AD-751 058

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

H. F. Haller, et al

Holmes and Narver, Incorporated

Prepared for:

Advanced Research Projects Agency

September 1972

HN-8128.1

Semi-Annual Technical Report No. 1

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

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order 1579, Amendment 3
Program Code No. 2F10

September 1972

Report Period
February 16, 1972 - August 31, 1972

HOLMES & NARVER, INC.

A Resource Sciences company

Advanced Technology / Engineering / Construction / Management / Maintenance & Operations

400 EAST ORANGETHORPE AVENUE • ANAHEIM, CALIFORNIA 92801

See also AD 740 781

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

HOLMES & NARVER, INC.
400 East Orangethorpe Avenue
Anaheim, California 92801

2a. REPORT SECURITY CLASSIFICATION

N/A

2b. GROUP

3. REPORT TITLE

Study of Interrelationship of In-Situ Rock Properties, Excavation Method, and Muck Characteristics

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Annual Technical Report No. 1 February 16, 1972 -- August 30, 1972

5. AUTHOR(S) (First name, middle initial, last name)

H. F. Haller, H. C. Pattison, Dr. O. C. Baldonado

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September, 1972		6

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
HO 220023	HN-8128.1
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	NONE

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D. C. 20301

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's, preliminary regression analyses, and equipment selection are described.

Data available 8/31/72 from 50 samples at 23 sites (16 samples from 8 sites in 1972) is presented in raw data printout and narrative-graphic summary form, showing lithology, rock properties, operating data, and muck properties. Tentative MDN's are described by composite size and distribution curves, with preliminary regression analyses of 27 data sets and prediction accuracies of over 90 percent. Applications to equipment selection/design include input for design formulae used in mathematical models 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, dynamic testing for coefficients of rock strength in addition to current tests, and predictor refinements.

ia

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Tunneling						
Rock and Muck Property Interrelationships						
Muck Designation Number						
Muck Characteristics						
Transport Equipment Selection/Design						
Materials Handling in Tunnels						
Muck Transportation						

16

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the U. S. Bureau of Mines under Contract No. HO220023, ARPA Order Number 1579, Amendment No. 3, Program Code 2F10.

Effective Date: February 16, 1972

Expiration Date: April 16, 1972

Estimated Amount of Contract: $81,416

Short Title: Muck Designation Number (MDN) Study

Project Scientist: Dr. O. C. Baldonado
Telephone: (714) 870-5700

Principal Investigator: H. F. Haller
Telephone: (714) 870-5700

IC

Semi-Annual Technical Report No. 1

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

by
H. F. Haller
H. C. Pattison
Dr. O. C. Baldonado

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order 1579, Amendment 3
Program Code No. 2F10

September 1972

Report Period
February 16, 1972 - August 31, 1972

HOLMES & NARVER, INC.

A Resource Sciences company

Advanced Technology / Engineering / Construction / Management / Maintenance & Operations

400 EAST ORANGETHORPE AVENUE • ANAHEIM, CALIFORNIA 92801

FOREWORD

This report presents the results of research performed during 1971 and 1972 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.

AIME, Alexander R. Scott
Atlas-Copco Corporation, Pieter Berendsen
Bunker Hill Company, Frank Woodruff, John Parker, John Songstad, Keith Droste, Joe Gordon, Terry Butler, Norman Radford
Callahan Mining Corporation, George Beattie, James Thompson
Calweld Division, Smith International, Inc., Richard Wallers, N. M. Fillip, E. W. Brickle, Tom Bryant, Reynold Carlson
Cleveland Cliffs Iron Company, G. A. Dawe, Eric Beinlich, A. J. Andelin, J. P. Marietti, Jim Maina, Matt Korpi, E. A. Koski, John Reddy, Hugo Korpinen
City of Chicago, Department of Public Works, C. J. Kieffer, F. C. Neil, T. Maynard
Climax Molybdenum Company, American Metal Climax, D. B. Achttien, J. W. Powell, R. L. Elder
Dresser Industries, Inc., R. R. Durk, N. Nickerson
Fenix and Scisson, Inc., Daniel Geary
Fluor-Utah Engineers-Constructors, R. K. Duke, R. W. Franzen, J. D. Davenport, Bob Spaulding
Granite Construction Company, Lou Avery, Pat Loughry
Harza Engineering Company, Richard Acker, Frank Wheby
S. A. Healy Company, Don Zeier, Robert Ames, John Wagner, Carl Prescott, Ben Metros, Domenic DiSandro, Don Parus
Hecla Mining Company, Coeur D'Alene District, Gordon M. Miner, George Wilhelm, Merle Hutchinson, Jon T. Langstaff, William Anderson, Arthur Brown
Hecla Mining Company, Casa Grande District, J. H. Hunter, R. S. Hendricks, James Quinlan, Pedro Campino, D. W. Trepp, Jack Hight, Ken Jensen, S. L. Milne, Andrew Kannegaard, D. J. Ryzak

Homestake Mining Company, D. W. Delicate, Olin Hart, Gordon Nelson, Al Gilles, Bert Moorhead, Ernest Boint
Illinois University, Don U. Deere, Peter Tarkoy
Jarva, Inc., Ed Norman
Peter Kiewit Sons' Company, Norman Tennock, R. S. Allmon, P. E. Freeland
Kennametal, Inc., John J. Riley
Kerr-McGee Corporation, Rhoderick Tregembo, W. R. Dolezal, J. W. Burgess, Carl Johnson
Magma Copper Company, San Manuel, John Wise, Les Acton, John Goss, Don Cumming, Lloyd Thomas, Stewart Thomas
Magma Copper Company, Superior, Keith Staley, J. W. Murray, Jack Flanigan, Joe Vendiola, John Bodycomb, Doyle Dugan, Russ Webster, Dick Schall
Lawrence Manufacturing Company, Ingersoll-Rand Company, William Hamilton, Robert Gordon, Howard Handewith, Richard Pyle, Peter Gadzuk
Joseph W. LaComb, DOD, DNA
W. J. Lazynski Company, Thomas Peterson, J. Olouglin, H. Zewtzke
Joy Manufacturing Company (Canada), Thomas E. Howard
Lockheed Shipbuilding and Construction Company, Loren Savage, Berle Cook
A. A. Mathews, Inc., A. A. Mathews
Mathews and Chase, Martin Cooper, Dean S. Lodemell
G. W. Murphy Industries, Inc., A. B. Spiritelli
Metropolitan Water District of Southern California, R. J. Proctor, Garland Gray, James Brown
Perini Construction Company, Roy Anderson, Bruno Dietel
Reynold Electrical and Engineering Company, W. G. Flangas, R. S. Burton, Barge Massey
The Robbins Company, R. J. Robbins, N. J. Dahmen, P. T. Plypick, Pat Taylor
S&M Constructors, Ron Marra
SME, Jack C. Fox, John Beall, L. Donaldson
Tunnel Constructors, Inc., Fred Breu
Teetor-Dobbins, Alexander Valle
U. S. Atomic Energy Commission, T. W. Young
U. S. Department of Interior, Bureau of Reclamation, Harold Arthur, H. E. McInnes, Gordon Hill, A. S. D'Alessandro Bert Levine, Dewey Geary, Shannon Fowler, Lawrence Rhodes, Paul Randolph, George Terry
Viro Dyne Corporation, L. A. Garfield
Western Nuclear, Inc., D. R. Ketron, T. A. Miche
White Pine Copper Company, Walter Finlay, J. L. Patrick, C. C. Hanninen, T. J. Rohrbacher, William Lane, William Dorvinen, J. W. Sipola

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

INTRODUCTION AND SUMMARY

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 a means of selecting the most suitable transportation equipment for the muck through the concept of Muck Designation Numbers (MDN's).

MDN's range in whole numbers from 1 through 7. MDN 1 describes muck with a large maximum piece size, more than 5 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 20 percent is minus 200 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 in the first half of a contract initiated on February 16, 1972, for a 14-month period. The work is a continuation of a previous 12-month contract of which the results also are covered to summarize 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 tentative MDN's, preliminary correlation with rock properties, and establishing the parameters of muck handling systems.

Regression analysis of seventeen sets of rock property, Raise Boring Machine (RBM), and Tunnel Boring Machine (TBM) data produced a predictor equation with an apparent accuracy over 90 percent. Analysis of 10 sets of rock data with conventional excavation parameters produced an accuracy of nearly 100 percent. Inclusion of additional data is expected to improve prediction reliability.

Predictor accuracy probably will not be maintained at preliminary levels, and appropriate parameters remain to be developed for shield and drag cutter TBM's. However, it can be concluded that MDN's are predictable within the limits of reasonable accuracy for the majority of rocks and methods sampled under the program.

Preliminary analysis also shows that MDN data can be used as input for design formulae and performance-cost models of belt and hydraulic conveying systems.

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.

2. General Methodology

The research plan is 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's; and correlate rock and muck characteristics, MDN's, 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 (RQD's) 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, has been revised periodically. The current list is 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 current program, conventional operations in hard rock at deep mines have been sampled at client request.

3.2 Sample and Data Collection

In the current program, operating data and sixteen muck samples were collected from eight sites. Totals for the program are 50 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 39 formations at 21 sites. Nineteen of the specimens, some of which represent formations sampled in 1971, were collected from nine sites in 1972.

Two shield, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types sampled include four classified as Very High Strength, 20 High Strength, four Medium, 20 Low, and six Very Low Strength. Those remaining to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications. A 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 the fractions has been increased from 2 to 4 cubic feet. At the end of the reporting period, muck tests by commercial laboratories had been reported on 46 sets of samples and on 41 sets by the PMSRC.

Contracts to perform rock tests have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests. Of the 39 sets of rock specimens which have been collected, 31 test suites have been completed. Stress-strain data from testing initiated in 1972 was obtained on 11 rocks, including four sampled in 1971. Results from Schmidt hardness tests on rock cores, also initiated in 1972, have not been consistent. Modification of test methods is contemplated. Initial abrasiveness tests are planned for the third quarter of the contract.

3.4 Data Processing

Formats were developed for storage and printout of lithologic rock, muck, and tunnel data: data received to date has been stored on punch cards and printouts of these data are included as Appendix B. A form was developed for narrative and graphic presentation of data. These "System Data Sheets" are included as Appendix C.

3.5 Development of MDN's

Size distribution curves from initial sampling varied distinctly, generally as had been expected; and an algorithm to correlate MDN's, 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 required establishing additional categories. Using the data available at the end of the first year, curves of similar form were plotted together, and preliminary MDN's were assigned. The resulting composite curves are shown in Figures 3-3 through 3-11.

Initial regression analyses produced the predictor equations described in the "Conclusions" section, indicating accuracies over 90 percent for RBM/TBM and for conventional operations. Computer input data are shown in Section 3, and the output tabulations are shown as Figures 3-1 and 3-2.

Additional iterations will be performed when the data collected in 1972 is in final form. Values for Young's modulus, Poisson's ratio, and Schmidt hardness resulting from current tests will be substituted for the less important parameters and inferred values used in current analyses. Current efforts to obtain data on net torque for TBM's and RBM's, and to develop operating parameters for drag cutter TBM and shield operations will be continued.

3.6 Transport System Selection

A list of equipment capabilities, system constraints, and MDN applications, prepared for the Annual Technical Report for the first year, has been included as 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 is appropriate as input to design formulae and the models. Some clarification of design parameters and refinement of the models is planned for the second half of the current program. An example of MDN data use in design of an hydraulic system is in progress; a comparison between an existing installation and a belt conveyor design based on MDN data, and examples of MDN applications to other systems are planned.

4. DOD Implications

Data accumulated under the program are nonexistent elsewhere in rapid excavation technology and 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.

The MDN program provides basic data required for a rational engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used 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 projection of formations and excavation systems for which data is expected to be available at the end of the current contract.

Excavation Method	Rock Strength					
	Very High	High	Med-ium	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	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

To be consistent with good sampling and testing practice, data reliability should be confirmed by repetition of all single samples. Eleven sites previously sampled once are expected to be available in 1973. 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 TBM's 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 will be required.

5.2 Physical Testing

Continued development of testing methods to provide consistent results from Schmidt hardness tests is recommended because of the speed, low cost, and nondestructive nature of the only test for a dynamic rock property in current use.

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 General

Potential improvements in systems components which require the application of techniques which are technically sound but not yet developed to a point of practical application may appear in the collection and analysis of program data. These should be identified as attractive areas for research and development.

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 quantity and quality of information concerning subsurface conditions 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 information about conditions to be encountered, and to base cost estimates on methods and equipment which may not be well suited for conditions as they exist. Generally, significant allowances are made both for contingencies which can be anticipated and for those which cannot be foreseen.

The importance of a more logical approach to selection of methods and equipment for tunneling became apparent when the volume of this work probable in the future was estimated several years ago; it has been reemphasized by more recent studies which indicate that prior estimates 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 the extent that collection and dissemination of more and better quality exploratory information appears to be a current trend.

Progress has been made and is continuing in research to determine relationships between rock properties, drillability, excavation, and support requirements. Prior to inception of the program described in this report, practically no information had been collected on the characteristics of the muck produced by various excavation methods, and correlations between the engineering properties of rock, 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 optimum transportation methods 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 the higher rates of excavation predicted for the future.

2. GENERAL METHODOLOGY

Objectives of the program are to develop a method for predicting materials handling properties of muck from the in-situ properties of rock and a means of selecting the most suitable transportation equipment for muck produced by various excavation systems. 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.

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's); and to establish correlations between rock and muck characteristics, MDN's, the components of rapid excavation systems, and selection of 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. The latest revision is included as Appendix A. Six of the tunnels listed are expected to be completed in 1972. Letter inquiries inviting program participation by off-continent tunnel operators met with no response. These tunnels have been deleted from the list.

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. Scheduling sampling 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 current year seven conventional and nine mechanical operations have been sampled, and one more of each is expected in the second half of the year.

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

6,110 feet, a phyllite at 6,200 feet, a quartz monzonite at 2,075 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 have been collected from 23 mine and tunnel sites. Of 50 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 39 formations at 21 sites.

Two shield operations, two RBM, 18 conventional, and 28 TBM operations have been sampled to date. Rock types classified include four Very High, twenty High Strength, four Medium, five Low, and six Very Low Strength. Rocks which remain to be tested are expected to include three High Strength, six Medium, and two Low Strength classifications.

Nine of the sampled sites are no longer available for field work. Of the remaining sites, one is expected to complete excavation in October of 1972.

Early in the 1972 program 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. 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.

Operating data in the first year of the program was collected in sufficient detail to permit inclusion of all of the components of the tunneling system in the analysis and selection of optimum transportation subsystems for specific MDN's and tunnel configurations. Experience in data analysis has indicated a need for more precise thrust, torque, and cutter data than was expected to be required for mechanical tunneling. In the current year, these data are being collected for most of the TBM operations sampled to date.

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 current program 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 followed by U. S. Bureau of Mines research centers in measuring strains.

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, are available for only three of the rock formations sampled. Additional tests by this method were found to be beyond the scope of this study. Hardness testing by the Schmidt hammer, a portable device which also tests rebound hardness, is nondestructive and relatively inexpensive and was specified for inclusion 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, and a machine designed for such testing was located by the Project Officer at the PMSRC and will be available to the program in the second half of the current contract period.

Modification of the standard test procedure was found necessary in testing muck from some low strength rocks. Screen testing the samples in the natural state was performed prior to the standard tests to avoid distortion of the curves caused by the disintegration of material during the wash screening which normally precedes dry sieve analysis. Natural screen test results are identified and shown as dotted lines on the size distribution curves.

Contracts to perform muck tests have been 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. At the end of the reporting period, tests by commercial laboratories had been reported on 46 sets and by the PMSRC on 41 sets of muck samples. One set of samples tested commercially was lost in transit to the PMSRC.

Contracts to perform tests on rock specimens have been negotiated with five commercial laboratories. One laboratory is now performing all rock tests, which assures uniformity of results, but also delays some tests when the volume of work is high. Two sets of specimens destroyed in preparation for testing in 1971 were replaced in 1972. A total of 39 sets of rock specimens have been collected, on which 31 reports have been received, and 8 sets remain to be tested. Stress-strain data was obtained on 11 rocks, including 4 collected in the 1971 program. Specimens yet to be tested appear to be of the necessary quality for stress-strain testing.

Initial Schmidt hardness tests by project personnel 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 no obvious correlation with field tests or with values obtained from the hardness-compressive strength relationships established by previous 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 appears to be associated with core straightness. The cost and results of testing polished flat surfaces is being investigated.

3.4 DATA PROCESSING

A format was developed for computer printout of lithologic, rock, muck, and tunnel data. Test results received to date have been stored on punch cards. Printouts of these raw data are included as Appendix B. Blank spaces on the printout indicate that data is not available on the date of the report.

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 - 32,000 psi
Medium Strength	-	8,000 - 16,000 psi
Low Strength	-	4,000 - 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 grains above 2 mm, 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	S - Subangular
P - Platy	R - Rounded
E - Elongated	C - Cubic
I - Irregular	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

The abbreviation NA is used to indicate that an item of data is not available.

3.5 DEVELOPMENT OF MDN'S

In accordance with the program plan, which provided for placing major emphasis on data collection during the first year, analysis of data and development of MDN's has been preliminary. As data first became available, test results were reviewed to confirm the validity of the conceptual classification criteria. Based on a plan of classification by materials handling characteristics, the proposed designation system employed seven numbered categories in which to group excavation products by size and size distribution. Numbers were 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, in which the maximum size is relatively small and the predominant distribution is in the minus 50 mesh sizes. The concept also recognized that muck characteristics would vary with the excavation method and contemplated modifying the MDN's to distinguish between excavation techniques.

Initial field work was scheduled at sites where rock strengths varied over a wide range and which would provide examples of shield, machine, and conventional operations. The size distribution curves of the muck from these sites (Identification Numbers H-1, 5-1, CL-1, NAST-1, and SF-1, Appendix C), varied distinctly, in general accordance with the

criteria, except that the size range of the predominant distribution was somewhat higher than had been inferred.

Using the initial data as a guide, a preliminary algorithm was developed for data analysis to correlate MDN's, in-situ rock properties, and excavation methods. The quantitative relationship sought was a predictor equation, obtained by multiple regression of the physical property data obtained from the rock sample tests and a predictor equation for the MDN. A discussion of this technique is included as Appendix D.

During algorithm development, 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 designation numbers were assigned. The resultant composites are shown as Figures 3-3 through 3-11.

The "T" prefix was added to all MDN's to indicate the preliminary nature of the assignments. Parameters available for the analysis of all samples included values of uniaxial compressive strength (f_c), rock quality designation (RQD), and dry unit weight (DUW) for which quantitative values were determined by field observation and testing. To avoid reducing data derivatives to extremely small values, rocks with compressive strengths of 1K psi or less have been assigned arbitrary strengths of 1. Rock classifications by origin were quantified as igneous = 1, metamorphic = 2, and sedimentary = 3; and ground water occurrence was quantified as dry = 1, minor = 2, and wet = 3. The order and magnitude of the number assignment is immaterial since these are modified in the analysis in nearly any case. Schmidt hardness values (H) are 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.

Cutter spacing (CS) 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 is apparent, values were obtained by dividing the body spacing by the number of buttons 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 TBM's. Net thrust values per square foot of face area (T) were available for TBM's with the same exceptions.

No appropriate operating parameters were available for the Alpine and Atlas-Copco machines or for the shield operations sampled, and the number of observations was insufficient to warrant analysis as a special case.

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 were analyzed for machine operations using the values tabulated below:

DATA FOR ANALYSIS, MACHINE OPERATIONS

Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	f_c	RQD	DUW	H	GW	CS	T
5-1	1	2	3	22	92	166	49	1	0.20	3.56
7-2	2	2	3	22	92	166	49	1	0.20	2.91
LAW-2	3	3	3	19	100	160	42	1	0.20	4.28
LAW-3	4	3	3	19	100	160	42	1	0.20	4.28
LAW-4	5	3	3	19	100	160	42	1	0.20	3.76
MIL-1	6	4	3	36	85	166	50	2	0.16	6.09
MIL-2	7	4	3	36	85	166	50	2	0.18	6.09
QL-1	8	4	2	11	30	165	37	2	0.18	3.53
CL-1	9	5	2	9	10	174	45	2	0.09	5.09
NAST-2	10	5	1	18	90	167	55	2	0.09	3.89
NAST-4	11	5	1	24	90	160	55	2	0.09	8.45
LK-5	12	5	1	32	92	165	55	1	0.24	4.46
LK-6	13	5	1	7	86	137	50	1	0.13	17.20
NAST-1	14	5	1	18	90	167	55	2	0.09	3.89
LAY-1	15	6	3	10	84	150	47	1	0.24	2.73
NAV-1	16	6	3	2	70	142	25	1	0.30	1.31
NAV-2	17	7	3	1	60	117	25	1	0.30	0.37

Results of stepwise regression, as shown in detail on Figure 3-1, following, indicate an accuracy of slightly more than 90 percent with a standard error of 0.8360 and the listed residuals.

MULTIPLE CORRELATION COEFFICIENT..... 0.9081
F FOR ANALYSIS OF VAR. (D.F. = 8, 8) 4.7026
STANDARD ERROR OF ESTIMATE..... 0.8360

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-6.89554E-02	3.55858E-02	-1.93772
7	2.29717	1.14621	2.00414
2	-.469846	.381356	-1.23204
8	17.7298	11.4412	1.54964
3	-6.63157E-02	5.89690E-02	-1.12459
6	.104435	6.65627E-02	1.56898
4	-6.17628E-03	1.61827E-02	-.381659
9	-3.90019E-02	.103588	-.376511

INTERCEPT(A) 6.98974

TABLE OF RESIDUALS

OBS.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	2.000	2.928	-0.928	-1.110
2	2.000	2.953	-0.953	-1.140
3	3.000	2.732	0.268	0.320
4	3.000	2.732	0.268	0.320
5	3.000	2.752	0.248	0.296
6	4.000	3.637	0.363	0.435
7	4.000	3.991	0.009	0.011
8	4.000	5.270	-1.270	-1.519
9	5.000	4.084	0.916	1.095
10	5.000	5.037	-0.037	-0.044
11	5.000	4.944	0.056	0.067
12	5.000	4.574	0.426	0.509
13	5.000	5.231	-0.231	-0.276
14	5.000	5.037	-0.037	-0.044
15	6.000	5.409	0.591	0.707
16	6.000	5.399	0.601	0.718
17	7.000	7.288	-0.288	-0.345

COMPUTER OUTPUT-TBM AND RBM DATA ANALYSIS.

FIGURE 3-1

Ten sets of data were analyzed for conventional operations, using the values tabulated below:

DATA FOR ANALYSIS, CONVENTIONAL OPERATIONS

Column		1	2	3	4	5	6	7	8	9
Ident. No.	Obs. No.	MDN	Class	f_c	RQD	DUW	H	GW	A/H	PF
LK-1	1	1	1	25	83	162	55	1	5.4	4.0
LK-2	2	1	1	28	83	165	55	1	5.4	4.0
LK-3	3	1	2	26	80	178	50	1	5.0	5.0
LK-4	4	2	2	14	70	181	47	1	4.4	5.5
CA-1	5	3	1	35	96	161	55	1	2.1	6.1
11-3	6	3	3	22	90	152	43	1	5.1	3.5
H-1	7	3	1	32	80	162	52	2	2.6	5.5
NAST-3	8	3	1	13	90	152	42	2	2.2	6.3
H-2	9	3	1	39	80	164	55	2	2.6	5.6
WNG-2	10	7	3	1	30	125	20	3	2.5	5.0

Results of the analysis, as shown in detail on Figure 3-2 following, indicate an accuracy of over 99 percent with a standard error of 0.2062 and the listed residuals.

Incorporation of additional data from subsequent field work and testing will improve the reliability of prediction, although it is doubtful that the accuracy indicated for conventional operations will be maintained at the level of the preliminary analysis. In additional iterations of the analysis, it is proposed to substitute values of Young's modulus and Poisson's ratio being accumulated in the current program for the less important parameters. Current efforts to obtain data on effective or net torque for TBM's, to develop appropriate parameters for analysis of the drag cutter TBM and shield MDN's, and to confirm inferred Schmidt hardness values will be continued to provide additional variables for analysis. Analyses with complete data are scheduled for the remainder of the current program.

3.6 TRANSPORT SYSTEM SELECTION

A list of equipment capabilities, system constraints, and MDN applications which comprised this section of the annual report of the first year's program is included as Appendix E.

MULTIPLE CORRELATION COEFFICIENT..... 0.9992
F FOR ANALYSIS OF VAR. (D.F. = 8, 1) 82.4711
STANDARD ERROR OF ESTIMATE..... 0.2062

VARIABLE	REG. COEFF.	STD. ERR-COEFF.	COMPUTED T
5	-1.82976E-02	4.70338E-02	-.389031
9	-.237584	.534353	-.444621
2	.75977	.787339	.964985
7	-1.37212	.48862	-2.80816
4	-3.41264E-02	9.69424E-03	-3.52028
8	-.879842	.801093	-1.0983
3	-3.07083E-02	4.55421E-02	-.674285
6	4.07791E-02	.147084	.277251

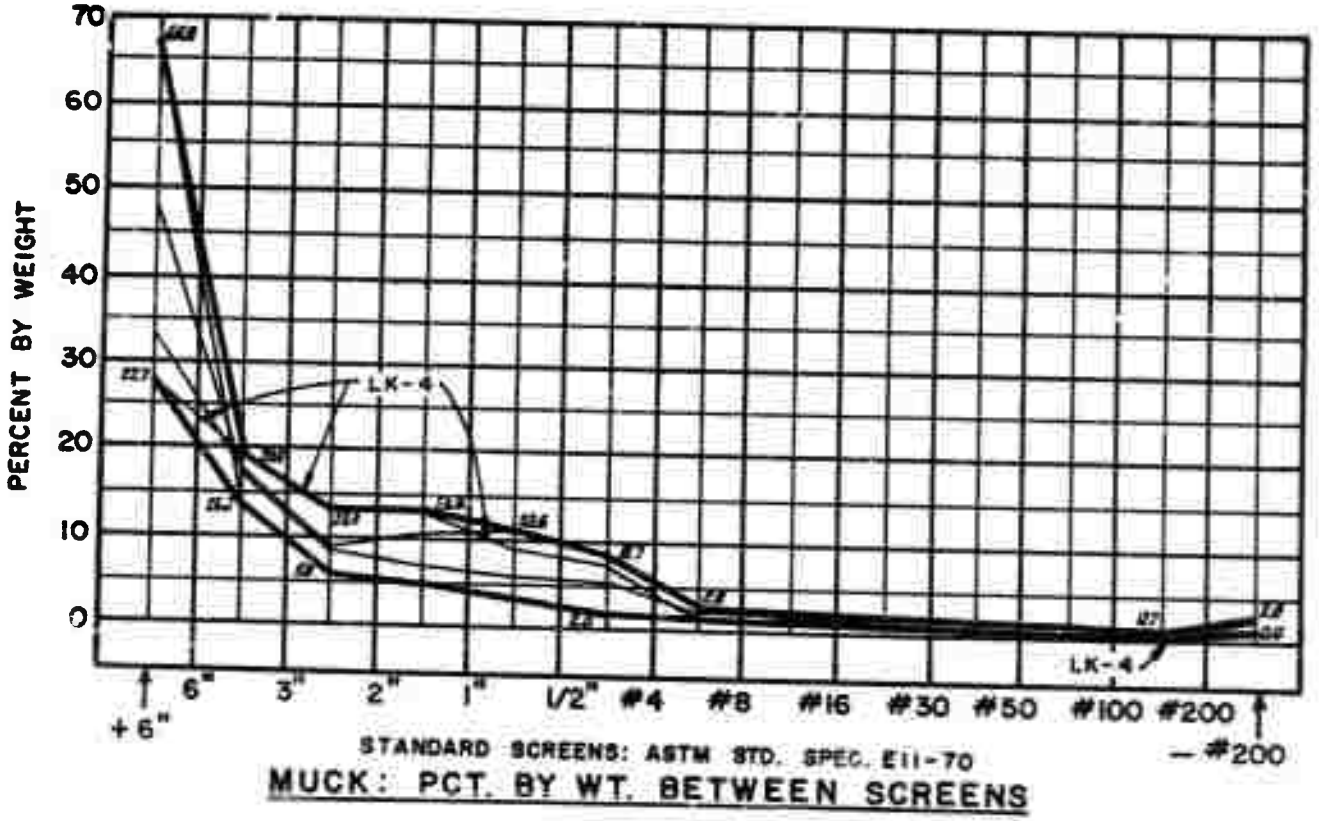
INTERCEPT(A) 15.7937

TABLE OF RESIDUALS

OBS. NO.	Y OBSERVED	Y ESTIMATED	RESIDUAL	STD. RESID.
1	1.000	1.065	-0.065	-0.318
2	1.000	0.918	0.082	0.395
3	1.000	1.069	-0.069	-0.336
4	2.000	1.954	0.046	0.221
5	3.000	3.013	-0.013	-0.065
6	3.000	2.983	0.017	0.080
7	3.000	3.115	-0.115	-0.558
8	3.000	2.978	0.022	0.109
9	3.000	2.898	0.102	0.495
10	7.000	7.005	-0.005	-0.022

COMPUTER OUTPUT-CONVENTIONAL DATA ANALYSIS.

FIGURE 3-2



ABBREVIATIONS

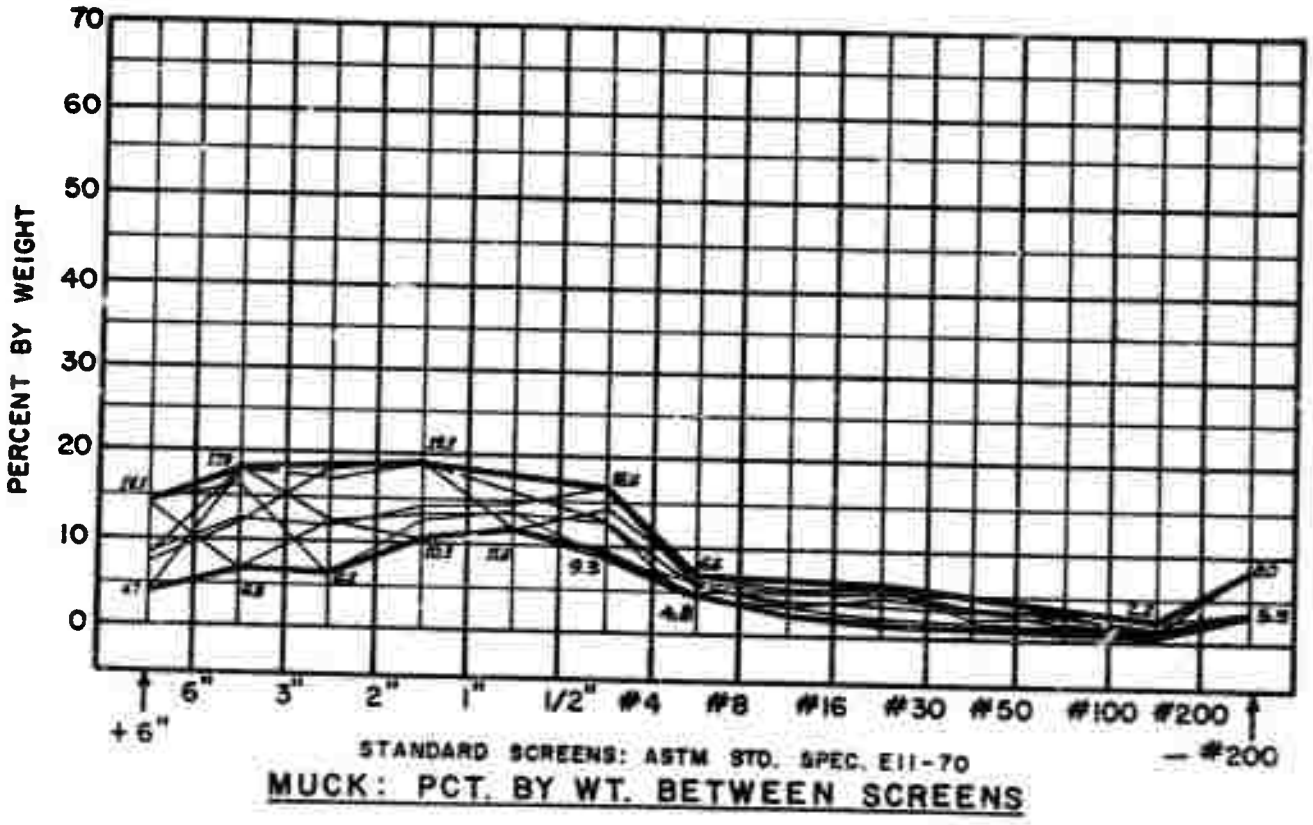
f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
LK-1	Conv	T-1	Ig=1	Qz M	Mr J	25	83	162	55	18W x 16	Dry=1	5.4	4.0	4'x 3 x 2'
LK-2	Conv	T-1	Ig=1	Qz M	Mr J	25	83	165	55	18W x 16	Dry=1	5.4	4.0	3-1/2'x 2'x 2'
LK-3	Conv	T-1	Met=2	Qe Te	L My J	26	80	178	50	16W x 14.5	Dry=1	5.0	5.0	2-1/2'x 1'x 1/2'
LK-4	Conv	T-2	Met=2	Te	My J	14	70	181	47	15W x 14	Dry=1	4.4	5.5	27"x 18"x 12"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966.

**Regression Data List.

FIGURE 3-3: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, CONVENTIONAL



ABBREVIATIONS

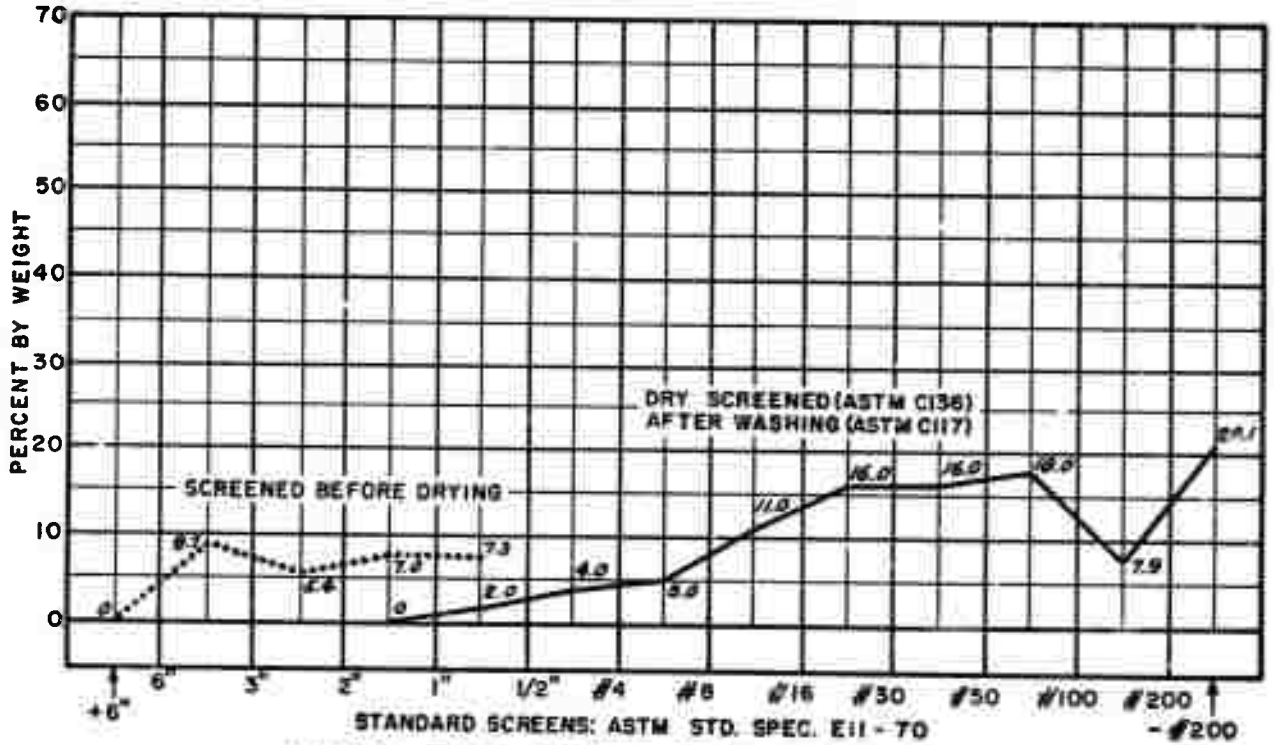
f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	CLASS	TYPE	ROCK PROPERTIES					TUNNEL		SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
					STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
GA-1	Conv	T-3	Ig=1	Gr	Mr J	35	96	161	55	10 x 10	Dry=1	2.1	6.1	2-1/2'x 2'x 1'
11-3	Conv	T-3	Sed=3	Sts Sh	Ma Mr L	22	90	152	43	24W x 7.5	Dry=1	5.1	3.5	18"x 18" x 4"
H-1	Conv	T-3	Ig=1	Gr	Mr J	32	80	162	52	10 x 10	Mr=2	2.6	5.5	3'x 2'x 1'
NAST-3	Conv	T-3	Ig=1	Gr	Mr J	13	90	152	42	16W x 10	Mr=2	2.2	6.3	2-1/2'x 1-1/2'x 1'
H-2	Conv	T-3	Ig=1	Gr Gn	Mr J	39	80	164	55	10 x 10	Mr=2	2.6	5.6	2' x 1-1/2'x 1'
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966.

**Regression Data List.

FIGURE 3-4: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-3, CONVENTIONAL



ABBREVIATIONS

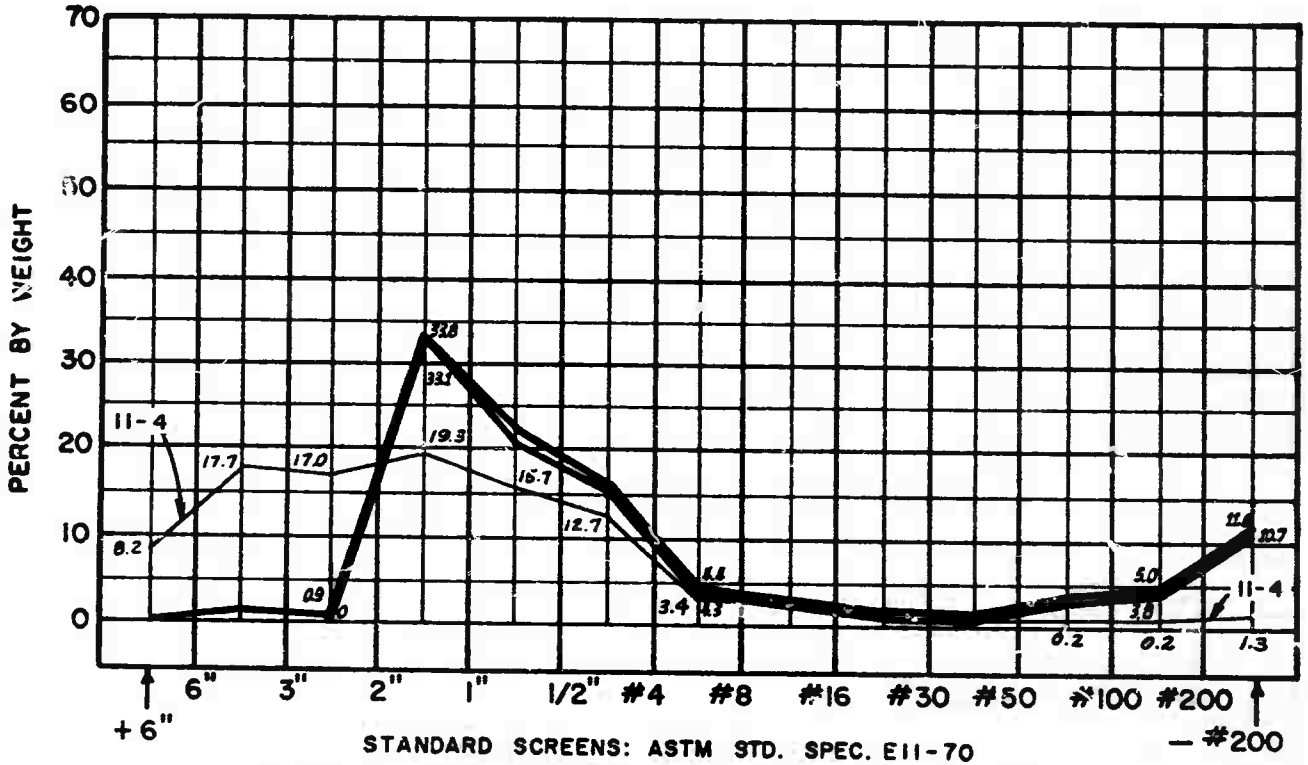
f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		SQ. FT. / HOLE	EXPL. #/CY.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
WNG-2	Conv	T-7	Sed=3	Ss	PC	1	30	125	20	5W x 9	Wet=3	2.5	5.0	18"x 10"x ·"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966.

