**Flow Index 4.00**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 0.9 % Moisture, 28°**	**Apparent Cohesion PSF** **@ 0.2 % Moisture, 282**	**Angle/Repose 10" Drop** **@ 0.9 % Moisture, 29°**
Angle Slide Steel Plate **@ 0.9 % Moisture, 28°**	**Bulk Density PCF** **@ 0.0 % Moisture, 100**	**Angle Internal Friction** **@ 0.2 % Moisture, 54°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High strength. RQD (Est.) 90%. DUW: 166 PCF. Ground water: Dry. Hardness: Shore 41-55, Schmidt 46.

System Class: TBM, Atlas-Copco. 18' wide x 8-1/2' rect. heading. Sandvik TC "drag" bits. 12/head, 4 heads. RPM 3 1/4 normal. Torque 80 KW/head, 100LT/boom. 480LT thrust. Mucking: Flight conveyor - starwheel-belt-loader. Haulage: Shuttle car to conveyor. Support: Rock bolts at 4'.

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	2	

ROCK DATA:

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Locally highly faulted and fractured. Grain size varies from fine to coarse.
Uniaxial Compressive Strength: 22 KPSI (weighted average).
RQD: (Estimated) 65%.
Dry Unit Weight: 168 PCF.
Ground Water: None.
Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular. Schmidt (av) 46.
Youngs Mod.: 8.37 PSI x 10^6.
Poisson Ratio: 0.35.

TUNNEL DATA:

Size: 18'-1" diameter. Grade: (+) 10%.
Ventilation System: 18K CFM, exhaust, 36" diameter pipe, 120 HP @ 7200'.
Utility System: 2" water, 4" pump line from sump at 4200' approximate.
Water Inflow: 5-10 gpm.
Power System: 4160/480V.
Haulage System: Muck, 30" - "piggy back" conveyor supported by monorail advances with TBM, feeds a 36" conveyor suspended from back of tunnel. Supply and Personnel: Diesel jeeps and trucks.
Support System: 6" x 8.2# channels x 13.5' at 2', secured by 6-5/8" x 6' rock bolts, lagging under channels.

EXCAVATION DATA:

Machine: Robbins 181-122. Total Weight: 260 tons.
Cutters: 47 Robbins, steel disc, w/Esco rings, Gage: 3-12". Center: 1-7 1/2" triple. Interior 43-12".
Rotation: 4 1/2 RPM.
Torque: 1,147 K#.
Thrust: 769 K#.
Muck System: Buckets fixed to head, discharge on conveyors.
Power System: Four - 480V, 200 HP motors drive head.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-)0.056" : 0

Spec. Gravity, Material
Size (-)0.75" : 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.00 %
Plasticity Index 0.90 %

Plastic Limit 17.10 %
Toughness Index 0.20

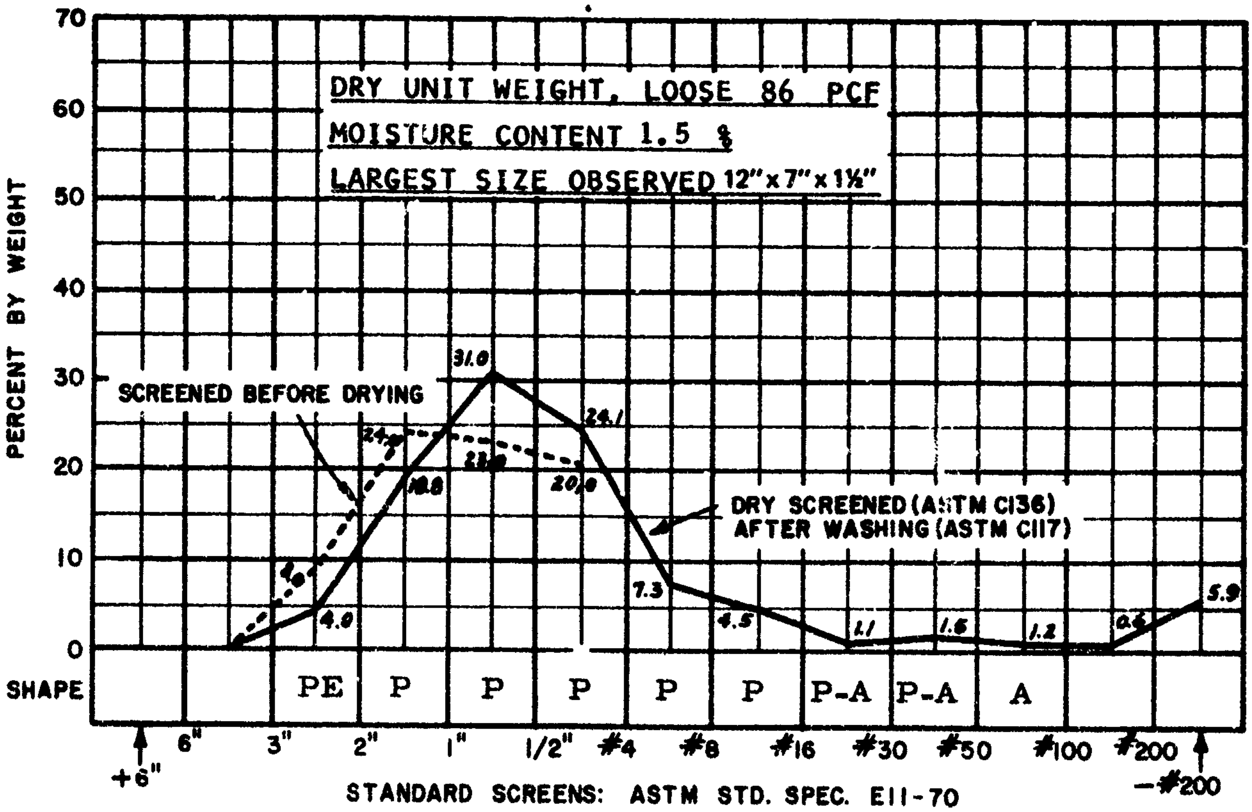
Shrinkage Limit 15.58 %
Flow Index 4.40

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop
@ 1.3 % Moisture, 36°
Angle Slide Steel Plate
@ 1.3 % Moisture, 30°

Apparent Cohesion PSF
@ 1.0 % Moisture, 170
Bulk Density PCF
@ 0.0 % Moisture, 100

Angle/Repose 10" Drop
@ 1.3 % Moisture, 32°
Angle Internal Friction
@ 1.0 % Moisture, 41°



MUCK: PCT. BY WT. AND SHAPE [ETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: "Shale" siltstone and shale interbedded, minor sandstone and limestone layers. Massive to thinly laminated, fine to coarse grained. High strength. RQD (Est.) 65%. DUW: 168 PCF. Ground water: None. Hardness: 41 - 55 Shore, Schmidt 46.

System Class: TBM, Robbins 181-122, 18'1" dia. 47 Robbins disc cutters. 4-1/2 RPM, 1,476 K FT # Torque, 769 K# Thrust. Mucking: Buckets to belt. Haulage: Conveyor.

ROCK DATA:

Lithology: Sedimentary, conglomerate ("breccia") 1/4"-10" rounded to angular boulders, cobbles, pebbles in a predominantly limestone matrix, w/chert, schist diabase fragments, well to moderately consolidated.
Uniaxial Compressive Strength: 11 KPSI (ASTM C-170).
RQD: (Estimated) 65%.
Dry Unit Weight: 171 PCF
Ground Water: Normally dry.
Hardness: Schmidt 36.
Youngs Mod.: 7.20 PSI x 10^6 (Note 2).
Poisson Ratio: 0.25 (Note 4).

TUNNEL DATA:

Size: 9' x 10' high. Grade: Level.
Ventilation System: 10 KCFM, pressure, 24" diameter pipe, 50 HP @ 1000', from coil heat exchanger.
Utility System: 6" air line, 2" water line.
Water Inflow: None.
Power System: 4160/480/120V.
Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives 44 CF rocker dump cars, 18" gage, 30# rail.
Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

EXCAVATION DATA:

Conventional Rail System.
Drilling: 3 boom hydraulic jumbo, 7' chain feeds, and 3" bore drifters, 7/8" hex steel.
Drill Round: 42 to 50-1 3/8" diameter holes including 4 hole V cut and 4 hole baby V or 5 hole burn cut, average advance 5 1/2'.
Explosives: 150#, 25# Amogel, #4-40% primers and cushion, 125# Carbamite PB. Powder Factor, 8.2#/CY.
Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.
Mucking System: Eimco Model 21 Loader.
Guidance: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size(-) 0.056" : 0

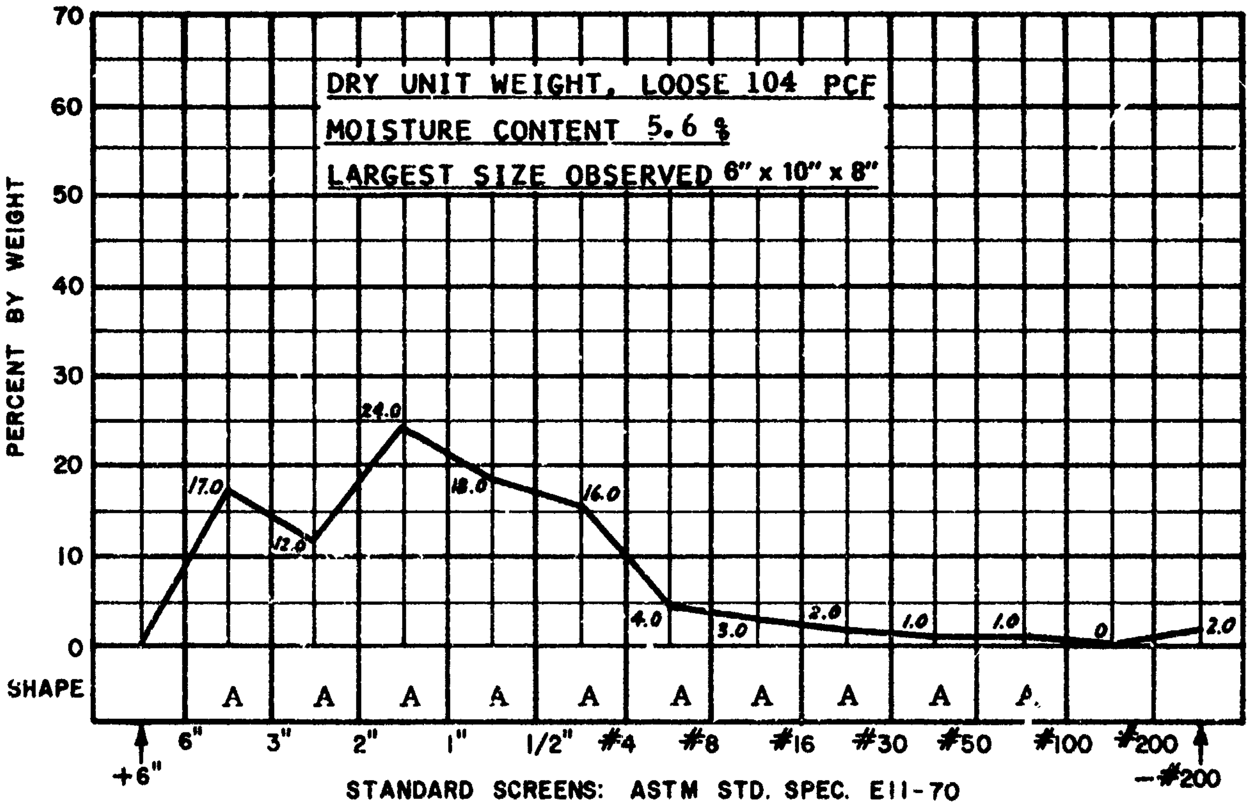
Spec. Gravity, Material
Size (-) 0.75" : 2.74

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 13.80 %
Plastic Limit 12.77 %
Shrinkage Limit 10.78%
Plasticity Index 1.03 %
Toughness Index 0.32
Flow Index 3.20

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 0.4 % Moisture, 35°
Apparent Cohesion PSF @ 0.3 % Moisture, 410
Angle/Repose 10" Drop @ 0.4 % Moisture, 29°
Angle Slide Steel Plate @ 0.4 % Moisture, 27°
Bulk Density PCF @ 0.0 % Moisture, 111
Angle Internal Friction @ 0.3 % Moisture, 46°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" to 10", limestone, chert, schist, diabase fragments, well to moderately consolidated. Strength: Medium. RQD (Est.) 65%. DUW: 171 PCF. Ground water: Dry. Hardness: Schmidt 36.

System Class: Conventional Rail, 9' wide x 10', three boom jumbo, 42 to 50-1-3/8" holes, burn cut. PF 8.2 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: Rock bolts and plates, continuous.

ROCK DATA:

Lithology: Sedimentary, conglomerate, ("breccia") 1/4"-4" boulders, cobbles, and pebbles, rounded to angular in a predominantly limestone matrix, w/chert, schist and diabase fragments, well consolidated.
Uniaxial Compressive Strength: 25 KPSI.
RQD: (Estimated) 80%.
Dry Unit Weight: 169 PCF
Ground Water: None
Hardness: Schmidt 45.
Youngs Mod.: 8.70 PSI x 10^6.
Poisson Ratio: 0.22.

TUNNEL DATA:

Size: 9' wide x 10' high, arched. Grade: Level.
Ventilation System: 9 KCFM, pressure, 24" diameter pipe, 50 HP @ 1300' from coil heat exchanger.
Utility System: 6" air line, 2" water line.
Water Inflow: None.
Power System: 4160/480/120V.
Haulage System: Muck, supplies, personnel by railcars, 4 and 6 ton battery locomotives, 44 cu. ft. rocker dump cars, 18" gage, 30# rail.
Support System: 5/8" x 6' rock bolts, 3', 4 1/2' or 6' roof plates, 21 bolts and 7 plates per 5' span.

EXCAVATION DATA:

Conventional Rail System.
Drilling: 2 boom jumbo, 6' chain feeds and 3" bore drifters.
Drill Round: 50-1 3/8" diameter holes, including 4 hole V cut and 4 hole baby V, 5 1/2' average advance.
Explosives: 122# average, 40% Amogel #4 or 40% primers and carbamite. Powder Factor, 6.7#/CY.
Blasting: #6 caps, 8' fuse, detonated electrically, timed by order of connection to igniter cord.
Mucking System: Eimco Model 21 loader.
Guidance: Laser.

MUCK DATA

Abrasiveness N. A.

Pot. Vol. Change, Material Size (-) 0.056": 0

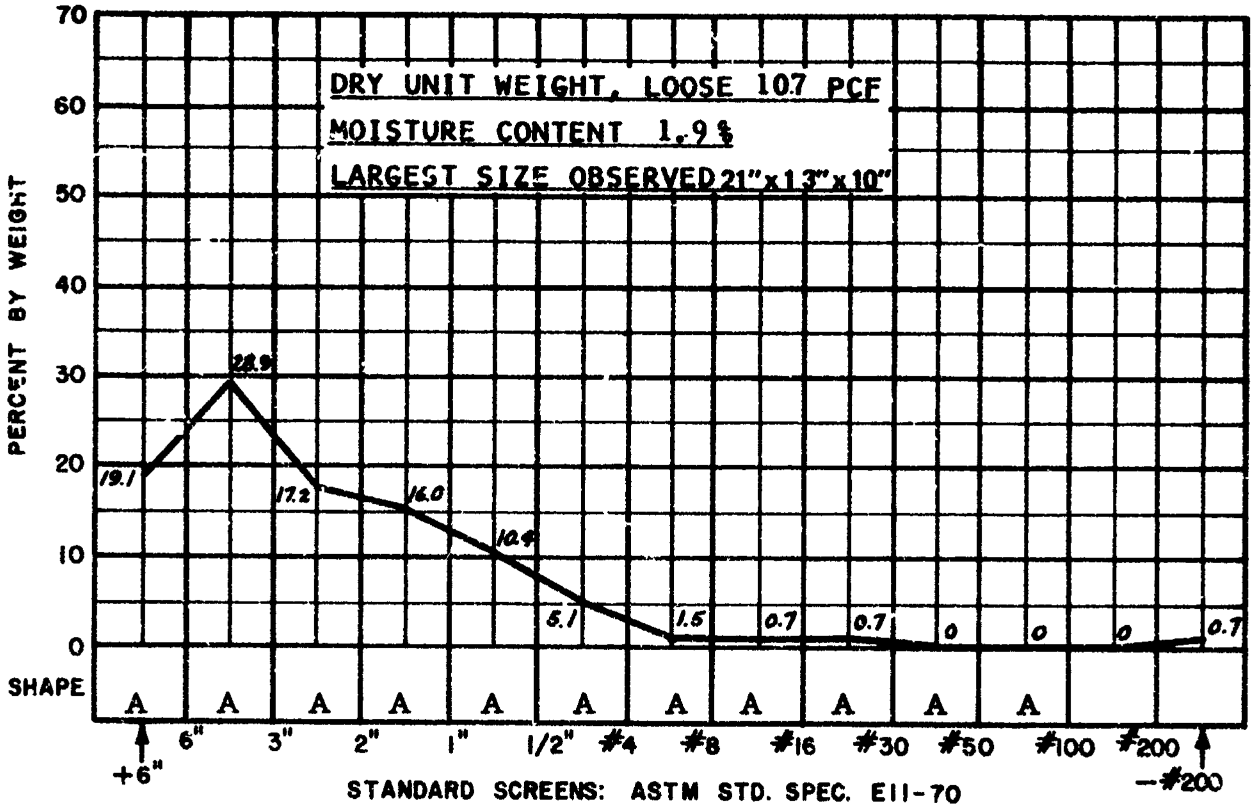
Spec. Gravity. Material Size (-) 0.75": 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.00%
Plastic Limit 13.99%
Shrinkage Limit 10.67%
Plasticity Index 6.01%
Toughness Index 1.40
Flow Index 4.5

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop @ 0.83% Moisture, 34.2°
Apparent Cohesion PSF @ 0.83% Moisture, 790
Angle/Repose 10" Drop @ 0.83% Moisture, 29.75°
Angle Slide Steel Plate @ 0.83% Moisture, 33.75°
Bulk Density PCF @ 0.83% Moisture, 96.15
Angle Internal Friction @ 0.83% Moisture, 43.45°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Conglomerate, "breccia," 1/4" - 4" limestone, chert schist, diabase fragments, well consolidated. High strength. RQD (Est.) 80%. DUW: 169 PCF. Ground water: None. Hardness: Schmidt 45.

