MAR. 1990

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

180 HOWARD ST.
SAN FRANCISCO, CA 94105

MONTANORE PROJECT
GEOTECHNICAL REPORT
TAILINGS IMPOUNDMENT SITE
VOLUME 2 OF 2
APPENDICES

Noranda Minerals Corp.
Montanore Project
101 Woodland Road
P.O. Box 1486
Libby, Montana 59923

by:
Morrison-Knudsen Engineers, Inc.
180 Howard Street
San Francisco, California 94105
March 1990

MONTANORE PROJECT

GEOTECHNICAL REPORT

TAILINGS IMPOUNDMENT SITE

CONTENTS

VOLUME 1 OF 2

Chapter		Page No.
1.0	SUMMARY AND CONCLUSIONS	1-1
2.0	INTRODUCTION	2-1
2.1	Background	2-1
2.2	Purpose and Scope	2-1
2.3	Authorization	2-2
3.0	GEOLOGIC SETTING	3-1
4.0	SEISMICITY	4-1
4.1	General	4-1
4.2	Regional Seismicity	4-1
4.3	Local Seismicity	4-3
4.4	Faults	4-4
4.5	Maximum Credible Earthquakes	4-5
4.6	Seismic Design Criteria	4-5
5.0	FIELD EXPLORATION AND LABORATORY TESTING	5-1
5.1	Field Exploration	5-1
A.	General	5-1
B.	Geologic Mapping	5-1
C.	Seismic Refraction Surveys	5-1
D.	Drilling	5-2
E.	Test Pits	5-4
F.	Density Tests	5-4
5.2	Laboratory Testing	5-5
6.0	SITE AND SUBSURFACE CONDITIONS	6-1
6.1	Site Conditions	6-1
6.2	Subsurface Conditions	6-2
A.	General	6-2
B.	Bedrock	6-2
C.	Soils	6-4
D.	Groundwater	6-6
REFERENCES		

FIGURES

Figure	1:	Project Location Map
Figure	2:	Vicinity Plan and Watershed Areas
Figure	3A	Historical Earthquakes in Montana, 1869-1979
Figure	3B:	Montanore Seismicity
Figure	4:	Exploration Plan
Figure	5:	Bedrock Contour Map
Figure	6:	Soils Isopach Map
Figure	7:	Piezometric Surface Map
Figure	8:	Geologic Section A
Figure	9:	Geologic Section B
Figure	10:	Geologic Section C
Figure	11:	Geologic Section D
Figure	12:	Geologic Section E
Figure	13:	Geologic Section F
Figure	14:	Geologic Section G
Figure	15:	Geologic Sections H & J

APPENDICES

VOLUME 2 of 2

Appendix	A:	Design Basis Memorandum
Appendix	B:	Seismic Refraction Survey
Appendix	C:	Drill Logs
Appendix	D:	Test Pit Logs
Appendix	E:	Field Density Test Results
Appendix	F:	Laboratory Test Data

APPENDIX A

DESIGN BASIS MEMORANDUM

1.0 INTRODUCTION

Noranda Minerals Corporation is currently planning the further development of the Montanore Project located between Libby and Noxon in Sanders and Lincoln Counties, Montana, for mining and milling copper - silver ore. This Design Basis Memorandum describes the scope of work, design criteria and work approach for final design of the Little Cherry impoundment, to store tailings resulting from milling operations.

Structures required for tailings impoundment development include the following:

- Tailings dam, consisting of starter dam and toe dike.
- Two saddle dams
- Diversion dam
- Diversion channel
- Seepage collection dam

A geotechnical investigation is part of the final design and the investigation supplements the 1988 geotechnical data base developed during the preliminary design stage.

2.0 PROJECT GOAL

The goal of the engineering work and geotechnical investigation outlined in this Design Basis Memorandum is to finalize the design for the Little Cherry tailings impoundment. To accomplish this goal, the scope of work described in Section 3.0 has been developed to (1) better define geotechnical conditions at the impoundment site, (2) prepare a final design and (3) provide construction cost estimates. The design will form the basis for which contract plans and specifications can subsequently be prepared.

3.0 SCOPE OF WORK

The scope of work for final design consists of the following tasks:

- o Conduct a field investigation that includes the following activities:
  - Seismic refraction surveys
  - Exploratory drilling
  - Test pit excavations
  - Laboratory testing

- o Perform the following final design studies:
  - Stability analyses
  - Tailings settlement analysis
  - Diversion channel design
  - Dam and dike design
  - Reclamation plan
  - Construction cost estimates

- o Prepare the following technical reports:
  - Geotechnical Report
  - Tailings Impoundment Final Engineering Report

- o Attend meetings with Noranda Minerals Corporation and regulatory agencies.

4.0 DESIGN CRITERIA

4.1 Tailings Production

During the operational stages of the impoundment, the embankment dam will be constructed by the downstream method using cycloned tailings sand. A two-stage cycloning process will be required to produce a sand having about 10 percent passing the No. 200 Sieve. The amount of fines should not be greater than about 10 percent in order to promote drainage within the embankment dam. The

anticipated gradation of the tailings feed (based on flotation test results) is shown in Table 4-1 below:

TABLE 4-1
TAILINGS FEED GRADATION

Tyler Sieve No.	Particle Size (Microns)	Cumulative % Passing Sieve
65	208	99.5
100	147	90.2
150	104	69.4
200	74	52.1
270	52	35.9
400	37	25.0

For tailings impoundment sizing, the tailings production rate will be as shown in Table 4-2 below:

TABLE 4-2
TAILINGS PRODUCTION

Year	Tailings Production (tons per day)
1	11,000
2	15,000
3	15,000
≥4	20,000

The cyclone overflow (fine tailings) will be stored in the impoundment. The total required storage for both fine and coarse tailings will be about 120,000,000 tons. Coarse and fine tailings production curves and impoundment staging curves will be developed. A cyclone analysis will be done to determine the percent split of coarse and fine tailings. Dry unit weights of tailings will be determined by laboratory testing of flotation test samples (Subsection 5.2.E). For preliminary planning, the dry unit weight of the coarse tailings will be 100 pcf and for the fine tailings, 70 pcf will be used.

4.2 Stability

The following stability analyses will be performed:

- Conventional static and seismic stability analyses
- Dynamic response and deformation analyses
- Liquefaction analyses.

Conventional stability analyses will be performed for the starter and final stages of the tailings dam. The starter dam will be evaluated for the end-of-construction, steady-state seepage and seismic conditions. The final dam will be evaluated for steady-state seepage, seismic and flood conditions. The analyses will be performed by using the strength parameters determined from the results of the laboratory testing program (Subsection 5.2.E). The tailings in the impoundment will be conservatively assumed to behave as a dense fluid and, therefore, will be assigned zero shear strength.

The minimum acceptable factors of safety for use in design are shown in Table 4-3. The criteria for long-term, end-of-construction and seismic conditions are as recommended by the Corps of Engineers (Ref. 1).

TABLE 4-3
STABILITY CRITERIA

Load Condition	Embankment Stage	Slope	Minimum Acceptable Factor of Safety
End-of-Construction (before tailings deposition)	Starter Dam	Upstream & Downstream	1.3
Long-term (full tailings pond)	Starter and Final Dams	Downstream	1.5
Flood Condition	Final Dam	Downstream	1.4
Seismic	Starter and Final Dams	Downstream	1.0

The project site is located close to the boundaries of Seismic Zones 1, 2 and 3 (see Figure 1). Based on a review of site seismicity during preliminary design, a seismic coefficient of 0.10g will be used in the seismic stability computations as recommended by the Corps of Engineers for Seismic Zone 3 (Ref. 1).

In the "pseudo-static" method of stability analysis, the effects of an earthquake on a potential slide mass are represented by an equivalent static horizontal force determined as the product of a seismic coefficient and the weight of the potential slide mass. The use of the maximum ground acceleration as the seismic coefficient would produce an equivalent static horizontal force equal to the maximum transient inertia force developed on the mass during the design earthquake. However, the length of time for which the force acts is an important factor in the development of deformations. Therefore, the use of the maximum transient force as an equivalent static force would be unduly conservative (Ref. 2) and the recommended seismic coefficient of 0.10g should be used.

An MCE event for use in both seismic deformation and liquefaction analyses was determined based on magnitudes of historical earthquakes and correlations between magnitude and length of active faults (potential activity during Pleistocene or Holocene). The MCE is defined as the largest rationally conceivable event that

could occur in the tectonic environment in which the project is located (Ref. 3). For impoundment design, the MCE was determined to be as follows (Ref. 4):

o	Source:	Bull Lake Fault
o	Distance:	20 km
o	Magnitude:	7.0
o	Peak Bedrock Acceleration:	0.22g

Due to the large size of the ultimate dam (nearly 400 feet high) and the potential for a strong nearby earthquake, an analysis will be conducted to confirm that embankment deformations resulting from the design earthquake will be acceptable. Of particular concern is that there should not be an excessive reduction of embankment freeboard due to seismically-induced deformations. The analysis approach is described (Subsection 5.3.A.2).

Foundation liquefaction analyses will be performed. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking (Ref. 5). Soil deposits that are particularly susceptible to liquefaction consist of loose, saturated sands. Liquefaction potential of sandy foundation soils due to the Maximum Credible Earthquake (MCE) event will be evaluated by methods outlined in Refs. 6 and 7.

4.3 Design Flood

The designation of the tailings impoundment design flood is based on size and hazard potential classifications. The tailings retention dam will be raised incrementally to increase impoundment storage capacity. Size classification is determined by either impoundment storage or dam stage height, whichever gives the larger size category. For this project, dam stage heights control size classification.

The distance, in river miles, to the nearest dwelling and to U.S. Highway 2 from the Little Cherry impoundment site is 5.4 and 5.7, respectively. The review agencies consider the impoundment site to have moderate to high hazard potential.

Based on dam stage size and hazard potential classifications, the agencies designated the following design flood criteria:

o	For containment:	24-hour general storm Probable Maximum Precipitation (PMP)
o	For diversion:	72-hour general storm Probable Maximum Flood (PMF)

Because thunderstorm events should also be considered, for small watersheds, the local storm PMF (resulting from the 6-hour PMP) was also considered for diversion. This flood is the more critical of the two diversion floods and will therefore be used for diversion system design.

For interim stages less than 100 feet high that would be present for short term (less than 5 years), the containment flood will be calculated from the 24-hour general storm 1/2 PMP.

The minimum embankment dam freeboard (above the peak flood water surface) will be 3 feet.

4.4 Channel Design

The 6-hour local storm PMF will be used to develop the channel design flow rate. The design flow rate will be calculated by routing the inflow flood hydrograph through the diversion pond and the diversion channel. The U.S. Army Corps of Engineers HEC-1 computer program will be used for this purpose. The peak flood inflow was computed to be 5230 cfs. (Ref. 8).

The diversion channel will have adequate longitudinal slope and cross-sectional area to pass the design flow with a minimum of 2 feet of freeboard to the top of the riprap. Velocities will be sufficiently high to flush out sediments. The channel will have a trapezoidal cross-section. The bottom width, side slopes and channel gradient will be designed to promote stability and minimize erosion potential.

To protect against erosion, portions of the channel in soil will be lined with rock riprap. The Safety Factors Method (Ref. 9) will be used to design the median (D50-min) rock size. Rock properties, including specific gravity, friction angle and porosity, will be estimated from published values that are typical for riprap. Manning's roughness coefficient will be calculated using the U.S. Army Corps of Engineers method (Ref. 10).

Gradation and thickness of the riprap lining will be designed based on the Corps of Engineers method (Ref. 10). Bedding layers beneath the riprap will be provided to prevent the migration of finer subgrade materials through riprap materials. Filter criteria for the bedding will be as indicated in Ref. 11.

The outlet will be designed to reduce flow velocities to a level that will not erode the natural material in the receiving drainage channel. This design concept could be accomplished by providing for a gradually divergent outlet and reduction of the channel slope. A rockfill toe will be provided to protect the channel outlet against potential headward erosion.

Initially, erosion protection is not planned for the stream channel downstream of the diversion channel. Erosion protection will be constructed if erosion is observed during operations. Such protection would consist of rockfill check dams to dissipate flow energy. The stream channel erosion protection would be based on the 100-year flood. If needed, check dams will be constructed of well-graded, durable rockfill that will retain sediment. The rockfill gradation will be designed to be stable under the design flood. The check dams will be keyed into the stream channel.

The spacing of the rockfill check dams will be based on check dam height, channel gradient and the expected final slope of the channel after sediment has accumulated behind the dams. For a final sediment deposit slope, the height and spacing of the check dams will be calculated to minimize the total required rockfill volume.

The check dams will be considered as broad-crested weirs and the discharge relationship will be based on weir flow formulas. Rockfill aprons will be

constructed, if necessary, to dissipate energy of the flow over the check dams. The lengths of the aprons will be based on the heights of the check dams and channel slope.

4.5 Waste Rock Production

The mine waste rock available for dam construction is shown in Table 4-4 below:

TABLE 4-4
MINE WASTE ROCK SCHEDULE

Year	Project Stage	In-Place Tons (X1000)	Cum. Tons (X1000)	Rock Designation
1	Evaluation	192	192	Crushed
2		187	379	Crushed
3	Preproduction Development	587	966	Run of Mine
4		535	1501	Run of Mine
5	Initial Production	0	1501	--
6		664	2165	Run of Mine
7		1091	3256	Run of Mine
8	Full Production	537	3793	Gobbed in Mine
9		485	4278	Gobbed in Mine
10		75	4353	Gobbed in Mine
11-17		75/yr.	4878	Gobbed in Mine
≥18		0	4878	Gobbed in Mine

Table 4-5 shows the anticipated gradations of both crushed and run of mine waste rock. If gobbed rock is needed for construction, it will have to be crushed for transportation to a loading area via conveyor.

TABLE 4-5
WASTE ROCK GRADATIONS

Crushed Rock		Run of Mine Rock	
Size (in.)	% Passing	Size (in.)	% Passing
10	100	24	100
8	90	16	90
7	80	13	80
6	70	10	70
5	60	9	60
4	50	7	50
3	40	5	40
2	30	3	30
1 1/2	20	2	20
3/4	10	1	10

The dry unit weight of all mine waste rockfill placed and compacted in embankments will be 140 pcf.

5.0 APPROACH

5.1 General

This section presents the approach for final design of the Little Cherry Tailings impoundment site. The section is divided into the following tasks as outlined in Section 3.0:

- Geotechnical Investigation
- Final Design Engineering
- Technical Reports
- Review Meetings

5.2 Geotechnical Investigation

A. General - A field investigation program was undertaken during the summer of 1989 to supplement the 1988 geotechnical data base developed for the permit application. The program consisted of seismic refraction surveys, drilling and test pit excavations. The locations of the 1988 and 1989 seismic lines, drill holes and test pits are shown on the Exploration Plan, Figure 2.

Due to access limitations during the initial investigation program in July and August 1988, drilling could not be performed along the diversion channel alignment. Therefore, a large part of the 1989 investigation was focused on the diversion channel.

Existing tracks and roads were used for site access to the maximum possible extent. However, since the investigation plan involved access track construction in timbered areas for drill sites, close coordination with the Forest Service was required for timber cutting and construction activities. All tracks and sites for drilling and test pits will be restored as required by the Forest Service.

B. Seismic Refraction Surveys - The subsurface investigation began with a seismic survey of the impoundment site. Seismic refraction surveys were performed along the diversion channel alignment to (I) estimate depths to bedrock, (2) confirm boring locations and (3) estimate rippability of the materials to be excavated. Seismic velocities also will be useful to contractors to estimate excavation equipment requirements. Seismic refraction surveys also were performed in the dam foundation to provide supplemental data on depths to bedrock. Thirty-five surveys were performed in the impoundment site.

C. Drilling - Drilling was done in the impoundment site to explore dam foundation conditions and materials to be excavated from the diversion channel. For the 1989 investigations, 20 borings totaling 2265 linear feet were drilled. A summary of the drilling program is shown in Table 5-1 below.

TABLE 5-1

SUMMARY OF DRILLING PROGRAM

Area	Boring No.	Total Depth (feet)
Tailings Dam	DH-1	100
	DH-2	110
	DH-3	367
	DH-3A	25
South Saddle Dam	DH-4	40
North Saddle Dam	DH-5	197
Tailings Impoundment	DH-6	60
Diversion Channel	DH-7	73
	DH-8	98
	DH-9	82
	DH-10	87
Diversion Dam Abutment	DH-11	192
Tailing Dam	DH-12	110
South Saddle Dam	DH-13	80
	DH-14	60
Tailings Impoundment	DH-15	120
	DH-17	80
	DH-18	65
Tailings Dam	DH-19	105
	DH-20	214
	TOTAL =	2265

Eighteen borings were cased with PVC pipe to monitor groundwater levels in the dam foundation, proposed diversion channel excavation and tailings impoundment. Field permeability tests were performed in borings to supplement permeability values measured previously. Tests in overburden were performed by using constant head open-end casing tests conforming to procedures in the U.S. Bureau of Reclamation's "Earth Manual", Method E-18 (Ref. 12). Water pressure tests in bedrock were conducted by using a single pneumatic packer. Permeability tests also were performed in borings drilled in the diversion channel site. The

results of these tests will indicate the magnitude of anticipated groundwater flow into the channel excavation. This information will be used to estimate groundwater control measures.

Standard Penetration Tests (SPT's) were performed in the borings at approximately 5-foot intervals to a depth of about 25 feet and at selected depths below 25 feet. The results of the SPT's will be used to characterize foundation materials for use in stability and liquefaction analyses (Subsection 5.3. A.).

Undisturbed samples were collected during the drilling program. Shelby tube samplers were used to obtain undisturbed samples of clayey soils. These samples will be used for strength testing as described in Subsection 5.2.E below.

D. Test Pits - Twenty-five backhoe test pits were excavated in the proposed borrow area and diversion channel excavation to confirm the suitability and condition of the soils for use as construction materials. Also, test pits were excavated in the impoundment site to identify any areas of permeable materials that may need to be blanketed with clayey soils. Samples from the test pits were taken for laboratory testing.

A backhoe with a 20-foot reach was used for final design exploration. All test pit sites will be restored as required by the U.S. Forest Service.

Field density tests to measure soil densities were performed in 6 shallow test pits excavated in the proposed dam foundation. The results of these tests will be used to prepare samples for strength testing as described in Subsection 5.2.E below.

E. Laboratory Testing - A laboratory testing program will be performed to obtain engineering parameters of the soil at the tailings impoundment site. The test data will be evaluated for use in dam design and stability analyses.

Testing of soil samples collected from the drilling and test pit excavation program will follow American Society for Testing and Materials (ASTM) procedures and consist of the following:

- Grain size analyses - ASTM D422
- Natural moisture contents - ASTM D2216
- Plasticity index characteristics - ASTM D4318
- In-situ dry densities - ASTM D2937
- Moisture/density characteristics - ASTM D698
- Relative Density - ASTM D4254
- Triaxial compression - ASTM D2850
  (for unconsolidated-undrained tests)
- Consolidation - ASTM D2435

Grain size and plasticity index tests will be performed to classify foundation soils and potential borrow materials. Natural moisture contents will be measured to determine requirements for construction moisture content conditioning of borrow materials. Dry densities of undisturbed soil samples will be measured for use in stability analyses. Moisture/density tests will be performed to determine maximum densities and optimum water contents for embankment construction. A relative density determination will be performed on a sand tailings sample for use in liquefaction and stability analyses (Sub-section 5.3.A).

Strength parameters will be used in final design stability analyses. Unconsolidated-undrained (UU) triaxial compression tests will be performed on undisturbed samples of clayey foundation soils. Consolidated-undrained (CU) triaxial compression tests with pore pressure measurements will be performed on both foundation and embankment soil samples. Samples of granular soils from the foundation will be prepared for CU testing by compacting them to the densities and moisture contents determined from the results of field and laboratory tests. Samples from test pits excavated in borrow areas will be compacted to densities and moisture contents that are representative of those expected in the earthfill dams (i.e., 95% of the maximum dry density and at optimum moisture content as determined by ASTM D698).

Since the dam will be constructed primarily of sand tailings, CU triaxial compression test will be performed on tailings samples obtained from Noranda's

flotation tests. The sand tailings sample gradation will be based on the results of cyclone analyses. Sample density will be based on research of densities reported for tailings dams.

To estimate settlement of the fine tailings (Subsection 5.3.B), consolidation tests will be performed on fine tailings samples obtained from the flotation tests. The fine tailings gradation will be based on the results of cyclone analyses.

5.3 Final Design Engineering

A. Stability Analyses - The following analyses will be performed:

- Limit equilibrium static and seismic stability analyses
- Dynamic response and deformation analyses
- Liquefaction analyses

A.1 Limit Equilibrium Analyses - Static and seismic stability analyses will be performed for the initial and final dam stages by using the Bishop and infinite slope methods of analysis. The computer program STABL (Ref. 13) or other program will be used to determine the factor of safety for circular sliding surfaces. For cohesionless materials, calculations also will be performed using the infinite slope method. The minimum factor of safety calculated for each loading condition will be compared to the minimum acceptable values given in Section 4.2. Stability will be evaluated for a wide range of phreatic surface conditions. In addition, factors of safety will be computed for various foundation piezometric surfaces. The stability analyses will be coordinated with relief well system design (Subsection 5.3.D.2).

A.2 Dynamic Response and Deformation Analyses - The peak bedrock acceleration (0.22g) determined for permit application studies (Ref. 4) will be used in the dynamic response and deformation analysis. The predominant period of the site due to design earthquake motion

will be estimated from Seed, Idriss and Kiefer (Ref. 14). The duration of significant ground shaking at the site will be estimated by procedures described in Bolt (Ref. 15).

An earthquake acceleration time-history record will be selected based on peak acceleration, predominant period and site conditions that are similar to those for the project site. To compute dynamic response of the dam, the record will be scaled to the peak ground acceleration determined for this project. Response spectra will be computed to verify that the record is appropriately conservative.

The dynamic response of the dam (maximum crest acceleration) due to the design ground motion will be computed by using the computer program SHAKE (Ref. 16) for a one-dimensional seismic wave propagation analysis. Shear modulus parameters of tailings and foundation materials for use in the analysis will be obtained from published literature. Earthquake induced deformations will be estimated from the procedures developed by Makdisi and Seed (Ref. 17).

A.3 Liquefaction Analyses - Foundation liquefaction analyses will be performed. Shear stresses caused by seismic shaking (MCE acceleration) will be computed during the dynamic response analysis described in Subsection 5.3.A.2 above. The resistance of soils to liquefaction will be obtained from published correlations with Standard Penetration Test data obtained during drilling (Ref. 18). The effect of silt content in soils on liquefaction potential will be evaluated (Ref. 7). Factors of safety against potential liquefaction (resistance to liquefaction/seismic shear stress) will be computed.

B. Tailings Settlement Analysis - Settlement of the fine pond tailings will be calculated by using one-dimensional finite strain consolidation of fine-grained material. Void ratio-effective stress and void ratio-permeability relationships from one-dimensional consolidation testing will be used to estimate

settlement. Estimates of settlement with time will be obtained from the results of laboratory consolidation tests and procedures that relate percent consolidation to time (Ref. 19). Procedures have been developed for different void ratio distributions within the consolidating material and different drainage boundary conditions. Consolidation of soft layers will be calculated by use of the computer program CSLFS (Consolidation of Soft Layers, Finite Strain) (Ref. 20). This information will be used for designing the final reclaimed pond surface configuration and estimating the amount of required earthwork.

C. Diversion Channel Design - The design of the diversion channel will be based on the results of the geotechnical investigation. The results of the investigation may indicate the need to revise the channel location or modify the channel invert profile.

To determine the size of the channel and diversion dam height, the design flood produced by the 6-hour local storm PMP event will be routed through the diversion pond by using HEC-1 procedures. A peak discharge of 5230 cfs produced by the 6-hour PMF (Ref. 8) will be used as the design flood to calculate flow depths and velocities in the diversion channel.

The location of bedrock will be a major consideration in channel design. Ideally, the lower portion of the channel will be in sound bedrock, thus eliminating the need for riprap. If the channel invert will be in soil or soft rock, riprap protection will be designed to resist erosion from the routed design flood flows. The required thickness and gradation of the riprap layer will be determined from the results of hydraulic analyses. Filter requirements between the riprap and foundation soils will be determined. Flow energy dissipation measures at the downstream end of the channel will be designed to minimize potential scour. Channel side slopes will be analyzed to confirm that they will have adequate stability.

The following diversion channel drawings will be prepared:

- o Plan and Profile
- o Channel Sections and Details
- o Inlet and Outlet Plans, Sections and Details

D. Dam and Dike Design

D.1 Embankments - The earthfill embankment structures required for the Little Cherry tailings impoundment will consist of the following:

- o Tailings dam, consisting of starter dam and toe dike
- o Two saddle dams
- o Diversion dam
- o Seepage collection dam

The design of the structures developed during the preliminary stage will be used as a starting point for final design. Final construction quantities and material availability will be estimated. Construction quantities will be used to compute mass-balance relationships.

The embankment dams will be constructed of (1) required excavation material, e.g. diversion channel, (2) materials excavated from the impoundment, (3) evaluation adit and mine waste rock and (4) tailings sands. The embankment dam zone configurations will be designed to take economical advantage of material availability.

A major effort of this work item will be directed towards designing the filter and drain system of the dam. Mine waste rock will be processed to provide materials for filters and drains. To prevent piping (internal erosion) of embankment materials the gradations of filters and drains will be designed on the basis of established filter criteria (Ref. 11). Drains will be designed to conduct

estimated seepage through the dam and from the foundation to the downstream toe. Required thickness of the drain will be based on seepage volume and permeability of the drain. Permeability of the drain material will be based on the D15 size of the drain rock material (Ref. 21).

Construction requirements for the embankment zones, including material gradations, placement and compaction will be determined. These requirements will form the basis for preparing construction specifications.

The ultimate impoundment will be sized to store 120 million tons of tailings. The starter impoundment will be sized to store tailings resulting from at least the first year of production. For capacity calculations, the tailings density will be based on results of the laboratory soil testing plus experience with similar tailings materials. Area-capacity curves and tailings production rates will be used to develop construction staging curves.

Final design of the tailings dam will include an instrumentation plan to measure piezometric pressures and seepage. A plan showing the seepage measurement weir and piezometer installation details will be prepared.

The following drawings will be produced:

- Impoundment Site Plan - Starter Stage
- Impoundment Site Plan - Final Stage
- Dam Sections and Details - Starter Stage
- Dam Sections and Details - Final Stage
- Instrumentation Plan and Installation Details
- Construction Staging Curves

Survey control will be shown on the plans. This arrangement of drawings will expedite future preparation of construction drawings for the starter stage.

D.2 Pressure Relief Well System - The groundwater levels measured in borings in the dam foundation indicate that artesian pressures exist in the foundation. The highest pressure measured was 21 feet above the ground surface at Boring DH-15. In order to prevent excessive pressures from developing in the foundation during impoundment operations, a pressure relief well system will be required.

Designing the pressure relief well system requires determination of the most cost-effective spacing, depth and diameter of the wells. Procedures described in Ref. 22 and solutions of well drawdown analysis will be used to design the system. Parameters required for the analysis are foundation permeability, thickness of soil strata and hydraulic head. Permeability parameters will be obtained from the results of constant head tests and pump tests.

The maximum allowable head between relief wells will be based on the results of stability analyses (Subsection 5.3.A.1). As described in Subsection 5.3.A.1, various foundation pressure heads will be used in stability analysis calculations. Factors of safety will be compared with pressure heads to determine the maximum allowable pressure head in the foundation.

The relief well system will be installed during the life of the impoundment. As heads increase during the expansion of the tailings impoundment, additional wells will be installed.

Typical well details will be prepared. The wells will have screens or filters to prevent piping of the foundation soils. Filter criteria are specified in Ref. 22.

E. Reclamation Plan - A final impoundment reclamation scheme will be presented. Montana regulations require that the land be returned to comparable utility that existed prior to impoundment construction (Ref. 23). The reclamation plan will basically consist of (1) soil stripping and stockpiling at the beginning of each impoundment construction stage, (2) placing geofabric and waste rock in depression areas, (3) deposition of coarse tailings along the upstream side of the crest during the final year of operation, (4) capping the final tailings surface and downstream slope of the tailing dam with soil, including the stockpiled soil, and (5) seeding the cap and downstream slope of the dam. The crest of the tailings dam will be built up to prevent runoff from draining over the downstream slope of the dam. The north saddle dam will be removed so runoff from the tailings surface will flow through the north saddle into Bear Creek.

The following drawings will be produced:

- Impoundment Reclamation Plan
- Impoundment Reclamation Sections and Details

F. Construction Cost Estimates

F.1 Initial Estimate - For planning purposes, an initial construction cost estimate of the starter, operation and reclamation stages of the impoundment has been prepared. Quantities were estimated from preliminary drawings prepared for the permit application. Standard unit costs adjusted for the project area were used for most line items. Preliminary estimates were made for major cost items such as the diversion channel excavation. For minor items, where design details have not yet been developed to permit quantity estimation, lump sum allowances were included in the estimate. Unit costs and subtotals of each impoundment structure were presented in the estimate.

Only civil construction items were included in the cost estimates; mechanical equipment (e.g., cyclones and pumps) and pipelines were

not included. A construction materials flow diagram was included to show the source and placement of earth and rock material. A conceptual impoundment construction schedule for the life of the project was included in the estimate. To assist Noranda in their planning, a cash flow forecast table was also presented.

F.2. Final Estimate - After design studies have been completed, construction cost estimates will be prepared for the (1) starter stage, (2) civil work during operation and (3) reclamation of the tailings impoundment. Costs will be estimated by assuming that the work will be performed by an independent contractor. As Noranda directed, only civil construction items will be estimated; mechanical equipment (e.g., cyclones and pumps) and pipelines will not be included in the estimate. Also, operational costs for raising the dam by cycloning tailings will be excluded.

Supporting documentation will show the estimated quantity and labor, material construction equipment and subcontract cost, if applicable, for each line item in the estimate. Unit cost details will be shown where appropriate. The estimate will be accompanied by a narrative describing basic assumptions and criteria used in the development of estimated costs. Studies will be performed to establish crew composition, productivity and schedules for all significant construction activities.

Hourly construction craft labor rates (union or non-union) will be agreed on with Noranda prior to preparation of the estimate. Material and permanent equipment costs will be based on vendor quotations or experience from prior projects, as appropriate.

Allowances for material loss, damage and waste will be identified. Standard construction equipment rental and operating costs will be adjusted for project location and working conditions for use in the estimates.

Contractor mark-up including administration and overhead costs, contingency and profit will be calculated separately and distributed to the various estimate line items in proportion to direct labor costs.

Contingency allowances and inflation rates to be included in the estimate will be discussed and agreed upon with Noranda to ensure conformance with established policy.

Estimates will be prepared using the computerized estimating package (CAES). Estimated costs will be sorted and presented in an easy readable format.

A construction schedule will be prepared for the starter stage based on the final design and cost estimate, and will identify all relevant procurement and construction tasks. Schedule tasks will be selected that have easily identifiable start and finish events to enable objective monitoring of progress. Cash flow tables will be produced from cost estimates and task activities.

5.4 Technical Reports

The following reports will be prepared:

- Geotechnical Report
- Tailings Impoundment Final Engineering Report

The Geotechnical Report will contain the following:

- Site exploration plans, showing geologic data and locations of drill holes, test pits and seismic refraction lines
- Maps showing bedrock contours, soil depth contours and potentiometric surface contours
- Geologic sections
- Results of seismic refraction surveys

- Drill hole and test pit logs
- Laboratory test results

The geotechnical report will include field and laboratory test results from the 1988 preliminary engineering study.

The final engineering report will present the results of the tailings impoundment engineering studies. The report will include results of stability and settlement analyses. For completeness, the results of hydrologic studies performed for the preliminary report will also be included in the final report. Drawings (plans and sections) will be presented showing the impoundment features. Analysis back-up will be presented in readily accessible appendices.

The technical reports will be organized in formats agreed upon with Noranda Minerals Corporation. Each report will begin with a summary section that gives a complete overview of the work completed and results. All support information and data will be contained in readily referenced appendices.

5.5 Review Meetings

As the work progresses, periodic meetings will be held with Noranda Minerals Corporation, the Montana Department of State Lands and the U.S. Forest Service. The meetings will be used to discuss results of investigations and any critical project decisions.

6.0 REFERENCES

1. U. S. Corps of Engineers, "Engineering and Design, Stability of Earth and Rock-fill Dams," EM 1110-2-1902, April 1970, and Change 1, 17 February 1982.

2. Seed, H. B. and Martin, G. R., "The Seismic Coefficient in Earth Dam Design," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 92, SM3, 1966

3. Seed, H.B., "The Selection of Design Earthquakes for Critical Structures," Bulletin of the Seismological Society of America, Vol. 72, No. 6, December 1982.

4. Morrison-Knudsen Engineers, Inc., Geotechnical Report, February 1989.

5. Seed, H. B., "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 105, GT2, February 1979.

6. Seed, H. B., and Idriss, I. M., Ground Motions and Soil Liquefaction During Earthquakes, Earthquake Engineering Research Institute, 1982.

7. Liquefaction of Soils During Earthquakes, Committee on Earthquake Engineering, National Academy of Sciences, 1985.

8. Morrison-Knudsen Engineers, Inc., Tailings Impoundment Preliminary Engineering Report, February 1989.

9. Stevens, M.A., Simons, D.B., and Lewis, G.L., "Safety Factors for Riprap Protection," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 102, No. 5, May 1976.

10. U.S. Army Corps of Engineers (USCE), Hydraulic Design of Flood Control Channels, EM 1110-2-1601, July 1, 1970.

11. Sherard, J.L. and Dunnigan, L.P., "Filters and Leakage Control in Embankment Dams," Seepage and Leakage from Dams and Impoundments, American Society of Civil Engineers, May 5, 1985.

12. U.S. Bureau of Reclamation, Earth Manual, 1974.

13. Siegel, R. A., "STABL User Manual," Joint Highway Research Project, Report JHRP-75-9, June 1988.

14. Seed, H.B., Idriss, I.M., and Kiefer, F.W. "Characteristics of Rock Motions during Earthquakes," Journal of Soil Mechanics and Foundations, American Society of Civil Engineers, Vol. 95, SM5, 1969.

15. Bolt, B.A., "Duration Of Strong Ground Motion," Proc. 5th World Conference on Earthquake Engineering, Rome, Vol. 2, 1973.

16. Schnabel, B., Lysmer, J., and Seed, H.B., "SHAKE User Manual" Earthquake Engineering Research Center, Report No. EERC 72-12, December 1972.

17. Makdisi, F.I. and Seed, H.B., "A Simplified Procedure for Estimating Earthquake-Induced Deformations in Dams and Embankments," Earthquake Engineering Research Center, Report No. UCB/EERC - 77/19, August 1977.

18. Seed, H.B., Idriss, I.M., and Arango, I., "Evaluation of Liquefaction Potential Using Field Performance Data," Journal of Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 109, No. 3, March 1983.

19. Cargill, K.W., "Prediction of Consolidation of Very Soft Soil," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 110, No. 6, June 1984.

20. Cargill, K.W., "Consolidation of Soft Layers by Finite Strain Analysis," Miscellaneous Paper GL-82-3, U.S. Army Engineer Waterways Experiment Station, March 1982.

21. Sherard, J.L., Dunnigan, L.P., and Talbot, J.R., "Basic Properties of Sand and Gravel Filters," Journal of Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 110, No. 6, June 1984.

22. Cedergren, H.R. Seepage, Drainage, and Flow Nets, J. Wiley & Sons, Inc., 1967.

23. Administrative Rules of Montana, Chapter 4, Reclamation, Part 3 - Metal Mine Reclamation and Sub-Chapter 1, Rules and Regulations Governing the Montana Metal Mine Reclamation Act, 1 July 1980.

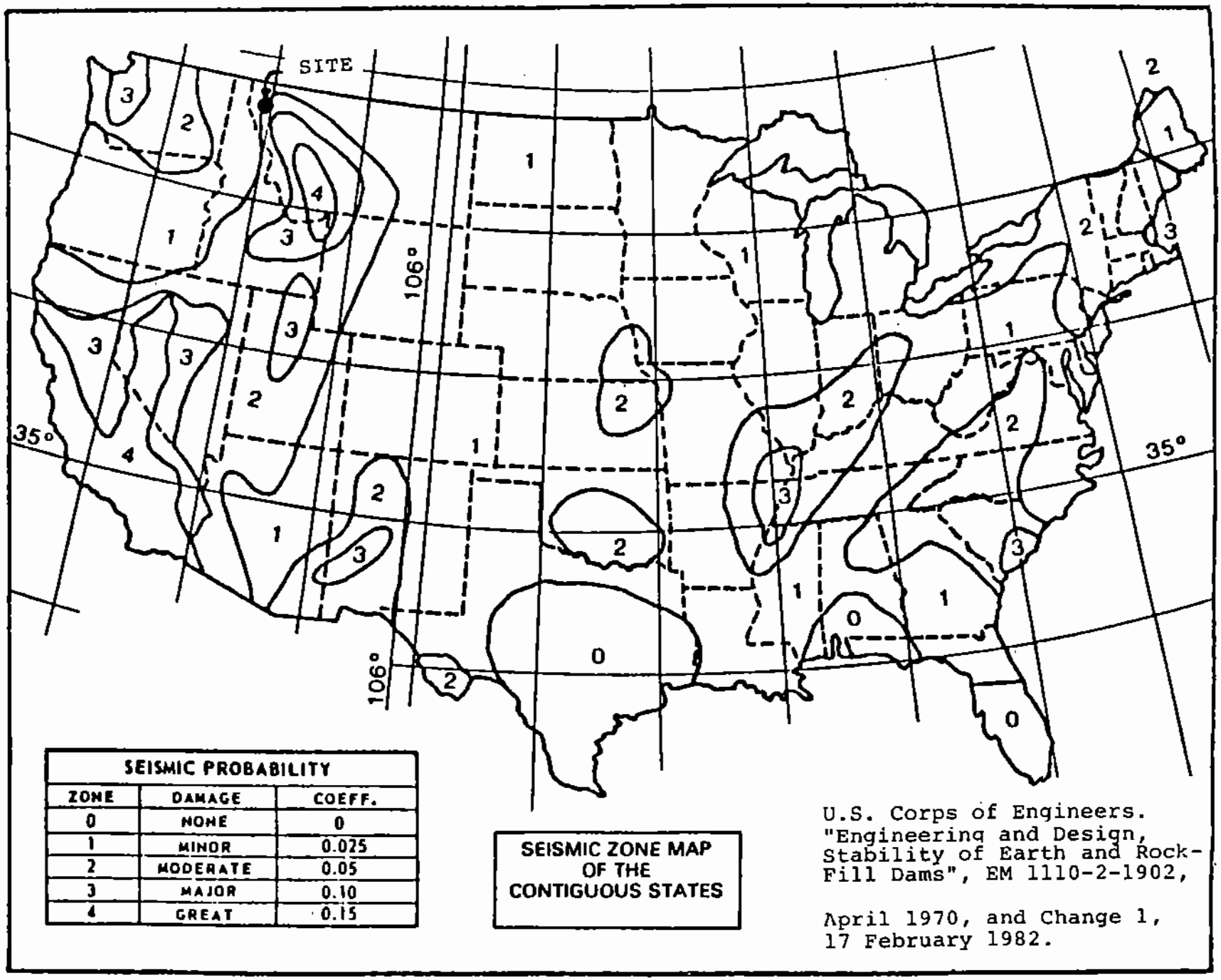
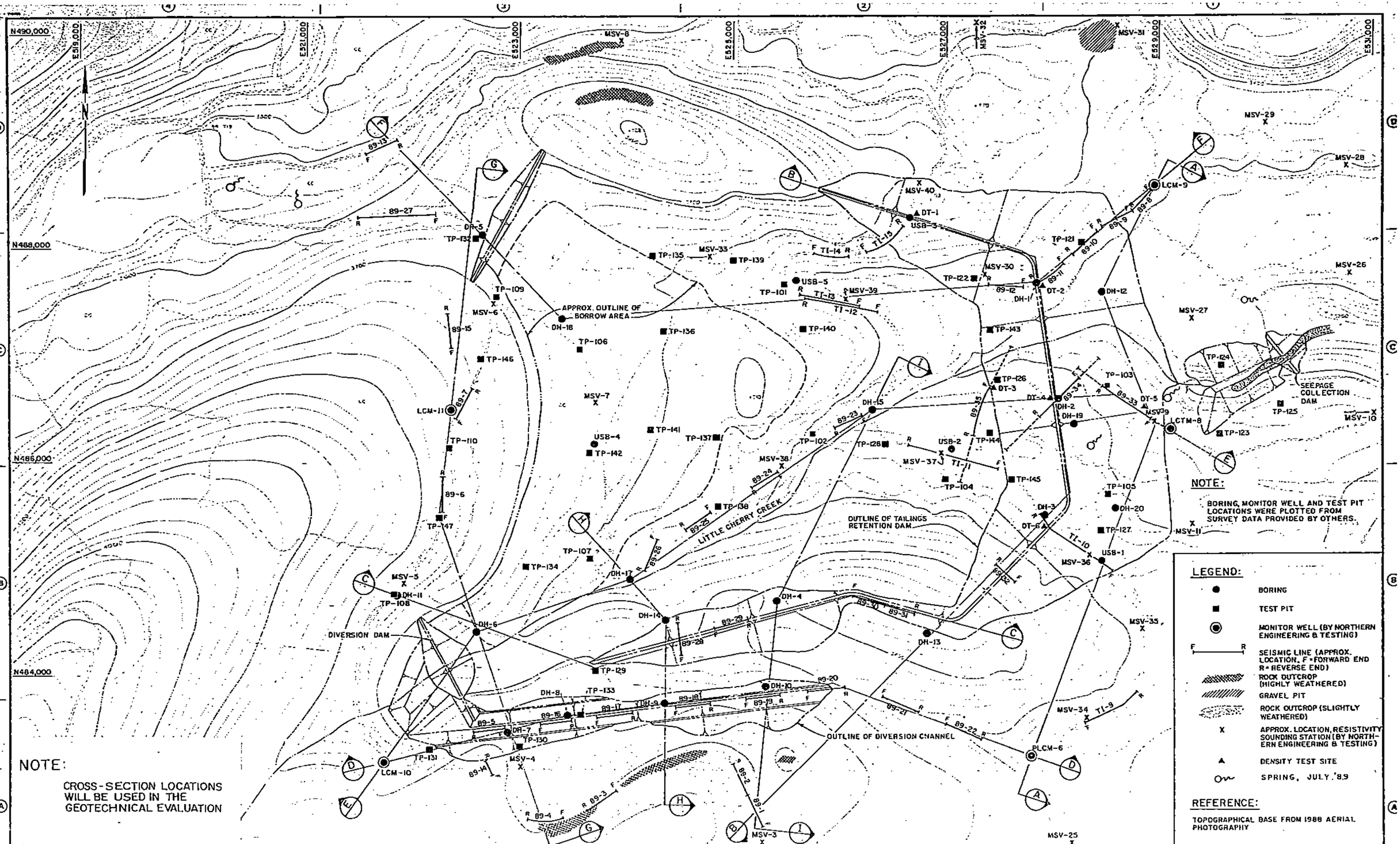

SITE
106°
35°
SEISMIC PROBABILITY
ZONE | DAMAGE | COEFF.
0 | NONE | 0
1 | MINOR | 0.025
2 | MODERATE | 0.05
3 | MAJOR | 0.10
4 | GREAT | 0.15
SEISMIC ZONE MAP OF THE CONTIGUOUS STATES
U.S. Corps of Engineers. "Engineering and Design, Stability of Earth and Rock-Fill Dams", EM 1110-2-1902, April 1970, and Change 1, 17 February 1982.

FIGURE 1



SCALE 400 0 400 800 FEET

NO.	DATE	REVISIONS	BY	CHK	APP'D

MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

DESIGNED DJU | DRAWN RBC | CHECKED MPF | RECOMMENDED
DATE OCTOBER 1988 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
EXPLORATION PLAN

MAP NO. | SHEET OF | REV.

FIGURE 2

APPENDIX B
SEISMIC REFRACTION SURVEY

APPENDIX B
SEISMIC REFRACTION SURVEY

B.1 PURPOSE

The purpose of the seismic refraction survey is to provide information on the depths to soil layers, the approximate depth to bedrock, and the rippability of near surface material. The locations of the seismic lines are shown on the exploration plan (Figure 4).

B.2 SEISMIC REFRACTION METHOD

The seismic refraction method permits calculation of seismic velocity versus depth of near-surface soil and rock layers. A seismic survey is performed by producing a seismic wave and measuring the time of arrival of the waves at varying distances from the source. In this survey, seismic waves were generated by detonating one-third pound explosive charges in shallow holes or striking an aluminum plate with a 10-pound sledge hammer.

Arrivals of resulting compressional seismic waves were detected by 12 geophones generally placed at 25-foot intervals along a straight line from the shot point. Electric signals generated at the geophones were transmitted through a coaxial cable to a signal enhancement seismograph (Nimbus 1225 or 1210F). The seismograph contains amplifying and timing circuits and an electric writing oscillograph which provides a permanent record of seismic waves received.

On a time-distance graph plotted from the data, each subsurface layer is represented by a straight line segment of constant velocity. Compressional wave velocities of these layers are equal to the inverse slopes of the line segments. Depths to increasingly higher velocity material can be calculated from the locations of the changes in slope of the plotted data on the graph. The maximum depth that can be determined is approximately 1/3 to 1/4 of the total distance from either shot point to the farthest geophone.

The interpretation of seismic data is generally well established and straightforward. A potential problem inherent in the method, however, is that of velocity reversals. The reversal problem exists when lower seismic velocity material underlies higher velocity material. Refraction data analysis is based on the assumption that seismic velocity increases with depth.

B.3 SEISMIC REFRACTION PROGRAM AND RESULTS

Forty-two seismic refraction lines were surveyed to determine velocity layers at the Little Cherry tailings impoundment site. Shot points were generally located 25 feet from the nearest geophone. For some lines, in order to evaluate subsurface horizons to a greater depth, the shot points were offset by as much as 500 feet from the nearest geophone.

Table B.1 summarizes the results of the seismic refraction investigation at the site. The table lists the seismic velocity values and depths to the velocity interfaces. Seismic velocities ranged from 1200 feet per second to approximately 15,000 feet per second. Three to four subsurface horizons were defined based on seismic velocity ranges.

Seismic velocities below 2,500 feet per second correspond to surface materials consisting of silt, sand, or gravel. Velocities in the 4,500 to 9,000 feet per second range probably correspond to increasingly denser or compacted gravels, sands or silts. Velocities greater than 7,000 feet per second correspond to weathered rock or possibly very dense gravel, cobbles and boulders.

In some cases, as noted in the table, the minimum depth to a layer with an assumed velocity was calculated. This layer was not observed on the seismic record, but assuming a value for velocity enabled the minimum depth to rock to be estimated.

EXPLANATION OF SEISMIC REFRACTION TABLES

V1F	:	Velocity of surficial deposits from forward seismic shot.
V1R	:	Velocity of surficial deposits from reverse seismic shot.
V2, V3, V4	:	Average velocity of intermediate layers.
DiF	:	Depth to bottom of layer i at forward end of seismic line.
DiR	:	Depth to bottom of layer i at reverse end of seismic line.

*	:	Assumed velocity.
**	:	Minimum depth to layer with assumed velocity
***	:	Velocity and corresponding depth obtained at offset shot point.

NOTE: Not all layers are present at each location.

TABLE B.1 SEISMIC REFRACTION RESULTS

	Layer 1				Layer 2			Layer 3			Layer 4
	Seismic Velocity (feet/second)		Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)
Line No.	V1F	V1R	D1F	D1R	V2	D2F	D2R	V3	D3F	D3R	V4
TI-9	2000*	2000*	18	1	5600	62	70	-	-	-	10,400
							140				15,000***
TI-10	2000*	2000*	4	4	4900	32	54	6250	186**	206**	12,000*
TI-11	2500*	2000*	8	2	5550	16	10	7200	148**	156**	12,000*
TI-12	2000*	2000*	4	6	5400	12	31	7200	83**	153**	12,000*
TI-13	2200	2000*	8	1	5600	27	26	7850	138**	-	12,000*
TI-14	2500	2000*	7	7	4600	94	80	-	-	-	15,000
TI-15	3300	1900	21	13	4950	135	88	-	-	-	12,320***
89-1	3800	2000	9	18				6400	51	38	12,000
89-2	1500	4200	14	16				6400	34	46	12,200
89-3	-	-	-	-				5300	21	13	11,000
89-4	-	2700	0	20				6250	29	22	9,200
89-5	1250	1900	12	9				4600	34	31	10,000
89-6	1400	1500	4	3				4100	52	27	7,700
89-7	2800	1300	12	4				6200	57	28	10,000
89-8	3000	3125	4	6	5000	18	28	7200	51	46	8,300
89-9	3000	2800	16	7	5800	-	21	7100	57	52	9,100
89-10	2500	2600	8	7	5500	19	25	7100	51	70	8,300
89-11	2100	2800	9	7	6250	20	16	7250	74	44	8,300
89-12	2800	-	7	7	5900	45	31	7400	79	90	9,000
89-13	2500	2300	8	11				6700	32	28	8,000
89-14	1400	1600	8	-				5000	-	13	10,000
89-15	3300	1300	3	4				6500	23	43	10,000
89-16	1800	-	12	0				4200	82	49	10,300
89-17	1500	1500	11	4				4600	51**	34**	10,000*
89-18	1400	1800	7	3				4200	46	41	9,500
89-19	1900	2500	9	25					-	-	12,300
89-20	1200	1250	8	6				5000	49	18	11,000
89-21	2100	2400	9	8				6100	55	45	12,000
89-22	2200	2200	1	9				5000	64	76	12,500
89-23	2100	2800	8	21				6600	66**	44**	8,300*
89-24	2700	1500	12	10				6300	65**	63**	8,300*
89-25	2400	2600	8	7				5500	50	42	9,300
89-26	2500	2100	8	9				6500	35	68	10,000
89-27	4000	3600	22	20				6000	77	154	7,400
89-28	1700	1800	11	10				6400	40	85	15,000
89-29	1800	1900	10	8				4500	42	30	11,000
89-30	1400	2100	10	10				5500	18	18	7,500
89-31	1900	3200	8	10				5700	55	-	9,500
89-32	2000	1800	12	7				4500	46	38	8,200
89-33	3600	2500	14	17	7100	83	91	8300	160	143	10,000***
89-34	3600	3800	13	8	7100	51	31	8600	190	150	13,000***
89-35	3600	-	12	-	5600	75	23	8400	167	126	10,000***

APPENDIX C
DRILL LOGS

APPENDIX C
DRILL LOGS

C.1 DRILLING

During the 1988 and 1989 field explorations, drilling equipment consisted of a Mobile B-53, an Acker AD II, a Schramm Rotadrill and a skid-mounted Longyear 28 drill rig. One hole, DH-15, was drilled as a monitor well, using the Schramm Rotadrill rig and air-rotary drilling method. All other holes were drilled with a continuous hollow stem flight auger, tricone rotary bit or diamond bit in soil and a diamond bit in rock. An engineering geologist or geotechnical engineer of Morrison-Knudsen Engineers (MKE) observed the drilling progress and kept a log of soil, rock and water encountered.

Where soil conditions permitted, hollow stem augers with outside diameters (O.D.) of 7 to 9 inches were initially used to advance the borings. In dense or gravelly soils or where the auger could not be advanced, rotary drilling with a 2-15/16 inch tricone drill bit and clean water or an NQ or HQ diamond drill bit and triple-tube core barrel were used to advance the hole. Three-inch I.D. (NW) flush joint casing was used when drilling with tricone drill bits. Descriptions of the auger and tricone drill cuttings, core recovery, and drill water return were entered on the boring logs.

Bedrock was cored with a 2.98-inch O.D. (NQ) diamond drill bit and double or triple-tube core barrel, or with a 3.78-inch O.D. (HQ) diamond drill bit and triple-tube core barrel. Each piece of core was withdrawn from the core barrel and placed in proper sequence in the core box. Core boxes were labeled with project name and number, boring number, coring interval, core box number and date. Photographs were taken of the cores.

Rock information entered on the drill logs includes percent recovery, Rock Quality Designation (RQD), rock type, color, weathering, hardness, texture, structure and any other notable features. RQD is the ratio of the cumulative length of the core pieces greater than 4 inches to the total length of the core run. Mechanical core breaks caused by drilling or handling are disregarded.

Other conditions recorded on the drill logs included color of the return water, areas of water loss, penetration rates and drill action. The boring locations were surveyed by others, with the exception of DH-3A which was located by the MKE geotechnical engineer.

Water levels measured in the borings during and after drilling are presented in Table C.1

C.2 SAMPLING

Soil samples were generally taken at 5-foot intervals to a depth of 25 feet; below 25 feet, samples were generally taken at 10- to 40- foot intervals where possible. Both undisturbed and Standard Penetration Test (SPT) samples were obtained. The number of undisturbed samples was limited due to the absence of cohesive non-gravelly soils.

Disturbed soil samples were obtained using standard 2-inch (ASTM D1586) and 2.5-inch O.D. split barrel samplers, driven by a 140-pound hammer with a 30-inch free-fall drop. After a boring was cleaned of all loose material, the sampler was inserted and measurements made to verify that the sampler reached the bottom of the boring. The sampler was driven 18 inches or until refusal (more than 50 blows to penetrate 6 inches). The number of blows required to drive each 6 inches of penetration was recorded. The sampler was removed from the boring and opened. The length of material recovered from the sampler was measured and recorded. A pocket penetrometer was used to obtain an approximate unconfined compressive strength in sections of the recovered sample that appeared cohesive. A complete material description was entered on the boring log including soil type, particle shape, color, moisture, density or consistency and plasticity. Visual classification of the samples was made in conformance with the Unified Soil Classification System (Figure C-1). Samples were double sealed in plastic bags labeled with sample number, boring number, project number and sample depth interval. Drive samples were not taken from DH-9, 10 or 15 because the skid mounted Longyear 28 and Schramm Rotadrill drill rigs were not equipped with a hammer or cathead.

Undisturbed Shelby tube samples were obtained in cohesive soil in conformance with ASTM D1587. The boring was cleaned of all loose material and the sampler inserted to the bottom of the hole. A thin-walled 3-inch or 2-inch diameter sampler, 30 inches long, was advanced 2 feet, or until refusal, by hydraulically pushing in one continuous motion with the drill rig. Upon retrieval, the length of the sample was measured and recorded. Any space at the end of the tubes was filled with plastic bags, the ends sealed with plastic caps, and the caps sealed with duct tape. The sample tubes were labelled with project number, boring number, sample number and sample depth interval. The tubes were also marked "Top" and "Bottom" to show sample orientation. Care was taken during handling and transport to maintain the tubes in a vertical position and to minimize soil disturbance.

Two and one-half inch diameter brass tube samples were obtained in non-gravelly soils that were too dense for Shelby samplers. The equipment used for taking ring samples was similar to that used for SPT samples, except that the split tube was lined with three 6-inch long brass tubes. The sampler was pushed or driven into the soil to a maximum distance of 18 inches to obtain a relatively undisturbed sample. The tubes were sealed as described for the Shelby tubes. The brass tubes were identified by project name and number, boring number, depth interval and sample number.

C.3 PERMEABILITY TESTS

Field permeability tests consisted of constant head tests in soil and water pressure tests in bedrock. Tests were performed by using method E-18 procedures outlined in the U.S. Bureau of Reclamations "Earth Manual" (1974).

Constant head tests were performed in an uncased section at the bottom of the boring. After advancing the hole and pulling up the core barrel to the top of the test section (typically 10 to 30 foot length), the uncased section was cleaned out with water. A single pneumatic wireline packer was used to seal

the hole below the core barrel. No pressure was applied using this method, except in Boring DH-11 where 10 psi was applied due to artesian conditions at the time of testing.