**Regression Data List.

FIGURE 3-5: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-7, CONVENTIONAL



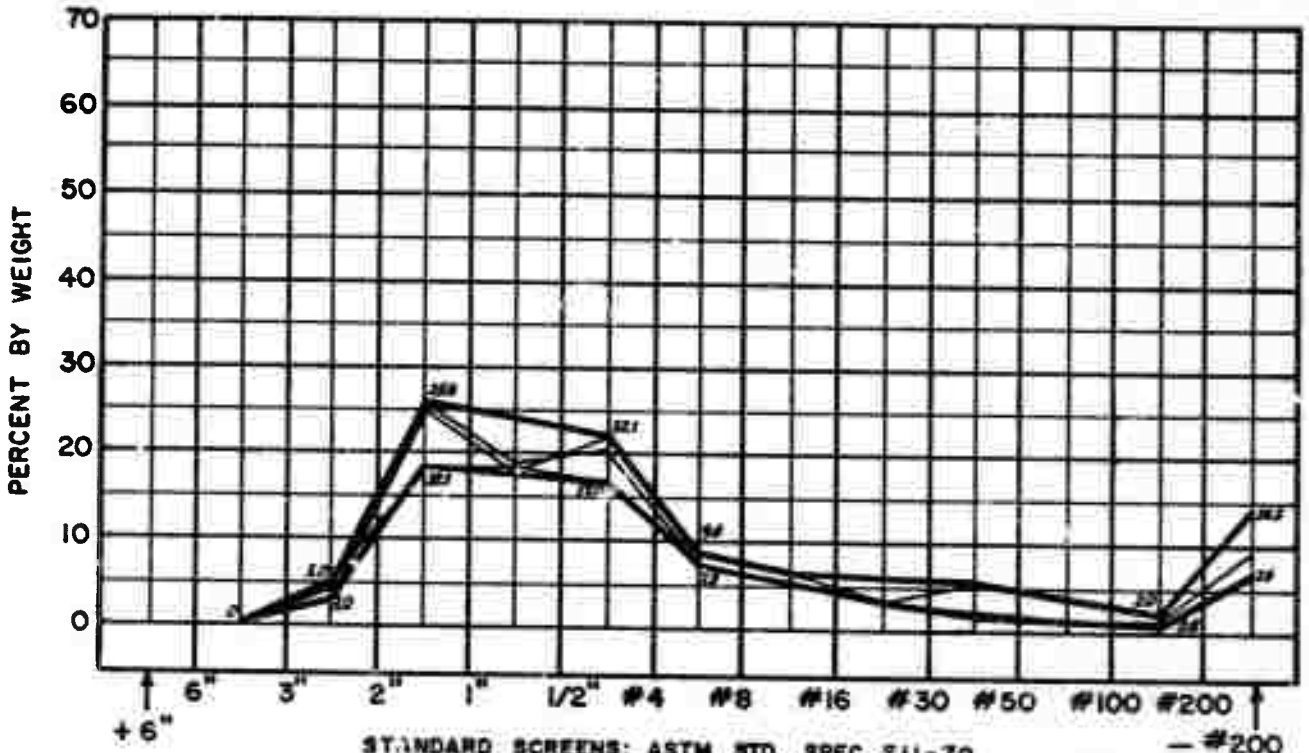
ABBREVIATIONS

f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
11-4	TBM	T-1	Sed=3	Sts Sh	Ma Mr L	22	90	166	43	18W x 8.5	Dry=1	NA	NA	8"x 8"x 4"
5-1	TBM	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1	0.20	3.56K	2-1/2"x 8"x 3/4"
7-2	TBM	T-2	Sed=3	Ss	Ma	22	92	166	49	18.08 dia.	Dry=1	0.20	2.91K	3"x 9"x 1"
COL. NO.**		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 640 610-1966. **Regression Data List.

FIGURE 3-6: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-1 AND T-2, MACHINE



MUCK: PCT. BY WT. BETWEEN SCREENS

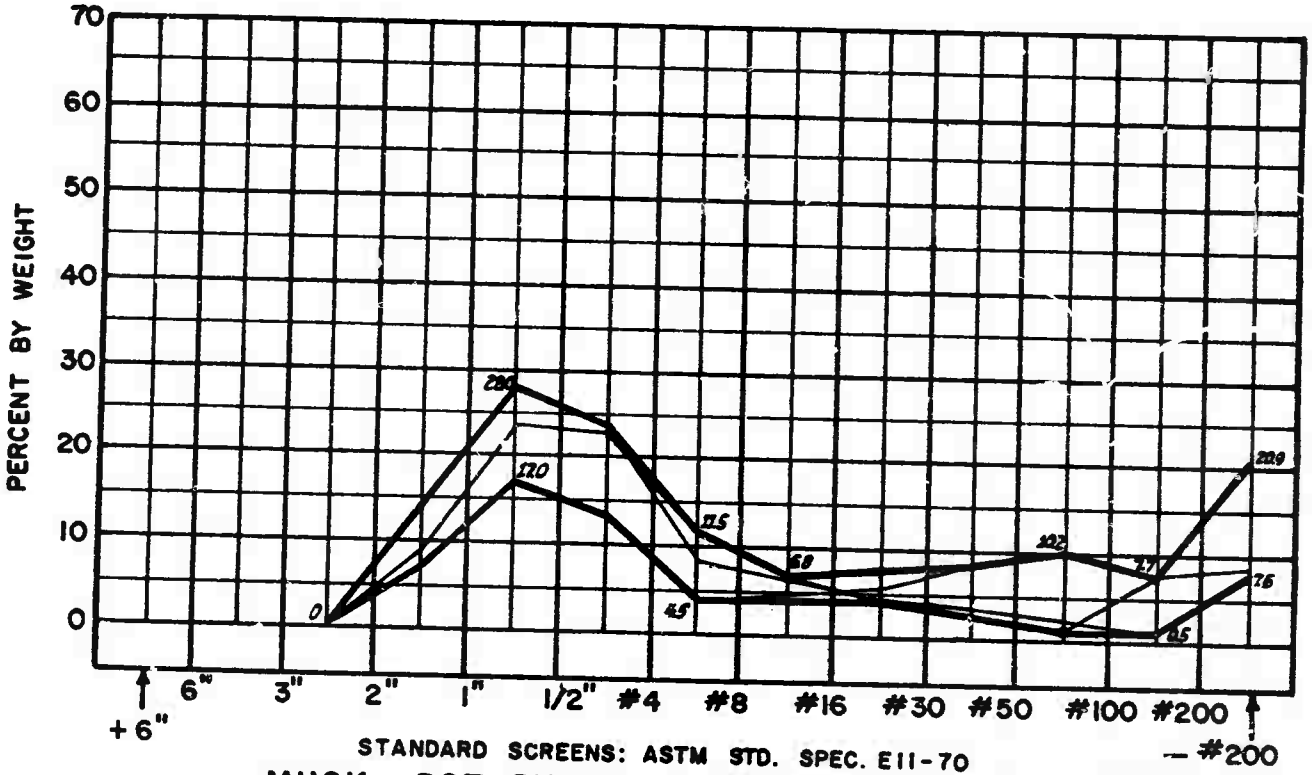
ABBREVIATIONS

f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
LAW-2	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	4.28	3"x 2"x 1/2"
LAW-3	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	4.28	3"x 2-1/2" x 1/2"
LAW-4	TBM	T-3	Sed=3	Ls	Ma	19	100	160	42	13.67 dia.	Dry=1	0.20	3.76	3-1/2"x 2-1/2" x 3/4"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966. **Regression Data List.

FIGURE 3-7: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-3, MACHINE



ABBREVIATIONS

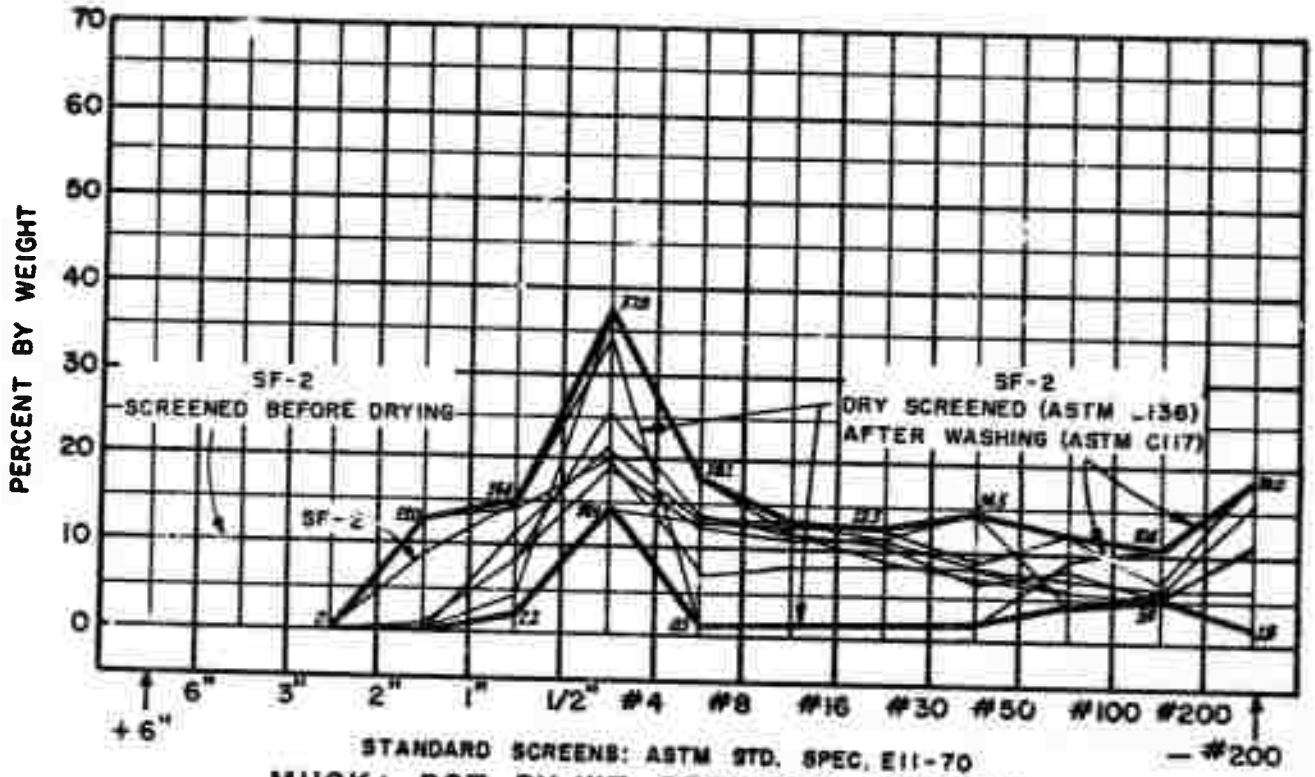
f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
M1L-1	TBM	T-4	Sed=3	Ls	My J	36	85	166	50	11.17 dia.	Mr=2	0.16	6.09	2"x 1"x 1/2"
M1L-2	TBM	T-4	Sed=3	Ls	My J	36	85	166	50	11.17 dia.	Mr=2	0.18	6.09	3"x 2"x 1/2"
QL-1	TBM	T-4	Met=2	Sch	L	11	30	165	37	11 dia.	Mr=2	0.18	3.53	2"x 1"x 1/2"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966.

**Regression Data List.

FIGURE 3-8: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-4, MACHINE



MUCK: PCT. BY WT. BETWEEN SCREENS

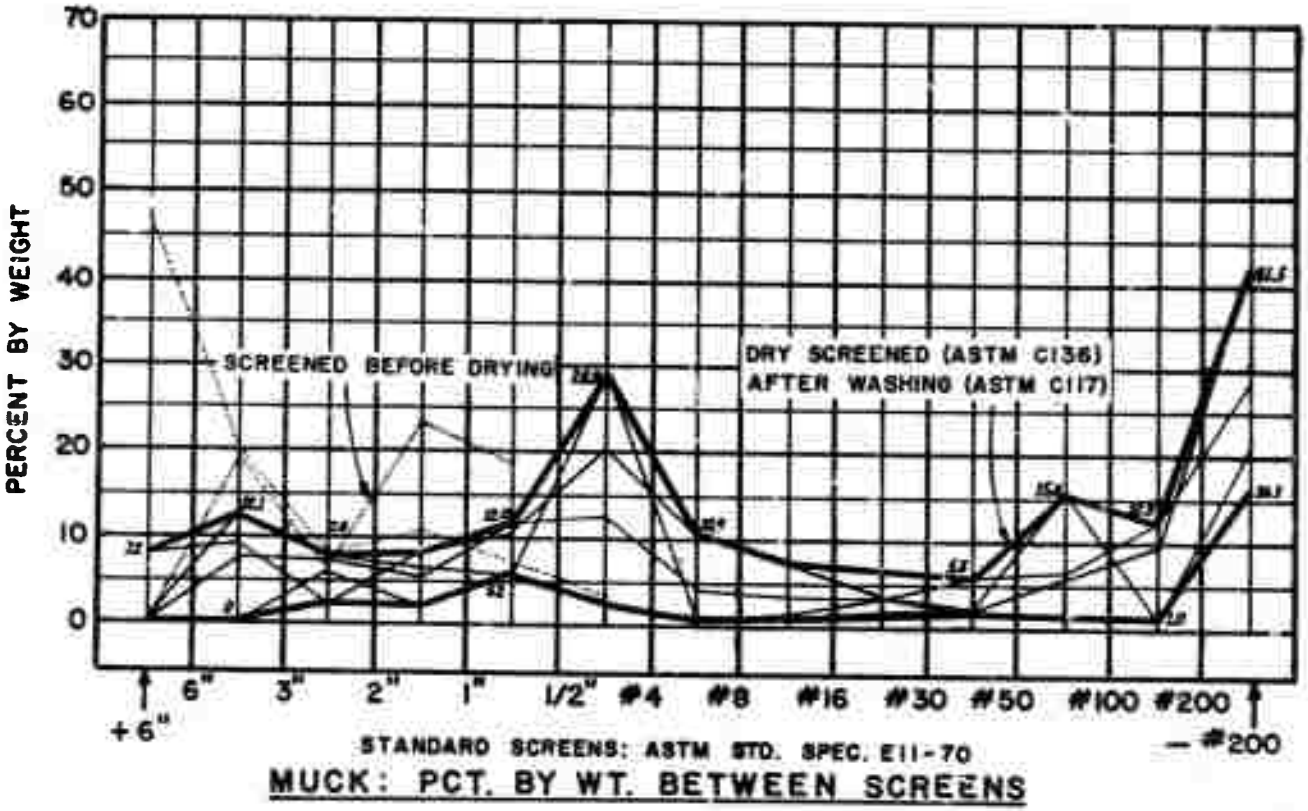
ABBREVIATIONS

f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qr	:	Quartzite
Te	:	Tactite
He	:	Hematite
Ma	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv.	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
CL-1	TBM	T-5	Met=2	Gr Gn	Hy J	9	10	174	45	13 dia.	2	0.09	5.09	1-1/2"x 2-1/2"x 3/4"
SF-2	Shld	T-5	Sed=3	Ss	PC	2	50	142	30	21 dia.	3	NA	NA	3"x 2"x 8"
NAST-2	TBM	T-5	Ig=1	Gr	My J	18	90	167	55	9.75 dia.	2	0.09	3.89	1"x 1"x 1/2"
NAST-4	TBM	T-5	Ig=1	Gr	My J	24	90	160	55	9.83 dia.	2	0.09	8.45	1-1/2"x 1"x 1/2"
LR-5	RBM	T-5	Ig=1	Qz M	My J	12	92	165	55	12 dia.	1	0.24	4.46	2-1/2"x 4"x 3/4"
LR-6	RBM	T-5	Ig=1	Qz M	Hy J	7	86	137	50	4 dia.	1	0.13	17.20	2"x 3-1/2"x 1-1/4"
NAST-1	TBM	T-5	Ig=1	Gr	My J	18	90	167	55	9.75 dia.	2	0.09	3.89	1"x 3/4"x 1/2"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966. **Regression Data List.

FIGURE 3-9: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-5, MACHINE AND SHIELD



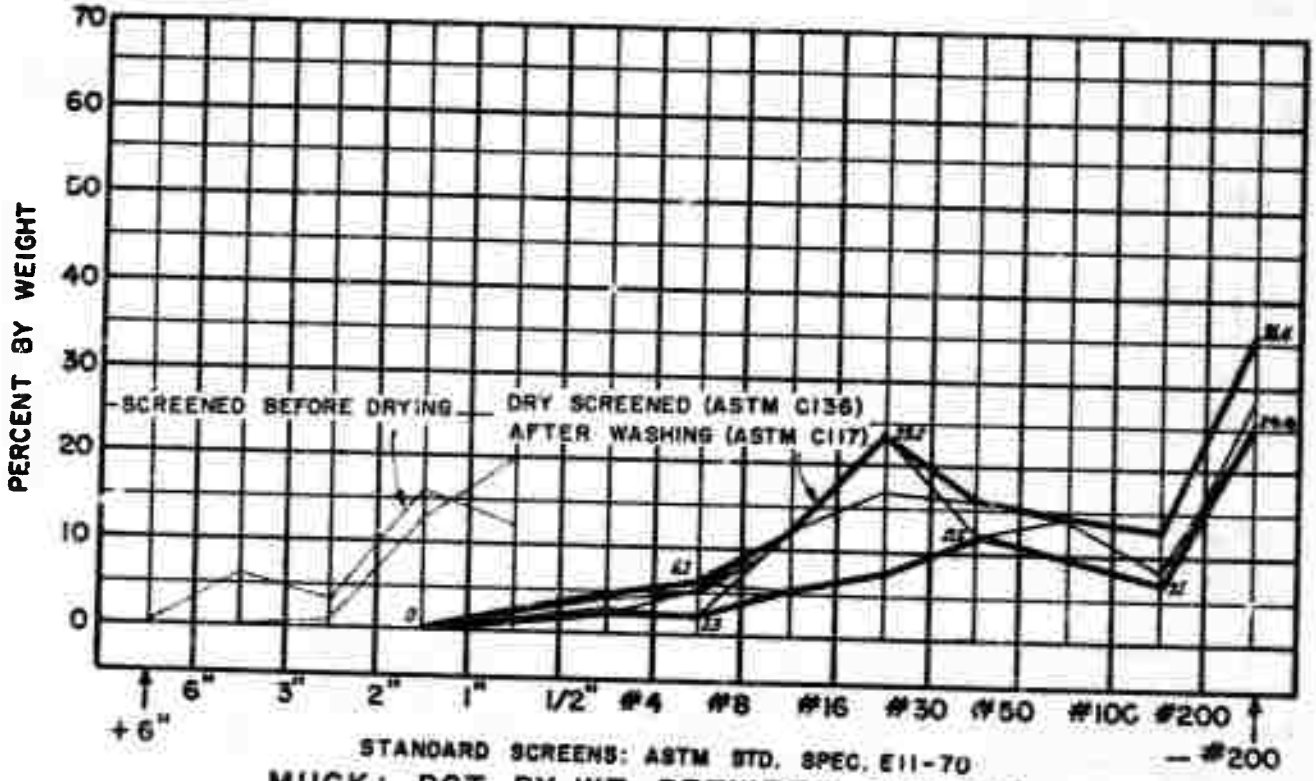
ABBREVIATIONS

f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qe	:	Quartzite
Te	:	Tactite
He	:	Hematite
Me	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv	:	Conventional
DUW	:	Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
KM-1	TBM	T-6	Sed=3	Md	Ma	11	90	144	40	10W x 9	Dry=1	NA	NA	36"x 14"x 8"
MB-1	TBM-O	T-6	Met=2	He Me	L Hy J	7	10	207	28	9.96 dia.	Dry=1	NA	NA	2'x 1-1/2'x 8"
LAY-1	TBM	T-6	Sed=3	Ss	Ma	10	84	150	47	12.92 dia.	Dry=1	0.24	2.73	4"x 4"x 1/2"
NAV-1	TBM	T-6	Sed=3	Sts	Ma	2	70	142	25	20.5 dia.	Dry=1	0.30	1.31	6"x 5"x 2"
COL. NO.**		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966. **Regression Data List.

FIGURE 3-10: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-6, MACHINE



MUCK: PCT. BY WT. BETWEEN SCREENS

APPREVIATIONS

f_c	:	Uniaxial Compressive Strength, KPSI
Ig	:	Igneous
Sed	:	Sedimentary
Met	:	Metamorphic
Gr	:	Granite
Gn	:	Gneiss
Ss	:	Sandstone
Sch	:	Schist
Sh	:	Shale
Ls	:	Limestone
Qz	:	Quartz
M	:	Monzonite
Sts	:	Siltstone
Qs	:	Quartzite
Te	:	Tectite
He	:	Hematite
Ma	:	Martite
Md	:	Mudstone
L	:	Laminated
Ma	:	Massive
J	:	Jointed
Hy	:	Highly
My	:	Moderately
Mr	:	Minor
PC	:	Poorly Cemented
O	:	Oscillator
Shld	:	Shield
Conv:		Conventional
DUW:		Dry Unit Weight, PCF
GW	:	Ground Water

IDENT. NO.	EXCAV. METHOD	MDN	ROCK PROPERTIES							TUNNEL		KERF SPACE	THRUST /SQ. FT.	MAX. SIZE OBSERVED
			CLASS	TYPE	STRUCT.	f_c	RQD	DUW	HARDNESS*	SIZE, FT.	GW			
NAV-2	TBM	T-7	Sed=3	Ss	PC	1	60	117	25	3.05 dia.	Dry=1	0.30	8.37	5"x 2"x 1"
WNG-1	TBM	T-7	Sed=3	Ss	PC	1	30	125	20	10H x 8	Wet=3	NA	NA	14"x 4"x 4"
SF-1	Shld	T-7	Sed=3	Ss	PC	1	15	113	20	21 dia.	Wet=3	NA	NA	5"x 4"x 3"
COL. NO. **		1	2			3	4	5	6		7	8	9	

*Inferred from D. U. Deere, et al, AD 646 610-1966.

**Regression Data List.

FIGURE 3-11: ROCK, TUNNEL, OPERATING, AND MUCK DATA, MDN T-7, MACHINE AND SHIELD

Belt conveyor and hydraulic transportation parameters have been studied under the current program. Standard belt conveyor design publications and available literature on hydraulic conveying were reviewed to determine the data required and the methods used in system designs.

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's are based, as well as other physical property characteristics determined in the program can be used as input for the design formulae and the models.

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. Some design parameters are not well defined in the references, and further study will be necessary to resolve differences in design philosophy which appear in the literature.

A preliminary design of a hydraulic muck disposal system based on data from a TBM tunnel is in process. Comparison between a design based on study data and an extensive suspended conveyor installation is planned. One example of MDN application to each of the other transport systems will be provided.

4. DOD IMPLICATIONS

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 as showing 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.

Current selection of transportation systems usually 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.

Previous investigations have indicated 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.

A second alternate is in providing 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 periodically. Again, muck characteristic data is a necessity to design the separation equipment and to estimate the capacity required in the secondary system.

In the course of the current program and subsequent use of the data produced, 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 will be identified as attractive areas for research.

In summary, the current MDN program provides the basic data required for a rational, engineering approach to problem solutions in a most important subsystem of the rapid excavation process. It will show examples of data application and should be used 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

At the end of the current contract, it is expected that the following samples will have been collected, including 19 in 1972 and 1 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 Machine	0	0	0	0	2	2
Drag Cutters	0	1	1	2	1	5
Disc Cutters	2	7	5	1	0	15
Roller Cutters	0	4	1	0	0	5
Combination Cutters	0	3	1	1	2	7

At completion, the current program will have produced samples from 11 operations and/or formations which have not been sampled previously and which will be available for additional field work. 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, such as the fine grained igneous and volcanic rocks.

Statistically, the number of samples used in developing a predictor equation should be greater than the number of the variables used in the analysis. Because the reliability of prediction is of major importance, additional samples should be obtained in 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 enough data to analyze this method by a separate regression.

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.

5.2 PHYSICAL TESTING

Although problems have been encountered in obtaining consistent results from Schmidt hardness tests on core samples, development of test methods should continue because it is the only fast and inexpensive known test to measure the property of rocks.

Abrasiveness testing should be initiated as soon as possible and continued within the limit of available funds to provide data for the 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's.

5.3 INNOVATIVE TECHNIQUES

Unusual rock breaking techniques now under development, such as the electron beam, the water cannon, the conical borer, and continuous application of explosives may become standard practice in the future. Sampling muck from tests of these methods whenever possible 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

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
Lakeshore Mine Casa Grande, Arizona	Hecla Mining Co. El Paso Natural Gas	14'x14' 14'x18' Plus Level Development	7,500'	Hecla Mining Company Own Force

The two 7,500' headings, declines at a minus 15°, are nearing completion. Levels are being developed at 900' and 1,400' vertically below the portal. Formations include mylonite, quartzite, tactite, and quartz monzonite. A raise boring machine has started a series of holes to the development levels.

Superior Mine Superior, Arizona	Magma Copper Company	10'x10'	Various	Own Force

Drifting on five levels to connect existing workings with a new shaft, now within 300' of completion at 4,200' depth. Formations are cretaceous conglomerate 7K to 10K psi, limestone 7K psi, quartzite to 20K psi. Operations are conventional.

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' depth. A 9,000' drift is planned to explore a new ore body from the bottom level of the new shaft.

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
Hunter Tunnel Fryingpan Project Merideth, Colorado	U.S. Bureau of Reclamation Denver, Colorado	10'x10'	4.4 Miles	Granite Construction Company

A conventional operation in formations similar to the Nast tunnel. Lithologic and engineering property data have been collected from the U. S. Bureau of Reclamation. Excavation is scheduled for completion in October, 1972.

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 18K to 24K psi. Rock is highly sheared in zones from a few feet to 400' thick.

Foggy Bottom Rosslyn Tunnel Section C-4 Washington, D.C.	WMATA Washington, D. C.	16'8" Diameter Finished	4,000' Each of Two Bores	Shea-Ball-S&M Construction J. V.

Excavation by conventional methods in gneiss under the Potomac River. The schistose rock structure is reported to result in high shear strength and low compressive strength. Lithologic and engineering property data has been collected from the WMATA.

Crescent Mine Osburne, Idaho	Bunker Hill Company Kellogg, Idaho	10'x10'	Various	Own Force

Conventional drifting on several levels. Trackless equipment is used on the lowest level, at 6,100' depth in quartzite, from which a lower level will be developed by a decline. The USBM Spokane Mining Research Center has collected voluminous rock property data at this site.

Project and Location	Owner or Agency	Size	Length	Contractor
Star Mine Burke, Idaho	Hecla Mining Company, Wallace, Idaho	9'x10'	Various	Own Force

Conventional drifting on several levels. Rail mounted equipment is in use on the lowest level, at 7,094' depth, in quartzite.

Mt. Greenwood Tunnel Chicago, Illinois	Dept. of Public Works, City of Chicago, Illinois	10'4" Diameter	1.8 Miles	S. A. Healy Construction Company

A Robbins machine has finished Mt. Greenwood No. 1. Preparations are in progress to start Mt. Greenwood No. 2 in limestone, reported similar to that in the Mt. Greenwood No. 1. Geologic and rock data has been collected from the owner agency.

White Pine Copper Company White Pine, Michigan	Copper Range Company New York, New York	18'1" Diameter 18'x8-1/2' Rectangular	Various	Tunneling by White Pine With Own Force

A Robbins machine, operating in sandstone since 1969, has passed through a conglomerate horizon into the overlying shale. An Atlas-Copco machine is operating in the shale. Normal drifting is conventional. Existing rock property data includes compression, Brazilian tensile, and Shore hardness test results.

Nevada Test Site Mercury, Nevada	USAEC and Defense Atomic Support Agency (DASA) Mercury, Nevada	Various	Various	Reynolds Electrical and Engineering Company

Conventional and Alpine Miner tunnels may provide an opportunity for comparison of the muck produced by the two systems. Formations are volcanic tuffs which vary from 600 to 4,500 psi in unconfined compressive strength. Engineering property data has been collected by the U. S. Geological Survey and by DASA.

Project and Location	Owner or Agency	Size	Length	Contractor
Navajo Irrigation Project Farmington, New Mexico	U.S. Bureau of Reclamation Denver, Colorado	20.5' Diameter	3 Miles	Fluor-Utah Engineering & Construction Company

A Dresser boring machine is operating in sandstone with an unconfined compressive strength of less than 1K psi, and is expected to reach a 9.7K psi sandstone as the tunnel advances. Completion is scheduled for November, 1972.

Section 35 Uranium Mine Grants (Ambrosia Lake), New Mexico	Kerr-McGee Corporation	10'x10' and 8'x8'	Various	Kerr-McGee Own Force

An Alpine Miner is operating in sandstone development headings, in which normal operations are conventional.

Kermac Potash Carlsbad, New Mexico	Kerr-McGee Corporation	13'x5'	Various	Own Force

Goodman continuous miners are operating in salt-potash formations reported from 3K to 6K psi in strength.

Cross-Irondequoit Interceptor Tunnel, Rochester, New York	Dept. of Public Works, Rochester, New York	18'4" Diameter	5-1/2 Miles	Tunnel Constructors (Greenfield-Ferrera-S.A. Healy, J. V.)

A Lawrence TBM is operating in formations reported as shale, limestone, and sandstone, compressive strengths 2K to 20K psi. Geologic and rock data has been collected from the owner agency.

Project and Location	Owner or Agency	Size	Length	Contractor
New York City, New York Contract #13	Dept. of Public Works, New York, New York	11'6" and 8'6"	9,200'	Perini-B&R-G.H. Ball-S&M Constructors, J. V.

Two Jarva TBM's are operating in mica schist, with compressive strength reported 15K to 30K psi. Cores and rock test data are available from the owner.

Homestake Mine, Lead, South Dakota	Homestake Mining Company	7-1/2'x 8-1/2'	Various	Own Force

Conventional main level development drifting at 150' vertical intervals to 7,100' depth in phyllites, quartz mica schists, quartzites, carbonates and silicates, ranging in strength from 5K to 40K psi.

Cross Town Wastewater Interceptor Austin, Texas	City of Austin, Texas	9' Diameter	27,300'	Granite Constr. Co.
		10' Diameter	30,500'	Peter Kiewit & Sons Company

A Calweld machine will bore 30,500' in clays and limestones. A Robbins machine will bore 27,300' in limestones. Geologic and test data has been provided by the City of Austin.

Currant and Layout Tunnels Strawberry Aqueduct Heber City, Utah	U.S. Bureau of Reclamation Denver, Colorado	10'4" Diameter	Combined Length 4.9 Miles	S. A. Healy Construction Company

The Layout tunnel has been completed. A Robbins boring machine has started the Currant tunnel in conglomerate. Existing logs of drill holes show lithology. Compressive strength test results, from 14K psi to over 38K psi in the conglomerate, have been provided by the Bureau of Reclamation.

Project and Location	Owner or Agency	Size	Length	Contractor
Golden Goose II Uranium Mine Jeffrey City, Wyoming	Western Nuclear, Inc.	8' x 10'	Develop-ment Drifts	Owner Operated

An Alpine Miner equipped with a Serpentix conveyor is driving mining headings in soft sandstone. Conventional drifts are also being driven in similar formations.

Mathe~ "B" Mine	Cleveland Cliffs Iron Company Ishpeming, Michigan	10' x 10'	Various	Own Force

Conventional timbered and untimbered development drifting on the 12th level in graywacke at 3,480' depth, conventional and Alpine Miner stope development in iron formation and ore above main levels.

APPENDIX B

RAW DATA SHEETS

APPENDIX B

RAW DATA SHEETS

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST.	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
1	NAST SAMPLE NO NAST-1	IGNEOUS: GRANITE, GRAY, MEDIUM TO FINE GRAINED, MODERATELY TO SLIGHTLY FRACTURED AND JOINTED 10 TO 20 PCT QUARTZ, 50 TO 60 PCT FELDSPAR, BALANCE DARK MINERALS.	167	18	90	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.065 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.185IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	14.50	14.00	13.50	0.50	3.0	0.16

(-) 0.50IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-) 0.50 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 9.0 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 9.0 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 9.0 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)0.185 IN. ANGLE INTER FRICTION DEGREES AT 8.5 PCT MOIST
2.69	37	36	41	NA	NA	42

NAST-1 CURRENT: 1 SEPT. 1972

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 9IN	ROUND	+0.22PCT	10K		X	221N		5-20	6IN	21N	61N	4160V	480V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL, 361N GAGE, 70LB RAIL, 16 CY CARS MOTOR 12 TON	RAIL	RAIL	4-11N X 7FT GROUTED	13IN X 10FT 16 GAGE	4IN RING AND HALF SETS 4FT, 3FT, AND 2FT IN BAD 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	
WIRTH ERKELENZ	HARDROCK	67 TONS	2 HUGHES/WIRTH TCB 11.5IN ROLLER 2-TCH 11.5IN TCB CONE	15 HUGHES/WIRTH TCB 11.5IN ROLLER	6 HUGHES/WIRTH TCB 11.5IN TCB ROLLER	8.5 INTEG	KFTLB 150 KFTLB 110	KFTLB KFTLB	KLB KLB 290

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET FROM FACE, 221N CONVEYOR TO REAR	HYDRAULIC, POWERED BY 3-200HP MOTORS	LASER	KLB 3.89

CONVENTIONAL EXCAVATION

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

NAST-1 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
2	NAST SAMPLE NO NAST-2	IGNEOUS: GRANITE, GRAY, MEDIUM TO FINE GRAINED, MODERATELY TO SLIGHTLY FRACTURED AND JOINTED 10 TO 20 PCT QUARTZ 50 TO 60 PCT FELDSPAR HALANCE DARK MENERALS.	167	18	90	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
76	I0.8	0.0	0.0	0.0	0.8	8.0	25.0	I3.8	II.5	I0.3	6.6	7.7	5.5		I0.8

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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I9.5	I8.2	I7.9	I.3	4.6	0.28

(-) 0.50IN.SIZE SPECIF GRAVITY	ANGLE/REPOSE I IN DROP DEGREES AT 8.7 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 8.7 PCT MDIST	MATERIAL SIZE(-) 1.0 IN. ANGLE/SLIDE STEEL PLATE DEGREES AT 8.7 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)I.0 IN. ANGLE INTER FRICTION DEGREES AT 8.5 PCT MOIST
2.66	38	38	49	NA	NA	3I

NAST-2 CURRENT: I SEPT. 1972

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 9IN	ROUND	+0.22PCT	10K		X	22IN		5-20	6IN	2IN	6IN	4160V	480V

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

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 ERKELENZ	HARDROCK	67 TONS	2 HUGHES/WIRTH TCB 11.5IN ROLLER, 2-TCB 11.5IN CONE	15 HUGHES/WIRTH. TCB 11.5IN ROLLER	6 HUGHES/WIRTH TCB 11.5IN TCB ROLLER	8.5 INTEG	KFTLB 150 KFTLB 110	KFTLB KFTLB	KLB KLB 290

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 22IN CONVEYOR TO REAR	HYDRAULIC, POWERED BY 3-200HP MOTORS	LASER	KLB 3.89

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
3	NAST SAMPLE NO NAST-3	IGNEOUS: BIOTITIC GRANITE FINE GRAINED, MAJOR QUARTZ, MINOR FELDSPAR AND DARK MINERAL CONTENT.	I52	I3	90	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	1/2IN.	ND4	NO8	ND16	ND30	ND50	NDI00	ND200	PCT (-) NO200
II7	3.4	I4.5	I6.2	6.2	I2.6	I3.7	8.9	5.8	5.3	6.I	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	AI

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I9.50	I7.4I	I7.I3	2.03	4.I0	0.5I

(-) 0.75IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 2.8 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 2.8 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 2.8 PCT MOIST	APPARENT COHESION PSF AT 3.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST
2.65	39	36	3I	80	9I.2	38

NAST-3 CURRENT: 1 SEPT. 1972

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 16FT X8FT	ALCOVE	0.0	10K		X	22IN		5-10	6IN	2IN	4IN	NA	

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

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
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 2-55JF	DEPTH 9FT	TOTAL LBS 300 GELEX 2, 60PCT	0-7 REGULAR	FRONT END	
	DIAM. 1-3/4IN	PRIMERS,	DELAYS	LOADER	
FEED LENGTH 4FT	CUT, DOUBLE V	TRIM			
		INTERIOR			
	SF/HOLE 2.2	CUT			
		LIFTERS			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
4	NAST SAMPLE NO NAST-4	IGNEOUS, GRANITE, FINE GRAINED MODERATELY FRACTURED, MAJOR QUARTZ AND MINOR FELDSPAR CONTENTS.	160	24	90	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	19.20	18.97	17.50	0.23	3.40	0.06

(-) 0.75IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 6.9 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 6.9 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 6.9 PCT MOIST	APPARENT COHESION PSF AT 7.1 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 7.1 PCT MOIST
2.64	39	34	40	0	91	33

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 10IN	ROUND	+0.22PCT	10K	X	22IN		5-20	6IN	2IN	6IN	4160V	480V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL, 36IN GAGE, 70LB RAIL, 16 CY CARS MOTOR 12 TONS	RAIL	RAIL	4-11IN X 7FT GROUTED APPROX. 1200FT	13IN X 10FT 16 GAGE	4IN RING AND HALF SETS, 4FT, 3FT, AND 2FT IN BAD GROUND APPROX. 650FT	

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 ERKELENZ HUGHES HEAD	HARDROCK	67 TONS	2 HUGHES TCB 11.5IN ROLLER, 2-11.5IN CONE	19 HUGHES TCB 11.5IN ROLLER	6 HUGHES TCB 11.5IN ROLLER	8.5 INTEG	KFTL8 150 KFTL8125	KFTL8 KFTL8	KL8 KL8 630

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KL8	BUCKET FROM FACE, 22FT CONVEYOR TO REAR	HYDRAULIC POWERED BY 3-200HP MOTORS	LASER	KL8 8.45

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
5	GRANITE ADIT	IGNEOUS: GRANITE, MASSIVE, MAJOR QUARTZ AND FELDSPAR, MINOR DARK MINERAL CONTENT.						
	SAMPLE NO GA-I		161	35	96	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) 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	AI

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	16.2	15.78	13.67	0.42	3.00	0.14

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 0.9 PCT MOIST	ANGLE/REPOSE IO IN DROP DEGREES AT 0.9 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST	APPARENT COHESION PSF AT 0.9 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.9 PCT MOIST
2.59	39	36	34	215	106	46

GA-I CURRENT: I SEPT. 1972

KEY

SA
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 10FT	HORSESHOE	-0.22PCT	AK		X	22IN			6IN	2IN			110V

HAULAGE SYSTEM				SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
EIMCO 912 LHD DIESEL	NONE	EIMCO 912 LHD DIESEL	1IN X 7FT GROUTED APPROX 35FT		4IN WF STEEL SETS AT 4FT, APPROX. 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/50 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	
FEED LENGTH 10FT	CUT, DOUBLE V	TRIM			
	SF/HOLE 2.1	INTERIOR			
		CUT			
		LIFTERS			

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
6	HUNTER SAMPLE NO H-1	IGNEOUS: GRANITE. GRAY. FINE GRAINED, MODERATELY JOINTED, WITH 1.5 TO 2 FT BANDS OF LIGHT TAN PEGMATITE AND LAMINATED GRANITIC GNEISS.	163	32	80	NA	NA	NA

MUCK DATA

ORY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
107	3.4	I4.3	6.8	I2.7	I3.2	I3.6	I2.9	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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I8.0	I7.0	13.4	1.0	4.6	0.23

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 1.3 PCT MOIST	ANGLE/REPOSE 10' IN DROP DEGREES AT I.3 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 1.3 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.2 PCT MOIST
2.70	40	37	32	NA	NA	44

H-1 CURRENT: 1 SEPT. 1972

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 10FT	HORSESHOE MODIFIED	+0.25PCT	15K		X	26IN	125	20-400	8IN	4IN	10IN	4160V	440V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL, 36IN GAGE 75LB RAIL, 4.8 CY CARS, 15TON LOCOMOTIVE	RAIL	RAIL	11IN X 7FT GROUTED 17PCT		4IN WF SETS, 4FT, 3FT, 2FT FOR 23PCT	500PSI 18 HRS 3750PSI 28 DAYS 16 PCT OF 7200 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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND,	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO 4 BOOM HYDROJIB MACHINES 4-CF99 1-CF133	NO. HOLES 38 DEPTH 10.5FT DIAM. 1-3/4IN CUT, SPIRAL BURN 5IN CENTER HOLE	POWDER FACTOR 5.5LB/CY TOTAL LBS 200 PRIMERS, GELEX 2-I 1/2 IN TRIM 20LB SMOOTHTEX 70PCT X 7/8IN INTERIOR GELEX 2-I 1/2 IN CUT GELEX 2-1 1/2 IN LIFTERS GELEX 2-I 1/2 IN-	ELECTRICAL 0-10 REGULAR DELAYS	EIMCO N025 RAIL, AIR OPERATED	LASER
FEED LENGTH 12FT	SF/HOLE 2.6				

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARONESS SHORE	HARONESS MOH	HARONESS SCHMIDT
7	HUNTER SAMPLE NO H-2	IGNEOUS: GRANITE GRAY, GNEISSIC, MODERATELY JOINTED.	164	39	80	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
I09	3.4	7.3	II.7	I8.2	I9.3	II.6	9.3	4.8	4.2	4.5	3.4	I.3	I.I		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	AI

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I8.I0	I7.95	II.00	0.I5	3.20	0.04

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 3.8 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.8 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.8 PCT MOIST	APPARENT COHESION PSF AT 2.6 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.00 IN. ANGLE INTER FRICTION DEGREES AT 2.6 PCT MOIST
2.60	3P	35	38	30	I05	44

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

MUCK	PERSONNEL	SUPPLY
RAIL, 36IN GAGE 75LB RAIL, 4.8 CY CARS, 15TON LOCOMOTIVE	RAIL	RAIL

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
MINOR ROCK BOLT 1IN X 7FT GROUTED			

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	KFTLB KFTLB	KLB KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUMBO 4 BOOM HYDROJIB MACHINES 4-CF99 1-CF133	NO. HOLES 36-40 DEPTH 11FT DIAM. 1-3/4IN CUT, SPIRAL BURN 5IN CENTER HOLE	POWDER FACTOR 5.6LB/CY TOTAL LBS 225 PRIMERS, GELEX 2 TRIM 25LB 30PCT OUPONT 7/8IN X 24IN INTERIOR GELEX 2 CUT GELEX 2 LIFTERS GELEX 2	ELECTRICAL 0-10 REGULAR DELAYS	EIMCO NO25 RAIL, AIR OPERATED	LASER
FEED LENGTH 12FT	SF/HOLE 2.6				