System Class: Conventional Rail. 9' wide x 10'. Two machine jumbo, 50 holes, V cut. PF 6.7 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: Roof plates and rock bolts, continuous.

MDN STUDY
4/1/73

SYSTEM DATA SHEET
MDN
2

Ident. No. MSU-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestore, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 29 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 161 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46, Schmidt 42.
Youngs Mod.: 8.70 PSI x 10^6.
Poisson Ratio: 0.41.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.
Ventilation System: 21 K CFM exhaust, 28" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 40 to 120 gpm.
Power System: 4160/480V.
Haulage System: Muck, supplies, personnel, by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.
Rotation: Center cutter-30 RPM, Head-9 RPM.
Torque: Head 206 K ft. #
Thrust: 614 K# operating
Muck Collection: Buckets from face discharging on 24" belt conveyor.
Power System: Electro-Hydraulic. Total HP: 910.
Guidance System: Laser.

MDN STUDY
1/1/73

SYSTEM DATA SHEET
MDN
4

Ident. No. LAW-2
Sheet 1

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material Size (-) 0.065": 0

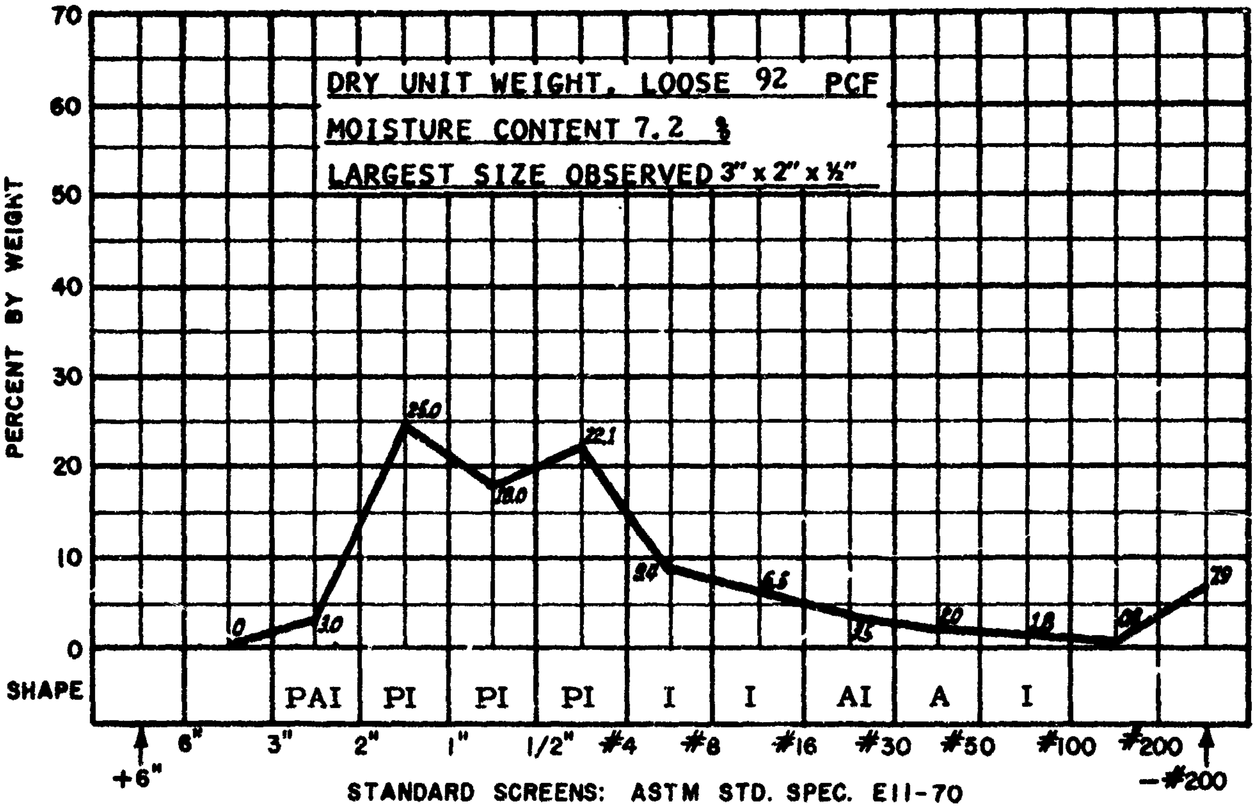
Spec. Gravity, Material Size (-) 0.75": 2.83

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.185 IN.

Liquid Limit 12.5 %	**Plastic Limit** 12.3 %	**Shrinkage Limit** 9.6 %
Plasticity Index 0.2 %	**Toughness Index** 0.05	**Flow Index** 4.0

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 5.4 % Moisture, 39°	Apparent Cohesion PSF @ 7% Moisture, 0	Angle/Repose 10' Drop @ 5.4 % Moisture, 38°
Angle Slide Steel Plate @ 5.4 % Moisture, 31°	Bulk Density PCF @ 0.0% Moisture, 83.97	Angle Internal Friction @ 7 % Moisture, 30°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 161 PCF. Ground water: Minor. Hardness: Shore 46, Schmidt 42.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 29 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 161 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46, Schmidt 42.
Youngs Mod.: 8.70 PSI x 10^6 (Note 4).
Poisson Ratio: 0.41 (Note 4).

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.
Ventilation System: 20 K CFM exhaust, 28" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 40 to 120 gpm.
Power System: 4160/480V.
Haulage System: Muck, supplies, personnel, by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.
Rotation: Center cutter-30 RPM, Head-9 RPM.
Torque: 206 K ft. #.
Thrust: 614 K# operating.
Muck Collection: Buckets from face, discharging on 24" belt conveyor.
Power System: Electro-Hydraulic. Total HP: 910.
Guidance System: Laser.

NOTE 4: Inferred from Tests of Similar Specimens.

MUCK DATA

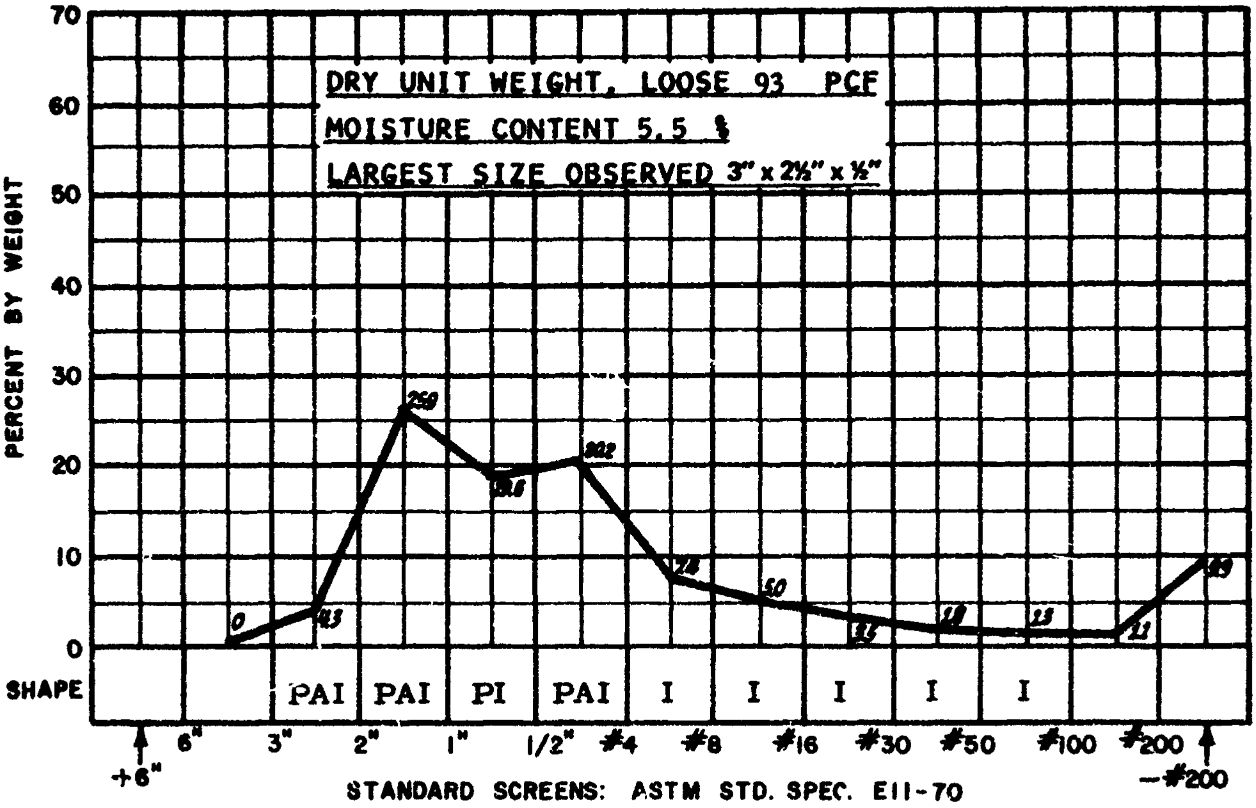
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.065" : 0**	**Spec. Gravity, Material** **Size(-) 0.75": 2.80**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 11.8 %	**Plastic Limit 10.6 %**	**Shrinkage Limit 10.0 %**
Plasticity Index 1.2 %	**Toughness Index 0.41**	**Flow Index 2.9**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 6.1% Moisture, 41°**	**Apparent Cohesion PSF** **@ 7% Moisture, 0**	**Angle/Repose 10" Drop** **@ 6.1 % Moisture, 40°**
Angle Slide Steel Plate **@ 8.4% Moisture, 38°**	**Bulk Density PCF** **@ 0.0% Moisture, 84.04**	**Angle Internal Friction** **@ 7 % Moisture, 32°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules occasional clay partings. High strength. RQD (Est.) 100%. DUW: 161 PCF. Ground water: Minor. Hardness: Shore 46, Schmidt 42.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 614 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 20 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 157 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46, Schmidt 52 (Note 2).
Youngs Mod.: 4.61 PSI x 10^6.
Poisson Ratio: 0.50

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent.
Ventilation System: 21 K CFM exhaust, 28" pipe.
Utility System: 6" air line, 2" water line, 6" pump line.
Water Inflow: 40 to 120 gpm.
Power System: 4160/480V.
Haulage System: Muck, supplies, personnel, by rail cars.
Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.
Rotation: Center cutter-30 RPM, Head-9 RPM.
Torque: Head 206 K ft. #.
Thrust: 540 K ft. #.
Muck Collection: Buckets from face discharging on 24" belt conveyor.
Power System: Electro-Hydraulic. Total HP: 910.
Guidance System: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

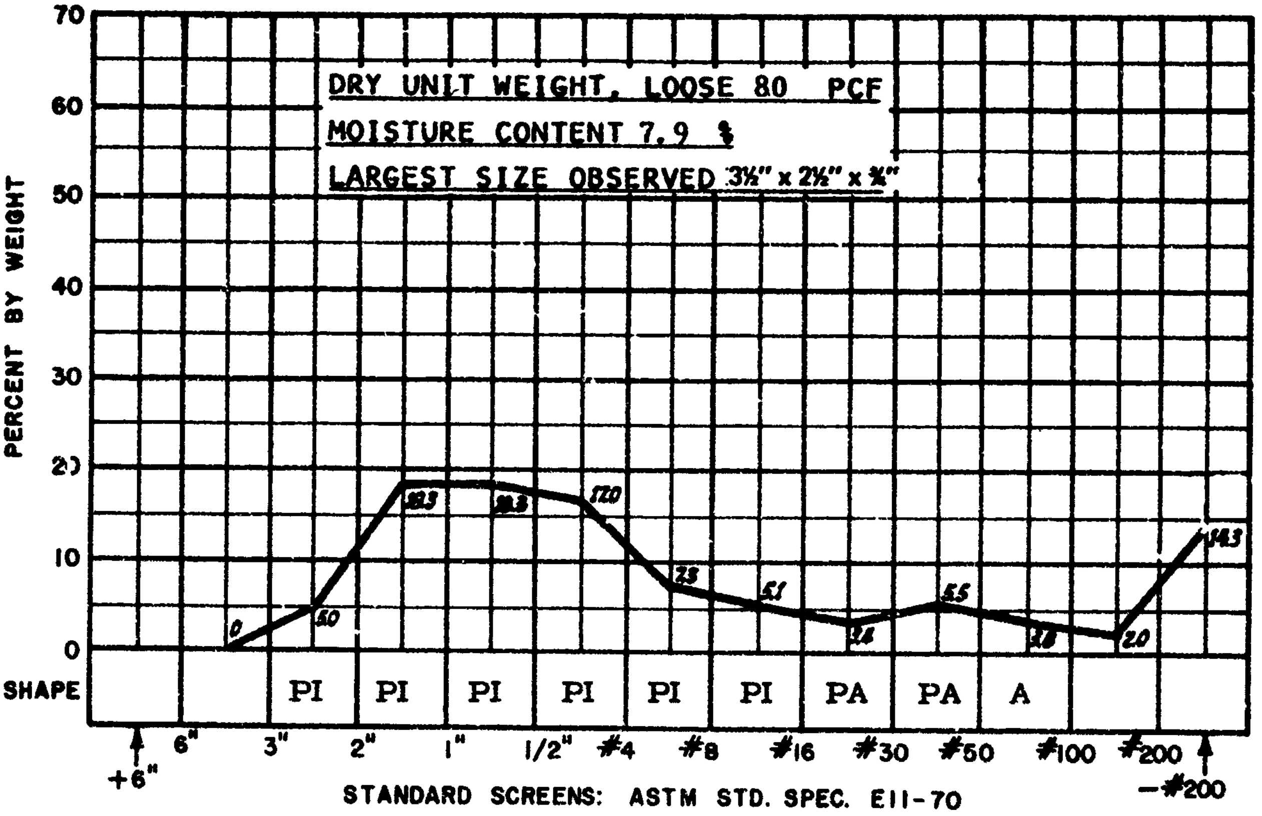
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056" : 0**	**Spec. Gravity, Material** **Size (-)0.75": 2.73**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 20.2 %	**Plastic Limit 20.0 %**	**Shrinkage Limit 13.5 %**
Plasticity Index 0.2 %	**Toughness Index 0.05**	**Flow Index 4.7**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 8.9 % Moisture, 42°**	**Apparent Cohesion PSF** **@ 8.8% Moisture, 210**	**Angle/Repose 10" Drop** **@ 8.9 % Moisture, 34°**
Angle Slide Steel Plate **@ 8.9 % Moisture, 37°**	**Bulk Density PCF** **@ 0.0% Moisture, 84.57**	**Angle Internal Friction** **@ 8.8 % Moisture, 28°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. High strength. RQD (Est.) 100%. DUW: 157 PCF. Ground water: Minor. Hardness: Shore 46, Schmidt 52.

System Class: TBM, Alkirk hardrock, 13' 8" dia. 28 Lawrence TCB roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: 206 K ft #. Thrust: 540 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1'.
Uniaxial Compressive Strength: 36 KPSI.
RQD: (Estimated) 85%
Dry Unit Weight: 166 PCF.
Ground Water: Minor, in fault zones.
Hardness: Schmidt 59 (Note 2).
Youngs Mod.: 10.00 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 11'-2" round. Grade: (+) .2%.
Ventilation System: 4 KCFM, exhaust, 18" pipe, 25 HP.
Utility System: 6" air line, 1" water line, 6" pump line.
Water Inflow: 5-10 gpm.
Power System: 4680/440V.
Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".
Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva Mark 11-1100. Total weight: 65 tons.
Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc. Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.
Rotation: Cutterhead RPM 9.3.
Torque: Maximum 170 K ft#.
Thrust: 1,104 K# maximum, 596 K #-operating. Anchor Pressure: 1,650 K#.
Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.
Power System: 440 volt, 6 - 50 HP motors drive head and 1-40 HP motor for hydraulic system.
Guidance: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056" : 0

Spec. Gravity, Material
Size (-) 0.75": 2.89

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 16.90 %
Plasticity Index 1.21 %

Plastic Limit 15.69 %
Toughness Index 0.24

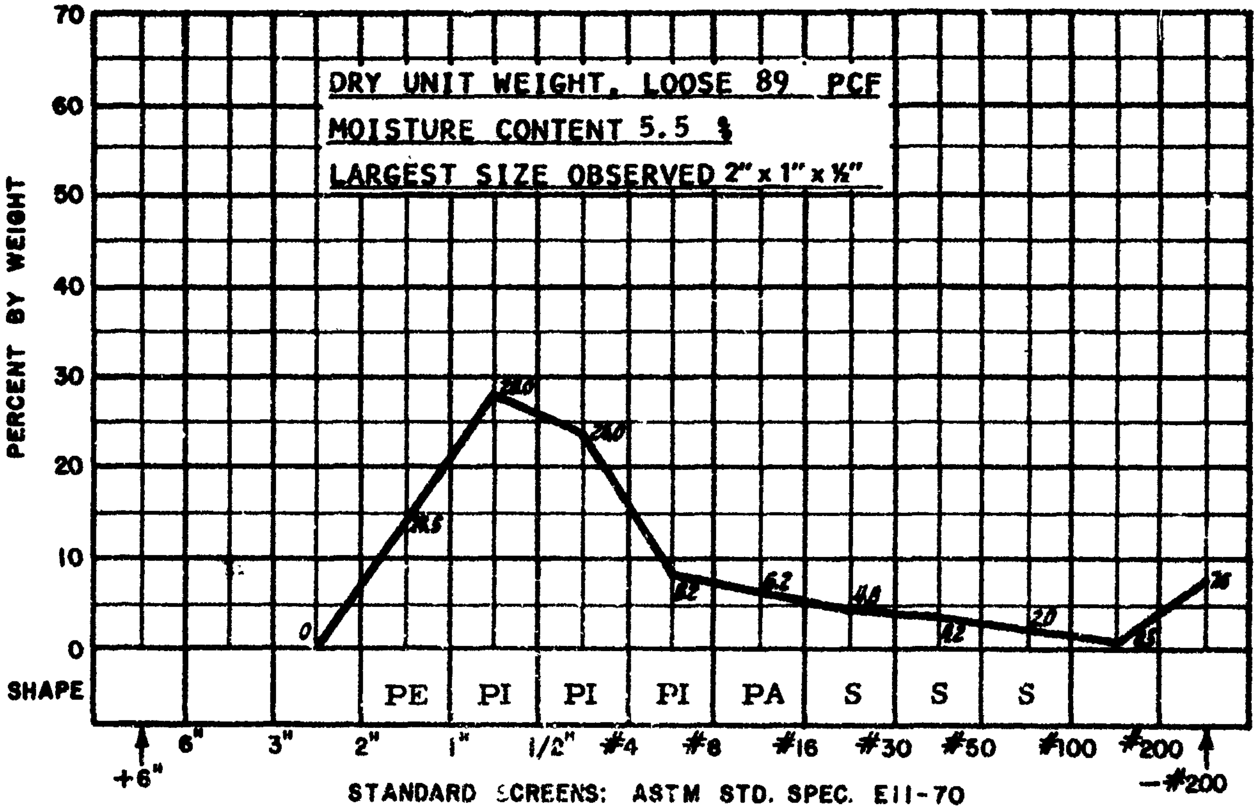
Shrinkage Limit 15.46 %
Flow Index 5.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop
@ 2.5 % Moisture, 36°
Angle Slide Steel Plate
@ 2.5 % Moisture, 30°

Apparent Cohesion PSF
@ 4.1 % Moisture, 95
Bulk Density PCF
@ 0.0 % Moisture, 86

Angle/Repose 10" Drop
@ 2.5 % Moisture, 35°
Angle Internal Friction
@ 3.5 % Moisture, 35°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD (Est.) 85%. DUW: 166 PCF. Ground water: Minor. Hardness: Schmidt 59.