Water inflow was measured by two methods. A flow metering system was used to measure flow at constant head. When flow was not sufficient for the flow meter to operate accurately, the water level was allowed to drop a minimal measured amount (approximately 0.1-foot) and the casing was refilled at intervals to the original water level. The rate of flow into the hole was then determined from the total water level drop.

During the 1988 field exploration, some constant head tests (in USB-4 and USB-5) were performed in casings. The casing was lowered to the bottom of the boring and carefully cleaned out. The water inflow was measured by the two methods described above. In these tests, permeabilities were computed from the following formula:

$$K = Q/(5.5rH)$$

where: K = permeability
Q = constant rate of flow into the hole
r = internal radius of casing
H = differential head of water

Permeability values for tests performed in uncased sections in soils were determined from the formula given below for water pressure tests using packers. For this type of constant head test, the differential head of water equals the gravity head only (except in Boring DH-11) since there is no applied pressure.

Water pressure tests in bedrock were performed by using a single pneumatic wireline packer. Prior to testing, the holes were flushed with clean water until the water return was clear. The maximum applied water pressure was approximately 1 psi per foot of depth above the packer. However, due to equipment limitations, the total maximum applied pressure was 75 psi. Each packer test was generally run in three segments of water pressure: the first at one-half of the maximum

water pressure determined for the test interval, the second at the maximum water pressure, and the third at one-half of the maximum pressure. Tests were run at a constant pressure and a generally constant flow rate for 5 minutes. The flow meters were calibrated periodically.

The permeability was calculated from the following formula:

$$k = Q \ln(L/r)/2\pi LH$$

where: k= permeability
Q= constant rate of flow into the hole
L= test section length
H= differential head of water (gravity head plus applied pressure head)
r= radius of hole tested

The results of the constant head and packer tests are shown in Table C.2.

C.4 PIEZOMETER INSTALLATION

Piezometers were installed in selected borings immediately after drilling was completed. A piezometer typically consisted of 1-inch I.D., Schedule 80 PVC pipe, with 20 feet of 0.02-inch width machine slotted screen section at the bottom. Number 16 silica sand was used to backfill around the bottom of the piezometer. The sand extended to at least 5 feet above the slotted section. In borings where artesian conditions were encountered, holes were sealed by grouting, from above the slotted portion to ground level, in accordance with Montana state well installation regulations. A steel protective casing with a lockable lid was set in concrete at each piezometer. Construction details of the piezometers are presented on Figures C-2 and C-3.

TABLE C.1

DEPTH TO WATER FROM GROUND SURFACE (FEET)

BORING	USB-1	USB-2	USB-3 (1)	USB-5	PLCM-6 (2) A	PLCM-6 (2) B	LCTM-8	LCM-9	LCM-10	LCM-11	DH-1	DH-2	DH-3 (2)	DH-4	DH-5 (1)	DH-6	DH-7	DH-8	DH-9	DH-10	DH-11	DH-12	DH-13	DH-14	DH-15	DH-17	DH-18	DH-19	DH-20
DATE COMPLETED	8-3-88	8-1-88	7-29-88	8-24-88	7-21-88		7-27-88	7-20-88	7-25-88	7-22-88	8-14-89	9-20-89	9-18-89	9-8-89	8-25-89	8-21-89	8-11-89	8-12-89	9-25-89	9-29-89	10-10-89	9-28-89	9-8-89	9-9-89	9-7-89	8-18-89	8-19-89	10-4-89	10-8-89
HOLE DEPTH (FT)	80.8	80.8	70.0	50.3	56.0		140.0	72.0	40.0	62.5	100.0	110.0	367.0	40.0	197.0	60.0	73.0	98.0	82.0	87.0	192.0	110.0	80.0	60.0	120.0	80.0	65.0	105.0	214.0
7-28-88 (3)			31.5/34.3		7.2	3.7 psi		9.2	12.9	11.3																			
8- 6-88	21.6	2.8																											
8-12-88	23.4	2.9																											
8-18-88 (3)	22.9				7.4	3.6 psi	12.4	9.8	12.9	13.8																			
8-26-88	22.9	2.1		27.1																									
10- -88 (3)					7.6	3.5 psi	13.6	10.9	13.2	12.8																			
1- -89 (3)					5.8		10.4	8.5	5.5	4.7																			
3- -89 (3)					4.0	3.5 psi	9.9	7.8	5.2	4.5																			
4- -89 (3)						4.1 psi																							
7- -89 (3)	21.0	0.2		22.1			10.7	7.7	12.2	13.6																			
8-11-89																	49.0												
8-12-89																		DRY											
8-14-89																	35.5	62.0											
8-18-89																										2.5			
8-21-89																AF													
8-22-89															11.0														
8-23-89											21.0				49.6		DRY										DRY		
8-26-89															125.0														
8-29-89											21.0					AF													
9- 6-89																									110.0				
9- 7-89																									12 psi				
9-11-89													GRD. LVL.																
9-12-89											21.6		AF	DRY				DRY					DRY	13.9					
9-13-89													AF																
9-14-89													AF																
9-15-89													AF													23.0	DRY		
9-19-89												6.0																	
9-24-89											21.5				141.7				DRY										
9-25-89																			69.0										
9-26-89																						4							
9-27-89																						3							
9-28-89																						1							
9-29-89											21.3				139.6							AF				23.2	DRY		
10- 1-89																												2.0	
10- 2-89														DRY				DRY					DRY	15.0				AF	
10- 3-89																				DRY								1.3 psi	
10- 4-89																												1.7 psi	
10- 5-89																													6.5
10- 6-89																													17.0
10- 8-89																					15.0								
10- 9-89																					4.0								
10-10-89																					125.0								
11-10-89 (3)	21.6 GRD. LVL.			25.7			11.3	8.5	12.1		19.6	4.1 psi	.80 psi	DRY		9.5 psi			72.6	85.2	189.1	.30 psi	DRY	16.9	10.4 psi	60.7	DRY	4.6 psi	
11-16-89 (3)					2.0	3.0 psi	10.5	8.0		6.1							DRY	DRY							6.8 psi				8.8
11-19-89 (3)									6.6								DRY	DRY			105.2						50.3		

NOTES:

(1) Piezometers were not installed in these borings.

(2) Two piezometers were installed in these borings. In DH-3 water level readings were equal.
In PLCM-6, A is shallow well, B is deep well.

(3) Water levels on this date were measured and reported by Noranda and/or Chen-Northern.

(4) AF = Artesian Flow

TABLE C.2
FIELD PERMEABILITY TEST RESULTS

HOLE	DEPTH TO BEDROCK (FT)	TOP SECTION (FT)	BOTTOM SECTION (FT)	LENGTH (FT)	Q (GPM)	APPLIED PRESSURE (PSI)	WATER TABLE (FT)	k (10-6 CM/SEC)
USB-3	27.0	38.8	55.0	16.2	0.000	20	34.3	<1
	27.0	38.8	55.0	16.2	0.000	40	34.3	<1
	27.0	38.8	55.0	16.2	0.000	20	34.3	<1
	27.0	50.3	70.0	19.7	0.760	25	34.3	26
	27.0	50.3	70.0	19.7	1.360	50	34.3	29
	27.0	50.3	70.0	19.7	0.680	25	34.3	23
USB-4	NE	15.0	15.0	0.0	0.280	0	NE	1800
	NE	20.0	20.0	0.0	0.020	0	NE	100
USB-5	NE	10.0	10.0	0.0	0.007	0	NE	70
	NE	10.0	15.0	5.0	0.022	0	NE	14
	NE	10.0	20.0	10.0	0.019	0	NE	6
	NE	10.0	25.0	15.0	0.013	0	NE	3
	NE	10.0	40.0	30.0	0.064	0	NE	7
DH1	77.0	30.0	35.0	5.0	0.000	0	21	<1
	77.0	35.0	40.0	5.0	0.020	0	21	6
	77.0	65.5	70.0	4.5	0.020	0	21	6
	77.0	80.0	90.0	10.0	0.040	42	21	2
	77.0	80.0	90.0	10.0	0.100	75	21	2
	77.0	80.0	90.0	10.0	0.080	41	21	3
DH2	54.0	55.0	74.0	19.0	0.460	25	6	18
	54.0	55.0	74.0	19.0	0.720	40	6	19
	54.0	55.0	74.0	19.0	0.400	25	6	16
	54.0	70.0	90.0	20.0	8.500	38	6	234
	54.0	70.0	90.0	20.0	10.100	50	6	215
	54.0	70.0	90.0	20.0	6.200	35	6	184
	54.0	90.0	110.0	20.0	6.600	40	6	173
	54.0	90.0	110.0	20.0	10.800	65	6	179
	54.0	90.0	110.0	20.0	4.800	40	6	126
DH4	9.0	18.0	40.0	22.0	0.300	10	NE	14
	9.0	18.0	40.0	22.0	0.620	20	NE	20
	9.0	18.0	40.0	22.0	0.400	10	NE	18
DH5	145.0	8.0	15.0	7.0	0.067	0	140	28
	145.0	30.0	40.0	10.0	0.001	0	140	<1
	145.0	60.0	65.0	5.0	0.010	0	140	1
	145.0	147.0	167.0	20.0	0.140	20	140	2
	145.0	147.0	167.0	20.0	0.140	40	140	2
	145.0	147.0	167.0	20.0	0.100	20	140	1
	145.0	167.0	187.0	20.0	0.000	20	140	<1
	145.0	167.0	187.0	20.0	0.000	40	140	<1
	145.0	167.0	187.0	20.0	0.000	20	140	<1
	145.0	187.0	197.0	10.0	0.040	15	140	1
	145.0	187.0	197.0	10.0	0.040	50	140	1
	145.0	187.0	197.0	10.0	0.000	15	140	<1

NE = Not Encountered

TABLE C.2
FIELD PERMEABILITY TEST RESULTS
page 2 of 2

HOLE	DEPTH TO BEDROCK (FT)	TOP SECTION (FT)	BOTTOM SECTION (FT)	LENGTH (FT)	Q (GPM)	APPLIED PRESSURE (PSI)	WATER TABLE (FT)	k (10-6 CM/SEC)
DH6	40.0	8.0	15.0	7.0	0.000	0	*	<1
	40.0	22.0	30.0	8.0	0.000	0	*	<1
DH7	34.0	47.0	64.0	17.0	2.900	23	NE	79
	34.0	61.0	73.0	12.0	0.820	30	NE	23
	34.0	61.0	73.0	12.0	1.500	60	NE	28
	34.0	61.0	73.0	12.0	0.000?	30	NE	<1?
DH8	15.0	65.0	73.0	8.0	0.120	32	NE	4
	15.0	65.0	73.0	8.0	0.280	64	NE	7
	15.0	65.0	73.0	8.0	0.100	32	NE	4
DH9	41.0	60.0	82.0	22.0	4.000	30	NE	72
	41.0	60.0	82.0	22.0	9.300	58	NE	115
	41.0	60.0	82.0	22.0	6.400	30	NE	115
DH10	18.0	63.0	73.0	10.0	9.170	0	86	621
	18.0	68.0	73.0	5.0	9.150	12	86	721
	18.0	78.0	87.0	9.0	4.500	40	86	131
DH11	180.0	97.0	125.0	28.0	0.500	10	125	7
	180.0	180.0	192.0	12.0	0.060	50	125	1
	180.0	180.0	192.0	12.0	0.200	70	125	3
	180.0	180.0	192.0	12.0	0.100	50	125	2
DH13	16.0	29.5	80.0	50.5	1.240	15	NE	17
	16.0	55.0	80.0	25.0	0.070	15	NE	2
	16.0	55.0	80.0	25.0	0.210	30	NE	3
	16.0	55.0	80.0	25.0	13.700	60	NE	146
	16.0	55.0	80.0	25.0	5.800	30	NE	93
	16.0	55.0	80.0	25.0	1.500	15	NE	32
DH14	30.0	30.0	50.0	20.0	0.880	15	14	46
	30.0	50.0	60.0	10.0	0.180	15	14	16
	30.0	50.0	60.0	10.0	0.300	30	14	16
	30.0	50.0	60.0	10.0	0.140	15	14	12
DH17	65.0	34.5	45.0	10.5	0.000	0	23	<1
	65.0	64.5	70.0	5.5	0.000	10	23	<1
	65.0	64.5	70.0	5.5	0.000	30	23	<1
	65.0	64.5	70.0	5.5	0.000	40	23	<1
DH18	NE	8.0	15.0	7.0	0.000	0	NE	<1
	NE	25.0	30.0	5.0	0.000	0	NE	<1
	NE	55.0	60.0	5.0	0.020	0	NE	2
DH19	60.0	59.5	80.0	20.5	3.200	30	A	116
	60.0	59.5	80.0	20.5	5.500	60	A	101
	60.0	59.5	80.0	20.5	2.400	30	A	87
	60.0	79.0	105.0	26.0	8.700	40	A	196
	60.0	79.0	105.0	26.0	13.000	70	A	169
	60.0	79.0	105.0	26.0	7.000	40	A	157
DH20	205.0	38.0	68.0	30.0	0.005	0	17	<1
	205.0	177.0	214.0	37.0	0.025	0	17	2
	205.0	205.0	214.0	9.0	0.040	50	17	1
	205.0	205.0	214.0	9.0	0.020	70	17	1
	205.0	205.0	214.0	9.0	0.000	50	17	<1

NE = Not Encountered
A = Artesian

* = Tests were performed above the elevation at which artesian water was encountered.

TABLE C-3
LITTLE CHERRY CREEK IMPOUNDMENT SITE
DRILLHOLE LOCATIONS

DRILLHOLE	NORTHING	EASTING	ELEVATION AT COLLAR	GROUND ELEVATION
DH-1	487758.694	527863.995	3446.3	3445.6
DH-2	486677.992	528074.238	3415.9	3414.4
DH-3	485575.782	527949.715	3437.6	3435.4
DH-4	484764.905	525439.967	3612.3	3609.5
DH-5	488154.584	522665.375		*3674.4
DH-6	484440.829	522630.763	3594.2	3593.7
DH-7	483509.749	522930.633	3769.5	3769.3
DH-8	483675.677	523498.066	3746.3	3745.9
DH-9	483792.201	524412.699	3678.3	3677.7
DH-10	483951.939	525350.672	3658.3	3657.5
DH-11**	484783	521863	3761.9	3760.4
DH-12	487651.28	528476.99	3394.6	3393.2
DH-13	484474.478	526856.254	3684.0	3682.5
DH-14	484568.628	524408.593	3575.6	3574.7
DH-15	486561.096	526331.806	3443.1	3440.5
DH-16	DRILLHOLE	DELETED	FROM	PROGRAM
DH-17	484957.903	524076.336	3542.0	3541.8
DH-18	487382.832	523415.049	3660.7	3659.2
DH-19	486436.632	528220.918	3415.4	3413.4
DH-20	485644.762	528624.176	3429.0	3428.4
LCTM-8	486397.755	529138.762	3383.1	3380.5
LCM-9	488681.850	528960.135	3423.7	3420.6
LCM-10	483218.556	521784.337	3743.2	3740.2
LCM-11	486511.636	522369.022	3758.9	3756.2
PLCM-6	483342.261	527855.229	3447.6	3445.1
USB-1	485165.718	528493.950	3463.4	3462.6
USB-2	486208.367	527088.738	3441.9	3440.9
USB-3	488365.499	526659.469		*3580.7
USB-4	486220.404	523741.162		*3646.6
USB-5	487654.050	525610.845	3517.0	3516.0

* Elev. at ground surface only, no casing installed
** Location approximate; surveyed before hole was drilled

EXPLANATION OF BORING LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications were modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure C-1. The relative proportions of the various soil types in a soil sample are defined by the following terms:

fine-grained	coarse-grained
o trace: less than or equal 5%	o few: less than or equal 10%
o some: 5% to 12%	o little: 10% to 20%
o suffix "y" (e.g., silty): 12% to 50%	

3. Blow count values shown on the logs were influenced by the presence of gravels, cobbles and boulders.

4. The description of weathering is based on the following:

	decomposition	disintegration	discolorization	fracture condition
highly or intensely	moderate to complete	extensive	extensive	extensively coated with mud, oxides, or carbonates
moderately	slight change	little	moderate	moderately coated
slightly	no megascopic decomposition	little or no affect on cement	slight	few stains on fractured surface
fresh	unaffected	unaffected	none	fractures less numerous than joints

5. Rock Quality Designation (RQD) is defined as the sum of the lengths of rock core pieces greater than 4 inches divided by the length of core run.

6. Groundwater level data are shown in Table C.1.

7. Field permeability test data are summarized in Table C.2.

8. Piezometer construction details are shown on Figures C-2 and C-3.

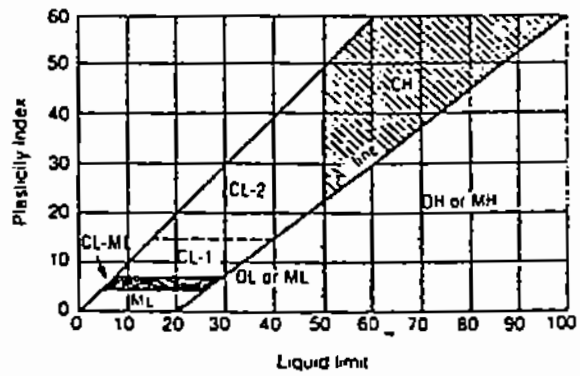
9. Boring locations were surveyed by others. Coordinates, boring collar elevations and ground elevations are presented in Table C.3.

10. Borings were drilled by a Mobile B-53, Acker AD II, Shramm Rotadrill or skid mounted Longyear 28 drill rig.

11. The sampler types indicated on the boring logs are as follows:
    - o SPT: 2-inch O.D. Standard Penetration Test Sampler (ASTM D1586)
    - o S: 2-1/2-inch Split Spoon Sampler
    - o SH: Shelby Tube Sampler
    - o BR: Brass Ring Sampler

Unified Soil Classification System

Major Divisions			Group Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-grained Soils More than half of material is larger than No. 200 sieve	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean Gravels (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% ..... GW, GP, SW, SP; More than 12% ..... GM, GC, SM, SC; 5% to 12% ..... Borderline cases requiring use of dual symbols**	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM d / u	Silty gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, or PI greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines.		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM d / u	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols
			SC	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits above "A" line, or PI greater than 7	
Fine-grained Soils More than half of material is smaller than No. 200 sieve	Silts and Clays Liquid limit less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity			
			CL 1 / 2	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silt-clays of low plasticity			
	Silts and Clays Liquid limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity, organic silts			
Highly Organic Soils			Pt	Peat and other highly organic soils			

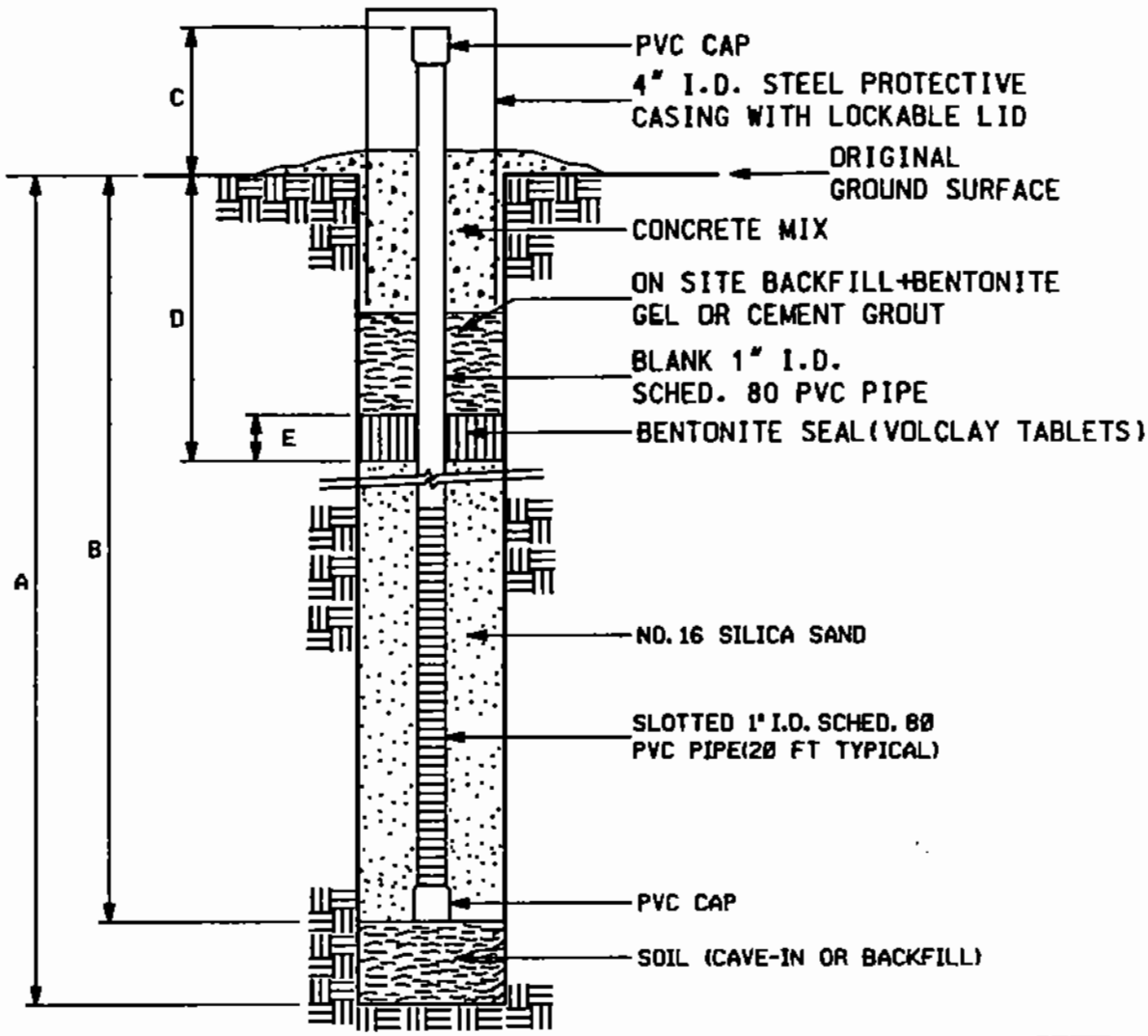


Plasticity Chart
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits, suffix d used when liquid limit is 28 or less and the PI is 6 or less; the suffix u used when liquid limit is greater than 28.

**Borderline classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

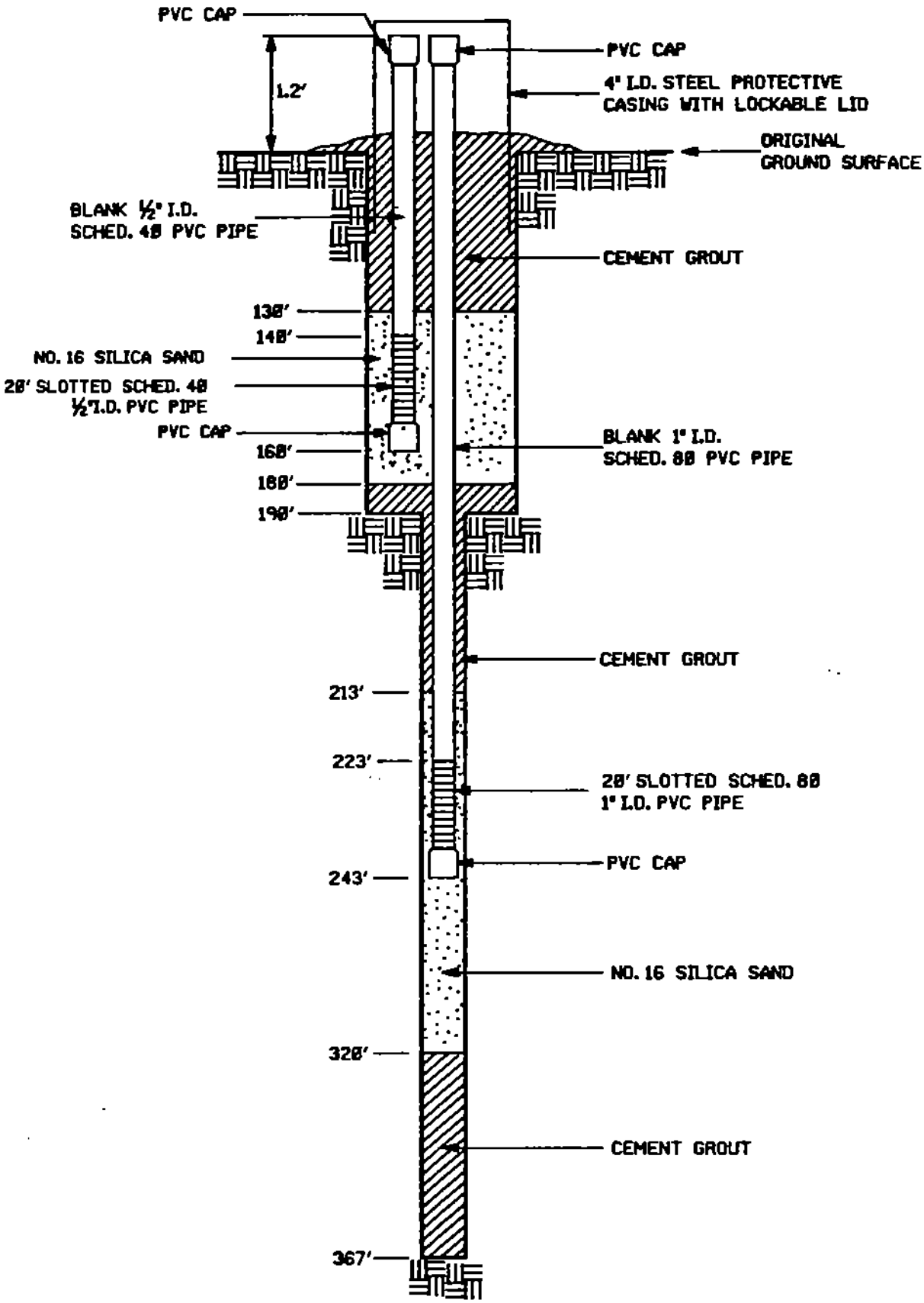
Figure No. C-1



BORING NO.	DIMENSIONS(FT.)					NOTES
	A	B	C	D	E	
USB-1	81	81	0.9	49	0.0	
USB-2	81	81	1.0	55	0.0	
USB-5	50	50	1.0	26	3.0	
DH-1	100	100	0.6	75	1.0	
DH-2	110	110	1.3	78	1.0	CEMENT GROUT TO 77 FT.
DH-3	367	160	1.2	-	-	SEE FIGURE C-3 FOR DETAILS
	-	243	1.2	-	-	
DH-4	40	40	2.7	21	6.0	
DH-5	-	-	-	-	-	
DH-6	60	60	0.5	36	4.0	PUT ABOUT 4 FT. CEMENT MIXTURE+CONCRETE
DH-7	73	73	0.2	47	2.5	AT TOP TO SEAL OFF ARTESIAN FLOW
DH-8	98	98	0.4	73	2.5	
DH-9	82	82	0.5	51	6.0	
DH-10	87	87	0.8	57	6.0	
DH-11	192	190	1.5	165	5.0	
DH-12	110	110	1.3	84	1.5	
DH-13	80	80	1.0	56	11.0	
DH-14	60	60	0.7	35.5	5.5	
DH-15	120	113	2.1	80	8.0	INSTALLED 2" SCHED.40 PVC PIPE +20 FT OF 6"
-	-	-	-	-	-	CASING AS STEEL PROTECTION, CEMENT GROUT
DH-17	80	80	0.2	59	6.0	TO 72 FT.
DH-18	65	65	1.1	40	5.0	
DH-19	105	105	1.8	76	-	CEMENT GROUT TO 76 FT.
DH-20	214	154	0.7	136	5.0	USED 10 FT. SCREEN IN DH20

PIEZOMETER CONSTRUCTION

FIGURE C-2 (Not to scale)



PIEZOMETER CONSTRUCTION FOR DH-3

FIGURE C-3 (Not to scale)

BORING LOGS
(1988)

PROJECT	MONTANA SILVER VENTURE	JOB NO.	8029	HOLE NO.	USB-1
SITE	Little Cherry Tailings	DATE - STARTED / FINISHED	AUG 2 88 - AUG 3 88	HOLE SIZE	3"
ORIENTATION	vertical				
LOCATION	Libby, Montana	ELEVATION(FT)	3463	DEPTH TO WATER(FT)	21.6
DEPTH TO ROCK (FT)					
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES	12	CORE BOXES	0
DEPTH OF HOLE (FT)	80.8				
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY	M.I. Schauer	REVIEWED BY	D.A. Baskin

ELEV. (FT)	DEPTH (FT)	SAMPLER NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
									Road fill at surface		Started drilling (8/2/88, 9:00 AM) Temperature 40-50 deg.F, overcast, calm
3460									**SILTY SANDY GRAVEL (GM),** fine to coarse, brown, wet, dense, maximum gravel size 1-3/8"; sand is fine to medium.		
	5	SPT-1		14 16 20	0						Rotary drilled to 5.0', used 4" tricone bit, drilling fluid return light brown, loss 0% Recovered 20% with basket catcher Spun casing to 5.0' (NWFJ, 3-1/2"OD, 3"ID) Rotary drilled 5.0'-55.0', used 2-15/16" tricone bit 5.0'-10.0' and 17.5'-55.0', and finger bit 10'-17.5'
	10	SPT-2		7 9 12	93				**SANDY SILTY CLAY - SANDY CLAYEY SILT (CL-ML),** orangish brown, low plasticity, wet, medium stiff.		
3450									**SILTY SAND - CLAYEY SILT -SILTY CLAY (CL-ML),** wet, very dense, hard, interlayered. Silty sand layers are light gray, 2" to 3" thick, nonplastic, recovered one coarse gravel-size piece (looks like decomposed rock). Clayey silt layers are orangish brown, 1" to 2" thick, slightly plastic, with some fine, rounded to subrounded gravel.		
	15	SPT-3		14 27 33	73						Sandy cuttings and white fluid return at 16.5'-19.8'* Hard drilling at 17.5'-18.5'*
	20	SPT-4		28 41 60	73				**SILTY SAND (SM),** light gray to orangish brown, non plastic, wet, very dense; some gravel, fine to coarse, angular, quartzite, maximum size 1". Light gray zones are often hard but can be broken by hand (looks like soft rock). Orangish brown zones have some very fine, rounded to subrounded gravel.	▼	
3440											
	25	~~SPT-5~~		~~50/.4~~	~~100~~						
	30								**SILTY SANDY GRAVEL (GM),** orangish brown, wet, very dense, rounded to subrounded; sand is fine; fines are non plastic. Contains occasional light gray, hard, silty sand pieces (looks like decomposed rock).		
3430											
	35	SPT-6		29 18 31	100				**SILTY SAND (SM),** fine, orangish brown, non plastic, dense, wet; some gravel, fine, rounded to subrounded.		
	40										
3420											
	45	SPT-7		18 30 50	100				Very dense, trace medium to coarse sand; some gravel, fine to coarse, rounded to subrounded, occasionally angular.		

PROJECT **MONTANA SILVER VENTURE** | JOB NO. 8029 | HOLE NO. USB-1

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3410											
	55	SPT-8		32 / 50/.4	100				Gravelly, dark orangish brown to light gray, very dense; gravel is coarse, rounded to subrounded.		Stopped drilling at 55.0' (8/2/88, 3:00 PM) Resumed drilling at 55.0' (8/3/88, 7:00 AM) Temperature 40 deg.F, clear, calm Water level - dry (hole caved at 13.0') Rotary drilled 55.0'-65.0'
	60										
3400											
	65	SPT-9		27 / 50/.3	88				Some coarse gravel, rounded to subrounded		Spun casing 5.0'-20.0' Rotary drilled 65.0'-80.0'
	70										
3390											
	75	SPT-10		50/.3	67				Some fine gravel, rounded to subrounded		
		SPT-11		50/.3	100						
	80	SPT-12		22 / 50/.3	75				**GRAVELLY SILTY SAND (SM),** fine to coarse, orangish brown, wet, very dense; gravel is fine, rounded to subrounded.		Stopped drilling (8/3/88, 1:00 PM)
3380									**BOTTOM OF HOLE AT 80.8'**		Installed piezometer to 80.8' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 49.0') Removed all casing Set steel protective surface casing in concrete,.9' stickup above ground surface)
	85										
	90										
3370											8/6/88 - Water level 21.6 * Reported by driller
	95										NOTE: Drilled new hole USB-1A 4.5' SE along road, augered to 10', pushed Shelby tube 10'-11.8' (1.8'), used pocket penetrometer on bottom of sample: UC=3.5-3.75 tsf
	100										
3360											
	105										

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2 | HOLE NO. USB-1

PROJECT	MONTANA SILVER VENTURE	JOB NO.	8029	HOLE NO.	USB-2
SITE	Little Cherry Tailings	DATE - STARTED FINISHED	JUL 29 88 - AUG 1 88	HOLE SIZE	3"
ORIENTATION	vertical				
LOCATION	Libby, Montana	ELEVATION(FT)	3441	DEPTH TO WATER(FT)	2.8
DEPTH TO ROCK (FT)					
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES	11	CORE BOXES	0
DEPTH OF HOLE (FT)	80.8				
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY	M. I. Schauer	REVIEWED BY	D. A. Baskin

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3440											Started drilling (7/29/88, 12:30 PM)
		SPT-1		17 50/.2	100				**GRAVELLY SILTY SAND (SM),** orangish brown, non plastic, dry, very dense; gravel is fine to coarse, angular to subangular, maximum size 1-1/2". Boulder at 4.5'-5.5'*	▼	Temperature 95-100 deg.F, clear, slight wind Augered to 18.5' with hollow stem auger (9"OD, 3-3/8"ID)
	5										
		SPT-2		25/0	0				Boulder at 8.0'-10.5'*		
	10										
3430											
		SPT-3		49 50/.2	100				Orangish brown to light brown, damp, sample looks like decomposed rock. Boulder at 13.2'-14.5'*	▽	
	15								Boulder at 16.0'-17.5'* light brown, damp, sample looks like decomposed rock. Boulder at 17.9'-18.5', 18.5'-18.8'*		
		SPT-4		50/.4	100						Stopped drilling at 18.5'(7/29/88, 2:30 PM)
	20										Resumed work (7/30/88, 8:00 AM)
3420		SPT-5		50/.3	100				**SILTY SANDY GRAVEL (GM),** fine to coarse, orangish brown, wet, very dense, angular to subangular, quartzite, maximum size 1-1/2"; sand is fine; fines are non plastic.		Temperature 65 deg.F, clear, calm Removed augers Drove casing to 18' (NWFJ, 3-1/2"OD, 3"ID)
	25	SPT-6		50/.3	83						Rotary drilled 18.5'-44.5', using 2-15/16" tricone bit, drilling fluid water, return light brown, no loss
									Hard gravel/boulders at 27.5'-30.2'*		
	30										
3410									Boulders at 31.0'-33.2'		
	35	SPT-7		50/.2	0				Sand, gravel, and boulders at 34.7'-41.0'*		
	40										
3400											Bit keeps blocking off due to silty/clayey matrix at 41.0'-44.5'*
	45	SPT-8		50/.3	100				**SANDY SILTY GRAVEL (GM),** fine, orangish brown to whitish gray, wet, very dense, maximum size 3/4"; sand is fine; fines are non plastic to slightly plastic.		Hole caved in when pulled tricone to do SPT test at 44.5' Drove casing 18'-40' Stopped work (7/30/88, 3:15 PM) Resumed work (7/31/88, 9:00 AM) Temperature 65 deg.F, clear, calm Drove casing 40.0'-44.6'

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

HOLE NO. USB-2

PROJECT	JOB NO.	HOLE NO.
MONTANA SILVER VENTURE	8029	USB-2

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3390									Gravel with silty/clayey lumps at 44.9'-54.5'*		Rotary drilled 44.5'-64.5'
	55	SPT-9		50/.3	100				**SILTY SANDY GRAVEL (GM),** fine to coarse, orangish brown, wet, very dense, angular to subangular, maximum size 1-1/2"; sand is fine; fines are non plastic to slightly plastic. Gravel at 54.8'-64.5'*		
3380	60										
	65	SPT-10		9 50/.2	0						Stopped drilling at 64.5' (7/31/88, 3:30 PM) Resumed drilling at 64.5' (8/1/88, 7:00 AM) Temperature 50-60 deg.F, clear, calm
3370	70										
	75								Gravel at 74.5'-80.0'* light brown		Hole caved in when pulled tricone to do SPT test at 74.5'
	80	SPT-11		22 50/.3	100						Stopped drilling (8/1/88, 12 NOON)
3360									**BOTTOM OF HOLE AT 80.8'**		Installed peizometer to 80.8' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 55') Removed all casing Set steel protective surface casing in concrete (2"ID, 5' long, 1' stickup above ground surface)
	85										
3350	90										
	95										WATER LEVEL date level 7/30/88 13.5' 7/31/88 2.4' 8/1/88 2.4' 8/6/88 2.8'
3340	100										
	105										* Reported by driller

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2 HOLE NO. USB-2

PROJECT	MONTANA SILVER VENTURE	JOB NO.	8029	HOLE NO.	USB-3
SITE	Little Cherry Tailings	DATE - STARTED / FINISHED	JUL 26 88 - JUL 29 88	HOLE SIZE	3"
				ORIENTATION	vertical
LOCATION	Libby, Montana	ELEVATION(FT)	3581	DEPTH TO WATER(FT)	34.3
				DEPTH TO ROCK (FT)	27.0
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES	7	CORE BOXES	3
				DEPTH OF HOLE (FT)	70.0
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY	M. I. Schauer	REVIEWED BY	D. A. Baskin

ELEV. (FT)	DEPTH (FT)	SAMPLER NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3580									Road fill at surface		
		SPT-1		13 21 23	93				**SILTY SAND (SM),** orangish brown, nonplastic, dry, dense; gravelly, fine to coarse, subangular, maximum size 2".		Started drilling (7/26/88, 11:30 AM) Temperature 95 deg.F, clear, calm Augered to 35.0' with hollow stem auger (9"OD, 3-3/8"ID)
	5										
		SPT-2		17 21 25	93				Gravel at 7.0'-7.5'* damp		
	10										
3570									Gravel at 11.0'*		
		SPT-3		18 41 43	93						
	15										
									SILTY SAND-SANDY SILT (SM-ML), fine, orangish brown, non plastic, very dense, damp; some gravel, fine, gray, angular to subangular, siltite, maximum size 1/2".		
		SPT-4		18 41 40/.1	100						
	20										
3560											Hard drilling at 21.5' *
		SPT-5		41 50/.1	100				**SILTY SAND (SM),** fine, orangish brown, non plastic, very dense, damp; some gravel, angular, white and buff quartzite and gray and white siltite, maximum size 1/2".		
	25										
		SPT-6		26/0	0				**? TOP OF BEDROCK AT 27.0' ?** Cuttings include coarse, subangular, gravel size pieces of white to gray quartzite, siltite, and argillite.		Drilling very hard 27.0'-35.0'* Probably have been in coreable rock
	30										Stopped drilling at 35.0' (7/26/88, 3:00 PM)
3550										▽	Resumed drilling at 35.0' (7/27/88. 7:00 AM) Temperature 65 deg.F., clear, calm, water level - dry
		SPT-7		50/.1	0					▼	
	35	C-1		30	70				**QUARTZITE** at 35.0' to 37.0', white with some iron oxide staining, wet, moderately weathered, fine grained. Contains large square, darkened glassy crystals, possibly andalusite, almandine, or garnet. Gradational contact with underlying rock.		Cored 35.0'-55.0' (NQ, hole diameter 2.98", core diameter 1.875") using augers as casing. Used diamond impregnated coring bit Drilling fluid water, return light orangish brown, loss 0%, 10.0' long double tube core barrel.
	40	C-2		28	96						Drilling rate 3 min/ft 35.0'-40.0'
3540									**SILTITE/ARGILLITE** at 37.0', orangish brown and light to medium gray, silt-size grains, occasionally clay-size, wet, soft, highly weathered, sometimes vuggy. Bedding spacing 1/4" to 1-1/2", to laminated in places, dip angle 40-50 degrees. Fracture spacing 1" to 6". Fractures are generally parallel to bedding, planar, rough to smooth, closed, occasionally with thin.		Drilling rate 2 min/ft 40.0'-50.0'
	45	C-3		16	72						* Reported by driller

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. USB-3

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE	WATER DATA	REMARKS SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS
3530		C-4		0	42				smooth, closed, slightly slickensided, clay filling. Other fractures are irregular, rough, open, vuggy, with iron-and manganese-oxide staining.		Drilling rate 1 min/ft 50.0'-55.0'
	55	C-5		0	40						Stopped drilling at 55.0'(7/28/88, 4:15 PM) Resumed work (7/28/88, 7:00 AM) Temperature 50-60 deg.F, broken clouds, slight wind Water Pressure Test 1: 38.8'-55.0'
3520	60	C-6		0	50				Very soft at 50.0' to 65.0', completely weathered, highly fractured core pieces. (length < 2-1/2").		Stopped work (7/28/88, 9:30 AM) Resumed drilling at 55.0' (7/29/88, 6:30 AM) Temperature 50-55 deg.F, clear, calm
	65	C-7		10	92				Fracture spacing to 2-1/2", 65.0'-70.0'		Cored 55.0'-70.0' Stopped drilling at 70.0' (7/29/88, 8:15 AM) Water Pressure Test 2: 50.3'-70.0'
3510	70								**BOTTOM OF HOLE AT 70.0'** Average RQD of bedrock = 12% Average recovery = 66% Average drilling rate = 2 min/ft		No piezometer installed Removed all casing
	75										
3500	80										**WATER LEVEL** date time level 7/28/88 7:00 AM 31.5' 7/29/88 6:30 AM 34.3'
	85										
3490	90										
	95										
3480	100										
	105										

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

PROJECT	MONTANA SILVER VENTURE	JOB NO.	8029	HOLE NO.	USB-4
SITE	Little Cherry Tailings	DATE - STARTED FINISHED	AUG 20 88 - AUG 23 88	HOLE SIZE	3"
ORIENTATION	vertical				
LOCATION	Libby, Montana	ELEVATION(FT)	3645 ±	DEPTH TO WATER(FT)	not encount.
DEPTH TO ROCK (FT)					
DRILLING CONTRACTOR	Northern Eng & Test.	SAMPLES	4	CORE BOXES	0
DEPTH OF HOLE (FT)	25.0				
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY	D. A. Baskin	REVIEWED BY	M. P. Forrest

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3640	5	SPT-2		49 47 50/.4	33				**SILTY SANDY GRAVEL (GM),** orangish brown and gray, nonplastic, very dense, damp; gravel is fine, gray, slightly weathered, hard, fine grained quartzite.		Started drilling (8/20/88, 7:55 AM) Rotary drilled with water using a 2-15/16" tricone bit Cobbles on surface to approximately 1.0' Brown water return, 100% return Reamed casing to 5.0' (NWFJ 3"ID, 3-1/2"OD)
									gray, subrounded to subangular, hard, fine grained quartzite.		Reamed casing to 10.0'
	10	SPT-3		50/.3	40						Constant head water test at 10.0', water leaking at surface hard to seal casing in gravel Alternates brown and brownish gray water return
3630	15	S-1		50/.1	0				Cobbles and boulders 10.0' to 25.0', gray and white, quartzite and siltite, alternating with layers of silty sand.		Stopped drilling at 15.0' (8/20/88, 11:45 AM) Remove casing, put on driving shoe (8/23/88, 9:45 AM) Casing driven to 15.0' Constant head water test at 15.0'
	20	SPT-4		50/.5	70				Silty sand, brown, non plastic, wet; some gravel, fine, gray, hard, fine grained quartzite.		Casing driven to 20.0' Constant head water test at 20.0'
									Boulder at 21.5' to 23.0', white and gray siltite, hard.		Hole keeps caving after drill rods removed
3620	25								**BOTTOM OF HOLE AT 25.0'**		Stopped drilling (8/23/88, 3:00 PM)
	30										
3610	35										
	40										
3600	45										

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1 HOLE NO. USB-4

PROJECT	MONTANA SILVER VENTURE	JOB NO.	8029	HOLE NO.	USB-5
SITE	Little Cherry Tailings	DATE - STARTED / FINISHED	AUG 24 88 - AUG 24 88	HOLE SIZE	3"
ORIENTATION	vertical				
LOCATION	Libby, Montana	ELEVATION(FT)	3516	DEPTH TO WATER(FT)	27.1
DEPTH TO ROCK (FT)					
DRILLING CONTRACTOR	Northern Eng & Test.	SAMPLES	7	CORE BOXES	0
DEPTH OF HOLE (FT)	50.3				
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY	D. A. Baskin	REVIEWED BY	M. P. Forrest

ELEV. (FT)	DEPTH (FT)	SAMPLER NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
											Started drilling (8/24/88, 9:20 AM) 2-16/16" tricone bit and water Cobbles and boulders at surface
	5								**GRAVELLY SANDY SILT (ML),** orangish brown, non plastic, very dense, moist to wet; sand is fine; gravel is fine to coarse, gray and white, slightly weathered to completely weathered, fine grained.		Ream casing to 5.0' (NWFJ 3"ID, 3-1/2"OD) Orange brown water return
3510		SPT-1		21 30 50/.2	100						
	10	SPT-2		50/.45	85				**GRAVELLY SILTY SAND (SM),** orangish brown, non plastic, very dense, moist; gravel is fine to coarse, orangish brown, gray, and white, fine grained to aphanitic. Cobbles 11.0' to 19.0'		Ream casing to 10.0' Constant head water test at 10.0' .007 GPM Return water alternates orangish brown and gray, silty sand and cobbles
	15								**SILTY CLAY - CLAYEY SILT (CL-ML),** hard, trace to some fine gravel, gray, fine grained, completely weathered.		Constant head water test at 15.0', casing at 10.0'
3500	20	SPT-3		16 19 50	80						
	25	SPT-4		32 50/.4	88				Some coarse gravel, gray, slightly weathered		Constant head water test at 25.0', casing at 10.0'
3490	30								Cobble at 31.0' Cobble at 33.0'		
	35	SPT-5		50/.25	0						
3480	40	SPT-6		50/.2	90				Cobbles 41.0' to 50.0'		Constant head water test at 40.0', casing at 10.0'
	45										Stop drilling at 50.0' (8/24/88, 4:15 PM) Installed piezometer to 50.2' (1"ID Schedule 80 PVC pipe, bottom 20' slotted .02" width, backfilled to 25' with no. 16 silica sand, backfilled to 3' with bentonite pellets)
3470											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 HOLE NO. USB-5

PROJECT **MONTANA SILVER VENTURE** | JOB NO. 8029 | HOLE NO. USB-5

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT/RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE	WATER DATA	REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS
		SPT-1		80/.3	20				**SANDY GRAVEL (GM)** gray, white, and orangish brown, slightly weathered, subrounded to rounded, maximum size 1/2".		Depth to water 27.1' (8/26/88, 7:10 AM)
									BOTTOM OF HOLE AT 50.3'		
	55										
3460											
	60										
	65										
3450											
	70										
	75										
3440											
	80										
	85										
3430											
	90										
	95										
3420											
	100										
	105										

BORING LOGS
(1989)

PROJECT	JOB NO.	HOLE NO.
NORANDA	8029	DH-1

SITE	DATE - STARTED / FINISHED	HOLE SIZE	ORIENTATION
Near north abutment of tailings dam	08-12-89 / 08-14-89	3.782"	VERTICAL

LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
Libby, Montana	~ 3435'	21'	77'

DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
J.D. Welsh	5	3	100'

DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY
ACKER ADII	A.M. SILVA	U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3435'	0				%					GRAVELLY SANDY SILT - SILTY SAND (ML-SM) - dry, brn., non-pl., m. dense.		Advanced hole with hollow-stem auger
	1											
	2											
	3											
	4	SPT #1		10 / 17 / 21	100 %					GRAVELLY, SANDY, SILTY CLAY (CL-ML) brn., dry, non-plastic, m. dense-dense; gravels < 1" ϕ, subangular.		Advanced hole with standard split-spoon sampler. Lab. Class.
	5											
	6											
	7											
	8											
	9											(4.5 ton/ft² pressure makes ⅛" indentation in ML)
3425'	10									ML - clayey w/ few cobbles; cobble fragments consist of metasandstone and metaquartzite.		Began HQ coring. Lost drilling water return (10'-16.5'). Noticed water coming out in test pit DT-2 across road.
	11											
	12											
	13											
	14											
	15											
	16											
	17	SPT #2		22 / 35 / 31	100 %					CLAYEY, SANDY SILT (ML) - with gravels; brn., dry, sl. pl., v. stiff		
	18											
	19											
3415'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 5 | HOLE NO. DH-1

PROJECT			JOB NO. 8029	HOLE NO. DH-1
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3415'	20									CLAYEY, SANDY SILT (ML)- with gravels; brn., dry, sl. pl., v. stiff		
	21										▼	Encountered water at 21' (8-23-89)
	22											
	23	SPT #3		19 / 29 / 26	100%					SANDY, SILTY CLAY (CL-ML) with some gravel		Lab. Class. LL=22, PI=4
	24											
	25											
	26											
	27									↓ some cobbles of metaquartzite & metasandstone.		
	28									Occ. gravelly sections		
	29											
3405'	30											
	31											
	32											
	33											
	34									ML - as above, dry-damp, v. stiff. Gravels & cobbles sub-angular, hard		
	35											Conducted permeability test #1 at 35' (30-35')
	36											
	37											
	38											
	39											
3375'	40											Conducted permeability test #2 at 40' (35-40')

PROJECT		JOB NO. 8029	HOLE NO. DH-1
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3395'	40	SPT		50+	60%					CLAYEY, SANDY SILT (ML) - brn, dry-damp, v. stiff, non-plastic, with some gravels & cobbles (metaquartzite & metasandstone)		Refusal after 5" penetration
	41											
	42											
	43											
	44											
	45											
	46											
	47											
	48											
	49									Material becomes gravelly ML		
3385'	50											
	51											
	52											
	53											
	54	SPT		50+	60%					GRAVELLY, SANDY SILT (ML), brn., dry, non-plastic, tr. clay, v. stiff; possibly SM. Cobbles subrounded, consist of siltstone, argillite, metasandstone + metaquartzite		Refusal after 5" penetration
	55											
	56											
	57											
	58											
	59											
3375'	60											

PROJECT			JOB NO. 8029	HOLE NO. DH-1
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3375'	60									GRAVELLY SANDY SILT (ML) -SILTY SAND (SM) - brn., dry, non-plastic, v. stiff (dense sm) subrounded gravel & cobbles		
	61											
	62											
	63											
	64									} soft, siltstone - argillite frag.		Rough drilling
	65											Some vibrations
	66									Metasediment cobbles		
	67											
	68											
	69											
3365'	70											Performed permeability test #3 at 70' (65.5 - 70')
	71											
	72											
	73											
	74											
	75											
	76											
	77									BEDROCK AT 77' (METASEDIMENTS)		
	78			51%	100%	1				SILTSTONE, ARGILLITE, SOME METASANDSTONE -interbedded, org. brn., mod-int. fractured & weathered, soft-hard.		Smooth drilling
	79											
3355'	80											

PROJECT			JOB NO. 8029	HOLE NO. DH-1
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	Box #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3355'	80									SILTSTONE, ARGILLITE, SOME METASANDSTONE -interbedded, org. brn., dry, mod.-int. fractured and weathered, soft-hard.		
	81			0	85%							
	82											
	83			31%	93%	1				Fractures along Laminae at ∡ 45°-60°; surfaces are sl. rough, some smooth, few slickensides. Fe-oxide stains in some fract.		Smooth drilling
	84											
	85											
	86											
	87			28%	100%					grey, metasandstone, hard but fractured		
	88					2						
	89									int. fractured		
3345'	90											Conducted packer test #1 at 90' (80-90')
	91			62%	100%					← hard but m. fractured siltstone; (fr. > 6 fr/ft. at ∡ 60°) along Laminae		
	92											
	93											
	94			21%	100%							
	95											
	96											
	97									grey, hard, fractured metasediments.		
	98			33%	95%	3						
	99											
										int. fractured		
3335'	100									BOH AT 100'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 5 HOLE NO. DH-1

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-2
SITE Near center of tailings dam	DATE - STARTED 9-19-89 FINISHED 9-20-89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION 3410'	DEPTH TO WATER 6'	DEPTH TO ROCK 54'
DRILLING CONTRACTOR Chen-Northern/J. D. Welsh	SAMPLES 3	CORE BOXES 0	DEPTH OF HOLE 110'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY A.M. SILVA		REVIEWED BY U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3410'	0				%					SANDY SILT (ML) w/ clay - brn., dry, soft, sl. plastic		Advanced hole with hollow-stem auger
	1											
	2											
	3											
	4									GRAVELLY, SANDY SILT (ML) - brn., dry, sl. plastic, soft		Advanced hole w/ standard split-spoon sampler
	5	SPT #1		3 4 8								Lab. Class LL=20, PI=3
	6										▼	Encountered water at 6' (9-19-89)
	7											
	8											
	9	SH-1			0							Pushed Shelby 9" w/ 500 lbs pressure — NO RECOVERY
3400'	10											Began HQ coring
	11				100%					SANDY SILTY CLAY (CL) - damp, as above		Lab. Class.
	12											No unconfined strength LL=33 PI=17
	13											
	14									CLAYEY, SANDY SILT (ML) with gravels and cobbles		
	15			50+						ML as above Gravels & cobbles subrounded, m. hard, fract. metasediments.		Attempted SPT #2; REFUSAL at 1" Good drill water return
	16											
	17				88%	1						
	18									grey siltstone, m. hard, fractured		
	19											
3390'	20			50+								Attempted SPT #3; REFUSAL at 1"

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 HOLE NO. DH-2

PROJECT			JOB NO. 8029	HOLE NO. DH-2
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	% RQD	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3390'	20									CLAYEY SANDY SILT (ML) with gravels & cobbles; brn., damp, sl. pl.		
	21											
	22				62 %							
	23									↓ Increasing gr. & cobble content		
	24											
	25									COBBLES & GRAVELS in a sandy silt matrix.		
	26				68 %							
	27									Cobbles are metasediments (mostly argillite, siltstone, occ. metaqtzite and metasandstone); int. fract.		
	28											
	29									} int. fractured argillite		
										← ML		
3380'	30				62 %	2						
	31									← fract. metaquartzite		
	32									← ML w/ gr.		
	33											
	34				62 %							
	35									fract. metasandstone boulder (interbedded boulder - ML - boulder) (or boulder - siltstone - boulder)		
	36											
	37									← v. hard metaquartzite, Lt. grey, fract.		
	38				75 %							
	39					3						
3370'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 6 HOLE NO. DH-2

PROJECT			JOB NO. 8029	HOLE NO. DH-2
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3370'	40									METASEDIMENT COBBLES & BOULDERS in sandy silt (ML) matrix. Rock fragments/core is mainly metaquartzite w/ occ. siltstone, argillite, & meta-sandstone.		
	41				33 %							
	42											
	43									Rock core is m. hard, fract., sub-round. ML matrix is generally lost by washing during drilling		
	44											
	45											
	46				57 %	3						
	47											
	48											
	49											
3360'	50									Typical sequence:		
	51									← ML, brn., damp, sl. stiff, sl. pl.		
	52				71 %					← metasandstone, fract., m. hard		
	53									← metaquartzite, v. hard, fract		
	54									BEDROCK AT 54'		
	55									SILTSTONE, ARGILLITE, METASANDSTONE - interbedded org.-brn., friable (sections are int. fract), highly weathered.		Org. brn. drill water return
	56											
	57			0	45%	4						
	58									Fracturing occurs along thin laminae at ≈ 45°; some silt in fract. surfaces; occ. fract. near vertical; few slickensides		
	59											
3350'	60'									V. poor quality rock		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 6 HOLE NO. DH-2