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
8	LK SAMPLE NO LK-1	IGNEOUS, BIOTITIC QUARTZ MONZONITE. FINE TO MEDIUM GRAINED PORPHYRY.	I62	2S	83	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	ND30	NO50	NOI00	NO200	PCT (-) NO200
I02	0.4	66.8	I3.8	5.9	5.0	3.8	2.0	0.7	0.5	0.4	0.3	0.3	0.I		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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I8.I0	I7.98	I7.69	0.I2	3.90	0.30

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 0.8 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 0.8 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.8 PCT MOIST	APPARENT COHESION PSF AT 0.4 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.4 PCT MOIST
2.85	33	30	29	435	97.3	43

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 16FT	ARCHED BACK	+5.5PCT	76K	HEAD	SURF	48IN	150	NONE	6IN	2IN		4160V	220V

HAULAGE SYSTEM			SUPPORT SYSTEM				
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE	
WAGNER ST-8 SCOOPTRAM, RAIL SKIP	DIESEL TRUCK	DIESEL TRUCK	3/4IN X 6FT, AT 4FT	I3.5IN X 9FT			

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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES,	BLASTING	MUCKING	GUIDANCE
JUMBO 3 BOOM MACHINES GARDNER DENVER I-PRI23 2-DHI23 DRIFTER FEED LENGTH 12FT	NO. HOLES 47 DEPTH 10.5FT DIAM. I-3/4IN CUT, 6 HOLE BURN I-4IN CNTR HOLE SF/HOLE 5.4	POWDER FACTOR 4.0 LB/CY TOTAL LBS 365 PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT TRIM 25LB 7/8IN X 16IN, 30PCT INTERIOR ANFO CUT 40LB 1.5IN X 16IN, 45PCT LIFTERS ANFO	ELECTRICAL 0-15 REGULAR DELAYS	SCOOPTRAM	LASER

LK-1 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
9	LK SAMPLE NO LK-2	IGNEOUS: BIOTITIC QUARTZ MONZONITE, FINE TO MEDIUM GRAINED PORPHYRY, WITH MINOR STEEPLY INCLINED JOINTS.	165	28	83	NA	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
103	I.6	49.I	16.9	8.7	5.8	5.S	S.3	2.0	1.8	1.3	1.0	0.8	0.5		I.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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	20.50	I9.I4	17.29	0.36	6.2	0.058

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 4.7 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 4.7 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 4.7 PCT MOIST	APPARENT COHESION PSF AT 4.9 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 4.9 PCT MOIST
2.73	43	42	33	210	97.6	39

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 16FT	ARCHED BACK	+2.0PCT	22K	HEAD	SURF	48IN	150	NONE	6IN	2IN		4160V	220V

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
WAGNER ST-8	DIESEL	DIESEL
SCOOPTRAM, RAIL SKIP	TRUCK	TRUCK

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
3/4IN X 6FT AT 4FT	13.5IN X 9FT		

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	KFTLB KFTLB	KLB KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO 3 BOOM
MACHINES GAPONEM DENVER
3-PR123 DRIFTER

FEED LENGTH 12FT

ROUND,
NO. HOLES 47
DEPTH 10.5FT
DIAM, 1-3/4IN
CUT, 6 HOLE BURN
1-4IN CNTR HOLE
SF/HOLE 5.4

EXPLOSIVES,
POWDER FACTOR 4LB/CY
TOTAL LBS 365
PRIMERS, 25LB 1.5IN X 8IN, 60-75PCT
TRIM 25LB 7/8IN X 16IN, 30PCT
INTERIOR ANFO
CUT 40LB 1.5IN X 16IN, 45PCT
LIFTERS ANFO

BLASTING	MUCKING	GUIDANCE
ELECTRICAL 0-15 REGULAR DELAYS	SCOOPTRAM	LASER

LK-2 CURRENT: 09/01/72

KEY ID	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
LK	SAMPLE NO LK-S	IGNEOUS: BIOTITIC QUARTZ MONZONITE, FINE TO MEDIUM GRAINED PORPHYRY	I6S	32	92	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
94	16.8	0.0	0.0	0.0	I3.0	I4.0	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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	25.00	20.95	19.68	4.05	5.50	0.73

(-)0.056IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 3.4 PCT MOIST	ANGLE/REPOSE IO IN DROP DEGREES AT 3.4 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.4 PCT MOIST	APPARENT COHESION PSF AT 3.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST
2.67	33	32	38	75	100	37

LK-5 CURRENT: 1 SEPT. 1972

KEY

10A
TUNNEL DATA

TUNNEL

SIZE	SHAPE	GRADE
12FT	ROUND	VERT
13-7/8IN	PILOTHOLE	

VENTILATION

CFM	PRESS	EXHST	SIZE	HP
NONE		NONE		

WATER INFLOW

GPM
NONE

UTILITY LINES

AIR	WATER	PUMP
	NA	

POWER SYSTEM

PRIMARY	SECONDARY
	440V

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
WAGNER ST-8	DIESEL	DIESEL
SCOOPTRAM	TRUCK	TRUCK
RAIL SKIP		

SUPPORT SYSTEM

BOLT•TYPE SIZE	ROOF PLATE
NONE	

SET•SIZE•SHAPE
NONE

SHOTCRETE

MACHINE EXCAVATION

MACHINE

MAKE	MODEL	WT
ROBBINS	MBIR RAISE DRILL	49 TONS

CUTTERS•MAKE•TYPE•DIAM•CUTTING EDGES

CENTER	INTERIOR	GAGE
1 ROBBINS• 11IN STL DISC•2-11IN	19 ROBBINS 12IN STEEL DISC•2-II IN TWIN STEEL DISC	3 ROBBINS• 12IN STEEL DISC

RPM

HEAD•CENTER INTER
6

TORQUE•MAX/OPERATE

HEAD	CENTER
KFTLB 583	KFTLB
KFTLB 266	KFTLB

THRUST•MAX/OPERATE

KLB 814
KLB 490-510

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	GRAVITY	ELECTRIC MOTORS 3-100 HP	SURVEY IN PILOT HOLES	KLB 4.46

CONVENTIONAL EXCAVATION

MACHINE
JUMBO
MACHINES

FEED LENGTH

ROUND•
NO. HOLES
DEPTH
DIAM.
CUT•

EXPLOSIVES•
POWDER FACTOR
TOTAL LBS
PRIMERS•
TRIM
INTERIOR
CUT
LIFTERS

BLASTING

MUCKING

GUIDANCE

LK-5

CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI EST	ROD PCT EST	HARONESS SHORE	HARONESS MOH	HARONESS SCHMIOT
II	LK SAMPLE NO LK-6	IGNEOUS: BIOTITIC QUARTZ MONZONITE. FINE TO MEDIUM GRAINED PORPHYRY. FREQUENT FLAT ANGLED JOINTS.	I37	7 TEST SPECIMENS BROKE ALONG JOINTS DURING PREPARATION.	86	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NO100	NO200	PCT (-) NO200
90	I6.8	0.0	0.0	0.0	I.0	9.0	I9.0	I2.0	II.0	II.0	8.0	7.0	6.0		I6.0

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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I9.40	I8.I6	I7.27	I.24	4.00	0.3I

(-) 0.75IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-) 2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 3.7 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 3.7 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.7 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
2.53	30	29	32	0	I.1	40

LK-6 CURRENT: 1 SEPT. 1972

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	H81R RAISE DRILL	49 TONS	1 ROBBINS 121N STEEL DISC	4 ROBBINS 121N TWIN STEEL DISCS	1 ROBBINS 121N TWIN STEEL DISCS	6 INTEG	KFTLB 583 KFTLB 260	KFTLB KFTLB	KLB KLB 220

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	GRAVITY	ELECTRIC MOTORS 3-100 HP	SURVEY IN PILOT HOLE	KLB 17.2

CONVENTIONAL EXCAVATION

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

LK-6 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
12	LK SAMPLE NO LK-7	IGNEOUS: QUARTZ MONZONITE PORPHYRY: INTENSELY ALTERED COUPSE GRAINED	158	7	35			NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
107	8.7	13.1	14.0	11.2	12.3	15.5	14.2	4.3	3.7	3.1	1.9	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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	18.00	17.12	17.04	0.88	5.00	0.18

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP OEGREES AT 1.7 PCT MOIST	ANGLE/REPOSE 10 IN DROP OEGREES AT 1.7 PCT MOIST	ANGLE/SLIDE STEEL PLATE OEGREES AT 1.7 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK OENSITY PCF AT 0.0 PCT MOIST	SIZE(-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
2.68	29	26	28	70	114	45

KEY

12A
TUNNEL DATA

TUNNEL SIZE	SHAPE	GRADE	VENTILATION CFM	PRESS EXHST	SIZE	HP	WATER INFLOW GPM	UTILITY LINES AIR	WATER	PUMP	POWER SYSTEM PRIMARY	SECONDARY
15FT X 14 FT	ARCHED BACK	-26PCT	22K	X	48IN	150	MINOR	6IN	2IN	4IN	4160	220

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
WAGNER ST-8	DIESEL	DIESEL
SCOOP TRAM	TRUCK	TRUCK
RAIL SKIP		

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
6FTX3/4IN#4FT	13.5INX9FT		

MACHINE EXCAVATION

MACHINE MAKE	MODEL	WT	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES CENTER	INTERIOR	GAGE	RPM HEAD,CENTER	TORQUE,MAX/OPERATE HEAD	CENTER	THRUST,MAX/OPERATE
							KFTLB	KFTLB	KLB
							KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO 3 BOOM
MACHINES PR-123

FEED LENGTH 12FT

ROUND,
NO. HOLES 42
DEPTH 10.5
DIAM. 1.75
CUT. BURN
4 IN CENTER

EXPLOSIVES,
POWDER FACTOR 4.7 LB/CY
TOTAL LBS 350
PRIMERS, 25LB, 1.5X8IN, 60PCT
TRIM 25LB,7/8X16IN, 30PCT
INTERIOR
CUT
LIFTERS

BLASTING
ELECTRICAL
0-15 REGULAR
DELAYS

MUCKING
SCOOP TRAM

GUIDANCE
LASER

LK-7 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	ROO PCT EST	HARONESS SHORE	HARONESS MOH	HARONESS SCHMIDT
13	SM SAMPLE NO SM-I	IGNEOUS: QUARTZ MONZONITE COURSE GRAINED WITH MANY SULFIDE, VEINLETS HIGHLY FRACTURED, PRONOUNCED ORTHOGONAL FAULTING	165	19	50			NA

MUCK DATA

ORY WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
97	I.I	27.5	10.8	3.7	14.8	17.0	14.0	5.9	3.0	2.2	I.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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I2.50	II.02	I0.52	I.48	5.1	0.29

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 0.2 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 0.2 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.2 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
2.72	36	31	28	90	II2	44

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 12FT	RECT	+0.4PCT	14K	X	24IN	60		NONE	4IN	2IN	8IN	2400	480

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

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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO 3 BOOM
MACHINES CF79
OR O 89

FEED LENGTH 6 FT

ROUND,
NO. HOLES 52
DEPTH 5 FT
DIAM. 1 5/8 IN
CUT, WEDGE

EXPLOSIVE
POWDER FACTOR 3.0LB/CY
TOTAL LBS 100
PRIMERS, PRIMACORD
TRIM AMOGEL
INTERIOR AMOGEL
CUT AMOGEL
LIFTERS AMOGEL

BLASTING	MUCKING	GUIDANCE
IGNITER CORD	EIMCO 40	TRANSIT
FUSE, NO 6	LOADER	
CAPS		

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
I4	CLIMAX	METAMORPHIC: GRANITIC GNEISS, HIGHLY METAMORPHOSED, MODERATELY TO HIGHLY FRACTURED, HIGHLY SILICIFIED.						
	SAMPLE NO CL-I		174	9	I0	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	I/2IN.	NO4	NO8	NOI6	N030	N050	NO100	NO200	PCT (-) NO200
87	8.8	0.0	0.0	0.0	0.0	4.8	37.8	I8.I	II.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 (-)	IN.SIZE	ATTERBERG LIMITS..SIZE(-) IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
NA		NA	NA	NA	NA	NA	NA

(-) SPECIF GRAVITY	IN.SIZE	MATERIAL SIZE(-) IN. ANGLE/REPOSE I IN DROP DEGREES AT PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-) IN. ANGLE INTER FRICTION DEGREES AT PCT MOIST
NA		NA	NA	NA	NA	NA	NA

CL-1 CURRENT: 1 SEPT. 1972

KEY

I4A
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, 40	200 TONS	I SMITH TCB TRICONE, 24IN	I¢ SMITH TCB GTMH8 ROLLER	6 SMITH TCB GTSH8 ROLLER	12 26	KFTLB 347 KFTLB	KFTLB KFTLB	KLB 133 KLB 130

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET FROM FACE, CONVEYOR TO REAR 24IN	ELECTRO-HYDRAULIC 825 HP	LASER	KLB 5.09

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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
15	LK SAMPLE NO LK-3	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.	178	26	80	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.0S6 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.0S6IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	18.25	17.92	17.80	0.33	S.50	0.06

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 1.5 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 1.5 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 1.5 PCT MOIST	APPARENT COHESION PSF AT 0.4 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.4 PCT MOIST
3.21	30	29	29	175	117.8	41

LK-3 CURRENT: 1 SEPT. 1972

KEY

15A
TUNNEL DATA

TUNNEL

SIZE	SHAPE	GRADE
16FT X 14-1/2FTT	ARCHED BACK	+2.0PCT

VENTILATION

CFM	PRESS HEAD	EXHST SURF	SIZE	HP
52K			48IN	150

WATER INFLOW

GPM
NONE

UTILITY LINES

AIR	WATER	PUMP
6IN	2IN	

POWER SYSTEM

PRIMARY	SECONDARY
4160V	220V

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
WAGNER ST-8	DIESEL	DIESEL
SCOOPTRAM	TRUCK	TRUCK
RAIL, SHIP		

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
3/4IN X 6FT AT 4FT	13.5IN X 9FT		

MACHINE EXCAVATION

MACHINE

MAKE	MODEL	WT

CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES

CENTER	INTERIOR	GAGE

RPM	TORQUE,MAX/OPERATE		THRUST,MAX/OPERATE
HEAD,CENTER	HEAD	CENTER	
	KFTLB	KFTLB	KLB
	KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO 3 BOOM
MACHINES 3-PR123 DRIFTERS

FEED LENGTH 12FT

ROUND,
NO. HOLES 42
DEPTH 6FT
DIAM. 1-3/4IN
CUT, 6 HOLE BURN
1-4IN CNTR HOLE

SF/HOLE 5.0

EXPLOSIVES,
POWDER FACTOR 5LB/CY
TOTAL LBS 205
PRIMERS, 15LB 1.5IN X 8IN, 60-75PCT
TRIM 15LB 7/8IN X 16IN, 30PCT
INTERIOR ANFO
CUT 25LB 1.5IN X 16IN, 45PCT
LIFTERS ANFO

BLASTING
ELECTRICAL
0-15 REGULAR
DELAYS

MUCKING
SCOOPTRAM

GUIDANCE
LASER

LK-3 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROQ PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
16	LK SAMPLE NO LK-4	METAMORPHIC: TACTITE STRONGLY ALTERED CALCAREOUS META-SEDIMENTS, WITH REPLACEMENT PYRITE, CHALCOPYRITE AND MAGNETITE AND A HIGH PER-CENTAGE OF SILICATES, FINE TO VERY FINE GRAINED.	I8I	I4 EST	70	NA	NA	NA

TEST SPECIMENS BROKE ALONG STEEP INCLINED JOINTS DURING PREPARATION.

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
I24	2.I	26.3	I9.3	I3.7	I3.9	9.8	7.3	I.6	I.6	I.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 (-)0.0S6 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.0S6IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I9.00	I7.9S	I6.43	I.0S	S.40	0.I9

(-) 0.75IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-) 2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 2.0 PCT MOIST	ANGLE/REPOSE IO IN DROP STEEL PLATE DEGREES AT 2.0 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 2.0 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-) 2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
3.36	37	3S	30	I6S	II5	43

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 14FT	ARCHED BACK	+2.0PCT	50K	HEAD	SURF	48IN	150	NONE	6IN	2IN		4160V	220V

HAULAGE SYSTEM			SUPPORT SYSTEM				
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE	
WAGNER ST-8	DIESEL	DIESEL			6IN WF STEEL SETS		
SCOOPTRAM	TRUCK	TRUCK	NONE		AT 5FT		
RAIL, SHIP							

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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND	EXPLOSIVES	BLASTING	MUCKING	GUIDANCE
JUMBO 3 BOOM MACHINES GARDNER DENVER 3-PRI23 DRIFTERS	NO. HOLES 42 DEPTH 6 FT DIAM. 1-3/4IN CUT, 6 HOLE BURN 1-4IN CENTER HOLE SF/HOLE 4.4	POWDER FACTOR 5.5LB/CY TOTAL LBS 205 PRIMERS, 15LB 1.5IN X 8IN, 60-75PCT TRIM 15LB 7/8IN X 16IN, 30PCT INTERIOR ANFO CUT 25LB 1.5IN X 16IN, 45PCT LIFTERS ANFO	ELECTRICAL 0-15 REGULAR DELAYS	SCOOPTRAM	LASER
FEED LENGTH 12FT					

LK-4 CURRENT 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
I7	MATHER B SAMPLE NO MB-I	METAMORPHIC: INTER LAYERED BANDS HEMATITE AND MARTITE HIGHLY JOINTED NORMALLY FLAT LYING, OFTEN HIGHLY FOLDED. NATURAL IRON OVER 60 PCT MOISTURE 9 PCT, SILICA 5 PCT.	207	7	I0	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
I28	7.2	7.2	9.7	I.4	8.7	II.4	20.I	I0.3	7.4	3.3	I.8	I.3	I.I		16.3

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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I7.8	I5.I	I3.9	2.7	4.I	0.66

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 6.2 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 6.2 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 6.2 PCT MOIST	APPARENT COHESION PSF AT 6.9 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 6.9 PCT MOIST
4.34	37	35	3I	235	I4I	3S

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 11.5IN	ROUND	0.0	3K		X	8IN	5	NONE	2IN	1IN			440V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
42IN SCRAPER RAIL	RAIL HOIST	RAIL HOIST			9FT 6IN DIA. X 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 TONS		258 CARBOLOY DRAG BITS	20 CARBOLOY RIPPERS	8	KFTLB 1200	KFTLB	KLB 300
							KFTLB	KFTLB	KLB 285

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

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY	COMPR	RQD	.....	HARONESS	.....
I8	MB	METAMORPHIC: INTERLAYERED						
		HEMATITE AND MARTITE	WT	STRNTH	PCT	SHORE	MOH	SCHMIOT
	SAMPLE NO	HIGHLY JOINTED, NORMALLY	PCF	KPSI	EST			
	MB-3	FLAT LYING, OFTEN HIGHLY						
		FOLDED, NATURAL IRON	NA	NA	10			NA
		60 0/0, SILICA 5 0/0						

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

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

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

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

KEY

I8A
TUNNEL DATA

TUNNEL

SIZE	SHAPE	GRADE
10FTX 9FT 6 IN	RECT	0

VENTILATION

CFM	PRESS EXHST	SIZE	HP
4K	X	8IN	IS

WATER INFLOW

GPM
NONE

UTILITY LINES

AIR	WATER	PUMP
2IN	1IN	

POWER SYSTEM

PRIMARY	SECONDARY
2300	440

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
48IN SCRAPER 160 CF CARS 2-30T MOTORS 30 IN GAGE COU3 RAIL	RAIL	RAIL

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
		8IN-58LB WF SETS 7FT CAP, 8FT POSTS WOOD LAGGING PIPE SPILING 8-1IN DIA-6-2IN DIA	

MACHINE EXCAVATION

MACHINE

MAKE	MODEL	WT
ALPINE	F-6A	IIT

CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES

CENTER	INTERIOR	GAGE
68 KENNAMETAL ON TWIN RIPPER	43KH TC8 HEADS	

RPM	TORQUE,MAX/OPERATE		THRUST,MAX/OPERATE
HEAD,CENTER	HEAD	CENTER	
60	KFTLB49 HP KFTLB	KFTLB KFTLB	KLB 2-10 KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	GATHERING ARMS,FLIGHT CONVEYORS	440V	TRANSIT	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY	COMPR	ROD	.....HARDNESS.....		
I9	ST	METAMORPHIC: ARGILLIACEOUS	WT	STRNTH	PCT	SHORE	MOH	SCHMIDT
		QUARTZITE, MEDIUM TO THIN	PCF	KPSI	EST			
	SAMPLE NO	BEDDED,MODERATELY TO HIGHLY						
	ST-I	FOLDED, MODERATE FRACTURING						
			NA	NA	75			NA

MUCK DATA

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

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

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

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

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
9FTX10 FT 1.5IN	ARCH BACK	+0.5PCT	7	X	24 IN	40		NONE	4 IN	2 IN		2300	480

HAULAGE SYSTEM				SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY		BOLT+TYPE SIZE	ROOF PLATE	SET+SIZE+SHAPE	SHOTCRETE
60 CF SIDE DUMP 40 LB RAIL 24 IN GAGE 6 T MOTOR	RAIL	RAIL		6FTX.75IN 4/ MAT	9FTX13IN MATS 2I BACK+ 2I EACH RIB		

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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND+	EXPLOSIVES+	BLASTING	MUCKING	GUIDANCE
JUMBO 3 BOOM	NO. HOLES 44	POWDER FACTOR 5.4LB/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		
1-099	CUT+ BURN2-4 IN	TRIM NILITE			
FEED LENGTH 8FT		INTERIOR NILITE			
		CUT NILITE			
		LIFTERS NILITE			

KEY	IDENTIFICATION	ROCK PROPERTIES							
20	CR	METAMORPHIC: QUARTZITE	DRY	COMPR	RQD	.....HARDNESS.....			
		MODERATLEY FOLDED	WT	STRNTH	PCT	SHORE	MOH	SCHMIDT	
	SAMPLE NO	MODERATELY TO HIGHLY FRACTURED	PCF	KPSI	EST				
	CR-1	/JOINTED WITH MINOR FILLED							
		VEINLETS, DIPPING 75-90	NA	NA	50			NA	
		DEGREES							

MUCK DATA														
DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	*.....PER CENT BY WEIGHT BETWEEN SCREENS.....*											PCT (-) ND200
			6IN.	3IN.	2IN.	1IN.	1/2IN.	ND4	ND8	ND16	ND30	ND50	ND100	ND200

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

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

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

CR-1 CURRENT: 1 SEPT. 1972

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	135K	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.O•			@ 3.5 FT			
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
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 INAS/8 IN	PRIMERS• 15LB TROJAN 60 WR.	8-14	LHD	
FEED LENGTH 8FT	CUT• V	TRIM NILITE			
		INTERIOR NILITE			
		CUT NILITE			
		LIFTERS NILITE			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
21	HOMESTAKE SAMPLE NO HS-1	METAMORPHIC: PHYLLITE WITH VEINQUARTZ. CHLORITE SCHIST HIGHLY METAMORPHOSED AND FOLDED. WITH MINOR FAULTING	187	19	70			NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
136	2.2	25.3	15.5	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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	18.80	16.06	15.12	2.74	2.70	1.01

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 3.1 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.1 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.1 PCT MOIST	APPARENT COHESION PSF AT 2.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.0 PCT MOIST
2.84	40	34	31	160	99	39

HS-I CURRENT: 1 SEPT. 1972

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 8FT6IN	ARCH	BACK	7K	X	16 IN	30	MINOR	2 IN	2 IN		2400	440

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL I.ST ROCKER CARS 40LB RAIL 18 IN GAGE 6 OR 8 T MOTORS	RAIL	RAIL	6 FT X 5/8 IN			

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
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO AIR LEG
MACHINES 3IN JACK HAMMER

FEED LENGTH 6FT

ROUND,
NO. HOLES 34
DEPTH 10 FT
DIAM. 1.5 IN
CUT. BURN2-2 IN

EXPLOSIVES,
POWDER FACTOR 7.0 LB/CY
TOTAL LBS 140
PRIMERS, 4LB, 60 PCT 1X6 IN
TRIM ANFO
INTERIOR ANFO
CUT ANFO
LIFTERS ANFO

BLASTING	MUCKING	GUIDANCE
ELECTRICAL	EIMCO	TRANSIT
7-MILLESECOND	21	
10-REGULAR		

HS-1 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIO.
22	NEW YORK	METAMORPHIC: MICA SCHIST						
		OCCASIONAL QUARTZ						
	SAMPLE NO	LAMINATIONS						
	NY-1		NA	NA	80			NA

MUCK DATA DRY WT PCF	UNIT MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)	IN.SIZE	ATTERBERG LIMITS..SIZE(-) IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX

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

KEY

22A
TUNNEL DATA

TUNNEL

SIZE	SHAPE	GRADE
11 FT 6 IN	ROUND	-0.03PCT

VENTILATION

CFM	PRESS	EXHST	SIZE	HP
36K		X	20 IN	40

WATER INFLOW

GPM
40

UTILITY LINES

AIR	WATER	PUMP
4 IN	4 IN	6 IN

POWER SYSTEM

PRIMARY	SECONDARY
6600	440

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
RAIL	RAIL	RAIL
17CY CARS		
10T MOTORS		
70LB RAIL		
36 IN GAGE		

SUPPORT SYSTEM

BOLT•TYPE SIZE	ROOF PLATE	SET•SIZE•SHAPE	SHOTCRETE
		HALF CIRCLE	
		BOLTED STEEL	
		LAGGING IN	
		FAULT ZONES	

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	12-11	NA	2 REED	26 REED•3 DISC	6 JARVA TCB	NA			
			5 DISC	OK-3	DISC•OKC-3W		KFTLBNA	KFTLB	KLB NA
			OK-1				KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
	BUCKETS TO	NA	LASER	
KLB	BELT			KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO
MACHINES

FEED LENGTH

ROUND•
NO. HOLES
DEPTH
DIAM.
CUT•

EXPLOSIVES•
POWDER FACTOR
TOTAL LBS
PRIMERS•
TRIM
INTERIOR
CUT
LIFTERS

BLASTING MUCKING GUIDANCE

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
23	NEW YORK	METAMORPHIC: MICA SCHIST OCCASIONAL QUARTZ LAMINATIONS						
	SAMPLE NO NY-2		NA	NA	90			NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)	IN.SIZE	ATTERBERG LIMITS..SIZE(-) IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX

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

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 6 IN	ROUND	+0.03PCT	18K		X	12 IN	40	20	4 IN	4 IN	4 IN	6600	440

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

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	6-806	NA	2 REED TOOTH TYPE	12 REED QC-3 TCB BUTTON	3 JARVA DISC QKC-3W, TCB	NA	KFTLBNA KFTLB	KFTLB KFTLB	KLB NA KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS TO BELT	NA	LASER	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
24	QUEEN LANE	METAMORPHIC: GRAY MICA SCHIST OCCASIONAL QUARTZ SEAMS. MICA						
	SAMPLE NO QL-1	VARIES FROM DENSE, FINE GRAINED TO EXTREMELY COARSE.	165	II	30	NA	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	24.0	23.3	22.7	0.7	4.0	0.17

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 9.8 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 9.8 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 8.4 PCT MOIST	APPARENT COHESION PSF AT 9.3 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 9.3 PCT MOIST
2.57	39	37	40	125	75	30

QL-1 CURRENT: 1 SEPT. 1972

KEY

24A
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	+1-3PCT	4K		X	14IN				4IN		4160V	480V

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

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	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
	BUCKET FROM	4-125HP ELECT.	LASER	
KLB 3402	FACE,	MOTORS, 40HP		KLB 3.53
	CONVEYOR	MOTORS,		
	BELT TO 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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	..HARDNESS.. SHORE	MOH	SCHMIDT
25	MB	SEDIMENTARY, GRAYWACKE (ARGILLACEOUS QUARTZITE) MASSIVE TO MEDIUM BEDDED, HIGHLY FOLDED AND FRACTURED NORMAL DIP OF BEDDING 30 DEGREES TO 45 DEGREES						
	SAMPLE NO MB-2							

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

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

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

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

MB-2 CURRENT: I SEPT. 1972

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 10.8 FT	RECT	+2.0 PCT	8K		X	16 IN	30	NONE	6 IN	4 IN		2300	480

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT+TYPE SIZE	ROOF PLATE	SET+SIZE+SHAPE	SHOTCRETE
RAIL 140-200CF BOTTOM DUMPCARS 60-80LB RAIL 10T MOTOR 30 IN GAGE	RAIL	RAIL	6 FT X .75 IN	AS REQUIRED		

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	KFTLB KFTLB	KLB KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB				KLB

CONVENTIONAL EXCAVATION

MACHINE	ROUND+	EXPLOSIVES+	BLASTING	MUCKING	GUIDANCE
JUMBO 2 BOOM MACHINES D-93 ROUND 1 1/4 STEEL FEED LENGTH 10FT	NO. HOLES 36 DEPTH 8 FT DIAM. 1 5/8IN CUT. V	POWDER FACTOR 7.5LB/CY TOTAL LBS 210 PRIMERS+ 10LB+ 70PCT 7/8X8 IN TRIM ANFO INTERIOR ANFO CUT ANFO LIFTERS ANFO	IGNITER CORD FUSE+ CAPS DETAPRIME	EIMCO 40	TRANSIT

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
26	S-1	SEDIMENTARY: SANDSTONE FINE GRAINED, WELL COMPACTED, LIGHT BROWN OVER 50 PCT QUARTZ.	166	22	92	61	NA	NA
	SAMPLE NO S-1							

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.065 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.185IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	16.90	15.50	15.18	1.40	5.0	0.28

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 6.3 PCT MOIST	ANGLE/REPOSE 10 IN DROP STEEL PLATE DEGREES AT 6.3 PCT MOIST	ANGLE/SLIDE DEGREES AT 6.3 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 4.8 PCT MOIST
2.73	35	29	28	NA	NA	29

S-I CURRENT: 1 SEPT. 1972

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 I IN	ROUND	-7.0PCT	17K		X	36IN	7S	5-10		2IN	4IN	4160V	480V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT, TYPE SIZE	ROOF PLATE	SET, SIZE, SHAPE	SHOTCRETE
30IN PIGGYBACK CONVEYORS, 36IN SUSPENDED CONVEYOR	DIESEL TRUCKS, JEEPS	DIESEL TRUCKS, JEEPS	4-5/8IN X 4FT	8.2LB CHANNEL, 6IN X 9.5FT OR 13.5FT AT 4FT 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 TONS	1 ROBBINS, 7.5IN TRIPLE STEEL DISC	43 ROBBINS, 12IN STEEL DISC	3 ROBBINS, 12IN STEEL DISC	4.5 INTEG	KFTLB1720 KFTLB	KFTLB KFTLB	KLB 1580 KLB 914

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 30IN CONVEYOR TO REAR	6-200HP MOTORS FOR HEAD	LASER	KLB 3.56

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	HARDNESS SCLERE	HARDNESS MOH	HARDNESS SCHMIDT
27	7-2	SEDIMENTARY: SANDSTONE FINE GRAINED, WELL COMPACTED, LIGHT BROWN, OVER 50 PCT QUARTZ.	166	22	92	61	NA	NA
	SAMPLE NO 7-2							

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	ND8	NDI6	NO30	NO50	NO100	ND200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	23.0	17.63	17.58	5.37	6.90	0.78

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 2.6 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 2.6 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 2.6 PCT MOIST	APPARENT COHESION PSF AT 2.8 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.8 PCT MOIST
2.63	32	31	29	0	92.8	44

7-2 CURRENT: 1 SEPT. 1972

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 11IN	ROUND	+2.0PCT	17K		X	36IN	75	5-10		2IN	4IN	4160V	480V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
30IN PIGGYBACK CONVEYOR, 36IN SUSPENDED CONVEYOR	DIESEL TRUCKS JEEPS	DIESEL TRUCKS, JEEPS	4-5/8IN X 4FT	8.2LB CHANNEL 6IN X 9.5FT OR 13.5FT AT 4FT 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 TONS	I ROBBINS 7.5IN TRIPLE STEEL DISC	41 ROBBINS12IN STEEL DISC	ROBBINS 12 IN STEEL DISC	4.5 INTEG	KFTLBI720 KFTLB	KFTLB KFTLB	KLB 1580 KLB 747

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 30IN CONVEYOR TO REAR	4-200HP MOTORS FOR HEAD	LASER	KLB 2.91

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
28	II-3	SEDIMENTARY: SHALE, MASSIVE TO THINLY LAMINATED, INTERBEDDED SILTSTONE AND SHALE, WITH MINOR SANDSTONE AND LIMESTONE LAYERS. GRAIN SIZE FINE TO COARSE. QUARTZ 24 TO 33 PCT.	152	4 MAJOR BEDS 22 TO 29. 3 MINOR BEDS 12 TO 17. WT. AVE 23	90	PARALLEL 41-55. NORMAL 41-54.	NA	NA

SAMPLE NO
II-3

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
99	I.I	7.8	12.6	II.3	14.4	I4.9	16.4	5.7	3.5	2.0	I.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	PA	PA	PA	A	A	A	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	15.60	14.81	I4.5I	0.79	3.00	0.26

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 1.0 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 1.0 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 1.0 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
2.65	25	25	29	550	I00	46

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 .5FTSFT	HEXT	VARIES	80-100K	X				NONE	4IN	4IN	4IN		110V

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	111N X 10FT		
SCOOPTRAM,	TRUCKS,	TRUCKS,	4FT X 4FT			
16TON SHUTTLE CARS	JEEPS	JEEPS	PATTERN			

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
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-AR9J	DEPTH 10.5FT - 11FT	TOTAL LBS 234	M.S. DELAYS		LASER
ORIFTERS	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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
29	II-4	SEDIMENTARY: SHALE, MASSIVE TO THINLY LAMINATED, INTERBEDDED						
	SAMPLE NO II-4	SILTSTONE AND SHALE WITH MINOR SANDSTONE AND LIMESTONE LAYERS						
		GRAIN SIZE FINE TO COARSE, QUARTZ 24 TO 33 PCT.	I66		90		NA	NA
				4 MAJOR BEDS 22 TO 29.		PARALLEL 41-55.		
				3 MINOR BEDS I2 TO I7.		NORMAL 4I-54.		
				WT. AVE 22 .				

MUCK DATA DRY WT PCF	UNIT MOISTURE PCT.	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	1/2IN.	ND4	ND8	ND16	ND30	ND50	ND100	ND200	PCT (-) ND200
96	I.I	8.2	17.7	17.0	19.3	I5.7	I2.7	3.4	2.5	I.2	0.6	0.2	0.2		I.3

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	A	A	A

PCT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS, SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0.	I5.80	I5.60	I3.26	0.20	4.00	0.05

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 0.9 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 0.9 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.9 PCT MOIST	APPARENT COHESION PSF AT 0.2 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.2 PCT MOIST
2.79	28	29	28	282	I00	54

KEY

29A
TUNNEL DATA

TUNNEL			VENTILATION				WATER INFLOW	UTILITY LINES		POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP	GPM	AIR	WATER	PRIMARY	SECONDARY
19FTX8 .5FT	RECT	0.0	20K	ENTRY FACE		40	NONE	2IN		4160V	600V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
DIESEL SHUTTLE CAR, CONVEYOR	DIESEL TRUCK	DIESEL TRUCK	5/8IN X 6FT AT 4FT X 4FT			

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 - COPCO	4-HEAD	180 L.T.	48 T.C. DRAG HEADS	CUTTERS MOUNTED	ON 4 ROTATING	3 1/4UPPER 1 5-8LOWER	KFTLB KFTLB	KFTLB KFTLB	KLB 1,093 KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 1000	FLIGHT CONVEYOR STAR WHEEL, 2SIN CONVEYOR	4-80KW MOTORS HEAD ROTATION 2-78KW MOTORS HYDRAULICS	TRANSIT LASER	KLB

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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HOH	SCHMIDT
30	72-I	SEDIMENTARY: SHALE INTERBEDED SILTSTONE						
	SAMPLE NO 72-I	+ SHALE MINOR SANDSTONE + LIMESTONE+ FINE TO COURSE GRAINED	168	22	65	41-55		

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
86	I.5	0	0	4.0	I8.8	3I.0	24.1	7.3	4.5	I.I	I.5	I.2	0.6		5.9
		0.0	0.0	8	24	23	20								

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM CI36), AFTER WASHING (ASTM CI17), 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	I8.00	I7.I0	I5.58	0.90	4.40	0.20

(-)0.75 IN.SIZE	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT I.3 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT I.3 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT I.3 PCT MOIST	APPARENT COHESION PSF AT I.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT I.0 PCT MOIST
SPECIF GRAVITY						
2.72	36	32	30	170	100	41

72-I CURRENT: I SEPT. 1972

KEY

30A
TUNNEL DATA

TUNNEL SIZE	SHAPE	GRADE	VENTILATION CFM	PRESS	EXHST	SIZE	HP	WATER INFLOW GPM	UTILITY LINES AIR	WATER	PUMP	POWER SYSTEM PRIMARY	SECONDARY
18 FT 1 IN	ROUND	+10.0PCT	18K		X	36 IN	120	5-10	2 IN		4IN	4160	480

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

MACHINE EXCAVATION

MACHINE MAKE	MODEL	WT	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES CENTER	INTERIOR	GAGE	RPM HEAD,CENTER	TORQUE,MAX/OPERATE HEAD	CENTER	THRUST,MAX/OPERATE
ROBBINS	181-122	260	1ROBBINS DISC 7.5IN TRIPLE W/ ESCO RING	43 ROBBINS DISC 12IN, ESCO RING	3 ROBBINS DISC 12IN W/ESCO RIN	4.5 G	KFTLBI147 KFTLB	KFTLB KFTLB	KLB KLB 769

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 1000	BUCKETS TO BELT	4-200 HP FOR HEAD	LASER	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
31	MSU SAMPLE MSU-1	SEDIMENTARY: CONGLOMERATE (BRECCIA) .25 IN TO 10 IN ROUNDED TO ANGULAR BOULDERS COBBLES, PEBBLES, PREDOMINATELY LIMESTONE MATRIX, W/CHERT, SCHIST, DIBASE FRAGMENTS	171	NA	65			NA

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

A	A	A	A	A	A	A	A	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTENBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	13.80	12.77	10.78	1.03	3.20	0.32

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 0.4 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 0.4 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 0.4 PCT MOIST	APPARENT COHESION PSF AT 0.3 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 0.3 PCT MOIST
2.74	35	29	27	410	111	46

MSU-1 CURRENT: 1 SEPT. 1972

KEY

3IA
TUNNEL OATA

TUNNEL			VENTILATION					WATER INFLOW	UTILITY LINES			POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS EXHST	SIZE	HP		GPM	AIR	WATER	PUMP	PRIMARY	SECONOARY
9 FT 10 FT	RECT	0.0	10K	X	24 IN	50		NONE	6 IN	2 IN		4160	480

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

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
KLB				KLB

CONVENTIONAL EXCAVATION

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

FEED LENGTH 7FT

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY	COMPR	ROD	.....HARDNESS.....		
32	MSU	SEDIMENTARY: CONGLOMERATE I/4 - 10 IN ROUNDED TO ANGULAR BOULDERS, COBBLES, PEBBLES IN PREDOMINATELY LIMESTONE MATRIX, W/CHERT, SCHIST DIABASE FRAGMENTS WELL TO MODERATELY CONSOLIDATED	WT PCF	STRNTH KPSI	PCT	SHORE	MOH	SCHMIDT
	SAMPLE NO MSU-2				80			

MUCK DATA

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

	A		A	A	A	A	A	A	A	A	A	A

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

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

MSU-2 CURRENT: 1 SEPT. 1972

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 I	RECT	0.0	9K	X	24 IN	50	NONE	6 IN	2 IN	4160	480
0 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	3,4 1/2, 6 FT		
44CF ROCKER			21 BOLTS/5 FT	7 PLATES I		
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
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. I 3/8 IN	PRIMERS, AMOGEL	FUSE NO. 6 CAPS		
	CUT, V	TRIM			
FEED LENGTH 6FT		INTERIOR AMOGEL OR CARBAMITE			
		CUT			
		LIFTERS			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
33	LAWRENCE SAMPLE NO LAW-2	SEDIMENTARY: LIMESTONE LIGHT TO MEDIUM GRAY FINE GRAINED, SOME CHERT NODULES, TRACES TO OCCASIONAL CLAY PARTINGS	165	19	100	46	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 E=ELONGATED SP=SPHEROID

PAI	PI	PI	PI	I	I	AI	A	I

POT VOL CHANGE (-)0.065 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.185IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	12.5	12.3	9.6	0.2	4.0	0.05

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 5.4 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 5.4 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 5.4 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 7 PCT MOIST
2.83	39	38	31	NA	NA	30

LAW-2 CURRENT: 1 SEPT. 1972

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 8IN	ROUND	+0.25PCT	21K		X	28IN		40-12	6IN	2IN	6IN	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		
ALKIRK	HARDROCK	400 TONS	I LAWRENCE TCB 24IN TRICONE	II LAWRENCE TCB 15IN DISC, II-TCB 15IN	5 LAWRENCE TCB 15IN ROLLER	9 30	KFTLB KFTLB206	KFTLB KFTLB	KLB KLB 614	

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP HEAD 150 CENTER	LASER	KLB 4.28

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
24	LAWRENCE	SEDIMENTARY: LIMESTONE LIGHT TO MEDIUM GRAY, FINE GRAINED,						
	SAMPLE NO LAW-3	SOME CHERT NODULES. TRACES TO OCCASIONAL CLAY PARTINGS.	160	19	100	46	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 E=ELONGATED SP=SPHEROID

	PAI	PAI	PI	PAI	I	I	I	I	I

POT VOL CHANGE (-)0.065 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.185IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0.	11.8	10.6	10.0	1.2	2.9	0.41

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 6.1 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 6.1 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 8.4 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 7 PCT MOIST
2.80	41	40	38	NA	NA	32