System Class: TBM, Jarva Mark 11-100, 11' 2" dia. 27 Reed triple disc cutters/cone RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K #. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

ROCK DATA:

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1'.
Uniaxial Compressive Strength: 36 KPSI.
RQD: (Estimated) 85%.
Dry Unit Weight: 166 PCF.
Ground Water: Minor, in fault zones.
Hardness: Schmidt 59 (Note 2).
Youngs Mod.: 10.00 PSI x 10^6 (Note 2).
Poisson Ratio: 0.30 (Note 2).

TUNNEL DATA:

Size: 11'2" round, Grade: (+) .2%.
Ventilation System: 4KCFM, exhaust, 18" pipe, 25 HP.
Utility System: 6" air line, 1" water line, 6" pump line.
Water Inflow: 5-10 gpm.
Power System: 4680/440V.
Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".
Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA:

Machine: Jarva 11-1100, Total weight: 65 tons.
Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc. Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.
Rotation: Cutterhead RPM 9.3.
Torque: Maximum 170 K ft. #.
Thrust: 1,104 K# maximum, 596 K#-operating Anchor Pressure: 1,650 K#.
Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.
Power System: 440 volt, 6-50 HP motors drive head and 1-40 HP motor for hydraulic system.
Guidance: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.

MUCK DATA

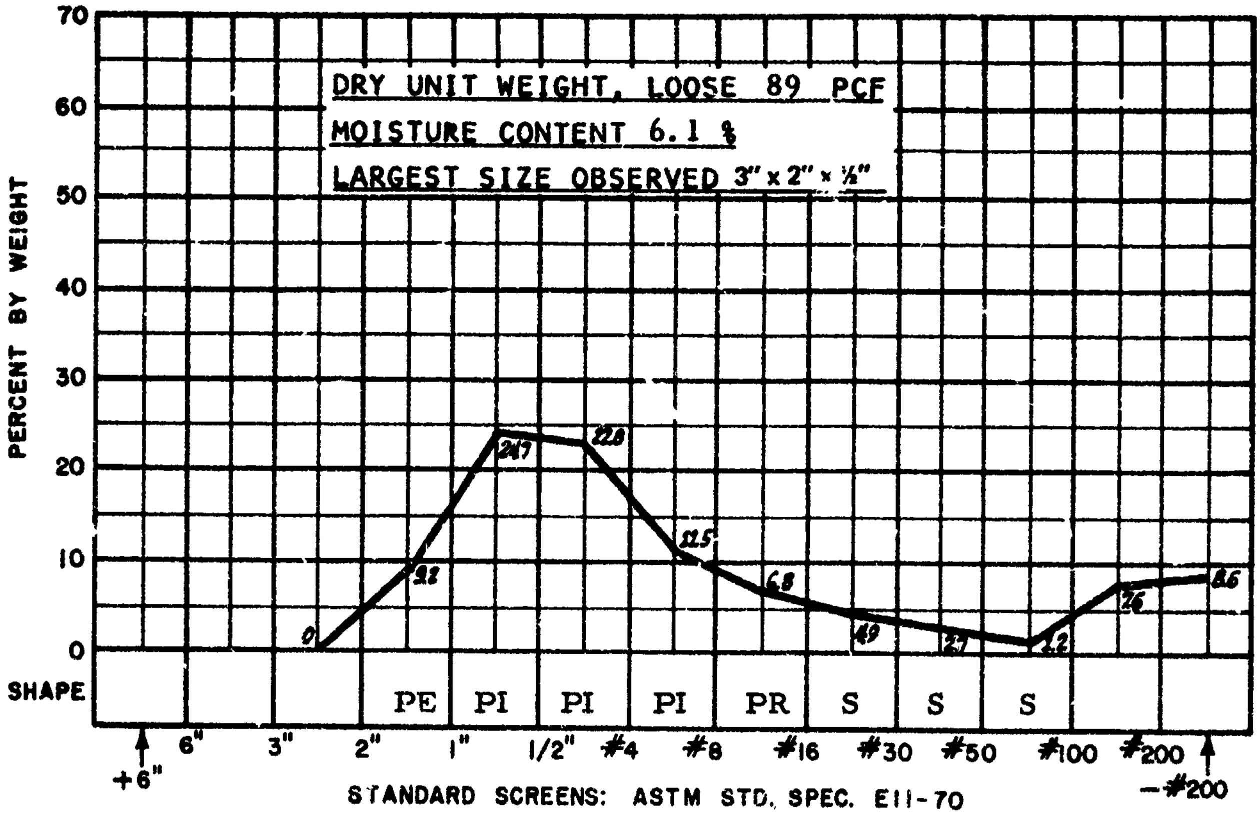
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-)0.056": 0**	**Spec. Gravity, Material** **Size (-)0.75": 2.93**

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 20.10%	**Plastic Limit 16.68 %**	**Shrinkage Limit 16.37 %**
Plasticity Index 3.42%	**Toughness Index 0.56**	**Flow Index 6.10**

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop **@ 5.8 % Moisture, 32°**	**Apparent Cohesion PSF** **@ 5.0 % Moisture, 110**	**Angle/Repose 10" Drop** **@ 5.8 % Moisture, 30°**
Angle Slide Steel Plate **@ 5.8 % Moisture, 30°**	**Bulk Density PCF** **@ 0.0 % Moisture, 90**	**Angle Internal Friction** **@ 5.0 % Moisture, 33°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal joint spacing 6" to 1'. Strength: Very high. RQD (Est.) 85%. DUW: 166 PCF. Ground water: Minor. Hardness: Schmidt 59.

System Class: TBM, Jarva Mark 11-100, 11'2" dia. 27 Reed triple disc cutters. RPM: 9.3. Torque: 170 K ft #. Thrust: 596 K #. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

ROCK DATA:

Lithology: Sedimentary, limestone, grey, fine grained, horizontal joint spacing 4"-8".
Uniaxial Compressive Strength: 22 KPSI.
RQD: (Estimated). 81%.
Dry Unit Weight: 164 PCF
Ground Water: Dry.
Hardness: Schmidt 40.
Youngs Mod.: 7.84 PSI x 10^6.
Poisson Ratio: 0.46.

TUNNEL DATA:

Size: 11' 2" diameter. Grade: (+) 0.2%.
Ventilation System: 4 KCFM, exhaust, 25 HP (through bore hole).
Utility System: 6" air line, 1" water line, 6" pump line.
Water Inflow: Minor.
Power System: 4680/440V.
Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive, 24" gage.
Support System: None.

EXCAVATION DATA:

Machine: Jarva, 11-1100, total weight 65 tons.
Cutters: 27 Reed steel disc: 4 gage QK5, 22 interior 2K3, 1 center QK1.
Rotation: 9.3 RPM.
Torque: 119K ft. lbs.
Thrust: 639K#
Muck Collection System: Buckets from face, belt to rear.
Power System: 6-50 HP motors drivehead, 1-40 HP motor for hydraulic system.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size(-) 0.056" : 0

Spec. Gravity, Material
Size (-) 0.75" : 2.78

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.20 %
Plasticity Index 0.80 %

Plastic Limit 14.40 %
Toughness Index 0.22

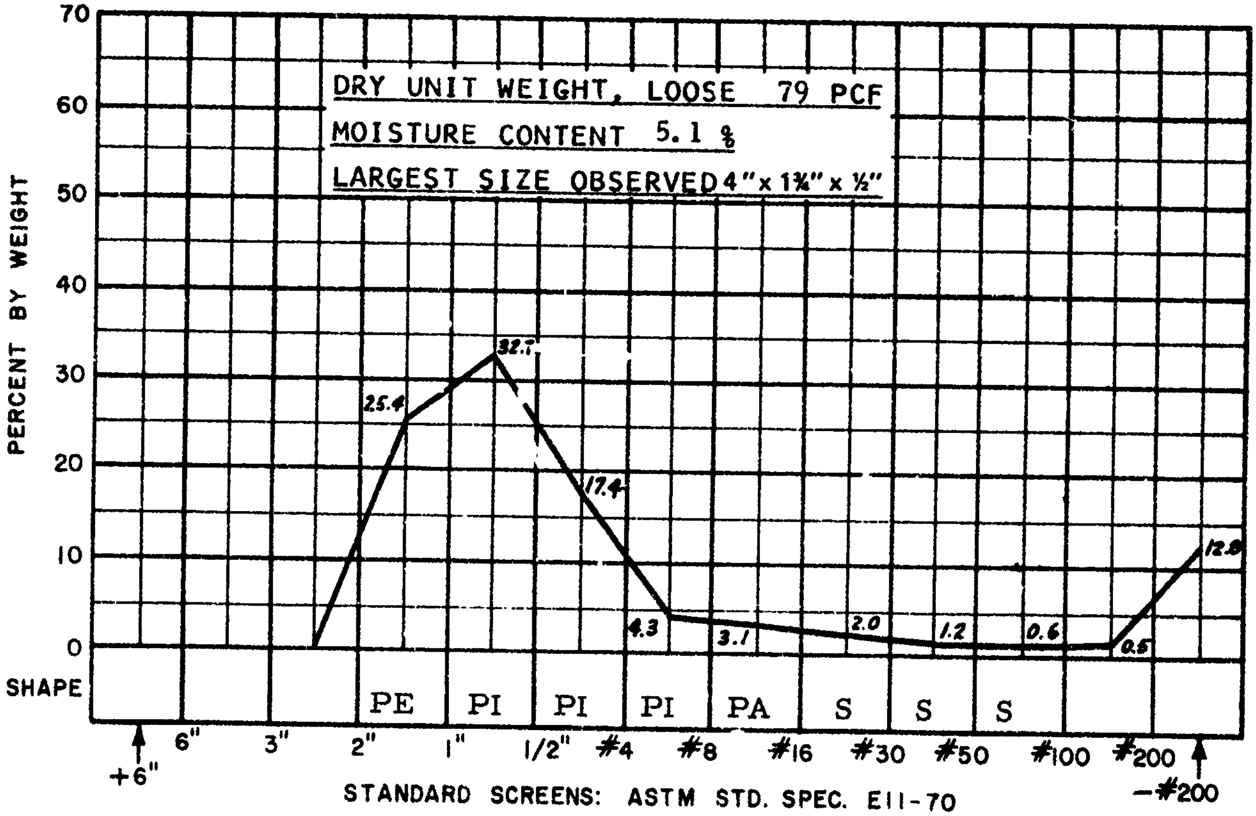
Shrinkage Limit 12.96 %
Flow Index 3.50

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 2.5 % Moisture, 36°
Angle Slide Steel Plate
@ 2.5 % Moisture, 32°

Apparent Cohesion PSF
@ 2.3 % Moisture, 60
Bulk Density PCF
@ 0.0 % Moisture, 95

Angle/Repose 10" Drop
@ 2.5 % Moisture, 32°
Angle Internal Friction
@ 2.3 % Moisture, 36°



MUCK. PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, horizontal jointing 4"-8". High strength. RQD: 81%. DUW: 164 PCF. Ground water: Dry. Hardness: Schmidt 40.

System Class: TBM, Jarva 11-1100, 11'2" dia. 27 Reed disc cutters. 9.3 RPM, 119 K ft Torque, 639 K # Thrust. Mucking: Buckets to belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.
Uniaxial Compressive Strength: 26K PSI.
RQD: 100%.
Dry Unit Weight: 168 PCF
Ground Water: Dry.
Hardness: Schmidt 44.
Youngs Mod.: 10.63 PSI x 10^6.
Poisson Ratio: 0.50.

TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.
Ventilation: 18 KCFM, exhaust, 30" diameter pipe, 90 HP @ 1980'.
Utility System: 3" water line.
Water Inflow: 300/400 gpm.
Power System: 7200/480V.
Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive, 4 CY cars, 24" gage, 54# rail.
Support System: None.

EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.
Cutters: 26 Robbins, 12" and 11" discs. 2 Gage and 21 interior, 12" diameter, 3 center, 11" diameter.
Rotation: 6 RPM.
Torque: 280K ft. lb.
Thrust: 230K lb.
Muck Collection System: Buckets from face, belt to rear.
Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.
Guidance: Laser.

MUCK DATA

Abrasiveness N. A.

Pot. Vol. Change, Material Size (-)0.056" : 0

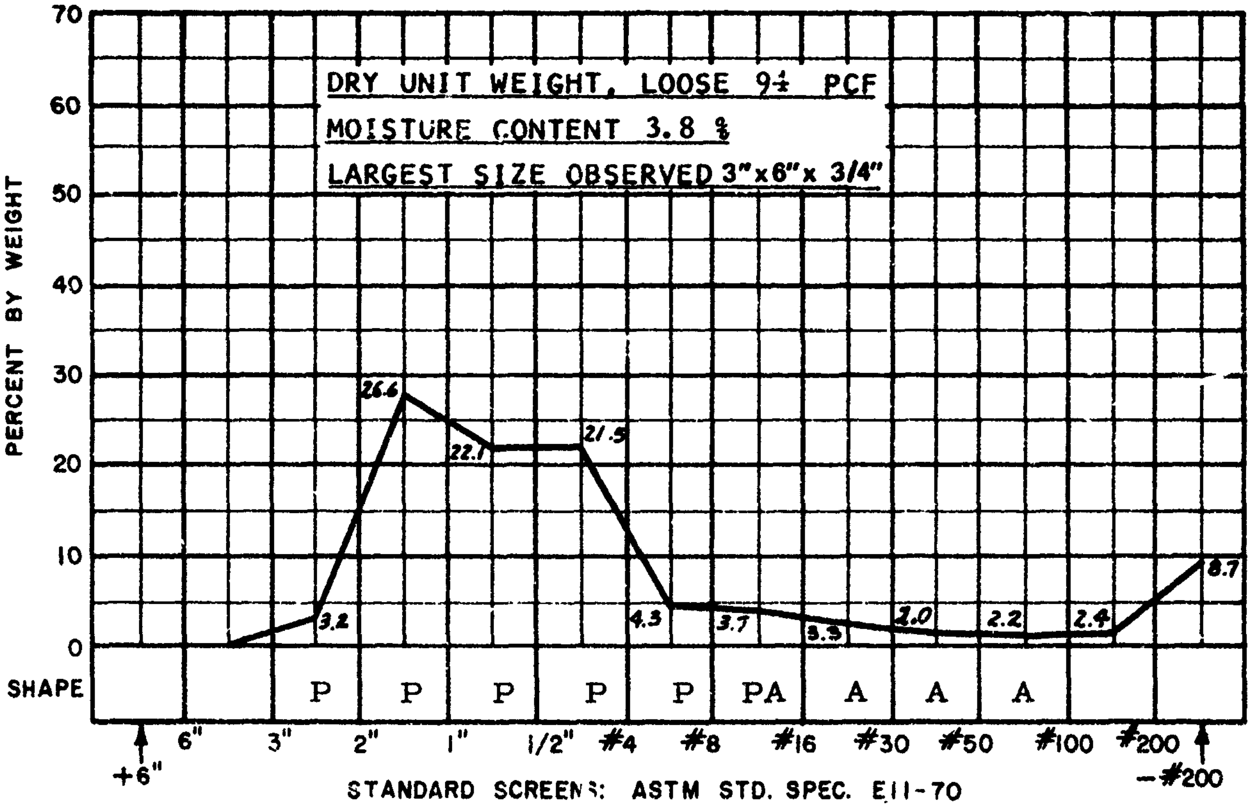
Spec. Gravity, Material Size (-) 0.75": 2.81

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.10% Plastic Limit 13.69% Shrinkage Limit 11.57%
Plasticity Index 1.41% Toughness Index 0.47 Flow Index 3.0

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.1 % Moisture, 37°
Apparent Cohesion PSF @ 3.0 % Moisture, 70
Angle/Repose 10" Drop @ 3.1 % Moisture, 31°
Angle Slide Steel Plate @ 3.1 % Moisture, 31°
Bulk Density PCF @ 0.0 % Moisture, 104
Angle Internal Friction @ 3.0 % Moisture, 42°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone fine grained. High strength. RQD 100%. DUW: 168 PCF. Ground water: Dry. Hardness: Schmidt 44.

System Class: TBM, Robbins, 105-144, 10' 4" dia. 26 Robbins disc cutters. RPM: 6. 280 K ft # torque. 230 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support· None.

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.
Uniaxial Compressive Strength: 30K.
RQD: 100
Dry Unit Weight: 170 PCF.
Ground Water: Dry.
Hardness: Schmidt 45.
Youngs Mod.: 10.82 PSI x 10^6.
Poisson Ratio: 0.30.