PROJECT		JOB NO. P029	HOLE NO. DH-2
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	RQD %	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3350'	60									SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded; org. brn., friable (breaks along laminae), h. weathered, soft.		
	61			0	83 %							
	62											
	63											
	64											
	65											
	66			0	64 %	4						
	67									Friable rock (easily broken by hand)		
	68											
	69											
3340'	70									white, talc coating on fract. surface		
	71											
	72			0	78 %					V. poor quality rock		
	73					5						
	74											Conducted packer test #1 at 74' (55' to 74')
	75			0	70 %					Rock becomes harder		
	76											
	77											
	78			27 %	100 %					Occ. metaquartzite interbeds; dk-grn.		
	79									Occ. vugs (< .5cm ϕ)		
										Tr. silt in fracture surfaces		
3330'	80											

PROJECT			JOB NO. 8029	HOLE NO. DH-2
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3330'	80									SILTSTONE, ARGILLITE w/ METAQUARTZITE & METASANDSTONE INTERBEDS - friable (soft-hard) mod.-int. fractured, h. weathered.		
	81			30%	100%							
	82											
	83					6				Fracture frequency: >6 fr./ft.; rock is not friable in most sections		
	84											
	85			35%	90%					tr. ML (weathered argillite?)		
	86									Poor quality rock		
	87											
	88									Brn., sl. hard, fract. (>3 fr/ft.) siltstone & argillite		
	89			40%	92%					grey, m. hard siltstone		
3320'	90											Conducted permeability test #2 at 90' (70' to 90')
	91									Fractures in siltstone & argillite are straight - sl. rough to smooth, some filled w/ silty clay & Fe-oxide stains; traces of slickensides. Most fract. are at ∡ 40°-60° and occ. near vertical.		
	92					7						
	93											
	94			0	44%							
	95											Slow drilling
	96									int. fractured siltstone		
	97											
	98											
	99									hard m. qtzite		
3310'	100											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 6 | HOLE NO. DH-2

PROJECT		JOB NO. 8029	HOLE NO. DH-2
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	RQD %	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3310'	100									SILTSTONE, ARGILLITE w/ occ. metasandstone & metaquartzite interbeds; — brn., mod.-int. fract., h. weathered. int. fractured		
	101											
	102			0	26 %	7						
	103											
	104									— m. qtzite		
	105									Siltstone not friable but fractured at ∡ 30°–50°; clean fract. surfaces		
	106											
	107			52 %	76 %	8						
	108											
	109											Conducted permeability test #3 at 110' (90' to 110')
3300'	110'									BOH AT 110'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 HOLE NO. DH-2

PROJECT	JOB NO.	HOLE NO.
NORANDA	8029	DH-3

SITE	DATE - STARTED / FINISHED	HOLE SIZE	ORIENTATION
Near center of tailings dam	09-9-89 / 09-18-89	3.782" / 2.986"	VERTICAL

LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
Libby, Montana	~3435'	ARTESIAN	NE

DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
Chen-Northern / J.D. Welsh	9	25	367'

DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY
ACKER AD II	A.M. SILVA	U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3435'	0									CLAYEY, SANDY SILT (ML) w/ gravels; reddish-brn., dry-damp, sl. plastic,		Advanced hole w/ HQ coring bit
	1											
	2											
	3											High unconfined strength
	4											
	5											Lab. Class.
	6	SPT #1		7, 12, 12	100%					SANDY, SILTY CLAY (CL-ML) - brn., dry-damp, sl. plastic, sandier at 5.8'-6.5, some gravels, sl. stiff		Set casing at 5'; Advanced hole w/ standard split-spoon sampler
	7									Gravels are subrounded, hard meta-quartzite, metasandstone, siltstone.		
	8				17%							
	9											
3425'	10	SPT #2		7, 8, 11	83%	1				CLAYEY, SANDY SILT (ML-SM) (as above) - m. soft		
	11											Using polymer drilling fluid
	12									Occ. areas as CL-SC		
	13				90%							
	14									few gravels		
	15	SPT #3		3, 6, 7	66%					SANDY, SILTY CLAY (CL) - brn., dry-damp, sl. pl.-plastic, soft, tr. gravels		Lab. Class. LL=33 PI=15
	16											
	17											
	18				70%	2						
	19											
3415'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 HOLE NO. DH-3

PROJECT		JOB NO. 8029	HOLE NO. DH-3
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3415'	20	SPT #4		3	44 %					SANDY SILTY CLAY (CL) - brn.-grey, moist, pl.-sl. pl., soft, some gravels & occ. cobbles; some sections are CH		Lab. Class. LL=37, PI=18
	21			6								
				7								
	22				80 %							
	23											
	24											
	25					2						
		SPT #5		47	44 %					CLAYEY SANDY SILT (ML-CL) - brn., damp, sl. pl., m. stiff, w/ some gravel & cobbles		
	26			19								
				17								
	27				80 %							
	28											
	29											
3405'	30											
	31									GRAVELS & COBBLES w/ clayey sandy silt. Subrounded, hard, meta quartzite, siltstone, metasandstone. Soil is org.-brn., damp, sl. plastic.		
	32				56 %	3						
	33											
	34									Cobbles at times soft, fractured, weathered		
	35									Increasing cobble content		Good drill water return
	36									(SC-SM)		Lab. Class.
	37				62 %							
	38											
	39											
3395'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 6 | HOLE NO. DH-3

PROJECT			JOB NO. 8029	HOLE NO. DH-3
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3395'	40				77 %	3				GRAVELS & COBBLES w/ sandy silt, some clay		
TE: CHANGE IN SCALE					73 %	4						
	50				100 %					SANDY SILT (ML) w/ gravels & cobbles; some clay, brn., damp, Loose-stiff, sl. pl.		
					100%	5				- friable siltstone, argillite cobbles, & occ. boulders		
	60				100%							
					80%	6				Gravels can be removed easily		
	70				100 %							
		#6								SANDY SILT (ML) - v. stiff; V. dense (ML) (SM) w/ few gravels		Attempted SPT #6; advanced 11" before refusal; n = 25/50+ Recovery 4"
					100%	7						
	80				100%					Soil matrix well cemented, brn.		Good drilling water return
					60%	8						
3345'	90				100%							
					100%	9						
	100				100%					Occ. siltstone & argillite boulders		
					80%	10						
	110				100%							
					100%	11						
	120	#7			68 %					Increasing content of cobbles & boulders (grey metasandstones & siltstones), fract., weathered.		Attempted SPT #7; advanced only 5" before refusal. NO RECOVERY
					72 %							
	130				88 %	12						
		#8								Loose/soft sandy silt (ML-SM)		Attempted SPT #8; advanced only 2"; RECOVERED 100%
					70%							
3295'	140											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 6 HOLE NO. DH-3

PROJECT		JOB NO. 8029	HOLE NO. DH-3
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3295'	140				100%	13				SANDY SILT (ML) w/ gravels & cobbles · org. brn., damp, sl. pl., v. dense. Subrounded gravels		
										friable		Attempted SPT #9; advanced only 1.5" (100% RECOVERY)
					100%							
	150				70%	14						Drilling rate ≈ .3 ft/min.
					68%					← gravels		
	160				64%					COBBLES & BOULDERS - subrounded, hard, few gravels, ML MATRIX Metaquartzite, metasandstone, argillite, siltstone, fractured & weathered		Drilling becomes more difficult
					100%	15						
					82%							
	170				80%					} int. fract.		
					88%							
	180				86%	16				← friable siltstone, argillite		
					62%							
3245'	190				29%	17						
					35%	18						Drilling rate: .16 ft/min.
	200				50%					Few fines - none recovered (washed)		
					11%							
	210									Only cobbles & boulders recovered		
					9%							Drilling rate: .4 ft/min.
	220											
					21%							
	230				47%					} int. fract.		Water seeping out of casing
					60%	19				ML recovered ↓		Unconfined strength ≈ 1.5-2.0 tons/ft²
3195'	240											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 6 | HOLE NO. DH-3

PROJECT		JOB NO. 8029	HOLE NO. DH-3
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3195'	240				50%					COBBLES & BOULDERS IN ML MATRIX		
										(as above)		
						19				Increasing ML content		Drilling rate: .16 ft/min
	250				27%							
										Decreasing content of ML		
					50%	20				BOULDERS & COBBLES		
	260									– Hard, siltstone, metas.s. (2-5 ft/ft)		
					67%							Smoother drilling
	270				?							
					46%	21				– conglomerate		
	280				44%					} int. fractured		
										Trace ML, mostly boulders		
					56%					– conglomerate		
3145'	290									Fract. ∡ 45°, rough surface		
					38%	22						
	300				65%					Hard metasediments, occ. Loose gravels, at times boulders are intensely fractured, few slickensides		
					35%							
	310				58%					– gravels, subrounded, < 6cm ϕ		
					22%	23				← fractured		
	320											
					31%							
	330											
					75%	24						
3095'	340											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 6 HOLE NO. DH-3

PROJECT		JOB NO. 8029	HOLE NO. DH-3
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3095'	340'				47%					BOULDERS (metasediments) mainly metaquartzite & metasandstone w/ cobbles, occ. gravels, and ML soil matrix; fractured, at times soft.		
					29%	24				← Hard metass.		
	350									← Some clayey silt in fractured boulders		Harder drilling
					87%							
					60%	25				— greenish color		
	360									— conglomerate wedge on metasandstone boulder		
					48%							
3068'	367'									BOH AT 367'		Installed 1" PVC pipe to 260' and a 1/2" PVC pipe to 160' NOTE: Water is flowing from well at ≈ rate of .15 gpm

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-3

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH 3A
SITE TAILINGS IMPOUNDMENT	DATE - STARTED FINISHED 9/15/89 — 9/15/89	HOLE SIZE (AUGER)	ORIENTATION
LOCATION HARRI MT.	ELEVATION	DEPTH TO WATER NE	DEPTH TO ROCK NE
DRILLING CONTRACTOR UTEM-NORTHERN / J.D. WELSH	SAMPLES 9	CORE BOXES —	DEPTH OF HOLE 25'
DRILL MAKE - MODEL KUKER AD II	LOGGED BY AILEEN M. SILVA		REVIEWED BY

ELEV.	DEPTH	SAMPLER	CASING	SPT/ROD	RECOVERY	N	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
	0											augured to 25' as an offset to DH-3 to obtain undisturbed samples in surface clays. BRASS RINGS=BR STEELY'S = SH
		BR 1			18"	5 20 26				SANDY SILTY SOIL (SM) w/gravels, sl. pl.		
	5											
		BR 2			6"	6 13 50/.5				SANDY SILTY CLAY TO CLAYEY SILT (CL-ML) Trace to some gravels.		
	10											
		SH 1			19"	5 8 8 psi						
		SH 2			21.5"	500 psi						LL=31, PI=13
	15											
		SH 3			18.5"	250 psi						
		SH 4			20"	500 psi						
	20	SH 5			24"	250 psi						
		SH 6			24"	<50 psi						
		SH 7			20"	500 psi						quit for the day 25' - filled hole back in.
	25									BOTTOM OF HOLE @ 25'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1 | HOLE NO. DH 3A

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-4
SITE South Saddle Dam	DATE - STARTED 9-8-89 FINISHED 9-8-89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3590'	DEPTH TO WATER N.E.	DEPTH TO ROCK 9'
DRILLING CONTRACTOR J.D. Welsh	SAMPLES 1	CORE BOXES 3	DEPTH OF HOLE 40'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY M. I. SCHAUER	REVIEWED BY U.J. CORDON	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3590'	0		← HWFJ (4" I.D.) →		%					SANDY SILT (ML) - Lt. brn., dry-moist, soft, some organics, non-plastic. Approx. 60% n-pl. fines 40% f. sand		
	1											
	2									?		Lt. brn. water return
	3									Increasing gravel content, ML→GM		
	4											
	5	SPT #1		25 / 25+	43					SANDY SILTY GRAVEL (GM) - Lt. brn., wet, v. dense, quartzite gravels < 4cm ϕ		SPT #1: Second set of blows 25+ only advanced hole .2'
	6									Approx. 65% coarse, ang. gravels 20% non-pl. fines 15% fine sand		Advanced hole w/ HQ-size diamond bit & split-tube core barrel
	7				27 %							
	8					1						
	9									BEDROCK AT 9'		
3580'	10									SILTSTONE, ARGILLITE, META-SANDSTONE/QUARTZITE - interbedded, Lt. brn., wet, m. hard, mod. weathered.		
	11			18 %	53 %							Drilling rate: .33 ft/min.
	12									— Siltstone & argillite break easily (friable) along laminae at ∡ 45°; Some areas are v. soft - soft; fracture surfaces occ. have soft clay filling or chlorite / talc.		
	13											
	14											
	15									— Metasandstone/metaquartzite is generally m. hard but fractured		
	16									Poor - fair quality rock		
	17			38 %	86 %					Fracture frequency: 2-5 fr/ft. Fractures are straight, sl. rough, w/ Fe & manganese oxide stains or clay, few exhibit slickenside surf. Few fract. near vertical		
	18											
	19											
3570'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 HOLE NO. DH-4

PROJECT			JOB NO. 8029	HOLE NO. DH-4
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3570'	20									SILTSTONE, ARGILLITE, META-SANDSTONE/QUARTZITE - interbedded, Lt. brn - brn-white, wet, m. hard, mod. weathered		Smooth drilling
	21											
	22			14%	66%					} crushed		
	23											
	24					2						
	25											
	26											
	27			40%	90%							
	28											
	29											
3560'	30											
	31											
	32			12%	76%					Mod. fractured, m. weathered, soft-m. hard rock. Poor-fair quality		
	33											
	34											
	35					3				} intensely fractured		
	36											
	37			14%	50%							
	38									- Fe-oxide stains & clay in fracture		Ran packer test #1 (18'-40')
	39									} int. fract.		
3550'	40									BOH AT 40'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2 HOLE NO. DH-4

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-5
SITE North Saddle Dam	DATE STARTED 8/21/89 FINISHED 8/25/89	HOLE SIZE 3.78" 2.98"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3670'	DEPTH TO WATER 49.6' (?)	DEPTH TO ROCK 145'
DRILLING CONTRACTOR Chen-Northern / J.D. Welsh	SAMPLES 2	CORE BOXES 17	DEPTH OF HOLE 197'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY A.M. SILVA		REVIEWED BY V.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3670	0									SILTY SAND - SANDY SILT (ML-SM) brn., dry, non plastic, loose, some clay, w/ occ. cobbles & boulders, few gravels		Advanced hole w/ hollow-stem auger to 5'
	1											
	2											
	3											
	4	#1			3"					Grey, aphanitic, v. hard metaquartzite boulder, fractured		Attempted SPT #1, advanced 3" before refusal.
	5											Began HQ coring
	6											Unconfined strength > 4.5 tons/ft²
	7				100 %					- appears as conglomerate but some sections are loose, friable		
	8											
	9					1						
3660	10											
	11										▽	Encountered water at 11' (8-22-89)
	12				?					- int. weathered		
	13											
	14											
	15	SPT #2		8	88 %					GRAVELLY, SANDY, SILTY CLAY (CL-ML) brn., dry, sl. plastic, stiff, w/ few gravels		Conducted permeability test at 15' (8' to 15')
	16			29								Lab. Class.
				22								
	17					2						
	18				0							
	19											
3650'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 HOLE NO. DH-5

PROJECT			JOB NO. 8029	HOLE NO. DH-5
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3650'	20									SANDY CLAYEY Silt (ML) Matrix brn., dry, sl. pl., v. stiff, w/gravels (conglomeratic appearance)		
	22				100%							
	24									-yellow-brn. at 23'		
	26					2				-white-grey, mod. hard metasandstone		
	28				100%					ML with metasandstone, siltstone, argillite & metaquartzite. GC-GM		Lab. Class.
	30											
	32				100%							
	34											
	36				100%	3						
	38									Fe-ox stains on fract. surfaces		
3630	40											Conducted permeability test at 40' (30' to 40')
	42				50%					Fractured boulders		
	44					4						
	46				78%							
	48											Encountered water at 49.6 on 08/23/89
	50										▽	Unconfined strength ~3 tons/ft²
	52				100%							
	54					5						
	56									org-brn. siltstone, argillite, laminated		
	58				100%					-gravels & cobbles in ML matrix		
3610	60											

NOTE: CHANGE IN SCALE

PROJECT			JOB NO. 8029	HOLE NO. DH-5
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY %	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3610	60									SANDY SILT (ML) & COBBLES & BOULDERS, w/ gravels, clay.		
	62				34%					ML matrix is brn., damp, sl.pl.-non pl., stiff - v. stiff		
	64									Cobbles are subrounded metasediments, hard (mixed w/ gravels)		
	66				100%	6				Boulders are fractured, soft-hard, weathered, w/ Fe-ox on fract.		Conducted permeability test at 65'
	68											
	70											
	72				100%							
	74					7						
	76				100%							
	78											
3590	80											
	82				70%				?	Core boxes possibly mislabeled Field notes describe run from 80'-85' and 85'-88'		Core box #7 ends at 80' Core box #8 begins at 88' (8' of core missing)
	84											
	86				0							Began NQ coring at 85'
	88											
	90				38%	8				Metasandstone, metaquartzite, siltstone, argillite, ML, interlayered boulders & fines		
	92											
	94				42%							
	96											
	98				64%							
3570	100											

PROJECT		JOB NO. 8029	HOLE NO. DH-5
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3570	100									BOULDERS (METASEDIMENTS) w/ SANDY SILT & GRAVELS (occ.), COBBLES. Some conglomerate		
	102											
	104				50%	8				ML is brn., clayey, coarse sand gr., (loose sand at times) soft-stiff, conglomeratic in some intervals.		
	106									Boulders are fractured, hard, sl. weathered.		
	108				100%							
	110					9				- metasandstone		
	112				62%					- conglomerate		
	114				38%					- metasandstone		
	116									- metaquartzite		
	118				38%					- ML w/gravels, loose		
3550	120									} fract. metas.s.		
	122				87%					few gravels & ML		
	124											
	126				40%	10						
	128				?					- conglomerate (well cemented ML + gravels)		
	130				33%					metaquartzite, hard, fract.		
	132									Few to no soil matrix (washed?)		
	134				52%					Possibly upper bedrock (?); ML or argillite washed out metasandstone, sl. fract., appears fresh		
	136											
	138				24%					} int. fract.		
3530	140											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 6 | HOLE NO. DH-5

PROJECT			JOB NO. 8029	HOLE NO. DH-5
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3530	140			36%		10				METASEDIMENTS (BOULDERS?) - possibly weathered bedrock - org.-brn., soft-hard, fract., weathered, argillite is friable.		
	142											
	144											
										BEDROCK AT 145'		
	146			?	?					(METASEDIMENTS) SILTSTONE, ARGILLITE, META-SANDSTONE, interbedded, hard-friable, mod. fractured, org.-brn., mod. weathered		Water return changes to orange color
	148											
	150					11						
	152			7%	40%							
	154									poor quality rock		
	156											
	158											
3510	160			17%	70%							
	162											
	164			48%	66%					- brn. siltstone		
	166									} int. fract. siltstone, argillite		
										- white-brn, hard, metasandstone		Conducted permeability at 167' (147' to 167')
	168											
	170			13%	?							
	172									- talc filling on ∡45° fract.		
						12						
	174			28%	68%							
	176											
	178			28%	54%					friable argillite - mod. fractured; fractures along thin laminae at ∡ 45°		
3490	180											

PROJECT			JOB NO. 8029	HOLE NO. DH-5
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3490	180					12				METASEDIMENTS (as above)		
	182											
	184			20%	70%							
	186											Conducted permeability test at 187' (167' to 187')
	188					13				} friable, brn. argillite		
	190			7%	32%							
	192											
	194			77%	100%							
										– metaquartzite, hard, white		
	196					14				– siltstone, fract. w/ Fe-Ox. stains		Conducted permeability test at 197' (187' to 197')
3473'	197									BOH AT 197'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 HOLE NO. DH-5

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-6
SITE Near toe of Little Cherry CK. diversion dam (TAILINGS impoundment)	DATE - STARTED 08-20-89 FINISHED 08-21-89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~ 3620'	DEPTH TO WATER ARTESIAN	DEPTH TO ROCK 40'
DRILLING CONTRACTOR J.D. Welsh	SAMPLES 2	CORE BOXES 6	DEPTH OF HOLE 60'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY A.M. SILVA		REVIEWED BY U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3620'	0				%					COBBLES & GRAVELS - in a clayey, sandy silt (ML-SM) matrix. ML - brn., dry, sl. plastic, m. dense. Cobbles & gr. are metasediments (metaquartzite & siltstone), hard, subrounded.		Advanced hole w/ auger
	1											
	2											
	3											
	4											
	5											Began coring w/ HQ bit
	6											
	7											
	8											
	9											
3610'	10	SPT #1		40	100%					GRAVELLY, SILTY SAND (SM-SC) brn., dry, sl. plastic, dense-v. dense.		Lab. Class. Advanced hole w/ standard split-spoon sampler LL=20, PI=3
	11			42 / 49								
	12											
	13				75%	1				ML (as above); lt. yellowish brn.		
	14											
	15									↓ increasing cobble & gravel content. Matrix is ML as above		Performed permeability test #1 at 15' (18' to 15')
	16											Unconfined strength of ML > 4.5 tons/ft²
	17				100%					Cobbles & gravels are grey, subrounded, ~ < 3" ϕ		
	18					2						
	19											
3600'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 3 HOLE NO. DH-6

PROJECT			JOB NO. 8029	HOLE NO. DH-6
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3600'	20									CLAYEY, SANDY SILT (ML) with cobbles & gravels, - as above		
	21											
	22					2						
	23											
	24									CL		Lab. Class.
	25	SPT#2		13	100%					CLAYEY SILT (ML) w/ sand; - brn., dry, sl.pl.-pl., stiff, tr. gravel		
	26			15								
				22								
	27									Fewer cobbles & gravels		
	28									brn. argillite, fract. (friable), boulder		(High unconfined strength)
	29					3						
3590'	30											Conducted permeability test #2 at 30' (22' to 30')
	31											
	32									CONGLOMERATE - well cemented coarse gr. sands, gravels, silt. Gravels vary in size & shape, most < 1" ϕ and subrounded.		
	33											
	34									Mod. fractured		
	35									} Some sections poorly cemented		
	36											
	37					4						
	38											
	39											
3580'	40									BEDROCK AT 40' (METASEDIMENTS)		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 3 | HOLE NO. DH-6

PROJECT			JOB NO. 8029	HOLE NO. DH-6
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3580'	40'									SILTSTONE, ARGILLITE, METASANDSTONE -interbedded, brn.-yellow, mod.-int. fractured, mod. weathered, soft-hard.		
	41											
	42			0	60%	4				Fractures easily along thin Laminae at ∡ 20°-30°		
	43											
	44									Fracture frequency: > 5 fr/ft.		
	45											
	46											
	47			0	90%							
	48					5						
	49									} occ. vugs < .5cm ϕ		
3570'	50											
	51									Friable, brn. argillite		
	52			12%	100%							
	53									} hard, white-grey, metasandstone.		
	54											
	55											
	56									Poor quality rock		
	57			30%	90%	6						
	58									Some clay, silt on fracture surfaces		
	59											Water flows out of hole at rate of ~ .5 gpm
3560'	60'									BOH AT 60'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 3 HOLE NO. DH-6

PROJECT	NORANDA	JOB NO.	8029	HOLE NO.	DH-7
SITE	Near inlet of diversion channel	DATE - STARTED / FINISHED	8-10-89 / 8-11-89	HOLE SIZE	3.782"
				ORIENTATION	VERTICAL
LOCATION	Libby, Montana	ELEVATION	~ 3770'	DEPTH TO WATER	35.5 ft.
				DEPTH TO ROCK	34'
DRILLING CONTRACTOR	J. D. Welsh	SAMPLES	7	CORE BOXES	3
				DEPTH OF HOLE	73'
DRILL MAKE - MODEL	ACKER ADT	LOGGED BY	A.M. SILVA	REVIEWED BY	U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY %	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3770'	0									SANDY GRAVEL (GW) - GRAVELLY SAND (SW) - Lt. brn - orange brn., dry, non-plastic, little-some silt,		Advanced hole using 6" auger
	1											
	2											
	3											
	4	SPT #1		6	78					SANDY GRAVEL (GM-GP) Lt. brn., dry, non-plastic, v. dense, some silt, angular to sub-angular gravels		Used standard 2" O.D. split-spoon sampler. Lab. Class.
	5			31								
				70								
	6											
	7									decreasing gravel content		
	8									Transition from GW to ML		
	9	SPT #2		20	66					GRAVELLY SANDY SILT (ML) to SILTY SAND (SM) - org.-brn, dry, non-plastic, v. dense, appears as weathered rock.		50+ blows for 4.5" advance
3760'	10			49								
				50+								
	11											
	12											
	13											
	14	SPT #3		33	39					SANDY SILT (ML) - org. brn., dry, non-plastic to sl. plastic, v. dense		50+ blows for 4" advance
				50+								
	15											
	16											
	17											
	18											
	19	SPT #4		50+	28					SANDY SILT (ML) - org. brn., damp to moist, sl. plastic, v. dense, tr. gravels, at times appears as weathered rock.		Advanced hole only 6" w/ 50+ blows
3750'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

PROJECT			JOB NO. 8029	HOLE NO. DH-7
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY		DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3750'	20				%					SANDY SILT (ML) - org. brn., damp to moist, sl. plastic, v. dense, tr. gravels, indurated but friable		Advanced hole using 6" auger and 2" ϕ split-spoon sampler for SPTs.
	21											
	22											
	23											
	24	SPT #5		33 / 50"	50					SANDY SILT (ML) - as above; well indurated but friable		
	25											
	26											
	27											Smooth augering
	28											
	29											
3740'	30											
	31											
	32											
	33											
3736'	34									BEDROCK AT 34'		
	35	SPT #6		12 / 50"	61					(METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE, interbedded, lt. brn., wet, m. hard, some Fe-oxide stains; m. fractured		(8-14-89) → Encountered water at 35.5' but hole was dry 9 days later (8-23-89)
	36											
	37									(Rock exhibits low-grade metamorphism but sedimentary texture is generally preserved) - lt. brn. to blk. Laminae Mod. weathered		
	38											Augered borehole (no core obtained to 44')
	39									Fractures occur along laminae of the siltstone & argillite (at ∡ 20°-30°)		
3730'	40											

PROJECT			JOB NO. 8029	HOLE NO. DH-7
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3730'	40				%					METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, lt. brn., wet, m. hard, mod. fract., some Fe-oxide stains along fracture surfaces. Moderately weathered (at times intensely weathered)		
	41											
	42											Attempted SPT# 7 at 44' - refusal. Auger refusal. Began coring w/ HQ bit & (3.782" ID) core barrel
	43									Poor - v. poor quality rock		
	44											
	45											
	46			6 %	100 %					Approx. 5 fract./ft. Fract. along Laminae at ∡ 20°-30° Siltstone & argillite are friable but metasandstone is m. hard.		
	47											
	48											
	49					1				Fractures generally straight, sl. rough surface, sometimes polished w/ layer of chlorite, talc, Fe-oxide. (Few slickensides on surfaces)	▽	water at 49' in a.m. 8-11-89. Rough drilling Rods vibrating
3220'	50											
	51			0	60 %							
	52									intensely fractured		
	53											
	54									moderately to intensely fract. (>15 fr/ft.)		
	55											Org. brn water return
	56			0	40 %							
	57											
	58									Occasional near-vertical fract. (sl. rough, closed, w/ occasional clayey filling & Fe-oxide stains)		
	59											
3710'	60					2						

PROJECT		JOB NO.	HOLE NO. DH-7
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3710'	60									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, Lt. brn-whitish brn., wet, m. hard to friable, mod. weathered, mod. to intensely fractured.		Rough drilling
	61											
	62			26%	100%							
	63									- 1½" vug at 63' (Occasional vugs throughout core)		
	64					2						Performed packer test #1 from 47' - 64'
	65									Fractures at ∡30° along Laminae Approx. 5-8 fract./ft.		
	66											
	67			0	100%					Rock is friable when dry. Harder and Less fractured rock is generally metasandstone		
	68											
	69					3						
3700'	70									Poor quality rock (RQD=0)		
	71			0	45%							
	72											Performed packer test #2 from 61' - 73'
3697'	73									BOH at 73'		INSTALLED PVC PIPE

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 4 HOLE NO. DH-7

PROJECT	JOB NO.	HOLE NO.
NORANDA	8029	DH-8

SITE	DATE - STARTED	FINISHED	HOLE SIZE	ORIENTATION
Near inlet of diversion channel	8-11-89	8-12-89	3.782"	VERTICAL

LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
Libby, Montana	~3743'	62'	15'

DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
J.D. Welsh / Chen-Northern	3	8	98'

DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY
ACKER ADII	A.M. SILVA	U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3743'	0				%					SAND (SP), org. brn - brn., dry, non-pl., w/ some rock fragments		Advanced hole with 6" auger
	1											
	2											
	3											
	4	SPT #1		12 / 22 / 23	33					SAND (SP), brn., dry, non-pl., w/ occasional angular weathered rock fragments		Advanced hole w/ standard 2" ϕ O.D. split-spoon sampler
	5											
	6											
	7											
	8											
	9	SPT #2		19 / 34 / 32	66					SANDY GRAVEL (GM-GP), brn., dry, non-pl., w/ some-few rock fragments, Some silt		Lab. Class.
3733'	10											
	11											
	12											
	13											
	14									SP - as above		Attempted SPT #3 at 13.5' Refusal (only advanced 2") Rec. = 11%
										BEDROCK AT 15'		
3728'	15									(METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn. to whitish-brn (metasandstone), wet, m. hard to friable, mod. fractured & weathered. Siltstone & argillite - brn., friable fract. along Laminae M. Sandstone generally hard & less weathered		Began coring w/ HQ bit & 3.782" ID. CORE BARREL
	16											
	17			0	100%	1						
	18											
	19											
3723'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 5 HOLE NO. DH-8

PROJECT			JOB NO. 8029	HOLE NO. DH-8
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV.	DEPTH	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3723'	20				%					METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn. to whitish-brn, hard to friable, mod. weathered & fractured.		
	21			≈29 %	100 %	1						
	22											
	23									Fracturing along Laminae ∡ 45°-30° generally in siltstone & argillite		Org.-brn - beige water return
	24									Fract. w/ talc-like filling		
	25									Poor quality rock (RQD=0)		
	26			0	86%					Occasional sections of intensely weathered & friable rock		
	27											
	28					2						
	29											
3713'	30			12 %	100 %							
	31									} intensely fractured		Smooth to rough drilling
	32									Fractures ≈ ∡ 20°-30° (few near vertical)		
	33									Fracturing: ~ > 10 fr./ft.		
	34									Fracture surfaces are straight, sl. rough to smooth, closed, some contain chloritic and talc-like filling (few slickensides)		
	35			0	50%							
	36											
	37											
	38											
	39			0	100%	3						
3703'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 5 HOLE NO. DH-8

PROJECT			JOB NO. 8029	HOLE NO. DH-8
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3703'	40									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., wet, mod.- highly weathered & fractured (metasandstone is m. hard)		
	41											
	42									intensely fractured/friable; brn. siltstone & argillite (soft)		
	43					3						Smooth-rough drilling
	44									Fair to poor quality rock		
	45			32%	100%							
	46									Brn to blk. fine Laminae in siltstone & argillite		
	47											
	48											
	49											
3693'	50			16%	100%					fractures along Laminae at 20°∡		
	51					4						
	52											
	53									Rock at times vuggy (< ½" vugs)		
	54											
	55			6%	100%							
	56									← 56' - whitish, powdery coating in fracture		
	57											
	58					5						
	59			0	100%							
3683'	60											

PROJECT			JOB NO. 8029	HOLE NO. DH-8
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY %	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3683'	60									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., wet, mod.-intensely weathered, friable, at times siltstone & argillite are soft (as in section from 60'-61') (Metasandstone is generally m. hard)		
	61											
	62										▼	Encountered water at 62' (8-14-89)
	63					5						
	64											
	65			7%	100%					63'-68' occ. vugs present (< 1cm ϕ)		Drilling rate ~ .25 ft/min.
	66									Int. fractured		
	67											
	68									— Siltstone & argillite are brn., friable (along laminae)		
	69											
	70			0	80%							Good water return
3673'	71									— Metasandstone is brownish-white, m. hard, not friable but at times m. fractured		
	72					6				Intensely weathered siltstone; v. soft		
	73									hard metasandstone & siltstone		Performed packer test #1 at 73' (65-73')
	74											
	75			8%	94%					Mod. fractured section Fractures at ∡30° along laminae; surface is straight, sl. rough to smooth, occ. talc & chloritic filling		
	76											
	77											
	78									Possible fracture filling (.5cm ϕ subrounded gravel fragments) Poor quality rock		Intermittent loss of water return
	79											
3663'	80					7						

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 5 HOLE NO. DH-8

PROJECT			JOB NO. 8029	HOLE NO. DH-8
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3663'	80									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., wet., mod. fractured, m.-highly weathered.		
	81			19 %	72 %							
	82											
	83					7						
	84											Intermittent Loss of water return
	85			44 %	100 %							
	86									- most fractures occur along the laminations in the siltstone & argillite		
	87											
	88											
	89									- Metasandstone mod. hard; breaks along contacts w/ siltstone & argillite		
3653'	90			26 %	100%					- Fractures ∡ 30° along laminae. Fracture frequency: ~ 3-6 fr/ft.		
	91					8						
	92											
	93									} vuggy interval (sl. vesicular)		
	94											
	95			10 %	60%							
	96									} Soft siltstone & argillite section (Int. fractured)		
	97											
3645'	98									BOH at 98'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 5 | HOLE NO. DH-8

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-9
SITE Near middle of diversion channel	DATE - STARTED 9-22-89 FINISHED 9-25-89	HOLE SIZE 2.986"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~ 3688'	DEPTH TO WATER 69'	DEPTH TO ROCK 41'
DRILLING CONTRACTOR Chen-Northern / J.D. Welsh	SAMPLES —	CORE BOXES 3	DEPTH OF HOLE 82'
DRILL MAKE - MODEL Longyear 28 (skid rig)	LOGGED BY A.M. SILVA		REVIEWED BY V.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY %	Box #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3688'	0				%					SILTY, SANDY GRAVEL (GM) - org.-brn., subangular gr., w/ roots.		Advanced hole using NQ-size core barrel
	1											
	2									Gravel fragments consist of whitish-grey quartzite & siltstone		
	3											
	4											Attempted to push Shelby at 5' (crushed)
	5											Cased hole to 5'
	6				17%							
	7											
	8									GRAVELLY SANDY SILT (ML) - brn., damp, sl. plastic, w/ some clay in matrix, v. dense, few cobble fragments.		
	9					1				Soil matrix (ML) ≈ 70% Gravels ≈ 30% (subang. to subround)		
3678'	10				10%							
	11											
	12									Clay content varies, at times may be CL		
	13											
	14											Easy drilling
	15				8%					From 13' to 42' Little to no core recovery		
	16											
	17											
	18											
	19											
3663'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 5 | HOLE NO. DH-9

PROJECT			JOB NO. 8029	HOLE NO. DH-9
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3668'	20									GRAVELLY, CLAYEY, SANDY SILT (ML-CL), brn., damp, sl. pl.-pl., well cemented, w/ cobbles & grey gravels		
	21				8%							
	22											
	23											
	24											
	25				8%							Smooth drilling
	26											
	27											
	28											
	29					1						
3658'	30				0							
	31											
	32											
	33											
	34									ML-CL (as above)		
	35				10%							
	36											Lost water return at 37'-38'
	37											
	38									38' — — — — ↓ Appears to contain weathered siltstone & argillite (bedrock?) fragments		
	39				73%							
3648'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 5 HOLE NO. DH-9

PROJECT			JOB NO. 8029	HOLE NO. DH-9
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3648'	40									ML-CL (as above) w/ siltstone frag.		Very slow drilling. Hole taking in lots of water
	41				90%					TOP OF BEDROCK AT 41' (METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, org.-brn., mod.-highly weathered, m. fract., (metasandstone generally m. hard).		
	42			0	50%							
	43											
	44									Siltstone & argillite fracture easily along laminae (friable rock)		
	45			0	40%	1						
	46											
	47									Fract. ∡ 10°-20°		
	48									Poor quality rock (RQD = 0-7%)		
	49											
3638'	50			7%	70%							Water return at 50'. Began drilling w/ mud
	51											
	52									Laminae consist of alternating layers of brn. & black clayey silt, indurated but friable		
	53											
	54											
	55			29%	50%							
	56											
	57					2						
	58									Mod.-int. weathered siltstone & argillite		
	59									No core recovered 58'-63' (possibly intensely fragmented siltstone & argillite that washed out)		
3628'	60			0	0							

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 5 HOLE NO. DH-9

PROJECT			JOB NO. 8029	HOLE NO. DH-9
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3628'	60									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., damp, mod.-highly weathered, mod.-intensely fractured, (metasandstone generally m. hard) v. poor - fair quality rock		
	61			0	0							
	62											
	63											
	64									brn., friable siltstone & argillite		
	65			0	38%							
	66					2						
	67											
	68											
	69										▼	Encountered water at 69' (9-25-89 a.m.)
3618'	70			13%	44%					Fragmented, soft siltstone & argillite wash out during drilling		
	71											
	72											
	73											
	74											
	75			0	62%							
	76											
	77					3				Metasandstone easily scratched w/ knife but not friable; may be broken w/ hands (mod. hard)		
	78											
	79			0	52%					poor quality rock		
3608'	80											

PROJECT			JOB NO. 8029	HOLE NO. DH-9
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV.	DEPTH	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3608'	80									METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., damp, mod.-highly weathered, m.-int. fractured. (as above)		Ran packer test #1 (60'-82')
	81					3						
3606'	82									BOH AT 82'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 5 HOLE NO. DH-9

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-10
SITE Diversion channel	DATE - STARTED 9-27-89 FINISHED 9-29-89	HOLE SIZE 2.98"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3670'	DEPTH TO WATER 73'	DEPTH TO ROCK 18'
DRILLING CONTRACTOR J.D. Welsh	SAMPLES —	CORE BOXES 8	DEPTH OF HOLE 87'
DRILL MAKE - MODEL Longyear 28 (skid rig)	LOGGED BY M. I. SCHAUER		REVIEWED BY U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY %	Box #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3670'	0				%					SANDY SILT (ML), rd.-brn., dry, soft, some organics, sl. pl., few gravels (subang.-subrounded) < 5cm ϕ		Advanced hole using NQ-size diamond bit.
	1											Drilling fluid is water & polymer (Fluidril Fluid-Vis)
	2											
	3									Increasing gravel & cobble content to GM - lt.-brn, wet, dense, sl. weathered gravels w/ sand & cobble fragm. (qtzite)		
	4				31%							
	5											Drilling rate ~ .25 ft/min (Some chatter)
	6					1						
	7											Lost water return 7'-8' but returned; lt. brn. to grey water
	8											
	9				92%					Lg. cobble fragments (>1'); most of soil matrix is washed out		Bit blocked at 10.5' & 15.5'
3660'	10											
	11											
	12				76%							
	13											
	14				52%							
	15											
	16											
	17				64%							
	18									BEDROCK AT 18' (METASEDIMENTS)		
	19			78%	100%	2				METAQUARTZITE, ARGILLITE, METASANDSTONE - interbedded lt.-grey, wet, m. hard-hard, sl. weathered		
3650'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 5 HOLE NO. DH-10

PROJECT			JOB NO. 8029	HOLE NO. DH-10
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	BPT/RQD	RECOVERY %	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3650'	20									METAQUARTZITE - METASANDSTONE, ARGILLITE - interbedded, Lt.-grey, wet, med. hard - hard, sl. weathered, sl. fract. - mod. fractured		
	21											
	22			40%	100%	2						Bit blocked at 22'
	23									Some Ca & Qtz stringers Fracturing: ~ 3-5 fr/ft. Fractures are horiz. to 20° (if in argillite fract. are along thin laminae)		
	24											
	25			44%	76%					Some fract. surfaces have clay coating, Fe-oxide stains, Ca. Most fract. are straight, rough to smooth, closed.		Rough drilling
	26											
	27					3						
	28											Drilling rate: .11 ft/min.
	29									V. Hard but fractured metaqtzite Mod. weathered		
3640'	30			0	45%							
	31											
	32			0	40%					Rock is hard w/ fair quality (poor quality zones common)		Bit blocked at 32' & 40'
	33											
	34											
	35			0	28%							
	36											
	37											
	38											
	39			0	100%					Some near-vertical fractures throughout (most filled w/ Manganese or Fe-oxide stains)		
3630'	40											

PROJECT			JOB NO. 8029	HOLE NO. DH-10
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3630'	40									METAQUARTZITE - METASANDSTONE, ARGILLITE - interbedded, Lt. grey, wet, m. hard - v. hard, sl. weathered & fractured.		Rough drilling
	41			10%	47%	3						
	42											
	43											
	44									V. hard metaqtzite		
	45			66%	100%					Fair-good quality rock		
	46											
	47					4						
	48									Fract. irreg. smooth-sl. rough, w/ occ. Ca. filling, Fe-oxide stains, & Manganese oxide stains		Lt. grey water return
	49			37%	100%					} intensely fractured		
3620'	50									Smooth fract. surfaces contain grn. chlorite (appear polished)		Rough drilling Rate ≈ .11 ft/min.
	51											
	52			20%	100%							
	53											
	54											Drilling rate .25 ft./min.
	55			60%	100%	5				Fracture frequency ≈ 2-4 fr./ft.		
	56											
	57											
	58											
	59			20%	100%							
3610'	60											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 5 | HOLE NO. DH-10

PROJECT			JOB NO. 8029	HOLE NO. DH-10
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3610'	60				%					METAQUARTZITE - METASANDSTONE ARGILLITE - interbedded (as above)		
	61			20%	100%							Rough drilling
	62											
	63											Drilling rate ≈ .17 ft/min
	64			17%	100%					Near vertical fract. w/ soft clay fill and fragmented rock		
	65											
	66					6						Bit blocked at 66'
	67			40%	100%							
	68											
	69											
3600'	70			26%	100%							
	71									Some brn. coloring (Fe-oxide?)		
	72									} crushed		
	73					7				73'-78' - Mod. fract., org.-brn. (Fe-oxide stained?), mod. weathered; some fract. coated w/ soft clay (near 75')	▼	(BOH) Encountered water at 73' but hole was dry next day
	74			80%	40%							Ran packer test #1 (63'-73')
	75											Ran packer test #2 (68'-73')
	76									Fracture freq. > 5 fr/ft. Fair quality rock (v. hard but m. fractured)		
	77											Lost water return (73'-78')
	78									qtz. stringer		
	79											
3590'	80											Water return 50%, lt. grey

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 5 HOLE NO. DH-10

PROJECT			JOB NO. 8029	HOLE NO. DH-10
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3590'	80									METAQUARTZITE -METASANDSTONE, ARGILLITE - interbedded (as above)		Drilling rate: .17 ft/min.
	81			44%	100%	7						
	82									Fract. ∡ 0-20°, straight, sl. rough		
	83									Mod. weathered, org. brn., m. fract. V. hard metazite		
	84			45%	100%	8						
	85											Bit blocked at 85' & 87'
	86			20%	100%							Ran packer test #3 (78'-87')
3583'	87									BOH AT 87'		Installed PVC pipe (Bottom 20' slotted)

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 5 HOLE NO. DH-10

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-11
SITE Diversion dam abutment	DATE STARTED 10/8/89 FINISHED 10/10/89	HOLE SIZE 3.782" 2.98"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3760	DEPTH TO WATER 15'	DEPTH TO ROCK 180'
DRILLING CONTRACTOR Chen-Northern / J.D. Welsh	SAMPLES 4	CORE BOXES 11	DEPTH OF HOLE 192'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY A.M. SILVA		REVIEWED BY U.J. CORDON

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY %	Box #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3760	0									CLAYEY SANDY SILT – SILTY SAND (ML-SM) – brn., dry, sl. plastic, stiff, tr. gravels.		Advanced hole by means of a hollow-stem auger
	1											
	2											Difficult augering
	3											
	4	SPT#1		6 / 20 / 21	72%					CLAYEY SANDY SILT (ML-SM) – brn.-grey, dry, sl. plastic, stiff, tr. gravels & rock fragments		Advanced hole w/ standard split-spoon sampler
	5											
	6											
	7											
	8											
	9	SPT#2		12 / 28 / 19	83%					ML-SM – as above, few gravels		
3750	10											
	11											
	12											
	13											
	14	SPT#3		14 / 27 / 20	28%					ML-SM (as above) damp		
	15										▼	Encountered water at 15'
	16									CLAYEY, SANDY SILT (ML-SM) w/ cobbles & gravels; ML is brn., damp, sl. plastic, stiff; cobbles + gr. are subangular - subrounded, grey, sl. hard		Began HQ coring
	17				28%	1						
	18									ML washed out; most of core consists of gravels + cobbles – metaquartzite, metasandstone, siltstone.		
	19											
3740	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 | HOLE NO. DH-11

PROJECT			JOB NO. 8029	HOLE NO. DH-11
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

NOTE: CHANGE IN SCALE

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3740'	20									COBBLES & GRAVELS in clayey silt (ML) matrix; mainly meta-sediments, grey-white, mod. hard, fractured.		
	22				18%							
	24											
	26											
	28				40%	1						Drilling rate: .25 ft/min.
	30											
	32				47%							Grey water return
	34									Little soil matrix recovered		
	36				34%							
	38											
3720	40											
	42				40%							
	44									CLAYEY SANDY SILT (ML-SM) brn., damp, sl.pl., stiff matrix with gravels & cobbles.		Began using drilling mud to recover soil matrix
	46				75%							Unconfined strength >4.5 tons/ft²
	48					2						Lab. Class.
	50									ML-SM		
	52				65%					– hard metasandstone		Grey water return
	54											
	56				30%							
	58											Lab. Class.
3700	60				100%	3				GM		Attempted SPT #4 at 59' – REFUSAL after 2" advance; recovered 1.5"

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 6 | HOLE NO. DH-11

PROJECT			JOB NO. 8029	HOLE NO. DH-11
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3700	60									BOULDERS and SANDY SILT (ML) w/ cobbles & gravels; hard-soft but fractured metasediments; brn. ML, interbedded, clayey, sl. pl., damp.		
	62					3						
	64				15%					— hard siltstone		
	66											
	68				65%					friable siltstone, argillite. fractures along laminae at ∡ 20°–45°		
	70											
	72				20%							
	74				55%							
	76									— fract. metaquartzite		
	78				20%							
3680	80											
	82				22%					gravels + ML (stiff)		
	84									increasing content of cobbles		
	86					4				COBBLES & GRAVELS in sandy silt matrix (ML-SM) w/ some clay.		
	88				64%							
	90									cobbles are subrounded, mod. hard, fract., mainly metasediments.		
	92				20%							
	94											
	96											Changed bit
	98				38%							
3660	100											

PROJECT			JOB NO. 8029	HOLE NO. DH-11
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3660	100									COBBLES & GRAVELS in stiff SANDY SILT (ML) matrix, brn, reddish-brn., damp, sl. pl. (some clay)		
	102				32 %	4						
	104									Composition varies: 30% fines 70% cobbles +		
	106											
	108				54 %					Occ. boulders		
	110					5						
	112				60 %					weathered rock fragments throughout		
	114									← gravels		
	116											
	118				40 %							
3640	120									soft siltstone, argillite w/ gravels		
	122				90 %							
	124									← sandy silty gravels		Conducted permeability test (97'-125')
	126				54 %					lg. boulders		
	128											
	130											
	132				100 %	6				Friable, grey, soft argillite (∡20°)		
	134									clay filling in fract.		
	136											
	138				68 %							
3620	140											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 6 | HOLE NO. DH-11

PROJECT			JOB NO. 8029	HOLE NO. DH-11
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3620	140									BOULDERS (metasediments) w/ cobbles & gravels in sandy silt matrix (ML) - brn, stiff, non pl.		
	142				56 %							
	144					7						
	146									Boulders are mod.-int. fractured, subrounded, hard - m. hard.		
	148				56 %							
	150											
	152				72 %							
	154									hard metasandstone, siltstone		
	156									Few to no gravels; core appears as weathered, fractured rock.		
	158				50 %							
3600	160					8						Difficult drilling
	162				92 %							
	164				58 %					} int. fract.		Changed bit to NQ-size at 164'
	166											
	168				53 %					} int. fract.		
	170					9				No gravels, possibly upper weathered bedrock (?); no continuous core - Loss of core may be due to: washing of ML matrix or soft argillite	
	172				52 %							
	174											
	176											
	178				70 %							
3580	180											

PROJECT		JOB NO. 8029	HOLE NO. DH-11
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3580	180									BEDROCK AT 180'		Org.-yellow water return
	182			0	88%					SILTSTONE, ARGILLITE; - brn, med- int. fractured (along Laminae at ∡ 50°); highly weathered, friable		
	184											
	186			8%	69%	10				v. poor rock quality		
	188											
	190			19%	85%							Conducted packer test (180'–192')
3568	192									BOH AT 192'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 HOLE NO. DH-11

REV. 60

PROJECT	NORANDA	JOB NO. 8029	HOLE NO. DH-12
SITE	Tailings dam near Little Cherry CK.	DATE - STARTED 09/26/89 FINISHED 09/28/89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION	Libby, Montana	ELEVATION ~ 3385	DEPTH TO WATER 4'	DEPTH TO ROCK 65'
DRILLING CONTRACTOR	Chen Northern / J.D. Welsh	SAMPLES 5	CORE BOXES 7	DEPTH OF HOLE 110'
DRILL MAKE - MODEL	ACKER ADII	LOGGED BY A.M. SILVA	REVIEWED BY U.J. CORDON	

ELEV. (ft)	DEPTH (ft)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3385'	0											Advanced hole w/ hollow-stem auger
	1											
	2											
	3											Lab. Class.
	4										▼	Encountered water at 4'
	5	SPT#1		6 8 10	72%					SANDY GRAVEL (GP-GM) brn., damp, non-plastic, rounded sand gr., some silt & cobbles		Advanced hole w/ standard split-spoon sampler PI=0 Auger refusal at 5.5'
	6									COBBLES & GRAVELS in clayey sandy silt (ML) matrix rocks are metaquartzite & siltstone, grey-brn, hard, subrounded. Cobbles & gravels ~ 80% Clayey sandy silt ~ 20%		Advanced hole w/ HQ coring bit
	7											
	8				27%	1						
	9											
3375'	10									SANDY CLAYEY SILT (ML) - w/ gravels & cobbles; brn, dry-damp, sl. pl., stiff. Gravels are rounded Fines ~ 80% Rocks ~ 20%		
	11											
	12				64%							
	13											
	14											
	15									SANDY CLAYEY SILT (ML) - brn, damp, sl. plastic, v. stiff, tr. gravels		
	16	SPT#2		12 20 50+	77%							
	17									Softer ML		
	18				52%							
	19											quit for the day at 20! Resumed drilling 9-27-89, water level 3'
3365'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 HOLE NO. DH-12

PROJECT			JOB NO. 8029	HOLE NO. DH-12
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3325'	60									CLAYEY SANDY SILT (ML) w/ gravels & cobbles; brn., damp, sl. pl., stiff - v. stiff.		
	61											
	62				80%							
	63					4						
	64											
	65									BEDROCK AT 65'		
		SPT#5		11						(METASEDIMENTS)		Conducted SPT#5 in soft bedrock; REFUSAL on last 6"
	66			32	88%					SILTSTONE, ARGILLITE, w/ occ. meta-sandstone - interbedded, white-brn, dry, soft - m. hard, mod-int. fract, highly weathered		
				50*								
	67											
	68			0	38%					Siltstone & argillite friable; breaks easily along thin brn-blk. laminae		
	69									} reddish color		
3315'	70											
	71											
	72			0	(≈50%)					Occ. near vertical fractures, sl. rough to smooth surfaces, some silt & Fe-oxide		
	73											
	74					5						
	75											
	76											
	77			0	92%					V. poor quality rock		
	78											
	79											
3305	80											

PROJECT			JOB NO. 8029	HOLE NO. DH-12
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3285'	100									ARGILLITE, SILTSTONE - brn., occ. reddish-brn., soft, friable, m.-highly weathered.		Stopped drilling at 100'. Resumed 9-28-89, water level 1' below ground.
	101											
	102			16 %	50 %							
	103											
	104									Some silt & talc-like coating on fracture surfaces		
	105											
	106											
	107			18 %	72 %							
	108											
	109											
3275'	110									BOH AT 110'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-12

PROJECT NORANDA			JOB NO. 8029	HOLE NO. DH-13
SITE – South Saddle Dam	DATE – STARTED 09-7-89 FINISHED 09-8-89		HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3665'	DEPTH TO WATER 45.5'		DEPTH TO ROCK 15.7'
DRILLING CONTRACTOR J.D. Welsh	SAMPLES 4	CORE BOXES 6		DEPTH OF HOLE 80'
DRILL MAKE – MODEL ACKER ADII	LOGGED BY M. I. SCHAUER		REVIEWED BY U.J. CORDON	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOLT %	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3665'	0									SANDY SILT (ML) – Lt. brn., dry to moist, soft, some organics, non pl. ~60% silt & fines ~40% fine sand		Advanced casing to 5'
	1											
	2		HWFJ							Some gravels		
	3											Lt. brn. water return
	4											
	5	SPT #1		9	73%					SANDY SILTY GRAVEL (GM) Lt. brn., wet, dense, subangular		Advanced hole w/ standard split-spoon sampler
	6			18						Gravel fragments < 5cm.ϕ		Lab. class.
				22								
	7											Advanced hole w/ HQ core
	8				77%	1				Gravels consist of metaquartzite and siltstone		
	9											
3655'	10	SPT #2		8	87%					CLAYEY, SILTY, GRAVELLY SAND (SM-SC) Lt. brn., wet, med. dense, non pl. ~55% gravels ~45% fines		Drilling rate: .3 ft/min
	11			17								Lab. Class
				17								
	12											
	13				63%	1				GRAVELLY SANDY SILT (ML) To GRAVELLY SILTY SAND (SM)		Lab. class.
	14											
	15	SPT #3		50"	100%					ML BEDROCK AT 15.7'		Advanced hole only 6" – REFUSAL.
	16									(METASEDIMENTS)		
	17			40%	72%	1				SILTSTONE, ARGILLITE, META-QUARTZITE – interbedded; brn, soft-hard, friable (not easily broken by hand), metaquartzite is hard. Sl. fractured & weathered. Siltstone & argillite have Lt. brn, brn., dark Laminations at ∡ of 20°–50°		
	18											
	19											
3645'	20				100%							Attempted SPT #4 at 20'; REFUSAL Recovered only 2"

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 4 | HOLE NO. DH-13

PROJECT			JOB NO. 8029	HOLE NO. DH-13
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3645'	20					1				SILTSTONE, ARGILLITE, META-QUARTZITE - grey-brn., interbedded, wet, soft-hard, mod. fract (at times intensely fract.), sl. weathered Thinly Laminated at ∡ 45°		
	21											
	22			17%	58%							
	23									int. fract.		
	24									Clay-silt grains, some sand grains (possibly weathered metasandstone)		SL. rough drilling
	25									int. fract.		
	26					2				Occ. Fe-oxide staining along straight, sl. rough-smooth surfaces; tr. clay, tr. slickensides		
	27			0	56%					← Hard, fract. metaquartzite		
	28											
	29											
3635'	30											
	31									Poor quality rock		
	32			16%	72%							
	33									int. fract.		
	34											
	35											
	36									Most fractures are along laminae at ∡ 45°		
	37			6%	68%							
	38					3						
	39											
3625'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 4 | HOLE NO. DH-13