LAW-3 CURRENT: 1 SEPT. 1972

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 8IN	ROUND	+0.25PCT	20K		X	28IN		40-120	6IN	2IN	6IN	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	
ALKIRK	HARDROCK	400 TONS	1 LAWRENCE TCB 24IN TRICONE	11 LAWRENCE TCB 15IN OISC, 11 TCB 15IN ROLLER	9 LAWRENCE TCB 15IN ROLLER	9 30	KFTLB KFTLB206	KFTLB KFTLB	KLB KLB 614

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP HEAD 150 CENTER	LASER	KLB 4.28

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
3S	LAWRENCE SAMPLE NO LAW-4	SEDIMENTARY: LIMESTONE LIGHT TO MEDIUM GRAY FINE GRAINED, SOME CHERT NODULES. TRACES TO OCCASIONAL CLAY PARTINGS.	160	19	100	46	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	20.2	20.0	13.5	0.2	4.7	0.05

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 8.9 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 8.9 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 8.9 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 8.8 PCT MOIST
2.73	42	34	37	NA	NA	28

LAW-4 CURRENT: 1 SEPT. 1972

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 8IN	ROUND	+0.25PCT	21K		X	28IN		40-120	6IN	2IN	6IN	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	
ALKIRK	HARDROCK	400 TONS	1 LAWRENCE TCB 24IN TRICONE	11 LAWRENCE TCB. 15IN DISC, 11 TCB 15IN ROLLER	5 LAWRENCE 15IN ROLLER	9 30	KFTLB KFTLB206	KFTLB KFTLB	KLB KLB 540

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS FROM FACE, 24IN CONVEYOR TO REAR	ELECTRO-HYDRAULIC 600HP 150 HEAD	LASER	KLB 3.76

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
36	MILWAUKEE	SEDIMENTARY: LIMESTONE, GRAY FINE GRAINED. HORIZONTAL						
	SAMPLE NO MIL-I	JOINT SPACING 6 IN. TO 1 FOOT.	166	36	85	NA	NA	NA

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

	PE	PI	PI	PI	PA	S	S	S

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	16.90	15.69	15.46	1.21	5.00	0.24

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 2.5 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 2.5 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 2.5 PCT MOIST	APPARENT COHESION PSF AT 4.1 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.5 PCT MOIST
2.89	36	35	30	95	86	35

MIL-I CURRENT: 1 SEPT. 1972

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 2IN	ROUND	+0.2PCT	4K		X	18IN	25	5.	6IN	11N	6IN	4680V	440V

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

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 TONS	1 REED STEEL CONE, 5 DISC	22 REED STEEL TRIPLE DISC	4 REED STEEL TRIPLE DISC	9.3 INTEG	KFTLB 170 KFTLB	KFTLB KFTLB	KLB 1104 KLB 596

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 1650	BUCKET FROM FACE, 18IN CONVEYOR TO REAR	6-50HP MOTORS FOR HEAD 1-40HP MOTOR HYDRAULIC	LASER	KLB 6.09

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			

MIL-1 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
37	MILWAUKEE SAMPLE NO MIL-2	SEDIMENTARY: LIMESTONE, GRAY, FINE GRAINED, HORIZONTAL JOINT SPACING 6 IN. TO 1 FOOT.	166	36	85	NA	NA	NA

MUCK DATA DRY WT	UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	20.10	16.68	16.37	3.42	6.10	0.56

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT S.8 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 5.8 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 5.8 PCT MOIST	APPARENT COHESION PSF AT 5.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 5.0 PCT MOIST
2.93	32	30	30	110	90	33

MIL-2 CURRENT: 1 SEPT. 1972

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 2IN	RDUND	+0.25PCT	4K		X	18IN	25	10	6IN	1IN	6IN	4680V	440V

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
RAIL, 24IN GAGE STDN MDTORS	RAIL	RAIL

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
	OCCASIONAL PINNED STEEL LAGGING	4IN H RING SETS IN FAULT ZONES	

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 TONS	1 REED STEEL CONE, 5 DISC	2< REED STEEL TRIPLE DISC	4 REED STEEL TRIPLE DISC	9.3 INTEG	KFTLB 179 KFTLB	KFTLB KFTLB	KLB 1104	KLB 596

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 1650	BUCKET FROM FACE, 18IN CONVEYOR TO REAR	6-50HP MOTORS FOR HEAD, 1-40HP MOTOR HYDRAULICS	LASER	KLB 6.09

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
38	MILWAUKEE SAMPLE NO MIL-3	SEDIMENTARY: LIMESTONE FINE GRAINED. GREY	164	24	81			

MUCK DATA DRY WT	UNIT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	I/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	15.20	14.40	12.96	0.80	3.50	0.22

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 2.5 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 2.5 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 2.5 PCT MOIST	APPARENT COHESION PSF AT 2.3 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 2.3 PCT MOIST
2.78	36	32	32	60	95	36

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 2 IN	ROUND	+0.2PCT	4		X	18IN	25	MINOR	6IN	11IN	6I N	4680	440

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL 24IN GAGE 5T MOTOR	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	
JARVA	11-1100	65	1 REED QK-1	22 REED 2K3	4 REED QK-5	9.3	KFTLB KFTLB119	KFTLB KFTLB	KLB KLB 639

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS TO BELT	6-50HP MOTORS DRIVE HEAD	LASER	KLB

CONVENTIONAL EXCAVATION

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

MIL-3 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	HARDNESS SHORE	HDH	SCHMIDT
39	MT GREEN	SEDIMENTARY: LIMESTONE FINE GRAINED, LIGHT GREY	168	26	100			
	SAMPLE NO EVG-I							

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

P	P	P	P	P	PA	A	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	15.10	13.69	11.57	1.41	3.0	0.47

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 3.1 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.1 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.1 PCT MOIST	APPARENT COHESION PSF AT 3.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST
2.81	37	31	31	70	104	42

KEY

39A
TUNNEL DATA

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

HAULAGE SYSTEM

SUPPORT SYSTEM

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

4CY CARS
ST MOTOR
24IN GAGE
54 LB RAIL

MACHINE EXCAVATION

MACHINE MAKE	MODEL	WT	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES CENTER	INTERIOR	GAGE	RPM HEAD,CENTER	TORQUE,MAX/OPERATE HEAD	CENTER	THRUST,MAX/OPERATE
ROBBINS	105-144	75 TONS	3 ROBBINS 11 IN DIA DISC	2 ROBBINS 12 IN DIA DISC	6 ROBBINS 12 IN DIA DISC	6	KFTLB KFTLB280	KFTLB KFTLB	KLB KLB 230

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET TO BELT	4-100 HP MOTORS DRIVE HEAD	LASER	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
40	MT GREEN	SEDIMENTARY: LIMESTONE						
		FINE GRAINED, LIGHT						
	SAMPLE NO	GREY						
	EVG-2		NA	NA	100			

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
94	2.5	0	0	2.2	24.2	26.7	17.8	4.8	3.0	3.0	2.3	3.4	2.9		9.5

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

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

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

EVG-2 CURRENT: 1 SEPT. 1972

KEY

40A
TUNNEL DATA

TUNNEL

SIZE	SHAPE	GRADE
10 FT 4 IN	ROUND	+0.2PCT

VENTILATION

CFM	PRESS	EXHST	SIZE	HP
18		X	30 IN	90

WATER INFLOW

GPM
400

UTILITY LINES

AIR	WATER	PUMP
	3IN	

POWER SYSTEM

PRIMARY	SECONDARY
7200	480

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
RAIL	RAIL	RAIL
4CY CARS		
5T MOTOR		
24 IN GAGE		
54 LB RAIL		

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
NONE			

MACHINE EXCAVATION

MACHINE

MAKE	MODEL	WT
ROBBINS	105-144	75 TONS

CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES

CENTER	INTERIOR	GAGE
3 ROBBINS 11 IN DIA DISC	21 ROBBINS 12 IN DIA DISC	2 ROBBINS 12 IN DIA DISC

RPM	TORQUE,MAX/OPERATE		THRUST,MAX/OPERATE
HEAD,CENTER	HEAD	CENTER	
6	KFTLB KFTLB246	KFTLB KFTLB	KLB KLB 230

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET TO BELT	4-100 HP MOTORS DRIVE HEAD	LASER	KLB

CONVENTIONAL EXCAVATION

MACHINE
JUMBO
MACHINES

FEED LENGTH

ROUND,
NO. HOLES
DEPTH
DIAM.
CUT,

EXPLOSIVES,
POWDER FACTOR
TOTAL LBS
PRIMERS,
TRIM
INTERIOR
CUT
LIFTERS

BLASTING MUCK.NG GUIDANCE

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
41	LAYOUT	SEDIMENTARY: SANDSTONE MEDIUM GRAINED, LIGHT BROWN TO RED, MASSIVE, POROUS, POORLY CEMENTED.						
	SAMPLE NO							
	LAY-1		159	10	84	NA	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	21.20	17.06	15.17	3.14	6.00	0.52

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.6 PCT MOIST	APPARENT COHESION PSF AT 3.6 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.6 PCT MOIST
2.66	37	35	27	210	97.4	38

LAY-1 CURRENT: 1 SEPT. 1972

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
12FT 11IN	ROUND	+0.125PCT	15-17K		X	36IN	100	20-100	6IN	3.5IN	8IN	7300V	480V

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

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-.27	125 TONS	1 ROBBINS 11IN STEEL THIPLE DISC	23 ROBBINS 11IN STEEL DISC	6 ROBBINS 12IN STEEL DISC	5.2 INTEG OR 2.6	KFTLB NA KFTL8498AV	KFTLB KFTLB	KLB 900 KLB 357AV

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/30 FT
KLB 1000	BUCKETS FROM FACE+ 30IN CONVEYOR TO REAR	6-100HP MOTORS FOR HEAD	LASER	KLB 2.73

CONVENTIONAL EXCAVATION

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

LAY-1 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
42	LAY	SEDIMENTARY: CONGLOMERATE WELL GRADED COBBLES TO						
	SAMPLE NO	PEBBLES OF QUARTZITE						
	LAY-2	POORLY CEMENTED WITH REDDISH BROWN SANDSTONE	NA	NA	85			

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) 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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	15.00	14.18	13.80	0.82	4.00	0.21

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 3.4 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.4 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.4 PCT MOIST	APPARENT COHESION PSF AT 3.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.0 PCT MOIST
2.65	38	32	32	15	88	39

LAY-2 CURRENT: 1 SEPT. 1972

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 11 IN	ROUND	+0.125PCT	15-7K		X	36IN	100	20-100	6IN	3.5IN	8IN	7300	460

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL 10 CY CARS 10T MOTOR 24 IN GAGE 65 LB RAIL	RAIL	RAIL			4 IN F FULL RINGS IN BAD 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	
ROBBINS	141-127	125 TON	1 ROBBINS 111N TRIPLE DISC	23 ROBBINS 11 IN DIA DISC	6 ROBBINS12IN DIA DISC	5.2 OR 2.6	KFTLB KFTLB491	KFTLB KFTLB	KLB KLB 585

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKETS TO BELT	6-100 HP MOTORS DRIVE HEAD	LASER	KLB 4.47

CONVENTIONAL EXCAVATION

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

LAY-2 CURRENT: 09/01/72

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
43	NAVAJO SAMPLE NO NAV-1	SEDIMENTARY: SILTSTONE, FINE GRAINED, GRAY, MORE THAN 33 PCT QUARTZ, 30 PCT CLAY, 10 PCT FELDSPAR, 15 PCT MICA, CHLORITE AND GYPSUM.	142	2	70	NA	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
86	8.1	0.0	12.1	7.4	6.9	5.9	2.2	0.6	I.3	1.8	2.I	5.9	9.3		44.5
		0.0	19.I	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 E=ELONGATED SP=SPHEROID

PI	PI	PI	PI	AI	SI	S	S	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.0561N. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
1.3	36.8C	23.6I	21.04	13.I9	7.00	I.8C

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 7.7 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 7.7 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 7.7 PCT MOIST	APPARENT COHESION PSF AT 7.5 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 7.5 PCT MOIST
3.I3	30	30	30	340	98	36

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 6IN	ROUND	+0.05PCT	18K		X	30IN	60	I	6IN		4IN	4160V	440V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL, 24IN GAGE 70LB, 16CY CARS 15TON MOTOR	RAIL	RAIL	3/4IN X 8FT OR 10FT SET IN EPOXY	5FT OR 13FT 16 GAGE		TO PREVENT AIR SLACKING

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	
ORESSER	TB-205	200 TONS	4IN CHISEL 6 KENNAMETAL TC PICK BITS	30 ORESSER STEEL DISC, 26 KENNAMETAL TCB PICK BITS	6 ORESSER TC DISCS	5 INTEG	KFTLB 879 KFTLB 586	KFTLB KFTLB	KLB 1583 KLB 431

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 6616	BUCKETS FROM FACE, 36IN CONVEYOR TO REAR	4-180HP DC MOTORS FOR HEAD 1-75HP MOTOR, HYDRAULICS	LASER	KLB 1.31

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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY	COMPR	RQD	.....HARDNESS.....		
44	NAVAJO	SEDIMENTARY: SANDSTONE GRAY MEDIUM GRAINED, MASSIVE,	WT	STRNTH	PCT	SHORE	MOH	SCHMIDT
	SAMPLE NO	FRIABLE AND POROUS. GRAINS	PCF	KPSI	EST			
	NAV-2	ANGULAR TO SUBROUNDED, PRIMARILY QUARTZ, POORLY CEMENTED.	117	LESS THAN 1.	60	NA	NA	NA

CORE DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	*.....PER CENT BY WEIGHT BETWEEN SCREENS.....*										PCT (-) NO200
			6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	
87	9.2	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 E=ELONGATED SP=SPHEROID

AI AI A AI AI RE AI A A

POT VOL CHANGE (-)0.056 IN.SIZE	*.....ATTERBERG LIMITS..SIZE(-) 0.056IN.....*					
	LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	18.20	16.91	16.60	1.29	4.50	0.28

(-)0.75 IN.SIZE SPECIF GRAVITY	*.....MATERIAL SIZE(-)2.0 IN.....*					SIZE(-)2.0 IN.
	ANGLE/REPOSE I IN DROP DEGREES AT 8.6 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 8.6 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 8.6 PCT MOIST	APPARENT COHESION PSF AT 8.1 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	ANGLE INTER FRICTION DEGREES AT 8.1 PCT MOIST
2.72	31	28	32	45	99	28

NAV-2 CURRENT: 1 SEPT. 1972

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 6IN	ROUND	+0.05PCT	18K		X	30IN	60	1	6IN		4IN	4160V	440V

HAULAGE SYSTEM			SUPPORT SYSTEM			
MUCK	PERSONNEL	SUPPLY	BOLT•TYPE SIZE	ROOF PLATE	SET•SIZE•SHAPE	SHOTCRETE
RAIL• 24IN GAGE 70LB RAIL• 16 CY CARS 15TON MOTOR	RAIL	RAIL	3/4IN X 8FT OR 10FT SET IN EPOXY	5FT OR 13FT 16 GAGE		TO PREVENT AIR SLACKING

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	
ORESSER	TB-205	200 TONS	4IN CHISEL 6 KENNAMETAL TC PICK BITS	30 ORESSER STEEL DISC• 26 KENNAMETAL TC PICK BITS	6 ORESSER TC DISC	5 INTEG	KFTLB 879 KFTLB 586	KFTLB KFTLB	KLB 1583 KLB 123

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB 616 6	BUCKETS FROM FACE• 36IN CONVEYOR TO REAR	4 -180HP DC MOTORS FOR HEAD 1-75HP MOTOR• HYDRAULICS	LASER	KLB 0.37

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
45	ROCHESTER	SEDIMENTARY: SANDSTONE FINE GRAINED, BROWN TO DARK RED, MASSIVE						
	SAMPLE NO RO-1		NA	NA	60			

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
89	4.3	0	0	2.0	9.0	12.0	13.0	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	PA	P	A	A	A	A

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

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

RO-I CURRENT: 1 SEPT. 1972

KEY

45A
TUNNEL DATA

TUNNEL SIZE	SHAPE	GRADE	VENTILATION CFM	PRESS	EXHST	SIZE	HP	WATER INFLOW GPM	UTILITY LINES AIR	WATER	PUMP	POWER SYSTEM PRIMARY	SECONDARY
18 FT 4 IN	ROUND	+0.045PCT	22K		X	48 IN	300	40	8IN	4IN	8IN	13200	440

HAULAGE SYSTEM

MUCK	PERSONNEL	SUPPLY
RAIL	RAIL	RAIL
10CY CARS		
36 IN GAGE		
1ST MOTOR		
50 LB RAIL		

SUPPORT SYSTEM

BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
5FT, 6FT, 8FTX	12FT 6IN OR		
5/8 IN 24 IN	8FT 6 IN X		
CENTER	8 IN, 14 GAGUE		

MACHINE EXCAVATION

MACHINE MAKE	MODEL	DIA	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES CENTER	INTERIOR	GAGE	RPM HEAD,CENTER	TORQUE,MAX/OPERATE HEAD	CENTER	THRUST,MAX/OPERATE
LAWRENC	HRT	NA	1-24IN TCB TRI CONE	24 DISC AND 2 TCB ROLLER	5 TBC ROLLER	11 30	KFTLB KFTLB364	KFTLB KFTLB	KLB KLB 492

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET TO BELT	ELECTRO-HYDRAULIC 960 HP	LASER	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
46.	WESTERN NUCLEAR SAMPLE NO WNG-I	SEDIMENTARY: SANDSTONE COARSE GRAINED. POORLY CONSOLIDATED. ARKOSIC. WITH MINOR LAYERS OF THIN SEAMED SILTSTONE.	125	LESS THAN 1.	30	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
92	10.5	0.0	0.0	0.0	0.0	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 (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	24.90	19.97	19.94	4.93	7.40	8.96

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 10.1 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 10.1 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 10.0 PCT MOIST	APPARENT COHESION PSF AT 10.6 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 10.6 PCT MOIST
2.71	34	31	32	0	85	27

WNG-1 CURRENT: 1 SEPT. 1972

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 8FT	RECT	+0.5PCT	5-7K	X	18IN			20-25	4IN			440V	110V

HAULAGE SYSTEM			SUPPORT SYSTEM				
MUCK	PERSONNEL	SUPPLY	BOLT+TYPE SIZE	ROOF PLATE	SET+SIZE+SHAPE	SHOTCRETE	
RAIL+ 24IN GAGE 40LB RAIL	RAIL	RAIL	NONE			IN BAD 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 MINER	F6-A	II TONS	72 KENNAMETAL U MOUNTED ON TWIN	43 K PICK BITS RIPPER HEADS		60	KFTLB KFTLB	KFTLB KFTLB		KLB KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
	GATHERING ARMS	440V ELECTRIC	TRANSIT	
KLB	14IN CHAIN CONV	MOTORS	LASER	KLB
	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			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIOT
47	WESTERN NUCLEAR SAMPLE NO WNG-2	SEDIMENTARY: SANDSTONE COARSE GRAINED, POORLY CONSOLIDATED, ARKOSIC, WITH MINOR LAYERS OF THIN SEAMED SILTSTONE, VARYING CONCENTRATIONS OF CARBONIFEROUS MATERIAL REPLACED BY SILICA.	125	LESS THAN 1.	30	NA	NA	NA

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
93	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		20.1
		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=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

AE	AE	AE	S	A	A	A	A	A	A	

PCT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	25.25	24.74	23.37	0.51	4.00	0.13

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE I IN DROP DEGREES AT 9.0 PCT MOIST	ANGLE/REPOSE IO IN DROP DEGREES AT 9.0 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 9.0 PCT MOIST	APPARENT COHESION PSF AT 9.0 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 9.0 PCT MOIST
2.72	32	31	40	0	86	28

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
SFT X FT	RECT	VARIES	S-7K	X	18IN			DRY	2IN	1IN		440V	110V

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
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 R01 MOOJS-AIRLEG	DEPTH 6FT DIAM. 1.5IN	TOTAL LBS 50, 40PCT GELEX 2 PRIMERS,	CAPS		
FEED LENGTH 6FT	CUT, BURN 5 HOLE	TRIM INTERIOR CUT			
	SF/HOLE 2.5	LIFTERS			

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
48	SAN FERNANDO SAMPLE NO SF-I	SEDIMENTARY: SANDSTONE ARKOSIC IPREGULARLY BEDDED, LOOSELY CONSOLIDATED WITH LAYERS AND LENSES OF SILTY MUDSTONE.	113		IS	NA	NA	NA

LESS THAN 1.

MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
91	18.5	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 S=SPHEROID

RE	SE	AI	AI	AI	AI	A	

POT VOL CHANGE (-)0.065 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.185IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	17.75	16.19	13.94	1.56	5.8	0.27

(-)0.185IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)0.185 IN. ANGLE/REPOSE I IN DROP DEGREES AT 14.3 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 14.3 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 12.5 PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK DENSITY PCF AT PCT MOIST	SIZE(-)0.185 IN. ANGLE INTER FRICTION DEGREES AT 13.0 PCT MOIST
2.86	38	33	36	NA	NA	42

KEY

48A
TUNNEL DATA

TUNNEL			VENTILATION					WATER INFLOW	UTILITY LINES			POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS FACE	EXIST	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
21FT	ROUND	+0.25PCT	20K		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	221S	285	HYDRAULIC	OPERATED RIPPER	TOOTH				
	RIPPER	TONS					KFTLB	KFTLB	KLB 7000
	SHIELD						KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
	BUCKET TO 6FT	HYDRAULIC	LASER	
KLB	CONVEYOR TO REAR			KLB

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			

KEY	IOENTIFICATION	ROCK PROPERTIES	ORY WT PCF	COMPR STRNTH KPSI	RQO PCT EST	.....HARONESS..... SHORE	MOH	SCHMIOT
49	SAN FERNANDO	SEOIMENTARY: SANOSTONE ANO BIOTITE RICH SILTSTONE.						
	SAMPLE NO SF-2	POORLY TO WELL CONSOLIOATEO. POORLY TO WELL SORTEO.	I42	2	50	NA	NA	NA

BUCK OATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	*.....PER CENT BY WEIGHT BETWEEN SCREENS..... 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
80	I7.5	0.0 I0	0.0 I0	0.0	8.6	I4.4	34.6	0.5	0.6	0.8	I.5	9.5	I0.5	I9.0	

SCHEFN ANALYSIS: UPPER LINE. ORY SCREENEU (ASTM CI36). AFTER WASHING (ASTM CII7). LOWER LINE. SCREENEO BEFORE DRYING

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

	PE	PE	NA	RS	RS	SI	SI	SI	SI	SI	SI

POT VOL CHANGE (-)0.056 IN.SIZE	*.....ATTERBERG LIMITS..SIZE(-) 0.056IN..... LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	3I.5	26.8	2I.5	4.7	7.6	0.6I

(-)0.75 IN.SIZE SPECIF GRAVITY	*.....MATERIAL SIZE(-)I.0 IN.....* ANGLE/REPOSE I IN DROP OEGREES AT I5.I PCT MOIST	ANGLE/REPOSE I0 IN DROP OEGREES AT I5.I PCT MOIST	ANGLE/SLIDE STEEL PLATE OEGREES AT I5.I PCT MOIST	APPARENT COHESION PSF AT PCT MOIST	BULK OENSITY PCF AT PCT MOIST	SIZE(-)I.0 IN. ANGLE INTER FRICTION DEGREES AT IS PCT MOIST
3.02	3P	36	30	NA	NA	27

KEY

49A
TUNNEL DATA

TUNNEL			VENTILATION					WATER INFLOW	UTILITY LINES			POWER SYSTEM	
SIZE	SHAPE	GRADE	CFM	PRESS FACE	EXHST X	SIZE	HP	GPM	AIR	WATER	PUMP	PRIMARY	SECONDARY
21FT	ROUND	+0.25PCT	20K			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	22IS RIPPER SHIELD	285 TONS		HYDRAULIC	OPERATED RIPPER	TOOTH		KFTLB KFTLB	KFTLB KFTLB	KLB 7000 KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
KLB	BUCKET TO 6FT CONVEYOR TO REAR	HYDRAULIC	LASER	KLB

CONVENTIONAL EXCAVATION

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

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	ROD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
50	KERR-MCGEE SAMPLE NO KM-I	SEDIMENTARY: MUDSTONE, DARK GRAY, FINE GRAINED, MASSIVE.	144	II	90	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	PER CENT BY WEIGHT BETWEEN SCREENS 6IN.	3IN.	2IN.	IIN.	I/2IN.	NO4	NO8	NOI6	NO30	NO50	NOI00	NO200	PCT (-) NO200
81	9.4	0.0	0.0	5.9	I.9	5.2	28.9	0.3	I.3	2.7	5.4	6.3	I2.5		29.6
		46.7	20.I	8.4	II.0	6.4	3.3								

SCREEN ANALYSIS: UPPER LINE, DRY SCREENED (ASTM CI36), AFTER WASHING (ASTM CII7), 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	PE	PI	PI	PI	A	A	A	A	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	28.30	24.97	I9.I2	3.33	3.60	0.92

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.00 IN. ANGLE/REPUSE I IN DROP DEGREES AT 12.7 PCT MOIST	ANGLE/REPOSE I0 IN DROP DEGREES AT 12.7 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 12.7 PCT MOIST	APPARENT COHESION PSF AT I0.9 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT I0.9 PCT MOIST
2.87	29	28	31	37	79	35

KM-1 CURRENT: I SEPT. 1972

KEY

50A
TUNNEL DATA

TUNNEL SIZE	SHAPE	GRADE	VENTILATION CFM	PRESS FACE	EXHST VENT	SIZE	HP	WATER INFLOW GPM	UTILITY LINES AIR	WATER	PUMP	POWER SYSTEM PRIMARY	SECONDARY
10FT X 9FT	RECT	+0.5PCT	5K			24IN	25	DRY					

HAULAGE SYSTEM MUCK	PERSONNEL	SUPPLY	SUPPORT SYSTEM BOLT,TYPE SIZE	ROOF PLATE	SET,SIZE,SHAPE	SHOTCRETE
RAIL, 36IN GAGE 45LB RAIL	RAIL	RAIL			4IN WF STEEL SETS AT 3FT OR 6FT	

MACHINE EXCAVATION

MACHINE MAKE	MODEL	WT	CUTTERS,MAKE,TYPE,DIAM,CUTTING EDGES CENTER	INTERIOR	GAGE	RPM HEAD,CENTER	TORQUE,MAX/OPERATE HEAD	CENTER	THRUST,MAX/OPERATE
ALPINE	F6-A	11	40 KENNAMETAL U	43 KH PICK BITS.	MOUNTED	78			
MINER		TONS	ON TWIN RIPPER	HEADS			KFTLB	KFTLB	KLB
							KFTLB	KFTLB	KLB

ANCHOR PRESS	MUCK SYSTEM	POWER SYSTEM	GUIDANCE	THRUST/SQ FT
	GATHERING ARMS	ELECTRIC MOTORS	TRANSIT	
KLB	14IN FLIGHT	50.4HP HEAD	LASER	KLB
	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			

KM-1 CURRENT: 09/01/72

APPENDIX C

SYSTEM DATA SHEETS

APPENDIX C

SYSTEM DATA SHEETS

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: NA

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 hydraulic motors.
Guidance System: Laser.

MUCK DATA

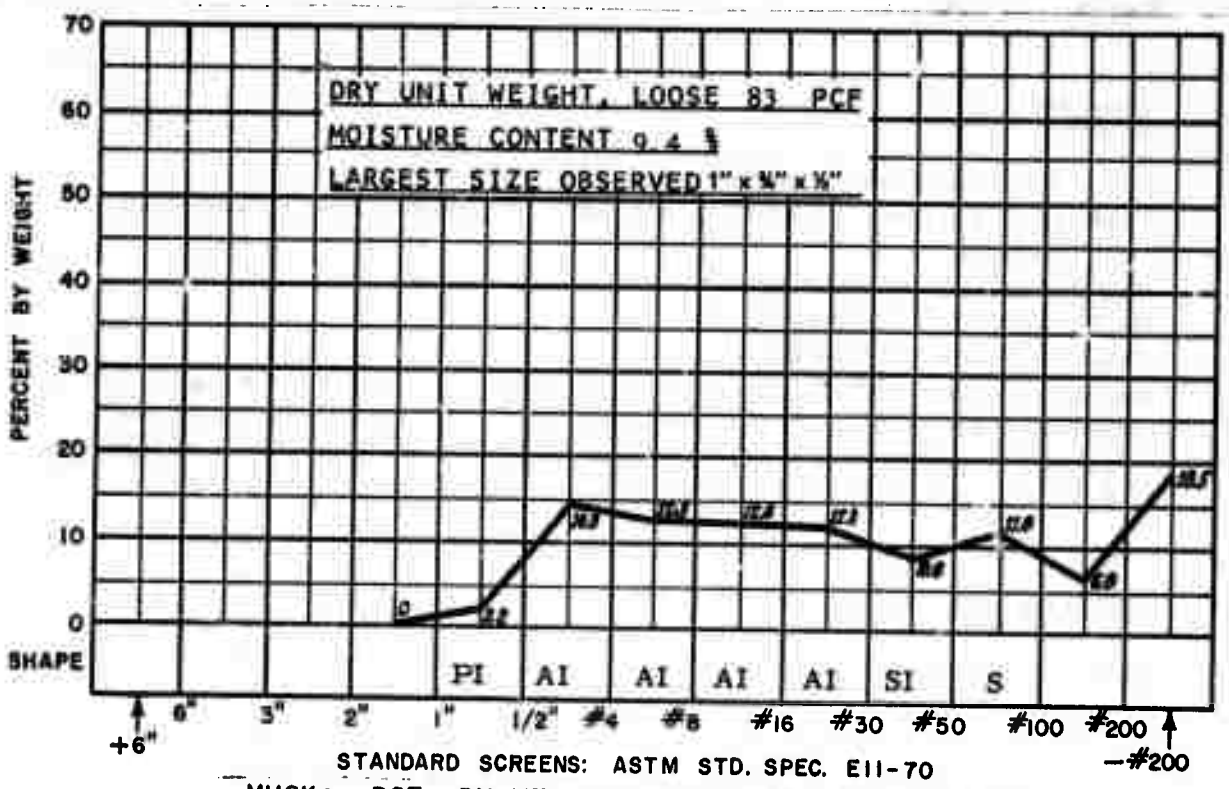
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.065" : 0	Size (-) 0.50" : 2.69

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	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 9.0 % Moisture, 37°	@ % Moisture, NA	@ 9.0 % Moisture, 36°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 9.0 % Moisture, 41°	@ % Moisture, NA	@ 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: NA

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.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. NAST-1
9/1/72	MDN	Sheet 2

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: NA

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 hydraulic motors and cylinders.
Guidance System: Laser.

MUCK DATA

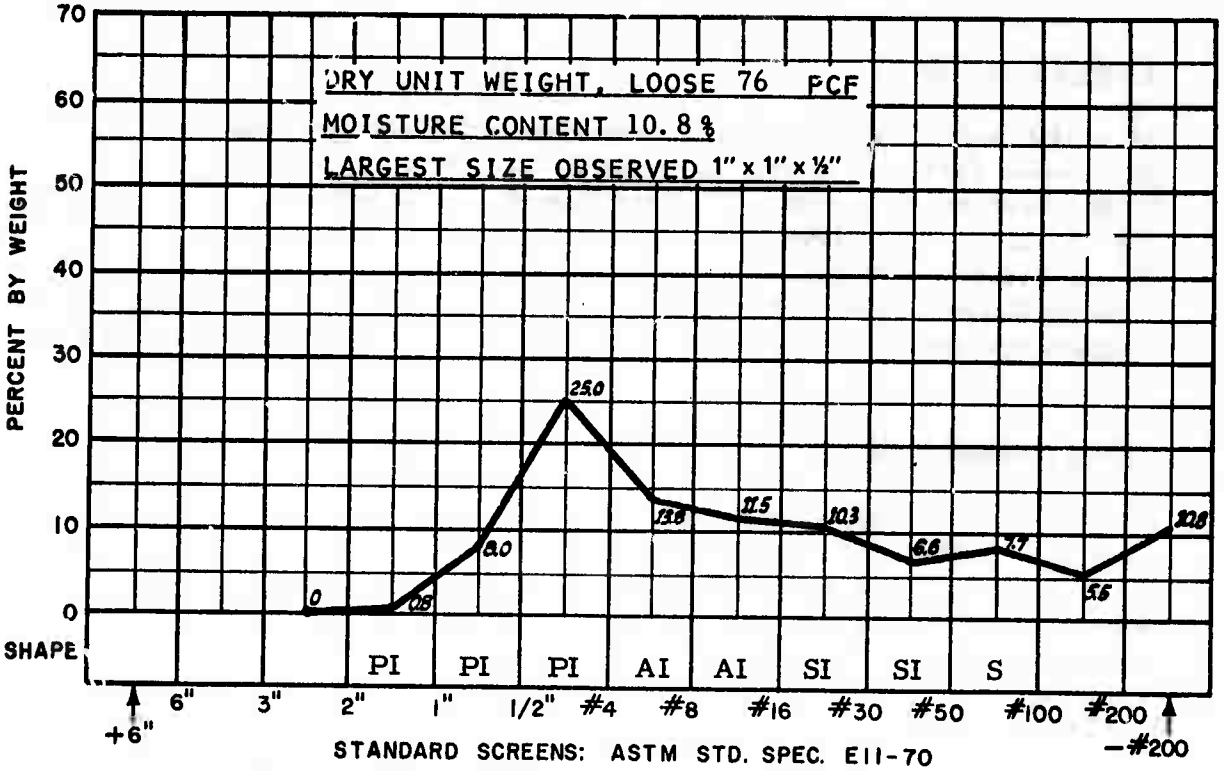
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-) 0.50" : 2.66

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°	@ % Moisture, NA	@ 8.7 % Moisture, 38°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 8.7 % Moisture, 49°	@ % Moisture, NA	@ 8.5 % Moisture, 31°



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: NA.

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 halt sets, roof plates and rock bolts.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. NAST-2 Sheet 2

ROCK DATA:

Lithology: Igneous, biotitic granite, fine grained, with major quartz and minor feldspar and dark mineral contents.
Uniaxial Compressive Strength: 13 KPSI.
RQD: (Estimated) 90%.
Dry Unit Weight: 152 PCF.
Ground Water: Minor, from fault zones.
Hardness: NA

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.

MUCK DATA

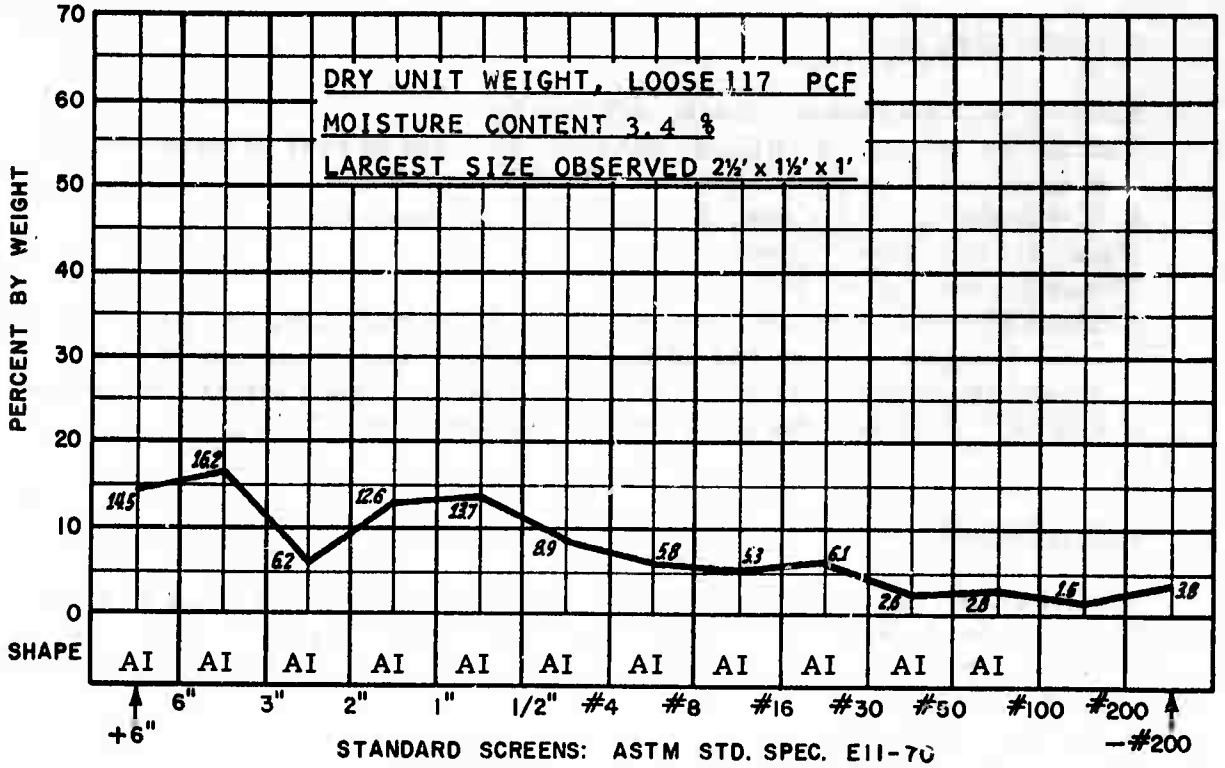
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 2.65

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 @ 2.8 % Moisture, 39°	Apparent Cohesion PSF @ 3.0 % Moisture, 80	Angle/Repose 10" Drop @ 2.8 % Moisture, 36°
Angle Slide Steel Plate @ 2.8 % Moisture, 31°	Bulk Density PCF @ 0.0 % Moisture, 91.2	Angle Internal Friction @ 3.0 % Moisture, 38°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, biotitic, fine grained. Medium strength. RQD (Est.) 90%. DUW: 152 PCF. Ground water: Minor. Hardness: NA.

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.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. NAST-3
9/1/72	MDN	Sheet 2

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: NA

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 hydraulic motors and cylinders.
Guidance System: Laser.

*Modified by replacement of original by a Hughes Tool Co. cutting head and cutters.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. NAST-4 Sheet 1

MUCK DATA

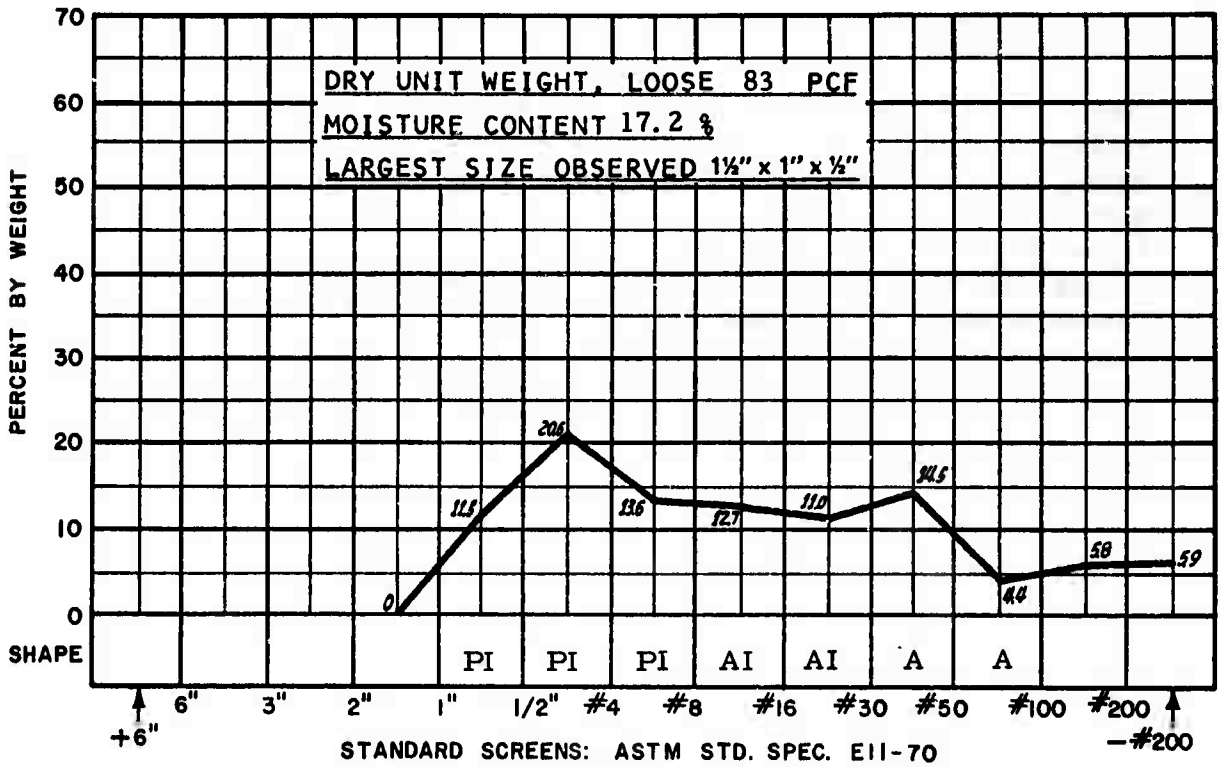
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056 : 0	Size (-) 0.75 : 2.64

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	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 6.9 % Moisture, 39°	@ 7.1 % Moisture, 0	@ 6.9 % Moisture, 34°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 6.9 % Moisture, 40°	@ 0.0 % Moisture, 91	@ 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: NA

System Class: TBM, Wirth Erkelenz, Hardrock, with Hughes Tool head, 9' 10" dia. 29 Hughes Tool TCB roller and cone cutters. RPM: 8 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.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. NAST-4
9/1/72	MDN	Sheet 2

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: NA

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.