TUNNEL DATA:

Size: 10' 4" diameter. Grade: (+) 0.2%.
Ventilation System: 18 KCFM, exhaust, 30" diameter pipe, 90 HP.
Utility System: 3" water line.
Water Inflow: 300/400 gpm.
Power System: 7200/480V.
Haulage System: Muck, supplies, personnel by railcars, 5 ton locomotive, 4 CY cars, 24" gage, 54# rail.
Support System: None.

EXCAVATION DATA:

Machine: Robbins 105-144. Total weight: 75 tons.
Cutters: 26 Robbins 12" and 11" discs, 2 gage and 21 interior-12" diameter 3 center-11" diameter.
Rotation: 6 RPM.
Torque: 246K ft. lb
Thrust: 267K lb.
Muck Collection System: Buckets from face, belt to rear.
Power System: 4-100 HP motors drivehead, 50 HP for hydraulic system.
Guidance: Laser.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-) 0.056: 0

Spec. Gravity, Material
Size (-) 0.75: 2.473

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.50%
Plasticity Index 2.70%

Plastic Limit 12.80%
Toughness Index 1.00

Shrinkage Limit 12.06%
Flow index 2.70

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop
@ 3.15% Moisture, 40.1°

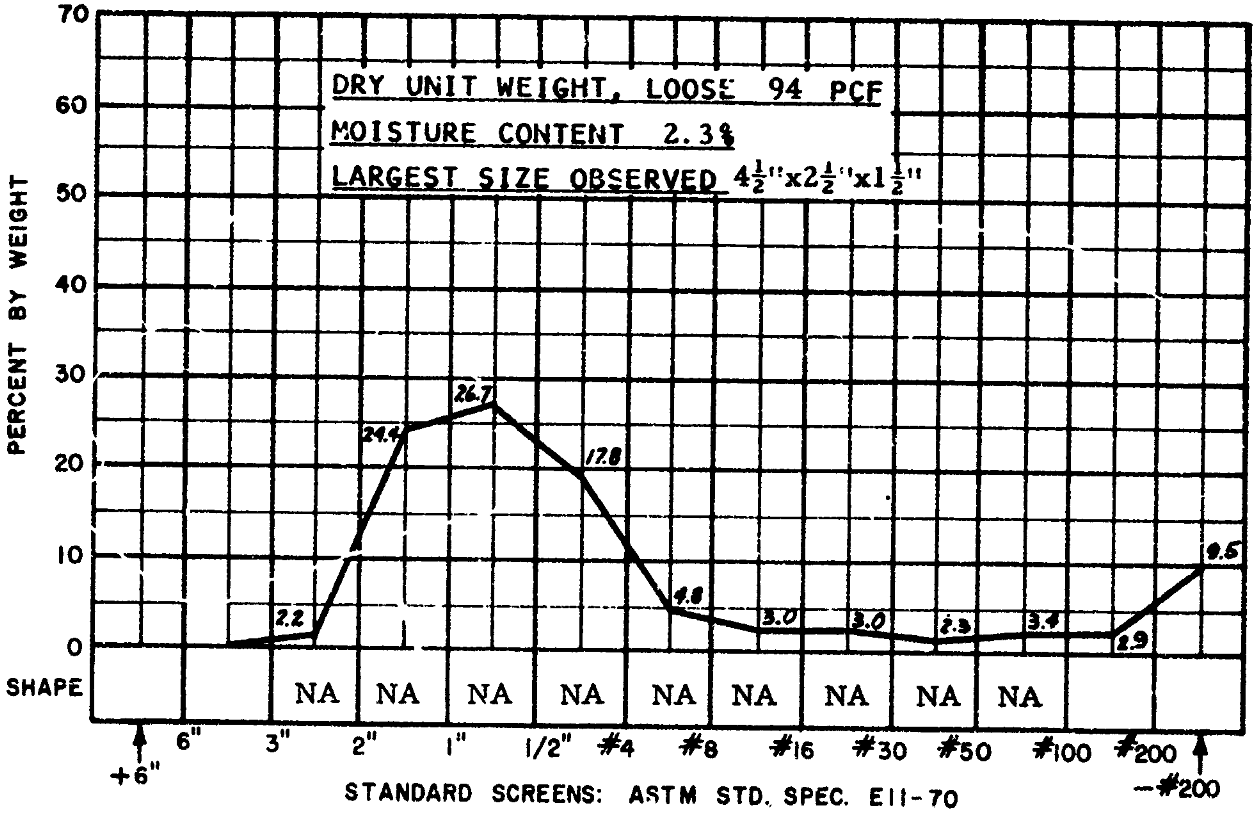
Apparent Cohesion PSF
@ 3.15% Moisture, 470

Angle/Repose 10" Drop
@ 3.15% Moisture, 34.4°

Angle Slide Steel Plate
@ 3.15% Moisture, 31.92°

Bulk Density PCF
@ 3.15% Moisture, 97.78

Angle Internal Friction
@ 3.15% Moisture, 36.1°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained. High Strength. RQD: 100%. DUW: 170 PCF. Ground water: Dry. Hardness: Schmidt 45.

System Class: TBM Robbins 105-144. 10'-4" dia. 26 Robbins disc cutters. RPM: 6. Torque: 246 K ft #. Thrust: 267 K #. Mucking: Buckets to belt. Haulage: Rail. Support: None.

MDN STUDY
4/1/73

SYSTEM DATA SHEET
MDN

Ident. No. EVG-2
Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, medium grained, light brown to red, massive, porous, poorly cemented.
Uniaxial Compressive Strength: 10 KPSI
RQD: (Estimated) 84%
Dry Unit Weight: 150 PCF
Ground Water: Generally dry.
Hardness: Schmidt 18.
Youngs Mod.: 1.80 PSI x 10^6 (Note 2).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 12'-11" diameter. Grade: (+) .125%
Ventilation System: 17 KCFM exhaust, 36" dia. pipe, 100 HP @ 4100'.
Utility System: 3 1/2" water line, 6" air line, 8" pump line.
Water Inflow: 20-100 gpm.
Power System: 7300/480V
Haulage System: Muck, supplies, personnel, 10 ton locomotives, 10 CY cars, 24" gage, 65 lb. rail, 800' trailing floor turnout.
Support System: 4" H full rings, 4' centers: 35%; 13" x 9' pans 3/4" x 7' rock bolts: 10%.

EXCAVATION DATA:

Machine: Robbins 141-127, total weight: 125 tons.
Cutters: 32 Robbins steel disc. Gage: 6-12". Center: 1-11" triple disc. Interior: 23-11". (31 Kerfs)
Rotation: Center cutter integral with head, 5.2 or 2.6 RPM.
Torque: 482 K ft #
Thrust: 357 K#, operating. Anchor pressure: 1,000 K#.
Muck Collection: Pickup by buckets fixed to head, discharging on 30" belt to a 24" x 204' belt on gantry.
Power System: 6-480/240V electric motors drive head. Hydraulic pumps power thrust and gripper cylinders.
Guidance System: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 5: Assigned Minimum Value.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-)0.056": 0

Spec. Gravity, Material
Size (-)0.75": 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 21.20%
Plasticity Index 3.14 %

Plastic Limit 17.06 %
Toughness Index 0.52

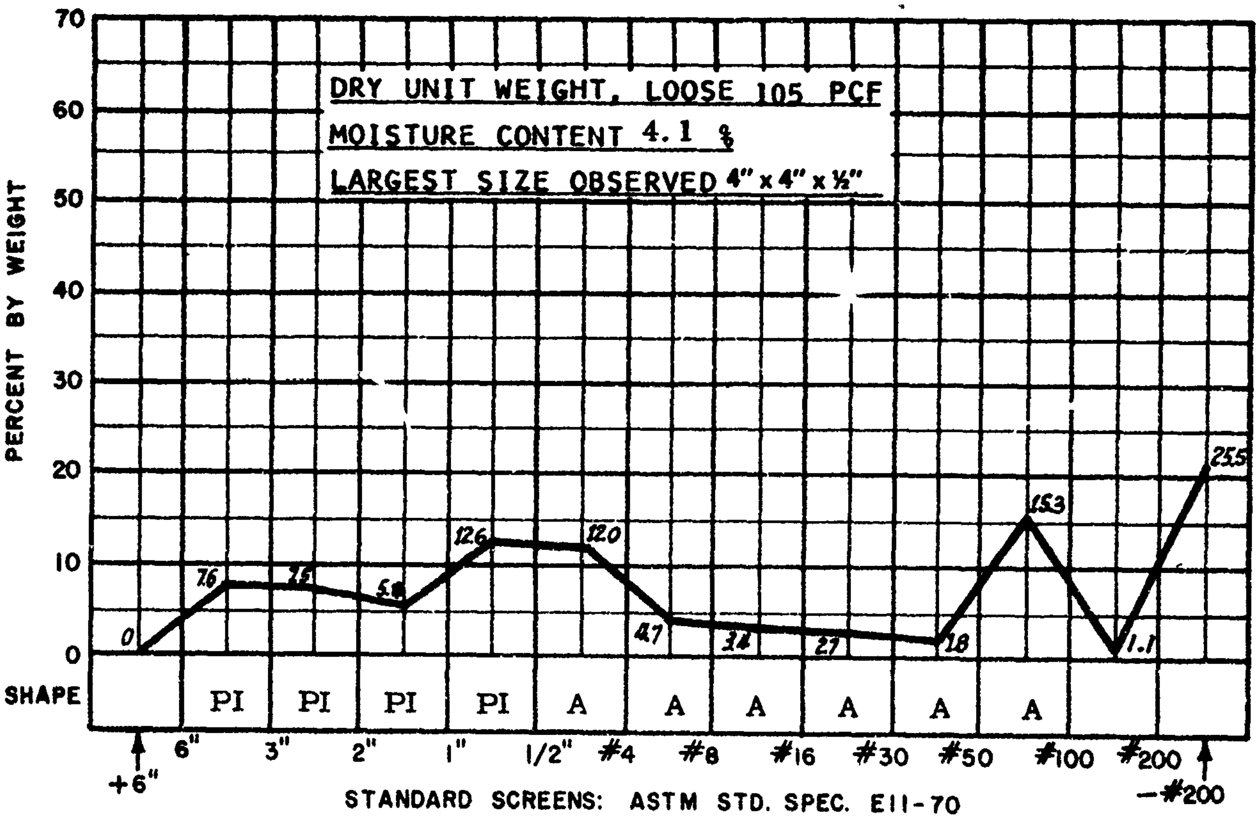
Shrinkage Limit 15.17 %
Flow Index 6.00

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 3.6 % Moisture, 37°
Angle Slide Steel Plate
@ 3.6 % Moisture, 27°

Apparent Cohesion PSF
@ 3.6 % Moisture, 210
Bulk Density PCF
@ 0.0 % Moisture, 97.4

Angle/Repose 10" Drop
@ 3.6 % Moisture, 35°
Angle Internal Friction
@ 3.6 % Moisture, 38°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, medium grained, massive, porous, poorly cemented. Strength: Medium. RQD (Est.) 84%. DUW: 150 PCF. Ground water: Dry. Hardness: Schmidt 18.

System Class: TBM, Robbins 141-127, 12' 11" dia. 32 Robbins disc cutters. RPM: 5.2. Torque: 482 K ft# av. Thrust: 357 K # av. Mucking: Buckets to belt conveyor. Haulage: Gantry conveyor to rail cars. Support: Steel ring sets, 35%, roof pans and rock bolts, 10% of 4100'.

ROCK DATA:

Lithology: Sedimentary, conglomerate, well graded cobbles to pebbles of quartzite poorly to well cemented with reddish brown sandstone, 20%.
Uniaxial Compressive Strength: 22 KPSI: Weighted average of sandstone at 11K (20%) and quartzite at 25K (80%).
RQD: (Estimated) 85%.
Dry Unit Weight: 153 PCF.
Ground Water: Dry.
Hardness: Schmidt 38 (Wtd. Average)
Youngs Mod.: 10.80 PSI x 10^6 (Note 1).
Poisson Ratio: 0.18 (Note 1).

TUNNEL DATA:

Size: 12' 11" diameter. Grade: (+) 0.125%.
Ventilation System: 15 KCFM, exhaust 36" diameter pipe, 200 HP @ 15000'.
Utility System: 3 1/2" water line, 6" air line, 8" pump line.
Water Inflow: 20-100 gpm.
Power System: 7300/480V.
Haulage System: Muck, supplies, personnel by railcar 10 ton locomotive, 10 CY cars, 24" gage 65# rail, 800' trailing floor turnout.
Support System: 4" H full rings in bad ground.

EXCAVATION DATA:

Machine: Robbins 141-127. Total Weight: 125 tons.
Cutters: 30 Robbins steel disc, gage 6-12", center 1-11" triple disc interior 23-11". (31 Kerfs)
Rotation: 5.2 RPM.
Torque: 581K.
Thrust: 585K lb.
Muck Collection: Buckets from face, belt to rear.
Power System: 6-100 HP motors drive head.
Guidance: Laser.

NOTE 1: 80% of Formation.

MUCK DATA

Abrasiveness N. A.

Pot. Vol. Change, Material Size (-)0.056": 0

Spec. Gravity, Material Size (-) 0.75": 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 15.00%

Plastic Limit 14.18 %

Shrinkage Limit 13.80 %

Plasticity Index 0.82 %

Toughness Index 0.21

Flow index 4.00

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 3.4 % Moisture, 38°

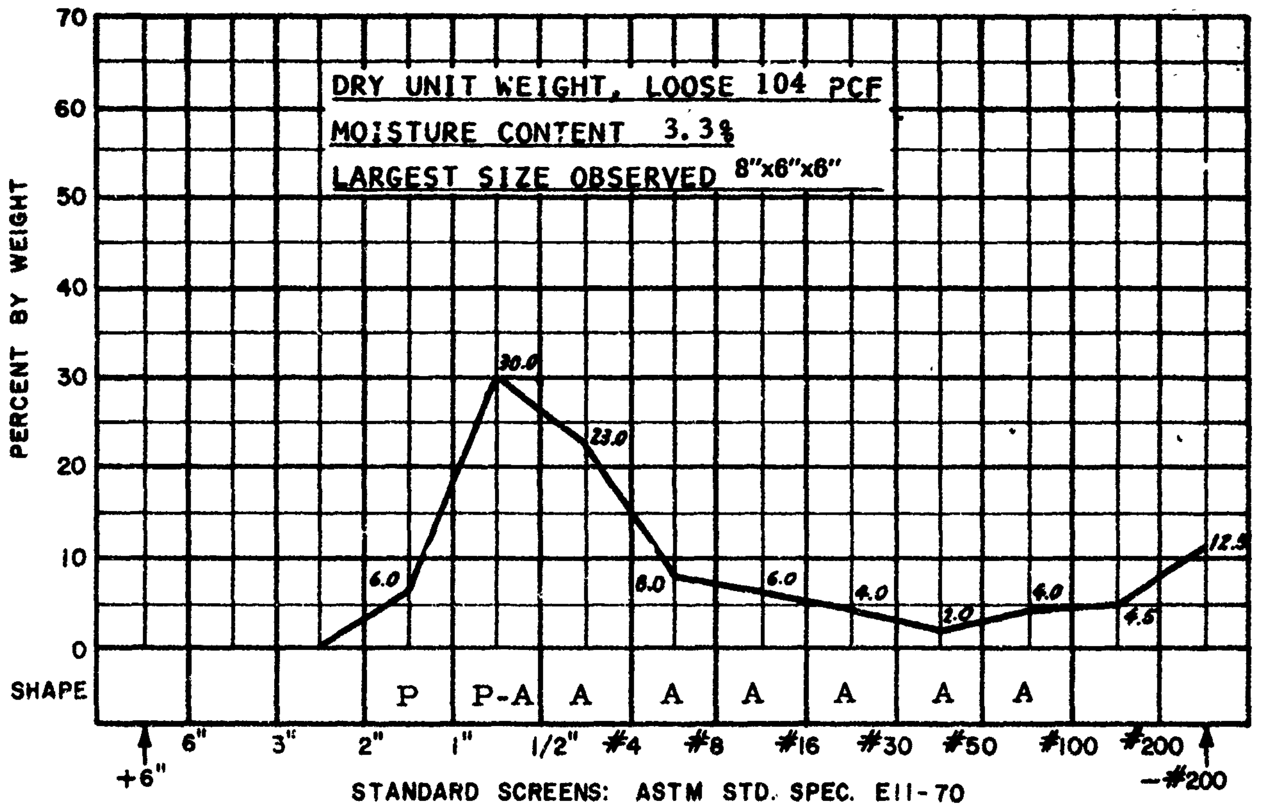
Apparent Cohesion PSF @ 3.0 % Moisture, 15

Angle/Repose 10" Drop @ 3.4 % Moisture, 32°

Angle Slide Steel Plate @ 3.4 % Moisture, 32°

Bulk Density PCF @ 0.0 % Moisture, 88

Angle Internal Friction @ 3.0 % Moisture, 39°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Conglomerate, quartzite cobbles grading to pebbles, poorly to well cemented with sandstone. High strength. RQD (Est.) 85%. DUW: 153 PCF. Ground water: Dry. Hardness: Schmidt 38 (Wtd. Avg.).

System Class: TBM Robbins 141-127. 32 Robbins disc cutters. RPM: 5.2 Torque: 581 K ft #. Thrust: 585 K #. Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts, normal, ring sets in bad ground.

ROCK DATA:

Lithology: Sedimentary, conglomerate, 80% quartzite pebbles to cobbles, 40% more than 12" dia., to 30". 20% calcareously cemented sandstone matrix.
Uniaxial Compressive Strength: 28 KPSI: Weighted average of sandstone at 7K (20%) and quartzite at 33K (80%).
RQD: (Estimated) 80%.
Dry Unit Weight: 165 PCF.
Ground Water: Saturated
Hardness: Schmidt 38. (Weighted average - see Note 1)
Youngs Mod.: 6.00 PSI x 10^6 (Notes 1 and 2).
Poisson Ratio: 0.18 (Notes 1 and 2).