PROJECT			JOB NO. 8029	HOLE NO. DH-13
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3625	40									SILTSTONE, ARGILLITE, META-QUARTZITE - interbedded; lt. brn. to grey, soft-hard, wet, mod. frac. and weathered.		
	41											
	42			22%	100%					Some areas v. soft (generally in weathered siltstone & argillite)		
	43					3				Metaquartzite is hard but fract.		
	44											
	45											
	46										▼	Encountered water at 45.5' (9-8-89 a.m.)
	47			28%	76%					Highly weathered & fractured		
	48											
	49											
3615'	50					4						
	51											
	52			14%	76%							
	53											
	54											
	55									Increasing sections with v. soft (soil-like) argillite & siltstone		
	56											
	57			6%	74%							
	58											
	59					5						
3605'	60											

PROJECT			JOB NO. 8029	HOLE NO. DH-13
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3605	60									SILTSTONE, ARGILLITE, META-QUARTZITE - interbedded; Lt. brn, grey, wet, v. soft - occ. hard., mod. fractured, mod. to extr. weathered.		
	61											
	62			16%	100%							
	63									Siltstone & argillite v. soft (at times soil-like); friable, breaks easily along 30-50° laminations		
	64											
	65									Occ. metaquartzite is hard		
	66									Most of core is siltstone & argillite		
	67			6%	56%	5						
	68											
	69											Lt. brn. water return
3595	70											
	71											
	72			12%	100%					Friable, m. soft		
	73									V. poor quality rock		
	74											Drilling rate: .3 ft/min.
	75					6						
	76											
	77			16%	94%							
	78											Conducted packer test #1 (29.5'-80')
	79											Conducted packer test #2 (55'-80')
3585'	80									BOH AT 80'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 4 HOLE NO. DH-13

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-14
SITE South Saddle Dam	DATE - STARTED 9-9-89 FINISHED 9-9-89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~ 3600'	DEPTH TO WATER 13.9'	DEPTH TO ROCK 30'
DRILLING CONTRACTOR Chen-Northern / J.D. Welsh	SAMPLES 2	CORE BOXES 3	DEPTH OF HOLE 60'
DRILL MAKE - MODEL ACKER AD II	LOGGED BY A.M. SILVA		REVIEWED BY V.J. CORDON

ELEV. (ft)	DEPTH (ft)	SAMPLER	CASING	SPT/RQD	RECOVERY	Box #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3600'	0				%					CLAYEY, SANDY SILT (ML)-(SM) - with gravels and cobbles, brn., damp-dry, sl. plastic, v. dense		Advanced hole with HQ-size diamond bit & wireline core barrel
	1				0							
	2											
	3											
	4				95 %							Cased hole to 5'
	5	SPT #1		12						CLAYEY, SANDY SILT (ML) - w/ gravels and cobbles, brn., damp, sl. pl., m. dense-dense. Gravels are angular to subangular		Advanced hole using standard 2"ϕ split-spoon sampler
	6			22 / 25								
	7									- siltstone boulder fragment		
	8				64 %					- ML w/ gravels & cobbles		Smooth drilling. Unconfined strength = 4.5 tons/ft² (using pocket penetrometer)
	9					1						
3590'	10	SPT #2		9						CLAYEY SANDY SILT (ML) - brn., damp-dry, sl. plastic, w/ gravel and cobbles, med. dense-dense		Advanced hole w/ split-spoon sampler
	11			16 / 22								
	12									- grey, m. hard, siltstone fragment		
	13				52 %							
	14									- CLAYEY, SANDY SILT (ML) w/ gravels, cobbles & boulder frag.; matrix is brn., damp-moist, sl. pl., dense. Rock fragments are grey, some metaquartzite, siltstone and argillite.	▼	Encountered water at 13.9' on 9-12-89
	15											
	16									- Boulder fragments weathered; easily broken by hand		Good water return; beige color
	17				80 %							
	18											
	19											
3580'	20											

PROJECT		JOB NO. 8029	HOLE NO. DH-14
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3580'	20									CLAYEY, SANDY SILT (ML) - w/ gravels and cobbles, org.-brn., damp, sl. pl., dense. Cobble-boulders may be upper bedrock mat'l - siltstone		Smooth drilling
	21											
	22											
	23											
	24									← siltstone fragments in a sandy silt (ML) matrix		
	25											
	26									— argillite, brn., friable, fract. ∡ 45°		
	27											
	28					2						
	29									— metasandstone fragments		
										BEDROCK AT 30'		
3570'	30									(METASEDIMENTS) SILTSTONE, METASANDSTONE, ARGILLITE - interbedded brn.-lt. brn, friable, m. weathered and fractured.		Good water return, org.-brn. color
	31											
	32			10 %	34 %							
	33									V. poor quality rock.		
	34									31'-35': intensely fractured (pieces <1" ϕ)		
	35									— few metaquartzite intervals		
	36											
	37			8 %	70 %							Drilling rate: .28 ft/min.
	38											
	39											
3560'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 3 HOLE NO. DH-14

PROJECT			JOB NO. 8029	HOLE NO. DH-14
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3560'	40									SILTSTONE, ARGILLITE, METASANDSTONE - interbedded, Lt. brn - brn., soft - m. hard, (friable), m. - int. fractured and weathered.		Sl. rough drilling
	41											
	42			17%	48%							
	43									Poor quality rock (friable; RQD < 17%)		
	44											
	45									Fractures along Lamination ∡ 45°, fract. surfaces are straight to wavy, sl. rough - some smooth & filled w/ silt, Fe-oxide stains, very friable rock.		
	46											
	47			8%	40%							
	48					3						
	49											
3550'	50											Performed permeability test #1 (30' to 50')
	51											
	52			0	32%					intensely fractured		
	53											
	54											
	55											
	56											
	57			0	46%							
	58									int. fract.		
	59											Performed permeability test #2 (50' to 60')
3540'	60									BOH AT 60'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 3 HOLE NO. DH-14

PROJECT	JOB NO.	HOLE NO.
NORANDA – MONTANORE	8029	MW DH 15

SITE	DATE – STARTED FINISHED	HOLE SIZE	ORIENTATION
TAILINGS IMPOUNDMENT	9-6-89 — 9-7-89	6"	

LOCATION	ELEVATION	DEPTH TO WATER (CARTESIAN)	DEPTH TO ROCK
LIBBY, MT.		70-110'	NE

DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
CHEN-NORTHERN / RUEN DRILLING	—	—	120'

DRILL MAKE – MODEL	LOGGED BY	REVIEWED BY
SCHRAMM ROTADRILL	AILEEN M. SILVA	

ELEV.	DEPTH	SAMPLER	CASING	SPT/RQD	RECOVERY	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
	0										USING AIR ROTARY TYPE DRILLING – CATCHING BUCKET SAMPLES EVERY 5' – NO SPLIT SPOONS OR H_2O TESTS.
	5										
	10								0-20' SAMPLES ARE SILTY SAND (SM) W/ CHIPS FROM COBBLES – brown, dry, non plastic. gravels are round to subround.		
	15										CASED HOLE TO 15' – ROCK @ 15', COULDN'T DRIVE CASING FURTHER.
	20								MORE FINES – SANDY SILT W/ TRACE OF CLAY – brown, dry, non plastic, poorly graded (ML)		
	25								SILT – grey/white, dry, non plastic, poorly graded (ML)		average drilling speed is 5' in 5-10 min.
	30								SILTY SAND TO SANDY SILT – (SM-ML) poorly graded – brown/beige, dry, non plastic, angular to subangular gravel cobble pieces, sands up to ¼" size – round.		
	35										
	40										
	45								SANDY SILT W/ TRACE OF CLAY (ML) – brown, dry, slightly plastic to non plastic.		
	50										

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 3 | HOLE NO. DH 15

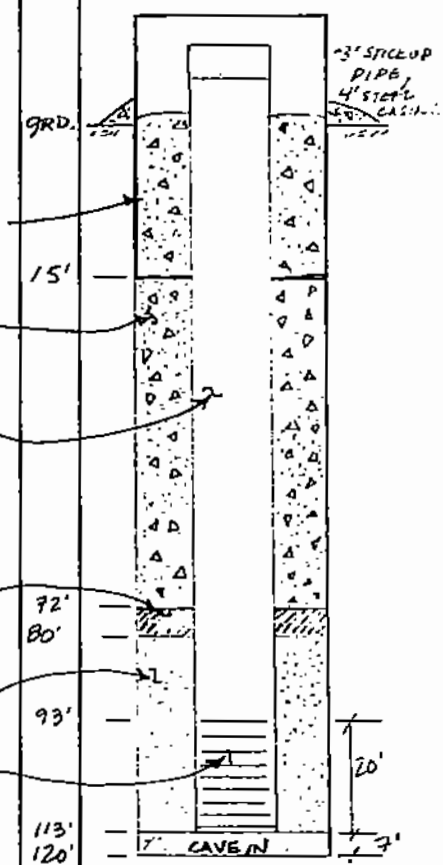
PROJECT		JOB NO. 8029	HOLE NO. MW DH 15
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV.	DEPTH	SAMPLER	CASING	SPT/RQD	RECOVERY		DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE	WATER DATA	REMARKS SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS
	50									SANDY SILT W/ TRACE OF CLAY (ML) - brown, dry, slightly to non plastic		
	55									COBBLES IN SANDY SILT TO SILTY SAND (ML-SM) - brown, dry, non plastic, poorly graded		drilling speed averages ~1'/min
	60											
	65											
	70									COBBLES IN SANDY SILT TO SILTY SAND (ML-SM) - brown to beige w/ trace of orange, dry to damp in spots, non-plastic		
	75											
	80									COBBLES (POSSIBLY BOULDERS) SILTY SAND W/ TRACE OF CLAY (ML) - brown, dry to damp in spots (clumps of damp cohesive soil come out of hole in return), slightly to non plastic. DOES NOT LOOK LIKE BEDROCK - FOUND IN OTHER DRILL HOLES - more like soil matrix avg. cobble (boulder) gravel chips. Sands are rounded.		soil is more damp past 80' - due to drilling speed - can not determine exactly where water is encountered.
	85											
	90											
	95											
	100											

PROJECT			JOB NO. 8026	HOLE NO. MW DH 15
SITE	DATE – STARTED	FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE – MODEL	LOGGED BY		REVIEWED BY	

ELEV.	DEPTH	SAMPLER	CASING	SPT/RQD	RECOVERY	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
	100								COBBLES / BOULDERS / GRAVEL IN SILTY SAND TO SANDY SILT W/TRACE OF CLAY – (ML) – orangish brown, dry to damp, slightly to non plastic.		
	105										
	110								GRAVELS / COBBLES / BOULDERS IN CLAYEY SILTY SAND (MLC) – orangish brown, slightly plastic to plastic, damp to dry. DOES NOT LOOK LIKE BEDROCK – SOME ROUND SANDS. MATL. IS MORE LOOSE, POROUS PAST 115' – [illegible]	▼	HIT SUBSTANTIAL FLOW OF H_2O @ 110' – ARTESIAN – H_2O SEEPING OUT OF HOLE @ ~4-5 gpm ESTIMATED BY DRILLER.* PULLED RODS AND QUIT FOR THE DAY @ 120'. INSTALLED PVC 9-7-89. AM. SEE WELL INSTALLATION DIAGRAM.
	115										
	120								BOTTOM OF HOLE = 120'		

WELL INSTALLATION DIAGRAM – NOT TO SCALE



*HEAD = 12psi – measured 9-8-89, Q = 2.5 gpm.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 3 | HOLE NO. DH 15

PROJECT NORANDA		JOB NO. 8029	HOLE NO. DH-17
SITE Tailings Impoundment	DATE - STARTED 08-17-89 FINISHED 08-18-89	HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3560'	DEPTH TO WATER 23.2'	DEPTH TO ROCK 65'
DRILLING CONTRACTOR J.D. Welsh	SAMPLES 5	CORE BOXES 4	DEPTH OF HOLE 80'
DRILL MAKE - MODEL ACKER ADII	LOGGED BY A.M. SILVA		REVIEWED BY U.J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3560'	0				%					COBBLES - of metasedimentary rocks in a clayey sandy silt soil		Advanced hole with hollow-stem auger
	1											
	2										▽	water at 2.5' 8-18-89, a.m.
	3											
	4											
	5	SPT #1		12 17 34	100 %					GRAVELLY, SANDY, SILTY CLAY (CL) brn., dry, sl. plastic, v. stiff.		Advanced hole with standard 2"ϕ split-spoon sampler Lab. class.
	6									Gravels & few rock fragments are metasediments (siltstone, meta-quartzite, metasandstone); gr. are subrounded		Difficult augering Some vibrations
	7											
	8											
	9											
3550'	10	SPT #2		21 20 31	72 %					CLAYEY SANDY SILT (ML) - as above		
	11											
	12											
	13											
	14											
	15	SPT #3		27 50	44%					ML - as above		Second set of blows only advanced sampler 3.5" REFUSAL - possibly cobble
	16									Increasing gravel content ↓		
	17											
	18											
	19											
3540'	20	SPT #5		17						ML - as above		

PROJECT			JOB NO. 8029	HOLE NO. DH-17
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3540'	20	SPT#5		29 / 49	88%					CLAYEY SANDY SILT (ML) - with gravels; brn., dry, sl. plastic, v. stiff		Advanced hole w/ standard 2" ϕ split-spoon sampler
	21											Resumed augering
	22									Occ. rock fragments & gravels are metaquartzite & siltstone (hard)		
	23										▼	Encountered water at 23.2' (9-15-89) However, during drilling - water was found at 2.5' below surface 8-18-89 a.m.
	24									ML - damp		
	25	SPT#6		9 / 31 / 42	83%					ML - as above - with metaquartzite rock fragments (boulder?)		
	26									BOULDERS - of metaquartzite and siltstone, grey, hard, mod. fractured, sl. weathered, in a clayey, sandy silt (ML) matrix, brn., damp, sl. plastic, stiff		Began HQ coring Good water return; beige color
	27											
	28				24%							
	29									Some gravels & cobbles		
3530'	30											
	31											
	32				42%							
	33											
	34					1						
	35									COBBLES & GRAVELS - grey-white, hard, subrounded, in a clayey, sandy silt (ML) matrix, brn., damp, v. dense (SM) - v. stiff (ML)		
	36											Unconfined strength: over 4.5 tons/ft²
	37				100%							
	38											
	39											
3520'	40											

PROJECT			JOB NO. 8029	HOLE NO. DH-17
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3520'	40									COBBLES & GRAVELS - grey, white, hard, subrounded, in a clayey, sandy silt (ML) matrix — brn., damp., v. stiff		
	41					1						
	42				20%							
	43									fewer cobbles		
	44											
	45									GRAVELLY SANDY SILT (ML) with clay, org. brn., damp, sl. plastic, v. stiff, with gravels - subrounded, grey-white-brn. metasediments, some conglomerate		Conducted permeability test #1 at 45' (34.5' to 45')
	46											Org. brn. water return
	47				100%							
	48											
	49											
3510'	50									- gravels < 4 cm. ϕ		Intermittent loss of drilling water return
	51					2						
	52				60%							
	53											
	54											
	55											Slow drilling
	56											
	57				10%							
	58									← occ. weathered rock fragments (siltstone, argillite, meta-sandstone)		
	59											
3500'	60											

PROJECT			JOB NO. 8029	HOLE NO. DH-17
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3500'	60				%					GRAVELLY, SANDY SILT (ML) with clay, org. brn. to tan, damp, sl. plastic, v. stiff		
	61											
	62				45 %					(as above)		
	63					3						
	64											
	65									BEDROCK AT 65'		
										(METASEDIMENTS) METASANDSTONE -w/ occ. siltstone + argillite interbeds; lt. brn., wet, soft-m. hard, mod. weathered and fractured.		
	66											
	67			0	60 %					} int. fract. interval		
	68									Some Fe-oxide staining throughout, along rough fracture surfaces		
	69											
3490'	70											Performed permeability test #2 at 70' (64.5' to 70')
	71									← fract. w/ whitish talc filling. (Fractures ∡ 30°, some near vertical, rough surface, closed, straight.)		
	72			0	40 %							
	73											
	74					4				Poor quality rock		
	75									← siltstone & argillite interbeds; soft-m. hard; laminae at ∡ 10°-20°		
	76									← hard metasandstone		
	77			43 %	100 %							
	78											
	79											
3480'	80									BOH AT 80'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 4 | HOLE NO. DH-17

PROJECT NORANDA			JOB NO. 8029	HOLE NO. DH-18
SITE Tailings Impoundment	DATE - STARTED 08-19-89 FINISHED 08-19-89		HOLE SIZE 3.782"	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3660'	DEPTH TO WATER NE		DEPTH TO ROCK NE
DRILLING CONTRACTOR J.D. Welsh	SAMPLES 4	CORE BOXES 7		DEPTH OF HOLE 65'
DRILL MAKE - MODEL ACKER ADII	LOGGED BY A.M. SILVA		REVIEWED BY D. J. CORDON	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3660'	0									GRAVELLY, SANDY SILT - SILTY SAND (ML-SM) - brn., dry, non-plastic, dense.		Advanced hole to 45' by means of hollow-stem auger.
	1											
	2											
	3											
	4											
	5	SPT #1		17 26 26	100%					SANDY SILT (ML-SM) with gravel; brn., dry, non-plastic, stiff (v. dense SM)		Began HQ coring
	6											
	7											
	8				100%	1				Gravels are subrounded, consist of metaquartzite and siltstone, fragments ~ < 5cm ϕ, hard		Beige water return
	9											
3650'	10	SPT #2		60+	100%					SILTY SAND - SANDY SILT (SM-ML) as above		Attempted SPT#2; only advanced 3" before refusal
	11											
	12				76%	1				Conglomerate fragments in ML matrix.		
	13											
	14									Increasing clay content		
	15											Performed permeability test #1 at 15' (8' to 15')
	16											
	17				100%	2						
	18											
	19											
3640'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 4 HOLE NO. DH-18

PROJECT		JOB NO. 8029	HOLE NO. DH-18
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	Box #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3640	20	SPT #3		28	100%					CLAYEY, SANDY SILT (ML) - (SM) w/ some gravels; brn., dry, sl. pl., stiff.		
	21			30								
				42								
	22											
	23				100%	2						
	24											
	25									Increasing content of cobbles		Unconfined strength of ML is ~ 3.5 tons/ft²
	26											
	27				100%							
	28					3						
	29											
3630	30											Conducted permeability test #2 at 30' (25' to 30')
	31											
	32				100%					ML-SM with gravels and cobbles tan- Lt. brn., dry, sl. pl., stiff		
	33									Cobbles are subrounded, hard, mainly metaquartzite and siltstone.		
	34									ML-SM		Lab. Class -
	35											Unconfined strength of soil matrix > 4.5 tons/ft²
	36									← Traces of conglomerate fragments		
	37				100%	4						
	38											
	39											
3620	40									↓ Increasing conglomerate fragments		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 4 | HOLE NO. DH-18

PROJECT		JOB NO. 8029	HOLE NO. DH-18
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft)	DEPTH (ft)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3620	40									CLAYEY SANDY SILT (ML-SM) with cobbles and gravels; tan-Lt. brn., dry, sl. pl., stiff		
	41											
	42				100%	4						
	43											
	44											
	45									Metaquartzite cobble		
		SPT #4		42 50/1"	0					Fractured conglomerate		Attempted SPT #4 at 45' NO RECOVERY Refusal after 7" penetration
	46											
	47									SILTY CLAY (CL) w/ some fine sand and gravel; red-brn., dry, sl. pl-pl., stiff.		LL=30, PI=11 Lab. Class.
	48				100%	5						
	49											
3610	50									Conglomerate - v. dense (m. hard) - silt & gravels consolidated into rock		
	51											
	52											
	53				100%					Occasionally conglomerate is loose gravels and sandy silt		
	54											
	55									Becoming loose		
	56									CLAYEY, SANDY SILT (ML-CL) org.-brn., dry, Loose, sl. pl.-pl. with gravels		
	57											
	58				100%	6						Unconfined strength of soil matrix is ~ 2 tons/ft²
	59									Traces of weathered metasandstone		
3600	60											Conducted permeability test #3 at 60' (55' to 60')

PROJECT			JOB NO. 8029	HOLE NO. DH-18
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3600	60									CLAYEY SANDY SILT (ML-CL) w/gravels - org. brn., dry, Loose, sl. pl., some dense (stiff) sections.		
	61											
	62				100%	6						
	63											
	64					7				← traces of metasandstone fragments		
3595'	65									BOH AT 65'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 4 OF 4 | HOLE NO. DH-18

PROJECT	NORANDA	JOB NO.	8029	HOLE NO.	DH-19
SITE	Near center of tailings dam	DATE - STARTED / FINISHED	09-30-89 / 10-4-89	HOLE SIZE	3.782"
				ORIENTATION	VERTICAL
LOCATION	Libby, Montana	ELEVATION	~ 3410'	DEPTH TO WATER	ARTESIAN
				DEPTH TO ROCK	60'
DRILLING CONTRACTOR	Chen-Northern / J.D. Welsh	SAMPLES	4	CORE BOXES	7
				DEPTH OF HOLE	105'
DRILL MAKE - MODEL	ACKER AD II	LOGGED BY	A.M. SILVA	REVIEWED BY	U.J. CORDON

ELEV. (Ft.)	DEPTH (Ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	Bar #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3410'	0									CLAYEY SILT (ML) w/ gravels, brn., moist-damp, slpl.-non pl., subrounded gravels, some sand.		Advanced hole w/ HQ coring bit
	1											
	2											
	3		9" ø									
	4											
	5											Cased hole at 5'; pushed Shelby easy - Last 6" took ~ 100 Lbs pressure
	6	SH-1			100%					SANDY CLAYEY SILT (ML) w/gravel, brn., damp, sl. plastic., soft.		Lab. Class.
	7									Gravels are hard, subrounded.		
	8											
	9				12%							
3400'	10											
	11											
	12	SH-2			55%					(ML)		LL = 21, PI = 1 Lab. Class.
	13					1						
	14											
	15	SH-3			0							Attempted to push Shelby at 15' - REFUSAL
	16											
	17											
	18				30%							
	19									Org.-brn. color, non plastic, sl. stiff		
3390'	20											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 | HOLE NO. DH-19

PROJECT			JOB NO. 8029	HOLE NO. DH-19
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3390'	20	SPT#1		22	66%					SANDY, SILTY GRAVEL (GM) — brn., non pl., damp.		PI = 0 Lab. Class.
	21			50"								
	22				99%					Gravels are subrounded, hard, most < 5 cm ϕ.		
	23											
	24				76%							
	25									Some cobbles (2"-3" ϕ), meta-quartzite, siltstone, gm-white, subrounded.		
	26				67%							
	27					1				Matrix is ML-SM		
	28											
	29				67%							
3380'	30											
	31									} gravels w/ ML matrix		Changed bit at 31'
	32				50%							
	33									Occ. Lg. boulders		
	34					2				Approx. 50% ML-SM 50% Gravels, cobbles & boulders		
	35				69%							
	36											
	37											
	38				83%							
	39											
3370'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 6 HOLE NO. DH-19

PROJECT			JOB NO. 8029	HOLE NO. DH-19
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3360'	60									SILTSTONE, ARGILLITE, METASANDSTONE -interbedded, org.-brn., friable, mod. weathered, (easily fractures along laminae at ∡ 45°-60°)		
	61											
	62			27 %	65 %					Some Fe-oxidation along fract. surfaces, few slickensides.		
	63											
	64									Fractures are sl. rough-smooth, straight; some near vertical; occ. vuggy sections		
	65											
	66					4						
	67			14 %	67 %							
	68									intensely fractured argillite, siltstone at ∡ 45°		
	69											
3340	70											
	71											
	72			23 %	100 %							
	73											
	74											
	75									int. fractured		
	76											
	77			20 %	80 %							
	78					5						
	79											
3330'	80											Conducted permeability test (59.5-80')

PROJECT			JOB NO. 8029	HOLE NO. DH-19
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE	WATER DATA	REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS
3330'	80									SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded; brn.-occ white metass., friable (easily broken along thin laminations), few slickensides.		
	81											
	82			22%	56%	5				Metasandstone generally hard		
	83									Lamination (& fractures at 50°-75°∡)		
	84											
	85									} extremely friable		Water level in rods above ground level
										← talc filling in fracture at ∡75°		33'
	86											
	87			20%	86%	6						
	88											
	89									} fract. along 60°∡ Laminae		
3320'	90											
	91											
	92			32%	84%					} v. hard metas.s.		
	93									- friable argillite		
	94											
	95									↓ Rock becomes slightly harder, better induration in metasediments		
	96											
	97			67%	100%	7						
	98											
	99											
3310'	100											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 6 | HOLE NO. DH-19

PROJECT		JOB NO. 8029	HOLE NO. DH-19
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3310'	100									SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded. (as above)		
	101											
	102			37%	78%	7						
	103											
	104											Conducted packer test (79'- 105')
3305'	105									BOH AT 105'		Installed PVC pipe

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-19

PROJECT			JOB NO. 8029	HOLE NO. DH-19
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3370'	40									CONGLOMERATE - Fine-med size gr. in a cemented clayey sandy silt (ML). Gravel is subrounded, hard. ML is brn, dry-damp, stiff matrix.		
	41				83%	2						
	42									SANDY SILT - SILTY SAND (ML-SM) w/ gravels & cobbles, occ. boulders; org-brn., damp, non plastic, stiff.		
	43											
	44									Gravels & cobbles are hard, subrounded, mainly metaquartzite		Good water return
	45				56%	3						Rods hard to turn during drilling operations.
	46											
	47											
	48											
	49				40%							
3360'	50											
	51											
	52				83%							
	53											
	54											
	55				65%							
	56											
	57											
	58				52%							
	59											
3350'	60									BEDROCK AT 60' (METASEDIMENTS)		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 6 | HOLE NO. DH-19

PROJECT NORANDA			JOB NO. 8029	HOLE NO. DH-20
SITE Tailings dam	DATE - STARTED 10-04-89	FINISHED 10-08-89	HOLE SIZE	ORIENTATION VERTICAL
LOCATION Libby, Montana	ELEVATION ~3410	DEPTH TO WATER ~25'-40' (confined)		DEPTH TO ROCK 205'
DRILLING CONTRACTOR Chen-Northern / J.D. Welsh	SAMPLES 12	CORE BOXES 15		DEPTH OF HOLE 214'
DRILL MAKE - MODEL ACKER ADT	LOGGED BY A.M. SILVA			REVIEWED BY D. J. CORDON

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY %	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3410	0									SANDY, CLAYEY SILT (ML) brn., sl.pl.-pl., m.soft-stiff, traces gravel		Advanced hole w/ hollow-stem auger
	1											
	2											
	3											
	4											Advanced hole by pushing Shelby tube
	5	SH-1	P=200psi		70%					SILTY GRAVELLY SAND (SM)		P= pressure exerted by rig to push Shelby tube
	6											LL=27, PI=3
	7	SH-2	P=75psi		60%						▽ 10/5/89	Lab. Class.
	8											
	9	SH-3	P=50psi		70%					SANDY SILTY GRAVEL (GM) Lenses		Lab. Class.
3400	10											
	11	SH-4	P=100psi		75%					Silt at bottom of tube		
	12											
	13	SH-5	P=50psi		100%					SILTY SAND - SANDY SILT (SM-ML)		Lab. class.
	14											
	15	SH-6	P=100psi		80%					Silty clay mat'l at bottom of tube		
	16											Lab. class PI=0
	17	SH-7	P=100psi		100%					SANDY SILT (ML) non-plastic	▼ 10/6/89	
	18											
	19	SH-8	P=100psi		85%					Clay & sands at bottom of tube		
3390'	20'											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 6 | HOLE NO. DH-20

PROJECT		JOB NO. 8029	HOLE NO. DH-20
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3390	20											
	21	SH-9	P=400 psi		50%					SANDY, CLAYEY SILT (ML) lt. brn., sl. pl.-pl., soft-stiff, tr. gravels		Pushed Shelby to 22' LL=24, PI=3 Lab. Class.
	22											Augered to 25'
	23											
	24											
	25									SANDY, SILTY CLAY (CL-ML) dry, sl. plastic, some gravels		Advanced hole w/ standard split-spoon sampler Lab. Class.
	26	SPT#1		10 14 12	72%							
	27									Increasing content of gravels & cobbles		Advanced hole w/ HQ coring bit
	28				46%							
	29									ML-CL w/ gravels & cobbles, v. soft - soft (occ. dense), sl. pl. to plastic, gravels are hard, subrounded		
3380'	30											
	31					1						
	32				18%							
	33											
	34											
	35									NO RECOVERY		
	36	SPT#2		3 6 9	0							
	37											
	38				28%							
	39									SANDY SILTY CLAY (CL) SOME Gravel		Lab. class. LL=36, PI=17
3370'	40											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 6 HOLE NO. DH-20

PROJECT		JOB NO. 8029	HOLE NO. DH-20
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONT INUITIES TYPE	DISCONT INUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3370'	40									CLAYEY SILT (ML-CL) w/ tr. fine sand and gravels, org. brn., dry, non pl.		(H2O seeps out of hole during perm. test - may be confined between 25' and 40')
	41											
	42				42 %					CL-ML - pl., wet		Losing drill water
	43											
	44					1						Difficult drilling
	45									COBBLES & GRAVELS in sandy silt (ML) matrix. Rocks are siltstone & metaquartzite, grey, subrounded. Soil is brn., damp, non pl.-sl. pl., soft.		
	46				52 %							
	47											
	48											
	49											
3360'	50											
	51				76 %							
	52					2						
	53											
	54				80 %							
	55											
	56											
	57											
	58				58 %					conglomerate		
	59											
3350'	60											

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 3 OF 6 | HOLE NO. DH-20

PROJECT			JOB NO. 8029	HOLE NO. DH-20
SITE	DATE - STARTED FINISHED		HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER		DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES		DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY		REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/RQD	RECOVERY	BOX #	DISCONT INJ-ITIES TYPE	DISCONT INJ-ITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3350'	60									COBBLES & GRAVELS in a sandy clayey silt matrix (as above)		
	61									metaquartzite cobble (hard)		
	62				51%	2						
	63											
	64											
	65									Soil becomes clayey silt (ML) w/ some sand and gravels & cobbles.		
	66				57%							
	67											
	68					3						Conducted permeability test #2 (38'-68')
	69				100%							
3340'	70									Occ metaquartzite cobbles-boulders		
	71				73%							
	72											
	73											
	74											
	75											
	76				43%	4						
	77											
	78											
	79											
3330'	80											

PROJECT		JOB NO. 8029	HOLE NO. DH-20
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3330 CHANGE IN SCALE	80				40%					BOULDERS & GRAVELS IN SANDY SILT MATRIX - brn, damp, sl. pl.-non pl., loose to stiff. Rock is subrounded metasediments (metasandstone, metaquartzite), fractured, few slickensides on long rock sections.		
					70%	4						
	90				45%							Attempted SPT #3 at 94' REFUSAL at 1" penetration
					88%							
	100				66%	5				ML & BOULDERS ~60% ML ~40% BOULDERS, COBBLES, GRAVELS		Drilling rate ≈ .13 ft/min.
					0							
	110				63%	6						
					45%							
	120				58%	7				Interlayered sequence of soil (ML) & boulders w/ gr.		
					60%					← conglomerate w/ clay		
3280'	130				100%							
					72%	8				Fractures on boulders have Fe-oxidation, tr. clay, few slickensides		
	140				87%					← gravels in a clayey silt matrix, sl. pl., damp., loose		
					37%							
					57%	9						
	150				72%							
					70%							
	160				49%							
					51%							
	170				69%	10				Larger cobbles & boulders separated by clayey silt (ML) matrix w/ gravels & sand.		
					42%					← conglomerate		
3230	180									Occ. gravels		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 6 | HOLE NO. DH-20

PROJECT		JOB NO. 8029	HOLE NO. DH-20
SITE	DATE - STARTED FINISHED	HOLE SIZE	ORIENTATION
LOCATION	ELEVATION	DEPTH TO WATER	DEPTH TO ROCK
DRILLING CONTRACTOR	SAMPLES	CORE BOXES	DEPTH OF HOLE
DRILL MAKE - MODEL	LOGGED BY	REVIEWED BY	

ELEV. (ft.)	DEPTH (ft.)	SAMPLER	CASING	SPT/ROD	RECOVERY	BOX #	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE)	WATER DATA	REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS)
3230'	180				58%					CLAYEY SILT (ML) w/ BOULDERS and gravels.		
					42%					← gravels in ML matrix		
	190				70%							
					72%							
	200				44%					int. fract. boulder, grey, hard		
										BEDROCK AT 205'		
				38%	100%					SILTSTONE, ARGILLITE - Lt. brn., friable, easily broken along laminations at ∡ 45° (> 10 fr/ft.)		Conducted packer tests #3, 4 (205'-214') (177'-214')
	210			7%	60%							
3196'	214'									BOH AT 214'		Installed PVC pipe to 154'

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 HOLE NO. DH-20

WELL LOGS
(1988)

(By Chen - Northern)

Northern Engineering and Testing, Inc.

WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: PLCH-6

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: Little Ch. Ck. Loop Rd., (Between Poorman & L.Ch. Sites)

Recorded By: M. Corbett Hole Started: Time: 1000 Date: 07/21/88 Hole Completed: Time: 1500 Date: 07/21/88 Driller : B & B

Drill Method: air rotary Drilling Fluids Used: water in silty sections Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 56' Total Depth Reamed: ____ Total Depth Cased Below G.S.: 45.5-55.5 56 ft (deep) Diameter and Type of Casing: 2" PVC tube + screen

Weight or Gage of Casing: ____ Interval Perforated or Screened Below G.S.: ____ Target Aquifer: Bedrock & shallow gravel zone Packer Type and Depth Below G.S.: ____

DURING INSTALLATION WAS:	YES	NO	
Well Developed?		X	
Well Test Pumped?		X	
Water Samples Taken?		X	
Material Samples Taken?	X		Bedrock
E-Logs?		X	

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- ____ Slotted with Hill's Knife
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots
  - Dual Completion
    - 5 ft. 0.03 cont slot deep
    - 10 ft. 0.01 cont slot, shallow
- ____ Other (specify) ____

Static Fluid Level Measured shallow SWL as 9.9' below MP (above ground-waiting to measure later) 07/23/88 0845
Below Measuring Point: Approx. 9.5' above ground before flow slows much on deep Date/Time Measured: 07/23/88 1000

Measuring Point Description/Elevation: north side steel casing, top MP Height Above (+/-) or Below G.S.: +2.5'

Well Annulus Completion Description: 56' to 52'8" Colorado 10/20 sand; 52'8" to 47'8" PVC .03 cont. slot screen with Colorado 10/20 sand filter pack; 47'8" to 46'4" Colorado 10/20 sand; 46'4" to 45'10" bentonite pellets; 45'10" to 44'10" Colorado 10/20 sand; 44'10" to 32'8" volclay grout; 32'8" to 19'6" cement sand; 19'6" to 7'. Silica sand Colorado 10/20; 18' to 8' PVC .01 cont. slot screen; 7' to 6.5' bentonite pellets; 6.5' to 6' cement sand; neat cement inside and outside surface casing from 6' to ground level (3 sacks)

Well Development Description: ____

Remarks: Use 5' 0.03 screen for bottom interval (approx. 48-57'); use 10' 0.01 screen for top (approx. 8-18) Put 10/20 sand over pellets to keep tremie pipe away -- pump 75 gal. Volclay grout include 2-3 quarts bentonite mixed in to thicken -- probe will not stabilize at a given depth -- water displaced up but void present and volclay grout remains fluid. Shut down at 1700 to let set overnite (Don't wish to have grout invade zone for upper screen

*Note: Lower screen moved up 4" on 1st pipe jacking -- then stablized

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG

PCLH-6

(Depth Below G.S.) From	To	DRILLING LOG	Geological, Drilling, and Water Conditions and Sampling
ground	4	Soil layer	
4	7	Gravelly colluvium	
7	9	Silty, some pebbles	
9	13	Clean gravel, medium coarse gravel. Water at 9.5'	
13	17	Dirty, silty gravel, fine-medium, tan-brown colors	
17	45.5	Silt, minor gravel in upper portion, Clean silt below 20', Buff to light yellow-orange browns	
45.5	49	Silty-clayey gravel, dark gray, medium coarse. Drilled a boulder at top. Let sit few minutes -- air blew water at 45.5'	
49	50	Very coarse sand-fine gravel, dark gray with coaser buff subrounded fragments	
50	52	Highly fractured coarse chips - bedrock. Dark gray argillite with	
52	55.5	fracture fillings (?). Changes to pinkish or brown. Making lots of water. Cleaning fast.	

Northern Engineering and Testing, Inc.

WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCTM-8

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: (Champion property) east side L. Ch. site, south of L. Ch. Ck

Recorded By: M. Corbett Hole Started: Time: 1035 Date: 07/26/88 Hole Completed: Time: 1730 Date: 07/27/88 Driller : B & B

Drill Method: Air Rotary Drilling Fluids Used: water as needed Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 140 ft. Total Depth Reamed: ____ Total Depth Cased Below G.S.: 93' Diameter and Type of Casing: 6" steel with 4" PVC liner

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 33-93; etc. for 48'-43' and 58'-53' and 88'-93'; total 45' screened Target Aquifer: ____ Packer Type and Depth Below G.S.: ____

DURING INSTALLATION WAS:	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?		X
E-Logs?		X

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- X Slotted with Mill's Knife outside steel casing
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots .016 (size) exc. .03; bet. 48'-53'. Total 45'.
- ____ Other (specify) ____

Static Fluid Level Below Measuring Point: ____ Date/Time Measured: +2.5'

Measuring Point Description/Elevation: Top well protector MP Height Above (+/-) or Below G.S.: ____

Well Annulus Completion Description: Backfilled with cement sand 140' to 94'; set screen column between 88' and 33', filter packed with Colo 10.20 sand from 94' to 26'; volclay grout from 25' to 6' (on top 1' cement sand); cemented 6' to surface

Well Development Description: ____

Remarks: Screen column = 88' to 33' w 10s, 5t, 5s, 5t, 30s (top dn); Steel casing could not be jacked. Effort resulted in lift and removal of 7' casing plus bending of upper above ground (?) segment. Slotting made of steel casing 2/ft. over total screened segments, 33-88 ft.

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG

LCTM-8

(Depth to G.S.) From	To	DRILLING LOG	Geological, Drilling, and Water Conditions and Sampling
surface	4	Silt rich soil.	
4	5	Boulder? minor gravel pebbles mixed with silt	
5	11	Mostly silt with occasional cobbles or gravel pebbles. Drilling boulder at 6'-9'; switched to hammer.	
11	13	Pea gravel, relatively clean	
13	15.5	Silty gravel, medium size clasts, very clayey/silty	
15.5	16	Silt, slight chocolate brown colors, dry	
16	18	Clean gravel pea size, slt water	
18	20	Very silty gravel (?). Still with hammer	
20	--	Very silty gravel; switch to tricone	
--	23	Chocolate brown silts followed by coarse gravel; cobbles silty gravels with yellow/orange brown colors	
23	--	Large boulder followed by more silty gravel with chocolate color and cobbles. Continued gray, dark gray, cobbles, boulders etc., with brown, orange brown, buff, silty/clayey matrix; medium/coarse grained, small clasts are brown, buff to orange and orange brown; coarse material gray-dark gray	
--	30	Change to yellow brown matrix material	
30	35	More of same	
35	38	Cleaner more rounded/subrounded gravels, medium coarse grained with multi color clasts (gray, red, brown, tan) Fluvial gravel; making fair amount water at 37'. Not much silt matrix.	
38	50	Back to coarse gravel with silty matrix. Boulders	
50	51	Clean well rounded pebble gravel -- make slt. water	
51	54	Silty gravel? Pebble gravel with silt matrix - making more water??	
54	58	Boulders, silty gravel. Water dec. to nothing	
58	59	Clean gravel -- some water (well rouned to subangular)	
59	67	Coarse cobbles and boulders. Tough drilling	
67	68	Small pea gravel - dirty. No visible water	
68	74	Silty gravel, coarse, boulders	

DRILLING AND LITHOLOGIC LOG

LCTM-8

(Depth to G.S.) From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
74	75	Clean gravel, minor water
75	79	Silty gravel as above
79	80	Clean gravel, small-medium brownish clasts
80	84	Silty gravel
84	85	Pea gravel (added more water)
85	92	Silty gravel, boulders, etc. Drilled large quartzite boulder
92	94	Cleaner medium gray gravel with some pea size clasts. No obvious water addit.
94	96	Drilling quartzite boulder
96	98	Pea gravel change to clasts 1" or more. No water
98	99	Drilling boulder
99	110	Back into gravel, boulders etc. Clean without silt matrix but not making much water (if any); highly variable clast compositions and colors (quartz, quartzite, argillite, and carbonate)
110	114	Some silty gravel for short distance
114	116	More gravel, boulders? bedrock?
116	--	Tripped out and in with hammer bit
116	120	Tough rock (bedrock?) Hole drilled ahead
120	125	Real dirty silty pea gravel -- made water? hole drilled ahead
125	140 TD	Very silty with pea gravel, with minor water, still open hole, silty content increasing.

Note: Driller added heavy amounts water to drill clean thru very silty gravel. Silty very much like lacustrine silts elsewhere. Gravel mostly all fine gravel sub to well rounded. Very low permeability due to silt.

Also, driller notes same mixture silt and fine pea gravel in Libby valley (recent well) down to 615' to bedrock

Northern Engineering and Testing, Inc.

WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCM-9

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: L. Ch. - Bear Creek area (on Champion northline)

Recorded By: M. Corbett Hole Started: Time: 1033 Date: 07/20/88 Hole Completed: Time: 1645 Date: 07/20/88 Driller : B & B

Drill Method: air rotary Drilling Fluids Used: mix or water Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 65.5 Total Depth Reamed: ____ Total Depth Cased Below G.S.: 72 Diameter and Type of Casing: 2" PVC, flush joint threaded

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 57'-67' Target Aquifer: ____ Packer Type and Depth Below G.S.: ____

DURING INSTALLATION WAS:	YES	NO	
Well Developed?		X	
Well Test Pumped?		X	
Water Samples Taken?		X	
Material Samples Taken?	X		Bedrock
E-Logs?		X	

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- ____ Slotted with Hill's Knife
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots .010 (size)
- ____ Other (specify) ____

Static Fluid Level Below Measuring Point: 15.3' BGS Date/Time Measured: 0900; 07/21/88

Measuring Point Description/Elevation: Top of steel, northside MP Height Above (+/-) or Below G.S.: +3.1

Well Annulus Completion Description: 72-64', concrete sand; 64'-56', 10/20 Colorado Silica Sand; 56'-55.5', bentonite pellets 55.5'-45', volclay grout; 45'-7', concrete sand; 1'-0' concrete surface seal; 6" steel from 10' to +3.1'

Well Development Description: ____

Remarks: Started completion at 1100 hours; 07/21/88, finished completion at 1530 hours

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG

LCM-9

(Depth Below G.S.)

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
ground	5	Residual soil
5	10	Dirty clay-silt rich gravel; yellow brown to red-orange brown
10	11	Medium-coarse gravel, gray-tan
11	15	Dirty clay/silt rich gravelly material; buff to orange-brown (colluvium); pebbles light-dark gray, clays/silts more orange yellow browns
15	19	Orange-brown silt (medium dark tones rather than lighter buff of other wells to south. Very dry; very little clay or sand
19	25	More yellow brown silt with more clay sticky and damp. Slight light gray mottling, water added by driller at 23 ft. in silt; silt getting richer in clays; medium yellow brown
25	28	Hit boulder -- gravel and clay/silt mixed
28	34	Clean medium gravel light-medium gray; drilling easy
34	38	Coarse gravel (boulders) drilling slow. Had very light water show at 32 ft.
38	43	Dirty gravel, clayey
43	48	Silty, dry, orange brown (drilled light gray boulder 44-45')
48	51	Silty + buff, minor rocks
51	58	Gravelly, with silts light gray rock chips alternating with silt (buff to orange brown)
58	59	Silt, buff, damp? clayey
59	61	Clean pea gravel - gray to dark gray. Damp; shut down for added drill stem and casing. Back in 2 ft. water (57 ft)
61	64	Silt, minor gravel. Dry. Driller adding water.
64	65	More gravel, dirty
65	65.5	Bedrock -- casing not driving. No water noted.
65.5	72	Drilled ahead for sample. Still no water.
		Note: Completion with 10 ft. screen on bedrock + up?

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG

LCM-10

(Depth Below G.S.)

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	1	Top soil, organic material
1	20	Gravel, silty, sandy, light brown, slightly moist, subangular to subrounded gravel clasts to 1"; occasional cobbles and boulders of gray argillite; 40% gravel, 30% sand, 30% silt; boulders at 6', 8', 15'
20	27	Gravel, silty, sandy, light brown, moist at 20', slight moist below
27	32	Gravel, bouldery, sandy, some grey-brown silt. Predominantly gray argillite clasts with minor yellow and green clasts. Approximately 0.5 gpm water at 32'
32	39	Gravel, silty sandy, light gray brown. Mostly gray clasts with some orange-yellow, green, and light brown clasts. Making approximately 1 gpm at 36'
39	40	Gravel, silty, sandy, orange silt, gray gravel clasts

Northern Engineering and Testing, Inc.

WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCM-11

Legal Location: T ___ R ___ Sec ___ Tract ___ Descriptive Location: Upper Little Cherry Creek site, northend

Recorded By: M. Corbett & D. Hazen Hole Started: Time: 0930 Date: 07/22/88 Hole Completed: Time: 1600 Date: 07/22/88 Driller : B & B

Drill Method: air rotary Drilling Fluids Used: minor water Pilot Hole Diameter: 6" Reamed Hole Diameter: ___

Total Depth Drilled: 62.5' Total Depth Reamed: ___ Total Depth Cased Below G.S.: ___ Diameter and Type of Casing: 2" PVC with 5' of 0.03 screen

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 57-62' Target Aquifer: ___ Packer Type and Depth Below G.S.: ___

DURING INSTALLATION WAS:	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?		X
E-Logs?		X

Method Perforated or Screened

- ___ No casing in hole
- ___ Open bottom
- ___ Slotted with Hill's Knife
- ___ Slotted with a torch
- ___ Screened by pulling casing
- ___ Field saw cut
- X Mechanical slots 0.03 (size) 1-5 ft. 2" sect.
- ___ Other (specify) ___

Static Fluid Level Below Measuring Point: 46.6' BGS Date/Time Measured: 07/26/88 1115

Measuring Point Description/Elevation: north side steel casing MP Height Above (+/-) or Below G.S.: +2.7'

Well Annulus Completion Description: 62'6" to 62', Colorado 10/20 Silica Sand; Base screen at 62' with top at 57', filter pack Colorado 10/20 sand from base to 54'7"; 54'7" to 53'7" voiclay pellets; 53'7" to 27' cement sand; 44'7" to 27' caved; 27' to 20' voiclay grout; 20' to surface cement sand; Neat Portland cement surface casing outside (sack)

Well Development Description: ___

Remarks: Some caving of hole after 10 ft. cement sand placed above Voiclay pellet seal. Steel jacked at 10 ft. increments (20 ft. sections)

Northern Engineering and Testing, Inc.

WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCM-10

Legal Location: T ___ R ___ Sec ___ Tract ___ Descriptive Location: ___

Recorded By: D. Hazen Hole Started: Time: 0900 Date: 07/24/88 Hole Completed: Time: 1400 Date: 07/25/88 Driller : B & B Drilling

Drill Method: air rotary Drilling Fluids Used: minor water Pilot Hole Diameter: 6" Reamed Hole Diameter: ___

Total Depth Drilled: 40' Total Depth Reamed: ___ Total Depth Cased Below G.S.: ___ Diameter and Type of Casing: 2" PVC flush joint threaded

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 25'-40' Target Aquifer: ___ Packer Type and Depth Below G.S.: ___

DURING INSTALLATION WAS:	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?	X	
E-Logs?		X

Method Perforated or Screened

- ___ No casing in hole
- ___ Open bottom
- ___ Slotted with Hill's Knife
- ___ Slotted with a torch
- ___ Screened by pulling casing
- ___ Field saw cut
- X Mechanical slots 0.010 (size)
- ___ Other (specify) ___

Static Fluid Level Below Measuring Point: ___ Date/Time Measured: ___

Measuring Point Description/Elevation: Top of steel well protector MP Height Above (+/-) or Below G.S.: +3.0

Well Annulus Completion Description: 40'-23', 10/20 Colorado Silica Sand; 23-19', bentonite pellets; 19'-3', cement sand; 3'-surface, concrete surface seal

Well Development Description: ___

Remarks: 1' piece of rebar left in sand pack

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG

LCM-11

(Depth Below G.S.)

From	To	DRILLING LOG	Geological, Drilling, and Water Conditions and Sampling
surface	1	Soil (brown)	
1	2	Boulder	
2	9	Gravel with silt (tan)	
9	13	Gravel water; small-medium size	
13	16	Gravel + silt; light brown	
16	28	Gravel, cobbles, water	
28	31	Silty, gravel;	
31	34	boulders (clay filling) dark gray to black argillites with yellow brown (acts as if very coarse talus mat. with 2-3 feet rocks	
34	41	Boulders (clay filling) clays filling, boulders. Lost water 28-41 ft.	
41	48	Orange-brown silt with angular gravel clasts; some sand; gravel is dark gray argillite with some light gray mottling	
48	55	Silty gravel with minor clay, gravel is angular, gray argillite with light brown friable sandstone, orange brown silt	
55	57	As above with orange silt	
57	58	Silt with minor gravel + sand, orange	
58	60.5	Sandy gravel with silt, light gray brown, subangular; subrounded gravel clasts, to 1", making water approximately 1 gpm gravel is light gray argillite and sandstone	
60.5	62.5	Light gray (boulder?), argillite, very hard drilling with tricone	
	TD	62.5'	
		6" casing to 62.5' (pulled)	

APPENDIX D
TEST PIT LOGS

APPENDIX D
TEST PIT LOGS

The exploration test pits were excavated by using Case 580D and Cat 215 backhoes. The pits were 3 to 3-1/2 feet wide and 10 to 22 feet long. The pits were at least 8 feet deep unless refusal on boulders or bedrock occurred. Test pit logs were kept and representative soil samples taken. Generally, 50 to 60 pounds of samples were taken from the piles of excavated materials and placed in bags. Approximately 1 pound of sample was also collected in plastic bags for moisture content determination. All pits were backfilled with the deeper soils first and topsoil last. The ground was then smoothed and compacted by backhoe. Test pit locations were surveyed by others, or were visually located.

Information entered on the test pit logs included soil type, color, moisture, density or consistency and plasticity. Zones of water inflow were also noted. Visual classification of the samples was made in conformance with the Unified Soil Classification System (Figure D-1).

EXPLANATION OF TEST PIT LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications are modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure D-1. The relative proportions of the fines in a soil sample are defined by the following terms:

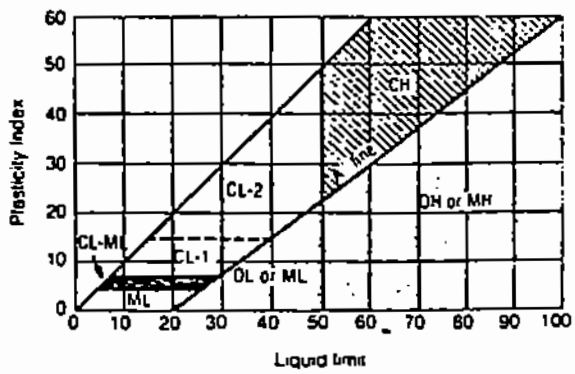
   - o trace: less than or equal to 5%
   - o some: 5% to 12%
   - o suffix "y" (e.g., silty): 12% to 50%

3. The relative proportions of gravels, cobbles and boulders were made visually in the field are therefore approximate.

4. All test pits were excavated by a Case 580D backhoe equipped with 2.0-foot wide bucket and Cat 215 backhoe equipped with 3.5-foot wide bucket.

Unified Soil Classification System

Major Divisions			Group Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-grained Soils More than half of material is larger than No. 200 sieve	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean Gravels (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Determine percentage of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% ..... GW, GP, SW, SP More than 12% ..... GM, GC, SM, SC 5% to 12% ..... Borderline cases requiring use of dual symbols*	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM d / u	Silty gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, or PI greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines.		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM d / u	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols
			SC	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits above "A" line, or PI greater than 7	
Fine-grained Soils More than half of material is smaller than No. 200 sieve	Silts and Clays Liquid limit less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity			
			CL 1 / 2	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silt-clays of low plasticity			
	Silts and Clays Liquid limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity, organic silts			
Highly Organic Soils			Pt	Peat and other highly organic soils			



Plasticity Chart
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits, suffix d used when liquid limit is 28 or less and the PI is 6 or less, the suffix u used when liquid limit is greater than 28.