MUCK DATA

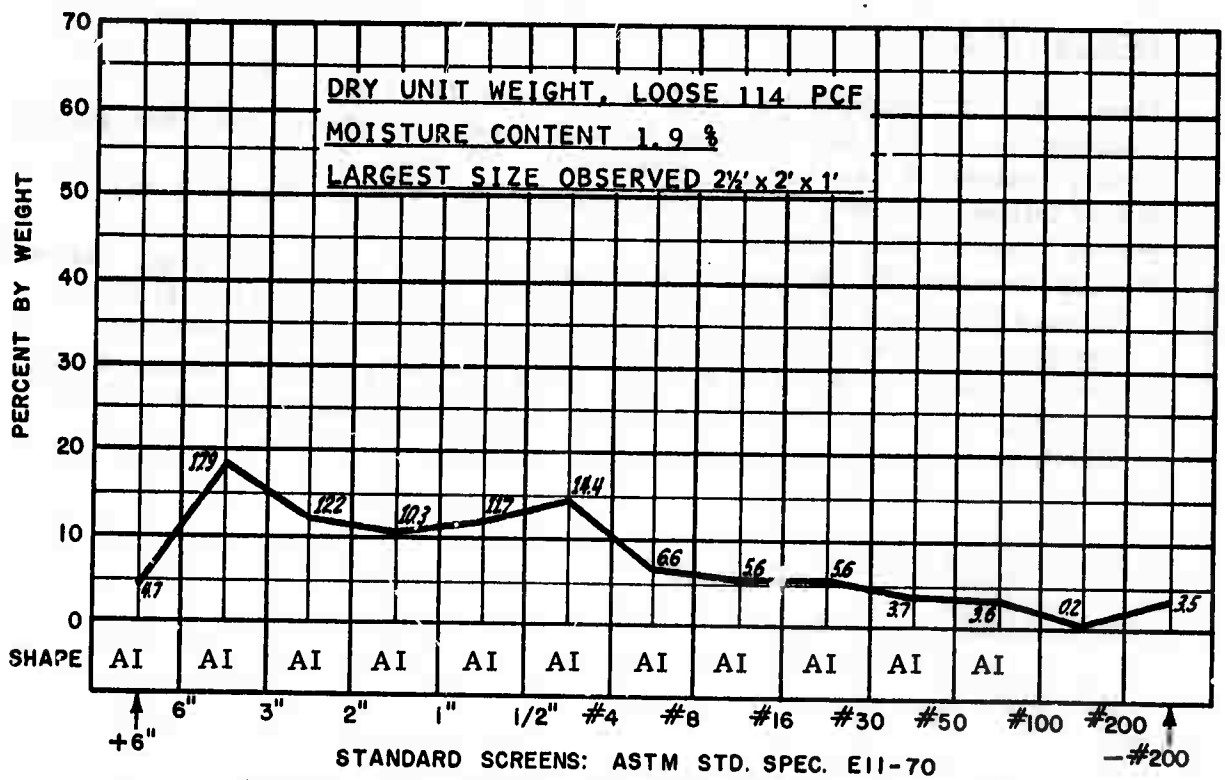
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.59

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: NA

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'.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. GA-1
Sheet 2

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: NA

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. Smooth-tex 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

MUCK DATA

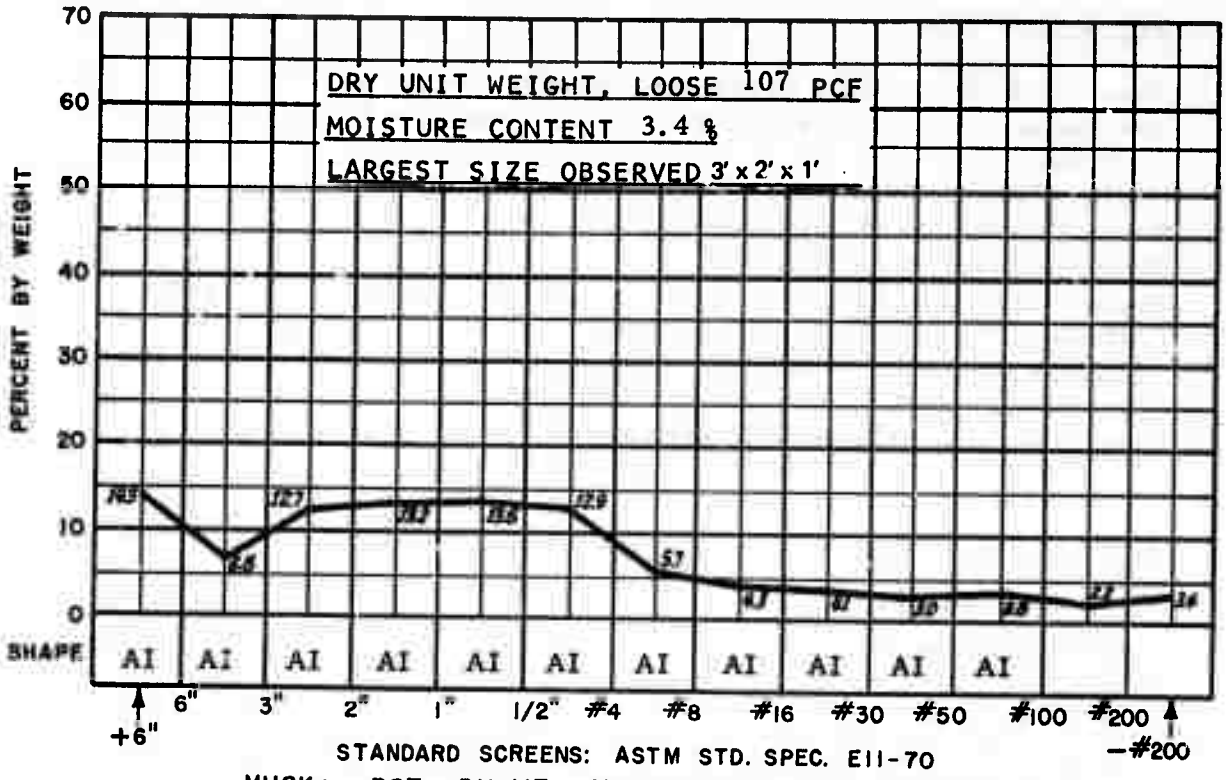
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 2.70

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 18.0%	Plastic Limit 17.0 %	Shrinkage Limit 13.4 %
Plasticity Index 1.0 %	Toughness Index 0.23 %	Flow Index 4.4 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 1.3 % Moisture, 40°	@ % Moisture, NA	@ 1.3 % Moisture, 37°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 1.3 % Moisture, 32°	@ % Moisture, NA	@ 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: NA.

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: NA

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-15T. 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 5.6#/CY.
Mucking: EIMCO #25, rail, air operated
Guidance: Laser

MUCK DATA

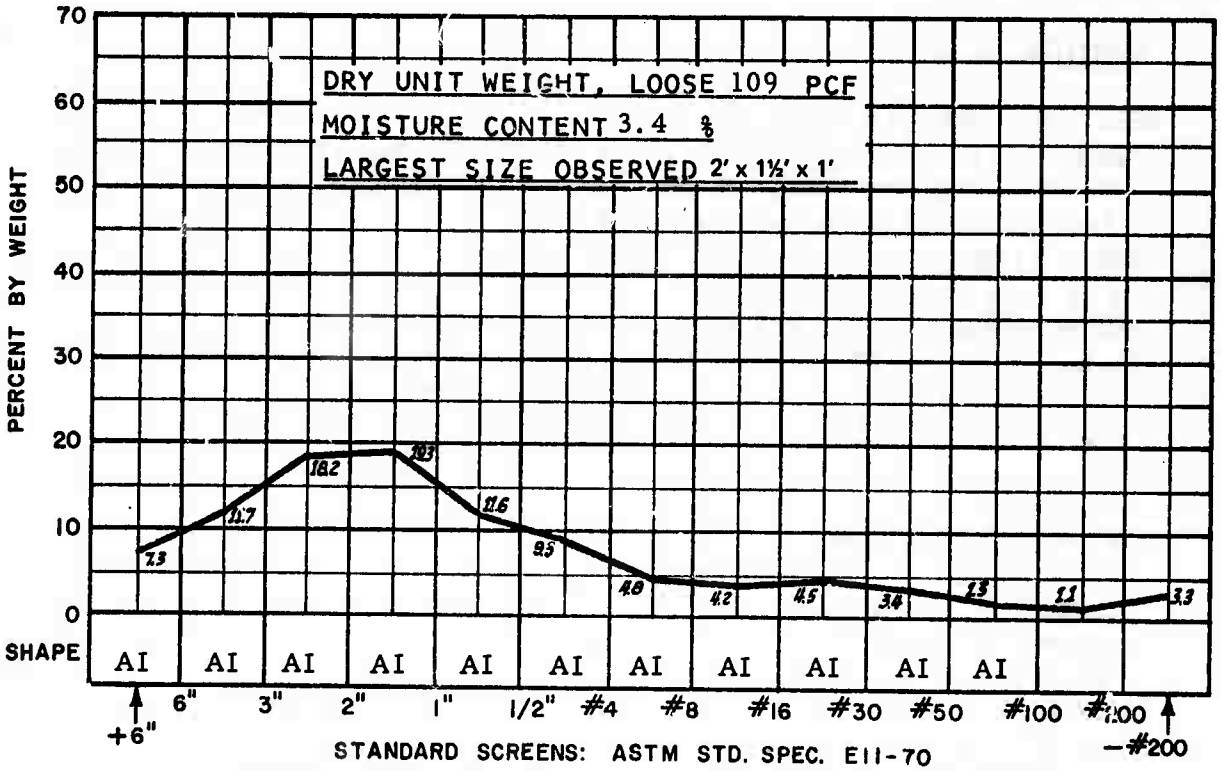
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.60

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°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, gneissic, moderately jointed. Very high strength. RQD (Est.) 80%. DUW: 164 PCF. Ground water: Minor. Hardness: NA

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 36 to 40 - 11' holes, burn cut. PF 5.6#/CY. Overhead loader mucking - rail haulage. Support: occasional rock bolts 7200' to 10,000'.

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: NA

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.

MUCK DATA

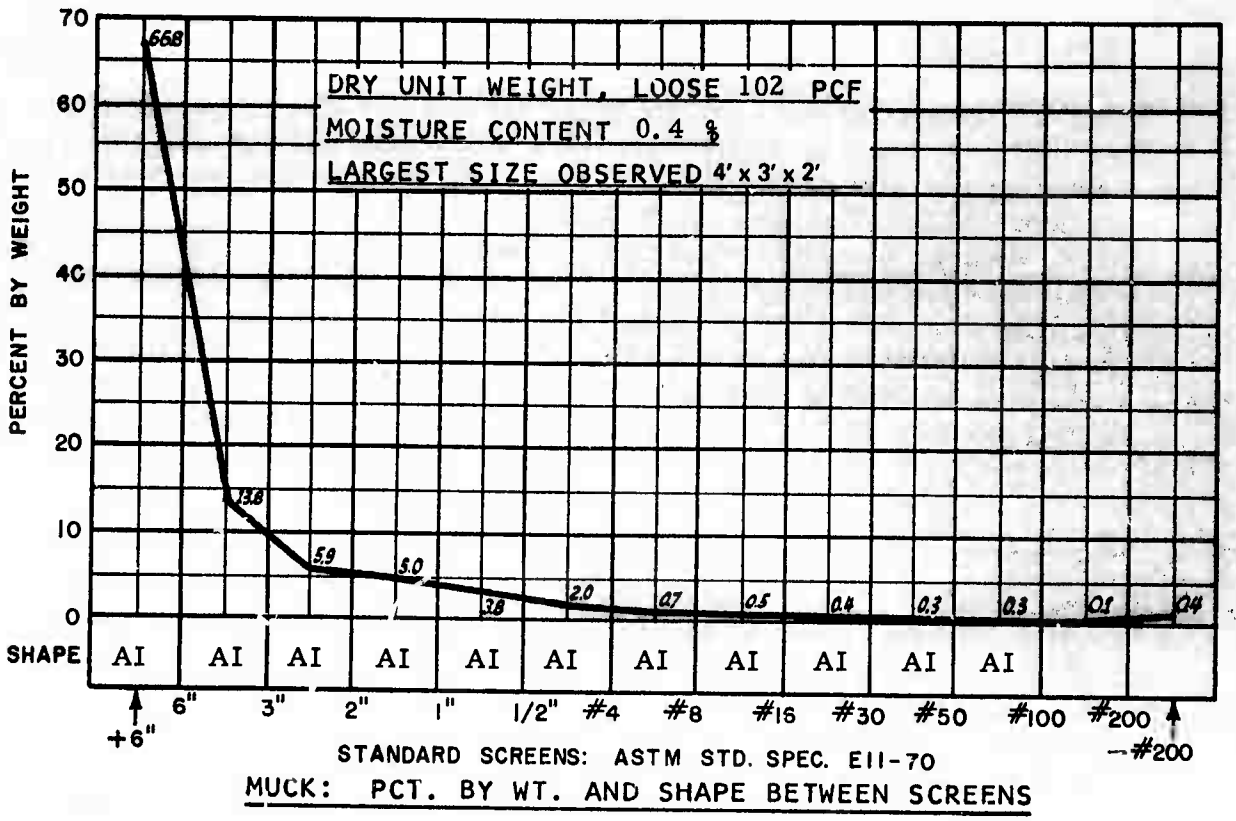
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.85

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: NA.

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	SYSTEM DATA SHEET	Ident. No. LK-1
9/1/72	MDN	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: NA

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 2%.
Ventilation System: 72 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.

MUCK DATA

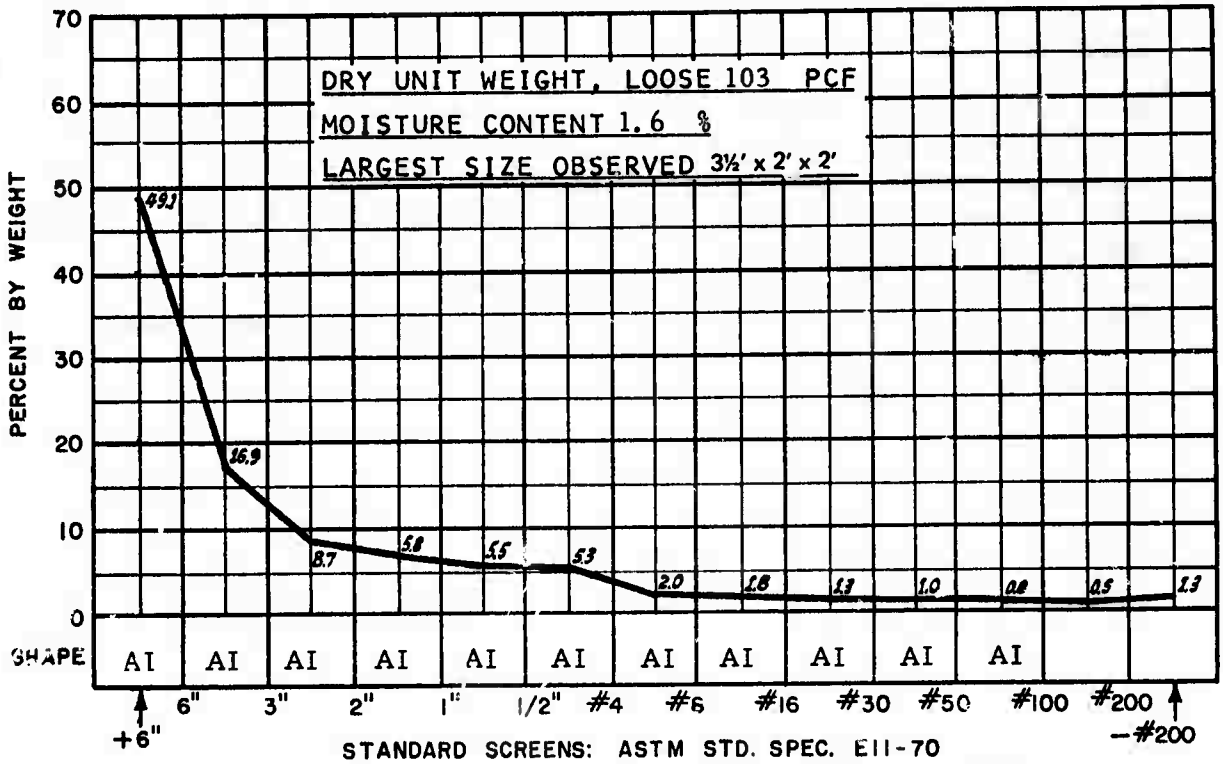
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75": 2.73

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: NA

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	SYSTEM DATA SHEET	Ident. No. LK-2
9/1/72	MDN	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: NA

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 FSI, 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.

MUCK DATA

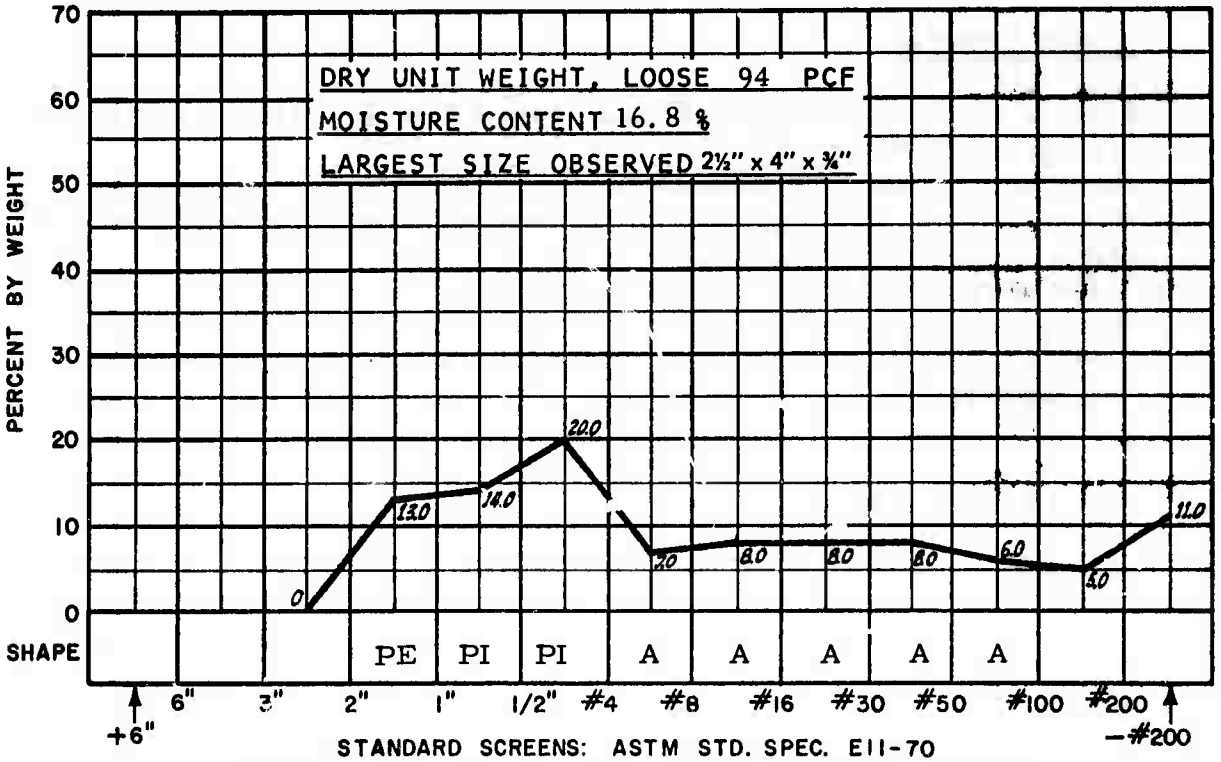
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.056": 2.67

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 25.00 %	Plastic Limit 20.95 %	Shrinkage Limit 19.68 %
Plasticity Index 4.05 %	Toughness Index 0.73 %	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°



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: NA.

System Class: RBM, Robbins H81R, 12' dia. 27 Robbins disc cutters, 6 RPM, 383.5 Kft. # torque, 507 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: (Estimated) 7 KPSI
RQD: (Estimated) 86%.
Dry Unit Weight: 137 PCF.
Ground Water: None apparent.
Hardness: N.A.

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.

MUCK DATA

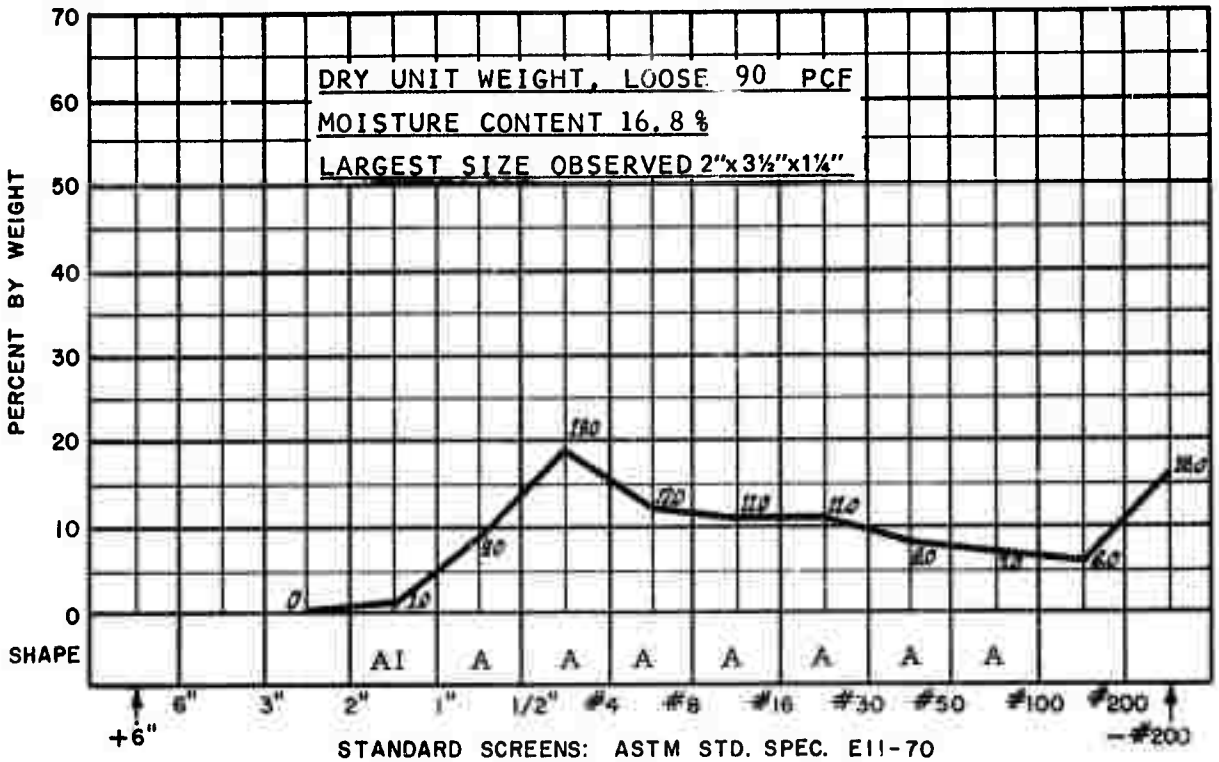
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.53

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. Low strength (Est.). RQD (Est.) 86%. DUW: 137 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 4' dia. 11 Robbins disc cutters. 6 RPM, 260 K ft # torque, 207 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: N.A.

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

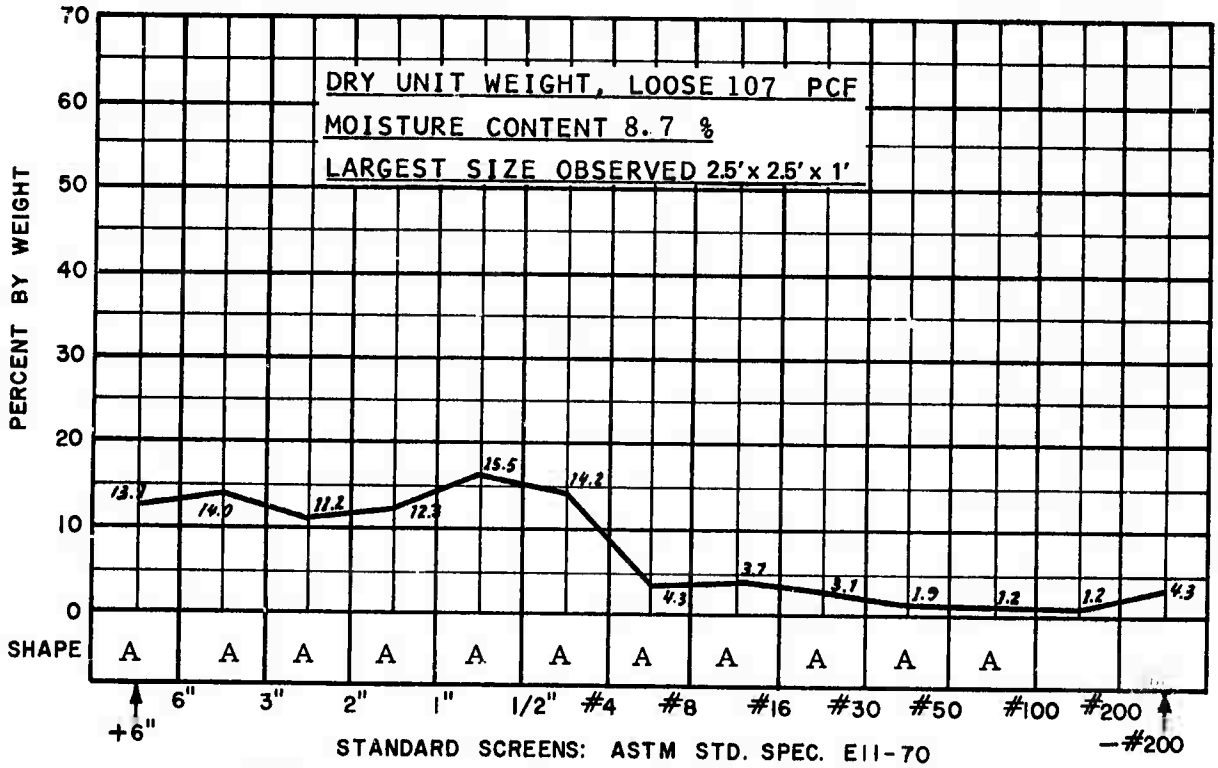
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 2.68

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	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 1.7 % Moisture, 29°	@ 0.2 % Moisture, 70	@ 1.7 % Moisture, 26°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 1.7 % Moisture, 28°	@ 0.0 % Moisture, 114	@ 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: N.A.

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: N.A.

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

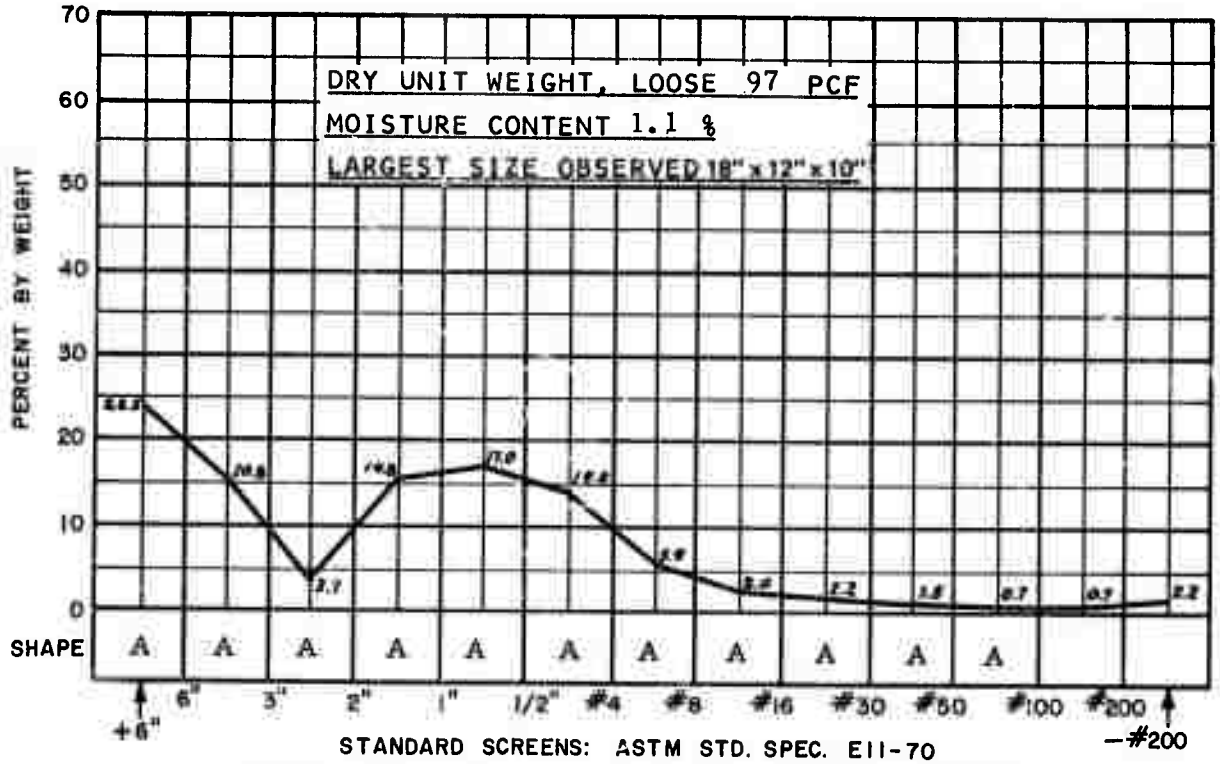
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size(-) 0.056" : 0	Size(-)0.75" : 2.72

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: N. A.

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'.

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: NA

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.

MUCK DATA

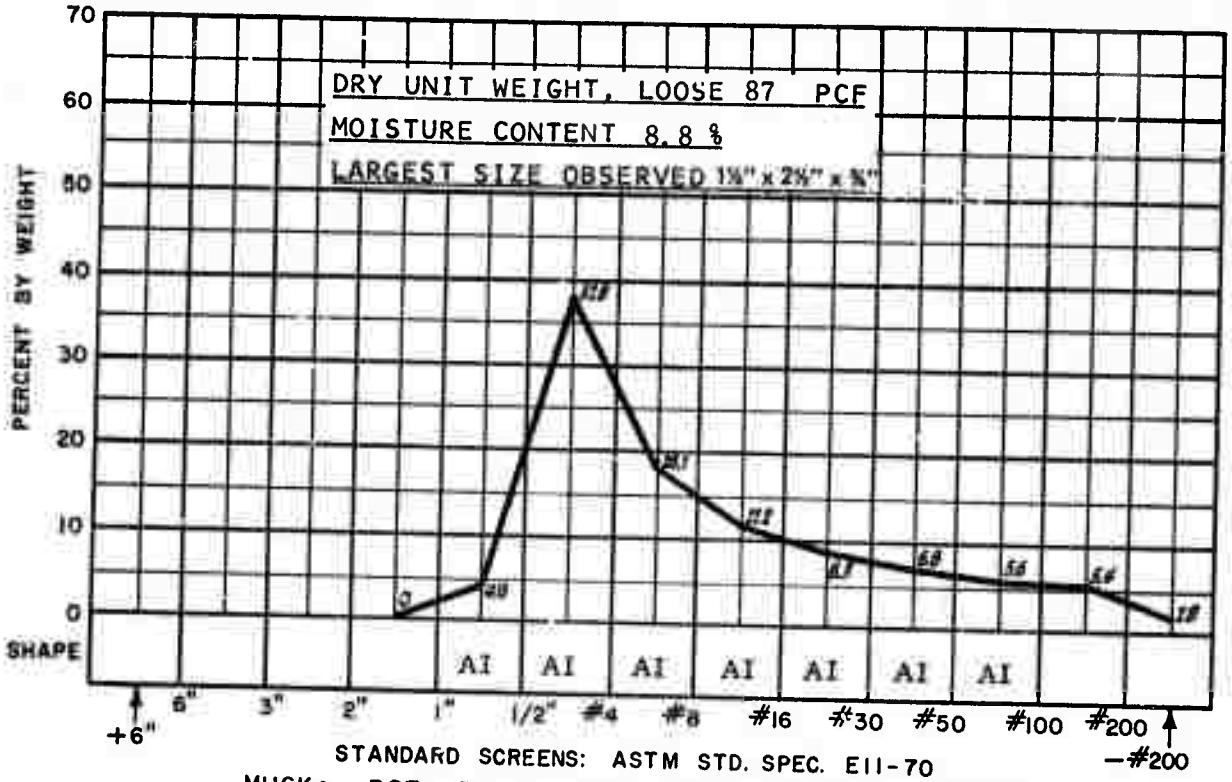
Abrasiveness N. A.	Pot. Vol. Change, Material Size : NA	Spec. Gravity, Material Size : NA

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: NA

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.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. CL-1
Sheet 2

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: NA

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. Undergrcund 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 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#/cy.
Blasting: Electrical, regular delays, 0 through 15.
Mucking: Scooptram.
Guidance: Laser.

MUCK DATA

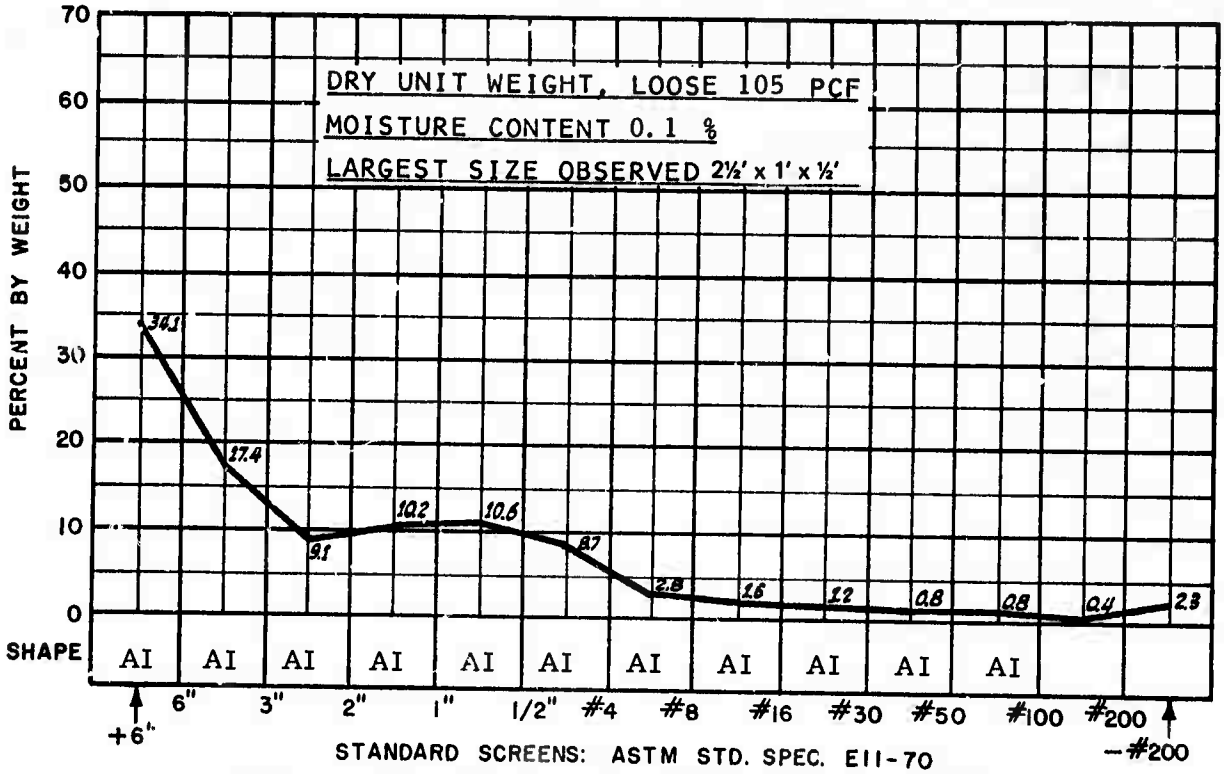
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 3.21

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: NA. 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
RQD: (Estimated) 70%
Dry Unit Weight: 181 PCF
Ground Water: None apparent.
Hardness: NA

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# - 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

MUCK DATA

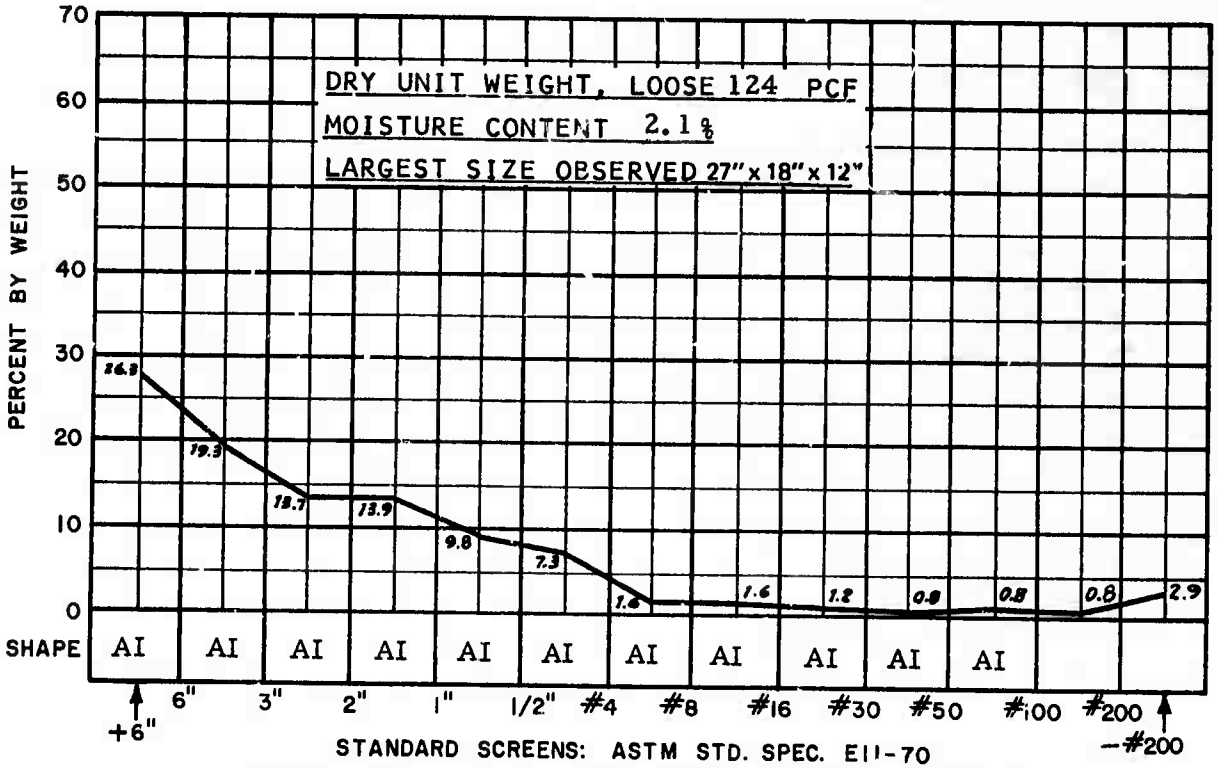
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 3.36

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 (Est.). RQD (Est.) 70%. DUW: 181 PCF. Ground water: Dry. Hardness: N.A.

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'.

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: NA

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.

MUCK DATA

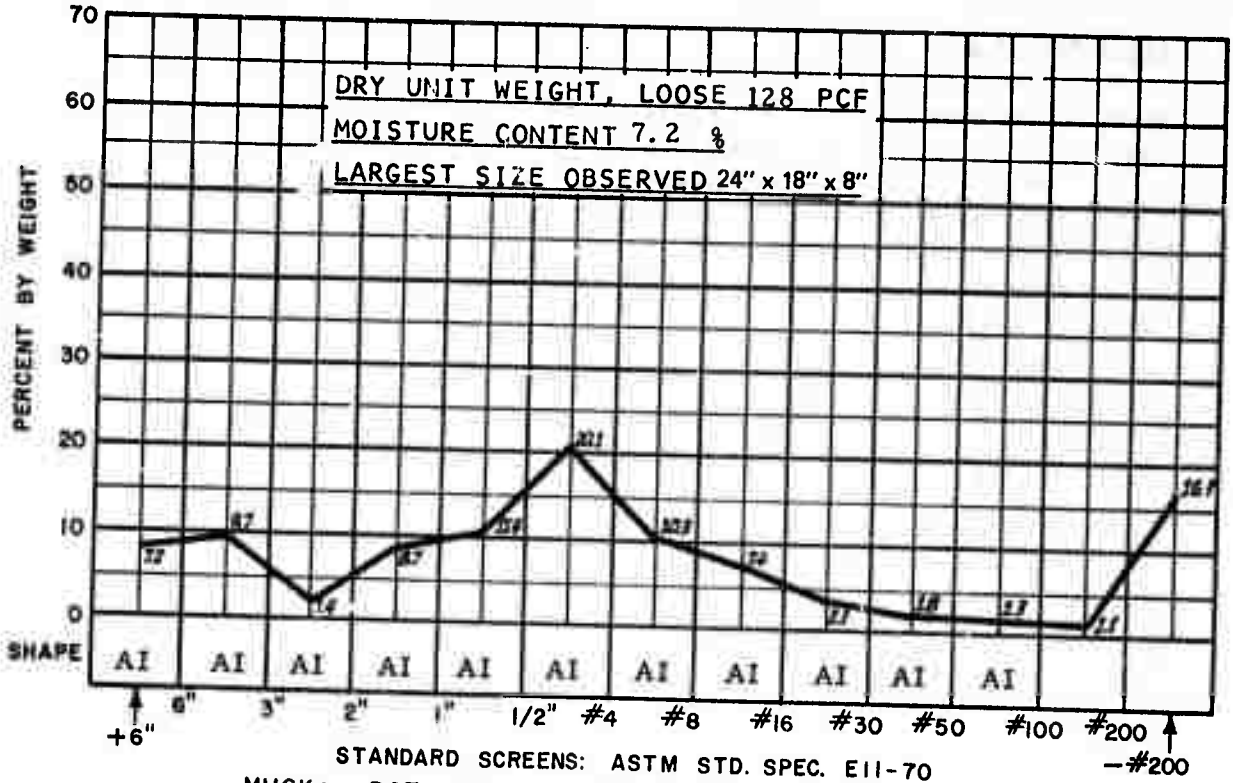
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-)0.056" : 0	Spec. Gravity, Material Size (-) 0.75" : 4.34

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 17.8 % Plasticity Index 2.7 %	Plastic Limit 15.1 % Toughness Index 0.66 %	Shrinkage Limit 13.9 % Flow Index 4.1 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 6.2 % Moisture, 37° Angle Slide Steel Plate @ 6.2 % Moisture, 31°	Apparent Cohesion PSF @ 6.9 % Moisture, 235 Bulk Density PCF @ 0.0 % Moisture, 141	Angle/Repose 10" Drop @ 6.2 % Moisture, 35° 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: NA.