TUNNEL DATA:

Size: 12' 11" diameter. Grade: (+) 0.125%.
Ventilation System: 15 KCFM, exhaust 36" diameter pipe, 100 HP @ 6700'.
Utility System: 3 1/2" water line, 6" air line, 8" pump line.
Water Inflow: 20-200 gpm.
Power System: 7300/480 V.
Haulage System: Muck, supplies, personnel by rail car, 10 ton locomotives 10 CY cars, 24" gage 65# rail, 800' trailing floor turnout.
Support System: 3/4" x 7' rock bolts.

EXCAVATION DATA:

Machine: Robbins 141-127-1. Total Weight: 125 tons.
Cutters: 30 Robbins steel disc, gage: 6-12", center: 1-11" triple disc interior: 23-11". (31 Kerfs)
Rotation: 5.2 RPM.
Torque: 515K ft. lb.
Thrust: 585K lb.
Muck Collection: Buckets from face, belt to rear.
Power System: 6-100 HP motors drive head.
Guidance: Laser.

NOTE 1: 80% of formation.
NOTE 2: Inferred from D. U. Deere AD 646610-66

MUCK DATA

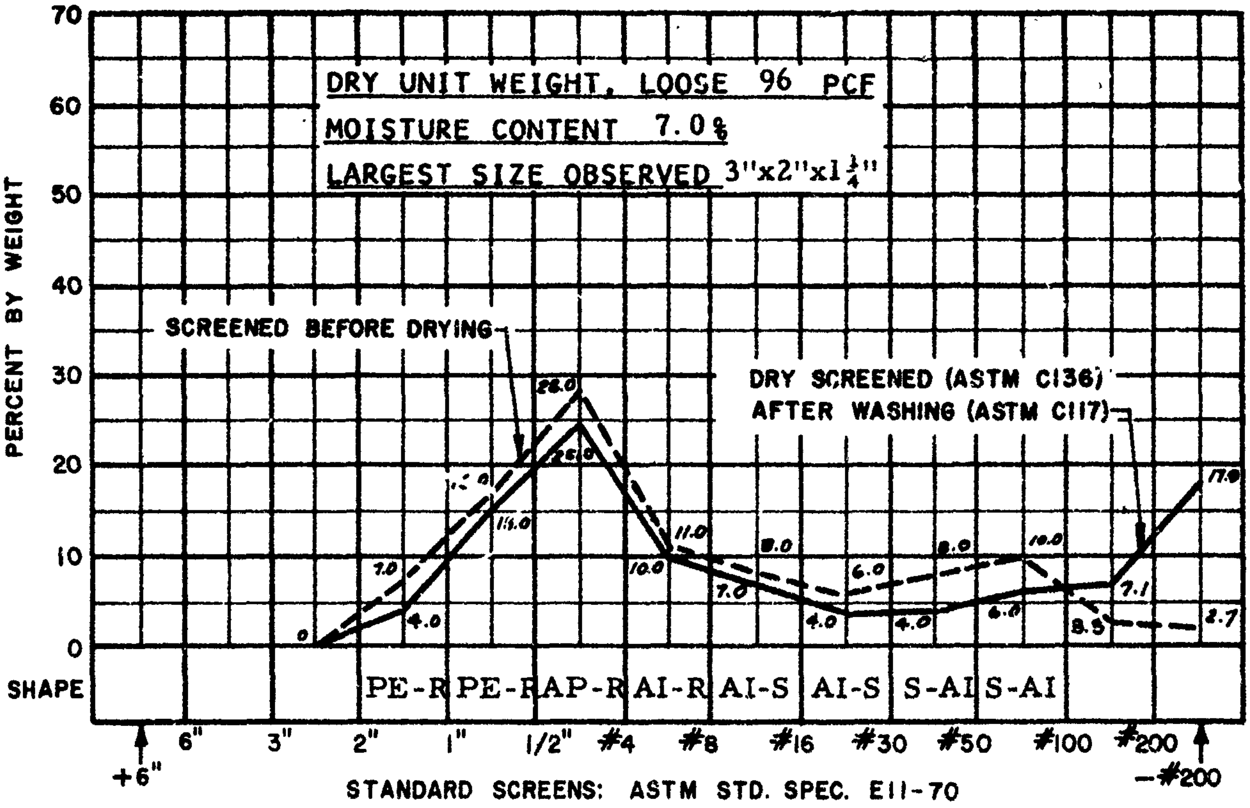
Abrasiveness	**Pot. Vol. Change, Material**	**Spec. Gravity, Material**
N. A.	**Size (-) 0.056": 0**	**Size (-) 0.75": 2.721**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.0%	**Plastic Limit 16.89%**	**Shrinkage Limit 15.66%**
Plasticity Index 1.11%	**Toughness Index 0.36**	**Flow Index 3.1**

MATERIAL SIZE (-) 2.00 IN.

Angle/Repose 1" Drop	**Apparent Cohesion PSF**	**Angle/Repose 10" Drop**
@ 6.57% Moisture, 39.65°	**@ 6.57% Moisture, 0**	**@ 6.57% Moisture, 34.55°**
Angle Slide Steel Plate	**Bulk Density PCF**	**Angle Internal Friction**
@ 6.57% Moisture, 31.67°	**@ 6.57% Moisture, 113**	**@ 6.57% Moisture, 39°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Conglomerate, 80% quartzite pebbles to cobbles, 40% more than 12" dia. to 30", 20% matrix calcareously cemented sandstone. High strength. RQD (Est.) 80%. DUW: 165 PCF. Ground water: Moderate to wet. Hardness: Schmidt 38. (Weighted Average)

System Class: TBM, Robbins 141-127-1. 32 Robbins disc cutters. RPM: 5.2. Torque: 515K ft. #. Thrust: 585K#. Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts.

ROCK DATA:

Lithology: Sedimentary, siltstone, fine grained, gray, more than 33% quartz, 30% clay, 10% feldspar, 15% mica, chlorite and gypsum.
Uniaxial Compressive Strength: 2 KPSI
RQD: (Estimated) 70%
Dry Unit Weight: 142 PCF
Ground Water: Table above tunnel but sealed off by overlying beds.
Hardness: Schmidt 7 (Note 2).
Youngs Mod.: 0.20 PSI x 10^6 (Note 2).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 20.5' round, Grade: (+) .05%
Ventilation System: 18 KCFM exhaust 30" pipe, 60 HP.
Utility System: 6" air line, 4" pump line
Water Inflow: 50 GPH.
Power System: 4160/440V, rectified to 440 DC for head drive motors.
Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.
Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons
Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44 TC bits mounted on 4 bit blocks.
Rotation: 0-6 RPM range, 5 RPM normal operating.
Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.
Thrust: Maximum 1,583 K # operating 431 K #.
Anchor Pressure: Maximum 6,616 K#.
Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.
Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.
Guidance System: Laser

NOTE 2: Inferred from D. U. Deere AD 646610-1966
NOTE 5: Assigned minimum.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material Size (-)0.056": 1.3

Spec. Gravity, Material Size (-)0.75": 3.13

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 36.80%
Plasticity Index 13.19%

Plastic Limit 23.61 %
Toughness Index 1.88

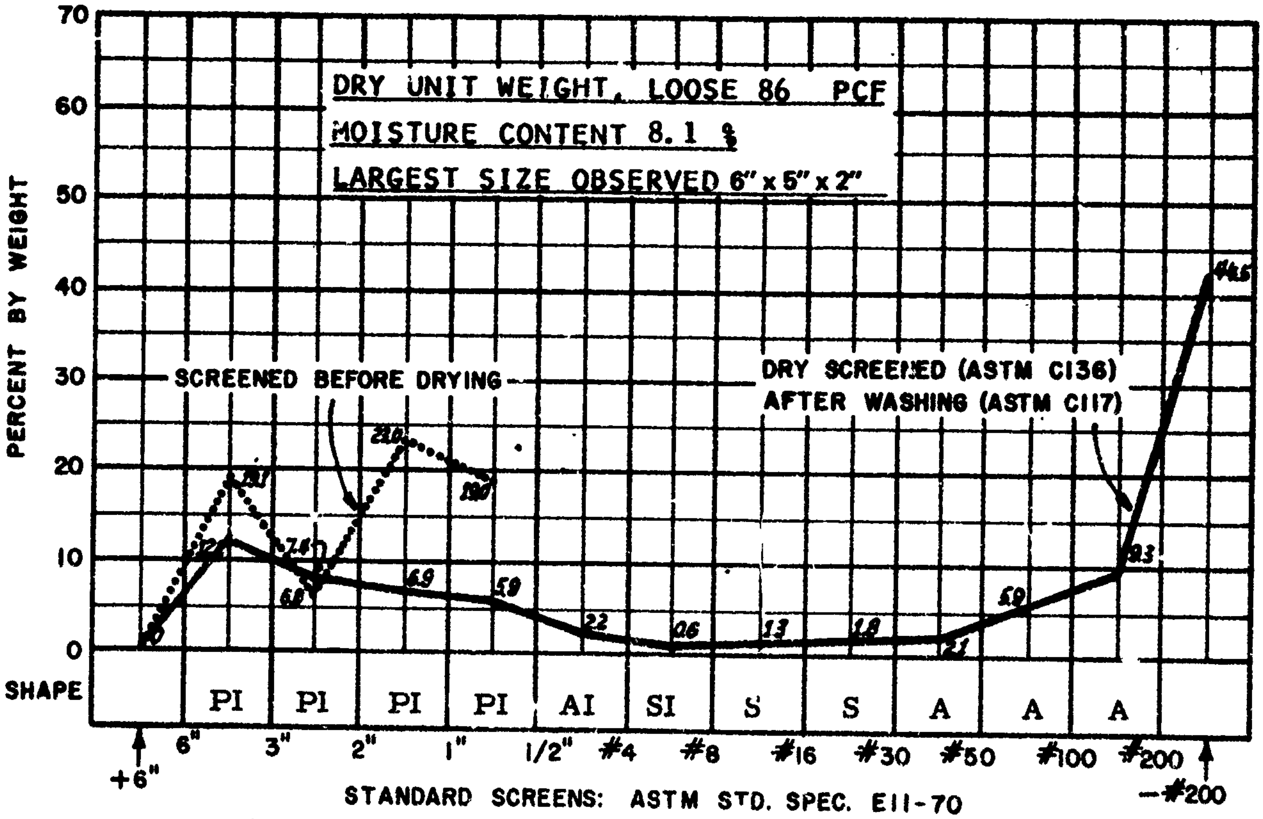
Shrinkage Limit 21.04 %
Flow Index 7.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop
@ 7.7 % Moisture, 30°
Angle Slide Steel Plate
@ 7.7 % Moisture, 30°

Apparent Cohesion PSF
@ 7.5 % Moisture, 340
Bulk Density PCF
@ 0.0 % Moisture, 98

Angle/Repose 10" Drop
@ 7.7% Moisture, 30°
Angle Internal Friction
@ 7.5% Moisture, 36°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Siltstone, fine grained. Strength: Very low. RQD (Est.) 70%. DUW: 142 PCF. Ground water: Minor. Hardness: Schmidt 7.

System Class: TBM, Dresser TB 205, 20.5' dia., Dresser disc cutters: 6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 526 K ft #. Torque: 431 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

ROCK DATA:

Lithology: Sedimentary, sandstone, gray, medium grained, massive, friable and porous. Grains angular to subrounded, primarily quartz, poorly cemented.
Uniaxial Compressive Strength: Less than 1 KPSI, disintegrates when wet.
RQD: (Estimated) 60%
Dry Unit Weight: 117 PCF
Ground Water: Table above tunnel but sealed off by overlying beds.
Hardness: Schmidt 5 (Note 5).
Youngs Mod.: 0.10 PSI x 10^6 (Note 5).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 20.5' diameter. Grade: (+) .05%
Ventilation System: 18 KCFM exhaust, 30" pipe, 60 HP.
Utility System: 6" air line, 4" pump line
Water Inflow: 50 GPH.
Power System: 4160/440V, rectified to 440 DC for head drive motors.
Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor, 24" gage 70 lb rail.
Support System: Rock bolts, 8' and 10' x 3/4", set in epoxy, with 5' and 13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons
Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted around a 4" chisel. Interior: 30 Type STD steel discs and 26 U44TC bits mounted on 4 bit blocks.
Rotation: 0-6 RPM range, 5 RPM normal operating.
Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.
Thrust: Maximum 1,583 K #. operating 123 K #.
Anchor Pressure: Maximum 6,616 K #.
Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.
Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.
Guidance System: Laser

NOTE 5: Assigned Minimum Value.

MUCK DATA

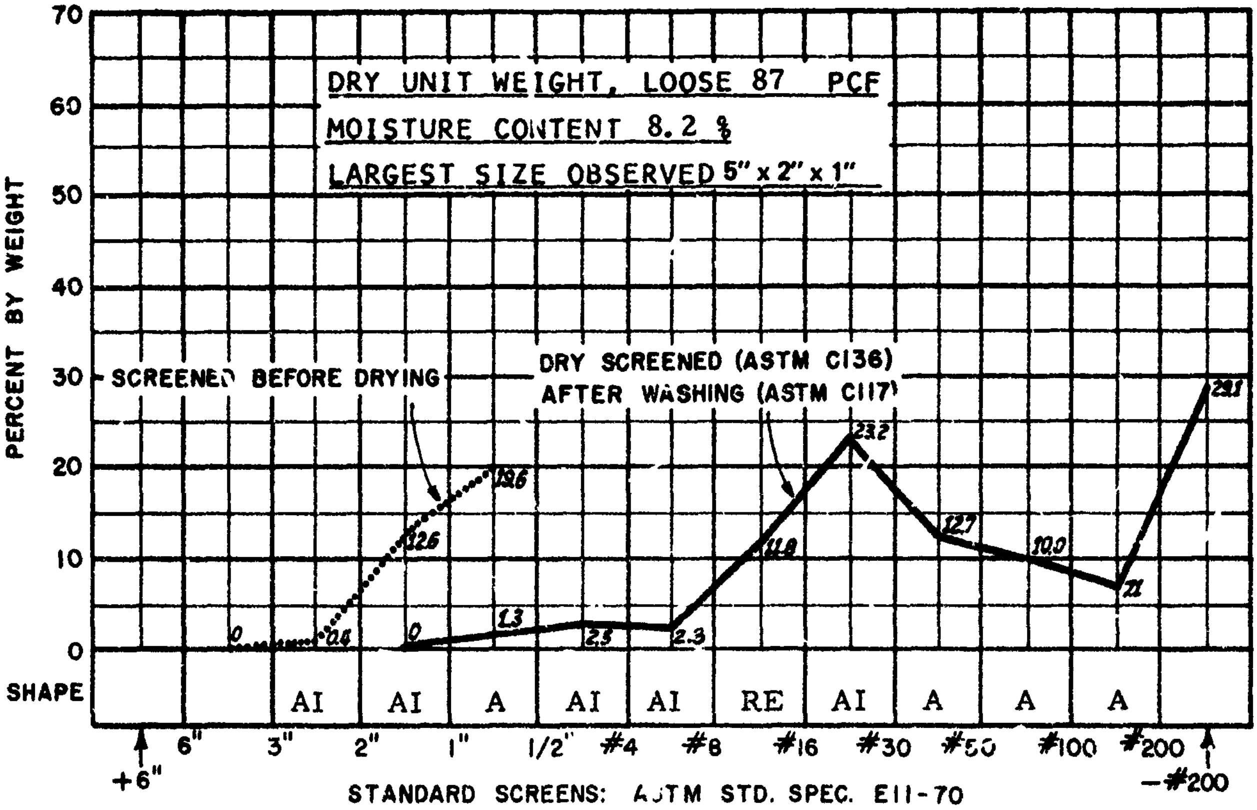
Abrasiveness N. A.	Pot. Vol. Change Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.75": 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.20%	Plastic Limit 16.91%	Shrinkage Limit 16.60 %
Plasticity Index 1.29 %	Toughness Index 0.28	Flow Index 4.50

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 8.6% Moisture, 31°	Apparent Cohesion PSF @ 8.1% Moisture, 45	Angle/Repose 10" Drop @ 8.6 % Moisture, 28°
Angle Slide Steel Plate @ 8.6% Moisture, 32°	Bulk Density PCF @ 0.0% Moisture, 99	Angle Internal Friction @ 8.1 % Moisture, 28°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, massive, friable, porous, medium grained. Very low strength. RQD (Est.) 60%. DUW: 117 PCF. Ground water: Minor. Hardness: Schmidt 5.

System Class: TBM, Dresser TB 205, 20.5' dia. Dresser, disc cutters 6TCB and 30 steel, 32 Kennametal, TCB "pick" bits. RPM: 5, 586 K ft # torque, 123 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 7 or 4(N)	Ident. No. NAV-2 Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, brown to dark red massive.
Uniaxial Compressive Strength: 11 KPSI.
RQD: 60%.
Dry Unit Weight: 166 PCF.
Ground Water: Generally dry.
Hardness: Schmidt 36.
Youngs Mod.: 4 47 PSI x 10^6.
Poisson Ratio: 0.24.

TUNNEL DATA:

Size: 18' 4" diameter. Grade: +.045%.
Ventilation System: 22 KCFM, exhaust, 48" diameter pipe, 2-150 HP
Utility System: 8" air line, 4" water line, 8" pump line.
Water Inflow: 40 gpm.
Power System: 13200/440V.
Haulage System: Muck, supplies, personnel by railcars, 15 ton locomotive 10 CY cars, 36" gage, 50# rail.
Support System: Rock bolts, 5', 6', 8' x 5/8", 24" centers, 14 gauge pans 12' 6" or 8' 6" x 8".