**Borderline classification. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

Figure No D–1

TEST PIT LOGS
(1988)

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-101

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	9x10x3	7/28/88	7/28/88	3518	See Below	N. Smith/M. Forrest

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1	S-1		**SANDY SILT (ML),** with some subrounded to subangular gravel, damp, dark brown. Roots extend to 1.0' depth.		
2			**SILTY SAND (SM),** brown, slightly plastic, moist, with some gravel, cobbles (5-10%), and a trace clay; cobbles and gravel are subrounded to subangular.		
3					
4			**SILTY SAND (SM),** orange, brown, and gray mottled, fissured 3"-15". Looks like decomposed rock.		Difficult digging below 4.0'
5					
6				▼	Seepage at 6.0'
7					
8					
9					Refusal at 9.0'
10			BOTTOM OF TEST PIT AT 9.0'		
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-101

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-102

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	10x14x4	7/28/88	7/28/88	3488	See Below	N. Smith/ M. Forrest

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1	S-1		**SANDY SILT (ML),** with some subrounded to subangular gravel, damp, dark brown. Roots extend to 1.0' depth.		
2			**SAND (SP),** light grayish brown, damp, with some gravel and cobbles (5-10%), and trace silt; cobbles and gravel are subrounded to subangular.		
3					
4	S-2				
5			**SILTY SAND (SM),** orange, brown, and gray with oxidized fissure surfaces, moist. Looks like decomposed rock.		
6					
7					
8				▼	Slight seepage at 8.0'
9					
10					Refusal at 10.0'
11			BOTTOM OF TEST PIT AT 10.0'		
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-102

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-103

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	11x16x4	7/28/88	7/28/88	3394	not encountered	N. Smith/ M. Forrest

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1, 2			SILT (ML), with some organic fibre to 0.5' depth, buff, dry to damp, non plastic.		
3, 4, 5, 6, 7, 8, 9, 10, 11	S-1		SANDY CLAYEY SILT - SANDY SILTY CLAY (CL-ML), orange, brown, and grey, slightly plastic, damp, with trace gravel, cobbles (5%), and boulders (5%); gravel, cobbles, boulders are subrounded, maximum size 12".		
12, 13, 14, 15, 16			BOTTOM OF TEST PIT AT 11.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-103

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-104

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	12x14x3	7/28/88	7/28/88	3449	See Below	N. Smith/ M. Forrest

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SANDY SILT (ML), with some organic fibre. Roots extend to 1.0' depth. Dark brown.		
2			CLAYEY SILT (ML), orange, brown, and gray, iron oxide staining, slightly plastic, moist, hard, fissured, with some sand, some gravel, cobbles (5%), and boulders (5%); gravel, cobbles, and boulders are subrounded to subangular.		
3					uc > 4.5 tsf
4	S-1			▼	
5					Seepage observed at 4.5'. As excavation progressed, seepage became very pronounced. Bottom of excavation filled to a depth of 8.0' after approximately 20 minutes.
6					
7					
8					
9					
10					
11					
12					Refusal on boulder at 12.0'
13			BOTTOM OF TEST PIT AT 12.0'		
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-104

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-105

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	14x15x4	7/28/88	7/28/88	3432	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1, 2, 3			**SILT (ML),** buff, non plastic, dry, with trace sand and trace gravel; gravel is fine to coarse, subrounded. Roots extend to 6" depth.		
3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	S-1		**SANDY GRAVEL (GW-GM),** orange brown, dry to damp, with some silt and some cobbles (5-15%) up to 6"; cobbles and gravel are subrounded.		Easy excavating Sides of excavation are very unstable in sand layer
14, 15, 16			**BOTTOM OF TEST PIT AT 14.0'**		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-105

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-106

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	10X16X3.5	8/2/88	8/2/88	3656	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), buff, dry, with some sand. Roots extend to 1.0' depth.		
2			CLAYEY SILT - SILTY CLAY (CL-ML), orange, brown, and gray, non plastic to slightly plastic, hard, dry to damp, with sand, trace gravel, and cobbles (5%); gravels and cobbles are subrounded to subangular.		
3					uc > 4.5 tsf
4					
5					
6	S-1				
7					
8					
9					
10			BOTTOM OF TEST PIT AT 10.0'		
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-106

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-107

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	9X17X6	8/2/88	8/2/88	3583	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), dark brown, non plastic, dry to damp, with trace sand, trace gravel, cobbles (5%), and boulders (5%); gravel and cobbles are subrounded. Roots extend to 1.5' depth.		
2			CLAYEY SILT - SILTY CLAY (CL-ML), orange, brown, and gray, damp, slightly plastic, hard, with some sand, some gravel, and cobbles (5%) up to. 6"; gravels and cobbles are subrounded. Looks like weathered rock.		
3					
4					uc > 4.5 tsf
5					
6					Difficult digging
7					
8	S-1				
9					Refusal on boulder at 9.0'
			BOTTOM OF TEST PIT AT 9.0'		
10					
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-107

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-108

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	12x19x3.5	8/1/88	8/1/88	3760	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), brown, dry, traces of organic fibre. Roots extend to 1.0' depth.		
2			SILTY SAND (SM), brown to grayish brown, non plastic, dry, with some gravel, cobbles (5%), and boulders (5%) to 15"; gravel, cobbles, and boulders are subrounded.		
3					
4					
5					
6					
7					
8	S-1				
9					
10					
11					
12					Refusal on Boulder at 12.0'
13			BOTTOM OF TEST PIT AT 12.0'		
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-108

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-109

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	12X16X3.5	8/2/88	8/2/88	3698	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), brown, dry, with some sand. Roots extend to 1.5' depth.		
2			SANDY SILT (ML), grayish brown, non plastic, hard, damp, with some gravel, trace cobbles, and boulders (5%). Gravels, cobbles and boulders are subrounded.		
3					
4					uc > 4.5 tsf
5					
6					
7					
8	S-1				
9					
10					
11					
12			BOTTOM OF TEST PIT AT 12.0'		
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-109

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Little Cherry Creek	MONTANA	8029	TP-110

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	16X16X5	8/2/88	8/2/88	3761.0	See Below	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1, 2			**SILT (ML),** brown, dry to damp, with organics, some sand, trace gravel, cobbles (5%), and boulders (5%); gravel, cobbles, and boulders are rounded to subrounded. Roots extend to 1.5' depth.		
3, 4, 5, 6, 7, 8, 9, 10	S-1		**SILTY SAND (SM),** orange, brown, and grey, slightly plastic, damp, with some gravels, cobbles (10-15%), and boulders (5%) up to 18"; gravel to boulder sizes are rounded to subrounded.		
11, 12, 13, 14, 15	S-2		**GRAVELLY SAND (GP),** gray brown, non plastic, wet, with cobbles (5-10%), subrounded to rounded.	▼	Seepage at 11.0'
16			BOTTOM OF TEST PIT AT 16.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-110

TEST PIT LOGS
(1989)

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-121

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	15x4x17	8/7/89	8/7/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILTY SANDY GRAVEL (GM), light brown, dry, non plastic, with some cobbles (5-10%) to 5" fines to 5" subangular to subrounded.	moderate digging
1				
2				
3				
4			damp	Test pit stable
5				
6	S-1		SANDY SILTY CLAYEY GRAVEL (GC)	Lab. class.
7				
8				
9	S-2		GRAVELLY, SANDY, SILTY CLAY (CL) orangish brown, slightly plastic, very stiff, damp, with some gravel (5-10%) subangular to subrounded	Easy digging. Pocket penetrometer at 10 = 3.0-4.0 Clear layer change @ 9' LL=24, PI=11 Lab. class.
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 2	TP-121

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-121

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	15x4x7	8/7/89	8/7/89		not encount.	M. A. Nylamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11				
12				
13			moist, decreasing sand content with depth grave & cobble.	Easy digging
14				
15	S-3		CLAYEY SILT (ML), orangish brown, moist to wet, very stiff, medium plasticity, with trace gravel subangular to subrounded	S-3 is better sample than S-2. S-2 may have been mix of two layers. Test pit stable - walls vertical out of reach at 17'
16				
17			BOTTOM OF TEST PIT AT 17'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
2 OF 2	TP-121

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-122

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
G. Sorlie	backhoe	13x5x8	8/7/80	8/7/80		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), Orangish brown, nonplastic, dry, with some cobbles and trace boulders (<5%) to 18" subangular to subrounded damp at 1.5'	Moderate digging
1				
2				
3			increasing cobbles/gravel/and boulders with depth.	
4			... grading to ...	
5	S-1		GRAVELLY, SANDY, SILTY CLAY (CL) Same as above except with 10-20% cobbles, 5-10% boulders to 1.5 max. Subangular to subrounded.	Lab. class. Hard digging Test pit stable
6				
7				
8			BOTTOM OF TEST PIT AT 8.0'	Refusal at 8'

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-122

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-123

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	16x5x16	8/5/87	8/5/87		not encount.	M. A. Hyrcamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), brown, nonplastic, damp, with some cobbles (5-10%), occasional boulder subangular to subrounderd. roots to 2'	
1				
2				
3				
4				
5				
6	S-1			Pocket penetrometer @ 6.0 = 2.5-3.5 dsf
7				
8			silt slightly plastic, stiff.	Easy digging Test pit stable
9			Boulder 3' x 2'	
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 | TEST PIT NO. TP-123

USH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-123

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	16x5x16	8/5/89	8/5/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
1			GRAVELLY SANDY SILT (ML)	
12				
13				
14				
15				
16				OUT OF REACH @ 16'
			BOTTOM OF TEST PIT AT 16.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
2 OF 2	TP-123

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8022	TP-124

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	13/4.5/17	8/8/80	8 8 80		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SILT (ML), brown, slightly plastic, damp, with some cobbles (5 10%) to 6", roots to 2'	Surveyed location not found. Location estimate.
1				
2			CLAYEY SILT (ML) - SILTY CLAY (CL) yellowish brown, slightly plastic, moist, very stiff, occasional gravel and cobble, sub angular to subrounded. Silt is layered w/ different colors of light and dark brown, silt breaks along these alternating layers, Layers are thin - 0.5 mm - 3 mm	
3				Penetrometer at 3' = > 4.5 tsf
4				
5				
6	S-1			Penetrometer at 6' = 2.5-3.5 tsf,
7			ML-CL	Penetrometer at 7' = > 4.5 tsf LL=33, PI=9 Lab. class.
8				Easy diggin
9			medium plasticity, occasional boulder, cobbles and boulders, increasing quantity with depth	
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP124

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-124

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Smith	backhoe	13'x5'x7'	8/8/89	8/8/89		not encount.	M.A. Hikamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11				
12				
13			... grading to ...	
14			GRAVELLY SANDY SILT (ML), yellowish brown, slightly plastic, moist, with some gravel (5-10%) and trace cobbles (<5%) and trace boulders (<5%) to 2' max, subrounded to subangular	
15	S-2			moderate digging
16				
17				out of reach at 17'
18			BOTTOM OF TEST PIT AT 17.0'	
19				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-124

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-125

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x45x17	8/5/89	8/5/89		not encount	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), light brown, dry, non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 24", roots to 1.0', subangular to subrounded	Surveyed location not found. Location estimated, approx. 100' from tree line. Moderate digging
1				
2			SANDY SILT (ML), brown, slightly plastic, moist, with some gravel (5-10%) and trace cobbles (<5%) and occasional boulder to 24".	Test pit stable. Easy digging
3				
4				
5			orangish brown silt	
6	S-1		very stiff	Pocket penetrometer at 7' = 4.0-4.5 tsf
7				
8				
9			Slightly increasing gravel content with depth,	Test pit sides vertical and stable
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-125

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-125

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15'x45'x17'	8/5/89	8/5/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SANDY SILT (ML)	Easy digging
12				
13				
14				
15	S-2			
16				
17				Out of reach at 17'
			BOTTOM OF TEST PIT AT 17.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-125

HEM420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-126

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	13x14.5x15	8/5/89	8/5/89		not encount.	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), light brown, non plastic, dry, with some cobbles (5-10%) to 8" max. occasional boulder to 18" max subrounded to subangular, organics to 0.5'	Start @ 9:30 Surveyed location not found, Location estimated. Test pit stable and vertical. Digging easy
1				
2				
3				
4	S-1		SANDY, SILTY CLAY (CL) with some gravel reddish brown, cobbles to 10" max. black and orangish staining, damp.	Lab. Class.
5				
6				
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-126

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-126

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	13'x4.5'x15'	8/5/89	8/5/89		not encount.	M. A. Hykarrp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SANDY SILTY CLAY (CL)	
12			moist	
13				
14			increasing gravel/cobble content with depth.	Digging hard.
15				Out of reach at 15'
			BOTTOM OF TEST PIT AT 15'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-126

HEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-127

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15'x4'x16'	8/4/89	8/4/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY GRAVELLY CLAYEY SILT (ML) brown, damp, non plastic, with some cobbles (5-10%), trace boulders (<5%) subrounded to subangular. organics to 0.5', roots to 3.0'. red and black staining on fissures.	Surveyed location not found. Test pit placed approx. 250' S-SE from end of good part of road.
1				
2				
3	S-1		GRAVELLY, SANDY, SILTY CLAY (CL)	Lab. class. Pocket penetrometer @ 4' - 3.5-4.0 tsf
4				Test pit stable. LL=26, PI=10
5			moist, increasing gravel and cobbles with depth. occasional boulder to 15" max.	
6				
7				
8				
9				
10			decreasing gravel and cobbles with depth. silt is slightly plastic.	
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP127

UEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-127

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x4x16	8/4/89	8/4/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			decreasing gravel and cobbles with depth	
12			Some pockets of dark greenish gray sand, in a silt matrix. easily crushed with hand (see picture)	
13				Pocket penetrometer @ 13 = 2.5-3.0 tsf
14				
15				
16				out of backhoe reach
			BOTTOM OF TEST PIT AT 16'	Stop @ 4:10 pm

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-127

HEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	80229	TP-128

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	16x1x17	8/4/89	8/4/89		not encount.	M A Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILTY CLAY (CL) yellowish brown, moist, slightly plastic, stiff, with some cobbles (5-10%), and occasional boulder to 30" max, subrounded to subangular organic mat'l to 1.0', roots to 3'	start @ 11:30 Penetrometer difficult due to gravel but @ 5' = 2.0 tsf Digging easy Test pit stable
1				
2				
3	S-1			LL=26, PI=10 Lab. Class.
4			CL	
5				
6				
7				
8				
9				
10				
			... grades to ...	
11			SILTY CLAY (CL)	LL=41, PI=19

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-128

HEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-128

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	16×4×17	8/4/89	8/4/89		not encount.	M. A. Hykowp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11	S-2		SILTY CLAY (CL), some sand, trace gravel – brown with orangish stains, wet, stiff, medium plasticity, <5% cobbles and occasional boulder (2' max), subrounded to subangular	Lab class. LL=41, PI=19 Penetrometer at 11' = 2.5-3.0 tsf
12				
13				
14			increasing gravel and cobbles, boulders to 15" max. ... grading to ...	
15			SILTY SANDY CLAYEY GRAVEL (GM-GC), yellowish brown, fines slightly plastic, Cobbles (10-20%), trace boulders (<5%) subrounded to subangular, wet,	Hard digging
16				Test pit unstable – large wedges from sides falling in.
17			BOTTOM OF TEST PIT AT 17.0'	Refusal @ 17' in gravel/cobbles Stop @ 1:40

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-128

HFH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-129

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	10x4.5x5	8/9/89	8/9/89		no account.	M.A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVEL (WEATHERED ROCK), trace silt, very angular, light brown organics to 0.5'	moderate digging.
1				
2				
3			BEDROCK, bedded at 10-20° angle. rock breaks along bedding.	sides of test pit are stable in rock.
4				
5				Refusal in rock
			BOTTOM OF TEST PIT AT 5.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-129

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-130

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	11x4x65	8/2/89	8/2/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILT (ML), yellowish brown, slightly plastic, damp, stiff, with organic material, roots down to 5' and trace sand to 0.5'	Test pit moved to west side of road. Started at 11:20 AM
1				Easy digging
2			GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), yellowish brown, fines are slightly plastic, damp, with gravel (30-50%) & cobbles (10-20%) to 6" max. subangular to angular.	Test pit stable
3			more angular with depth	
4				
5	S-1		BEDROCK. highly weathered, stained w/ orange & black on breaks. Can be broken with hand, siltstone, some quartzite. Large slabby pieces, angular and fissures. Black & orange stains along fissures	hard digging at 4.5
6				
7			BOTTOM OF TEST PIT AT 6.5'	Stopped at 12:05 AM
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-130

HEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-131

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x4.5x11	8/2/89	8/2/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILT (ML) orangish brown, slightly plastic, damp, 5-10% sand, subrounded to subangular, fine to coarse, occasional cobble to 3" max. Patches of white silt within orangish brown silt. white silt has no sand or gravel, slightly plastic, occurs in patches on side of pit with a max size of 2x4. It is not a continuous layer throughout pit	Start @ 2:30 Lab Class. LL=28, PI=5 2 baggie samples included, one with orangish brown silt, the other with the white silt. Picture shows white patch, in orangish brown silt.
1	S-1			
2				
3			BEDROCK, highly weathered, stained w/ orange & black along fissures, angular, can be broken w/ hand, siltstone	Moderate digging
4				
5				
6			Rock fragments are 6" max. size, still highly weathered	
7			Weathered bedrock, siltstone with occasional quartzite inclusions.	Hard digging
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 | TEST PIT NO. TP-131

MEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-131

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x45x14	8/2/89	8/2/89		not encount.	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			Weathered Bedrock	
12				
13			8" max. rock fragments	
14			Bottom of Test Pit at 14'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-131

FH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8429	TP132

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	13x4.5x14	8.85?	8.85?		not encount.	M A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILT (ML), dry, reddish brown, nonplastic, with some gravel (5-10%), occasional cobble & boulder to 2' ~~sub~~round. to subangular. roots to 2'	Surface boulder near pit 5'x4'x2'.
1			SANDY SILTY CLAY (CL), some gravel, brown, damp, slightly plastic, with some cobbles (5-10%), some boulders (5-10%) to 3'x2' max, subangular to rounded.	Lab. class. Hard digging.
2				
3	S-1			
4				
5				
6				
7				
			... grades to ...	
8			SILTY SANDY GRAVEL (GM) same as above, but more gravel. (40-60%), moist	Very hard digging.
9				Test pit stable
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 2	TP-132

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-132

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	13x4.5x14	8/8/89	8/8/89		not encount.	N. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SILTY SANDY GRAVEL (GM)	
12				
13				
14				Refusal on boulders + gravels
			BOTTOM OF TEST PIT AT 14'	
15				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-132

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-133

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorrie	backhoe	10x4.5x7	8/9/89	8/9/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILTY, SANDY GRAVEL (GM) light brown, subangular to angular, non-plastic, dry, roots to 1' organics to 0.5'	Surveyed location not found. TP-133 located 10' east of DH-8. Digging moderate
1	S-1			Lab. class.
2				
3				
4				
5			WEATHERED ROCK, very angular - same as TP-129. rock breaks along bedding planes in angular flat pieces	Very hard digging.
6				
7				Refusal in rock
8			BOTTOM OF TEST PIT AT 7.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-133

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-134

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	16x4x9	8/ /89	8/ /89		not encount.	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), brown, non plastic, damp, with some cobbles (5-10%), and occasional boulders to 2' max.	Start @ 10:00 AM
1	S-1 (small)			
2	S-2		GRAVELLY SILTY CLAYEY SAND (SM-SC) greyish brown, non plastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 18' max. soil matrix is stained orange and black in some places and some white silt is also visible. moisture and stiffness increasing with depth. At 4.' material is very stiff.	Lab. class. (SC)
3				
4				Hard digging
5				penetrometer inaccurate due to gravel.
6				Test pit stable
7	S-3 (small)			
8			SILTY SANDY GRAVEL (GM), brown, rounded to angular, damp, with cobbles (20-40%) and trace boulders (5-10%) silt is non plastic, rock is siltstone and quartzite (white)	
9			BOTTOM OF TEST PIT AT 9.0'	Refusal - backhoe scraping rock. Stop @ 11:10 AM

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-134

UEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-135

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	8x4x13	8/7/89	8/7/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT - GRAVELLY SILTY SAND (ML-SM), brown, non plastic, gravel subrounded to angular with some cobbles (5-10%) and trace boulders (<5%) to 2' max, damp.	Surveyed location not found, location estimated.
1				
2				
3				
4				
5				
			increasing gravel and cobbles with depth less sand with depth	
6	S-1			
7			GRAVELLY, SANDY, SILTY CLAY (CL)	Lab. class.
8				
9				
10			... grading to ...	Hard digging in boulders
11			GRAVELLY SANDY SILT (ML)	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-135

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-135

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	18x4x13	8/7/89	8/7/89		not encountered	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			GRAVELLY SANDY SILT (ML), brown, damp to moist, non plastic, with some cobbles and occasional boulder to 1.5' max. subangular to subrounded	Test pit stable
12				moderate digging
13				Refusal on boulder
			BOTTOM OF TEST PIT AT 13'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-135

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-136

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x3x13	8/3/89	8/3/89		not encount.	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), light brown w/ some orangish staining, nonplastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 15" max, subrounded to subangular, organic material and roots to 1.0' grading to:	Start @ 2:00 PM
1				Moderate digging Test pit stable
2	S-1		GRAVELLY SANDY SILTY CLAY (CL) large boulder in side of pit (4'x5' min)	Lab. Class LL=42, PI=22
3				
4				
5				5' - digging harder due to boulders.
6	S-2		GRAVELLY SANDY SILTY CLAY (CL) very stiff reddish brown, medium plasticity, moist, with occasional cobble, subrounded to subangular	Moderate digging Test pit sides below 6' are vertical, flat and stable.
7				
8				Pocket penetrometer @ 8' = 3.75-4 tsf
9				
10				
11			yellow, orange and white color variations in silty clay, moist,	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-136

MEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-136

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x3x13	8/ /89	8/ /89		not encount	M. A Hyatt

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			GRAVELLY SANDY SILTY CLAY (CL)	
12				Hard digging Refusal on @ 13'
13			BOTTOM OF TEST PIT AT 13'	Stop @ 3:00 PM
14				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-136

USH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-137

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15'x4'x3'	8/4/89	8/4/89		10.0'	M. F. Hyinny?

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), brown, non plastic, damp roots to 4.0' some gravel and cobbles, occas. boulder (3' max.)	Start @ 9:00 AM
1			GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), brown, non plastic, damp cobbles (20-40%), and trace boulders (<5%), subrounded to angular (one boulder was very square 1.5' each side w/ sharp corners)	Hard digging
2	S-1			
3			increasing gravel/cobbles/boulders with depth	
4			boulders to 3' max (20-30%)	
5				
6				
7				Very hard digging, sides of test pit stable
8				
9				
10				Seepage @ 10.0' water enters pit @ rate of approx 1 s.f. in 10 minutes
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 | TEST PIT NO. TP-137

4FH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-137

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	15x4x13	8/4/89	8/4/87		10.0'	M. A. Hyman

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SILTY SANDY GRAVEL (GM)	
12				
13				Refusal @ 13' on boulders & gravels
			BOTTOM OF TEST PIT @ 13.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-137

UEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-138

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	10x4x15	8/3/89	8/3/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY CLAYEY SILT (ML)	Start @ 4:20 PM
1			brown, non plastic, tough, with some cobbles (5-10%) and occasional boulders to 18" max, subround-subang silt is brown stained with orange and streaked with white silt organic mat'l to 0.5', roots to 2'	Easy digging.
2	S-1		GRAVELLY SANDY SILTY CLAY (CL)	Lab. class.
3			increasing gravel/cobble content with depth.	LL=25, PI=9
4			gravel & cobble content vary.	
5				
6				
7				
8				
9				
10			moist. occasional boulders to 18" max.	Hard digging.
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 2	TP-138

UEHA20

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	80209	TP-138

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	10×4×15	8/3/89	8/3/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			GRAVELLY SANDY SILTY CLAY (CL)	
12			silt matrix is slightly plastic, moist	test pit stable
13				
14				
15				out of reach at 15'
			BOTTOM OF TEST PIT AT 15'	Stop @ 5:16

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-138

4FH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-139

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	10x4x8	8/7/89	8/7/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELY SANDY SILT (ML), brown, non plastic, damp, with some cobbles (5-10%), and occasional boulder to 18' max subangular to subrounded	Moderate digging
1				
2			increasing gravel/cobbles with depth	
3	S-1			
4			... grading to ...	
5				Hard digging
6			SILTY SANDY GRAVEL (GM), brown, damp, subangular to subrounded with gravel (20-40%), cobbles (10-20%) and some boulders (5-10%) to 2.5' max, fines non plastic	Very hard digging Test pit stable but pitted
7				
8			BOTTOM OF TEST PIT AT 8'	Refusal in gravel

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-139

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-140

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	14"x14"x2	8/7/89	8/7/89		not encount.	M. A Hytamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), reddish brown, non plastic, damp, with some gravel (5-10%). trace cobbles (<5%) to 8", one boulder to 12", subangular to subrounded, organics to 1', roots to 3'.	
1				
2			...grading to... GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), yellowish brown, damp, fines non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 13"	Hard digging Test pit stable
3	S-1		SANDY, GRAVELLY, SILTY CLAY (CL)	Lab. class.
4			increasing gravel /cobbles /boulders with depth.	
5			5' - boulder - 3' x 1.5' x 1'	
6				
7				
8				
9			Some boulders (5-10%) to 2' max.	Very Hard diggin.
11			Large boulder (3'x5' min)	Refusal at 12'
12			BOTTOM OF TEST PIT AT 12'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-140

HFH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	80229	TP-141

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	20'x5'x12.5	8/3/89	8/3/89		not encount.	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), brown, non plastic, damp with some cobbles (5-10%) and occasional boulder to 2' max, subrounded to subangular, some orangish staining in silt, organics at'l to 0.5', roots to 3'	Start @ 11:50
1				
2				Hard digging
3				
	S-1			
4			trace boulders (5-10%) to 3' max.	
5				
6			Increasing gravel / cobbles / boulders with depth	
7				
8				
9			... grades to ...	
10			SILTY SANDY GRAVEL (GM), brown, subrounded to subangular, damp, fines are non plastic, cobbles (30-50%) and some boulders (5-10%) to 2' max size.	
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-141

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-141

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	20w 5x 12.5	8/3/89	8/3/89		not encount	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SILTY SANDY GRAVEL (GM)	
12				Very hard digging REFUSAL on large boulder (6'x4') min
13			BOTTOM OF TEST PIT AT 12.5'	Stop @ 1:30

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-141

IFH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-142

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	13x4x6	8/ /89	8/ /89		not encount.	M. A. Hybamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SILT (ML), reddish brown, non plastic, damp, with some sand (5-10%) and trace gravel (<5%) and occasional cobble subrounded to subangular. Organic mat'l to 0.5' and roots to 0.5'	Start @ 8:25 AM
1				
2	S-1		GRAVELLY, SANDY, CLAYEY SILT (ML) grayish brown, non plastic, damp, with some cobbles (5-10%) and occasional boulder to 15" max, subrounded to angular, well graded.	Hard digging
3			GRAVELLY SANDY SILTY CLAY (CL)	Lab. class.
4				
5			Boulders to 24" max, increasing gravel and cobble content with depth	Refusal on large boulder (9x4 min.)
6			BOTTOM OF TEST PIT AT 6.0'	Stop @ 9:20 AM

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-142

HEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-143

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	13x4x16	8/8/89	8/8/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM) light brown, dry to damp, fines are nonplastic, with some cobbles (5-10%) and some boulders (5-10%) subangular to subrounded, roots to 2'	Surveyed location not found, but location estimated. moderate digging
1				
2				
3			gravel/cobble/boulder content decreasing with depth, damp	
4				
5				Easy digging
6	S-1		SANDY, SILTY CLAY (CL) with some gravel	
7				
8				moderate digging
9				
10			gravel/cobble boulder content increasing with depth. moist	
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2

TEST PIT NO. TP-143

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8079	TP-143

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorrie	backhoe	[illegible]	8/8/83	8/8/83	-	not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
11			SANDY SILTY CLAY (CL) with some gravel	moderate digging Test pit stable
12				
13				
14				
15				
16				Out of reach @ 16'
			BOTTOM OF TEST PIT AT 16'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-143

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-144

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	14x4x16	8/5/89	8/5/89		10'	M. A. Hykany

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0–2			SILT (ML), dark reddish brown, damp, nonplastic, with some sand, and occasional cobble subrounded to subangular; organics in 0.5', roots to 2'.	Start at 8:10. Could not find surveyed location. Location estimated.
3–4	S-1		GRAVELLY, SILTY CLAY (CL) with some sand stiff to very stiff, grayish brown ... grading to ...	Lab. class. LL=26, PI=9. Penetrometer at 4.0' = 4.0-4.5'
5–9			SANDY SILT (ML), brown, slightly plastic, damp, very stiff, with some gravel (5-10%), trace cobbles, subrounded to subangular. ... grading to ...	Test pit sides stable and vertical. Seepage at 10' at approx 1 ft²/5 min.
10–11			SILTY SANDY GRAVEL (GM), brown, subrounded to subangular, moist, fines slightly plastic, some cobbles (5-10%) and	Test pit walls pitted.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 2 | TEST PIT NO. TP-144

IEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-144

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	14x4x16	8/5/89	8/5/89		10'	M. A. Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
1'			trace boulders to 18" max.	
12			increasing size and quantity of cobbles and boulders with depth.	
13			some pockets of green silty sand	Hard digging.
14				
15				
16			boulder (4'x5' min.)	Refusal on boulder
			BOTTOM OF TEST PIT AT 16.0'	Stop @ 9:00 AM

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 2 OF 2

TEST PIT NO. TP-144

UFH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	MONTANA	8029	TP-145

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O' Sorlie	backhoe	13x4x11	8/4/89	8/4/89		not encount.	M. A Hykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), brown, moist, non plastic, with some gravel (5-10%), trace cobbles and trace boulders (<5%) subangular to subround, 2' max. Organics to 0.5', roots to 3' Some lenses of gray clayey silt - slightly plastic, some orangish staining	Start @ 2:00 PM Test pit moved to other side of road. Easy digging
1				
2				
3	S-1			
4			SANDY SILTY CLAY (CL), with some gravel, light gray, medium plasticity, stiff, moist, subrounded to subangular. Thickness of layer varies throughout pit.	Pocket penetrometer at 5' = ~2.5 Lab. Class. LL=31, PI=15
5	S-2			
6				
7				
8			SANDY GRAVELLY SILT, brown, moist, slightly plastic, some cobbles (5-10%)	Hard digging
9				
10				
11			BOTTOM OF TEST PIT AT 11.0'	Refusal @ 11' in gravel Stop @ 2:50 PM

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP-145

IEH420

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-146

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	10x5x10	8/8/89	8/8/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY GRAVELLY SILT (ML), reddish brown, damp, nonplastic, with some cobbles (5-10%) and trace boulders (<5%) to 4x2x1' max. rounded to subangular,	Hard digging
1			... grades to ...	
2			SILTY SANDY GRAVEL, as above with cobbles (10-20%) and some boulders (5-10%) to 3' max, silt non plastic.	
3				No sample – too many boulders and cobbles for representative sample.
4				Very hard digging from 3-10'
5			increasing boulders with depth.	
6				
7				
8				
9				
10				Refusal in boulders
			BOTTOM OF TEST PIT AT 10.0'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1 | TEST PIT NO. TP-146

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	TP-147

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	12x4.5x7	8/8/87	8/8/87		not encount.	M.A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY, SILTY GRAVEL (GM) yellowish brown, subangular to subrounded, with cobbles (10-20%) and some boulders (5-10%) to 2.5' max, material is non plastic, damp, roots to 2'.	
1	S-1			Hard digging.
2			SANDY SILTY CLAYEY GRAVEL (GC)	
3				
4				
5			increasing gravel/cobbles and boulders with depth	
6				
7				Refusal @ 7'
8			BOTTOM OF TEST PIT AT 7'	

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-147

APPENDIX E
FIELD DENSITY TEST RESULTS

APPENDIX E
FIELD DENSITY TEST RESULTS

In August 1989, concurrently with the test pit excavation program, six pits (DT-1 through DT-6) were excavated in the tailings dam foundation to perform field density tests in the soils. These pits were excavated to depths of 5 or 6 feet by using a Cat 215 backhoe. Water was not encountered in any of these pits. Soils in the pits consisted of gravelly sandy clayey silt. Density test pit logs are included in this appendix.

The field density tests were performed by the nuclear densometer method (ASTM D2922) and by sand cone method (ASTM D1556). Results of these field tests are included in this appendix.

Chen-Northern, Inc.

A member of the HIH group of companies

528 SMELTER AVENUE
P. O. BOX 951
GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070

TECHNICAL REPORT

REPORT TO:

MORRISON-KNUDSEN ENGINEERS, INC. (2)
ATTN: MIKE FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: August 18, 1989
JOB NUMBER: 88-152-1
SHEET: 1 OF 2
INVOICE NO.: 74828

REPORT OF: Field density tests of in-place material for density determination in natural state, Montana Project, Libby, MT

SAMPLE IDENTIFICATION:

Attached are the results of field density tests performed on the above-referenced project on the dates and at the locations shown. Unless otherwise noted, our personnel utilized the nuclear densometer method of testing in accordance with ASTM D2922. In accordance with our quality control procedures, occasional routine correlation tests are performed using sand cone methods in accordance with ASTM D1556.

Contractor: Morrison-Knudsen Engineers, Inc.

Test Locations were selected by: Contractor personnel

Minimum required in-place density: N/A

Maximum density as determined by: N/A

Remarks:

Reviewed By: Kenneth H. Murrell

Distribution:

AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING.

Chen-Northern, Inc.

A member of the HIH group of companies

528 SMELTER AVENUE
P. O. BOX 951
GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070

TECHNICAL REPORT

REPORT TO:

MORRISON-KNUDSEN ENGINEERS, INC. (2)
ATTN: MIKE FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: August 18, 1989
JOB NUMBER: 88-152-1
SHEET: 1 OF 2
INVOICE NO.: 74828

REPORT OF: Field density tests of in-place material for density determination in natural state, Montana Project, Libby, MT

Sample Identification:
Summarized below are the results of field density tests performed on the above referenced project for the dates and at the locations shown. Unless otherwise noted, these tests were performed using sand-cone methods in accordance with ASTM D1556.

Test locations were selected by Chen-Northern at random locations.

~~The project specifications require a minimum in place density of 95 percent of the maximum density as determined by ASTM D1557.~~

TEST RESULTS:

Test Date	Lab No.	Field Moisture Content pcf	Field Dry Density pcf
8/10/89	38867	12.9	118.5
Location: DT-2, 6' below ground surface.			
8/10/89	38868	12.0	117.0
Location: DT-1, 5' below ground surface.			
8/10/89	38869	15.2	112.6
Location: DT-3, 6' below ground surface.			
8/10/89	38870	15.2	111.1
Location: DT-4, 4.5' below ground surface.			
8/10/89	38871	15.0	122.5
Location: DT-5, 6' below ground surface.			
8/10/89	38872	23.2	94.8
Location: DT-5, 4' below ground surface.			
8/10/89	38873	14.0	110.4
Location: DT-6, 4' below ground surface.			

REVIEWED BY: Kenneth Menzli

AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING.

Chen-Northern, Inc.

Nuclear Density Testing
Morrison-Knudsen Engineers, Inc.
San Francisco, California

August 18, 1989
Job No. 88-152-1
Sheet: 2 of 2

NUCLEAR
TEST RESULTS:

Test Date	Lab No.	Field Moisture Content pcf	Field Dry Density pcf
8/10/89	38867A	12.5	123.9
Location: DT-2, 6' below ground surface.			
8/10/89	38868A	14.0	116.2
Location: DT-1, 5' below ground surface.			
8/10/89	38869A	15.7	119.7
Location: DT-3, 6' below ground surface.			
8/10/89	38870A	15.0	113.0
Location: DT-4, 4.5' below ground surface.			
8/10/89	38871A	14.8	117.2
Location: DT-5, 6' below ground surface.			
8/10/89	38872A	23.9	98.1
Location: DT-5, 4' below ground surface.			
8/10/89	38873A	13.1	109.6
Location: DT-6, 5' below ground surface.			

EXPLANATION OF DENSITY TEST PIT LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications are modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure D-I. The relative proportions of the fines in a soil sample are defined by the following terms:

o	trace:	less than or equal to 5%
o	some:	5% to 12%
o	suffix "y" (e.g., silty):	12% to 50%

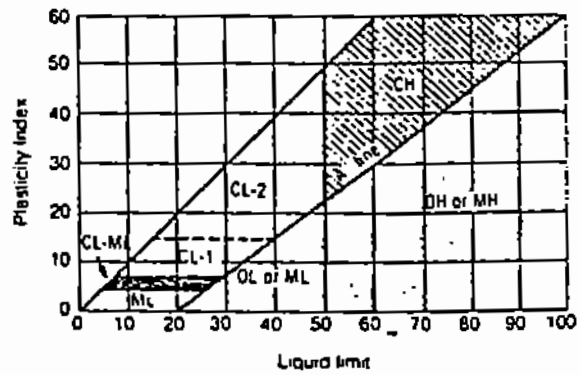
3. The relative proportions of gravels, cobbles and boulders were made visually in the field are therefore approximate.

4. All test pits were excavated by a Cat 215 backhoe equipped with a 3.5-foot wide bucket.

Unified Soil Classification System

Major Divisions			Group Symbols	Typical Names	Laboratory Classification Criteria	
Coarse-grained Soils More than half of material is larger than No. 200 sieve	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean Gravels (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM d u	Silty gravels, poorly graded gravel-sand-clay mixtures	Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures	Atterberg limits above "A" line, or PI greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines.	Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM d u	Silty sands, poorly graded sand-silt mixtures	Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols
			SC	Clayey sands, poorly graded sand-clay mixtures	Atterberg limits above "A" line, or PI greater than 7	
Fine-grained Soils More than half of material is smaller than No. 200 sieve	Silts and Clays Liquid limit less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity		
			CL 1 2	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silt-clays of low plasticity		
	Silts and Clays Liquid limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity, organic silts		
Highly Organic Soils			Pt	Peat and other highly organic soils		

Determine percentage of gravel and sand from grain size curve.
Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:
Less than 5% ..... GW, GP, SW, SP
More than 12% ..... GM, GC, SM, SC
5% to 12% ..... Borderline cases requiring use of dual symbols**



Plasticity Chart
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits, suffix d used when liquid limit is 28 or less and the PI is 6 or less; the suffix u used when liquid limit is greater than 28.
**Borderline classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

Figure No E-1

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-1

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	11x5x5	8/10/89	8/10/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML) brown, non plastic, dry; with some cobbles (5-10%) and trace boulders (<5%) to 14" max. subrounded to subangular.	
1				
2				
3			GRAVELLY SANDY SILTY CLAY (CL) damp	
4	S-1			
5				Density Test performed at 5'
			BOTTOM OF TEST PIT AT 5.0'	
6				
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. DT-1

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-2

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	10x5x6	8/10/89	8/10/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML) yellowish brown, silt non plastic, subangular to subrounded, damp, with some cobbles (5-10%) to 10" max, roots to 1'	
1				
2				
3				
4	S-1		GRAVELLY SANDY CLAYEY SILT - SILTY CLAY (ML-CL)	Lab. class - LL=23, PI=6
5				Density Test performed at 6.0'
6	D.T.		moist	
			BOTTOM OF TEST PIT AT 6.0'	
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. DT-2

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-3

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe	10×5×6	8/10/89	8/10/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), reddish brown, damp, non plastic, with trace gravel, cobbles & boulders (<5%) to 1.5' max, subangular to subrounded, roots to 2' ... grading to ...	
1				
2			SANDY CLAYEY SILT (ML), some gravel yellowish brown, damp, non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 1.5' max, subangular to subrounded.	
3				
4				
5			moist SANDY SILTY CLAY (CL) with some gravel	
	S-1			Density test performed at 6.0'
6			BOTTOM OF TEST PIT AT 6.0'	
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. DT-3

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-4

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe		8/10/89	8/10/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), brown, nonplastic, damp, with some gravel (5-10%) some cobbles (5-10%) and trace boulders (<5%) to 13"	
1				
			... grading to...	
2			GRAVELLY SANDY SILT (ML), yellowish brown, moist, nonplastic, with some cobbles and some boulders (5-10%), subangular to subrounded.	Digging easy
3				
4	S-1		SILTY GRAVELLY SAND (SM) nonplastic	Density Test performed at 4' Lab. class PI=0
5				
6			Wet	Density test not poss. @ 6' due to saturation of the soil.
			BOTTOM OF TEST PIT AT 6.0'	
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	DT-4

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-5

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O Sorlie	backhoe	10x5x6	8/ /89	8/ /89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML) reddish brown, non plastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 15" max, subangular to subrounded. yellowish brown below 1'	
1				
2				
3			moist, trace of gray silt in the sandy silt, gray silt clumps are non plastic	
4	S-1			Density Test performed at 4.0'
5			GRAVELLY SANDY SILTY CLAY (CL)	
6			wet	Density Test performed at 6.0'
			BOTTOM OF TEST PIT AT 6.0'	
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. DT-5

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
Montana Project	Little Cherry Creek	Montana	8029	DT-6

CONTRACTOR	EXCAVATION METHOD	SIZE	BEGUN	COMPLETED	GROUND ELEV.	GR. WATER DEPTH	LOGGED BY:
O. Sorlie	backhoe		8/10/89	8/10/89		not encount.	M. A. Nykamp

DEPTH	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	REMARKS PHOTOGRAPH
0			GRAVELLY SILTY SAND — GRAVELLY SANDY SILT (ML-SM) brown, non plastic silt, damp, with some cobbles (5-10%), subrounded to subangular, roots to to 1'	
1			... grades to ...	
2			GRAVELLY SANDY SILTY CLAY (CL) brown, slightly plastic, subrounded to subangular, moist.	Easy digging Test pit stable. Lab. class. LL = 30, PI = 12
3				
4	S-1			
5				Density test performed at 5.0'
			BOTTOM OF TEST PIT AT 5.0'	
6				
7				
8				
9				
10				
11				

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. DT-6

APPENDIX F
LABORATORY TEST DATA

APPENDIX F
LABORATORY TEST DATA

Laboratory testing of soils was performed by Chen-Northern, Inc., in Great Falls and Billings, Montana. Tests were performed on selected bag samples obtained from the test pits, and SPT, Shelby tube and ring samples obtained from the borings. Tests include dry density, grain size distribution (ASTM D422), Atterberg limits (ASTM D4318), moisture content (ASTM D2216), moisture-density (ASTM D698), specific gravity (ASTM D854), and triaxial compression (consolidated-undrained, CU, and unconsolidated-undrained, UU). The test results are summarized in Table F-1.

Visual classification of samples was made in conformance with the Unified Soil Classification System. Material descriptions noted in the boring and test pit logs were revised based on results obtained from the laboratory tests.

TABLE F-1 **SUMMARY OF SOIL TEST RESULTS**

Job No 8029 Project Name MONTANORE Feature Tailings Impoundment Area Date 1/24/90

Hole or Trench Number	Sample Number	Depth (feet) From	Depth (feet) To	Laboratory Classification	ASTM D422 Mechanical Analysis Gravel	Sand	Fines	D4318 Atterberg Limits LL	PI	D854 Specific Gravity G	Natural w %	Natural γ_d (PCF)	D698 Compaction Test	Optimum w %	Optimum γ_d (pcf)	Shear Strength Test	Initial w	Initial γ_d	G	ϕ	Permeability γ_d	k	Consolidation C_v	C_c	σ'	Notes
1988	Borings																									
USB-1	SPT-2	10	11.5	CL-ML	0	23	77																			
USB-1	SPT-3	15	16.5	CL-ML	6	36	58	25	4																	
USB-1	SPT-4	20	21.5	SM	24	42	34																			
USB-1A	ST-1	10	11.8	CL-ML							18	109														Interlayered silty sand and clayey silt-silty clay
USB-2	SPT-3	12.5	13.2	SM	34	41	25				4															
USB-3	SPT-3	12.5	14	SM	25	36	39				15															
USB-4	SPT-2	5	6.5	GM	39	33	28																			
USB-5	SPT-3	20	21.5	CL-ML	5	21	74																			

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Special - See Text

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

TABLE F-1 **SUMMARY OF SOIL TEST RESULTS**

Job No 8029 Project Name MONTANORE Feature Tailings Impoundment Area Date 1/24/90

Hole or Trench Number	Sample Number	Depth (feet) From	Depth (feet) To	Laboratory Classification	ASTM D422 Mechanical Analysis Gravel	Sand	Fines	D4318 Atterberg Limits LL	PI	D854 Specific Gravity G	Natural w % D2216	Natural γ (pcf)	D698 Compaction Test	Optimum w	Optimum γ (pcf)	Shear Strength Test	Initial w	Initial γ	C (psf)	φ	Permeability γ	Permeability k	Consolidation C	Consolidation C	Consolidation π	Notes
1989 Borings																										
DH-1	SPT-1	4	5.5	CL-ML	17	22	61																			
DH-1	SPT-3	22.5	24	CL-ML	7	26	67	22	4		19															
DH-2	SPT-1	4	5.5	ML	14	27	59	20	3		16															
DH-2	----	12	12.5	CL	5	23	72	33	17																	
DH-3	SPT-1	5	6.5	CL-ML	9	29	62				20															
DH-3	SPT-3	15	16.5	CL	5	29	66	33	15		22															
DH-3	SPT-4	20	21.5	CL				37	18																	
DH-3	----	36	36.5	SC-SM	22	44	34																			
DH-3A	SH-2	13	14.8	CL	5	17	78	31	13		15	118														
DH-3A	SH-3	15	17	CL												uu	35.2	86.7	1225	0						
DH-3A	SH-5	19	21	CL												cu uu	20.0 19.6	106.2 109.4	1690	0						
DH-3A	SH-6	21	23	CL	1	16	83				23	103				cu uu	23.0 22.6	103.0 102.6	1785	0						
DH-5	SPT-2	15	16.4	CL-ML	19	27	54				17															
DH-5	----	28	28.5	GC-GM	55	20	25																			
DH-6	SPT-1	10	11.5	SM-SC	28	30	42	20	3		10															
DH-6	----	24.5	25	CL	11	19	70																			
DH-7	SPT-1	4	5.5	GM-GP	49	39	12																			
DH-8	SPT-2	8.5	10	GM-GP	50	38	12																			
DH-11	----	49	49.5	ML-SM	19	31	50																			
DH-11	----	58.5	59	GM	32	26	42																			
DH-12	SPT-1	4	5.5	GM-GP	72	17	11	Granular NonPlastic			7															

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Special - See Text

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

TABLE F-1 SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANORE Feature Tailings Impoundment Area Date 1/24/90

Hole or Trench Number	Sample Number	Depth (feet) From	Depth (feet) To	Laboratory Classification	ASTM D422 Mechanical Analysis Gravel	Sand	Fines	D4318 Atterberg Limits LL	PI	D854 Specific Gravity G	Natural w % D2216	γ_t (PCF)	D698 Compaction Test	Optimum w	γ_d (pcf)	Shear Strength Test	Initial w	γ_t	C (psf)	ϕ	Permeability γ_t	k	Consolidation C_c	C_r	σ'	Notes
1989 Borings (continued)																										
DH-13	SPT-1	5	6.5	GM	42	36	22																			
DH-13	SPT-2	10	11.5	SM-SC	27	41	32																			
DH-13	-----	14.5	15	SM	20	35	45																			
DH-17	SPT-1	4.5	6	CL	22	23	55				9															
DH-18	-----	34.5	35	ML-SM	26	24	50																			
DH-18	-----	48	48.5	CL	9	21	70	30	11																	
DH-19	SH-1	5	7	ML		9	91				26	98.8				cu	26.3	101.7								
																uu	24.6	95.8	3150	0						
DH-19	SH-2	11	12	ML				21	1		14															
DH-19	SPT-1	20	21	GM	36	29	35	Granular NonPlastic																		
DH-20	SH-1	4	6	SM	24	60	16	27	3		13	98.6														
DH-20	SH-3	8	10	GM (1.)	50	21	29									cu	15.3	97.7								
DH-20	SH-5	12	14	SM-ML	5	45	50				26	95.6														
DH-20	SH-7	16	18	ML		39	61	NonPlastic			26	94.7				cu	29.3	91.1								
																uu	22.8	98.2	3350	0						
DH-20	SH-9	20	22	ML				24	3		20															
DH-20	SPT-1	25	26.5	CL-ML	9	18	73																			
DH-20	-----	39	39.5	CL	12	26	62	36	17																	
1988	Test	Pits																								
TP-102	S-2	4	8	SM	33	40	27	NonPlastic			12															
TP-103	S-1	4	11	CL-ML	14	22	64	21	4		2															
TP-105	S-1	8	14	GW-GM	48	45	7																			
TP-106	S-1	6	8	CL-ML	13	29	58			2.70	11		SP	9.5	125.5											
TP-107	S-1	8	9	CL-ML	15	28	57	20	6	2.66	6		SP	9.4	125.2											

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Special - See Text

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

Notes: 1. Sieve test on gravel fens ; cu test was performed on separate sample which was fine-grained

TABLE F-1 SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANORE Feature Tailings Impoundment Area Date 1/24/90

Hole or Trench Number	Sample Number	Depth (feet) From	Depth (feet) To	Laboratory Classification	ASTM D422 Mechanical Analysis Gravel	Sand	Fines	D4318 Atterberg Limits LL	PI	D854 Specific Gravity G	Natural w %	Natural γ (PCF)	D698 Compaction Test	Optimum w	Optimum γ (pcf)	Shear Strength Test	Initial w	Initial γ	C	φ	Permeability γ	k	Consolidation C_c	C_r	σ'_c	Notes
1988	Test	Pits	(continued)																							
TP-109	S-1	8	10	ML	14	32	54	20	1		13															
1989	Test	Pits																								
TP-121	S-1	6	9	GC	35	31	34				10															
TP-121	S-2	9	11	CL	17	20	63	24	11		19															
TP-122	S-1	5	8	CL	17	23	60				10															
TP-124	S-1	6	8	ML-CL		1	99	33	9		34															
TP-126	S-1	4	6	CL	7	18	75				13															
TP-127	S-1	3	5	CL	17	19	64	26	10		13															
TP-128	S-1	3	5	CL	15	14	71	26	10	2.68	20		SP	13.3	116.8											
TP-128	S-2	11	14	CL	3	7	90	41	19		27															
TP-131	S-1	1	2	ML	-	-	-	28	5		13/6	see note 1														
TP-132	S-1	3	7	CL	11	27	62				11															
TP-133	S-1	1	3	GM	53	31	16			2.54	8		SP	11.8	115.5											
TP-134	S-2	2	4	SC	15	37	48				6					cu	11.4	118.4								
TP-135	S-1	6	8	CL	17	26	57				12					cu	10.5	119.4								
TP-136	S-1	2	4	CL	17	16	67	42	22		22															
TP-138	S-1	2	4	CL	18	23	59	25	9		12															
TP-140	S-1	3	5	CL	21	20	59				16															
TP-142	S-1	2	3	CL	18	29	53			2.68	10		SP	10.3	124.9	cu	10.1	119.8								
TP-143	S-1	6	8	CL	11	22	67				14															

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Special - See Text

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

Note 1: Moisture Contents for different parts of same sample.