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".

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. MB-1
Sheet 2

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: NA PSI
RQD: (Estimated) 10%.
Dry Unit Weight: NA
Ground Water: None
Hardness: NA

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 NA.

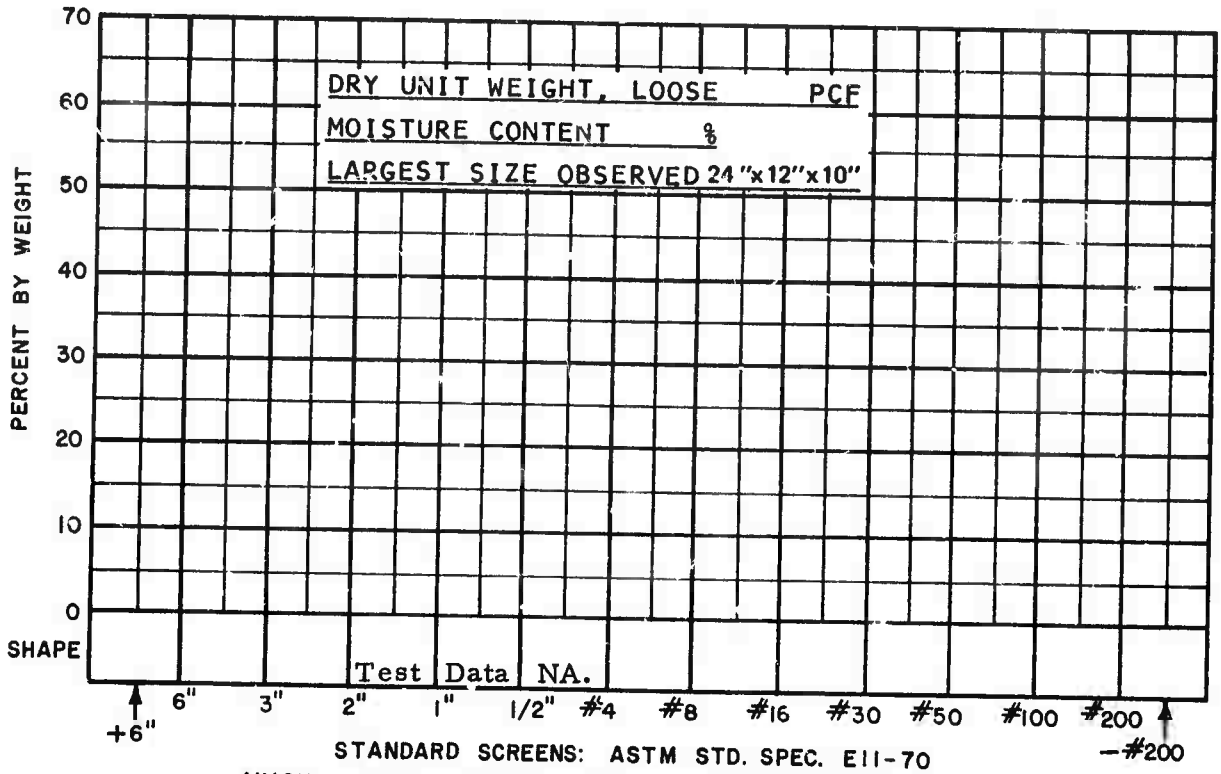
Abrasiveness	Pot. Vol. Change, Material Size :	Spec. Gravity, Material Size :
N. A.		

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit %	Plastic Limit %	Shrinkage Limit %
Plasticity Index %	Toughness Index %	Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisture,



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: NA. Ground water: Dry. Hardness: NA.

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.

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 Strenght: NA KPSI
RQD: 75% (Estimated for vertical hole).
Dry Unit Weight: NA PCF
Ground Water: None
Hardness: NA

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: 5.4#/CY.
Mucking System: Atlas-Copco LM56 overhead.
Guidance: Transit lines.

MUCK DATA Test Data NA.

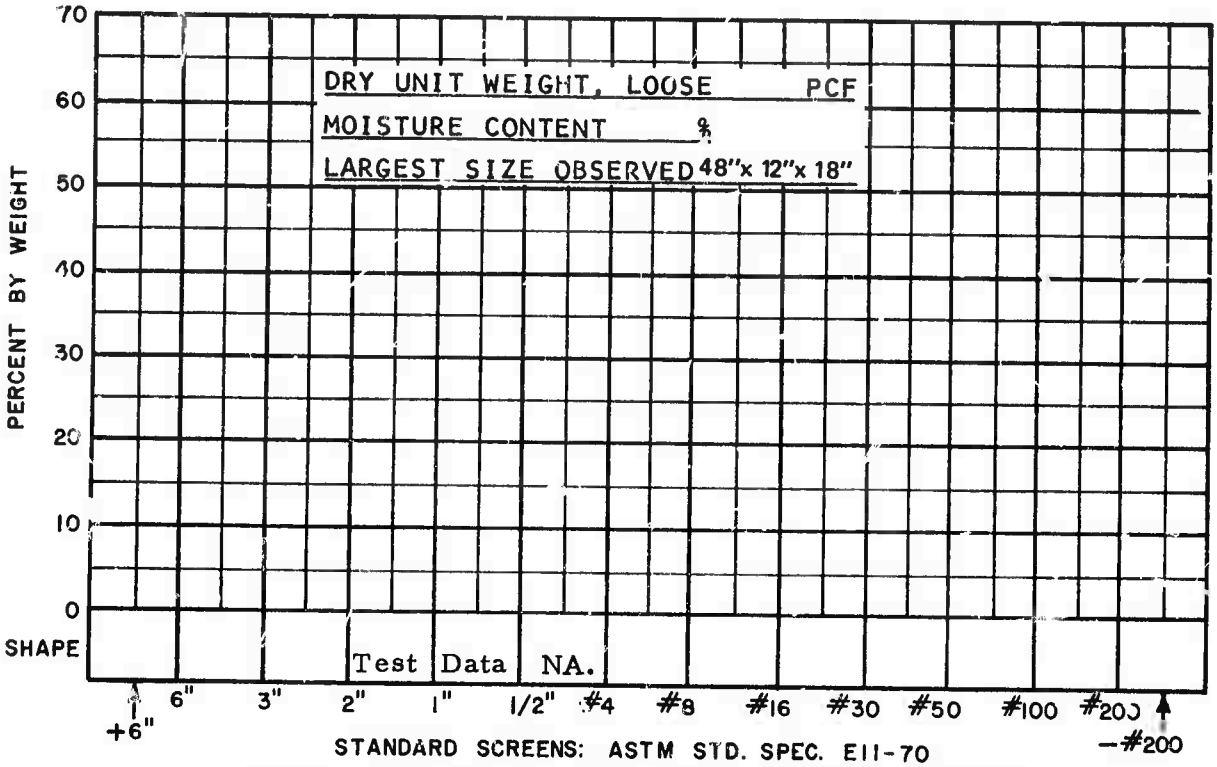
Abrasiveness	Pot. Vol. Change, Material Size :	Spec. Gravity, Material Size :
N. A.		

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit %	Plastic Limit %	Shrinkage Limit %
Plasticity Index %	Toughness Index %	Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisturc,



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Argillaceous quartzite, moderately fractured, moderately to highly folded, medium to thin bedded. Strength: NA. RQD (Est.) 75%. DUW: NA. Ground water: None. Hardness: NA.

System Class: Conventional Rail: 9' x 10'7", 3 boom jumbo, 44-7' holes, burn cut. PF 5.4 #/CY. Mucking: Atlas Copco LM56. Haulage: Rail. Support: Rockbolts and mats.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. ST-1
Sheet 2

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: NA
RQD: (Estimated) Vertical: 50%, horizontal 20-30%.
Dry Unit Weight: NA
Ground Water: Minor
Hardness: NA

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.

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 NA.

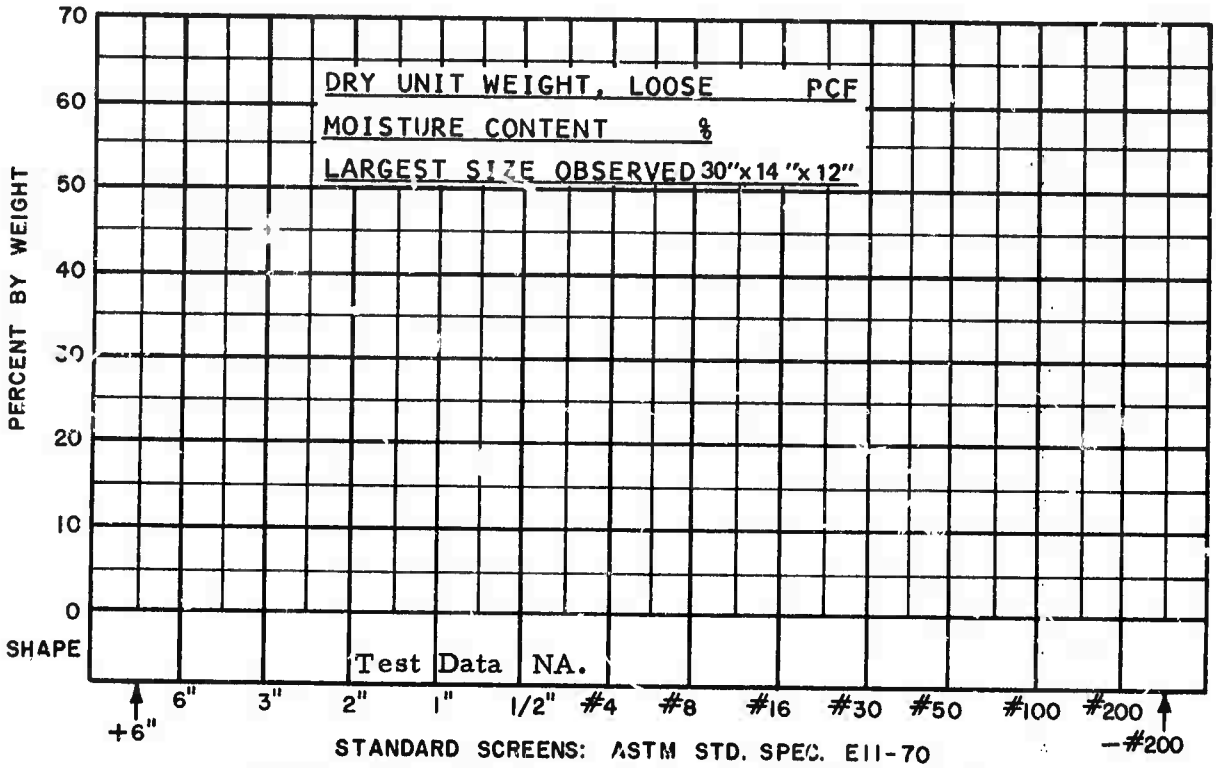
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size :	Size :

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit %	Plastic Limit %	Shrinkage Limit %
Plasticity Index %	Toughness Index %	Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,	Apparent Cohesion PSF @ % Moisture,	Angle/Repose 10" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,	Bulk Density PCF @ % Moisture,	Angle Internal Friction @ % Moisture,



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°. Strength: NA. RQD (Est.) 50%. DUW: NA. Hardness: NA.

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.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. CR-1 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: NA

TUNNEL DATA:

Size: 7'-6" wide x 8'-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

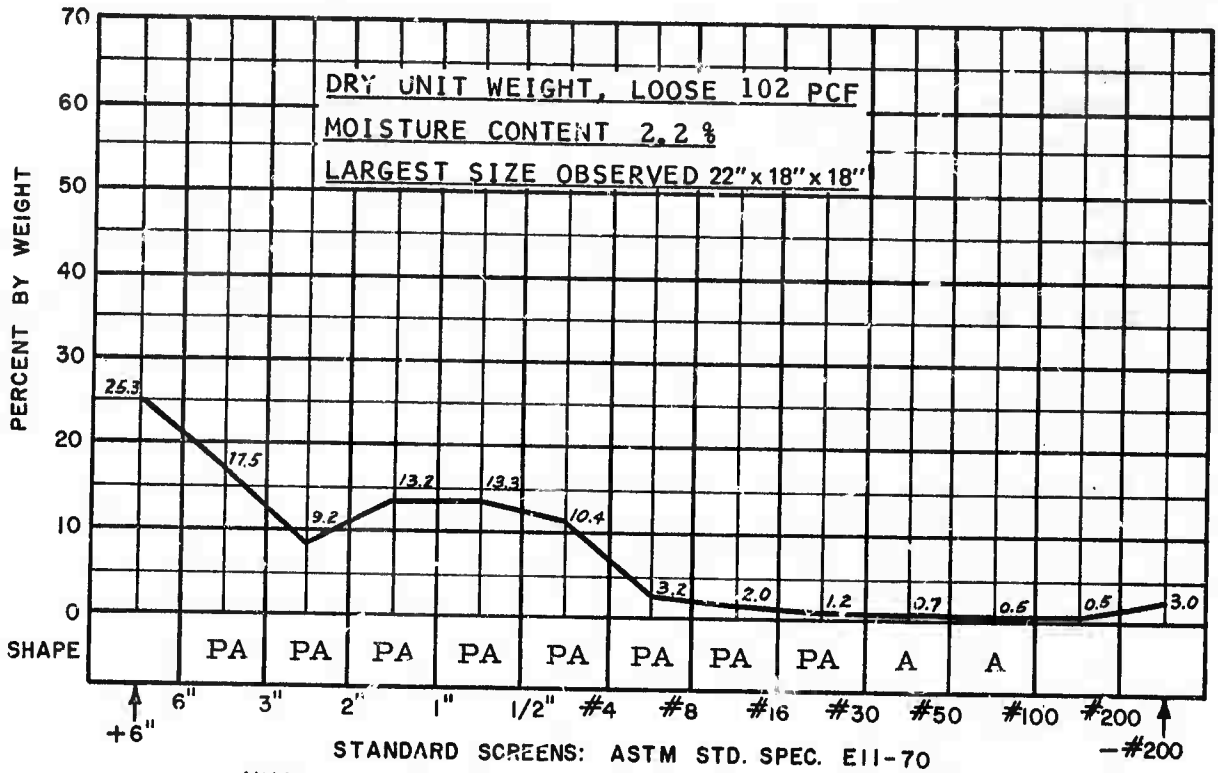
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.84

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: NA.

System Class: Conventional Rail. 7' 6" wide x 8' 6" arch, two air leg drills, 34-10' holes, burn cut. PF 7.0 #/CY. Mucking: Eimco 21. Haulage: Rail. Support: None.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. HS-1 Sheet 2

ROCK DATA:

Lithology: Metamoprhic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: NA
RQD: (Estimated) 80%.
Dry Unit Weight: NA
Ground Water: Dry
Hardness: NA

TUNNEL DATA:

Size: 11'-6" 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: NA RPM.
Torque: NA.
Thrust: NA.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

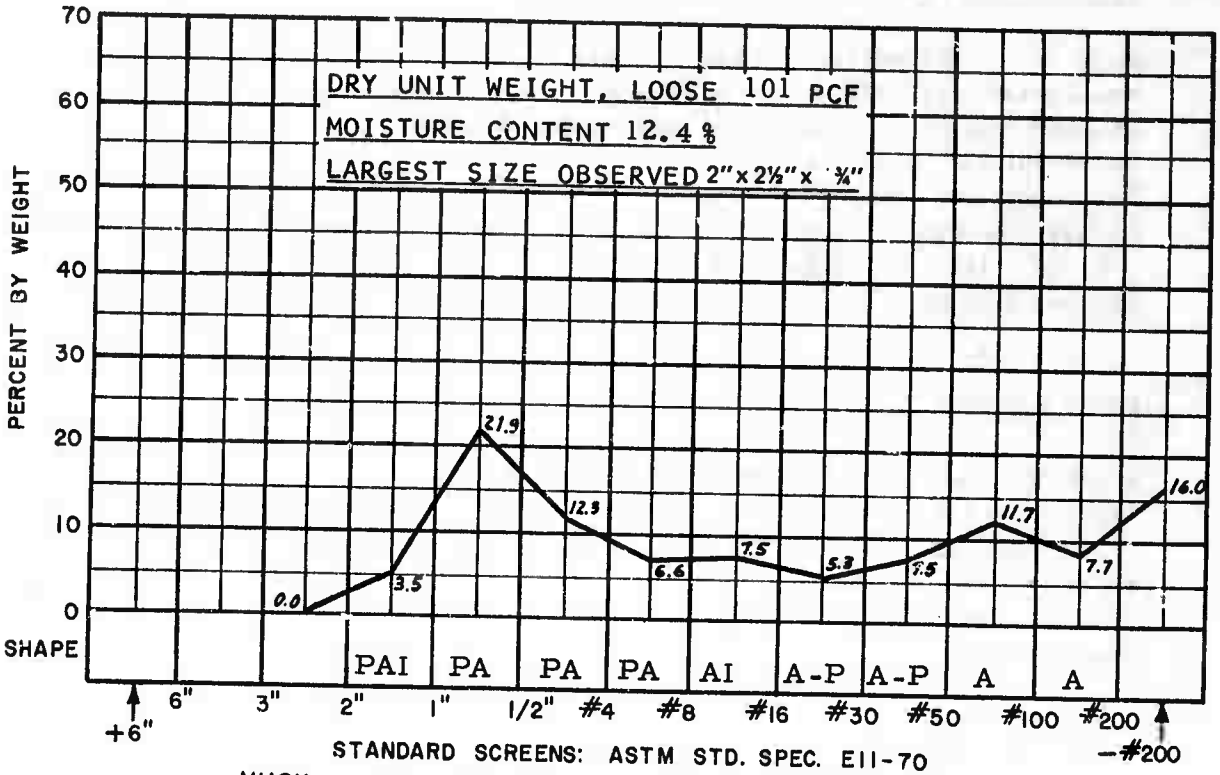
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size : NA	Size : NA

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: Mica schist, occasional quartz lamination. Strength: NA. RQD (Est.) 80%. DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM, Jarva 12-1100, 11'6" dia. 30 Reed and 6 Jarva discs. RPM: NA, Torque: NA, Thrust: NA. Mucking: Buckets to belt. Support: None.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NY-1
Sheet 2

ROCK DATA:

Lithology: Metamorphic, mica schist, occasional quartz laminations.
Uniaxial Compressive Strength: NA.
RQD: (Estimated) 90%.
Dry Unit Weight: NA.
Ground Water: Dry
Hardness: NA.

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: NA RPM.
Torque: NA.
Thrust: NA.
Muck Collection: Buckets from face, belt to rear.
Power System: NA.
Guidance: Laser.

MUCK DATA

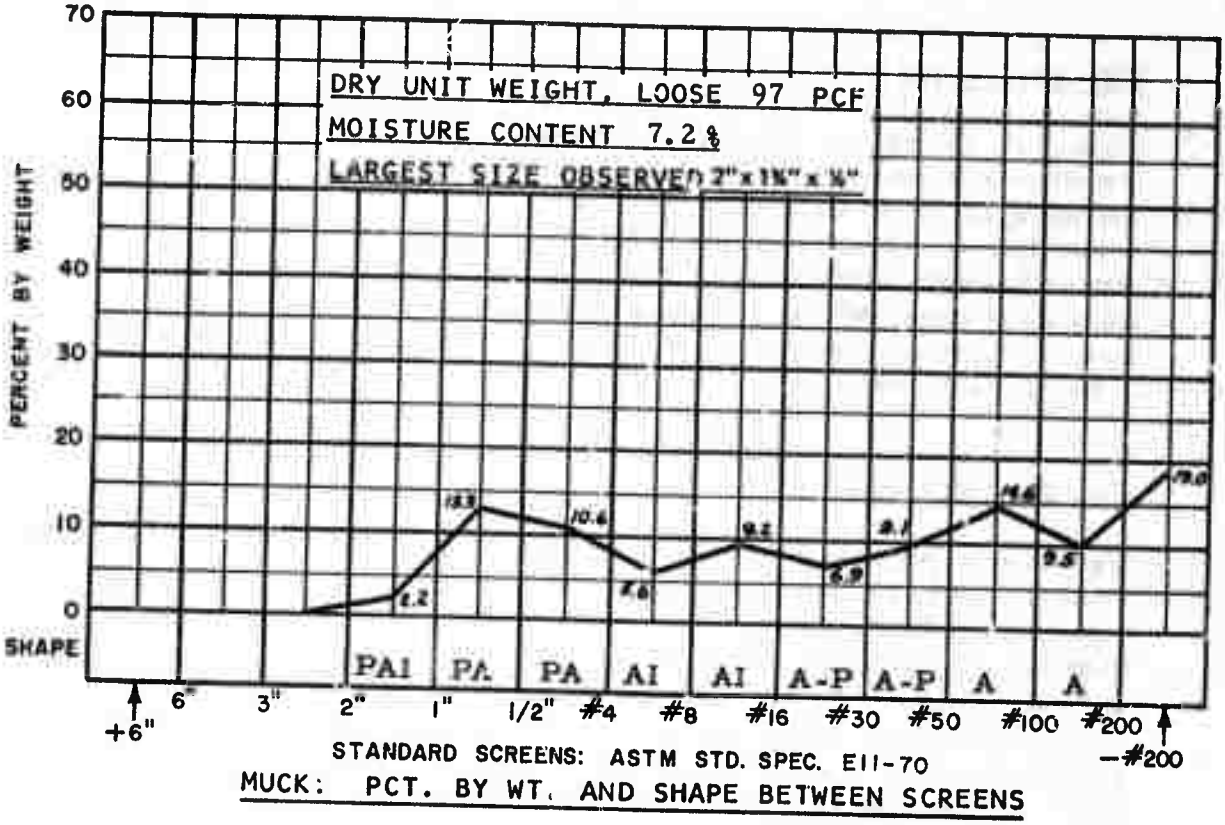
Abrasiveness	Pot. Vol. Change, Material Size :	Spec. Gravity, Material Size :
N. A.	NA	NA

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: Mica schist, occasional quartz laminations. Strength: NA. RQD (Est.) 90%. DI/W: NA. Ground water: Dry. Hardness: NA.

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.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. NY-2
Sheet 2

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: NA

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

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. QL-1
Sheet 1

MUCK DATA

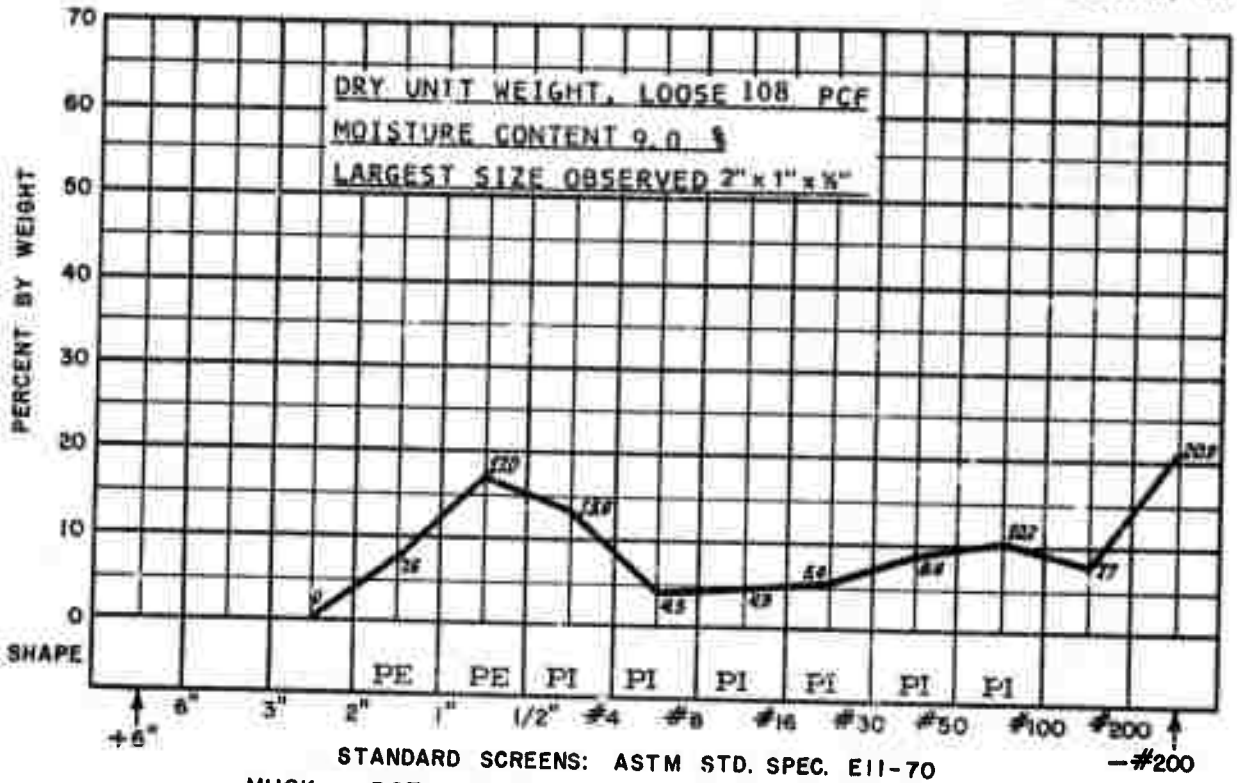
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 2.57

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: NA.

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: NA.
RQD: (Estimated) 35%.
Dry Unit Weight: NA.
Ground Water: None.
Hardness: NA.

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 C_F 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, 7.5#/CY.
Blasting: Detaprime primers, caps, fuse and igniter cord.
Mucking System: Eimco Model 40 mucker.
Guidance: Transit Lines.

MUCK DATA Test Data NA.

Abrasiveness N. A.

Pot. Vol. Change, Material Size :

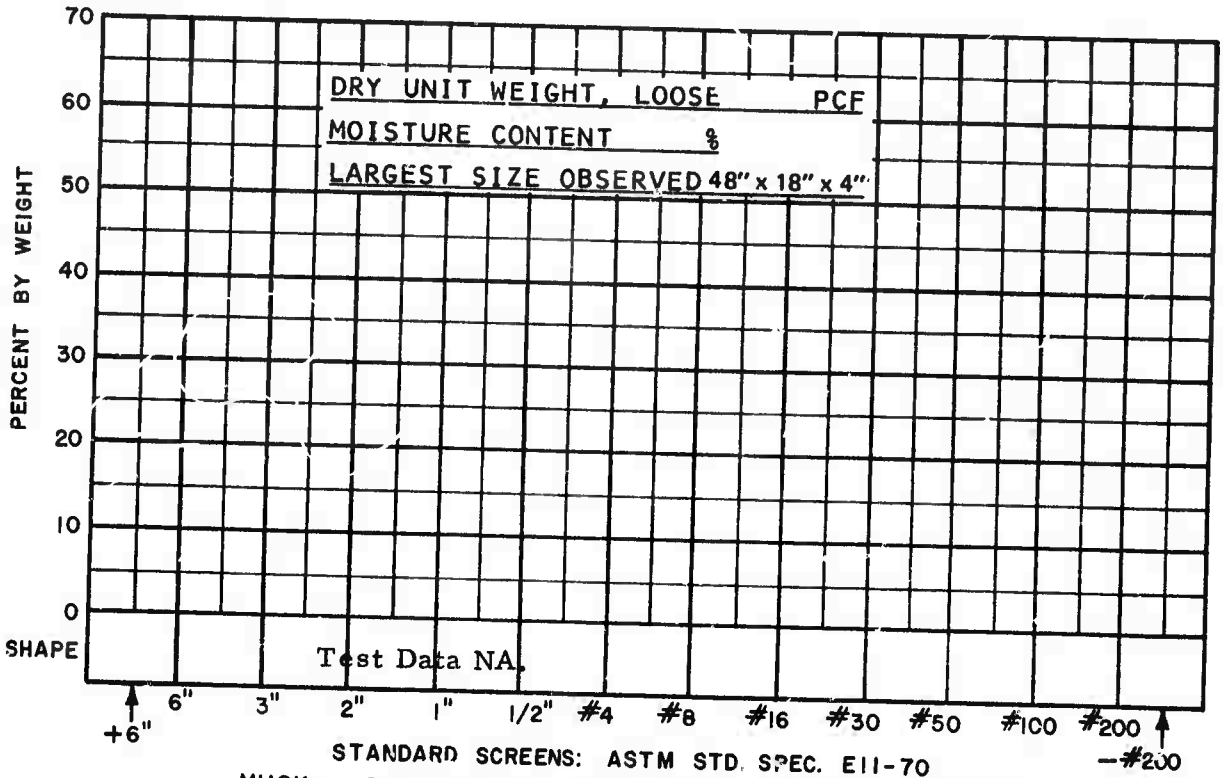
Spec. Gravity, Material Size :

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit %
Plasticity Index %
Plastic Limit %
Toughness Index %
Shrinkage Limit %
Flow Index %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture,
Angle Slide Steel Plate @ % Moisture,
Apparent Cohesion PSF @ % Moisture,
Bulk Density PCF @ % Moisture,
Angle/Repose 10" Drop @ % Moisture,
Angle Internal Friction @ % Moisture,



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. NA strength. RQD (Est.) 35%. DUW: NA PCF. Ground water: None. Hardness: NA.

System Class: Conventional rail, 10' wide x 10.8'. Two machine jumbo, 36 - 8' holes, V cut. PF 7.5 #/CY. Overhead loader mucking - rail haulage. Support: Rock bolts and plates as required.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. MB-2
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.

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

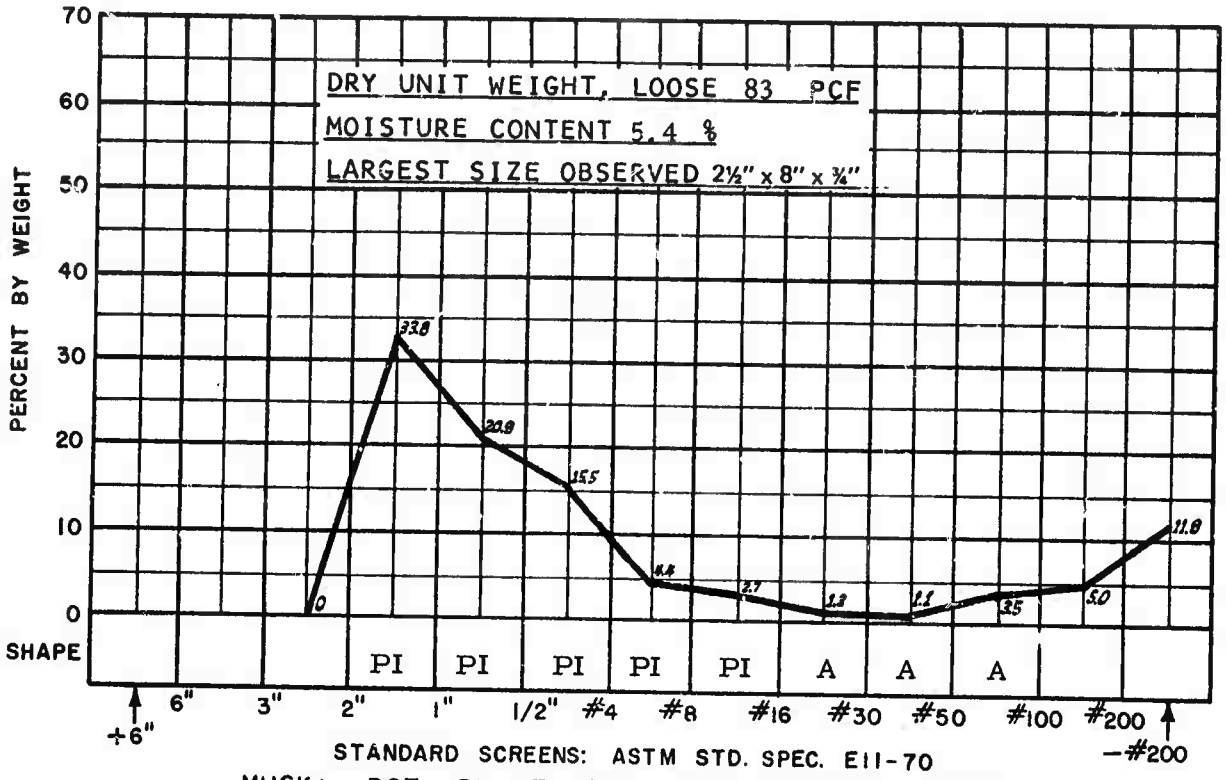
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.065" : 0	Size (-) 0.75": 2.73

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 @ % Moisture, NA	Angle/Repose 10" Drop @ 6.3 % Moisture, 29°
Angle Slide Steel Plate @ 6.3 % Moisture, 28°	Bulk Density PCF @ % Moisture, NA	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: 171 PCF. Ground water: Dry. Hardness: Shore 61.

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.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. 5-1
9/1/72	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.

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.

MUCK DATA

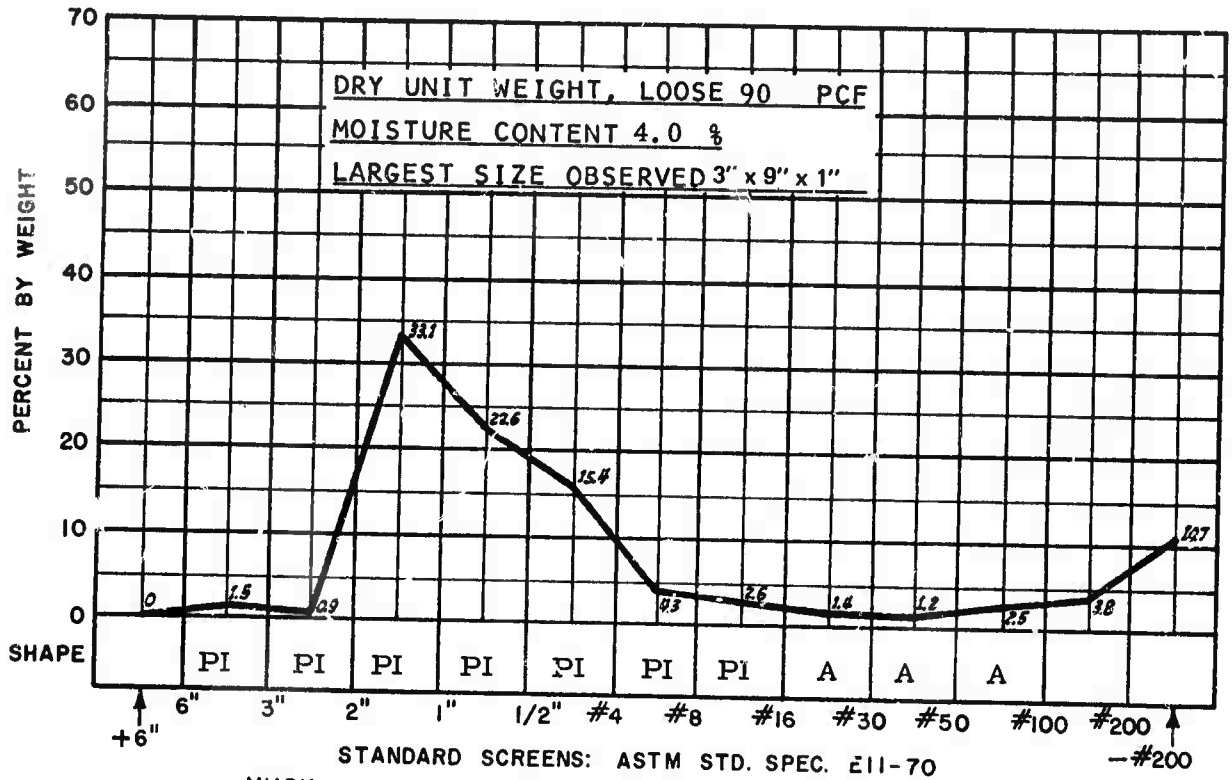
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056": 0	Size (-)0.75": 2.63

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	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 2.6 % Moisture, 32°	@ 2.8 % Moisture, 0	@ 2.6 % Moisture, 31°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 2.6 % Moisture, 29°	@ 0.0 % Moisture, 92.8	@ 2.8 % Moisture, 44°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandston , fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry. Hardness: Shore 61.

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: 152 PCF.
Ground Water: Dry
Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

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. Powder 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 %
Plasticity Index 0.79 %

Plastic Limit 14.81 %
Toughness Index 0.26 %

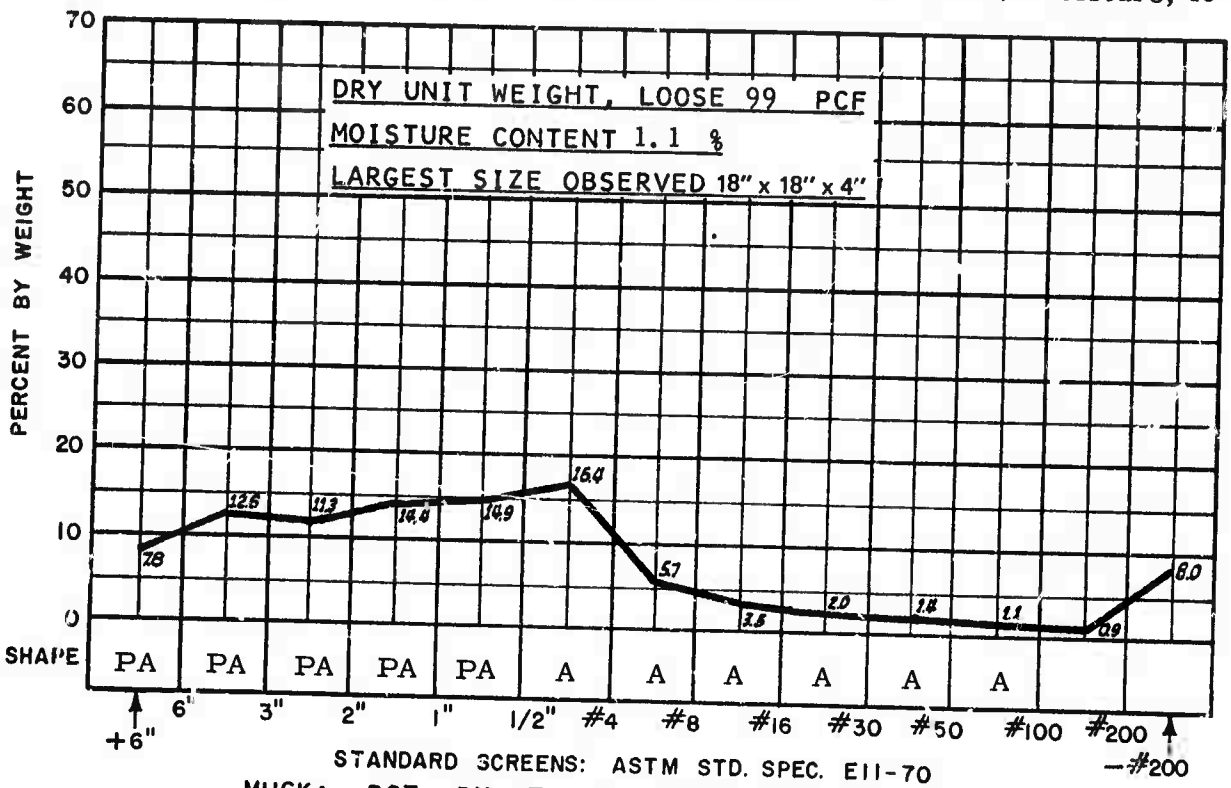
Shrinkage Limit 14.51 %
Flow Index 3.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 1 % Moisture, 25°
Angle Slide Steel Plate
@ 1 % Moisture, 29°

Apparent Cohesion PSF
@ 0.2 % Moisture, 550
Bulk Density PCF
@ 0.0 % Moisture, 100

Angle/Repose 10" Drop
@ 1 % Moisture, 25°
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: 152 PCF. Ground water: Dry. Hardness: Shore, 41-55.

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.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. 11-3
Sheet 2

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.

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, transfering 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.