EXCAVATION DATA:

Machine: Lawrence HRT. Total weight: NA.
Cutters: 32 Lawrence Mfg Tungsten Carbide Button, roller, disc and tricone. Gage: 5 TCB roller, Interior 24 disc and 2 TCB roller, center 1-24" TCB tricone.
Rotation: Head 11 RPM, center 30 RPM.
Torque: Center cutter 150 HP, head 750 HP, 364K ft. lb.
Thrust: 492K lbs.
Muck Collection: Buckets from face discharging to 24" belt.
Power System: Electro-Hydraulic. Total HP: 960
Guidance System: Laser

ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone.
Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.
RQD: (Estimated) 30%.
Dry Unit Weight: 125 PCF.
Ground Water: Saturated when first opened.
Hardness: Schmidt 5 (Note 5).
Youngs Mod.: 0.10 PSI x 10^6 (Note 5).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 10' high by 8' wide, rectangular. Grade (+) 1/2%.
Ventilation System: 5 to 7 KCFM, pressure, 18" dia. vent tube.
Utility System: 4" airline.
Water Inflow: 20-25 gpm.
Power System: 440/110V, trailing cable.
Haulage System: Muck, personnel and supplies by rail cars, 24" gage, 40# rail.
Support System: None, rock bolts and/or shotcrete in bad ground.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.
Cutters: 72, Kennametal U43K, Carbide tipped, "pick" type. Cutters, mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves the heads vertically and horizontally.
Rotation: 60 RPM, motor and gear box integral with boom.
Torque: 50.4 HP.
Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP. Vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.
Anchor Pressure: Crawlers only.
Muck Collection: Central 14" chain conveyor, fed by gathering arms, discharges on an 18" x 30' belt feeding 116' of 20" Serpentix conveyor. Transverse folds are molded into 20" x 8" long rubber Serpentix sections, which are bolt connected at reinforced flanges connected to an endless chain driven by a sprocket. Folds allow inside edge to compress and outside to expand on curves. Vertebral side rail sections, alternating with straight sections, are supported by wheeled gantry legs riding a 60" gage track, under which cars are spotted.
Power System: 440V, trailing cable.
Guidance System: Transit/Laser.

NOTE 5: Assigned Minimum Value.

ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30%.

Dry Unit Weight: 125 PCF.

Ground Water: Saturated when first opened.

Hardness: Schmidt 5 (Note 5).

Youngs Mod.: 0.10 PSI x 10^6 (Note 5).

Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 10' high by 8' wide, rectangular. Grade (+) 1/2%.

Ventilation System: 5 to 7 KCFM, pressure, 18" dia. vent tube.

Utility System: 4" airline.

Water Inflow: 20-25 gpm.

Power System: 440/110V, trailing cable.

Haulage System: Muck, personnel and supplies by rail cars, 24" gage, 40# rail.

Support System: None, rock bolts and/or shotcrete in bad ground.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.

Cutters: 72, Kennametal U43K, Carbide tipped, "pick" type. Cutters, mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves the heads vertically and horizontally.

Rotation: 60 RPM, motor and gear box integral with boom.

Torque: 50.4 HP.

Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP. Vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.

Anchor Pressure: Crawlers only.

Muck Collection: Central 14" chain conveyor, fed by gathering arms, discharges on an 18" x 30' belt feeding 116' of 20" Serpentix conveyor. Transverse folds are molded into 20" x 8" long rubber Serpentix sections, which are bolt connected at reinforced flanges connected to an endless chain driven by a sprocket. Folds allow inside edge to compress and outside to expand on curves. Vertebral side rail sections, alternating with straight sections, are supported by wheeled gantry legs riding a 60" gage track, under which cars are spotted.

Power System: 440V, trailing cable.

Guidance System: Transit/Laser.

NOTE 5: Assigned Minimum Value.

MUCK DATA

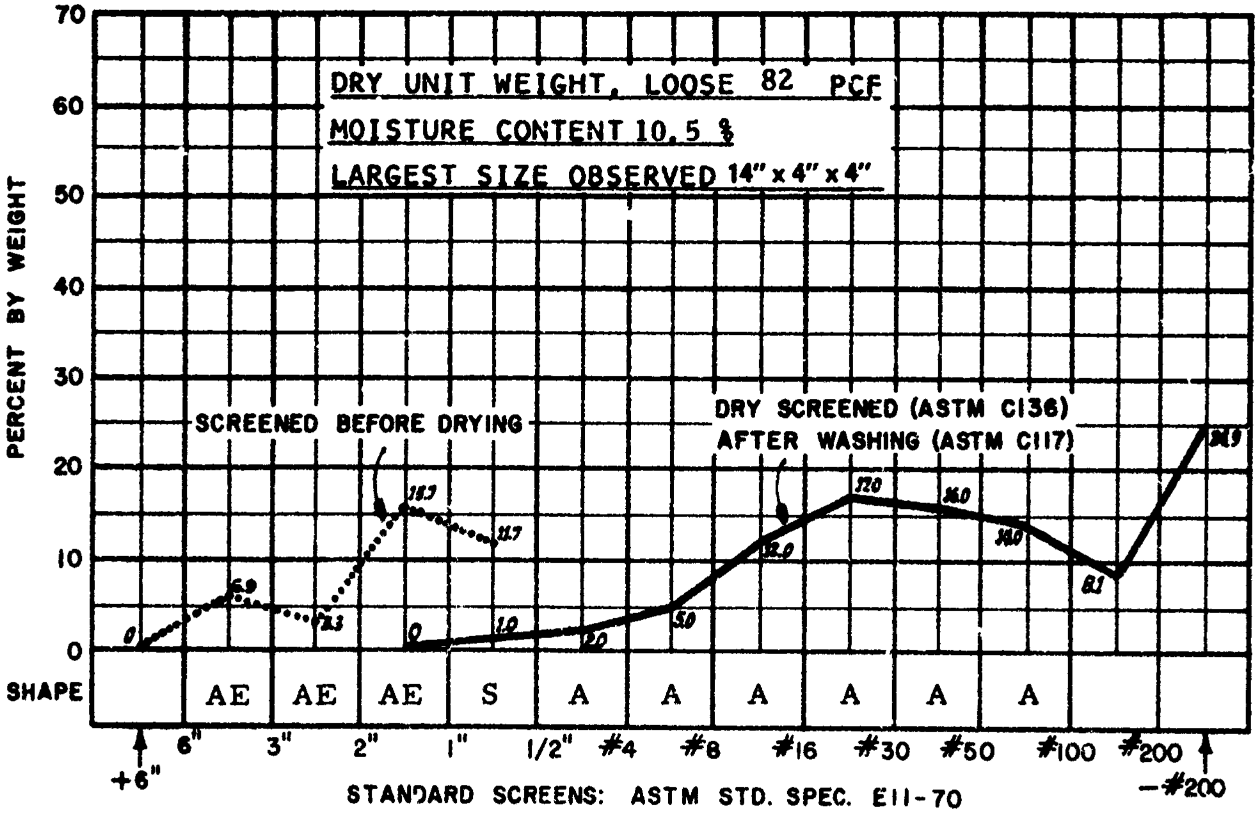
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056": 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.71**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 24.90%	**Plastic Limit 19.97%**	**Shrinkage Limit 19.94 %**
Plasticity Index 4.93%	**Toughness Index 0.66**	**Flow Index 7.40**

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop **@ 10.1 % Moisture, 34°**	**Apparent Cohesion PSF** **@ 10.6 % Moisture, 0**	**Angle/Repose 10" Drop** **@ 10.1 % Moisture, 31°**
Angle Slide Steel Plate **@ 10.0 % Moisture, 32°**	**Bulk Density PCF** **@ 0.0 % Moisture, 85**	**Angle Internal Friction** **@ 10.6% Moisture, 27°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone. Very low strength. RQD (Est.) 30%. DUW: 125 PCF. Ground water: Saturated. Hardness: Schmidt 5.

System Class: TBM, Alpine F6A, twin head, 10' high x 8' heading. 72 Kennametal TCB pick type bits. 60 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms-flight conveyor. Haulage: Elevating conveyor - Serpentix conveyor on gantry - rail cars. Support: Normally none.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 7 or 3(N)	Ident. No. WNG-1 Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone, varying concentrations of replacement silica.
Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.
RQD: (Estimated) 30%
Dry Unit Weight: 125 PCF
Ground Water: Saturated when first opened.
Hardness: Schmidt 5 (Note 5).
Youngs Mod.: 0.10 PSI x 10^6 (Note 5).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 5' wide x 9' high, nominally rectangular. Grade: Varies.
Ventilation System: 5 to 7 KCFM, pressure, 18" vent tube.
Utility System: 2" air, 1" waterline.
Water Inflow: 20-25 gpm when levels are first opened; generally dry after drainage.
Power System: None in development headings, 440V to scraper hoists, 110V lighting.
Haulage System: Muck is scraped from the face of a cross cut to a slusher drift, cross scraped to a muck raise, and loaded into 4 cu. ft. rocker dump rail cars on main level about 80' below. Scrapers are 42", hoists 15 HP. Personnel access by ladder, supplies by rail cars and air-powered hoists through raises.
Support System: None. Rockbolts in bad ground.

EXCAVATION DATA:

Conventional Scraper-Rail Haulage System.
Drilling: LeRoi Model 35 jackhammers mounted on 6' airfeed legs.
Drill Round: Five hole box or vertical line burn cut, 6' depth, included in 18 hole round, all holes 1 1/2" diameter.
Explosives: 50# Dupont 40% Gelex #2, Powder factor: 5#/cu. yd.
Blasting: Safety fuse and caps.
Mucking System: 42" Scrapers, 15 HP hoists.

NOTE 5: Assigned Minimum Value.

MUCK DATA

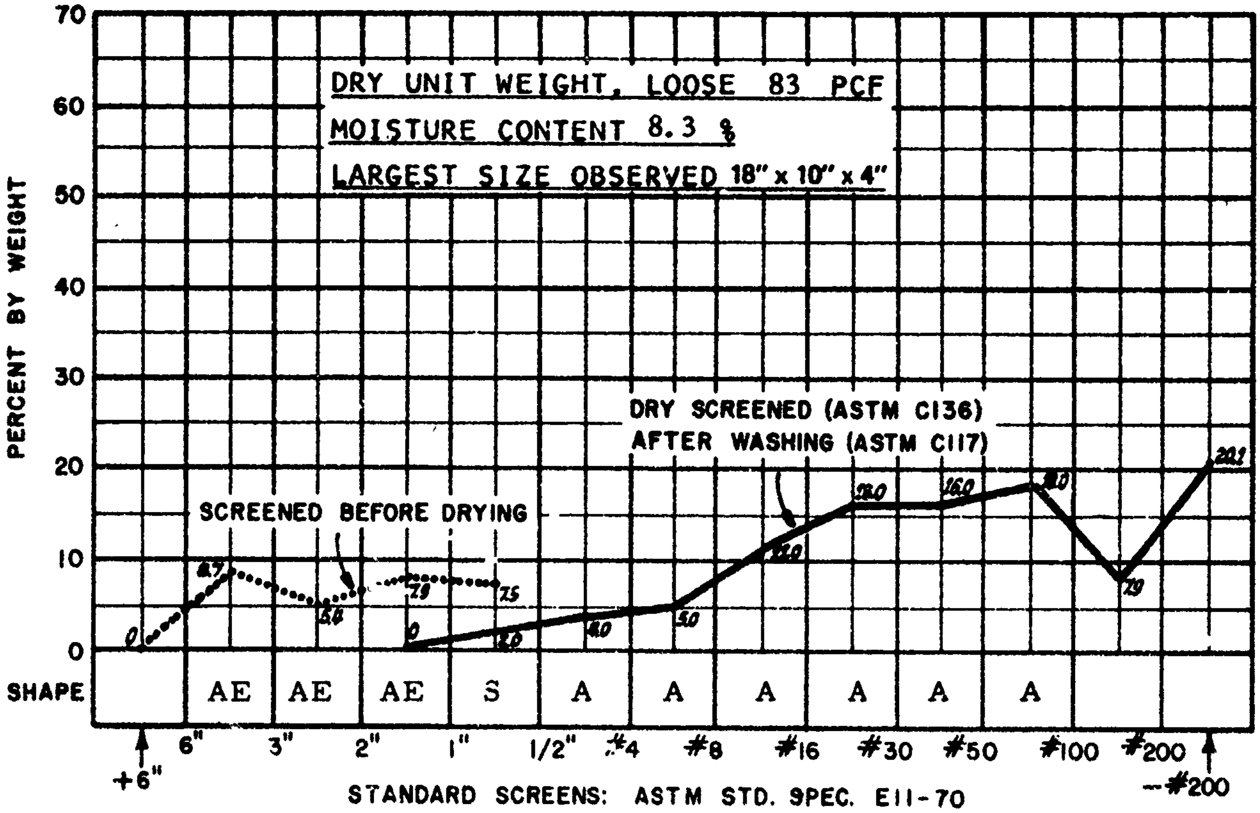
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.075": 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.25%	Plastic Limit 24.74%	Shrinkage Limit 23.37 %
Plasticity Index 0.51 %	Toughness Index 0.13	Flow Index 4.00

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 9.0 % Moisture, 32°	Apparent Cohesion PSF @ 9.0% Moisture, 0	Angle/Repose 10" Drop @ 9.0% Moisture, 31°
Angle Slide Steel Plate @ 9.0 % Moisture, 40°	Bulk Density PCF @ 0.0% Moisture, 86	Angle Internal Friction @ 9.0% Moisture, 28°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone, varying replacement silica. Very low strength. RQD (Est.) 30%. DUW: 125 PCF. Ground water: Saturated. Hardness: Schmidt 5.

System Class: Conventional Scraper-Rail. 5' wide x 9' high, rectanguiar. Airleg jackhammer, 18 - 6' holes, burn cut. PF 5#/CY. Mucking: Scraper to raise. Haulage: Rail cars - skip to surface. Support: Normally none.

ROCK DATA:

Lithology: Sedimentary, sandstone, arkosic, irregularly bedded, loosely consolidated with layers and lenses of silty mudstone.
Uniaxial Compressive Strength: Less than one KPSI.
RQD: (Estimated) 15%
Dry Unit Weight: 113 PCF
Ground Water: Saturated; water table above tunnel, heading is drained in advanced by lateral pilot holes in ribs.
Hardness: Schmidt 5 (Note 5).
Youngs Mod.: 0.10 PSI x 10^6 (Note 5).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 21 ft., diameter. Grade: (+) 0.2%.
Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in access.
Utility System: 6" air line, 6" pump line.
Water Inflow: 200 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars.
Support System: Continuous, precast concrete rings 8" and 10" thick, erected in four-4' segments.

EXCAVATION DATA:

Shield: Robbins 221S ripper, Total weight: 285 tons
Thrust: 3,500 tons total.
Muck Collection System: Muck is ripped from the face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram with a bucket opposite the ripper tooth.
Power System: Hydraulic.
Guidance System: Laser

NOTE 5: Assigned Minimum Value.

MUCK DATA

Abrasiveness
N. A.

Pot. Vol. Change, Material
Size (-)0.065" : 0

Spec. Gravity, Material
Size (-)0.185": 2.86

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 17.75%
Plasticity Index 1.56 %

Plastic Limit 16.19%
Toughness Index 0.27

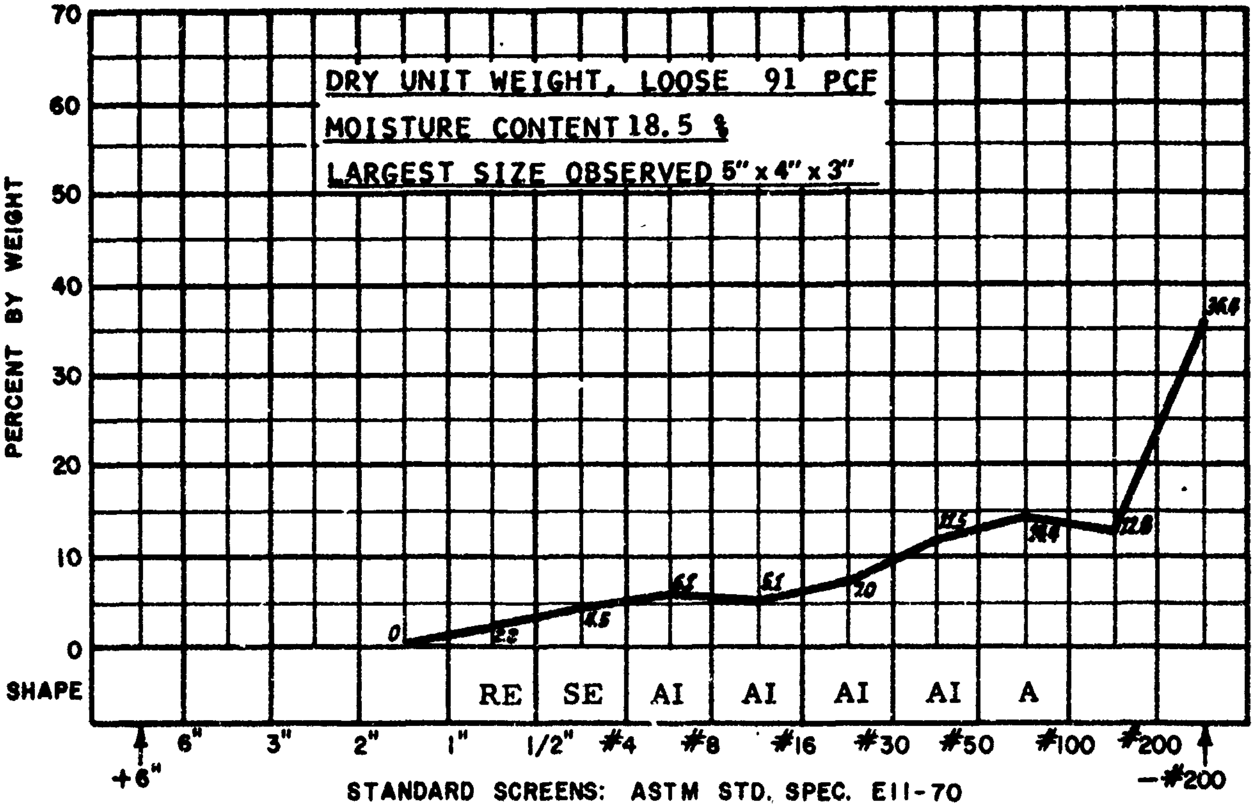
Shrinkage Limit 13.94 %
Flow Index 5.8

MATERIAL SIZE (-)0.185IN.

Angle/Repose 1" Drop
@ 14.3 % Moisture, 38°
Angle Slide Steel Plate
@ 12.5 % Moisture, 36°

Apparent Cohesion PSF
@ % Moisture, NA
Bulk Density PCF
@ 0.0% Moisture, 84.3

Angle/Repose 10" Drop
@ 14.3 % Moisture, 33°
Angle Internal Friction
@ 13.0 % Moisture, 42°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, arkosic, loosely consolidated, with layers and lenses of silty mudstone. Strength: Very low. RQD (Est.) 15%. DUW: 113 PCF. Ground water: Saturated. Hardness: Schmidt 5.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust: 3500 tons. Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail. Support: Continuous, precast concrete ring segments.