TABLE F-1 SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANORE Feature Tailings Impoundment Area Date 1/24/90

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	ASTM D422 Mechanical Analysis Gravel	Sand	Fines	D4318 Atterberg Limits LL	PI	D854 Specific Gravity G	Natural (1) w %	γ (PCF)	D698 Compaction Test	Optimum w	γd (pcf)	Shear Strength Test	Initial w	γ	C	φ	Permeability γ	k	Consolidation C	C	R	Notes
1989	Test	Pits	(continued)																							
TP-144	S-1	3	5	CL	25	11	64	26	9		16															
TP-145	S-2	5	7	CL	9	23	68	31	15		19															
TP-147	S-1	1	3	GC	33	28	39				9															
DT-1	S-1	4	5	CL	14	28	58				14.0 12.0	116.2 117.0														
DT-2	S-1	4	5	CL-ML	21	24	55	23	6		12.5 12.9	123.9 118.5														
DT-3	S-1	5	6	CL	8	18	74				15.7 15.2	114.7 112.6														
DT-4	S-1	4	6	SM	24	30	46	Granular NonPlastic			15.0 15.2	113.0 111.1														
DT-5	S-1	4	5	CL	21	26	53				23.9 23.2	98.1 94.8														
DT-5		6		(Field Density Test Only)	-	-	-				14.8 15.0	117.2 122.5														
DT-6	S-1	4	5	CL	17	20	63	30	12		13.1 14.0	109.6 110.4														

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Special - See Text

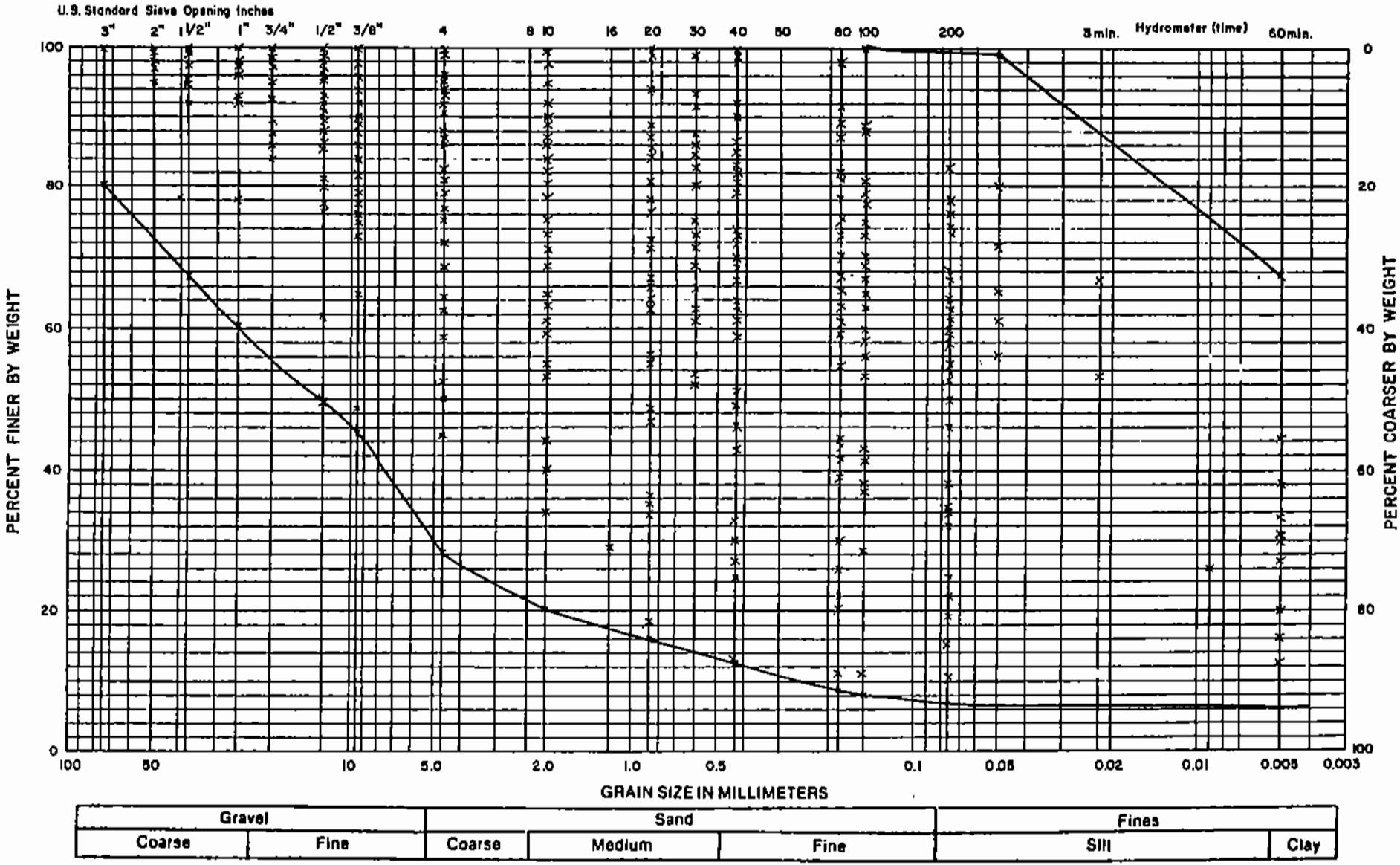
TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

Note 1: Top value by Nuclear Densometer; Bottom value by Sand Cone

INDEX OF LABORATORY TESTS RESULTS

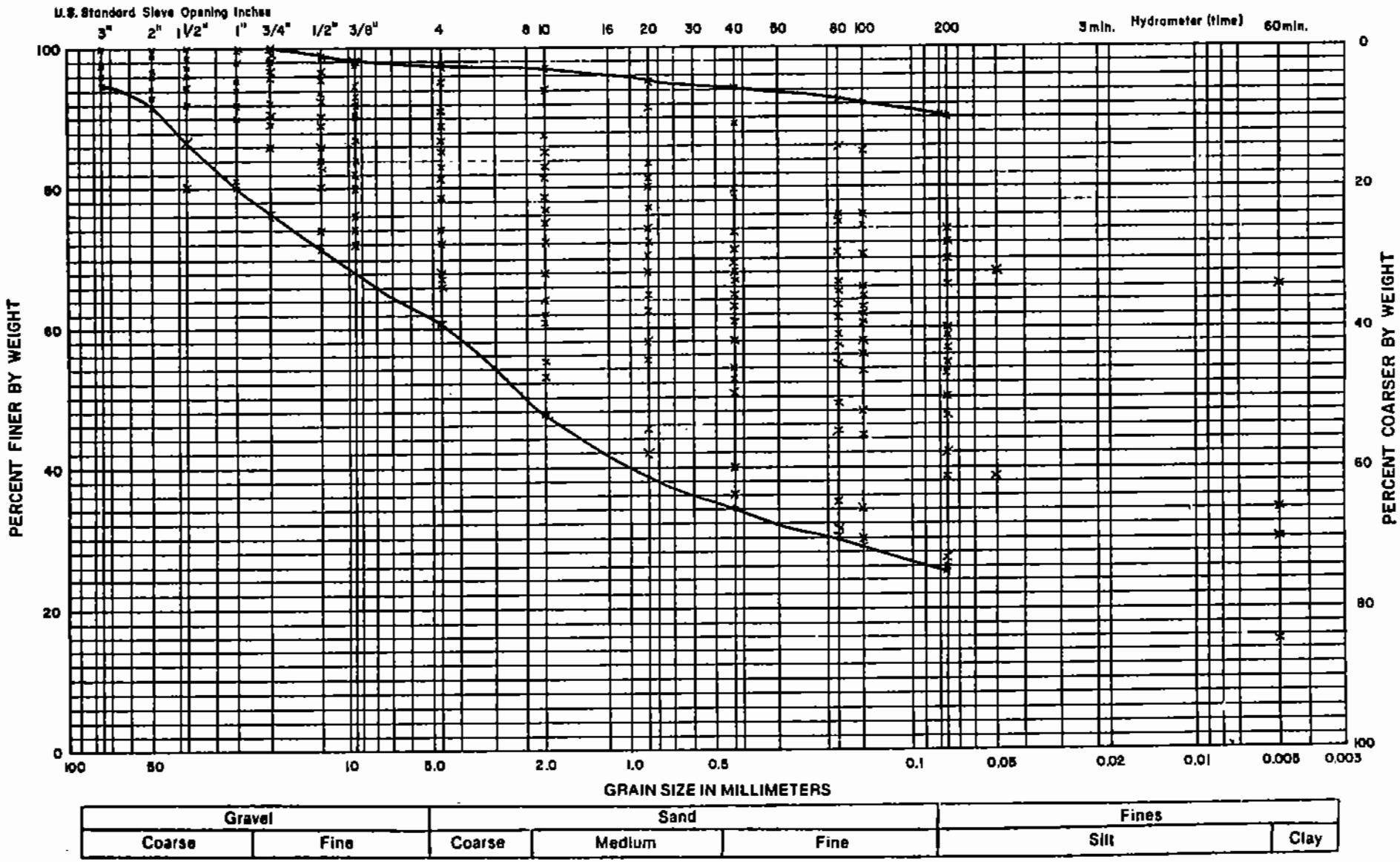
	TEST	FIGURE
1.	GRAIN SIZE	
1.1	Tailings Retention Dam Foundation	F - 1
1.2	Impoundment Area	F - 2
1.3	Diversion Channel Site	F - 3
2.	SUMMARY OF ATTERBERG LIMITS	F - 4
3.	MOISTURE CONTENT VS. PERCENT FINE GRAINED SOIL	F - 5
4.	UU TRIAXIAL TESTS - DAM FOUNDATION	
4.1	Mohr Circles	F - 6A
4.2	Deviator Stress-Strain Curves and Data Summary	F - 6B
5.	UNDRAINED SHEAR STRENGTH AND MOISTURE CONTENT VS. DEPTH	F - 7
6.	CU TRIAXIAL TESTS - DAM FOUNDATION	
6.1	P-Q Stress Paths	F - 8A
6.2	Mohr Envelope	F - 8B
6.3	Deviator Stress, Stress Ratio & Pore Pressure vs. Strain Curves and Data Summary	F - 8C (2 sheets)
7.	CU TRIAXIAL TESTS - COMPACTED EARTHFILL	
7.1	P-Q Stress Paths	F - 9A
7.2	Mohr Envelope	F - 9B
7.3	Deviator Stress, Stress Ratio & Pore Pressure vs. Strain Curves and Data Summary	F - 9C
8.	MOISTURE-DENSITY RELATIONSHIP DATA	-
9.	INDIVIDUAL GRAIN SIZE CURVES	-



MONTANORE PROJECT

TAILINGS RETENTION DAM
FOUNDATION GRADATIONS

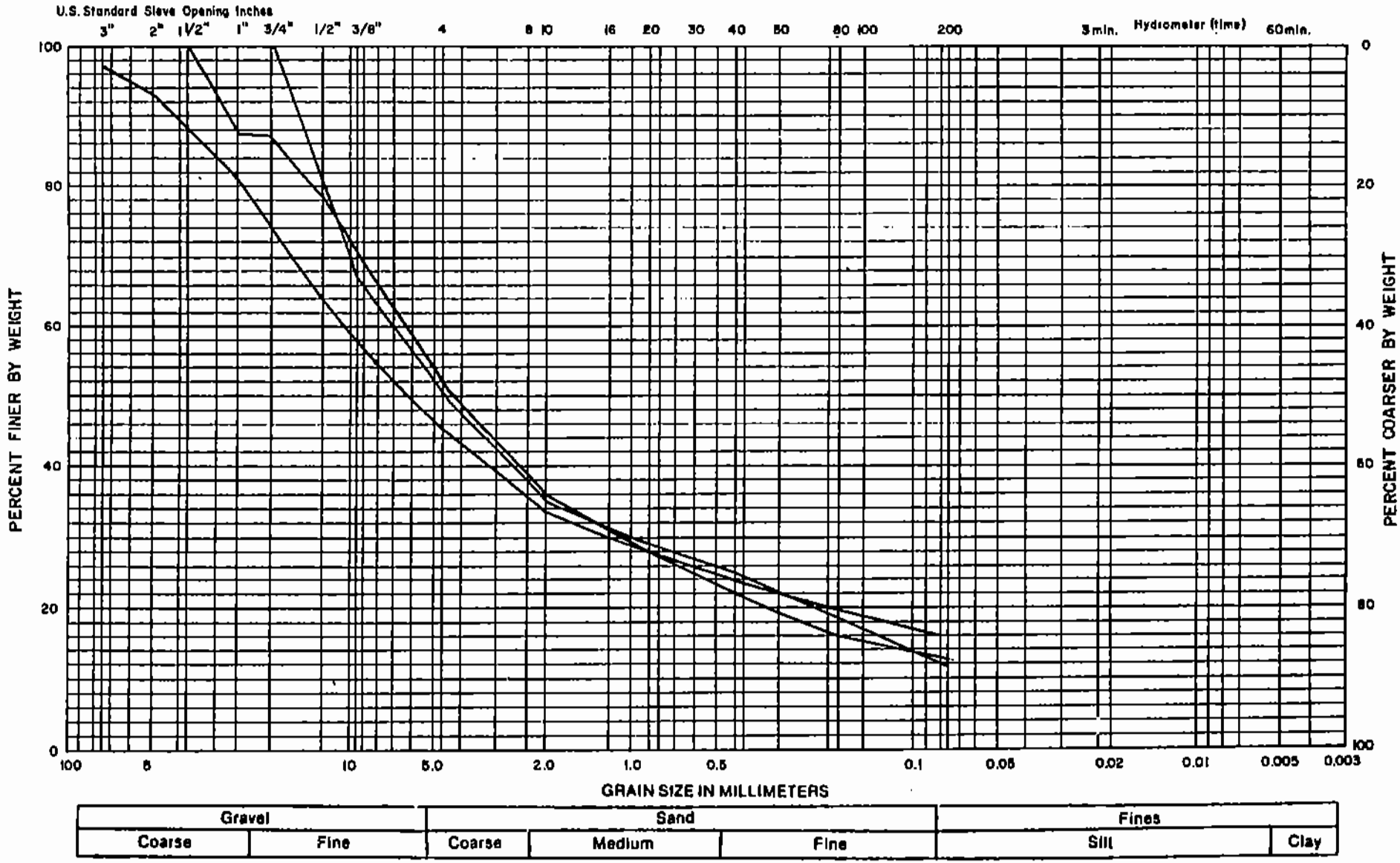
FIGURE F-1



MONTANORE PROJECT

IMPOUNDMENT AREA GRADATIONS

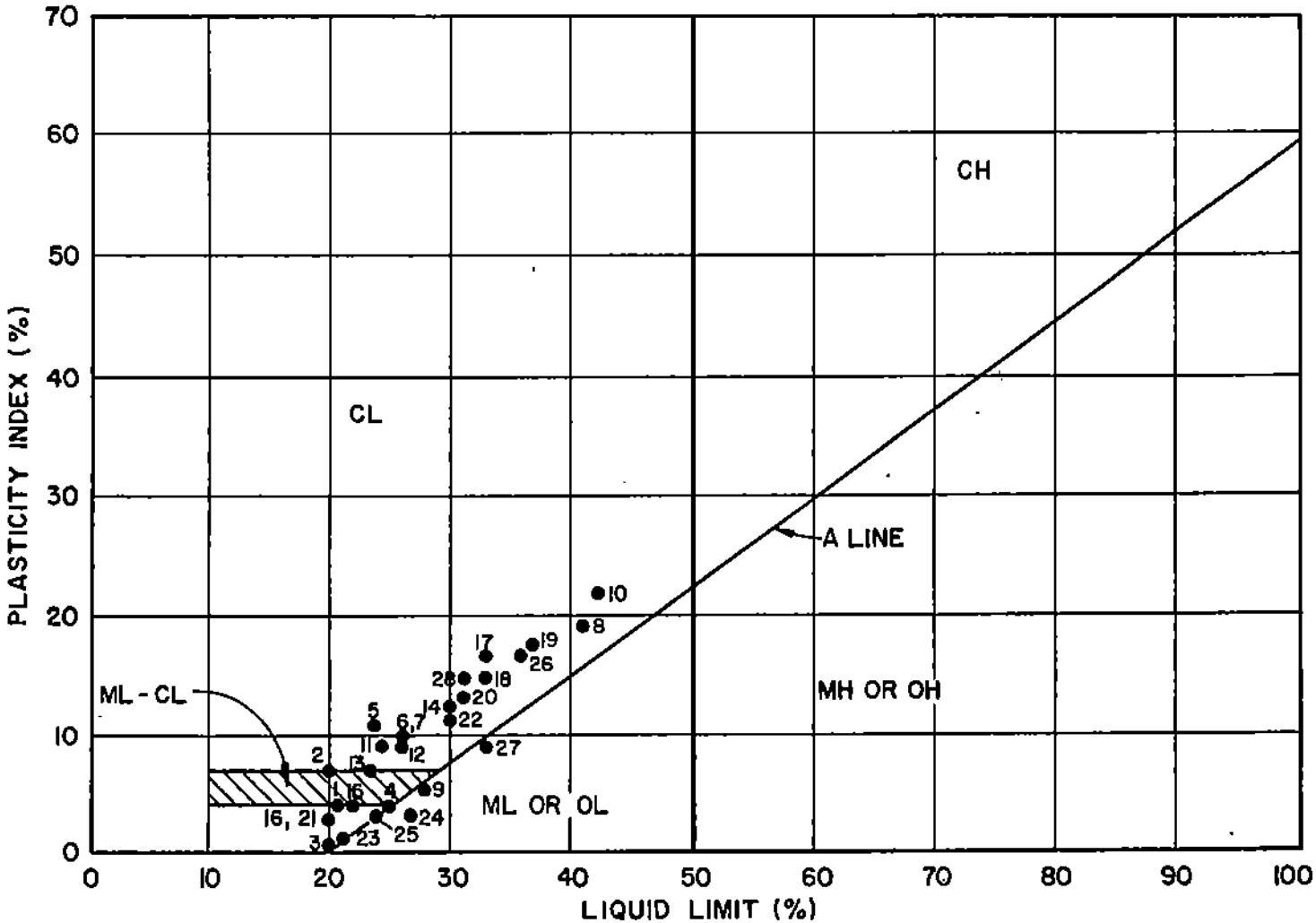
FIGURE F-2



MONTANORE PROJECT

DIVERSION CHANNEL SITE GRADATIONS

FIGURE F-3



NOTE: SEE SHEET 2 OF 2 FOR KEY.

MONTANORE PROJECT

SUMMARY OF ATTERBERG LIMITS
(SHEET 1 OF 2)

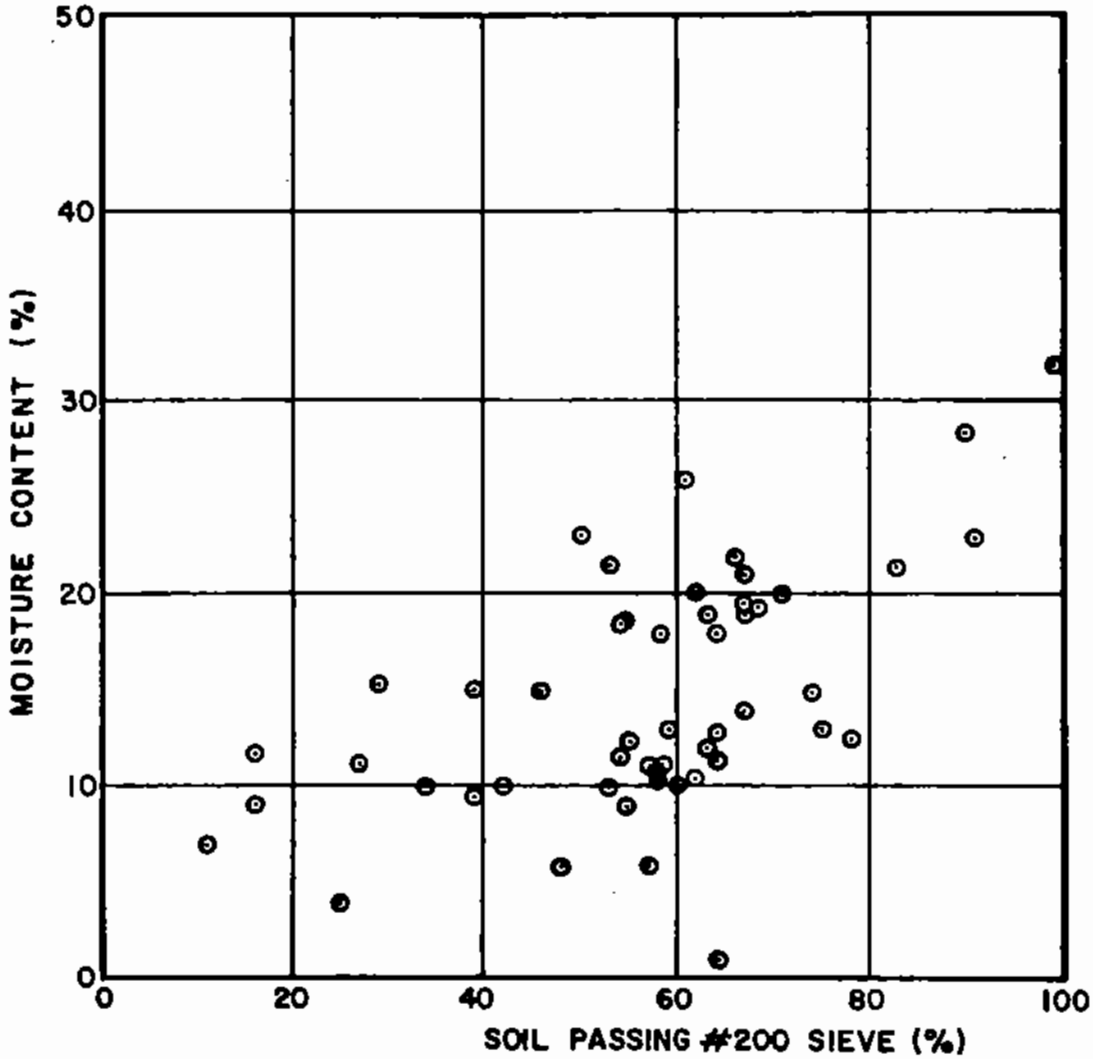
FIGURE F-4

SYMBOL	CLASSIFICATION AND SOURCE			LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% PASSING #200 SIEVE
1	TP-103	4'-11'	(CL-ML)	21	17	4	64
2	TP-107	8'-9'	(CL-ML)	20	14	6	57
3	TP-109	8'-10'	(ML)	20	19	1	54
4	USB-1	15'-16.5'	(CL-ML)	25	21	4	58
5	TP-121	9'-11'	(CL)	24	13	11	63
6	TP-127	3'-5'	(CL)	26	16	10	64
7	TP-128	3'-5'	(CL)	26	16	10	71
8	TP-128	11'-14'	(CL)	41	22	19	90
9	TP-131	1'-2'	(ML)	28	23	5	—
10	TP-136	2'-4'	(CL)	42	20	22	67
11	TP-138	2'-4'	(CL)	25	16	9	59
12	TP-144	3'-5'	(CL)	26	17	9	64
13	DT-2	4'-5'	(ML-CL)	23	17	6	55
14	DT-6	4'-5'	(CL)	30	18	12	63
15	DH-1	23'-24.5'	(CL-ML)	22	18	4	67
16	DH-2	4'-5.5'	(ML)	20	17	3	59
17	DH-2	12'-12.5'	(CL)	33	16	17	72
18	DH-3	15'-16.5'	(CL)	33	18	15	66
19	DH-3	20'-21.5'	(CL)	37	19	18	—
20	DH-3A	13'-14.8'	(CL)	31	18	13	78
21	DH-6	10'-11.5'	(ML)	20	17	3	42
	DH-12	4'-5.5'	(GM)		Non-Plastic		11
22	DH-18	48'-48.5'	(CL)	30	19	11	70
23	DH-19	11'-12'	(ML)	21	20	1	—
	DH-19	20'-21'	(GM)		Non-Plastic		35
24	DH-20	4'-5.4'	(SM)	27	24	3	16
	DH-20	16'-18'	(ML)		Non-Plastic		61
25	DH-20	20'-22'	(ML)	24	21	3	—
26	DH-20	39'-39.5'	(CL)	36	19	17	62
27	TP-124	6'-8'	(CL-ML)	33	24	9	99
28	TP-145	5'-7'	(CL)	31	16	15	68

MONTANORE PROJECT

SUMMARY OF ATTERBERG LIMITS
(SHEET 2 OF 2)

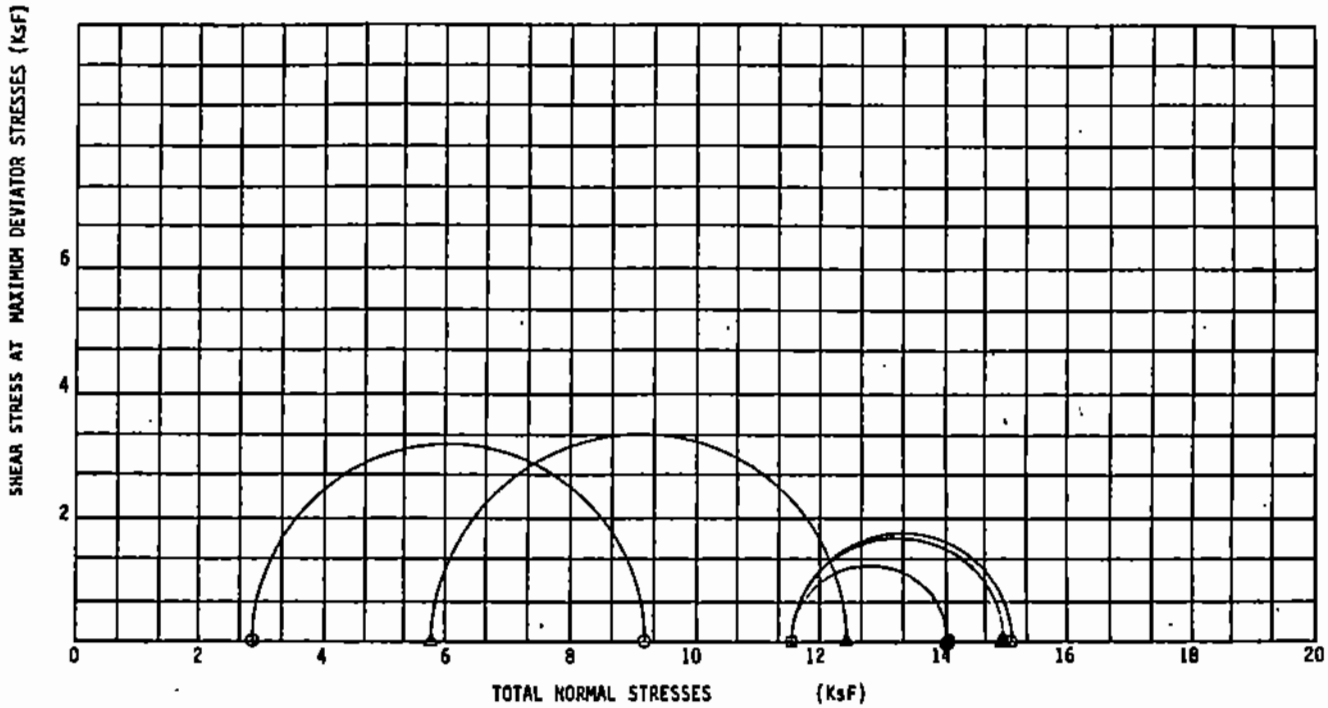
FIGURE F-4



MONTANORE PROJECT

MOISTURE CONTENT VS.
PERCENT FINE-GRAINED SOIL

FIGURE F-5



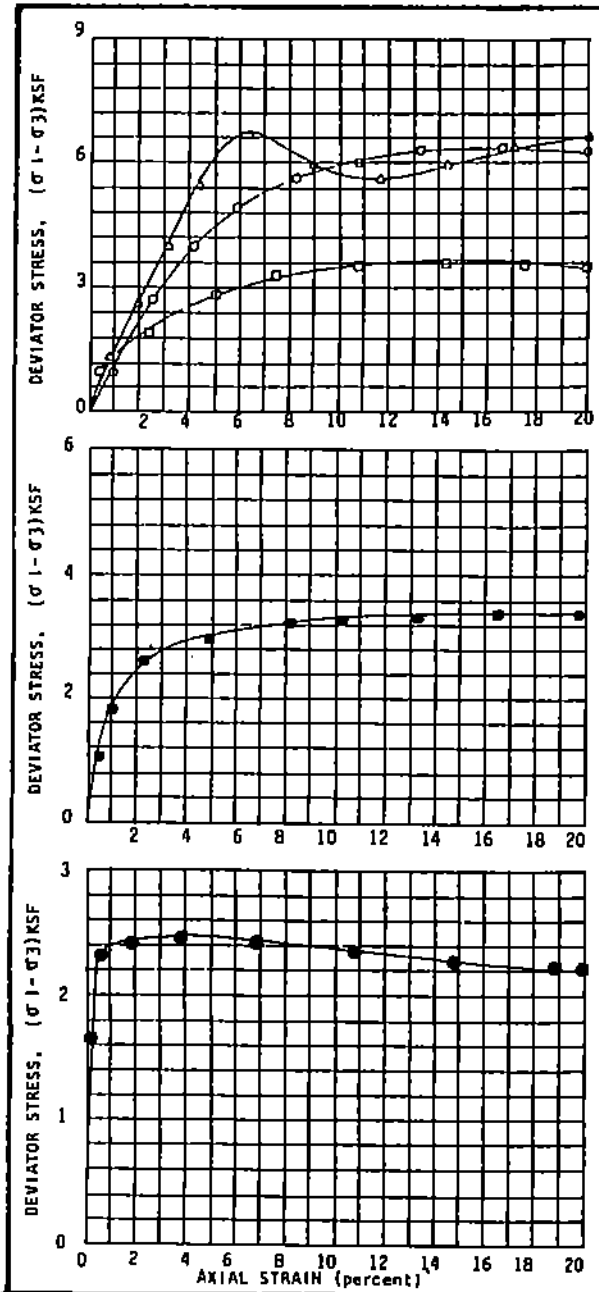
TEST NO. OR SYMBOL	BORING NO. AND DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	SAMPLE DATA: MOISTURE CONTENT (percent) Initial	SAMPLE DATA: MOISTURE CONTENT (percent) Final	PORE PRESSURE RESPONSE (percent)	CONFINING PRESSURE σ_3 PSI	MAXIMUM DEVIATOR STRESS $\sigma_1 - \sigma_3$ KSF	MAXIMUM PRINCIPAL STRESS RATIO σ_1 / σ_3	VALUES AT MOHR COULOMB FAILURE: MINOR PRINCIPAL STRESS σ_3 KSF	VALUES AT MOHR COULOMB FAILURE: MAJOR PRINCIPAL STRESS σ_1 KSF	HEIGHT TO DIAMETER RATIO	RATE OF STRAIN INCHES/MINUTE	Initial specimen dimensions (Inches)
○ SH 1	DH 19 5' - 7'	95.8	24.6	27.6	99	20	6.30	N/A	2.88	9.18	2.09	0.030	6.00 x 2.875
△ SH 7	DH 20 16'-18'	98.2	22.8	26.9	99	40	6.67	N/A	5.76	12.43	2.34	0.030	5.56 x 2.375
□ SH 6	DH 3A 21'-23'	102.6	22.6	22.9	98	80	3.57	N/A	11.52	15.09	2.09	0.030	6.00 x 2.875
● SH 3	DH-3A 15'-17'	86.7	35.2	37.2	99	80	2.45	-	11.52	13.97	2.17	0.020	3.55 x 7.71
▲ SH 5	DH3A 19-21	109.4	19.6	23.6	99	80	3.38	-	11.52	14.90	2.17	0.030	3.55 x 7.70

NOTE: SAMPLE DH-3A, SH-5 CONTAINS SHALE AND SANDSTONE FRAGMENTS

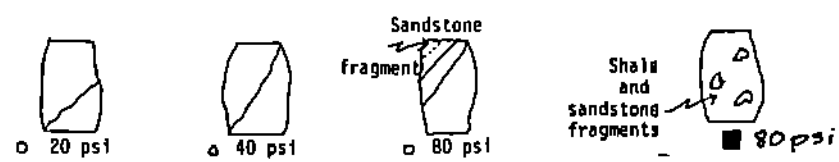
MONTANORE PROJECT

TAILINGS RETENTION DAM FOUNDATION
UU TRIAXIAL TESTS: MOHR CIRCLES

FIGURE F-6A



TEST NO OR SYMBOL	BORING NO AND DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	MOISTURE CONTENT (percent): Initial	MOISTURE CONTENT (percent): Final	PORE PRESSURE RESPONSE (percent)	CONFINING PRESSURE σ3 PSI	MAXIMUM DEVIATOR STRESS σ1 - σ3 KSF	MAXIMUM PRINCIPAL STRESS RATIO σ1/σ3	VALUES AT MOHR COULOMB FAILURE: MINOR PRINCIPAL STRESS σ3 KSF	VALUES AT MOHR COULOMB FAILURE: MAJOR PRINCIPAL STRESS σ KSF	HEIGHT TO DIAMETER RATIO	RATE OF STRAIN INCHES/MINUTE	Initial specimen dimensions (Inches)
○	DH 19 5' - 7'	95.8	24.6	27.6	99	20	6.30	N/A	2.88	9.18	2.09	0.030	6.00 x 2.875
△	DH 20 16'-18'	98.2	22.8	26.9	99	40	6.67	N/A	5.76	12.43	2.34	0.030	5.56 x 2.375
□	DH 3A 21'-23'	102.6	22.6	22.9	98	80	3.57	N/A	11.52	15.09	2.09	0.030	6.00 x 2.875
■	DH3A 19-21	109.4	19.6	23.6	99	80	3.38	-	11.52	14.90	2.17	0.030	3.55 x 7.70
●	DH-3A 15'-17'	86.7	35.2	37.2	99	80	2.45	-	11.52	13.97	2.17	0.020	3.55 x 7.71

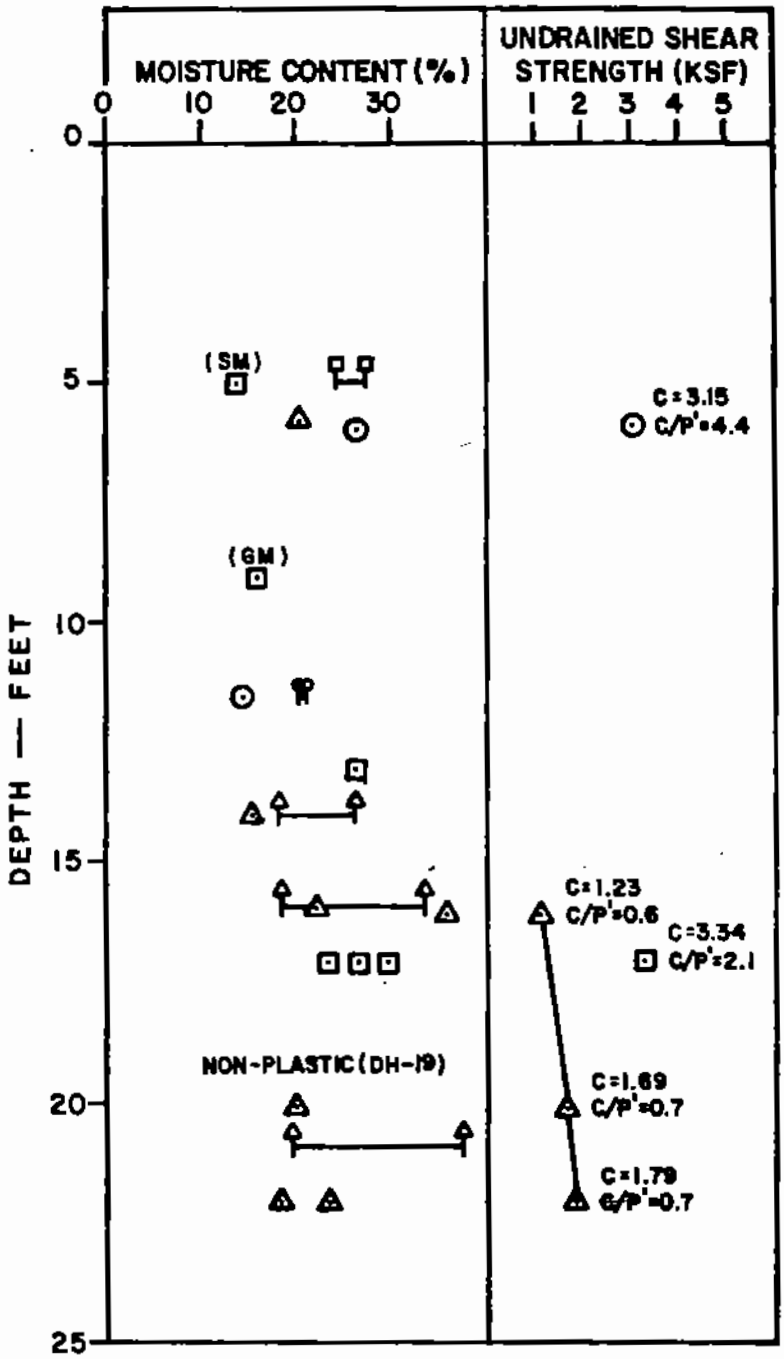


Post Shear Sketches

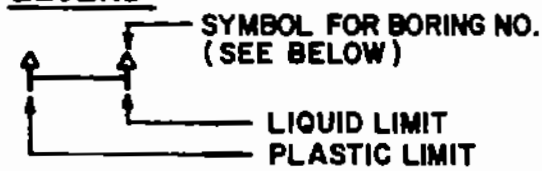
UNCONSOLIDATED UNDRAINED TRIAXIAL SHEAR TEST

Chen-Northern, Inc.	TRIAXIAL SHEAR TEST RESULTS		
	MONTANORE PROJECT M-K ENGINEERS		
	JOB NO.	DATE	PLATE NO.
	89-614	February 1990	

FIGURE F-6B



LEGEND:



MOISTURE CONTENT OR UNDRAINED SHEAR STRENGTH:

SYMBOL	BORING
△	DH-3 & DH-3A
⊙	DH-19
⊡	DH-20

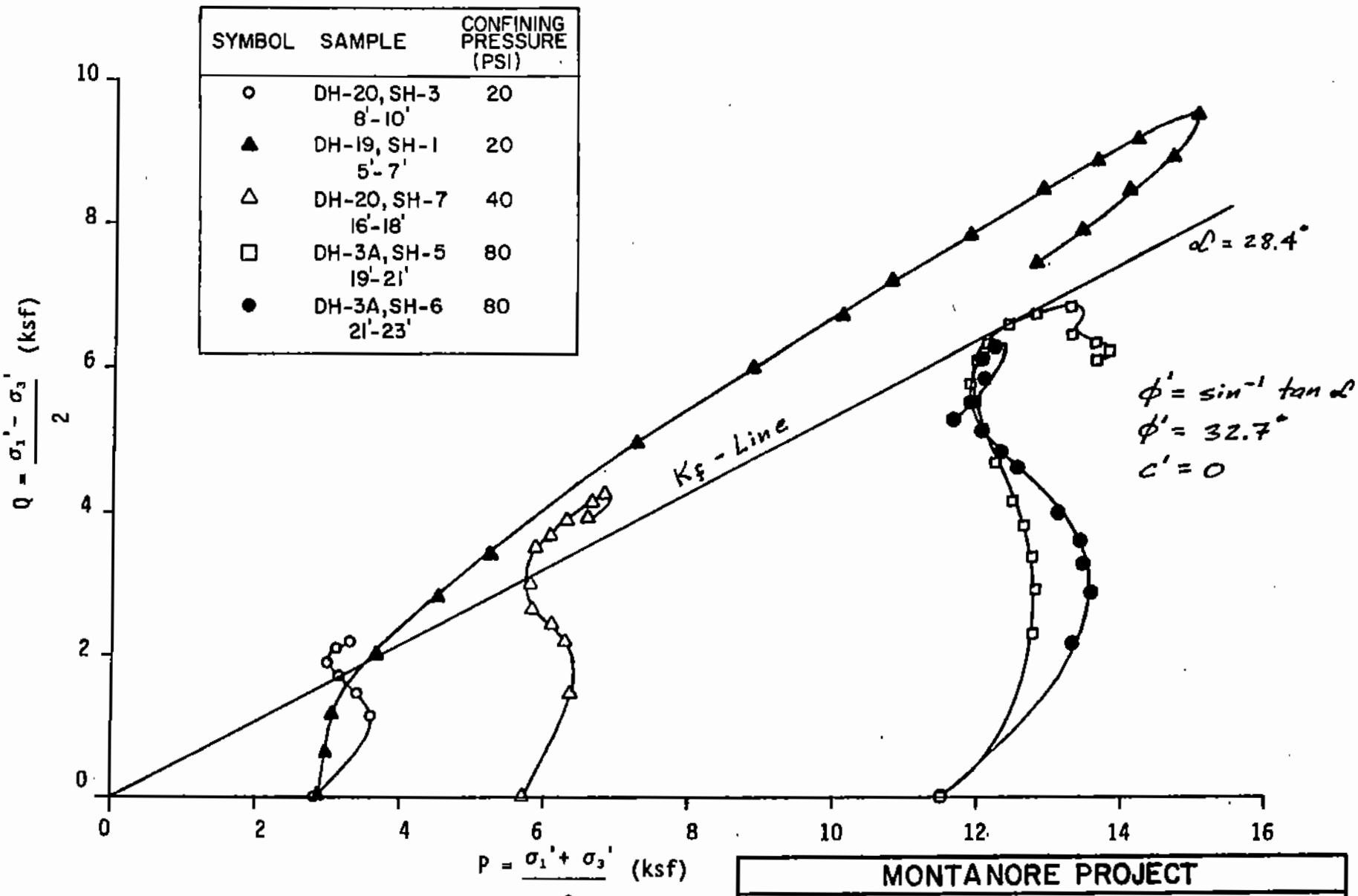
NOTES:

1. ALL TESTS WERE PERFORMED ON FINE-GRAINED (ML OR CL) SOIL, EXCEPT AS NOTED OTHERWISE.
2. $\frac{C}{P'} = \frac{\text{COHESION FROM UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST}}{\text{EFFECTIVE VERTICAL OVERBURDEN PRESSURE}}$

MONTANORE PROJECT

UNDRAINED SHEAR STRENGTH AND MOISTURE CONTENT VS. DEPTH

FIGURE F-7

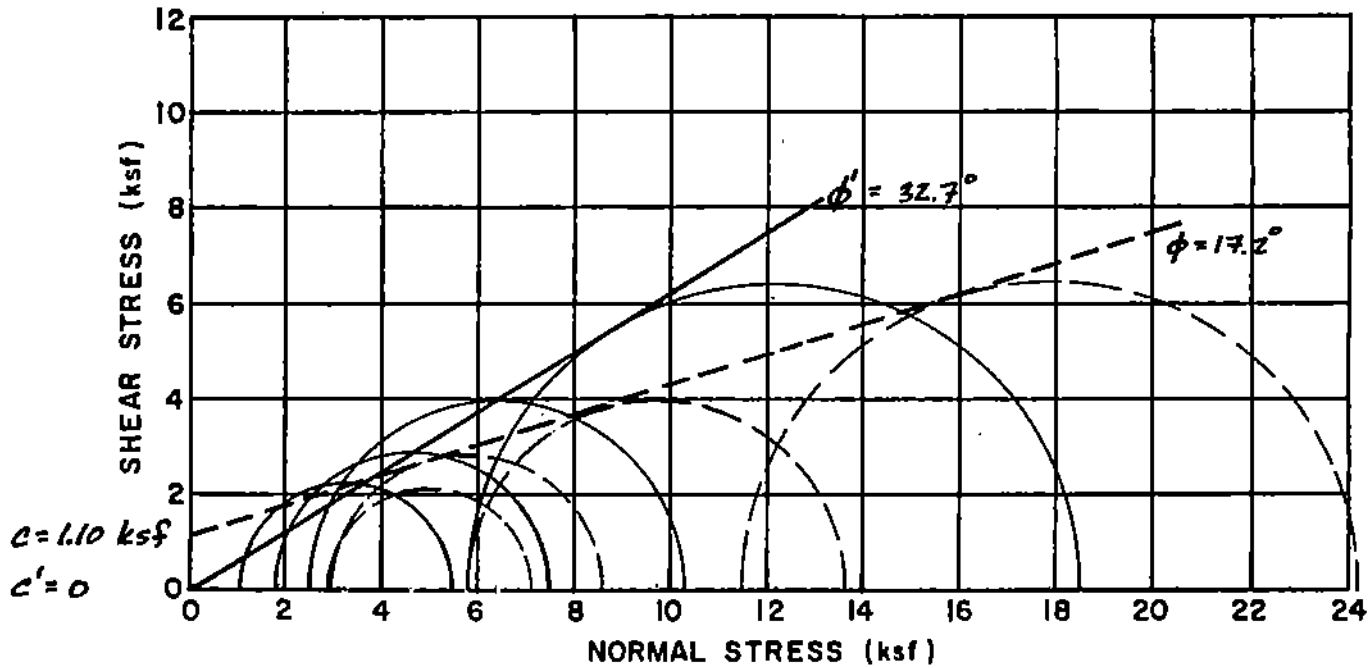


NOTE: 1. SAMPLES DH-3A, SH-5 AND SH-6, AND DH-20, SH-3 CONTAIN SHALE AND SANDSTONE FRAGMENTS.
2. DH-19, SH-1 FAILED ALONG A SILTY SAND ZONE.

MONTANORE PROJECT

TAILINGS RETENTION DAM FOUNDATION
CU TRIAXIAL TESTS: P-Q STRESS PATHS

FIGURE F-8A



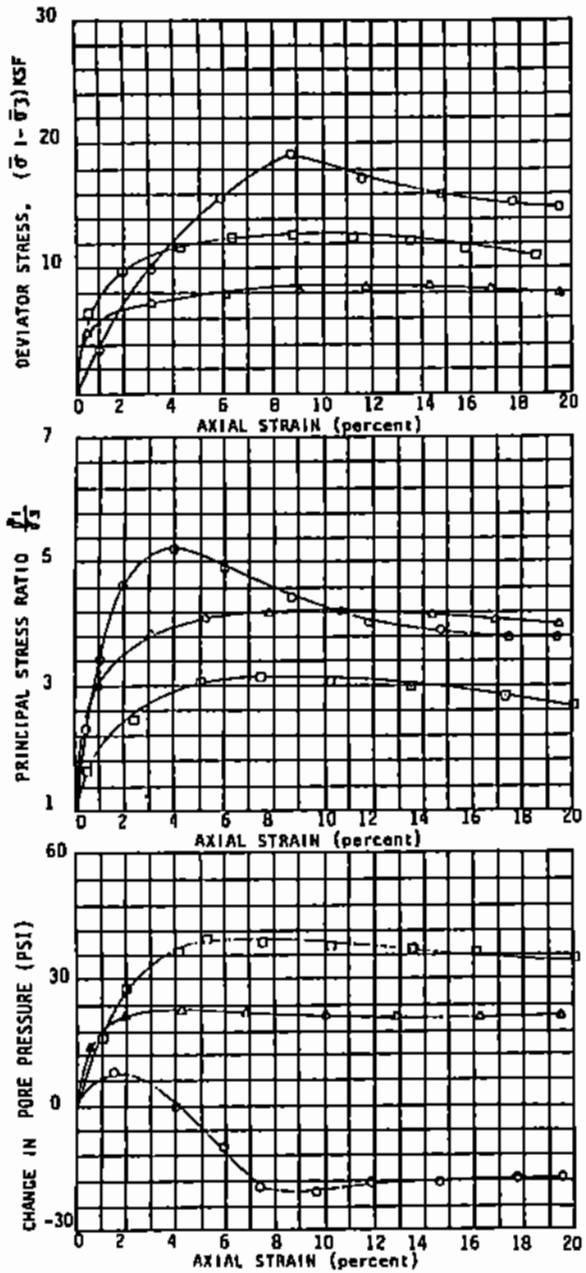
EFFECTIVE STRESS CIRCLES

TOTAL STRESS CIRCLES

MONTANORE PROJECT

TAILINGS RETENTION DAM FOUNDATION CU TRIAXIAL TESTS: MOHR ENVELOPE

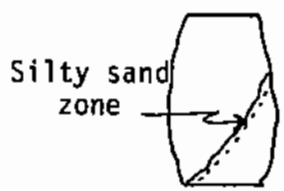
FIGURE F-8B



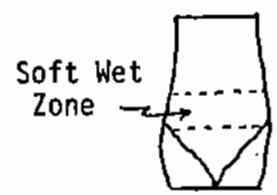
CONSOLIDATED UNDRAINED TRIAXIAL SHEAR TESTS

TEST NO. OR SYMBOL	BORING NO. AND DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	MOISTURE CONTENT (percent) Initial	MOISTURE CONTENT (percent) Final	PORE PRESSURE RESPONSE (percent)	Initial CONFINING PRESSURE $\bar{\sigma}_3$ PSI	HEIGHT TO DIAMETER RATIO	RATE OF STRAIN INCHES/MINUTE	Initial Specimen Dimensions (cm)
○ SH 1	DH 19 5'-7'	101.7	26.3	23.0	98	20	2.19	0.003	3.52 x 7.70
△ SH 7	DH 20 16'-18'	91.1	29.3	30.3	99	40	2.10	0.003	3.53 x 7.69
□ SH 6	DH 3A 21'-23'	103.0	23.0	20.8	99	80	2.17	0.003	3.56 x 7.73

Symbol ○



Symbol △

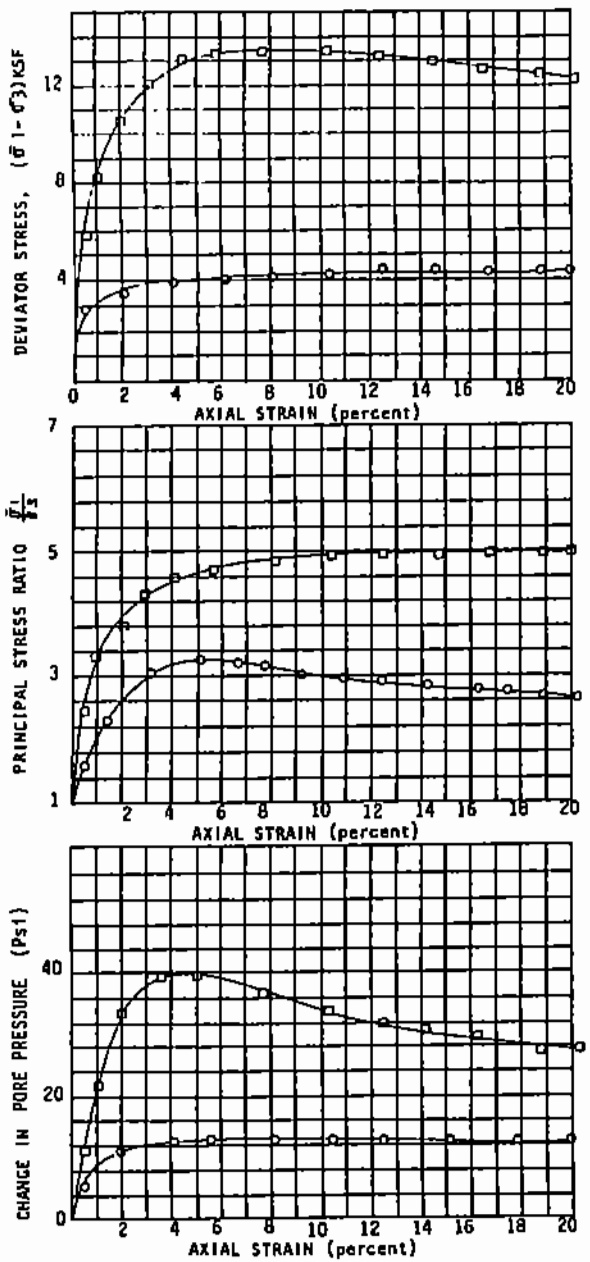


Symbol □

Post Shear Sketches

FIGURE F-8C SHEET 1 OF 2

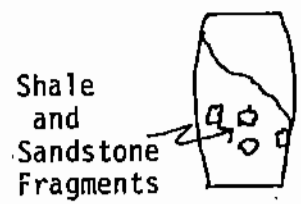
Chen-Northern, Inc.	TRIAXIAL SHEAR TEST RESULTS		
	Montanore Project M K Engineers		
	JOB NO.	DATE	PLATE NO.
	89-614	December, 1989	



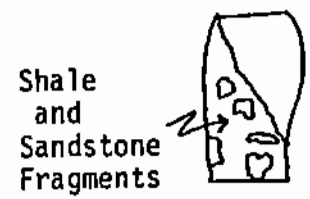
CONSOLIDATED UNDRAINED TRIAXIAL SHEAR TESTS

TEST NO OR SYMBOL	BORING NO. AND DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	MOISTURE CONTENT (percent): Initial	MOISTURE CONTENT (percent): Final	PORE PRESSURE RESPONSE (percent)	CONFINING PRESSURE σ3 psi	HEIGHT TO DIAMETER RATIO	RATE OF STRAIN INCHES/ MINUTE	Initial Specimen Dimensions (cm)
○	DH-20 8'-10'	97.7	15.3	22.1	98	20	2.18	0.006	3.56 x 7.77
	SH 3								
□	DH 3A 19'-21'	106.2	20.0	18.6	98	80	2.16	0.006	3.56 x 7.69
	SH 5								

Symbol ○



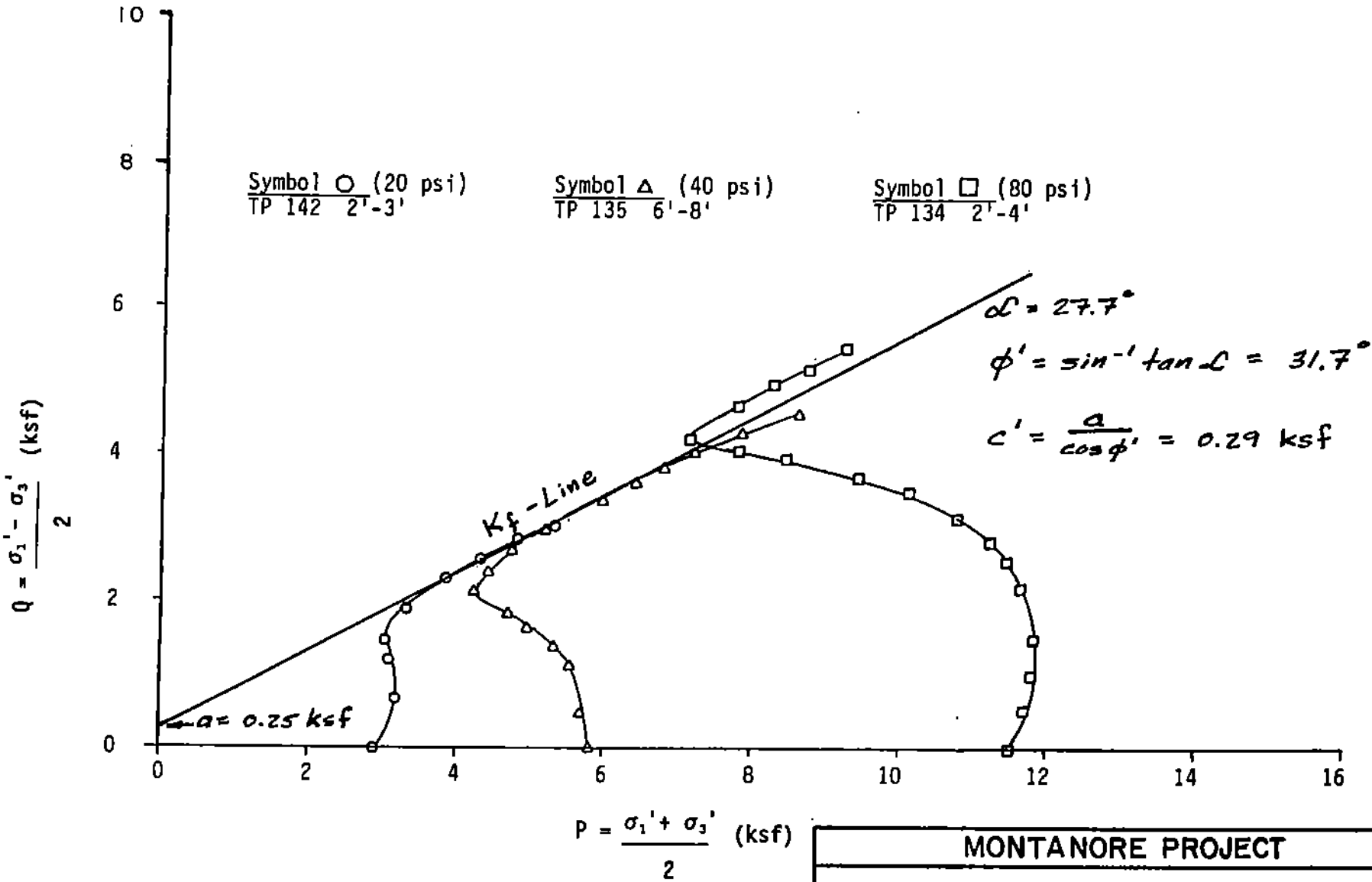
Symbol □



Post Shear Sketches

FIGURE F-8C SHEET 2 OF 2

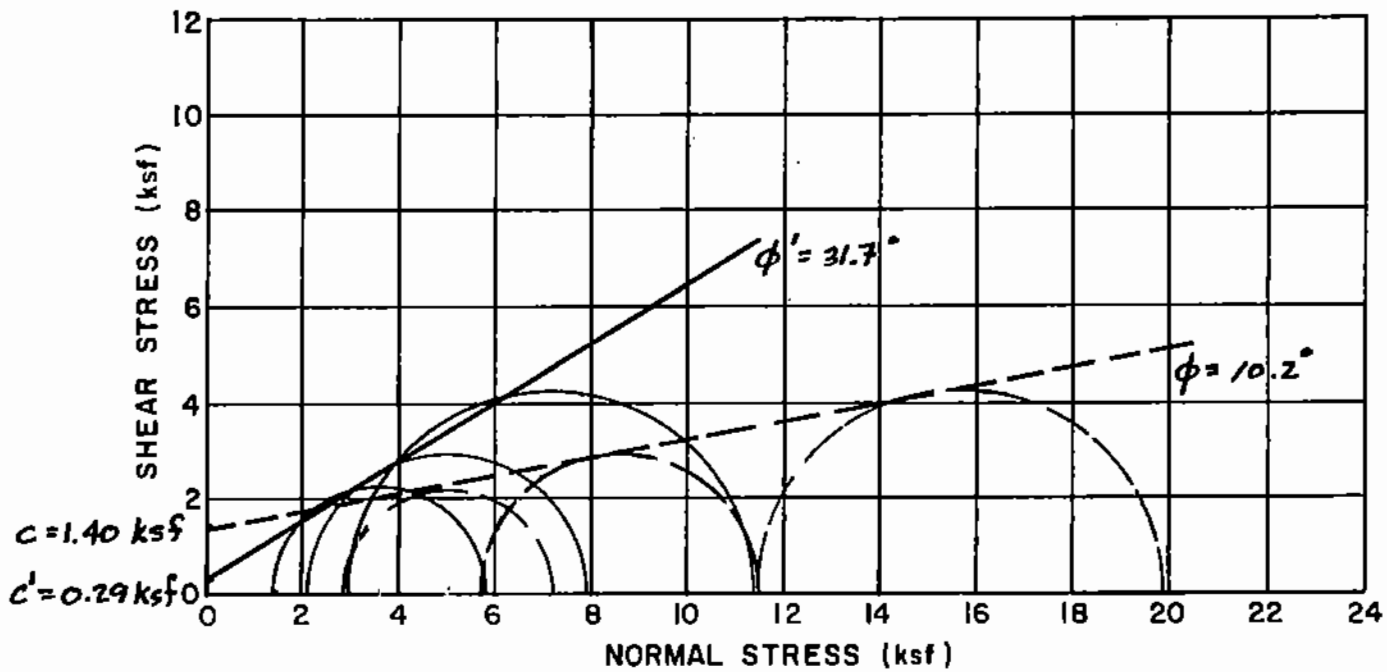
Chen-Northern, Inc.	TRIAXIAL SHEAR TEST RESULTS		
	MONTANORE PROJECT M K ENGINEERS		
	JOB NO.	DATE	PLATE NO.
	89-614	January, 1990	



MONTANORE PROJECT

COMPACTED ON-SITE EARTHFILL
CU TRIAXIAL TESTS: P-Q STRESS PATHS

FIGURE F-9A



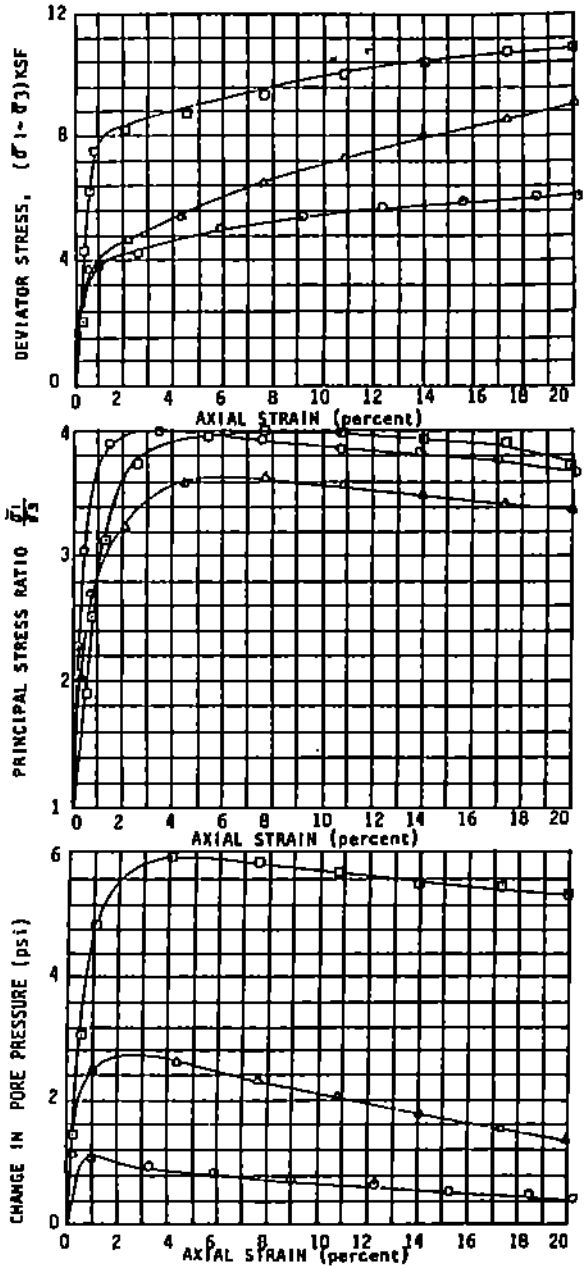
EFFECTIVE STRESS CIRCLES

TOTAL STRESS CIRCLES

MONTANORE PROJECT

COMPACTED ON-SITE EARTHFILL CU TRIAXIAL TESTS: MOHR ENVELOPE

FIGURE F-9B

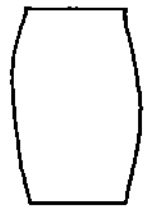


CONSOLIDATED UNDRAINED TRIAXIAL SHEAR TESTS

TEST NO. OR SYMBOL	BORING NO. AND DEPTH	SAMPLE DATA					HEIGHT TO DIAMETER RATIO	RATE OF STRAIN INCHES/ MINUTE	Initial Specimen Dimensions (Inches)
		DRY DENSITY (pcf)	MOISTURE CONTENT (percent)		PORE PRESSURE RESPONSE (percent)	CONFINING PRESSURE σ3 psi			
			Initial	Final					
○	TP 142 2'-3'	119.8	10.1	15.4	99	20	2.14	0.009	6.00 x 2.80
△	TP 135 6'-8'	119.4	10.5	14.9	99	40	2.14	0.009	6.00 x 2.80
□	TP 134 2'-4'	118.4	11.4	12.4	98	80	2.14	0.009	6.00 x 2.80

Symbol ○

Symbol △



Symbol □

Post Shear Sketches

FIGURE F-9C

Chen-Northern, Inc.	TRIAXIAL SHEAR TEST RESULTS		
	MONTANORE PROJECT M-K ENGINEERS		
	JOB NO.	DATE	PLATE NO.
	89-614	February 1990	

NFT 151

MOISTURE-DENSITY RELATIONSHIP DATA

Northern
Engineering and Testing, Inc.
528 Smelter Avenue
P.O. Box 951
Great Falls, MT 59403
(406) 453-1641

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO: Morrison-Knudsen Engineers, Inc.
San Francisco, California

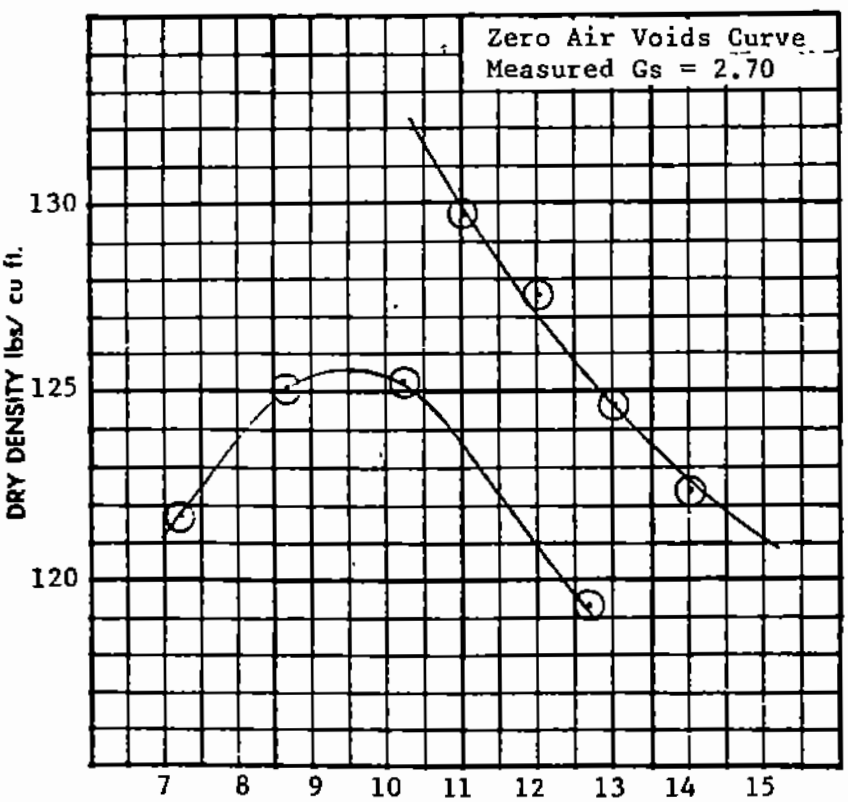
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32287
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Little Cherry Site
SAMPLE LOCATION: TP-106, 6.0'-8.0', S-1

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
N/A		

MOISTURE-DENSITY RELATIONSHIP



VISUAL CLASSIFICATION
Silty SAND
SPECIFIC GRAVITY: Fine Aggregate-2.70
SPECIFIC GRAVITY: Coarse Aggregate-2.69

TEST PROCEDURE ASTM D698 Method C
MAX. DENSITY: 125.5
OPT. MOIST.: 9.5
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

DISTRIBUTION:

AS A MUTUAL PROTECTION TO CLIENTS THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS, AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING

Northern
Engineering and Testing, Inc
528 Smelter Avenue
P.O. Box 951
Great Falls, MT 59403
(406) 453-1641

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

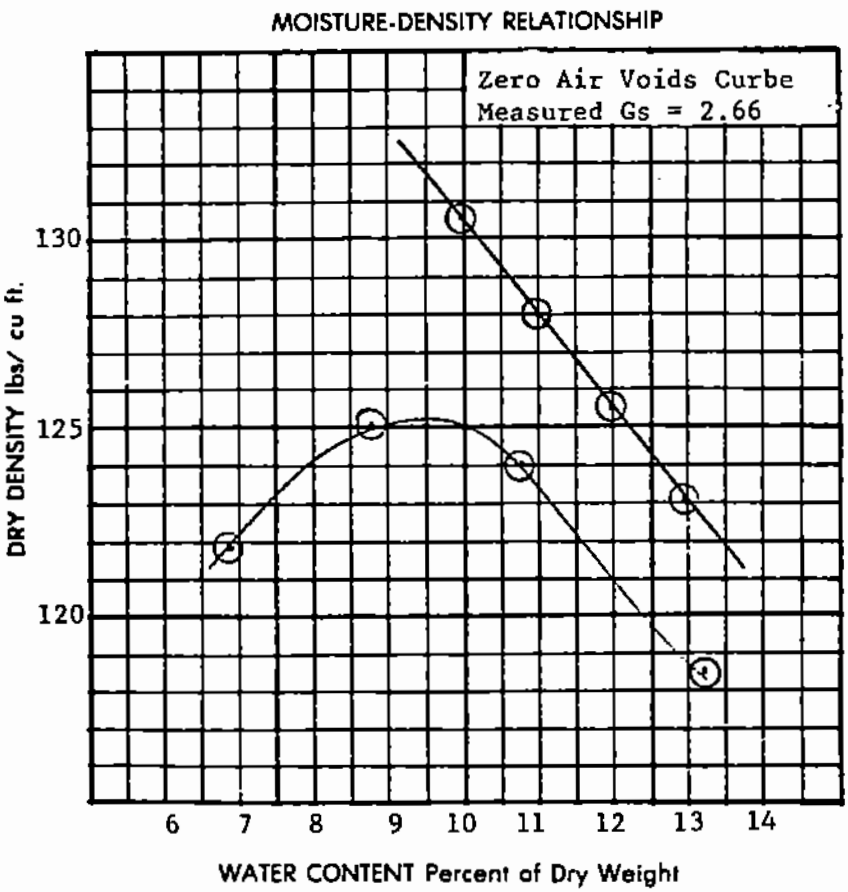
REPORT TO: Morrison-Knudsen Engineering Inc.
San Francisco, California

DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32288
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Little Cherry Site
SAMPLE LOCATION: TP-107, 8.0'-9.0', S-1

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
	N/A	



VISUAL CLASSIFICATION
Silty SAND
SPECIFIC GRAVITY: Fine aggregate-2.69
SPECIFIC GRAVITY: Coarse aggregate-2.65

TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 125.2
OPT. MOIST.: 9.4
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

DISTRIBUTION:

AS A MUTUAL PROTECTION TO CLIENTS THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS, AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING

Chen Northern, Inc.