MUCK DATA

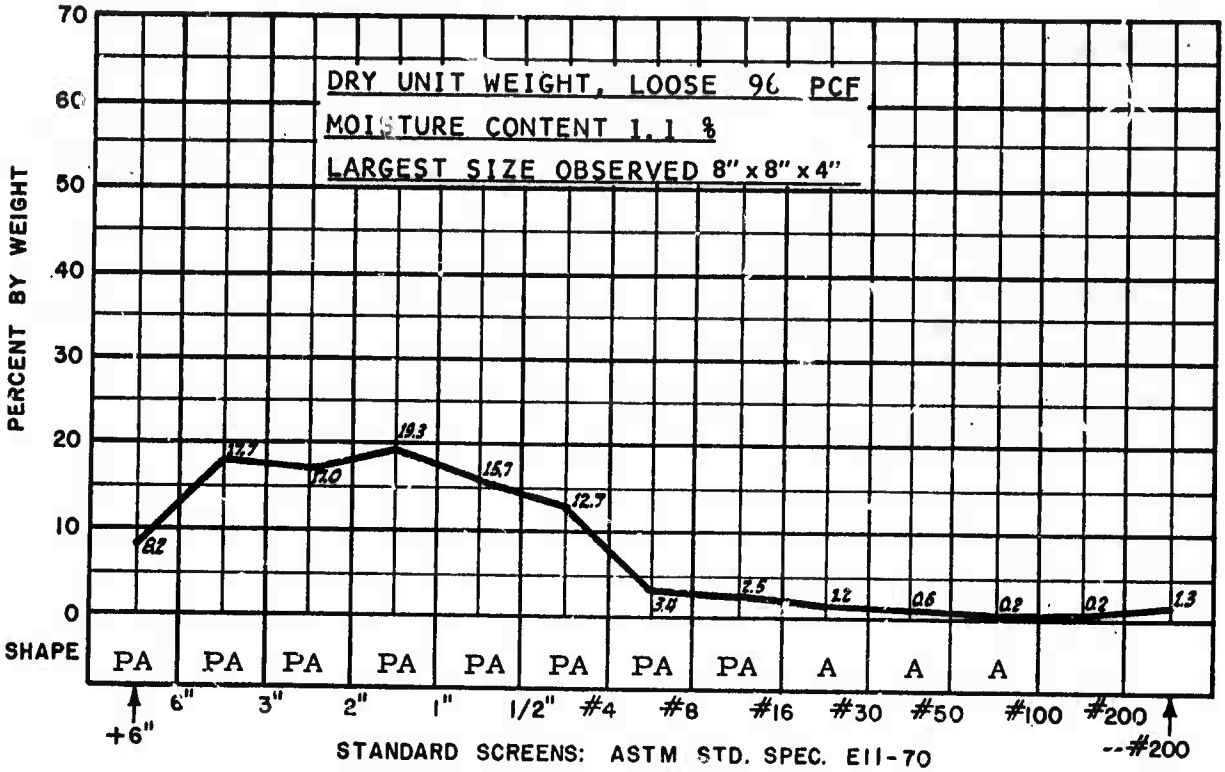
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056" : 0	Size (-) 0.75" : 2.78

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.

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'.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. 11-4 Sheet 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: 22K PSI (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.

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' ock 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: 769K#.
Muck System: Buckets fixed to head, discharge on conveyors.
Power System: Four - 480V, 200 HP motors drive head.
Guidance: Laser

MUCK DATA

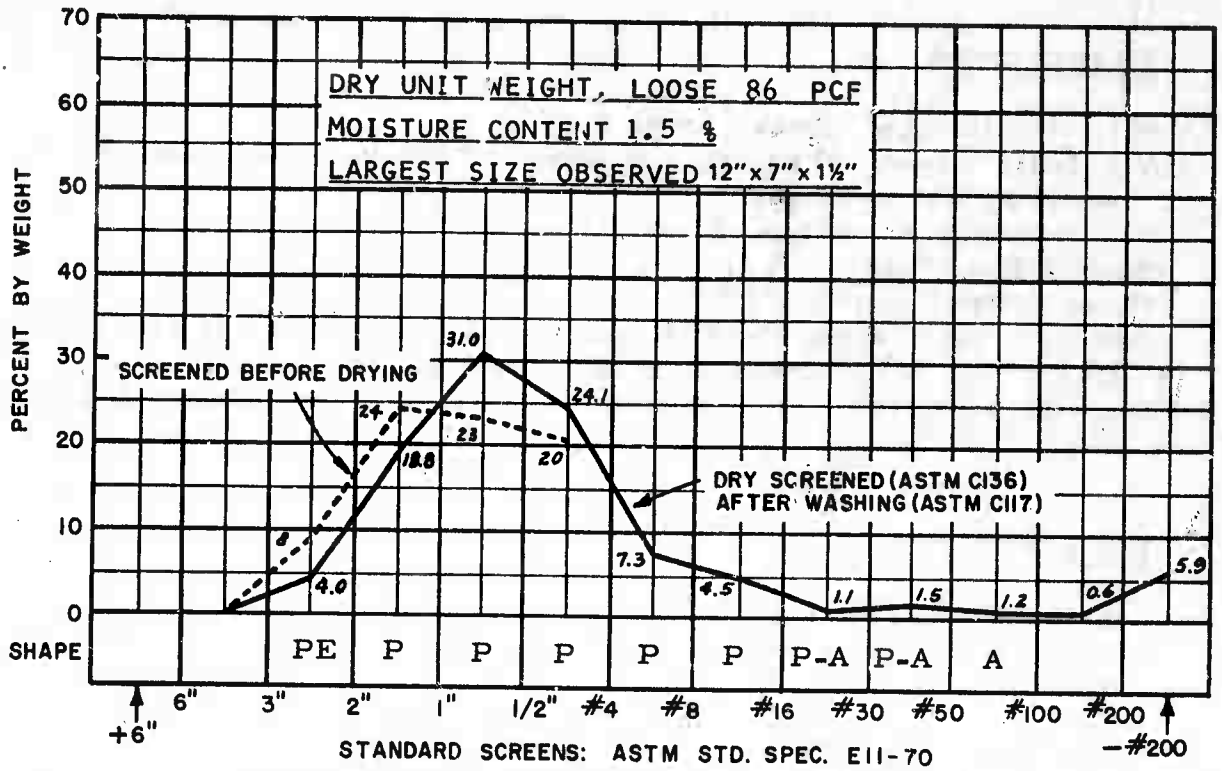
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-)0.75" : 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.00 %	Plastic Limit 17.10 %	Shrinkage Limit 15.58 %
Plasticity Index 0.90 %	Toughness Index 0.20 %	Flow Index 4.40 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 1.3 % Moisture, 36°	Apparent Cohesion PSF @ 1.0 % Moisture, 170	Angle/Repose 10" Drop @ 1.3 % Moisture, 32°
Angle Slide Steel Plate @ 1.3 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 100	Angle Internal Friction @ 1.0 % Moisture, 41°



MUCK: PCT. BY WT. AND SHAPE BETWEEN 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.

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: NA.
RQD: (Estimated) 65%.
Dry Unit Weight: 171 PCF
Ground Water: Normally dry.
Hardness: NA.

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

MDN STUDY	SYSTEM DATA SHEET	Ident. No. MSU-1
9/1/72	MDN	Sheet 1

MUCK DATA

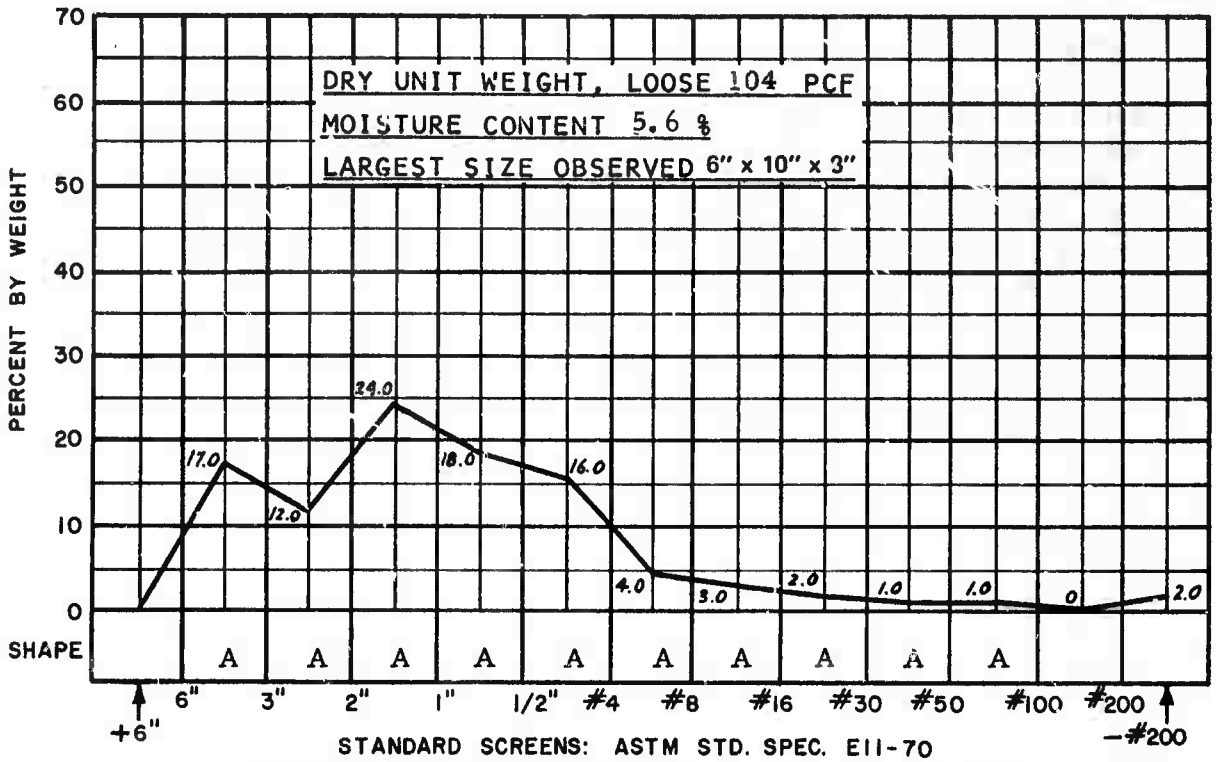
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size(-) 0.056" : 0	Size (-) 0.75" : 2.74

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	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 0.4 % Moisture, 35°	@ 0.3 % Moisture, 410	@ 0.4 % Moisture, 29°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 0.4 % Moisture, 27°	@ 0.0 % Moisture, 111	@ 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, NA. RQD (Est.) 65%. DUW: 171 PCF. Ground water: Dry. Hardness, NA.

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.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. MSU-1
9/1/72	MDN	Sheet 2

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: NA.
RQD: (Estimated) 80%.
Dry Unit Weight: 171 PCF
Ground Water: None
Hardness: NA.

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

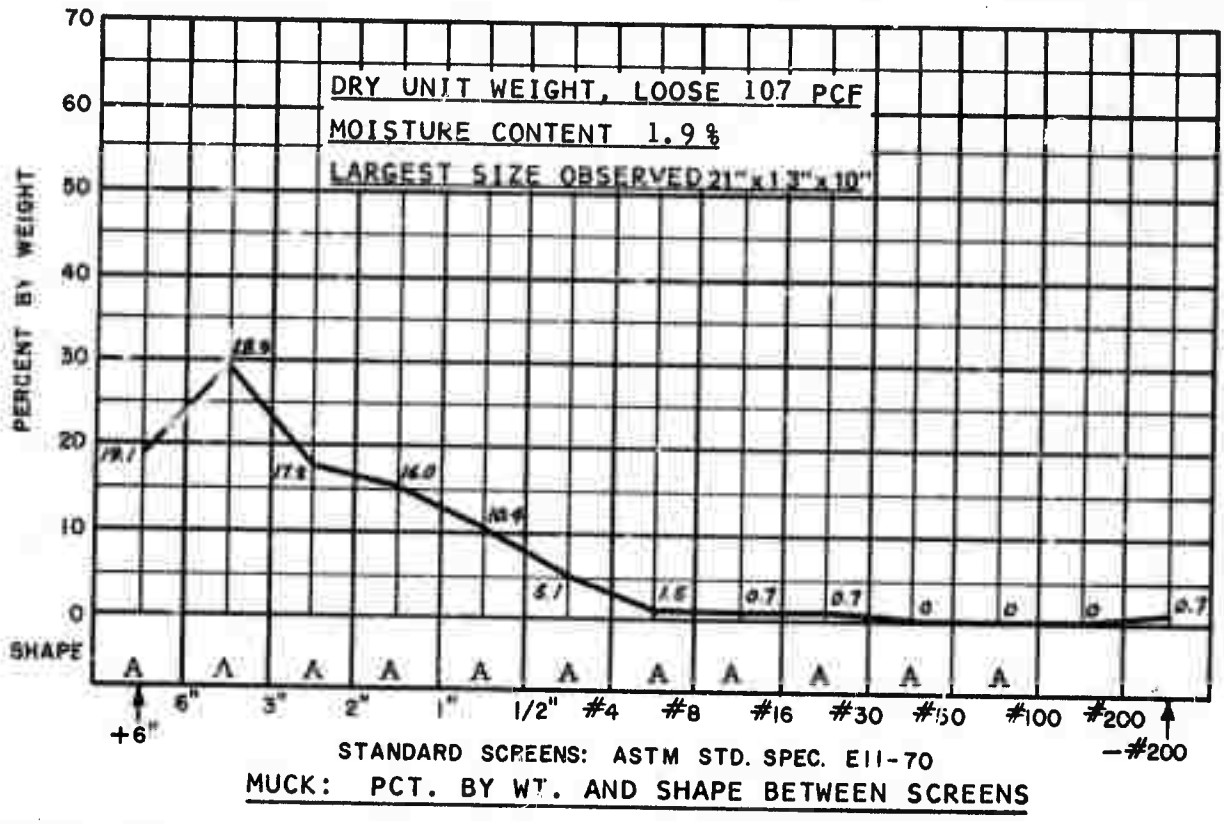
Abrasiveness N. A.	Pot. Vol. Change, Material Size : NA	Spec. Gravity, Material Size : NA

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: Sedimentary: Conglomerate, "breccia," 1/4" - 4" limestone, chert schist, diabase fragments, well consolidated. Strength: NA. RQD (Est.) 80%. DUW: 171 PCF. Ground water: None. Hardness: NA.

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 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. MSU-2 Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.
Uniaxial Compressive Strength: 19 KPSI
RQD: (Estimated) 100 percent.
Dry Unit Weight: 160 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46.

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.

MUCK DATA

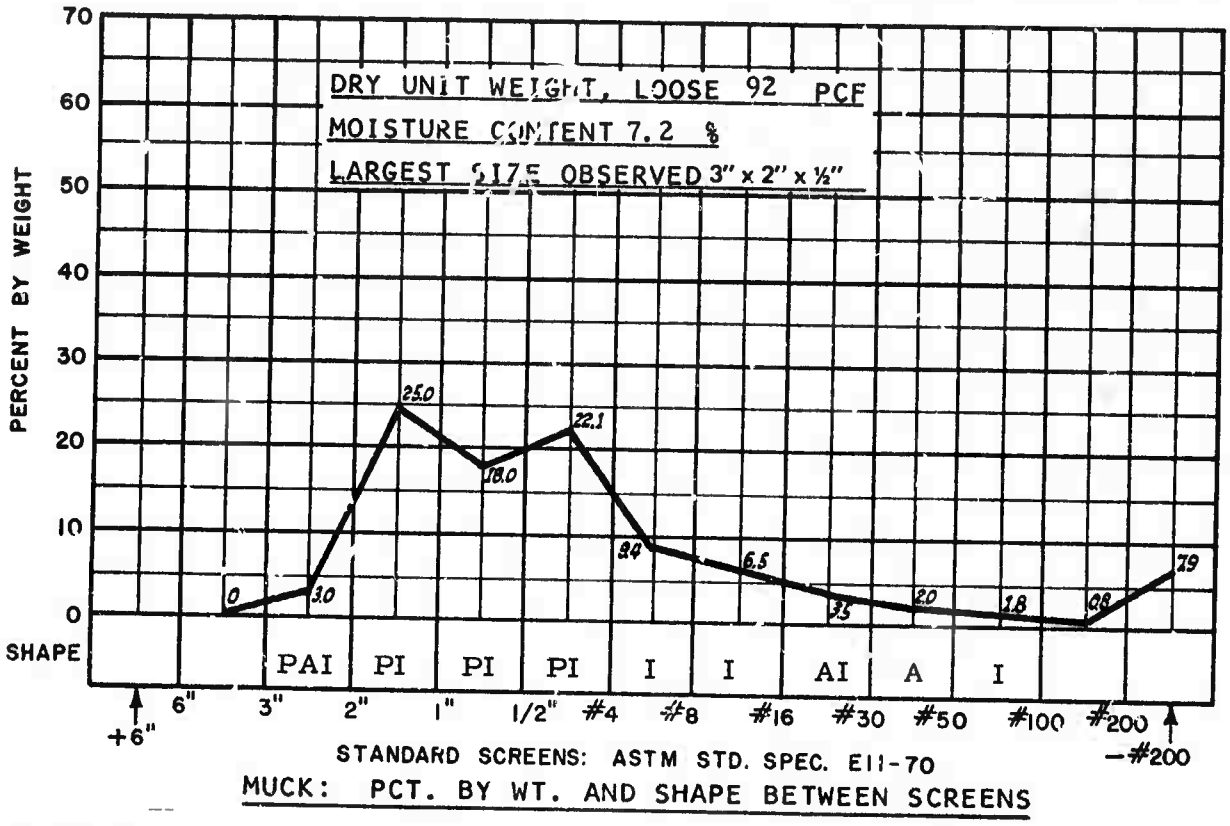
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.065": 0	Size (-) 0.75". 2.83

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 @ % Moisture, NA	Angle/Repose 10" Drop @ 5.4 % Moisture, 38°
Angle Slide Steel Plate @ 5.4 % Moisture, 31°	Bulk Density PCF @ % Moisture, NA	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: 160 PCF. Ground water: Minor. Hardness: Shore 46.

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: 19 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 160 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46.

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.

MUCK DATA

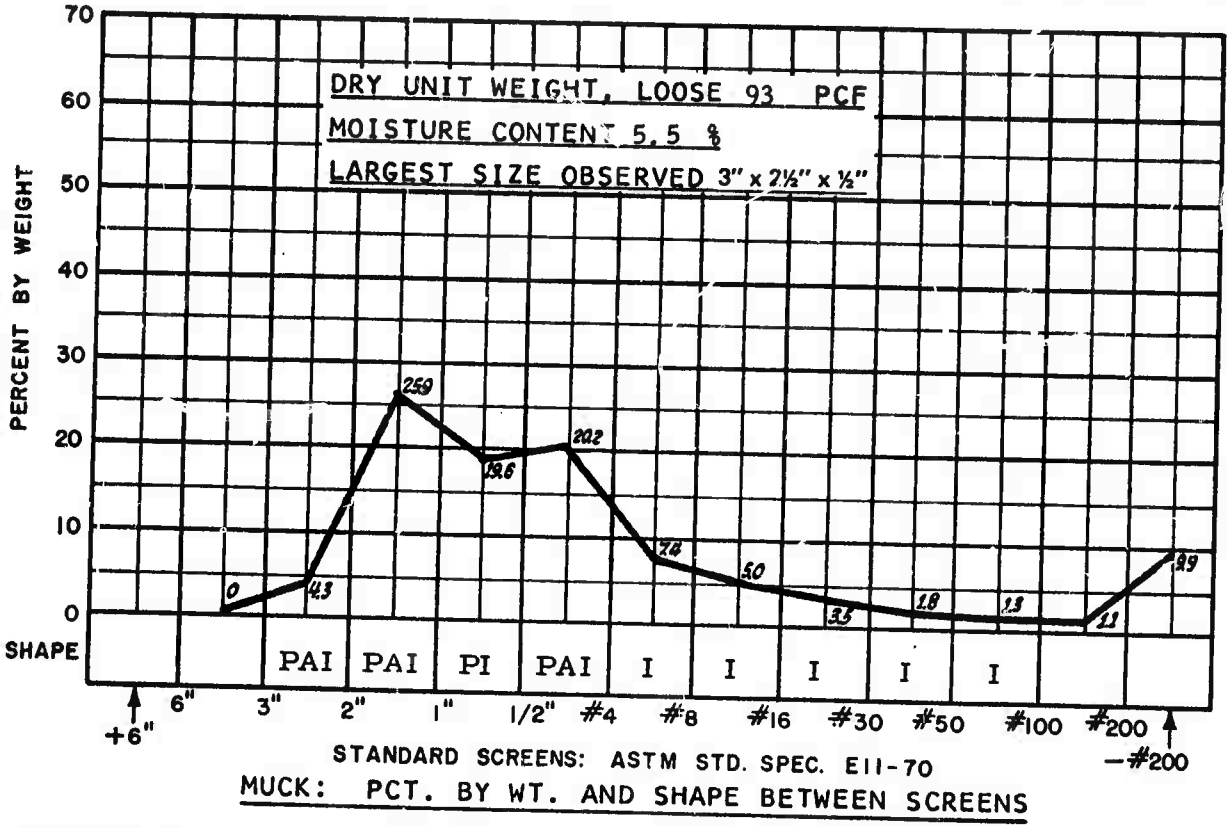
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.065": 0	Size (-) 0.75": 2.80

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 @ % Moisture, NA	Angle/Repose 10" Drop @ 6.1 % Moisture, 40°
Angle Slide Steel Plate @ 8.4% Moisture, 38°	Bulk Density PCF @ % Moisture, NA	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: 160 PCF. Ground water: Minor. Hardness: Shore 46.

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: 19 KPSI.
RQD: (Estimated) 100 percent.
Dry Unit Weight: 160 PCF.
Ground Water: Table above tunnel, occasional seepage from minor fractures and faults.
Hardness: Shore, 46.

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.

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 %
Plasticity Index 0.2 %

Plastic Limit 20.0 %
Toughness Index 0.05 %

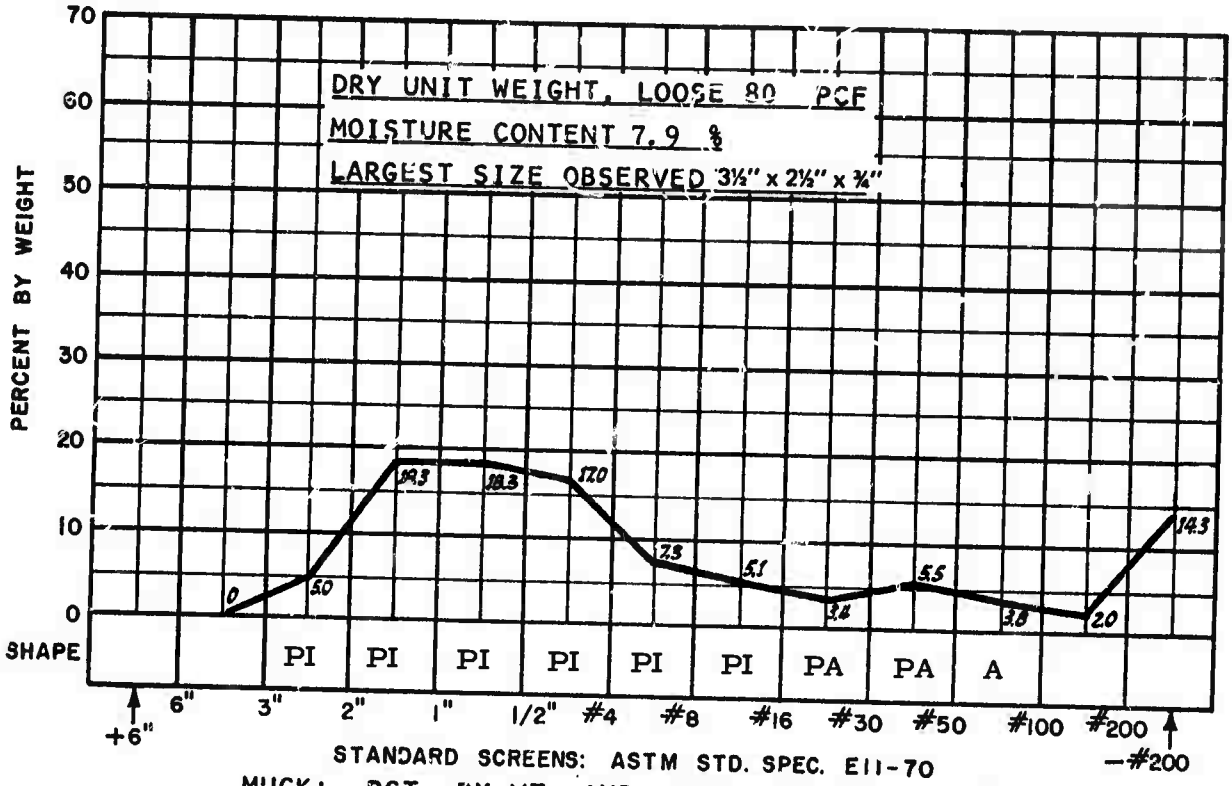
Shrinkage Limit 13.5 %
Flow Index 4.7 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 8.9 % Moisture, 42°
Angle Slide Steel Plate @ 8.9 % Moisture, 37°

Apparent Cohesion PSF @ % Moisture, NA
Bulk Density PCF @ % Moisture, NA

Angle/Repose 10" Drop @ 8.9 % Moisture, 34°
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: 160 PCF. Ground water: Minor. Hardness: Shore 46.

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.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. LAW-4
Sheet 2

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: NA

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.

MUCK DATA

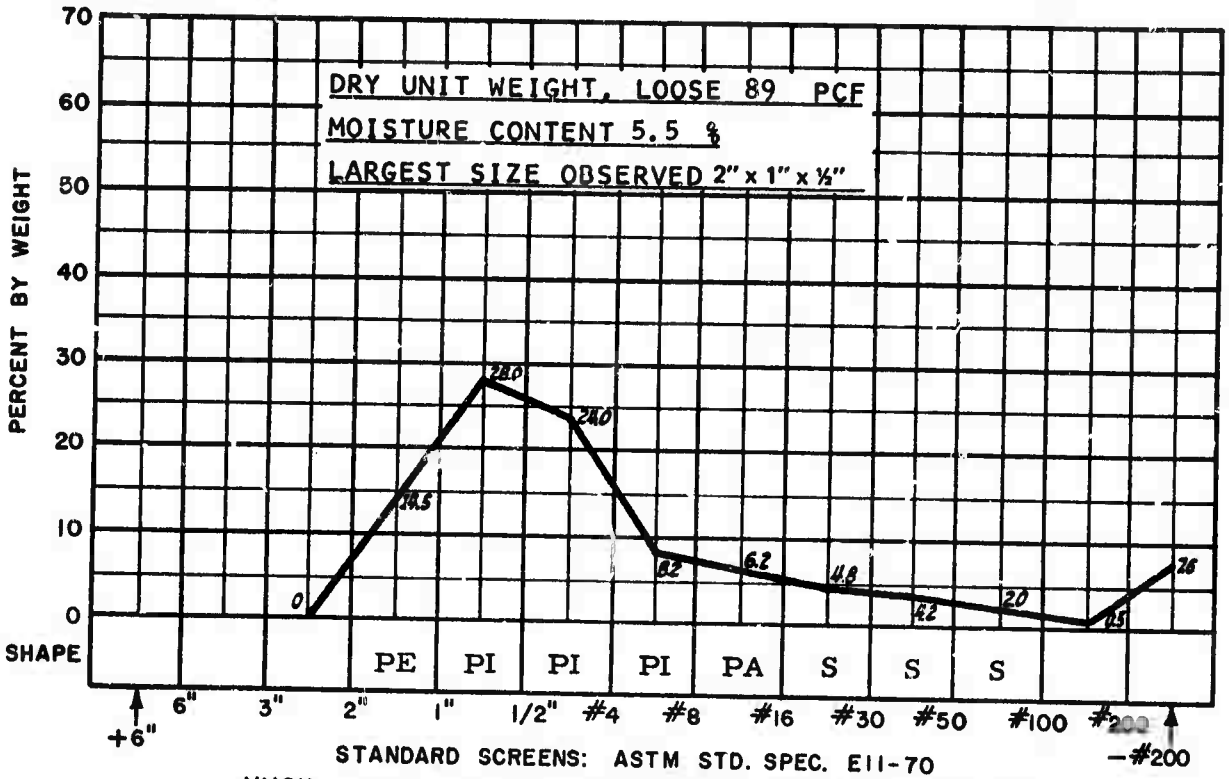
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056": 0	Size (-)0.75": 2.89

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 16.90%	Plastic Limit 15.69 %	Shrinkage Limit 15.46 %
Plasticity Index 1.21 %	Toughness Index 0.24 %	Flow Index 5.00 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 2.5 % Moisture, 36°	Apparent Cohesion PSF @ 4.1 % Moisture, 95	Angle/Repose 10" Drop @ 2.5 % Moisture, 35°
Angle Slide Steel Plate @ 2.5 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 86	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: NA.

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: NA

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.

MUCK DATA

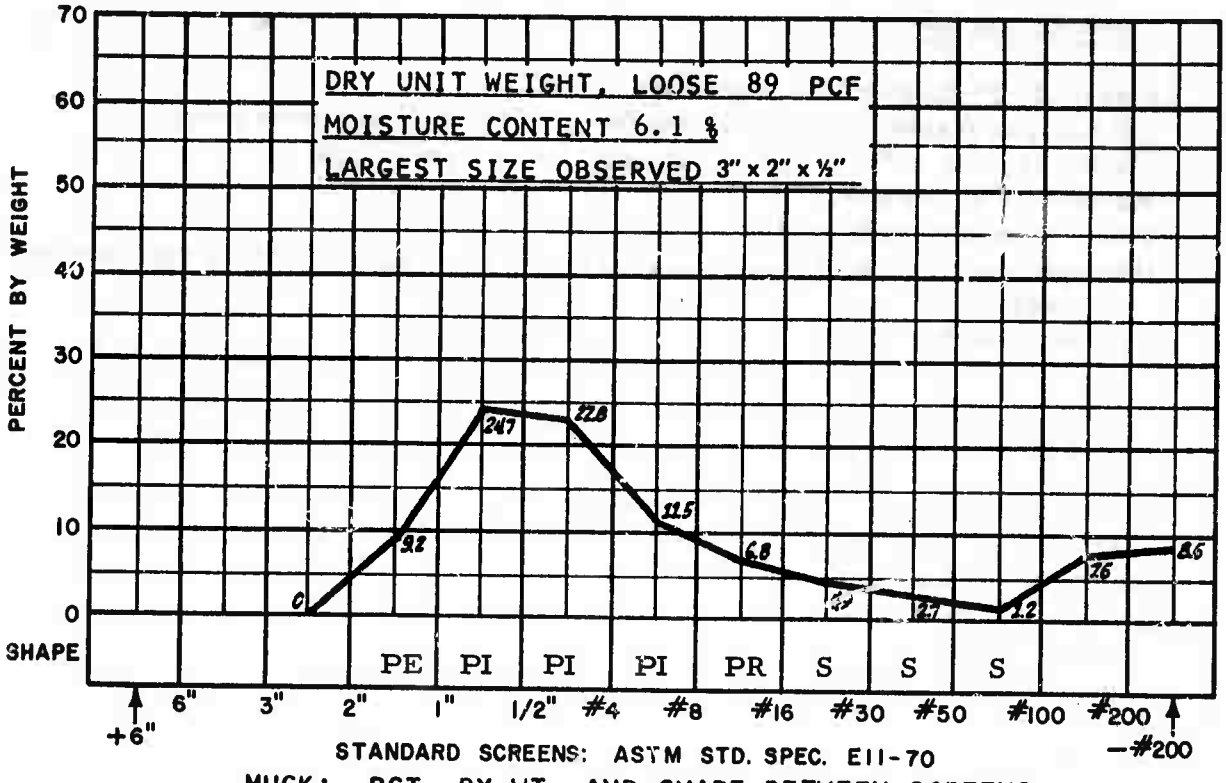
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.75": 2.93

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 20.10% Plasticity Index 3.42%	Plastic Limit 16.68 % Toughness Index 0.56%	Shrinkage Limit 16.37 % Flow Index 6.10 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 5.8 % Moisture, 32° Angle Slide Steel Plate @ 5.8 % Moisture, 30°	Apparent Cohesion PSF @ 5.0 % Moisture, 110 Bulk Density PCF @ 0.0 % Moisture, 90	Angle/Repose 10" Drop @ 5.8 % Moisture, 30° 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: NA.

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.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. MIL-2 Sheet 2

ROCK DATA:

Lithology: Sedimentary, limestone, grey, fine grained, horizontal joint spacing 4"-8".
Uniaxial Compressive Strength: 24K PSI.
RQD: (Estimated) 81%.
Dry Unit Weight: 164 PCF
Ground Water: Dry.
Hardness: NA.

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

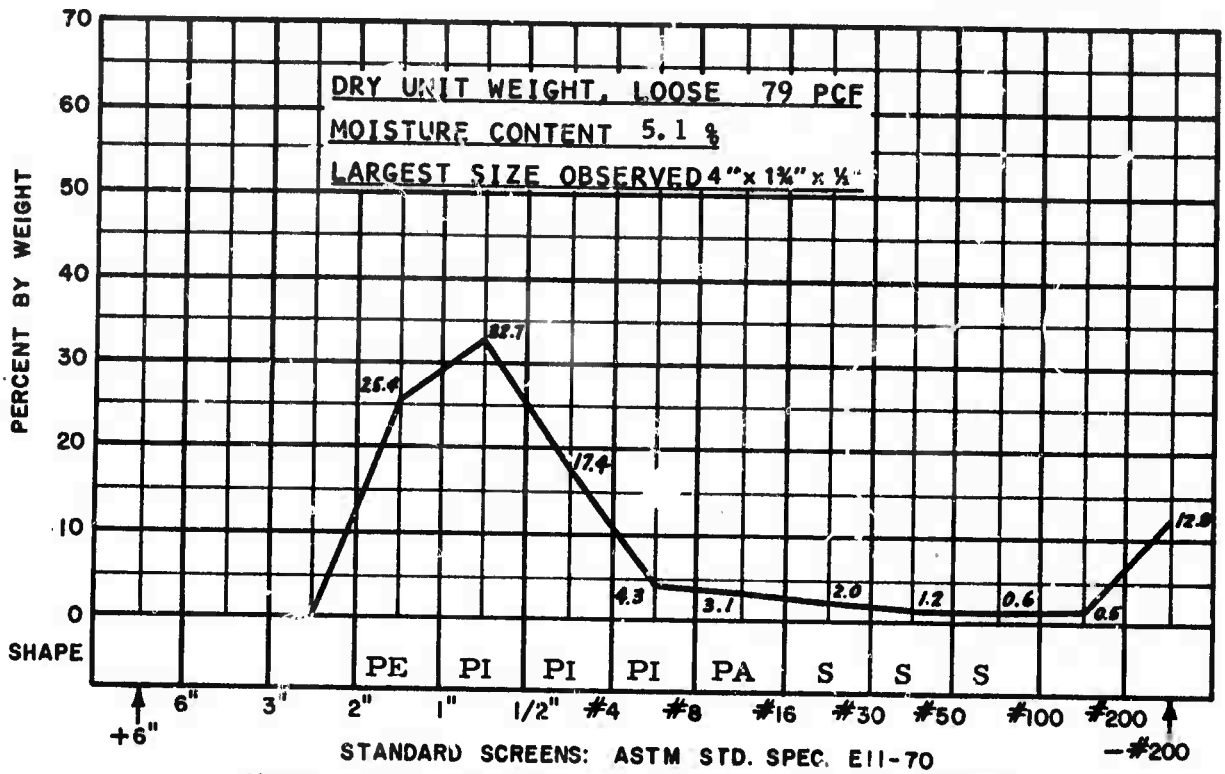
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size(-)0.056" : 0	Size (-)0.75" : 2.78

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 15.20 %	Plastic Limit 14.40 %	Shrinkage Limit 12.96 %
Plasticity Index 0.80 %	Toughness Index 0.22 %	Flow Index 3.50 %

MATERIAL SIZE(-) 2.0 IN.

Angle/Repose 1" Drop @ 2.5 % Moisture, 36°	Apparent Cohesion PSF @ 2.3 % Moisture, 60	Angle/Repose 10" Drop @ 2.5 % Moisture, 32°
Angle Slide Steel Plate @ 2.5 % Moisture, 32°	Bulk Density PCF @ 0.0 % Moisture, 95	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: NA.

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: NA.

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

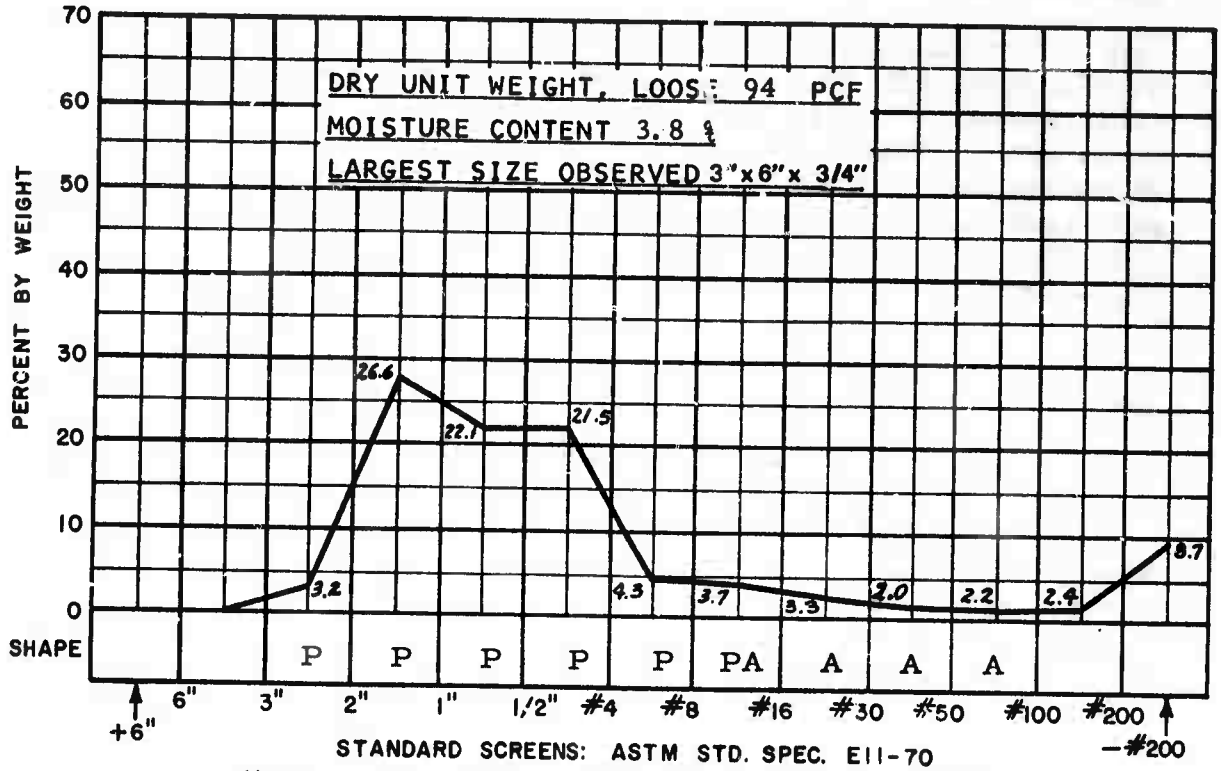
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056" : 0	Size (-) 0.75": 2.81

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, NA.

System Class: TBM, Robbins, 105-144, 10' 4" dia. 26 Robbins disc cutters. RPM: 6. 280 K ft # torque, 230 K # thrust. Mucking: Buckets tc belt. Haulage: Rail. Support: None.

ROCK DATA:

Lithology: Sedimentary, limestone, light grey, fine grained.
Uniaxial Compressive Strength: NA.
RQD: 100
Dry Unit Weight: NA.
Ground Water: Dry.
Hardness: NA.

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 : NA

Spec. Gravity, Material Size : NA

ATTERBERG LIMITS, MATERIAL SIZE IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA %
Toughness Index NA %

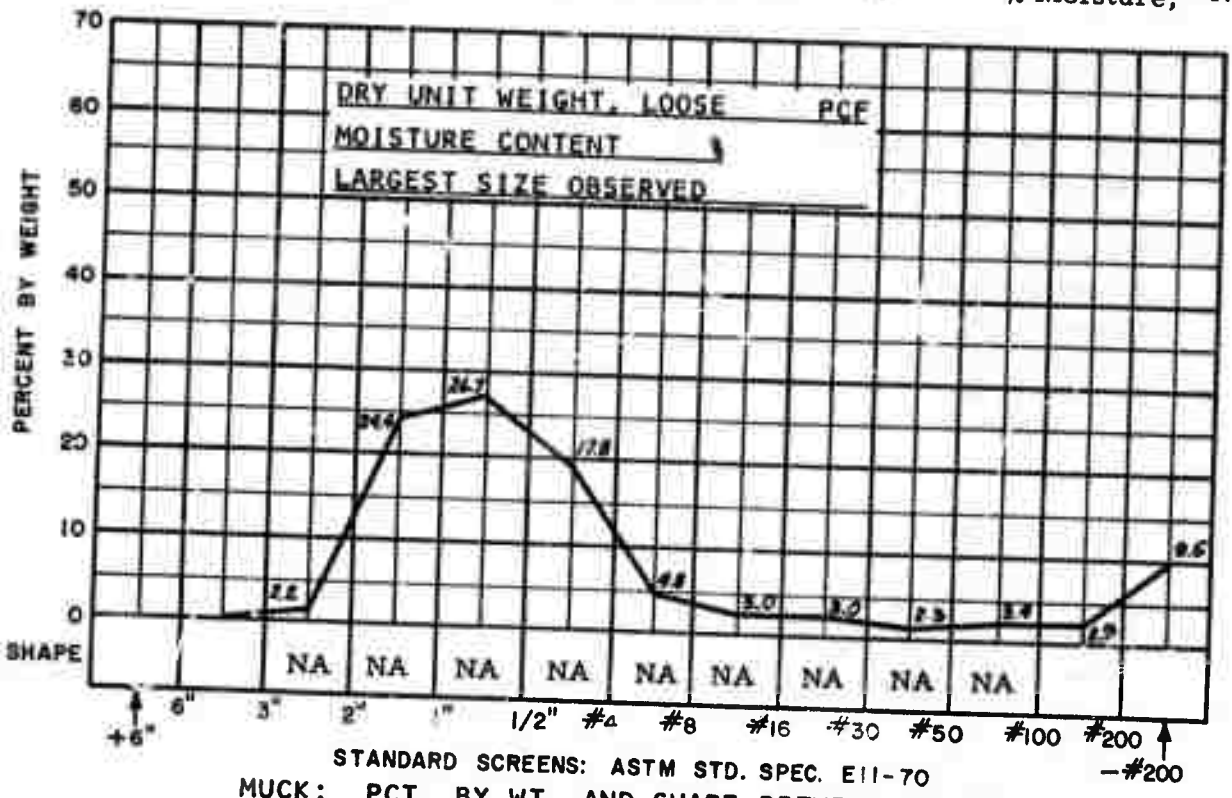
Shrinkage Limit NA %
Flow Index NA %

MATERIAL SIZE IN.