ROCK DATA:

Lithology: Sedimentary, sandstone, biotite rich siltstone, poorly to well consolidated, poorly to well sorted.
Uniaxial Compressive Strength: 2 KPSI.
RQD: (Estimated) 50%.
Dry Unit Weight: 142 PCF.
Ground Water: Sandstone saturated, water table above tunnel, heading drained in advanced by lateral pilot holes in ribs.
Hardness: Schmidt 7 (Note 2).
Youngs Mod.: 0.10 PSI x 10^6 (Note 5).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 21 ft., round, Grade: (+) 0.2 pct.
Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in access.
Utility System: 6" air line, 6" pump line.
Water Inflow: 20 gpm.
Power System: 4160/480V.
Haulage System: Muck, personnel, supplies by rail cars.
Support System: Continuous, precast concrete rings 8" and 10" thick, erected in four 4' segments.

EXCAVATION DATA:

Shield: Robbins 221S ripper, total weight: 285 tons.
Thrust: 3,500 tons total.
Muck Collection System: Muck is ripped from face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram with a bucket opposite the ripper tooth.
Power System: Hydraulic.
Guidance System: Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 5: Assigned Minimum Value.

MUCK DATA

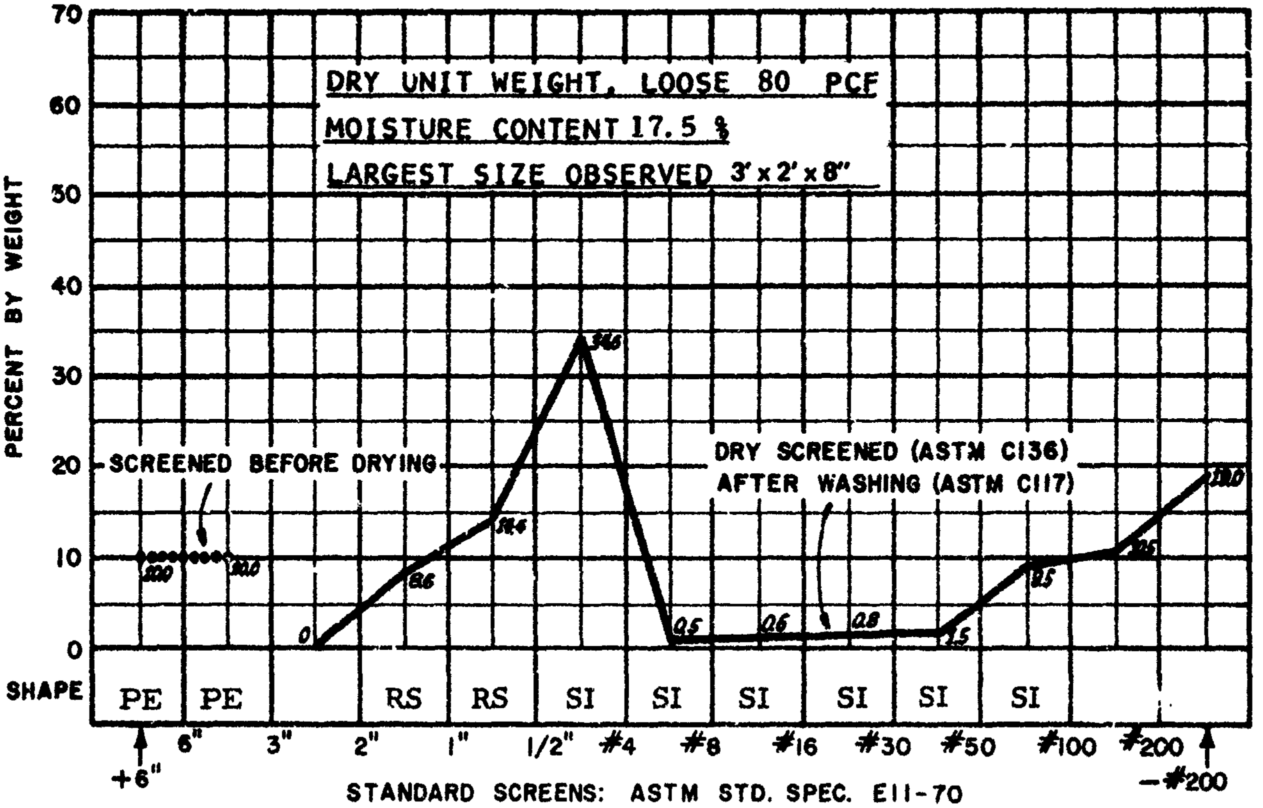
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-)0.056": 0	Spec. Gravity, Material Size (-)0.075": 3.02

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 31.5 %	Plastic Limit 26.8 %	Shrinkage Limit 21.5 %
Plasticity Index 4.7 %	Toughness Index 0.61	Flow Index 7.6

MATERIAL SIZE (-)1.0 IN.

Angle/Repose 1" Drop @ 15.1 % Moisture, 38°	Apparent Cohesion PSF @ 15% Moisture, 80	Angle/Repose 10" Drop @ 15.1 % Moisture, 36°
Angle Slide Steel Plate @ 15.1 % Moisture, 30°	Bulk Density PCF @ 0.0% Moisture, 75.36	Angle Internal Friction @ 15 % Moisture, 27°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone and siltstone, poorly to well consolidated. Strength: Very low. RQD (Est.) 50%. DUW: 142 PCF. Ground water: Saturated. Hardness: Schmidt 7.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust 3500 tons. Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail. Support: Continuous, precast concrete ring segments.

MDN STUDY 4/1/73	SYSTEM DATA SHEET MDN 6 or 2(N)	Ident. No. SF-2 Sheet 2

ROCK DATA:

Lithology: Sedimentary, mudstone, dark gray, fine grained, massive.
Uniaxial Compressive Strength: 11 KPSI dry.
RQD: (Estimated) 90%.
Dry Unit Weight: 144 PCF.
Ground Water: Generally dry.
Hardness: Schmidt 42 (Note 2).
Youngs Mod.: 5 0 PSI x 10^6 (Note 2).
Poisson Ratio: 0.10 (Note 5).

TUNNEL DATA:

Size: 10' high x 9' wide (7'-6" top, 9'-6" bottom). Grade: (+) 1/2%.
Ventilation System: 5 KCFM, exhaust from face, pressure to venthole, 16" flexhaust, 24" vent tube, 2-25 HP Axivane fans.
Water Inflow: Minor
Power System: 440V trailing cable.
Haulage System: Muck, personnel and supplies by rail cars, 36" gage, 45# rail.
Support: 4" WF steel sets at 3' or 6'.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.
Cutters: 40 Kennametal U43KH, Carbide tipped, "pick" type. Cutters mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves heads vertically and horizontally.
Rotation: 78 RPM, motor and gear box integral with boom.
Torque: 50.4 HP.
Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP, vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.
Anchor Pressure: Crawlers only.
Muck Collection: Central 14" flight conveyor fed by two gathering arms mounted on an inclined apron, discharges on an 18" elevating conveyor loading rail cars.
Power System: 440V, trailing cable.
Guidance System: Transit/Laser.

NOTE 2: Inferred from D. U. Deere AD 646610-1966.
NOTE 5: Assigned Minimum Value.

MUCK DATA

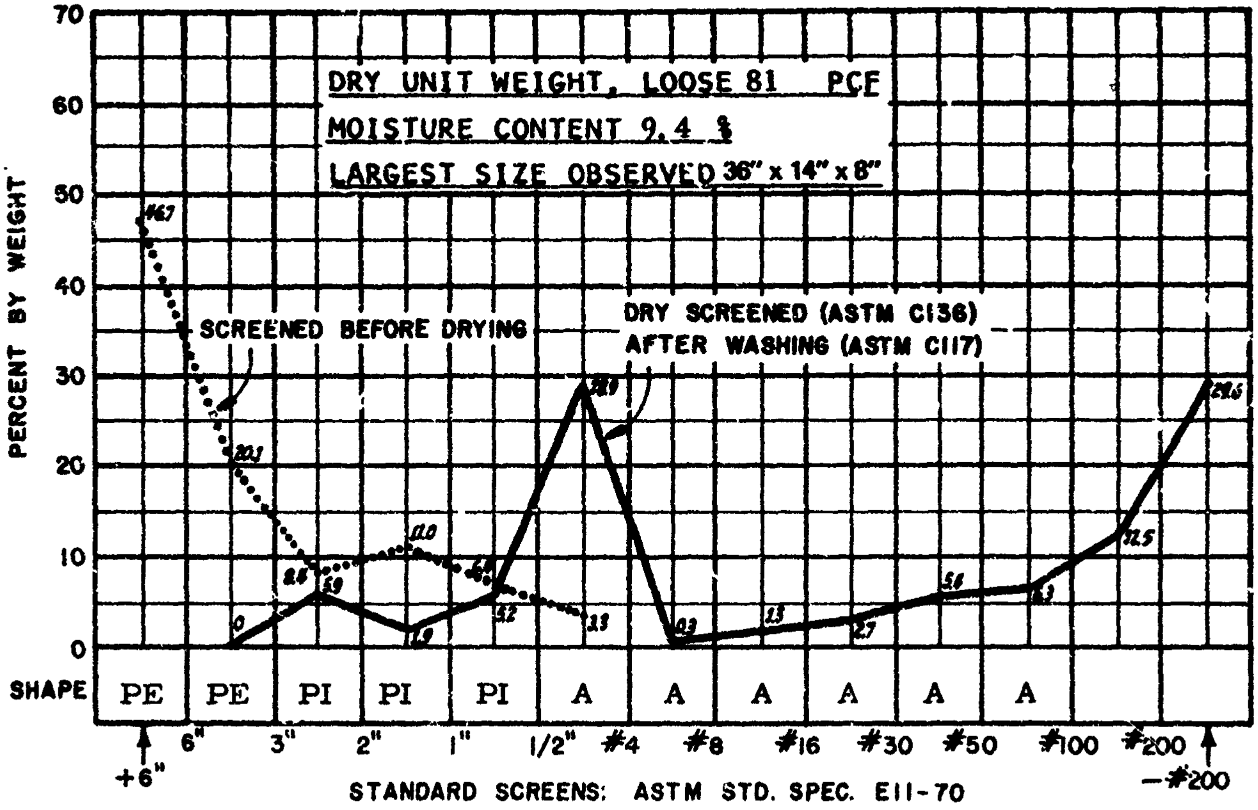
Abrasiveness **N. A.**	**Pot. Vol. Change, Material** **Size (-) 0.056": 0**	**Spec. Gravity, Material** **Size (-) 0.75": 2.87**

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 28.30%	**Plastic Limit 24.97 %**	**Shrinkage Limit 19.12 %**
Plasticity Index 3.33 %	**Toughness Index 0.92**	**Flow Index 3.60**

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop **@ 12.7 % Moisture, 29°**	**Apparent Cohesion PSF** **@ 10.9 % Moisture, 37**	**Angle/Repose 10" Drop** **@ 12.7 % Moisture, 28°**
Angle Slide Steel Plate **@ 12.7 % Moisture, 31°**	**Bulk Density PCF** **@ 0.0 % Moisture, 79**	**Angle Internal Friction** **@ 10.9 % Moisture, 35°**



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Mudstone ("shale") fine grained, massive. Medium strength. RQD (Est.) 90%. DUW: 144 PCF. Ground water: Dry. Hardness: Schmidt 42.

System Class: TBM, Alpine F6A, twin head, 10' high x 9' heading. 40 Kennametal TCB pick type bits. 78 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms - flight conveyor. Haul [illegible]: Elevating conveyor-rail cars. Support: Steel sets at 3' or 6', continuous.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. KM-1
4/1/73	MDN	Sheet 2
	4 or 1(N)	

APPENDIX D

ALGORITHM DEVELOPMENT

In simple regression, it is supposed that with each observation value, there is another quantity which can be observed or somehow related to the observation. After n observations, there exists a series of pairs, (x_1, y_1), (x_2, y_2), $\cdot \cdot \cdot$, (x_n, y_n). The question we wish to answer is to determine if there is a relationship between y and x and how this relationship can be obtained.

One may assume that there is such a relationship, and that this relationship is linear. With this assumption, one may write

$$y = \alpha x + \beta \tag{1}$$

The x_i, $i = 1, \cdot \cdot \cdot, n$, are the values of the independent variable x, and the y_i, $i = 1, \cdot \cdot \cdot, n$, are the values of the dependent variable y. α and β are the coefficients which will have to be determined from the observation points.

It is possible that a relationship exists between x and y, but the relationship is not linear. A possible alternate in this case is to find another variable, x^1, related to x, such that y can then be linearly related to x^1. The new variable x^1 will then be used in place of x in the discussions that follow.

Assuming that the linear relationship is valid, we can create an error term which is the sum of the squares of all deviations of observed values from the linear Equation (1). Thus the error ϵ is

$$\epsilon = \sum_{i=1}^{n} (y_i - (\alpha x_i + \beta))^2 \tag{2}$$

and determine α and β so ϵ is minimum. This simple regression is known as the method of "least squares". The solution can be shown to be:

$$\alpha = v_{xy}/s_x^2 \tag{3}$$

$$\beta = \overline{y} - \alpha \overline{x} \tag{4}$$

where

$$s_x^2 = \frac{1}{n - 1} \sum_{i = 1}^{n} (x_i - \overline{x})^2 \tag{5}$$

$$v_{xy} = \frac{1}{n - 1} \sum_{i = 1}^{n} (x_i - \overline{x}) (y_i - \overline{y}) \tag{6}$$

$\overline{x}$ and $\overline{y}$ are the arithmetic averages of the x_i and y_i respectively.

Equations (3) and (4) give the necessary coefficients in terms of observed values for the predictor Equation (1). If y had been the MDN, and x an in-situ rock property (or some transformation of it), then this simple regression would have resulted in a predictor equation for the MDN.

A procedure similar to the simple regression technique will be applicable if we want to relate a dependent variable y to several independent variables $x_1, x_2, x_3, \cdots, x_{m-1}$. (Note the $x_1, x_2, \cdots, x_{m-1}$ are independent variable and not the observation points themselves). If n observations are taken, then one has the following sets of points: $(y_1, x_{1,1}, x_{2,1}, x_{3,1}, \cdots, x_{m-1,1})$, $(y_2, x_{1,2}, x_{2,2}, x_{3,2}, \cdots, x_{m-1,2})$, $\cdots$, $(y_n, x_{1n}, x_{2n}, x_{3n}, \cdots, x_{m-1,n})$.

A linear relationship is assumed to exist between y and $x_1, x_2, \cdots, x_{m-1,n}$. Thus, one has

$$y = \alpha_o + \alpha_1 x_1 + x_2 y_2 + \cdots + \alpha_{m-1} x_{m-1} \tag{7}$$

The coefficients $\alpha_o, \alpha_1, \cdots, \alpha_{m-1}$ will have to be determined from the n observations of the variables.

To solve for the coefficients requires the manipulation of certain arrays. Defining the following one dimensional arrays:

$$\alpha = \begin{pmatrix} \alpha_o \\ \alpha_1 \\ \cdot \\ \cdot \\ \cdot \\ \alpha_{m-1} \end{pmatrix} \quad ; \quad w = \begin{pmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{pmatrix} \tag{8}$$

Let A be the two-dimensional array.

$$A = \begin{pmatrix} 1 & x_{1,2} & x_{2,1} & \cdots & x_{m-1,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots & x_{m-1,2} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ 1 & x_{1,n} & x_{2,n} & \cdots & x_{m-1,n} \end{pmatrix} \tag{9}$$

Define a vector error by:

$$z = w - A\alpha \tag{10}$$

The scalar error is:

$$\begin{aligned} \epsilon = z^T z = & \left[w - A\alpha\right]^T \left[w - A\alpha\right] \\ & = \alpha^T A^T A\alpha - (w^T A\alpha + \alpha^T A^T w) + w^T w \end{aligned} \tag{11}$$

The derivative with respect to α is:

$$\frac{d\epsilon}{d\alpha} = 2A^T A\alpha - 2A^T w \tag{12}$$

For minimum error, $d\epsilon/d\alpha = 0$, thus

$$\alpha = (A^T A)^{-1} A^T w \tag{13}$$

A^T is the transpose of the matrix A given by Equation (9).

The general computational procedure is as follows:

(1) Form the array A as given by Equation (9).

(2) Obtain the transpose, A^T, from A. This is just a matter of interchanging rows and columns.

(3) Compute $A^T A$, then $(A^T A)^{-1}$, then $(A^T A)^{-1} A^T$. This involves a series of matrix multiplications and matrix inversion. These techniques are readily available from a computer.

(4) Form the array w from Equation (8).

(5) Multiply the result of Step (3) by the result of Step (4). This yields a set of coefficients $\alpha_o \alpha_1, \cdot\cdot\cdot, \alpha_{m-1}$.

(6) Test for goodness of fit or the quality of the predictor equation.

A basic assumption is that the predictor equation is linear, and that the independent variables to use are the observation variables themselves. It may be necessary to define another set of variables $x_1', x_2', \cdot\cdot\cdot, x_{m-1}'$ to use in order to obtain a linear relationship.

It often happens that the independent variables are themselves related. If a linear relationship exists between any two of the independent variables, $(A^TA)^{-1}$ will be singular, i.e., A^TA will have zero determinant, and hence $(A^TA)^{-1}$ cannot be computed. If this is so, α is difficult to compute, and the standard errors of the calculated coefficients are huge, giving an inaccurate predictor equation. This problem can be circumvented by performing the regression analysis with one variable, then with two variables, etc. while being careful when this problem arises. One may combine linearly any two variables that are highly correlated and use the combined variable as in the independent variable.

Good computer routines exist which are available on most computers, including routines for matrix transpose, matrix multiplication and matrix inversion, together with standard routines to compute means and standard deviations of a set of observations. In fact, there also exists software that performs stepwise regression analysis, performing the above calculations plus multiple correlation coefficients and residuals.