Consulting Engineers & Scientists

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

☐ GREAT FALLS
528 SMELTER AVENUE
P. O. BOX 951
GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070

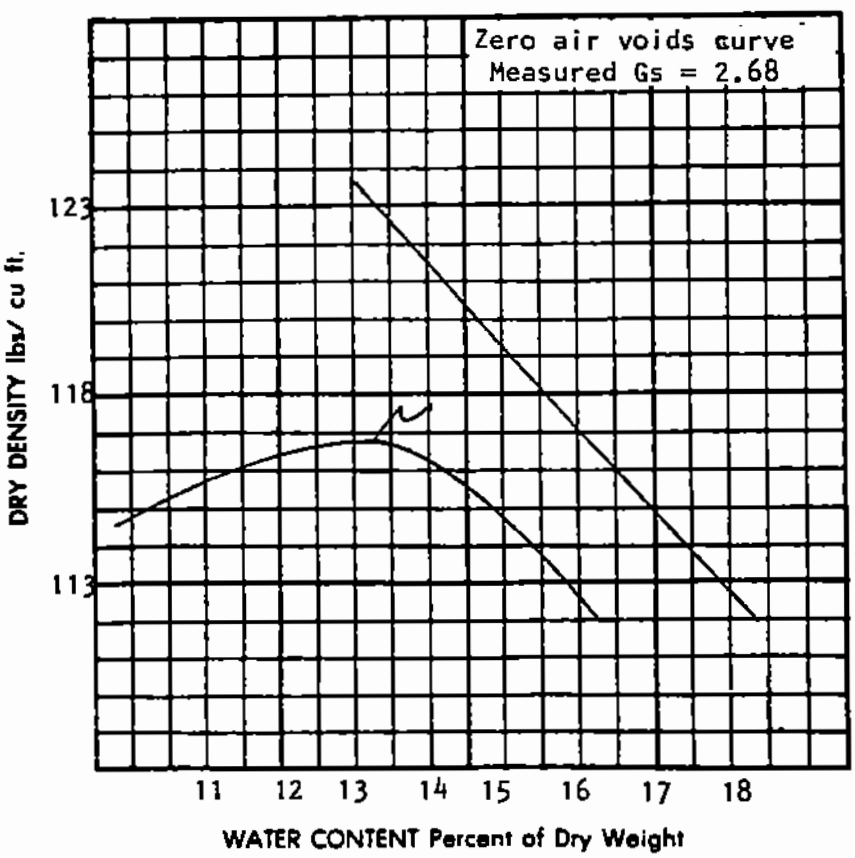
REPORT TO:
MORRISON-KNUDSEN ENGINEERS, INC.
ATTN: MICHAEL P. FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: Dec. 27,. 1989
JOB NUMBER: 88-152-2
SHEET: 1 OF 1
INVOICE NO.: 84837
LAB NO.: 39455
DATE SAMPLED: --
DATE RECEIVED: --
SAMPLED BY: Chen-Northern

PROJECT: Montana Silver Venture Mine
CONTRACTOR: N/R
SAMPLE LOCATION: TP 128, S-1, 3.0' - 5.0'

MATERIAL USE: Subgrade

MOISTURE-DENSITY RELATIONSHIP



MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
4"	100	
3"	96	
2"	92	
1-1/2"	92	
1"	90	
3/4"	90	
1/2"	88	
3/8"	87	
No. 4	85	
No. 10	83	
No. 20	80	
No. 40	79	
No. 80	76	
No. 200 (wash)	71	

UNIFIED CLASSIFICATION (ASTM D2487)
Lean CLAY with Gravel (CL)
SPECIFIC GRAVITY: 2.68
LIQUID LIMIT: 26
PLASTICITY INDEX: 10

TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 116.8
OPT. MOIST.: 13.3
RAMMER TYPE: 5.5 pound manual
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/A

REMARKS:

DISTRIBUTION:

Reviewed By: Kenneth D. Murnelé

AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS, AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING.

Chen Northern, Inc.

Consulting Engineers & Scientists

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

☐ GREAT FALLS
528 SMELTER AVENUE
P. O. BOX 951
GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070

REPORT TO:

MORRISON-KNUDSEN ENGINEERS, INC.
ATTN: MICHAEL P. FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: December 27, 1989
JOB NUMBER: 88-152-2
SHEET: 1 OF 1
INVOICE NO.: 84837
LAB NO.: 40747
DATE SAMPLED: --
DATE RECEIVED: --
SAMPLED BY: Chen-Northern

PROJECT: Montana Silver Venture Mine
CONTRACTOR: N/R
SAMPLE LOCATION: TP 133, S-1, 1.0' - 3.0'

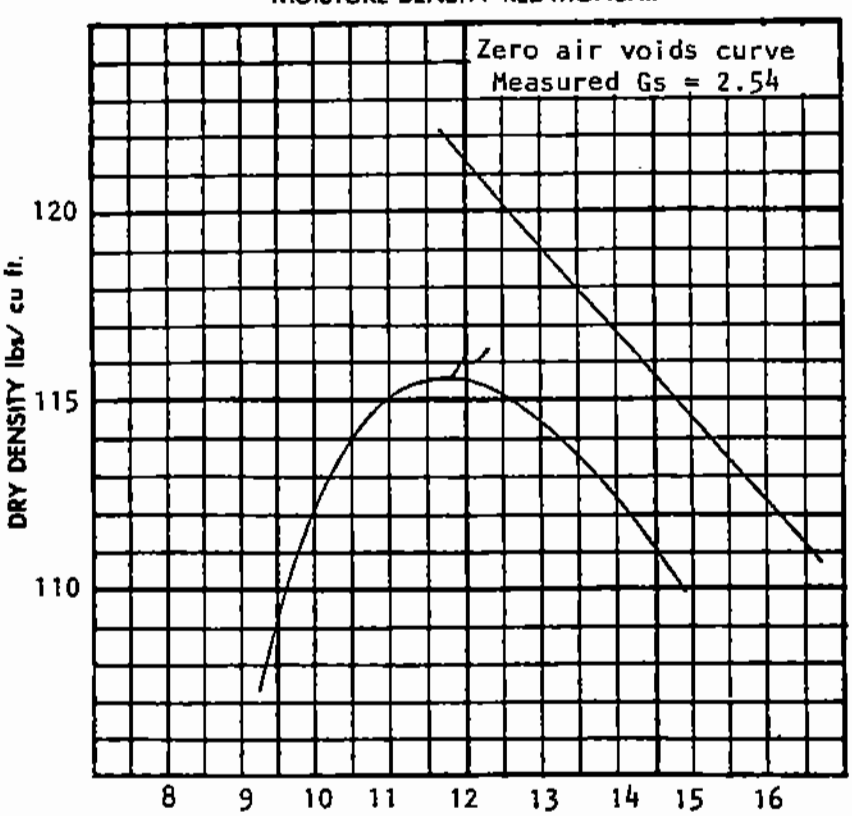
MATERIAL USE: Subgrade

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
4"	100	
3"	97	
2"	93	
1-1/2"	88	
1"	81	
3/4"	74	
1/2"	64	
3/8"	57	
No. 4	45	
No. 10	34	
No. 20	28	
No. 40	24	
No. 80	20	
No. 200(wash)	16	

UNIFIED CLASSIFICATION (ASTM D2487)
Silty GRAVEL with Sand (GM)
SPECIFIC GRAVITY: 2.54
LIQUID LIMIT: N/R
PLASTICITY INDEX: N/R

MOISTURE-DENSITY RELATIONSHIP



TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 115.5
OPT. MOIST.: 11.8
RAMMER TYPE: 5.5 pound manual
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/A

REMARKS:

DISTRIBUTION:

Reviewed By: Kenneth D. Murnelli

AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS, AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING.

Chen Northern, Inc.

Consulting Engineers & Scientists

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

☐ GREAT FALLS
528 SMELTER AVENUE
P. O. BOX 951
GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070

REPORT TO:
MORRISON-KNUDSEN ENGINEERS, INC.
ATTN: MICHAEL P. FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: December 27, 1989
JOB NUMBER: 88-152-2
SHEET: 1 OF 1
INVOICE NO.: 84837
LAB NO.: 39466
DATE SAMPLED: --
DATE RECEIVED: --
SAMPLED BY: Chen-Northern

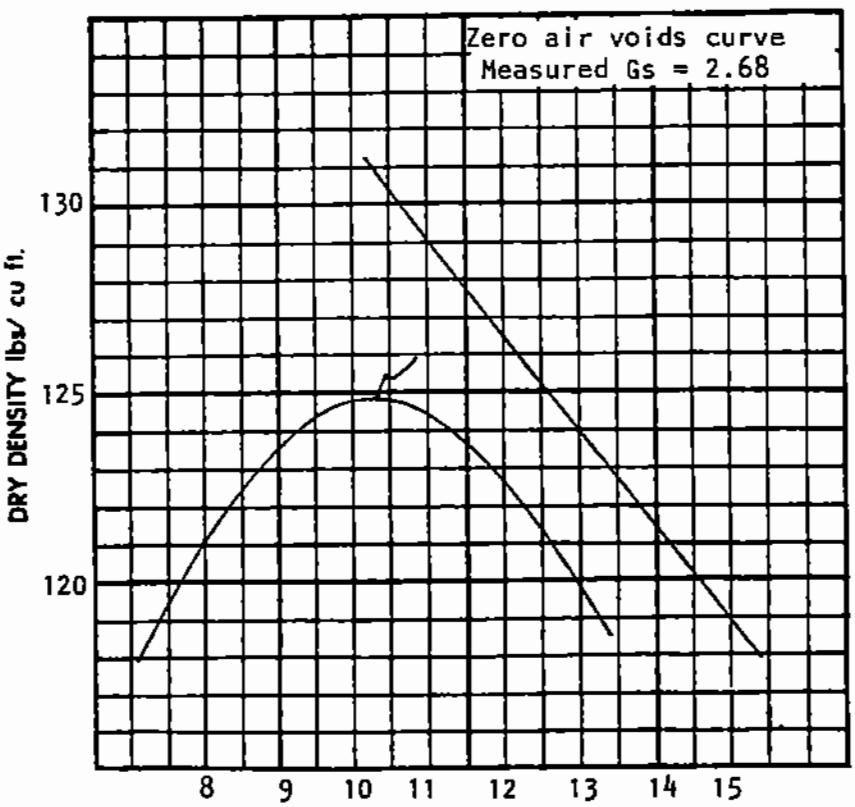
PROJECT: Montana Silver Venture Mine
CONTRACTOR: N/R
SAMPLE LOCATION: TP 142, S-1, 2.0' - 3.0'

MATERIAL USE: Subgrade

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
3"	100	
2"	99	
1-1/2"	97	
1"	94	
3/4"	92	
1/2"	88	
3/8"	87	
No. 4	82	
No. 10	75	
No. 20	68	
No. 40	63	
No. 80	59	
No. 200(wash)	53	

MOISTURE-DENSITY RELATIONSHIP



UNIFIED CLASSIFICATION (ASTM D2487)
Sandy Lean CLAY with Gravel (CL)
SPECIFIC GRAVITY: 2.68
LIQUID LIMIT: N/R
PLASTICITY INDEX: N/R

TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 124.9
OPT. MOIST.: 10.3
RAMMER TYPE: 5.5 pound manual
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/A

REMARKS:

DISTRIBUTION:

Reviewed By: Kenneth D. Murnelé

AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES, ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF OUR CLIENTS, AND AUTHORIZATION FOR PUBLICATION OF STATEMENTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING OUR REPORTS IS RESERVED PENDING OUR WRITTEN APPROVAL. SAMPLES WILL BE DISPOSED OF AFTER TESTING IS COMPLETED UNLESS OTHER ARRANGEMENTS ARE AGREED TO IN WRITING.

1988 BORING GRAIN SIZE CURVES

Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: USB-1, SPT-2, 10.0'-11.5'

Classification: Lean CLAY w/Sand (CL)

Sample No. 32317

Job No. 88-152

Date August 1988

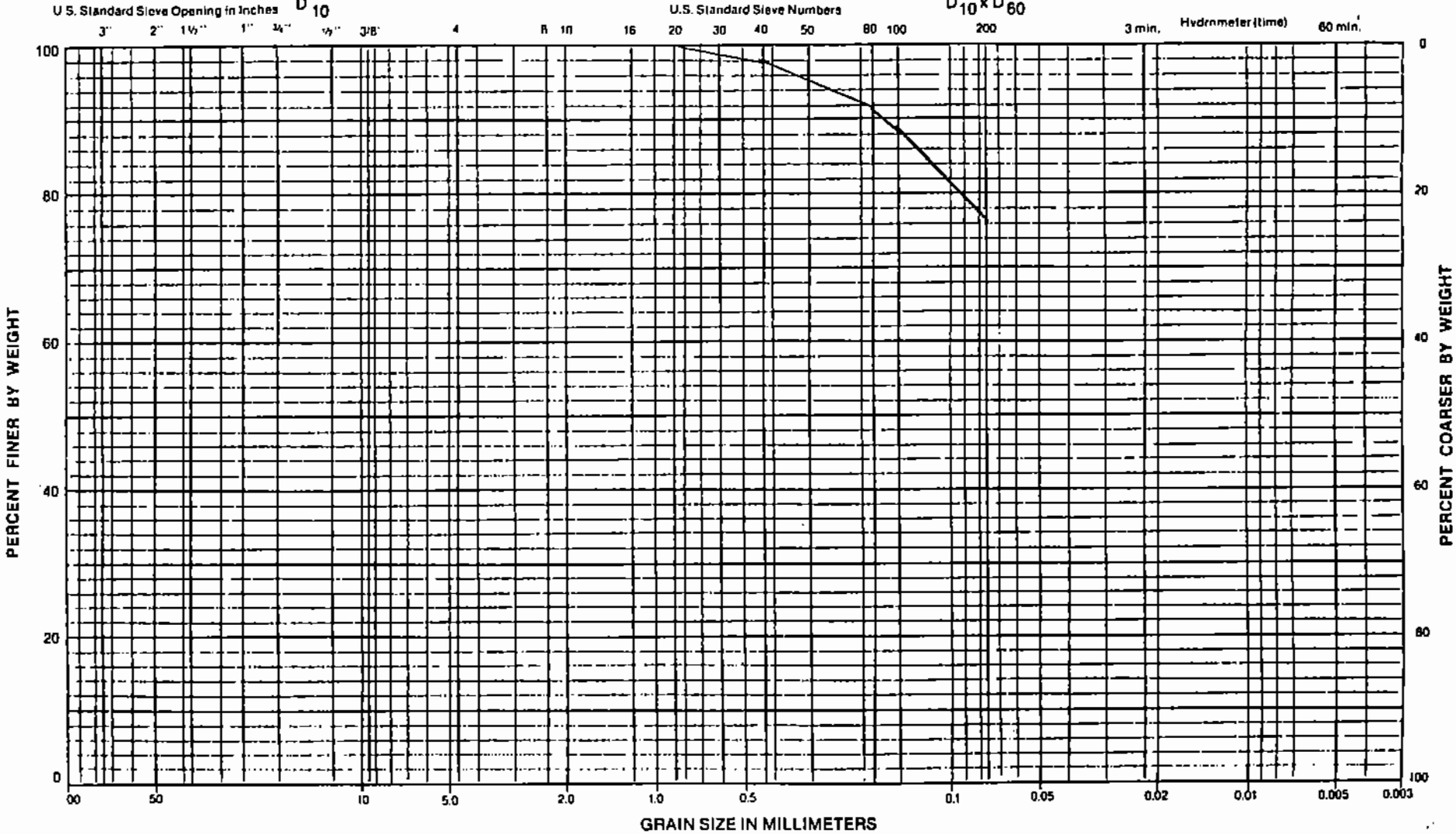
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: USB-1, SPT-3, 15.0'-16.5'

Classification: Sandy Silty CLAY (CL-ML)

Sample No. 32318

Job No. 88-152

Date August 1988

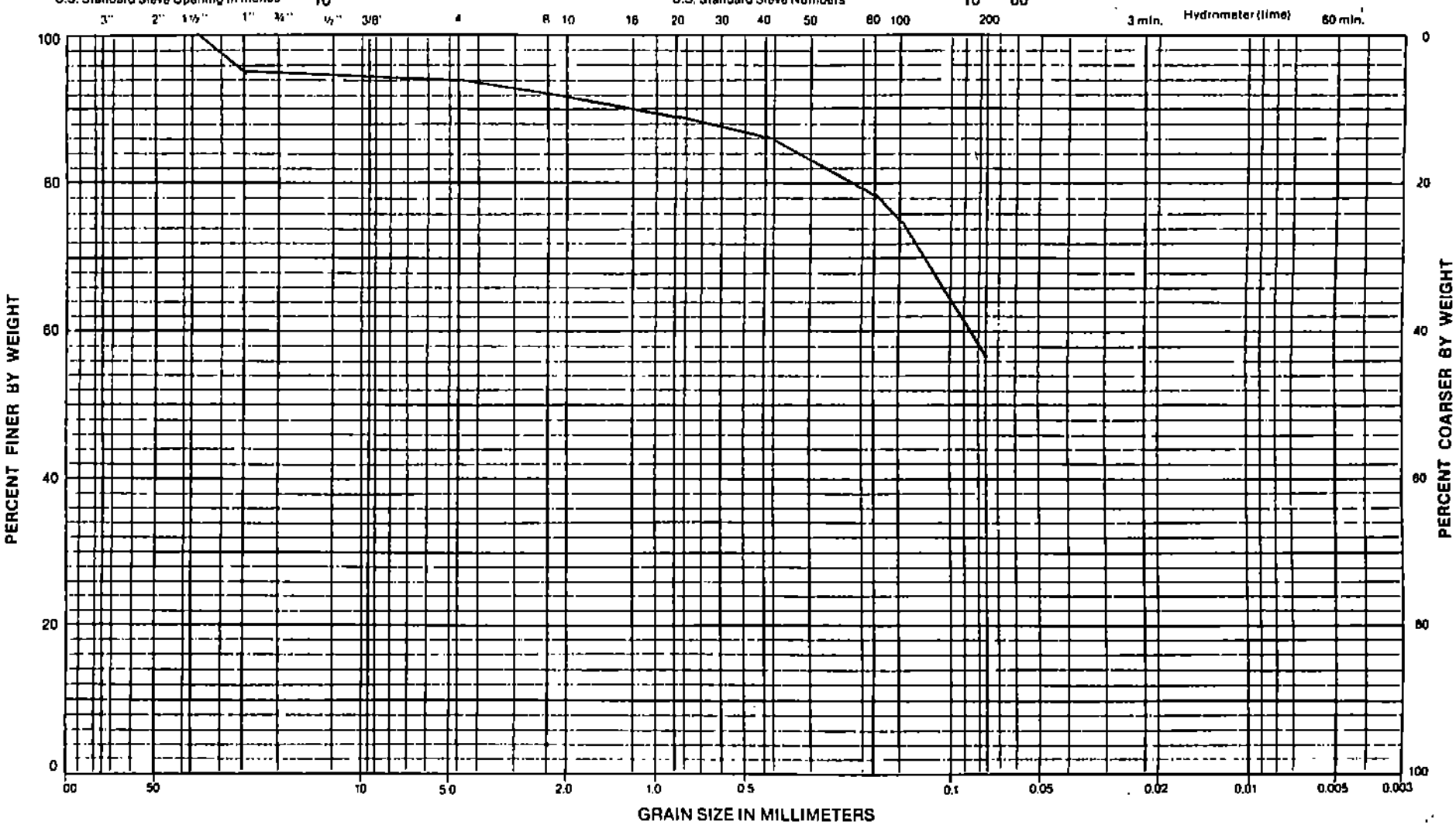
Moisture Content -- %

Liquid Limit 25 %

Plasticity Index 4 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Sample No. 32319

Location: USB-1, SPT-4, 20.0'-21.5'

Job No. 88-152

Classification Silty Clayey SAND w/Gravel (SC-SM)

Date August 1988

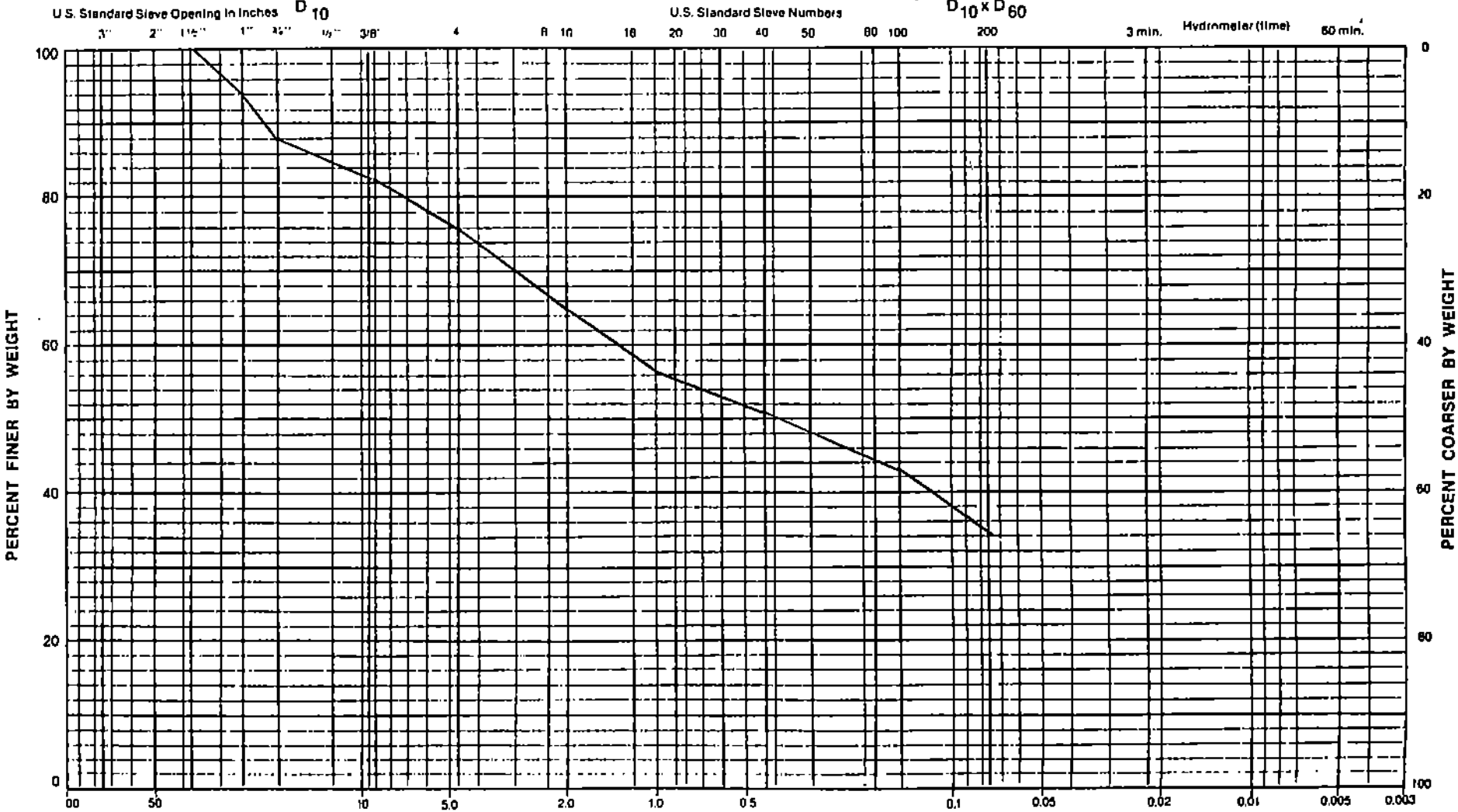
Moisture Content -- %

Liquid Limit * %

Plasticity Index * %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



* - Insufficient Sample

Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Sample No. 32329

Location: USB-2, SPT-3, 12.5' - 13.2'

Job No. 88-152

Classification Silty Clayey SAND w/Gravel (SC-SM)

Date August 1988

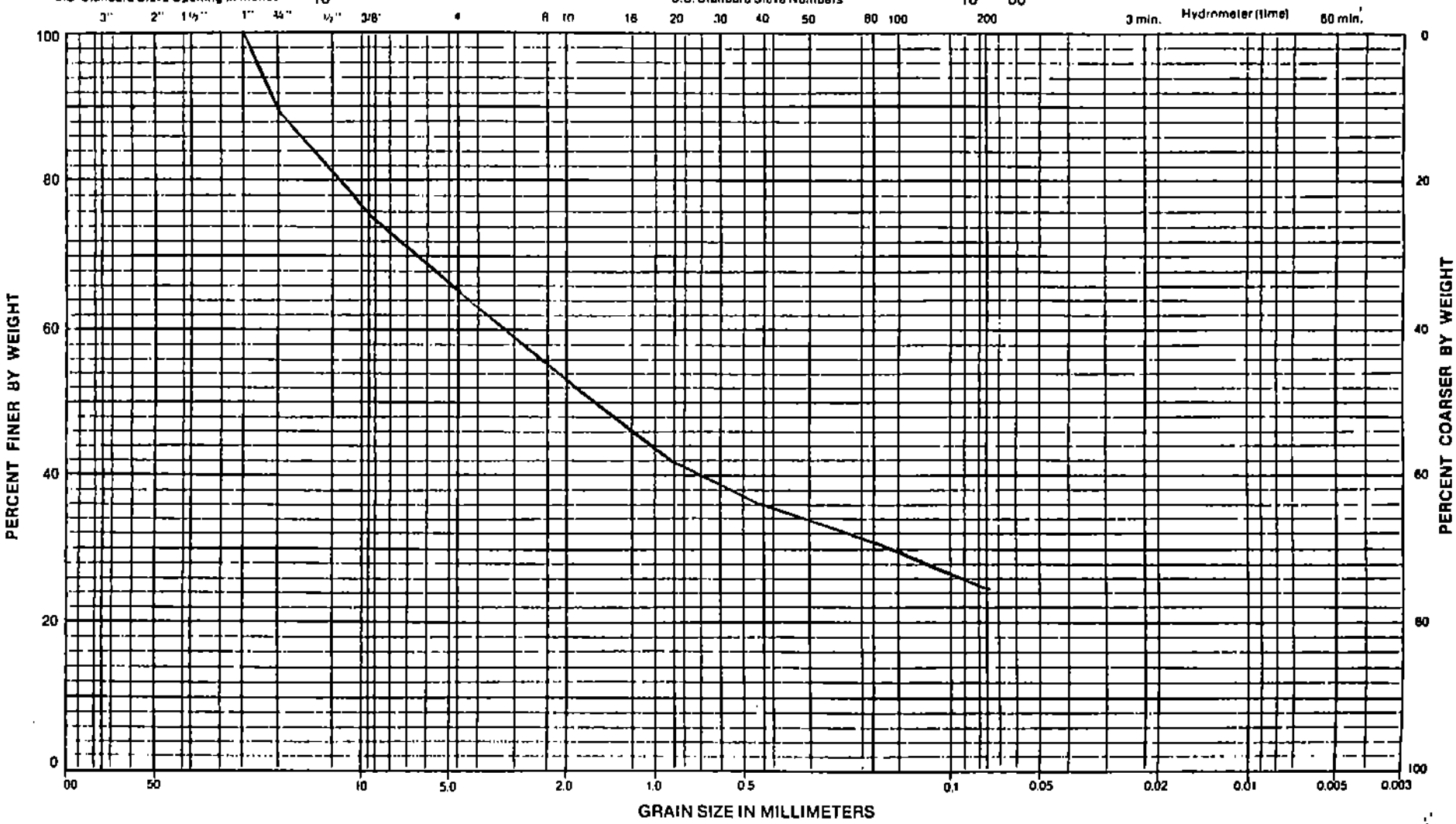
Moisture Content 4 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Sample No. 32338

Location: Little Cherry Site, USB-3, SP-3, 12.5'-14.0'

Job No. 88-152

Classification Silty SAND with Gravel

Date October 1988

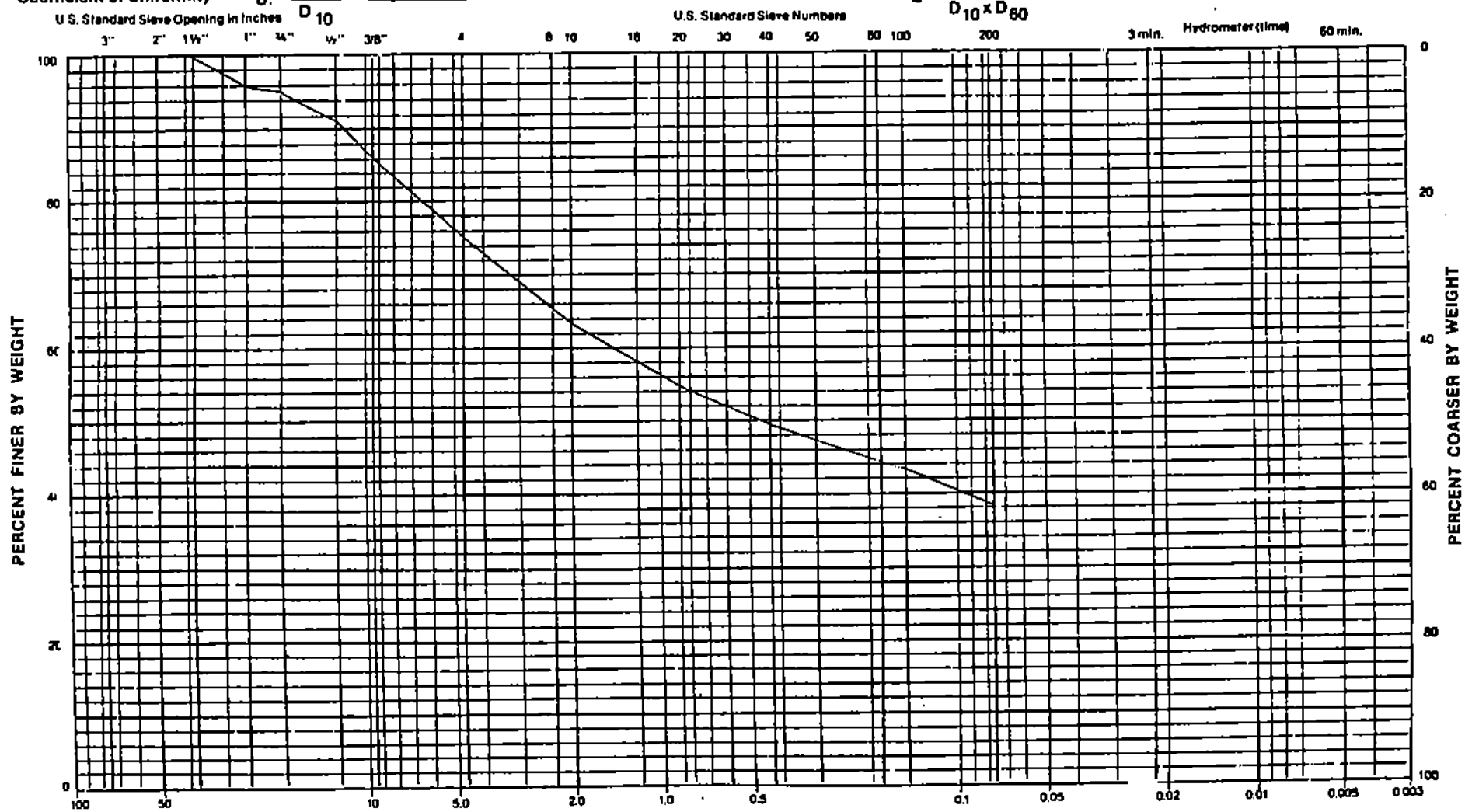
Moisture Content 15 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

NET-105

Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Sample No. 32971

Location: Little Cherry Site, USB-4, SPT-2, 5.0'-6.5'

Job No. 88-152

Classification: Clayey GRAVEL with Sand

Date: October 1988

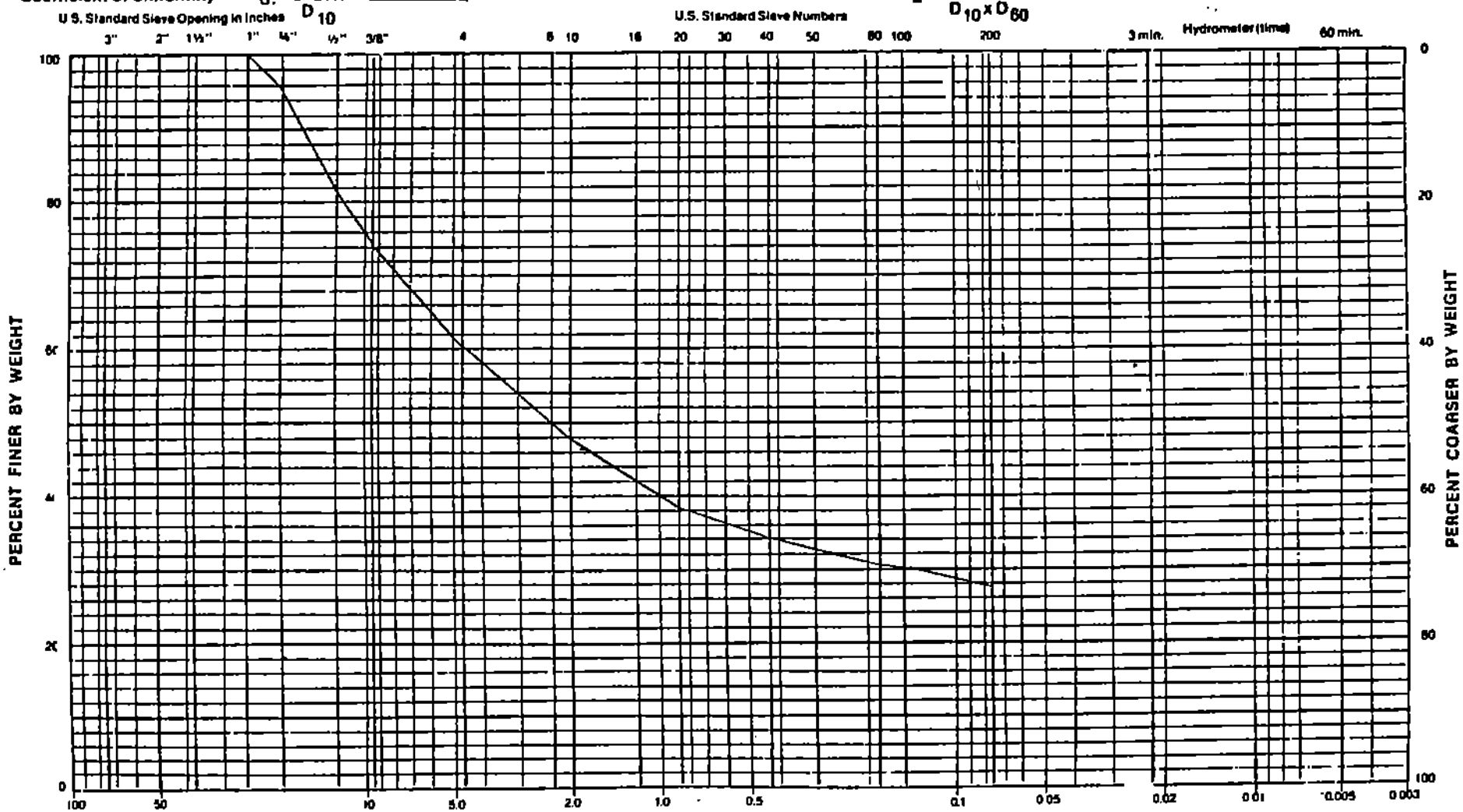
Moisture Content: -- %

Liquid Limit: -- %

Plasticity Index: -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

NET-105

Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Sample No. 32976

Location: Little Cherry Site, USB-5, SPT-3, 20.0'-21.5'

Job No. 88-152

Classification Lean CLAY with Sand

Date October 1988

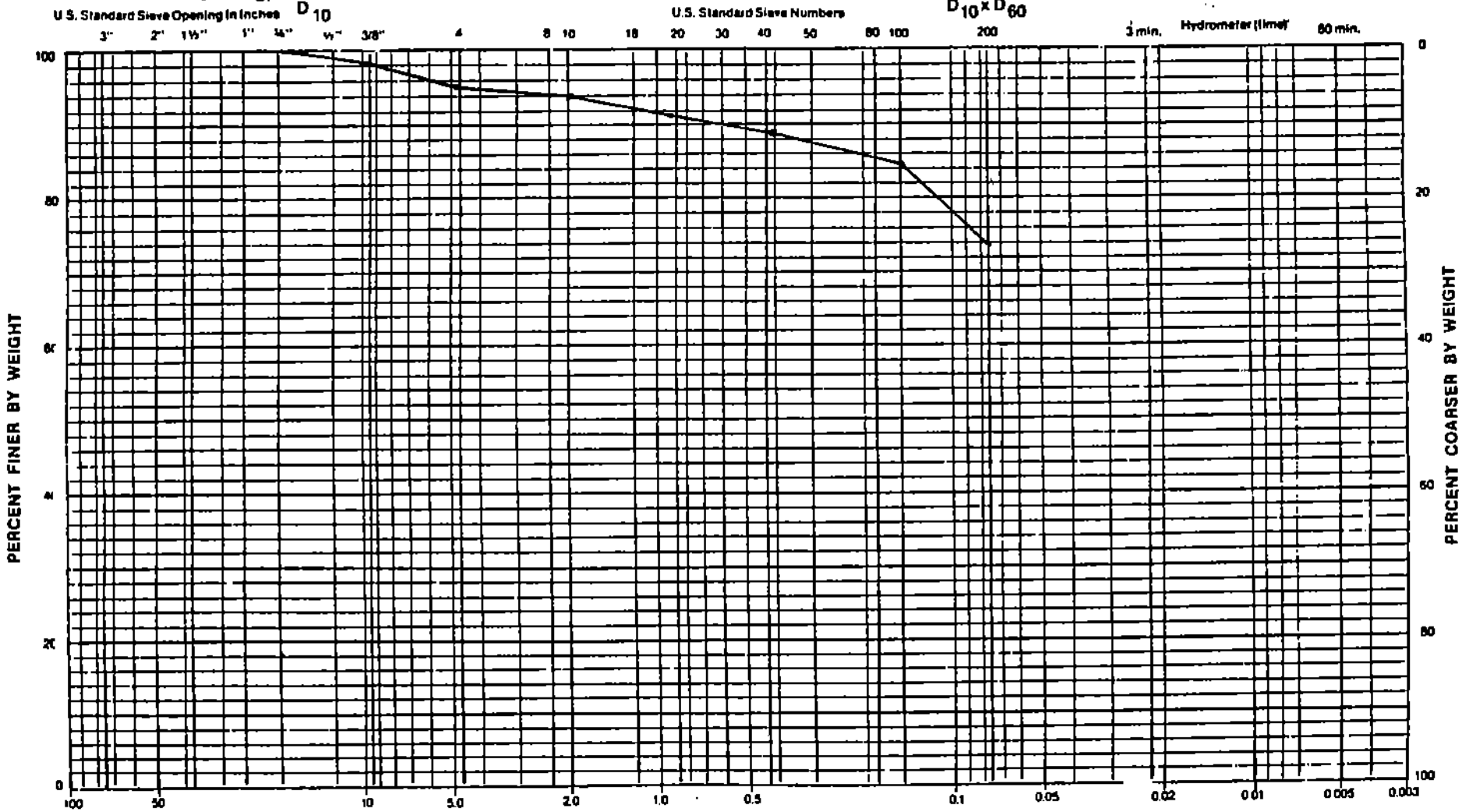
Moisture Content --%

Liquid Limit --%

Plasticity Index --%

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

NET-105

1989 BORING GRAIN SIZE CURVES

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-1, S-1, 4.0' - 5.5'

Classification Sandy Silty CLAY with Gravel (CL-ML)

Sample No. 40612

Job No. 88-152-2

Date 12/06/89

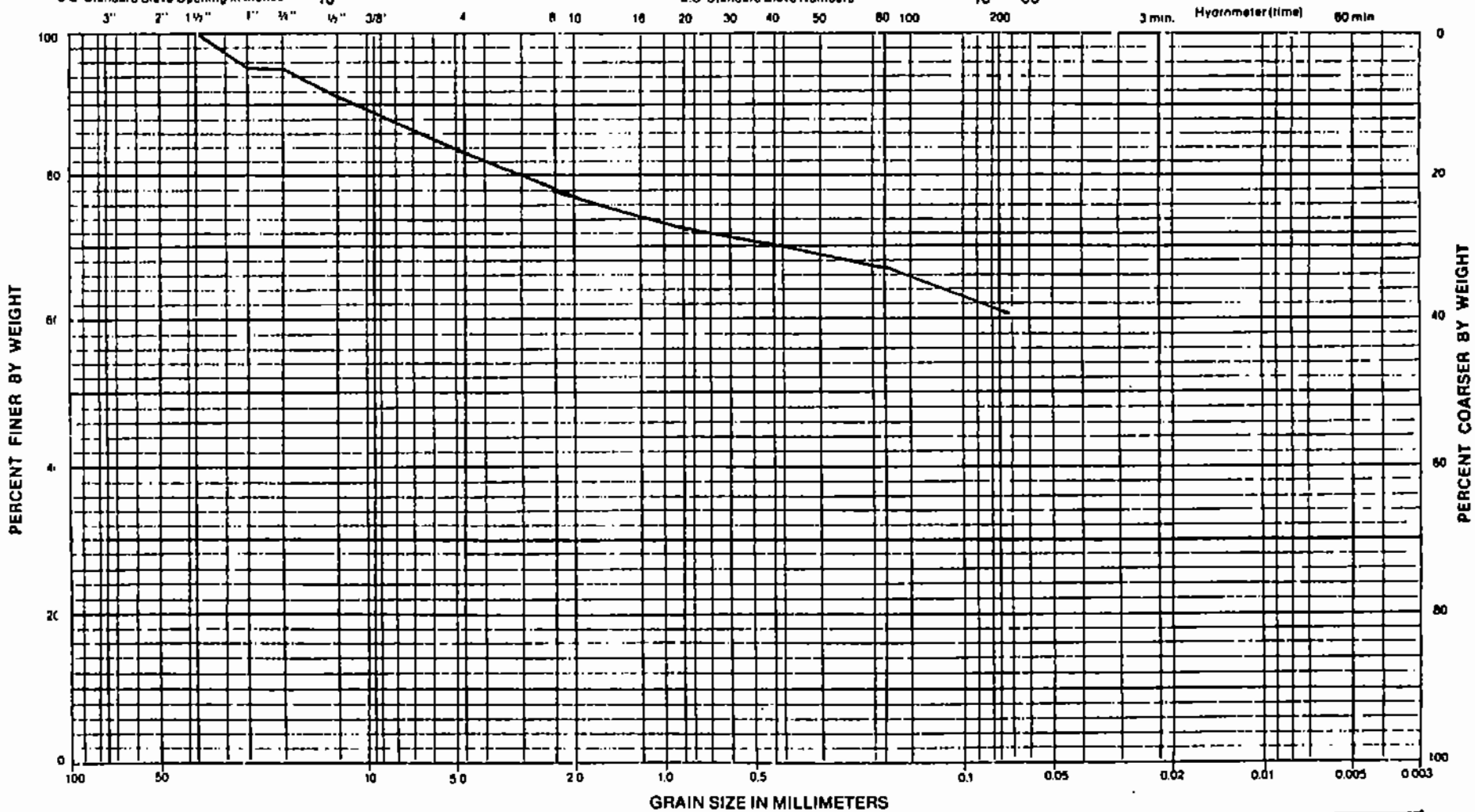
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/88) CN-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-1, S-3, 23.0' - 24.5'

Classification Sandy Lean CLAY (CL)

Moisture Content 19 %

Sample No. 40615

Job No. 88-152-2

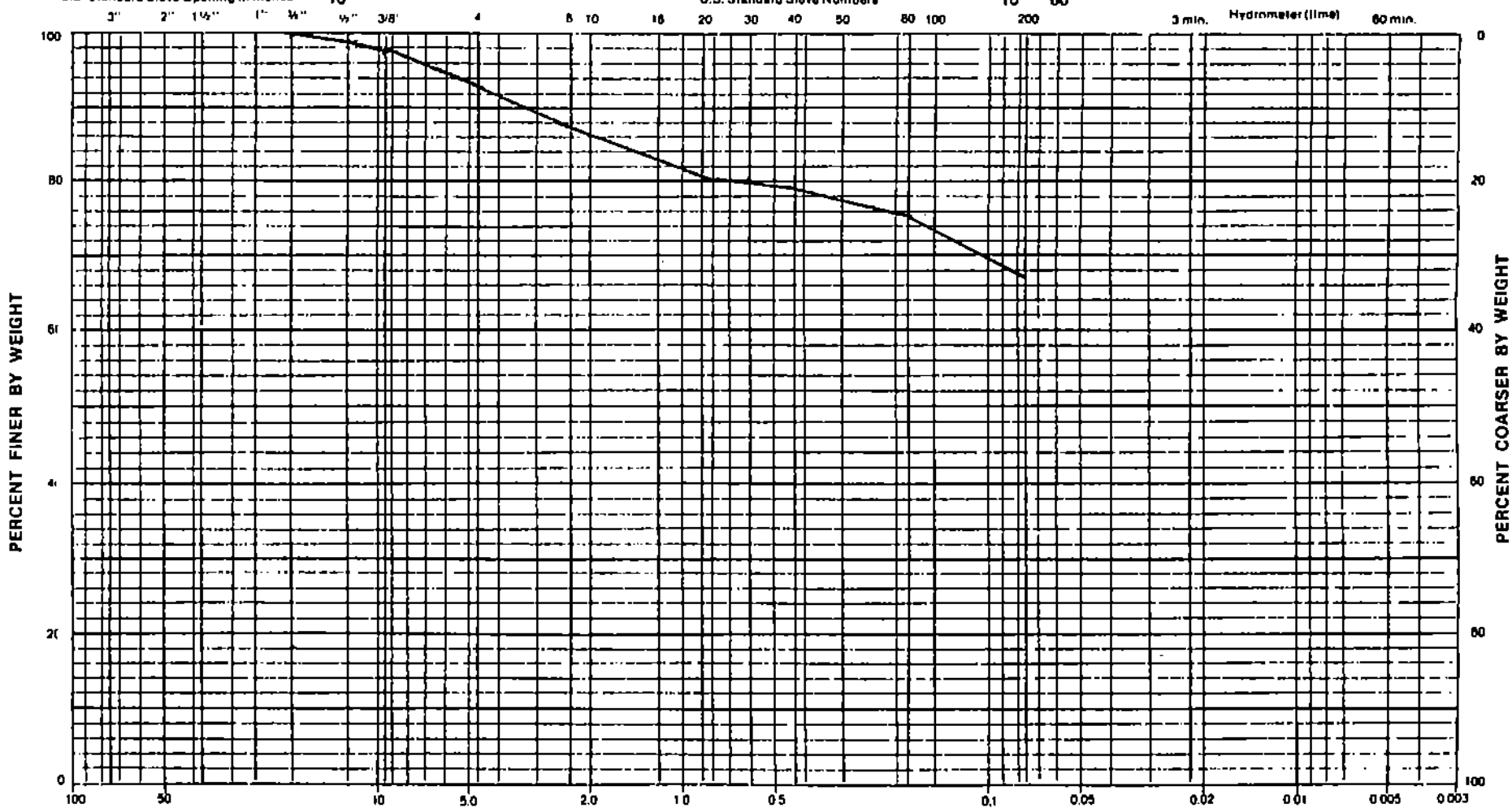
Date 12/06/89

Liquid Limit 22 %

Plasticity Index 4 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CN-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-2, S-1, 4.0' - 5.5'

Classification Sandy SILT with Gravel (ML)