Angle/Repose 1" Drop @ % Moisture, NA
Angle Slide Steel Plate @ % Moisture, NA

Apparent Cohesion PSF @ % Moisture, NA
Bulk Density PCF @ % Moisture, NA

Angle/Repose 10" Drop @ % Moisture, NA
Angle Internal Friction @ % Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained. Strength: NA. RQD: 100%. DUW : NA. Ground water: Dry. Hardness: NA.

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
9/1/72

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: NA

TUNNEL DATA:

Size: 12'-11" diameter. Grade: (+) .125%
Ventilation System: 15-17 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.
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".
Rotation: Center cutter integral with head, 5.2 or 2.6 RPM.
Torque: 472 to 524 K ft. #.
Thrust: 331 K# to 382 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

MUCK DATA

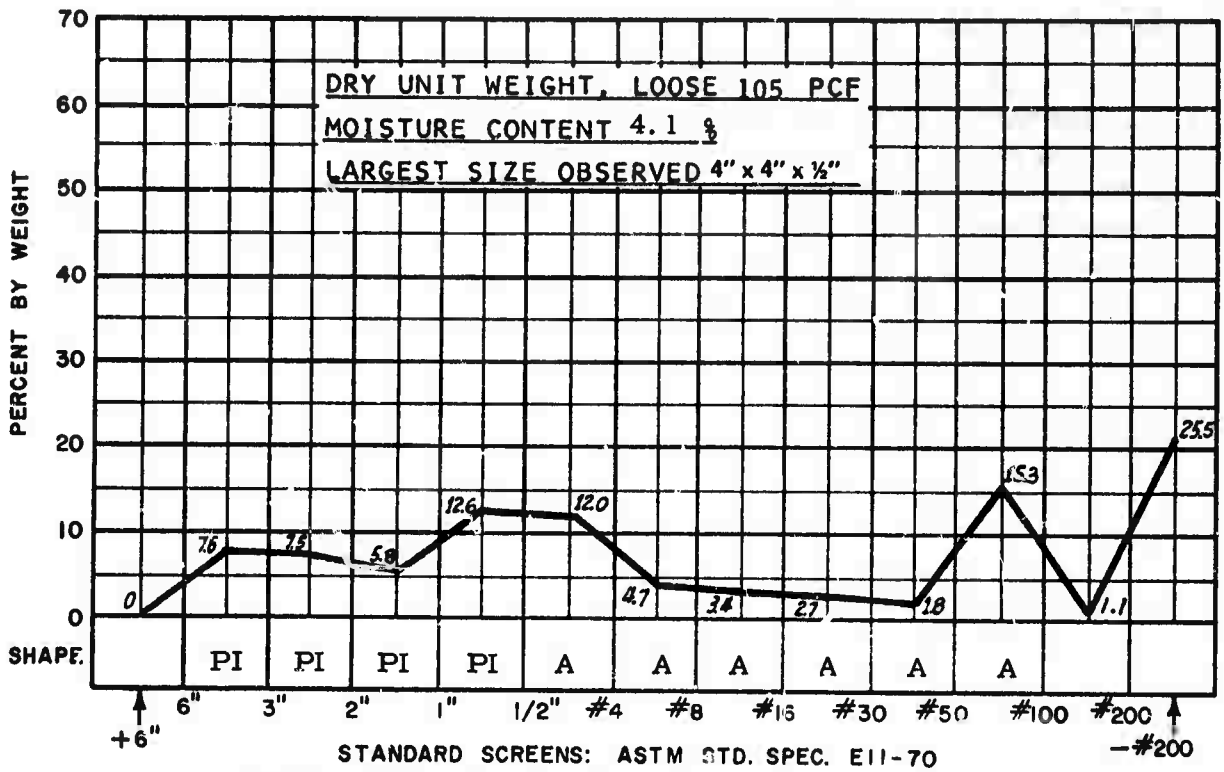
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

Liquid Limit 21.20%	Plastic Limit 17.06 %	Shrinkage Limit 15.17 %
Plasticity Index 3.14 %	Toughness Index 0.52 %	Flow Index 6.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop	Apparent Cohesion PSF	Angle/Repose 10" Drop
@ 3.6 % Moisture, 37°	@ 3.6 % Moisture, 210	@ 3.6 % Moisture, 35°
Angle Slide Steel Plate	Bulk Density PCF	Angle Internal Friction
@ 3.6 % Moisture, 27°	@ 0.0 % Moisture, 97.4	@ 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: NA.

System Class: TBM, Robbins 141-127, 12' 11" dia. 32 Robbins disc cutters. RPM: 5.2. Torque: 498 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'.

MDN STUDY	SYSTEM DATA SHEET	Ident. No. LAY-1
9/1/72	MDN	Sheet 2

ROCK DATA:

Lithology: Sedimentary, conglomerate, well graded cobbles to pebbles of quartzite poorly to well cemented with reddish brown sandstone.
Uniaxial Compressive Strength: NA.
RQD: (Estimated) 85%.
Dry Unit Weight: NA.
Ground Water: Dry.
Hardness: NA.

TUNNEL DATA:

Size: 12' 11" diameter. Grade: (+) 0.125%.
Ventilation System: 15-17 KCFM, 36" diameter pipe, 100 HP
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.
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".
Rotation: 5.2 RPM.
Torque: 490.7K ft. lb.
Thrust: 585.2K lb.
Muck Collection: Buckets from face, belt to rear.
Power System: 6-100 HP motors drivehead.
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 15.00%
Plasticity Index 0.82 %

Plastic Limit 14.18 %
Toughness Index 0.21 %

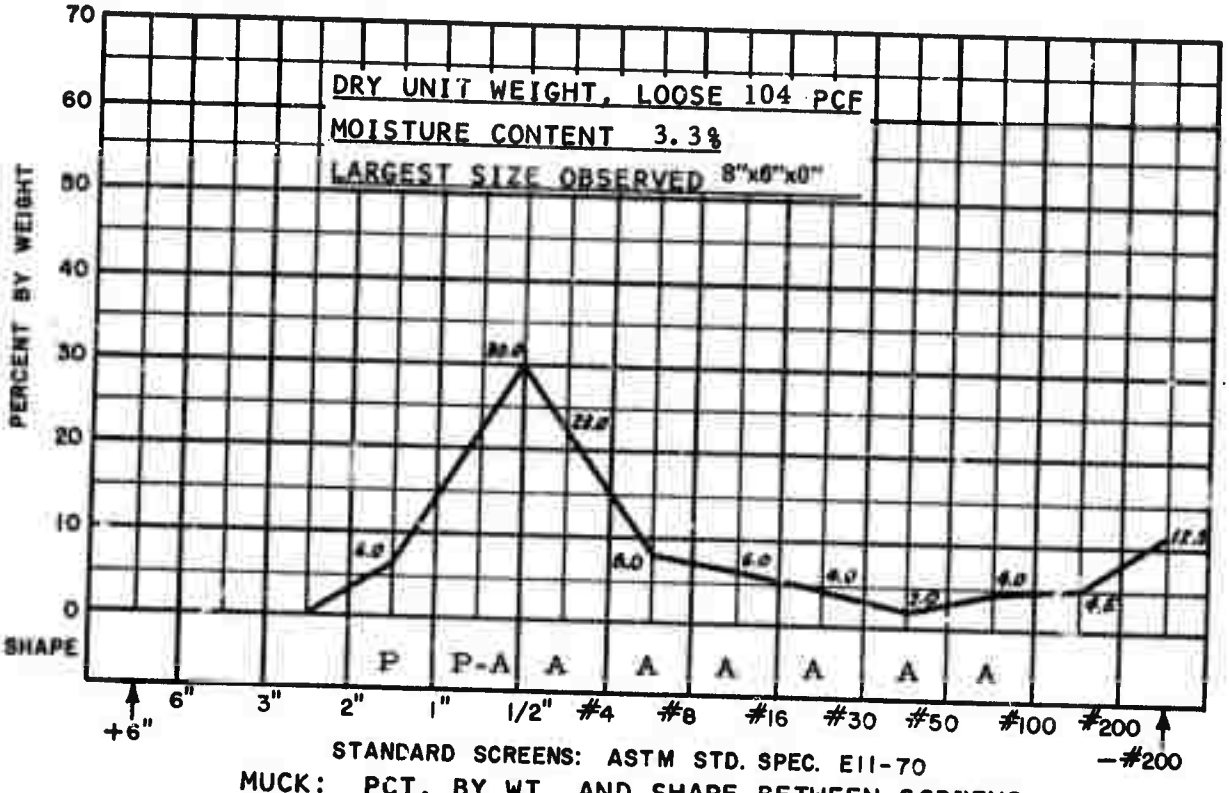
Shrinkage Limit 13.80 %
Flow Index 4.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop
@ 3.4 % Moisture, 38°
Angle Slide Steel Plate
@ 3.4 % Moisture, 32°

Apparent Cohesion PSF
@ 3.0 % Moisture, 15
Bulk Density PCF
@ 0.0 % Moisture, 88

Angle/Repose 10" Drop
@ 3.4 % Moisture, 32°
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. Strength: NA: RQD (Est.) 85%. DUW: NA. Ground water: Dry. Hardness: NA.

System Class: TBM Robbins 141-127. 32 Robbins disc cutters. RPM: 5.2 Torque: 491 K ft #. Thrust: 585 K #. Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts, normal, ring sets in bad ground.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. LAY-2
Sheet 2

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: NA

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

MUCK DATA

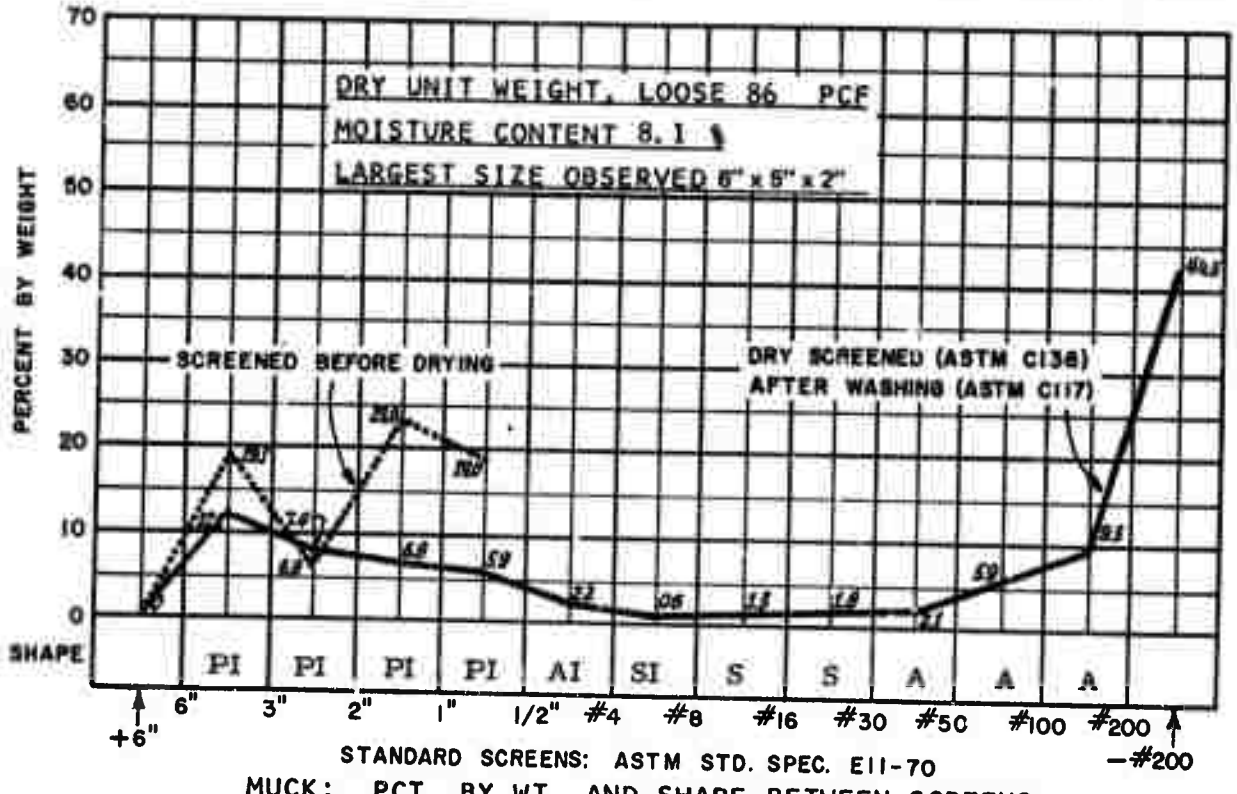
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056": 1.3	Size (-)0.75": 3.13

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 36.80%	Plastic Limit 23.61 %	Shrinkage Limit 21.04 %
Plasticity Index 13.19%	Toughness Index 1.88 %	Flow Index 7.00 %

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1" Drop @ 7.7 % Moisture, 30°	Apparent Cohesion PSF @ 7.5 % Moisture, 340	Angle/Repose 10" Drop @ 7.7 % Moisture, 30°
Angle Slide Steel Plate @ 7.7 % Moisture, 30°	Bulk Density PCF @ 0.0 % Moisture, 98	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: NA.

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: 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: NA

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

MUCK DATA

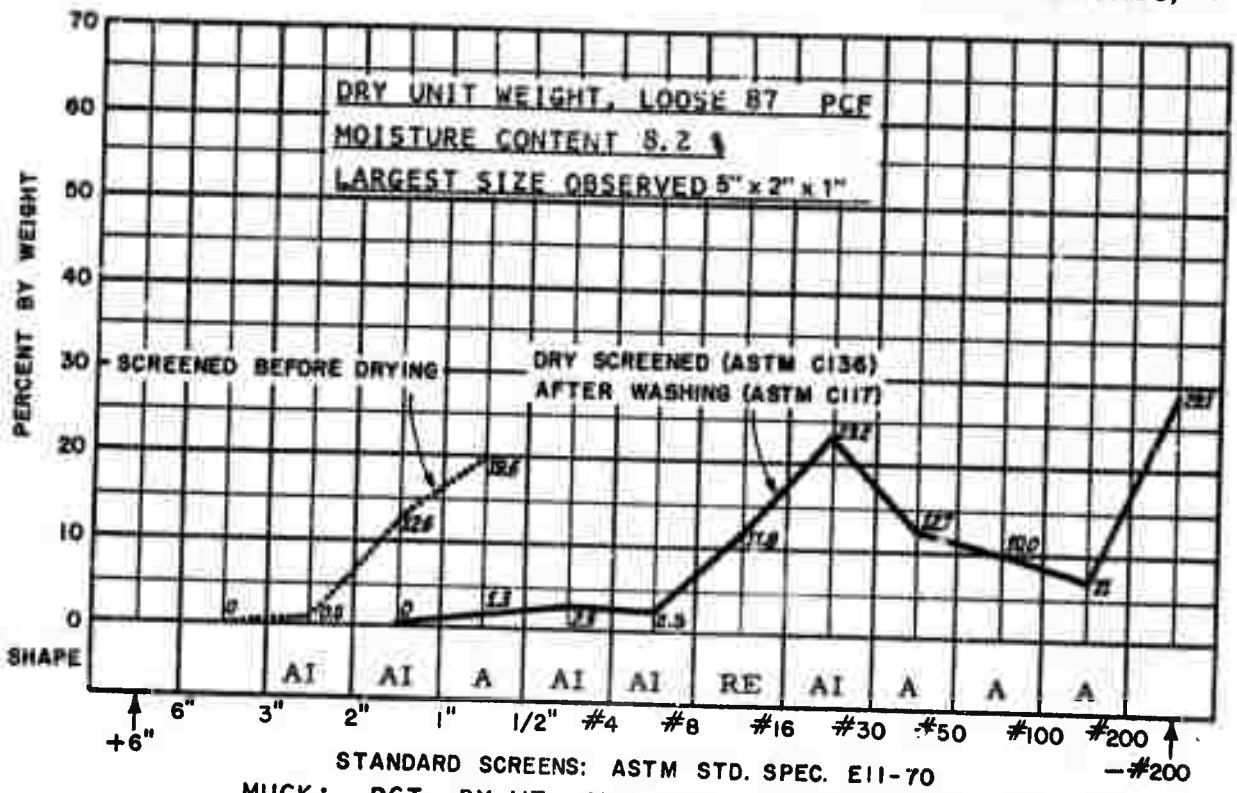
Abrasiveness	Pot. Vol. Change, Material Size (-) 0.056": 0	Spec. Gravity, Material Size (-) 0.75": 2.72
N. A.		

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: NA.

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	SYSTEM DATA SHEET	Ident. No. NAV-2
°/1/72	MDN	Sheet 2

ROCK DATA:

Lithology: Sedimentary, sandstone, fine grained, brown to dark red massive.
Uniaxial Compressive Strength: NA.
RQD: 60%.
Dry Unit Weight: NA.
Ground Water: Generally dry.
Hardness: NA.

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

MUCK DATA

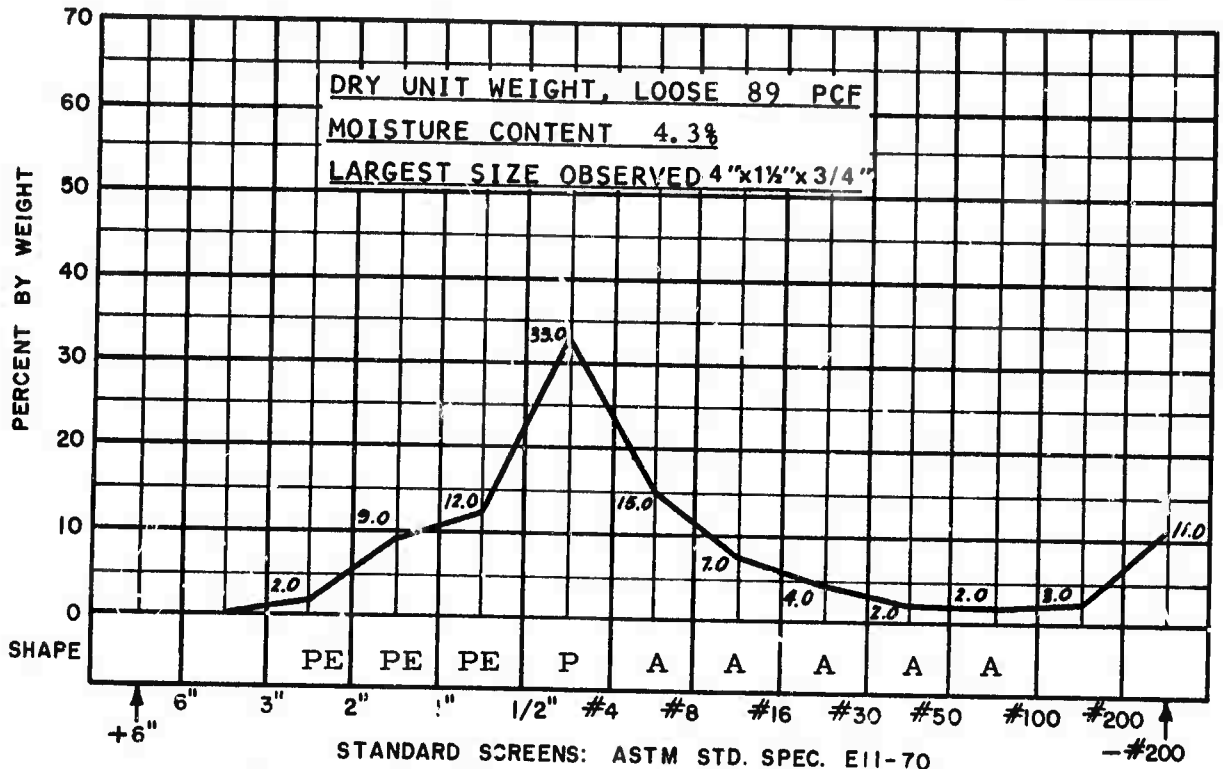
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size NA :	Size NA :

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: Sedimentary: Sandstone, fine grained, massive. Strength: NA. RQD: 60%. DUW: NA. Ground water: Dry. Hardness: 32, schmidt.

System Class: TBM Lawrence HRT 18' 4" dia. 32 Lawrence button roller, disc cutters. 11 RPM head, 30 RPM center. 364 K ft # torque. 492 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Rock bolts 24" centers.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. RO-1
Sheet 2

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: NA

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.

MDN STUDY 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. WNG-1 Sheet 1

MUCK DATA

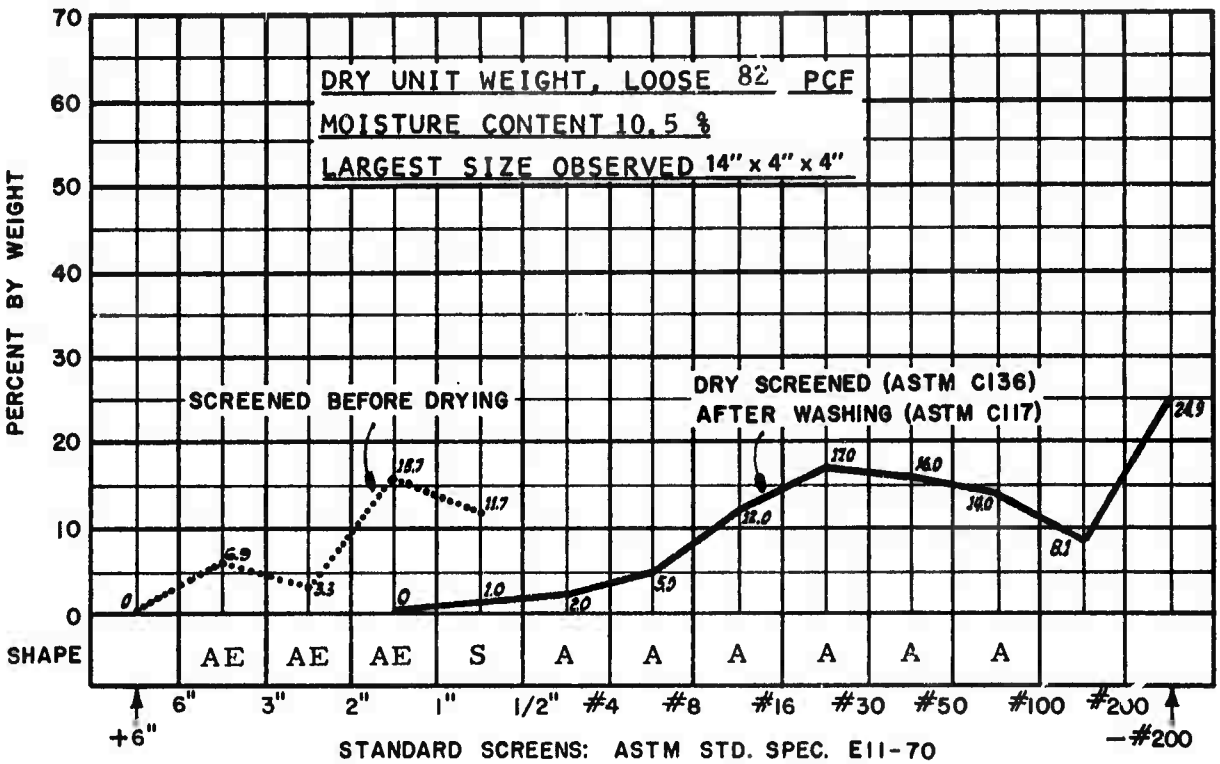
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.71

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: NA.

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	SYSTEM DATA SHEET	Ident. No. WNG-1
9/1/72	MDN	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: NA

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.

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%
Plasticity Index 0.51 %

Plastic Limit 24.74 %
Toughness Index 0.13 %

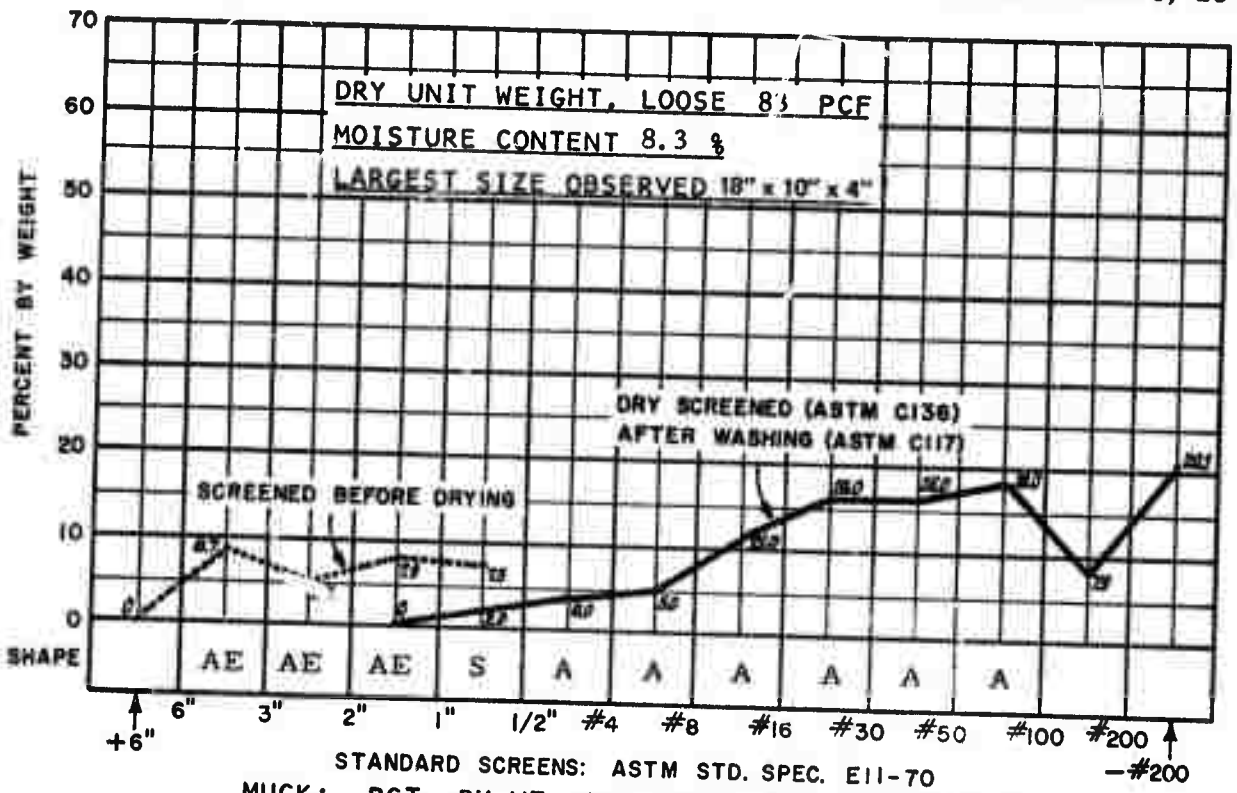
Shrinkage Limit 23.37 %
Flow Index 4.00 %

MATERIAL SIZE (-) 2.0 IN.

Angle/Repose 1" Drop @ 9.0 % Moisture, 32°
Angle Slide Steel Plate @ 9.0 % Moisture, 40°

Apparent Cohesion PSF @ 9.0 % Moisture, 0
Bulk Density PCF @ 0.0 % Moisture, 86

Angle/Repose 10" Drop @ 9.0% Moisture, 31°
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: NA.

System Class: Conventional Scraper-Rail. 5' wide x 9' high, rectangular. Airleg jackhammer, 18 - 6' holes, burn cut. PF 5#/CY. Mucking: Scraper to raise. Haulage: Rail cars - skip to surface. Support: Normally none.

MDN STUDY
9/1/72

SYSTEM DATA SHEET
MDN

Ident. No. WNG-2
Sheet 2

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: NA

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

MUCK DATA

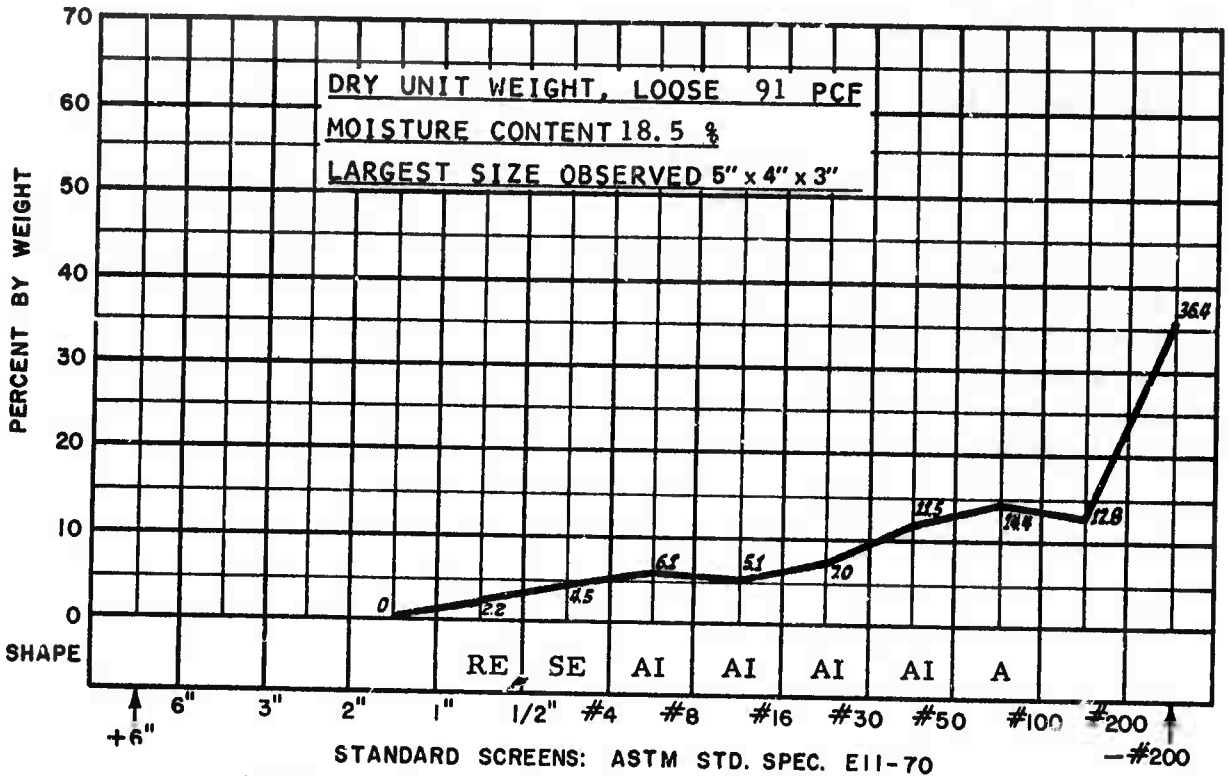
Abrasiveness N. A.	Pot. Vol. Change, Material Size (-)0.065" : 0	Spec. Gravity, Material Size (-)0.185": 2.86

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 @ % Moisture, NA	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: NA.

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 9/1/72	SYSTEM DATA SHEET MDN	Ident. No. SF-1 Sheet 2

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: NA

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

MUCK DATA

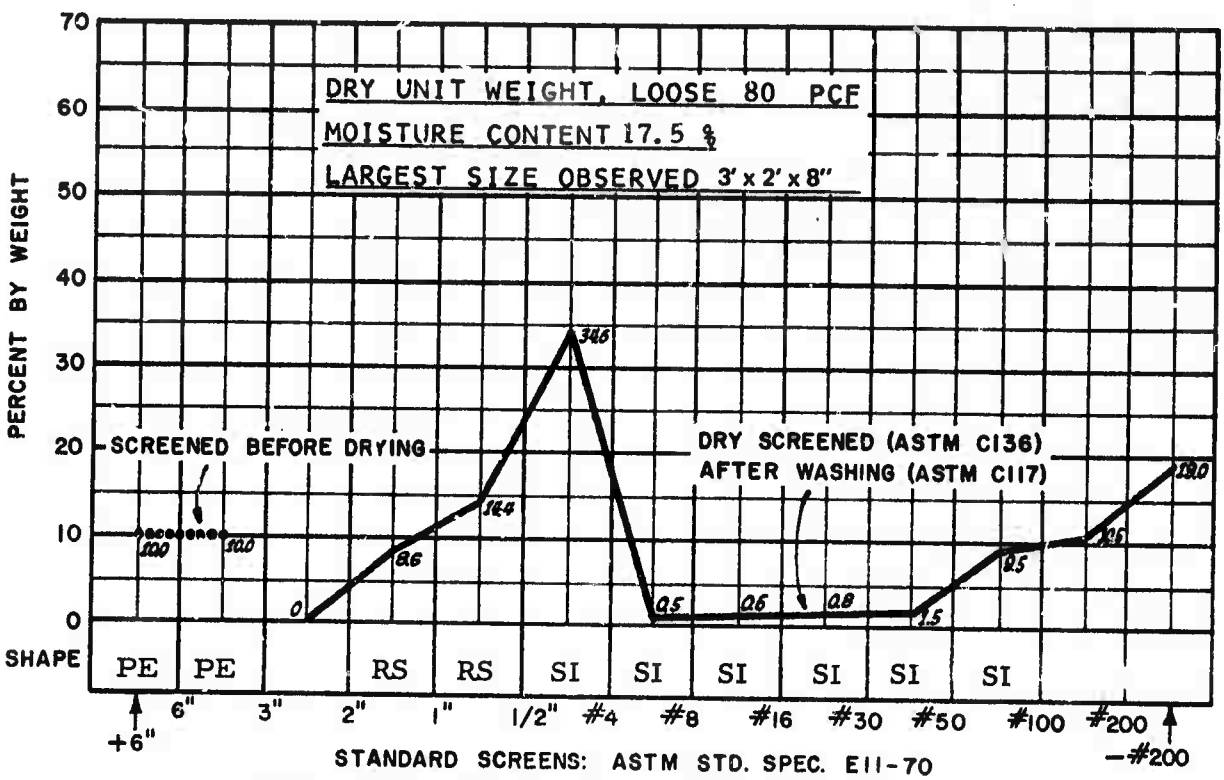
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-)0.056": 0	Size (-)0.075": 3.02

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 @ % Moisture, NA	Angle/Repose 10" Drop @ 15.1 % Moisture, 36°
Angle Slide Steel Plate @ 15.1 % Moisture, 30°	Bulk Density PCF @ % Moisture, NA	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: NA.

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
9/1/72

SYSTEM DATA SHEET
MDN

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: NA

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.
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.

MUCK DATA

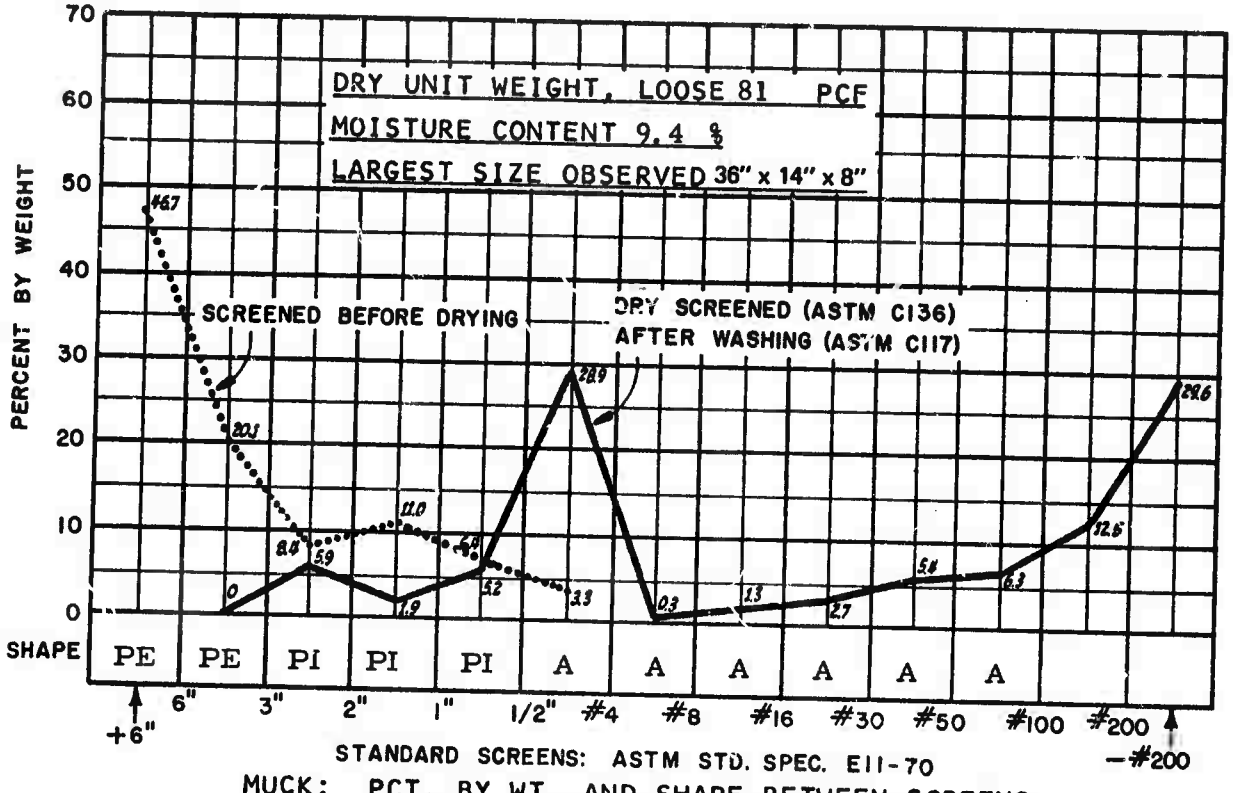
Abrasiveness	Pot. Vol. Change, Material	Spec. Gravity, Material
N. A.	Size (-) 0.056": 0	Size (-) 0.75": 2.87

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: NA

System Class: TBM, Alpine F6A, twin head, 10' high x 9' heading. 40 Kernametal 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. Haulage: Elevating conveyor-rail cars. Support: Steel sets at 3' or 6', continuous.

MDN STUDY — SYSTEM DATA SHEET — Ident. No. KM-1

9/1/72 — MDN — Sheet 2

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), $\cdots$, (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, $i = 1, \cdots, n$, are the values of the independent variable x, and the y_i, $i = 1, \cdots, n$, 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:

$$\alpha = v_{xy}/s_x^2 \tag{3}$$

$$\beta = \bar{y} - \alpha \bar{x} \tag{4}$$

where

$$s_x^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \tag{5}$$

$$v_{xy} = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}) \tag{6}$$

$\bar{x}$ and $\bar{y}$ 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:

$$\begin{aligned} \epsilon = z^T z &= [w - A\alpha]^T [w - A\alpha] \\ &= \alpha^T A^T A\alpha - (w^T A\alpha + \alpha^T A^T w) + w^T w \end{aligned} \tag{11}$$

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 $\alpha_o\ \alpha_1, \cdots, \alpha_{m-1}$.

(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', $\cdots$, 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 correction 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, Fc

(c) Rock quality designation, RQD

(d) Dry Unit Weight, DUW

(e) Hardness, H

(f) Ground Water, GW quantified, e.g., as Dry = 1, Minor = 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 still undefined may be included. The regression analysis may be performed using one or more of these variables.

A set of observations is obtained, and with each set of observations, an MDN is indicated. A table with the following entries will be created:

MDN	CLASS	Fc	RQD	DUW	H	GW

It is seen that y corresponds to MDN, and CLASS, Fc, 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).

Several iterations of this analysis should be performed on the computer in order to determine which variable or combinations of variables are appropriate to include in the predictor equation. Certain tests can be performed to determine the quality and accuracy of this predictor equation. With computer routines readily available, several iterations may be performed with reasonable cost and in a very short time.

APPENDIX E

TRANSPORT SYSTEM SELECTION 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 capacities 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 tunnel cross section is occupied by equipment.
- High speeds needed for short cycle time.
- Ideal road bed 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 event of accidents.

Combustion products complicate ventilation unless vehicles are powered electrically.

Applicability

Applicable to any of the MDN's so far developed. Special cars would be required for high speed operations with very wet muck, and special dumping facilities with MDN's 6 and 7.

Siderail 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 siderail 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.

Applicability

MDN's 1 through 7 could be transported by this system. Problems in unloading cars can be expected from MDN's 6 and 7 if wet, due to the high percentage of fines.

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 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.

Applicability

MDN's 1 through 5 can be transported by free vehicles. Excessive tire wear could be expected in the MDN 1 and 2 range due to angularity and abrasiveness of these materials. This system may not be practical for sites producing muck in the MDN 6 and 7 range 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.

Applicability

All MDN's can be transported by conveyors. Excessive belt damage and wear can be expected in the MDN 1 and 2 range because of piece size and shape unless the material is crushed prior to being placed in the system. In the MDN 6 to 7 range, through a wide range of water occurrence, considerable material will stick to the belt causing excessive cleaning problems. 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 to plus 2-inch material through centrifugal pumps has not been demonstrated in field usage.
Crushing 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.

Applicability

MDN 7 is best suited for pumping because of the low percentage of plus #4 material and a high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's by a through-centrifugal pump system.

Pneumatic Pipeline

Capabilities and Advantages

Pipelines use very little space in the tunnel.
Adaptable to any grade, including vertical.

System Constraints

Power requirements appear excessive.
Muck must be relatively dry.
Crushing or scalping equipment must be used if pieces are too large for system.
Pipe wear and maintenance may be excessive.
Secondary transportation must be provided for materials and personnel.
Methods of advancing blower units and pipe must be developed.
Dust at the discharge or from malfunctions may be hazardous to personnel.

Applicability

MDN 7 is best suited for pneumatic systems because of the low percentage of plus #4 material and the high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's.