In multiple regression to predict an MDN, the MDN is treated as the dependent variable. The set of independent variables may include the following in-situ rock properties:

(a) Rock classification, quantified, e.g., as Igneous = 1, Metamorphic = 2, Sedimentary = 3

(b) Compressive strength, CSTR

(c) Rock quality designation, RQD

(d) Dry Unit Weight, DUW

(e) Hardness, H

(f) Ground Water, GW quantified, e.g., as Dry = 1, Minor to Moderate = 2, Wet = 3

Additional parameters peculiar to the excavation method may also be included in the set of independent variables. Some of these variables may be excluded from the analysis; others may be included. The regression analysis may be performed using one of more of these variables.

A set of observations is obtained for each of which an MDN is indicated. For example, suppose a table with the following entries is created: MDN, CLASS, CSTR, RQD, DUW, H, and GW. It is seen that y corresponds to MDN, and CLASS, CSTR, RQD, DUW, H, and GW correspond to x_1, x_2, . . . , and x_3 , respectively. The matrix in Equation (9) corresponds to the observation points. The array in Equation (8) corresponds to the MDN indicated in Column 1. The predictor equation may be obtained from Equation (13).

Two programs which use the same basic algorithm described above are (a) Program STEPWISE, and (b) Program BMD02R. The first is for a time-sharing mode, whereas the second one is for batch mode processing.

Both programs compute a sequence of multiple linear regression equations in a stepwise manner. At each step, one variable is added to the regression equation. During this step, the numbers (constant and coefficients) that go into the predictor equation are computed. The variable added is the one which makes the greatest reduction in the error sum of squares.

For the second program, transgeneration was possible. That is, new variables were formed as desired, from the old variables, and these new variables were then used in the regression just as the original variables.

APPENDIX E

TRANSPORT SYSTEM AND EQUIPMENT SELECTION

SYSTEM PARAMETERS

The following list of equipment capabilities, system constraints, and MDN applications is taken in part from Report No. FRA-RT-71-57, "Materials Handling for Tunnels," HN-8080, Holmes & Narver, Inc., and Resource Management Corporation, September 1970, prepared for the U. S. Department of Transportation, Washington, D. C., with additional details provided by the authors. With some differences, the list was incorporated as Section 3.6 of the Annual Technical Report of the first year's program. MDN applicability is based only on muck characteristics, and is subject to constraints imposed by such factors as tunnel size, grade and length, equipment and power cost and availability, and environmental considerations.

UNITIZED SYSTEMS

Conventional Rail Systems

Capabilities and Advantages

Hauling capabilities can be varied by the addition or removal of cars or trains.
Materials, supplies, and personnel can be transported by the system.
Easily adaptable to automatically controlled operation.
Loading and dumping can be done rapidly.
Track extension is relatively simple.

System Constraints

A large percentage of the tunnel cross section is occupied by equipment.
High speeds needed for fast cycle time.
Ideal roadbed and track conditions are necessary if delays cannot be tolerated.
Passing tracks are required in long tunnels.
A secondary system or assisted haulage is needed if vertical grade is over 4 percent.
Supply of materials required for system extension is a major operation at high advance rates.

Small clearances, high speeds, and massive moving equipment combine to produce long delays and serious injuries in the event of accidents.

Combustion products complicate ventilation unless vehicles are powered electrically.

Application

Applicable to any MDN. Special cars would be required for high speed operations with very wet muck, and special dumping facilities with MDN 6 and 7.

Side Rail Systems

Capabilities and Advantages

Hauling capacities can be varied by the addition or removal of units.

Materials, supplies, and personnel can be transported by the system.

Automatically controlled operation.

Loading and dumping can be done rapidly.

Can be used on much steeper grades than conventional rail systems.

Vertical and horizontal guidance tends to reduce frequency of derails and other accidents.

System Constraints

Power units for side rail systems require electrical bus bars to be extended with the track.

The small size of units in current use limits haulage capacity, and the number of power units can result in maintenance problems and delays.

Continuous bus bars may be a personnel hazard.

Application

All MDN 1 through 7 could be transported by this system. Problems in unloading cars can be expected from MDN 6 and 7 if wet due to the high percentage of fines. The technology of the system is under development; there is no existing application to successful, long distance haulage.

Free Vehicles

Capabilities and Advantages

System capacity can be varied by the number of vehicles or by change in speed.
Materials can be transported inbound and outbound.
Guideway for operation is not required.

System Constraints

Tunnel size limits use of free vehicles in small tunnels unless turnouts are provided.
Roadway must be well graded and maintained to support weight and speed of vehicles.
Present design of high capacity vehicles uses excessive amounts of tunnel volume per ton of capacity and does not provide the ability to operate in both directions equally well.
Inability to climb grades of 8 to 12 percent at adequate speeds.
Operator required for each vehicle.
Small clearances, high speeds, and massive equipment combine to produce long delays in case of malfunction, and serious injuries in event of accident.
Combustion products complicate ventilation unless vehicles are powered electrically.

Application

MDN 1 through 7 can be transported by free vehicles. Excessive tire wear could be expected in some formations in the MDN 1 and 2 ranges due to lump size and angularity. The system may not be practical for some sites producing muck in the MDN 6 and 7 ranges because of traction and roadbed maintenance problems.

SEMICONTINUOUS SYSTEMS

Belt Conveyors

Capabilities and Advantages

Possible installation overhead or at sides of tunnel leaves floor space for other uses.
Capacities can be increased by changing belt speed.
Conveyors can go up or down slopes to 22 degrees.

System Constraints

Supplementary transportation which must be provided for incoming materials and personnel.
Delays inherent as the conveyor is extended from a temporary to a semipermanent installation.

Application

All MDN can be transported by conveyors. Excessive belt width, damage, and wear can be expected in the MDN 1 and 2 ranges because of piece size and shape unless the material is crushed prior to being placed in the system. In the MDN 3 to 7 ranges, through a wide range of water occurrence, considerable material from some formations will stick to the belt causing excessive cleaning and belt wear. In the entire MDN range it is mandatory that the water content be below the point where the muck will slip or flow on the belt or overflow the sides.

Hydraulic Pipelines

Capabilities and Advantages

Capacities adequate for the tonnage from any tunnel in the foreseeable future.
Pipelines use very little space in the tunnel.
Especially adaptable to very wet sites and to hydraulic excavation systems.
Adaptable to any grade including vertical.

System Constraints

Capacity to handle plus 1-inch muck from strong rocks through centrifugal pumps has not been demonstrated in field use.
Crushing, feeding, or scalping equipment for through-centrifugal pump systems, or lock-feed equipment for alternate designs may cause congestion in the near face area.
Large amounts of water are required.
Required electrical power may be difficult to provide for long tunnels in remote areas.
Dewatering, recirculation, and muck disposal systems may be elaborate.
For high advance rates, methods of advancing pumping units and pipelines must be developed.
The heat load from large electrical installations may be difficult to dissipate.
System malfunctions may be hazardous to personnel.

Application

MDN 6 and 7 are most suitable for pumping because of the low percentage of plus # 4 material and a high fines content. Preliminary crushing would be needed for transporting other MDN by a through-centrifugal pump system. Improved feeder and pump applications appear necessary. One trial in a tunnel is reported successful within volume design limitations.

Pneumatic Pipeline

Capabilities and Advantages

Pipelines use very little space in the tunnel.
Adaptable to any grade including vertical.

System Constraints

Feeding components congest the tunnel in the near face area.
Power requirements are high.
Muck must be relatively dry.
Crushing or scalping equipment must be used if natural feed is too large for system.
Pipe wear and maintenance may be excessive.
Secondary transportation must be provided for materials and personnel.
Dust at the discharge or from malfunctions may be hazardous to personnel.
Low pressure systems operate at an objectionable noise level.

Application

High pressure systems have not been developed to provide the capacity required for tunnels. Low pressure systems, designed to handled minus 3-inch material, would be suitable for MDN 4 through 7 provided the feed is granular and free flowing. The technology of the system is under development. Reported trials in tunnels were not completely successful.

EQUIPMENT SELECTION

Following are the detailed calculations for the examples of system and equipment selection methods described in Section 3.7. References are cited in the text.

Example 1: Hydraulic Conveying (Reference 1 is cited in text)

Particle Size: Nast 4 (Weighted mean diameter)

Percent	Inches Maximum	 Minimum	 Average	Average x Percent
11.5	1.0000	0.5000	0.7500	8.625
20.6	0.5000	0.1870	0.3435	7.076
13.6	0.1870	0.0937	0.1404	1.909
42.6	0.0937	0.0059	0.0498	2.121
11.7	0.0059	0.0000	0.0030	0.035
				19.766

19.766/100 = 0.198-Inch

Muck Volume, Weight, and Concentration

Tunnel Area = 76 Square Feet

Advance Rate = 3 Feet Per Hour

Solid Volume = 76 x 3 = 228 Cubic Feet Per Hour

= 3.8 Cubic Feet Per Minute

= .0633 Cubic Feet Per Second

Solid Weight = 228 x 2.65 x 62.4 = 37,702 Pounds Per Hour

= 628.4 Pounds Per Minute

= 10.47 Pounds Per Second

$$\text{For } C_W = 30\%,\ C_V = \frac{C_W}{S - (S - 1) \times C_W/100}$$

$$C_V = 30/(2.65 - 0.50)$$

$$= 30/2.15 = 13.95 \text{ Percent}$$

where C_W is concentration by weight and S is the specific gravity of the solid.

For $C_W = 40\%$, $C_V = 40/(2.65 - 0.66)$

$$C_V = 40/1.99 = 20.10 \text{ Percent}$$

Critical Velocity

From Figure 1, Reference 1, for a particle diameter of 0.198 inches, a (dimensionless) constant (F_L) of 1.35 is determined for substitution in the formula, Reference 1; in which D = pipe diameter in feet and g is the acceleration of gravity:

$$V_{CR} = F_L [2 g D (S - 1)]^{1/2}$$

For 3-Inch Pipe:

$$V_{CR} = 1.35 [2 \times 32.17 \times (3.068/12) \times (2.65 - 1)]^{1/2}$$

$$= 1.35 (64.34 \times 0.256 \times 1.65)^{1/2}$$

$$= 1.35 \sqrt{27.18}$$

$$= 7.03 \text{ Feet Per Second}$$

For 4-Inch Pipe:

$$V_{CR} = 1.35 [64.34 \times (4.026/12) \times 1.65]^{1/2}$$

$$= 1.35 (64.34 \times 0.336 \times 1.65)^{1/2}$$

$$= 1.35 \sqrt{35.67}$$

$$= 8.05 \text{ Feet Per Second}$$

Operating Velocity (V_T)

Volume of Mix (V_m) = Volume of Solid x $100/C_V$

For 30 Percent C_W, V_m = 0.0633 Cubic Feet x 100/13.95

= 0.4537 Cubic Feet Per Second

For 40 Percent C_W, V_m = 0.0633 Cubic Feet x 100/20.10

= 0.3149 Cubic Feet Per Second

Flow Rate (V_T) = V_m/Area

For 3-Inch Pipe (Area = 0.0513 Square Feet):

For 30 Percent C_W, V_T = 0.4537/0.0513

= 8.84 Feet Per Second

For 40 Percent C_W, V_T = 0.3194/0.0513

= 6.23 Feet Per Second

For 4-Inch Pipe (Area = 0.0884 Square Feet):

For 30 Percent C_W, V_T = 0.4537/0.0884

= 5.13 Feet Per Second

For 40 Percent C_W, V_T = 0.3194/0.0884

= 3.61 Feet Per Second

Operating Volume ($\overline{V}_m$)

For 3-Inch Pipe, 30 Percent C_W:

$\overline{V}_m$ = 0.4537 Cubic Feet Per Second

= 27.222 Cubic Feet Per Minute

= 27.222 x 7.4805

= 203.6 gpm.

Reynolds Number (N_R) (Reference 1)

$$N_R = V_T \times D\,(\text{Feet}) / \text{Viscosity} = 8.84 \times 0.256 \times 10^5/1.217$$

$$= 2.2630 \times 10^5/1.217$$

$$= 1.8594 \times 10^5$$

Drag Coefficient (C_d)

From Reynolds No. Chart = 0.44

Head Loss, Water (Cameron Hydraulic Data, 1951)

Cameron Table, C = 100, (i_w) = 16.7 Feet/100 Feet

Head Loss, Slurry (i_m)

$$i_m = i_w \left[1 + 81 \left(\frac{g\, D\,(S-1)}{{V_T}^2} \right)^{1.5} \frac{C_V}{{C_d}^{0.75}} \right]$$

$$81 \left[\frac{g\, D\,(S - 1)}{{V_T}^2} \right]^{1.5}$$

$$= 81 \left(\frac{32.17 \times 0.256 \times 1.65}{8.84^2} \right)^{1.5}$$

$$= 81\ (13.58/78.15)^{1.5}$$

$$= 81\ (0.1737)^{1.5}$$

$$= 81 \times 0.0724 = 5.86$$

$$\frac{C_V}{C_d^{0.75}} = \frac{0.1395}{0.44^{0.75}} = \frac{0.1395}{0.54} = 0.26$$

$$i_m = 16.7\,[1 + (5.86)\ (0.26)\,]$$

$$= 16.7\ (1 + 1.524) = 16.7 \times 2.524$$

$= 42.15$ Feet/100 Feet $= 18.25$ psi/100 Feet

Specific Gravity, Slurry

Sp. Gr. $= 100 \times [C_W$ Solids/Sp. Gr. Solids $+ C_W$ Water$]^{-1}$

$$= 100\,[30/2.65 + 70]^{-1} = 100\ (11.32 + 70)^{-1}$$

$$= 100/81.32 = 1.23$$

BHP

Average BHP $= \dfrac{\text{gpm (Slurry)} \times \text{Sp. Gr. (Slurry)} \times \text{Head in Feet}}{3,962 \times \text{Pump Efficiency}}$

$$= \frac{204 \times 1.23 \times 3,562}{3,962 \times 0.40} = 563.89$$

Maximum Head Loss = 6,914 or 2,994 psi

Maximum BHP $= 563.89 \times 165/85 = 1,094$

Equipment

Assume 46 pump stations at 350 feet.

Each pump is 25 hp, and 205 gpm at 150-foot head.

Cost Estimate

Pipe, Installed With Fittings, 16,000 Feet @ $10 Per Foot	$ 160,000
46 Pump Installations @ $1,000 Each	46,000
Capital Cost, Without Feeders or Power Transmission	$ 206,000

Example 3: Belt Conveyors (Reference 2 is cited in text)

Surcharge Angle

Design Angle of Repose: 31°

Surcharge Angle = 31° - 16° = 15°

Anticipated Production

6 Feet Per Hour x 257 Square Feet = 1,542 Cubic Feet Per Hour

Design Density = 170 pcf

1,542 Cubic Feet Per Hour = 262,140 Pounds Per Hour

= 4,369 Pounds Per Minute

Belt Capacity

From Table 3-1, Reference 2:

Surcharge Angle 20°, A = 0.774

Design Muck Weight, Dry, Loose = 94 pcf

Dry Weight Per Linear Foot = 0.774 x 94 = 63.4 Pounds

Edge Distance (Arbitrary) = 0.20 Belt Width

Weight Reduction Factor = **Table 3-9 = 0.45**

Reduced Weight Per Linear Foot = **63.4 x 0.45 = 28.53**

Belt Speed

4,369 Pounds Dry Weight Per Minute Production

Speed (V) = 4,369/28.53 Pounds Per Linear Foot

= 153 Feet Per Minute

Belt Loading

Dry Weight Per Linear Foot = 28.53 Pounds

Design Moisture = 7.9 Percent

W_m = Design Natural Weight = 28.53 + 2.25

= 30.8 Pounds Per Foot

Idler Spacing, Belt Weight, and Application Factors

From Reference 2:

Table 4-1: Troughing: 5 Feet; Return: 10 Feet

Table 4-2: Trough Idler Service Factor: 15(A)

Table 4-3: Est. Belt Weight (W_b): 9.2 Pounds Per Foot

Table 4-4: Weight and Lump Factor: 56 (B)

A x B = 840

Idler Class

From Reference 2:

Figure 4-19: Troughing Idler A.F. = III = 5-Inch Diameter

Figure 4-20: Return Idler A.F. = III = 5-Inch Diameter

6-Inch Diameter Selected for Later Service.

Power

From Reference 2, the formula for effective tension (T_e) with the reduced friction applicable to a declined belt is stated:

$$T_e = L \left[K_t (K_x + 0.01 W_b + C_1 K_y W_b)\right] + C_1 K_y LW_m - HW_m$$

$$+ \text{Accessories} \times C_1$$

L = Length = 1,200 Feet $C_1 = 0.66$ $W_b = 9.2$ Pounds $W_m = 32.8$ Pounds

K_t = Temperature Factor (Figure 8-1) = 1.0

K_x = Revolving Idler Resistance (reduced friction)

$= 0.00068 (W_b + W_m) = 0.00068 (30.8 + 9.2)$

$= 0.0272$

K_y = Moving Resistance, Belt and Load (Tables 8-2 and 8-3)

$= 0.019$

$H = 1200 \times \cos 9^\circ - 39$ Feet $= 1200 \times 0.16763$

$= 201.2$ Feet

Accessories consist of 2 pulleys and a 10-foot skirt board

$= (2 \times 40) + (3 \times 30) + 117$ (Reference 2)

$= 287$ Pounds

Expressed in tabular form, the formula components are:

(1) $LK_t K_x = 1200 \times 1.0 \times 0.0272 = 32.6$

(2) $LK_t \times 0.01 W_b = 1200 \times 1.0 \times 0.01 \times 9.2 = 110.4$

(3) $LK_t \times C_1 K_y W_b = 1200 \times 1.0 \times 0.66 \times 0.019 \times 9.2 = 138.4$

(4) $C_1 K_y LW_m = 0.66 \times 0.019 \times 1200 \times 32.8 = 493.6$

(5) $-HW_m = 201.2 \times 32.8 = -6596.1$

(6) Accessories x $C_1 = 287 \times 0.66 = 189.4$

T_e = Sum of (1) through (6) = -5631.7

Substituting in the power formulas, Reference 2:

Belt hp = $T_e \times V/33000$

$= -5631.7 \times 153/33000 = 26.1$

Motor hp = Belt hp + speed reducer loss (6 Percent, Reference 2)

$= -26.1 + 1.6 = 24.5.$