Moisture Content 16 %

Liquid Limit 20 %

Sample No. 40618

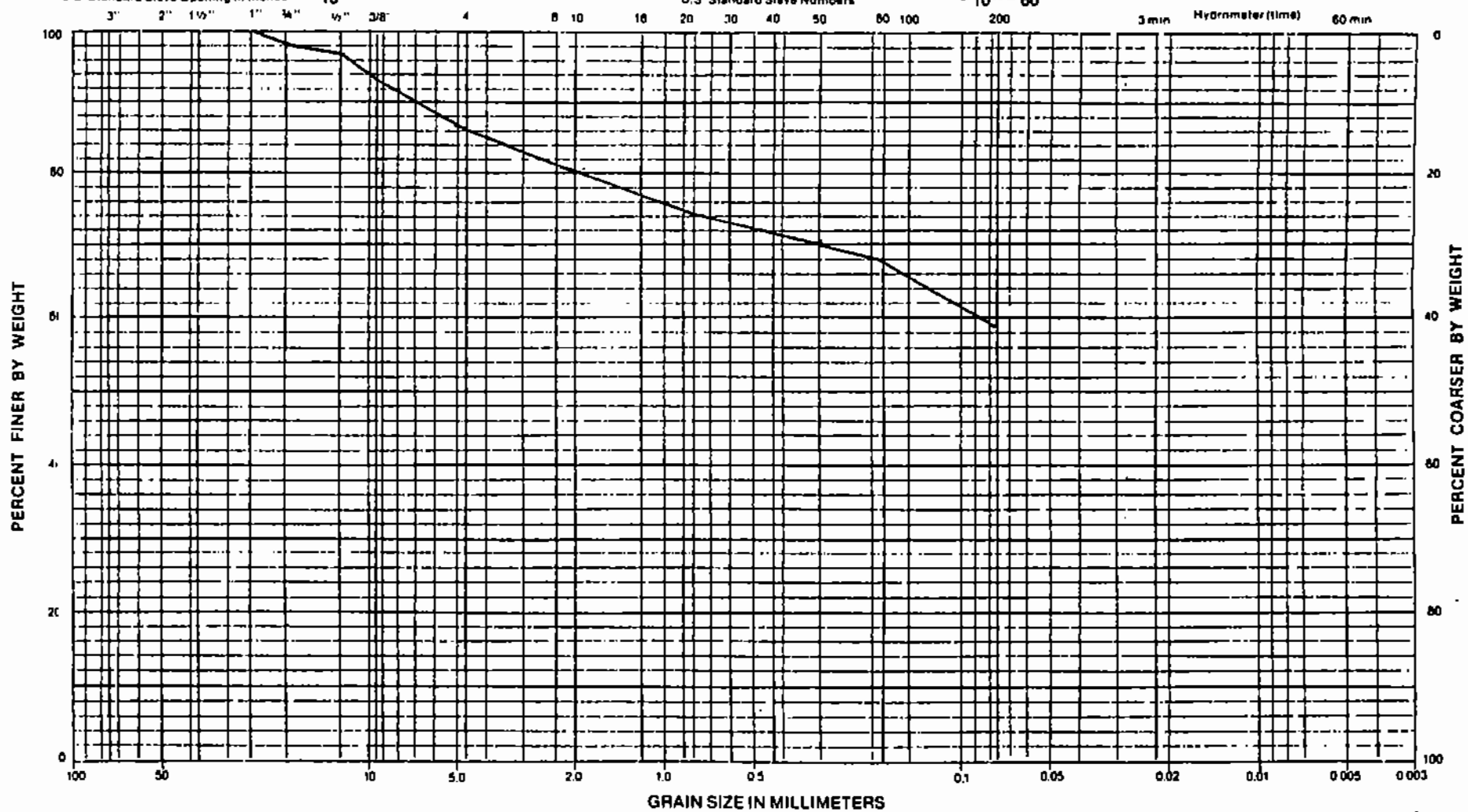
Job No. 88-152-2

Date 12/06/89

Plasticity Index 3 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/88) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-2, S-1, 12.0' - 12.5'

Classification Lean CLAY with Sand (CL)

Moisture Content -- %

Liquid Limit 33 %

Sample No. 40945

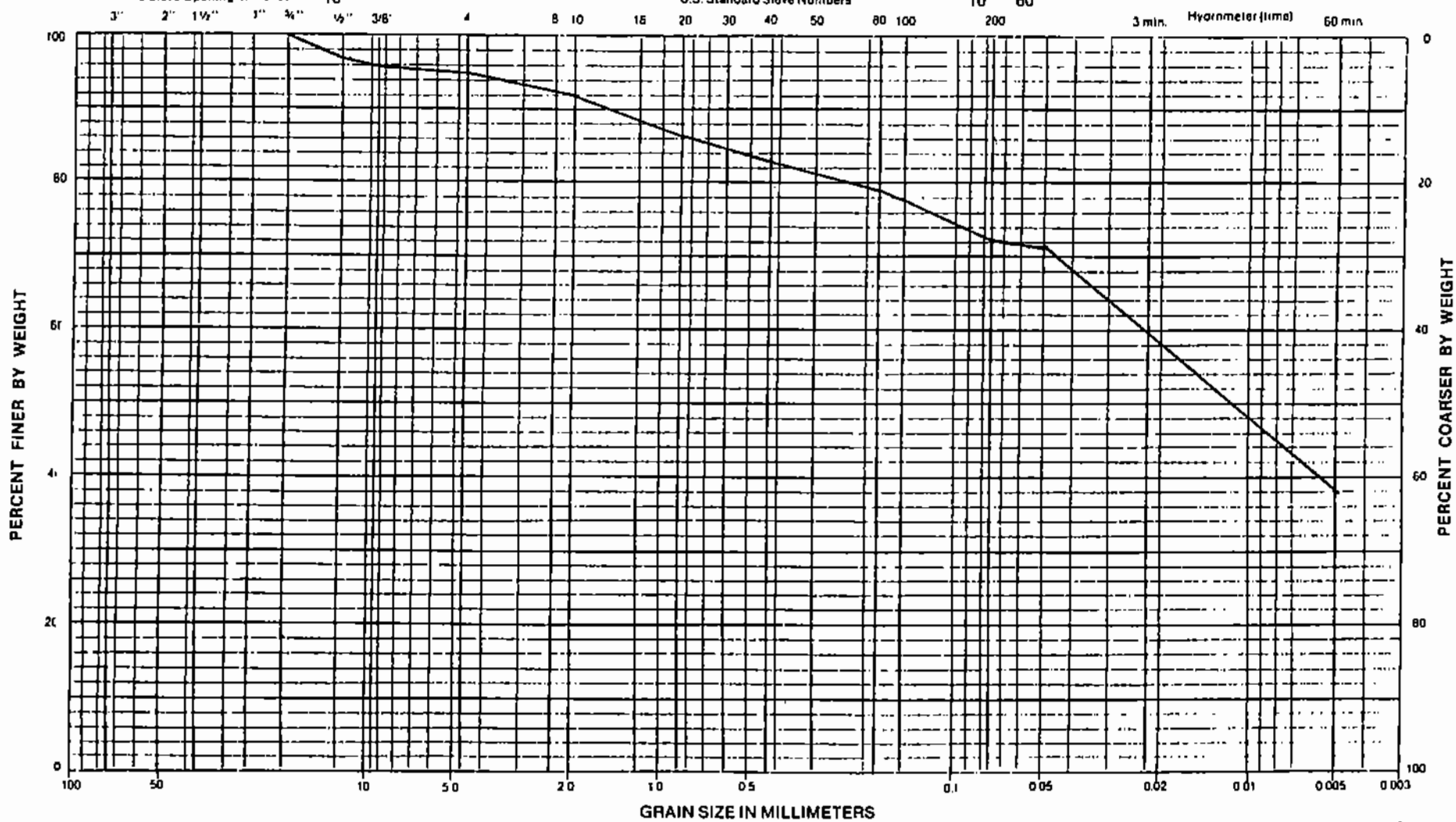
Job No. 88-152-2

Date 12/18/89

Plasticity Index 17 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-3, S-1, 5.0' - 6.5'

Classification Sandy Silty CLAY (CL-ML)

Moisture Content 20 %

Sample No. 40619

Job No. 88-152-2

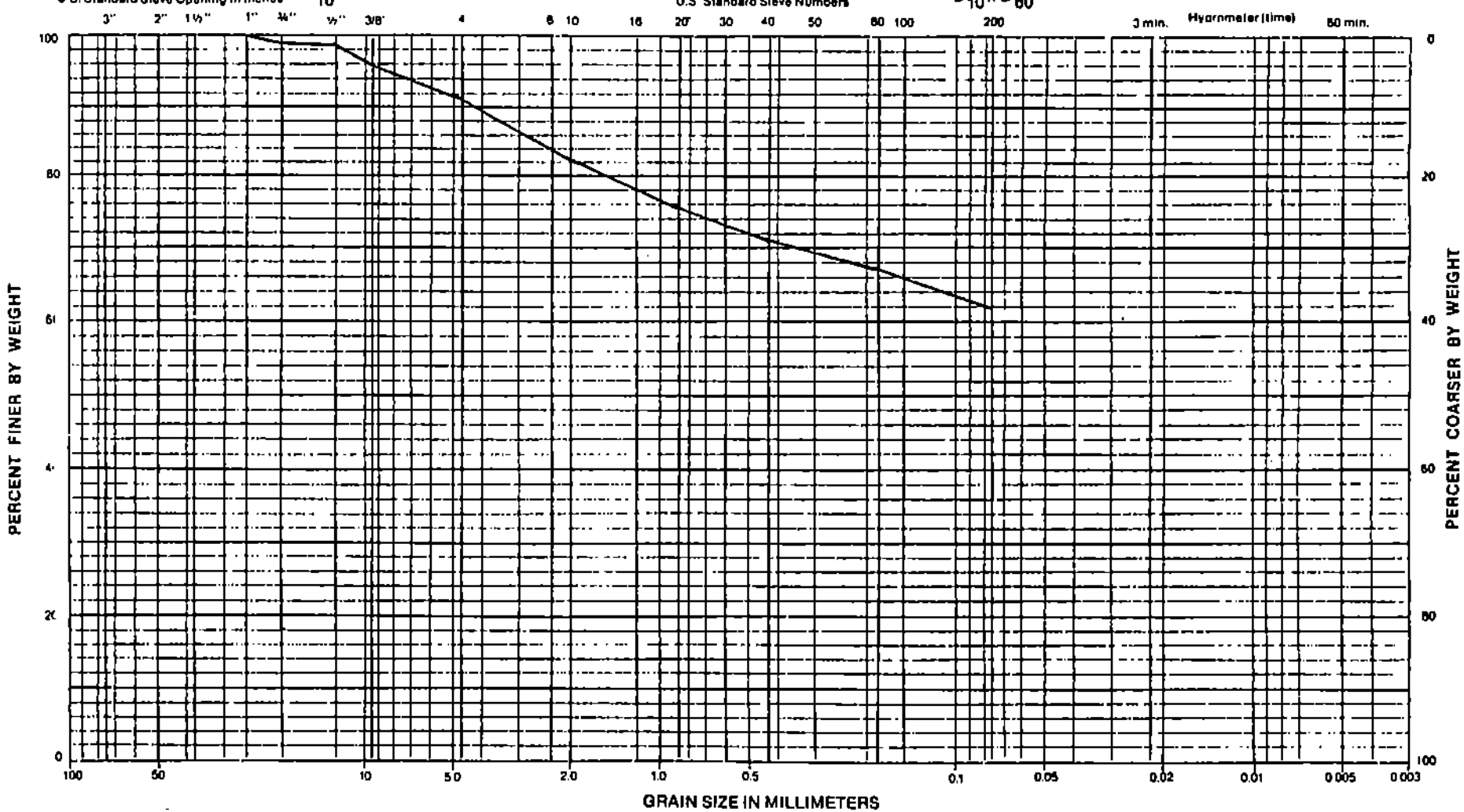
Date 12/06/89

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/88) CN-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-3, S-3, 15.0' - 16.5'

Classification Sandy Lean CLAY (CL)

Moisture Content 22 %

Liquid Limit 33 %

Sample No. 40622

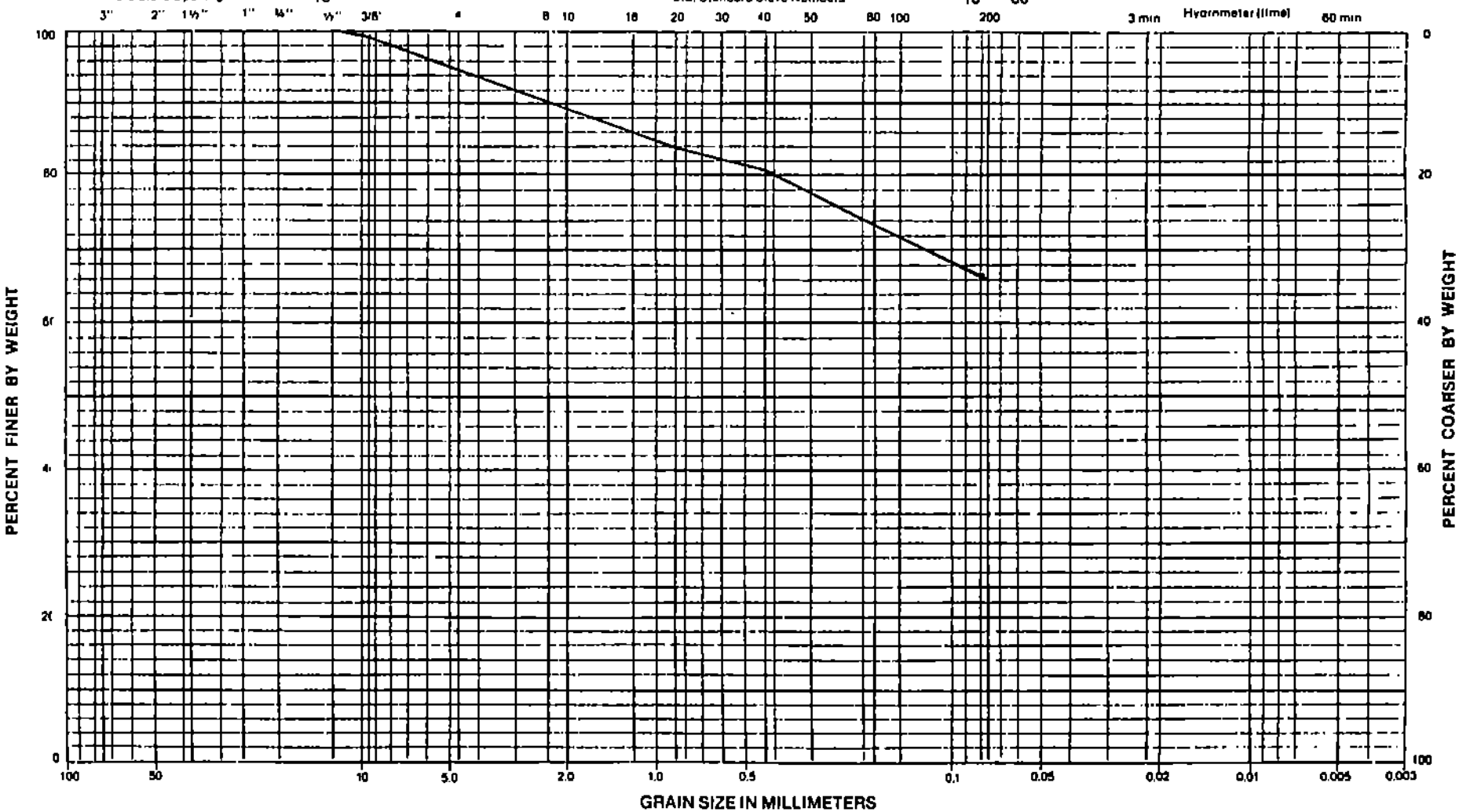
Job No. 88-152-2

Date 12/06/89

Plasticity Index 15 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-3, S-1, 36.0' - 36.5'

Classification Silty Clayey SAND with Gravel (SC-SM)

Sample No. 40946

Job No. 88-152-2

Date 12/18/89

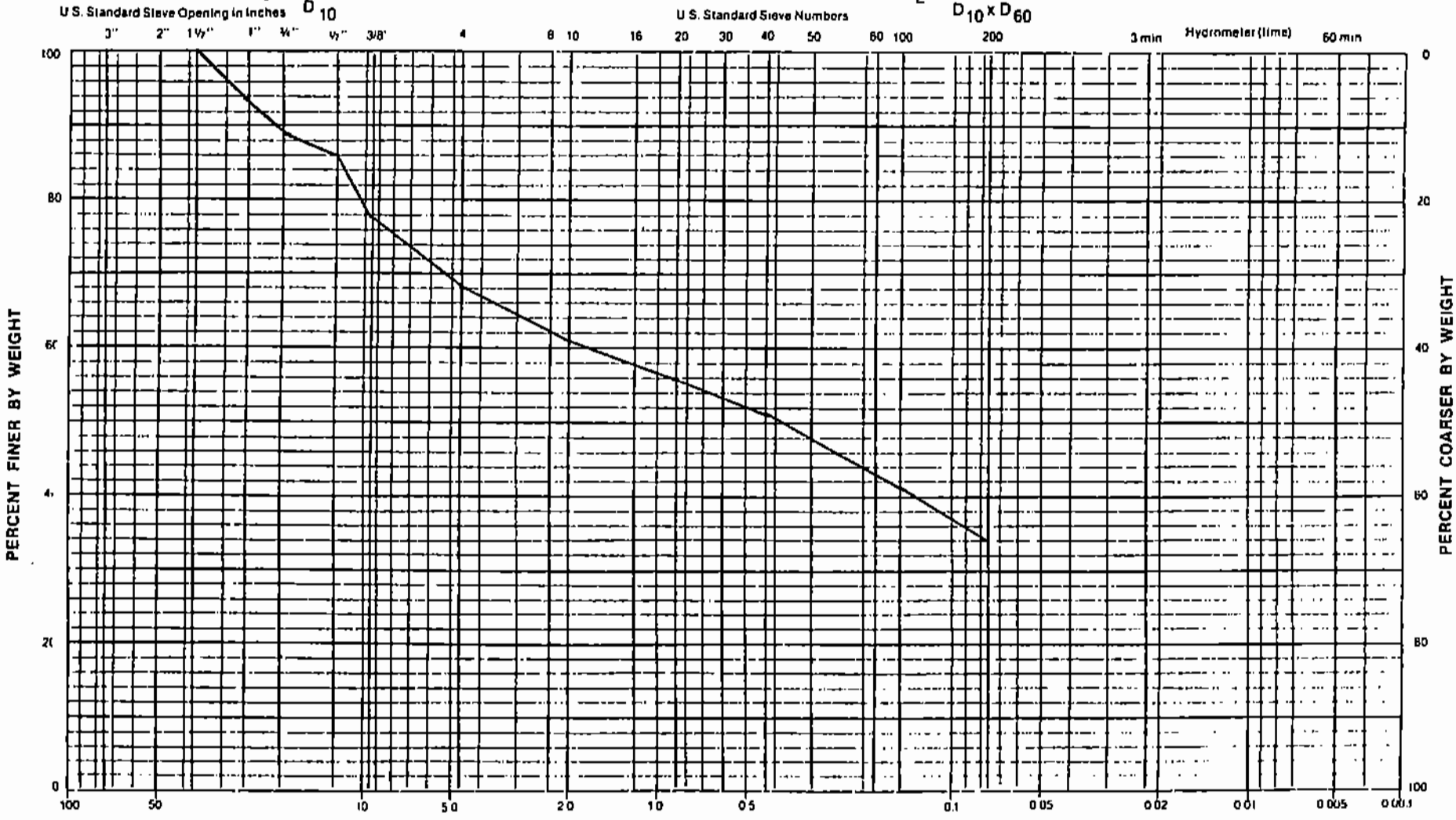
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore - Tailings Impoundment

Sample No. SH2

Location: DH-3A 13.0 - 14.8

Job No. 89-614

Classification Lean clay with sand

Date December, 1989

Moisture Content 15.3 %

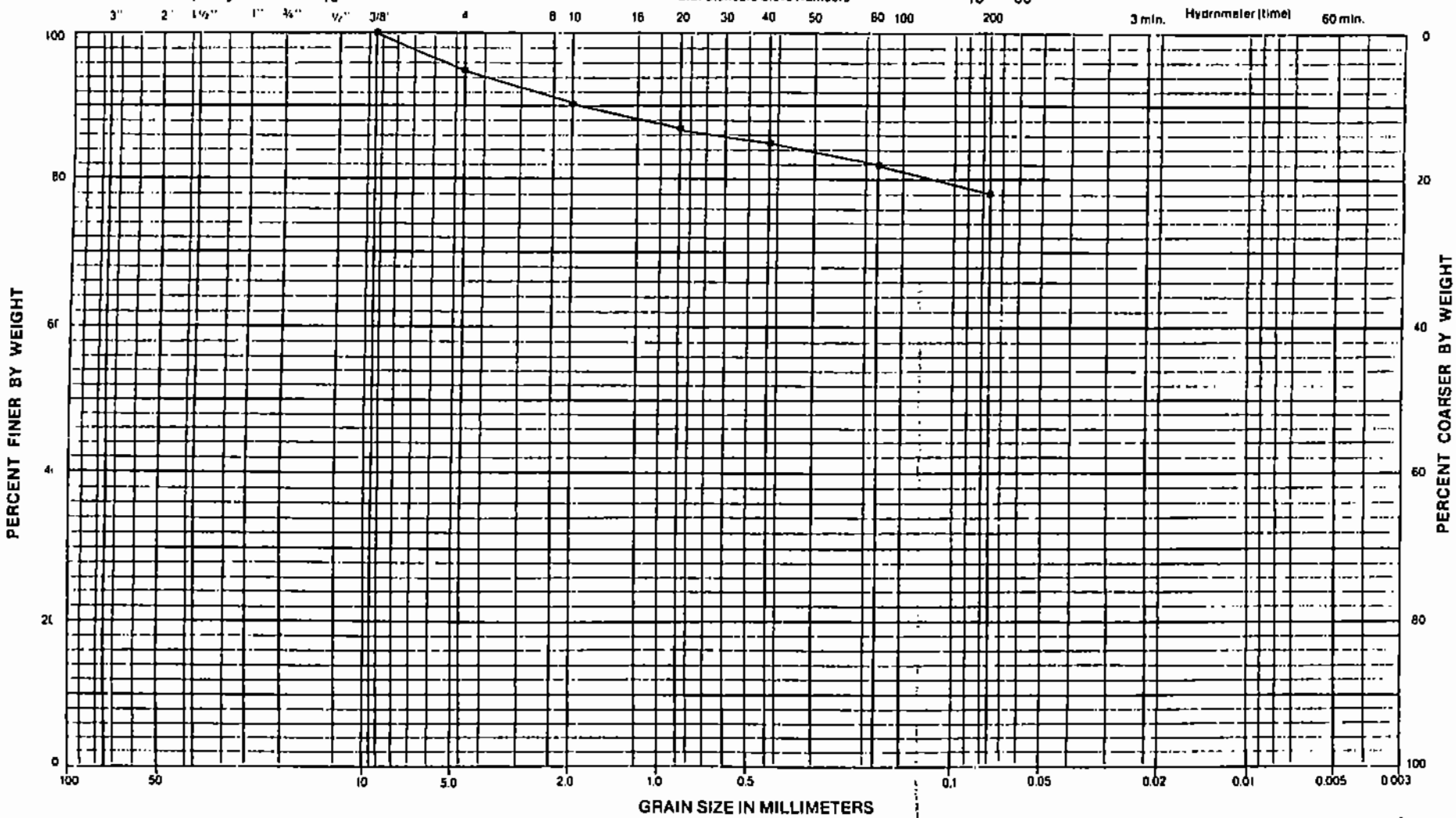
Liquid Limit 31 %

Plasticity Index 13 %

Dry unit weight 118.0 pcf

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = N/A

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Chen-Northern, Inc.

Project: Montanore - Tailings Impoundment **GRAIN SIZE DISTRIBUTION CURVE** Sample No. SH6

Location: DH 3A 21' - 23' Job No. 89-614

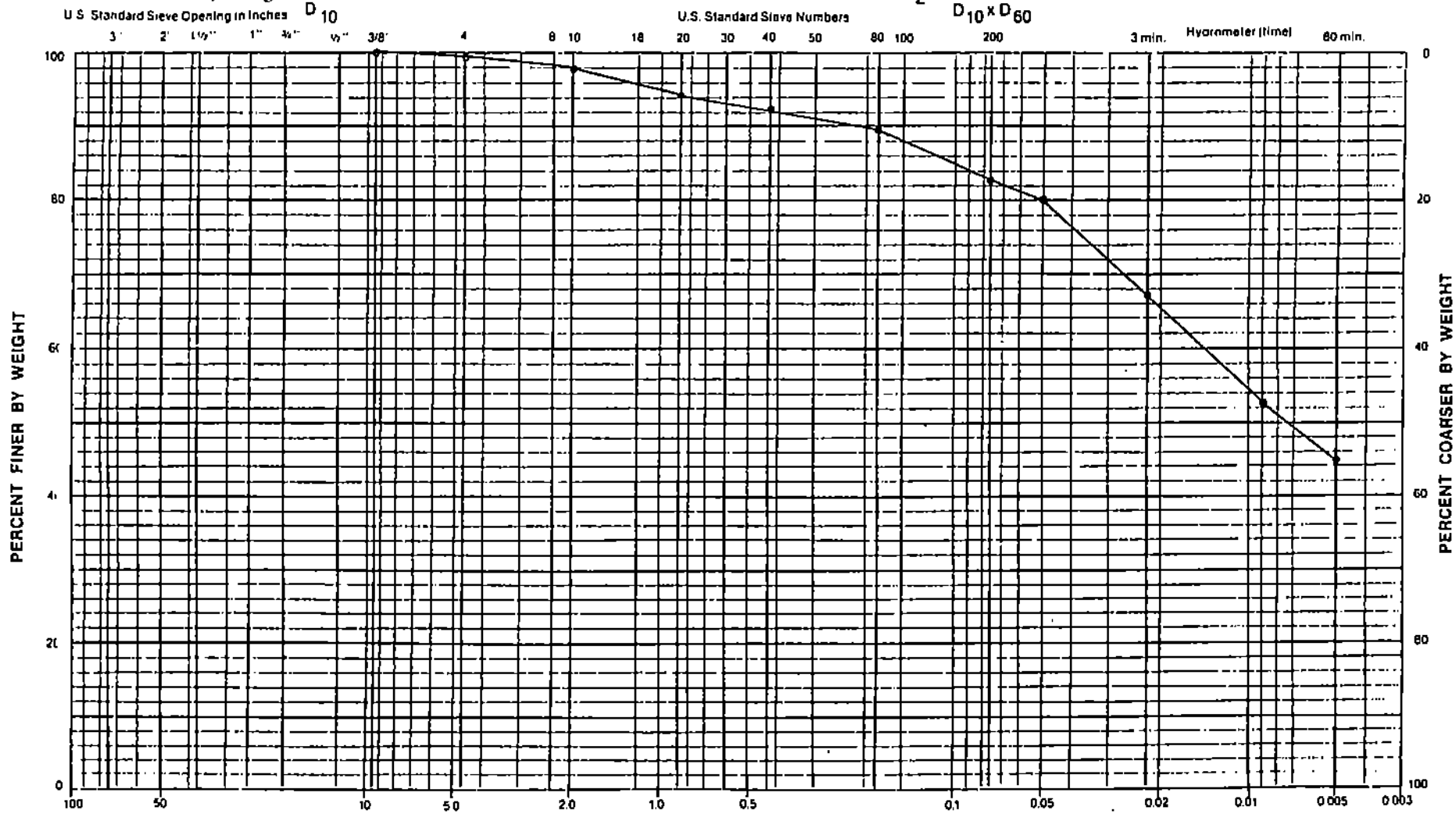
Classification Silty clay with sand Date December, 1989

Moisture Content 22.8 % Liquid Limit - % Plasticity Index - %

Dry unit weight - 103.0 pcf

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = N/A

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-5, S-2, 15.0' - 16.4'

Classification Sandy Silty CLAY with Gravel (CL-ML)

Moisture Content 17 %

Liquid Limit -- %

Plasticity Index -- %

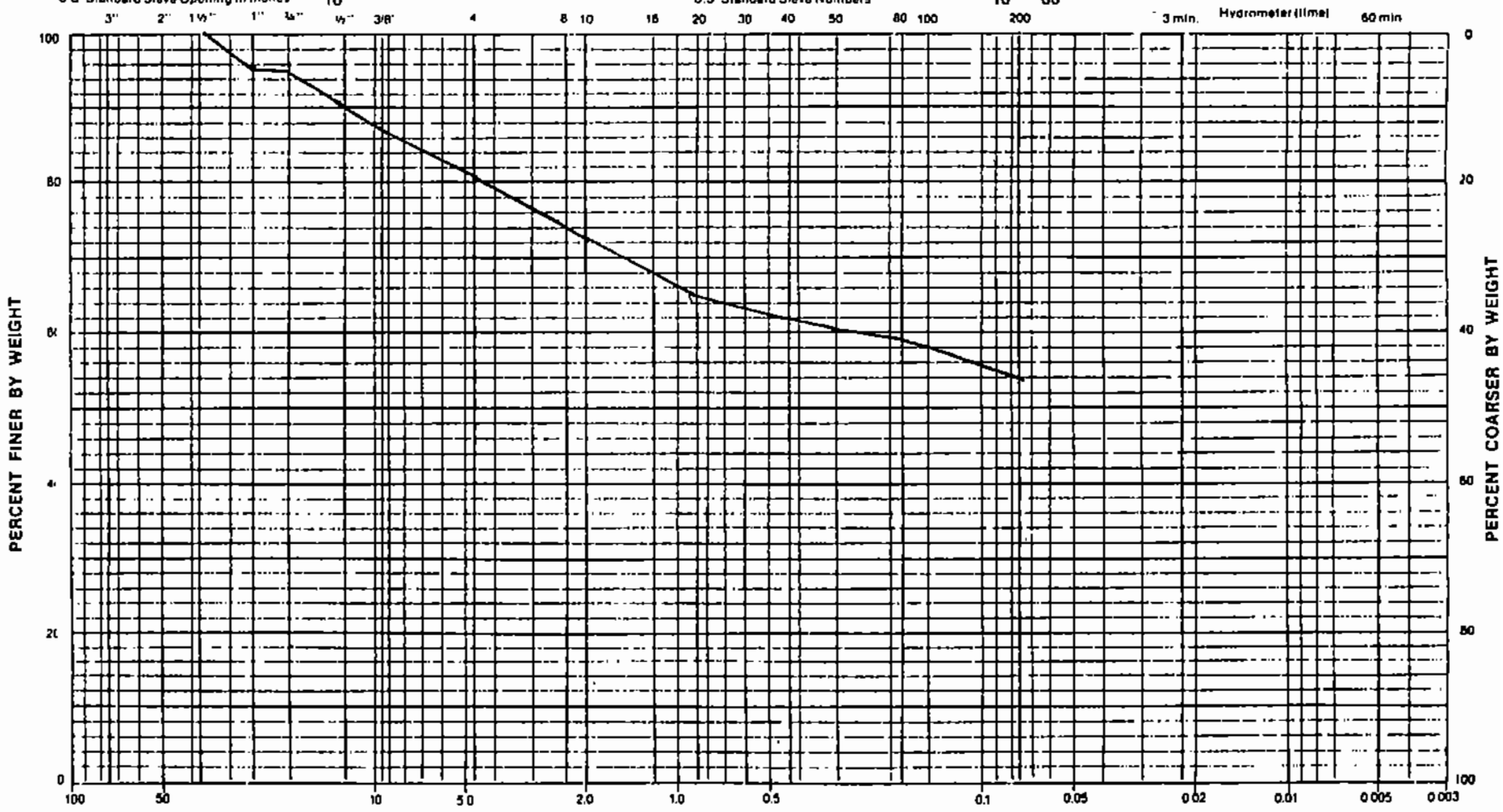
Sample No. 40629

Job No. 88-152-2

Date 12/06/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = ...

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = ...



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-5, S-1, 28.0' - 28.5'

Classification Silty Clayey GRAVEL with Sand (GC-GM)

Moisture Content -- %

Liquid Limit -- %

Sample No. 40947

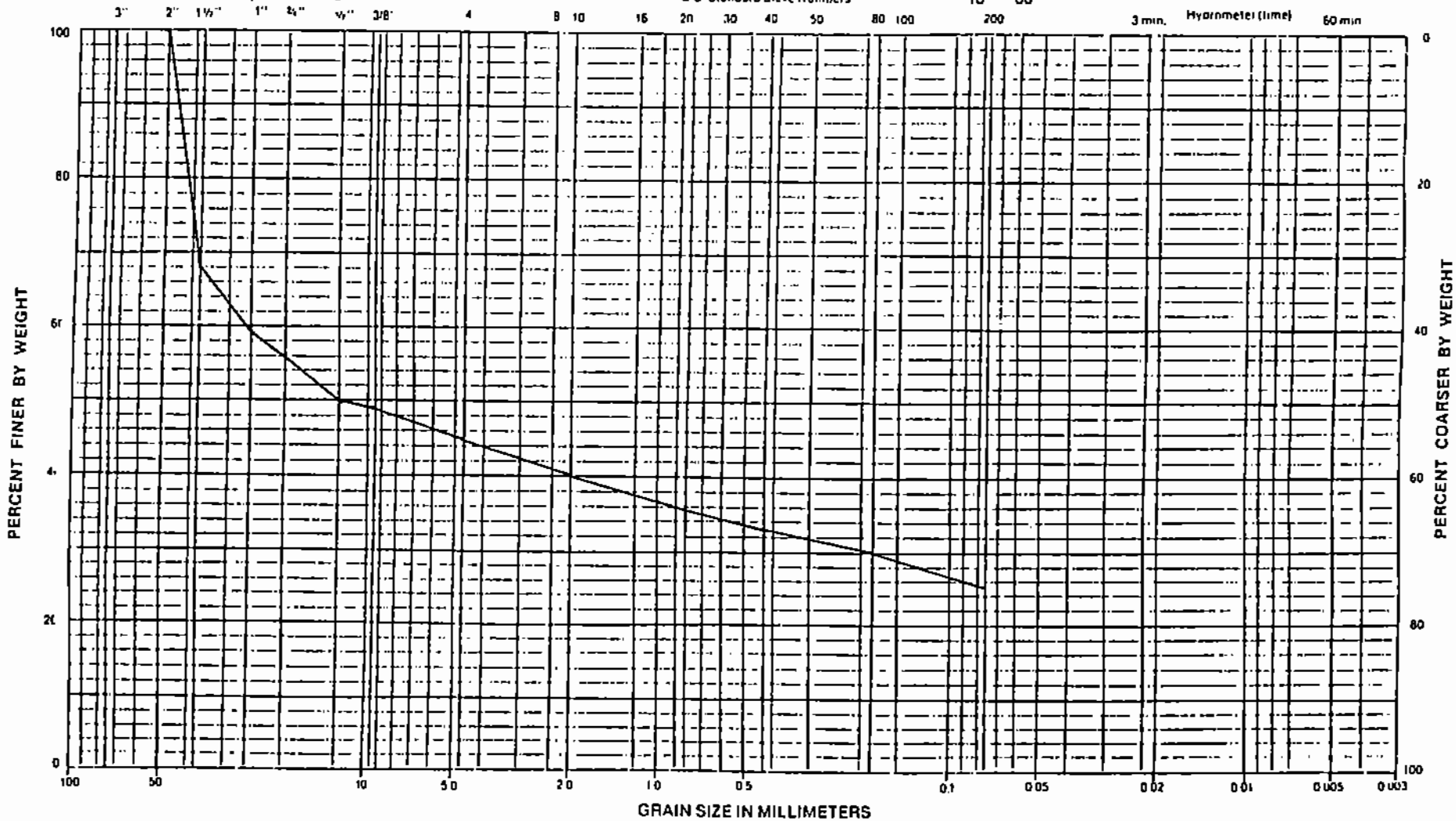
Job No. 88-152-2

Date 12/18/89

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev 1/89) CNI-101

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-6, S-1, 10.0' - 11.5'

Classification Silty SAND with Gravel (SC)

Moisture Content 10 %

Liquid Limit 20 %

Sample No. 40630

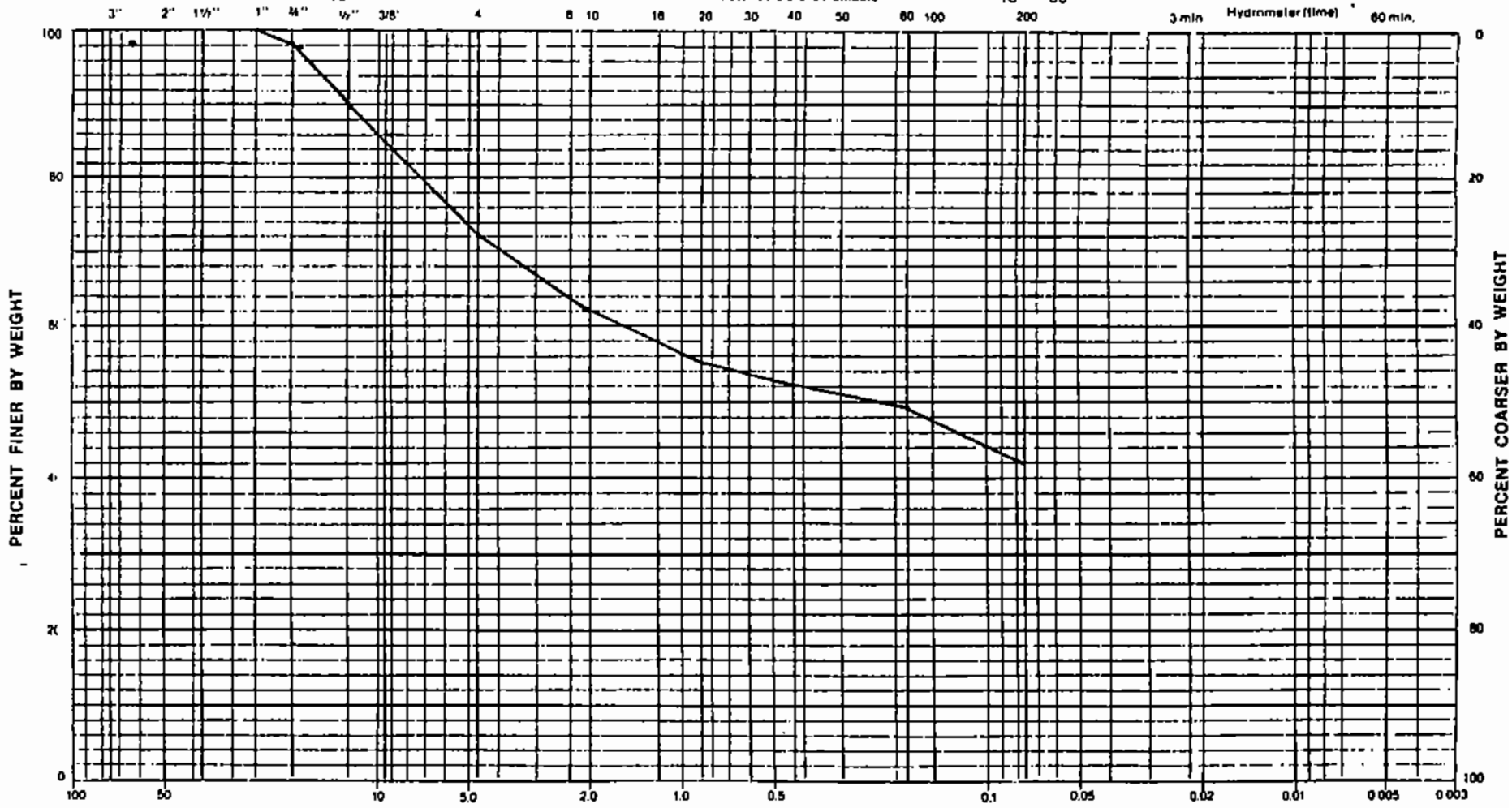
Job No. 88-152-2

Date 12/06/89

Plasticity Index 3 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-6, S-1, 24.5' - 25.0'

Classification Sandy Lean CLAY (CL)

Moisture Content -- %

Liquid Limit -- %

Sample No. 40949

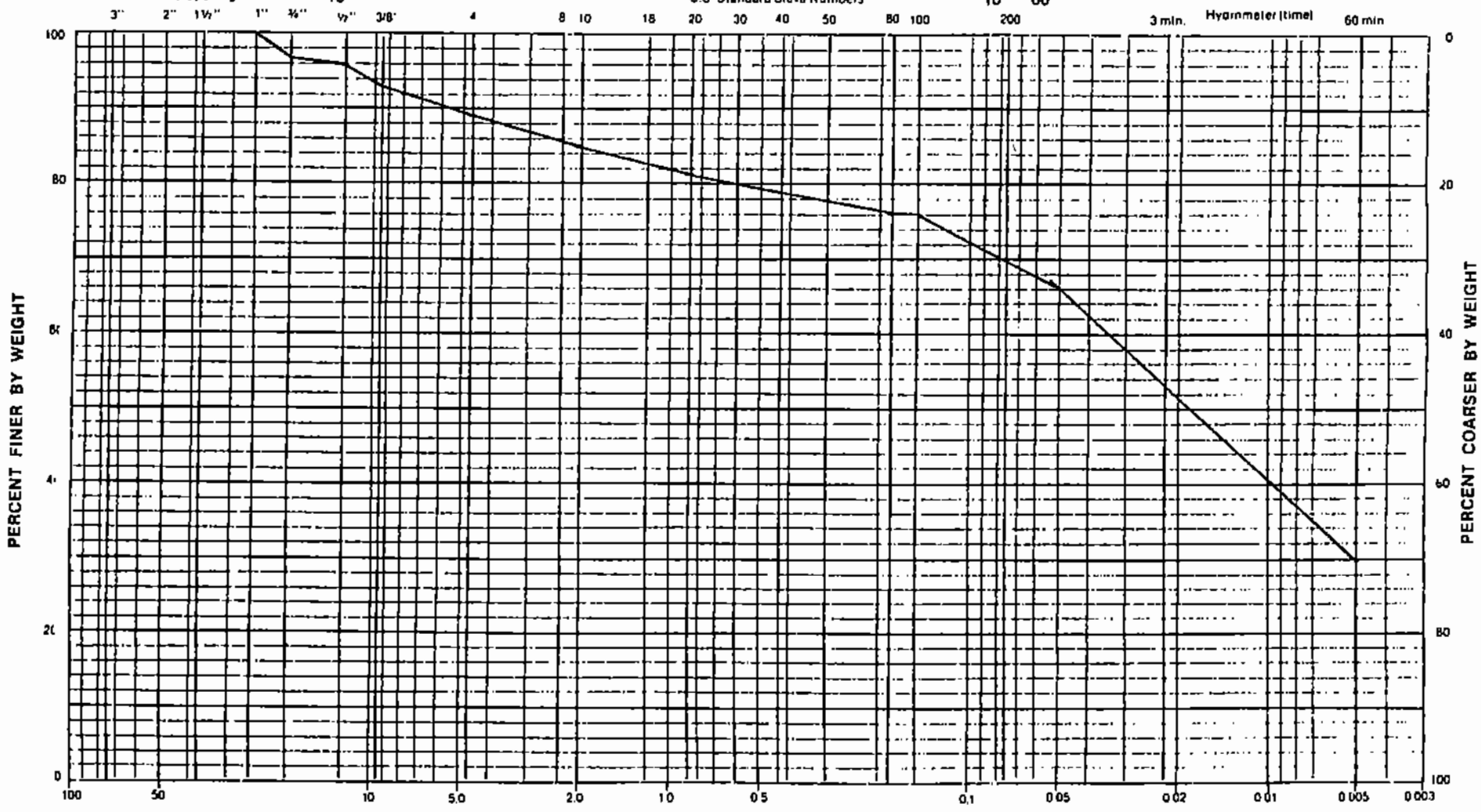
Job No. 88-152-2

Date 12/18/89

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-7, S-1, 4.0' - 5.5'

Classification Silty GRAVEL with Sand (GM)

Moisture Content -- %

Liquid Limit -- %

Sample No. 40633

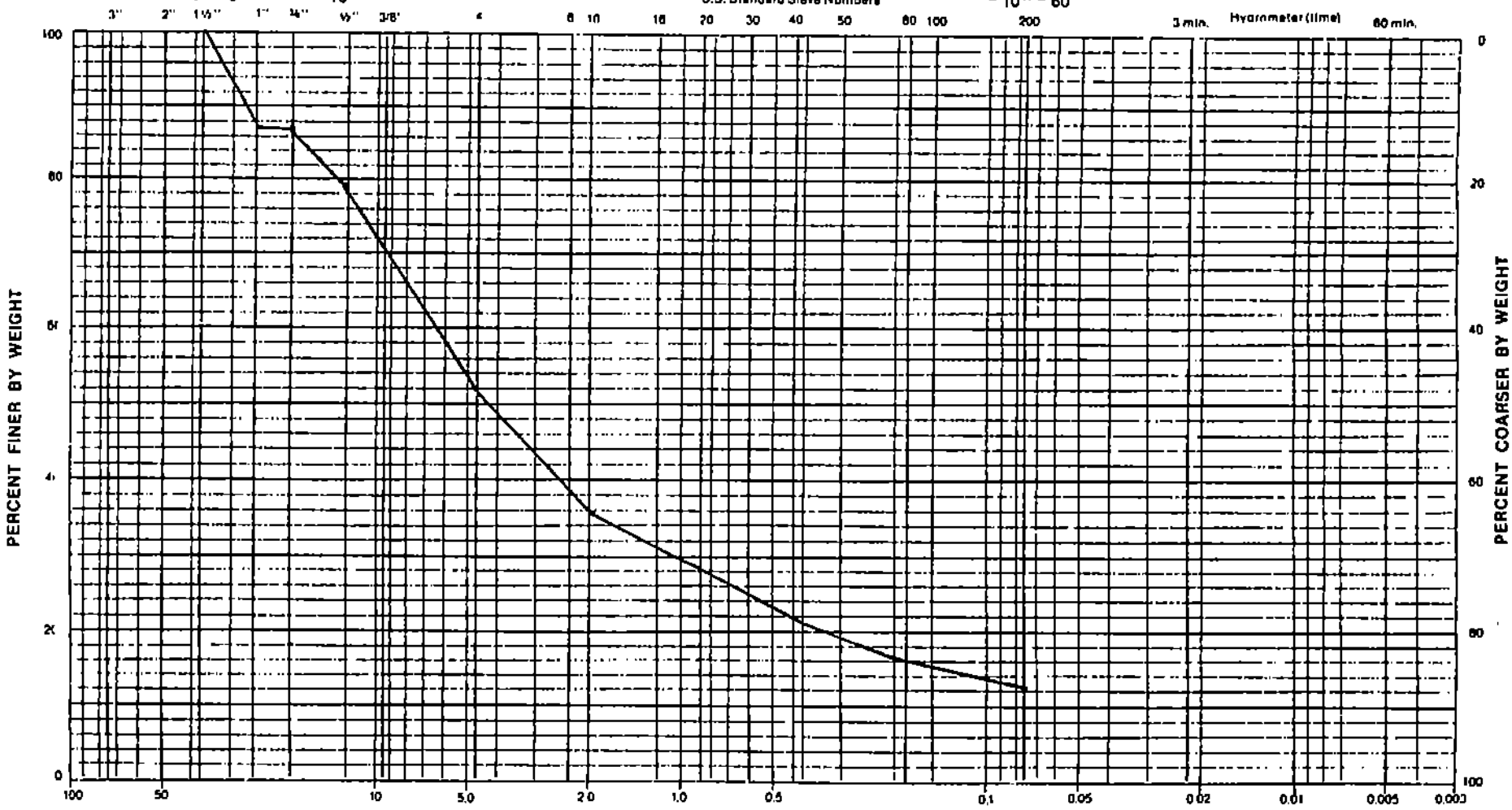
Job No. 88-152-2

Date 12/06/89

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-8, S-2, 8.5' - 10.0'

Classification Silty GRAVEL with Sand (GM)

Moisture Content -- %

Liquid Limit -- %

Sample No. 40640

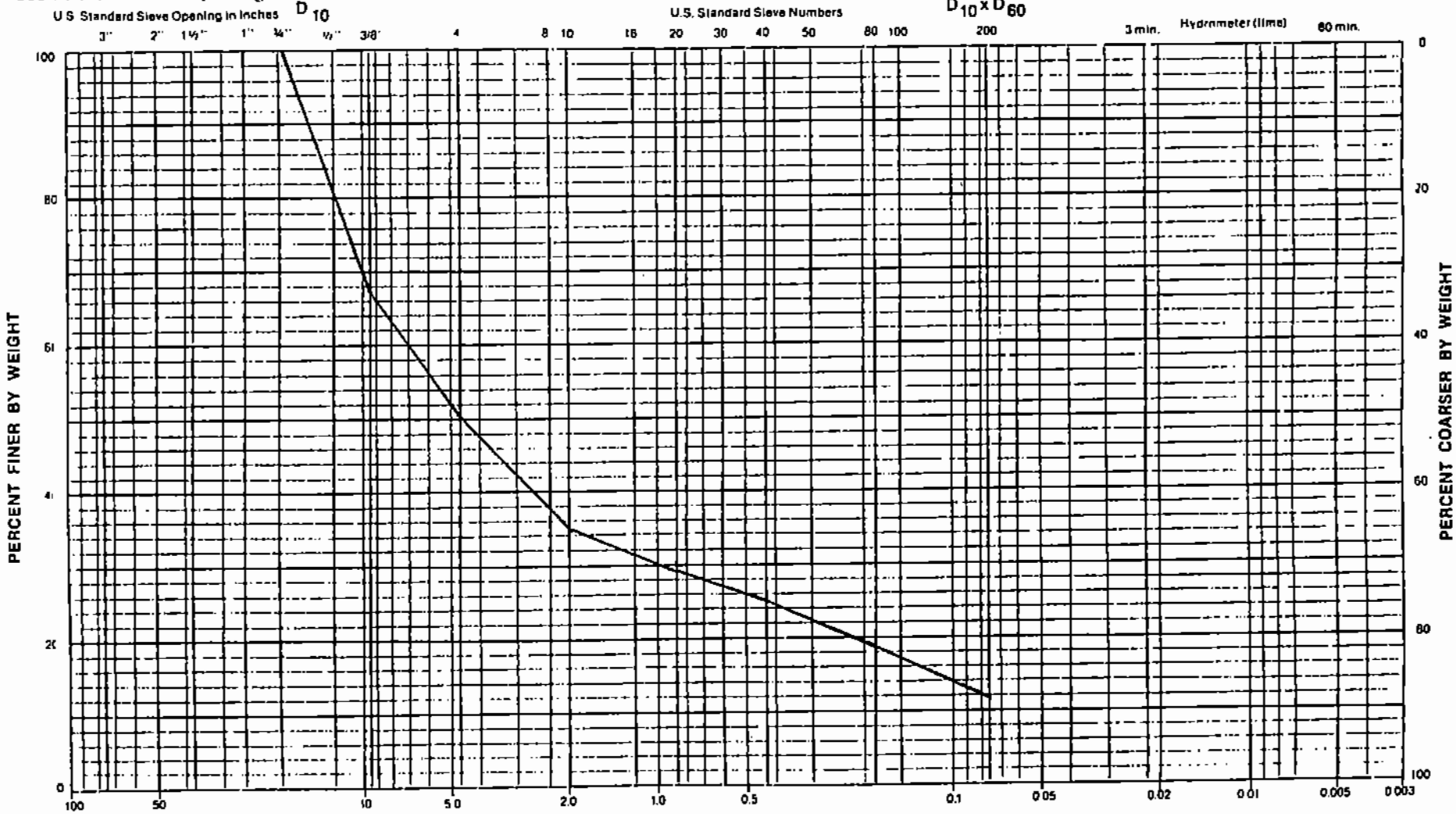
Job No. 88-152-2

Date 12/06/89

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-11, S-1, 49.0' - 49.5'

Classification Silty Clayey GRAVEL with Sand (GC-GM)

Sample No. 40951

Job No. 88-152-2

Date 12/18/89

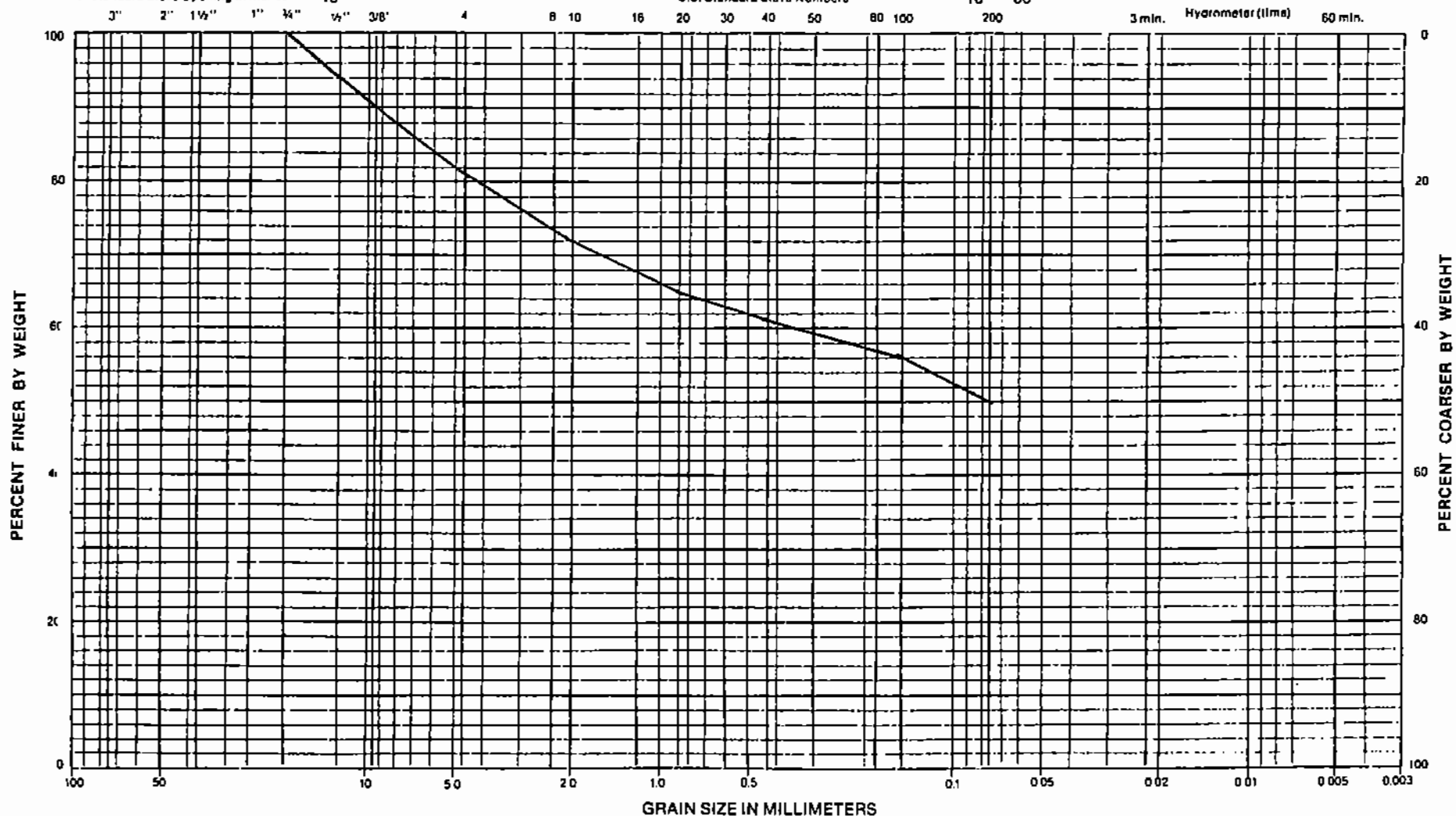
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-11, S-2, 58.5' - 59.0'

Classification Silty Clayey GRAVEL with Sand (GC-GM)

Sample No. 40952

Job No. 88-152-2

Date 12/18/89

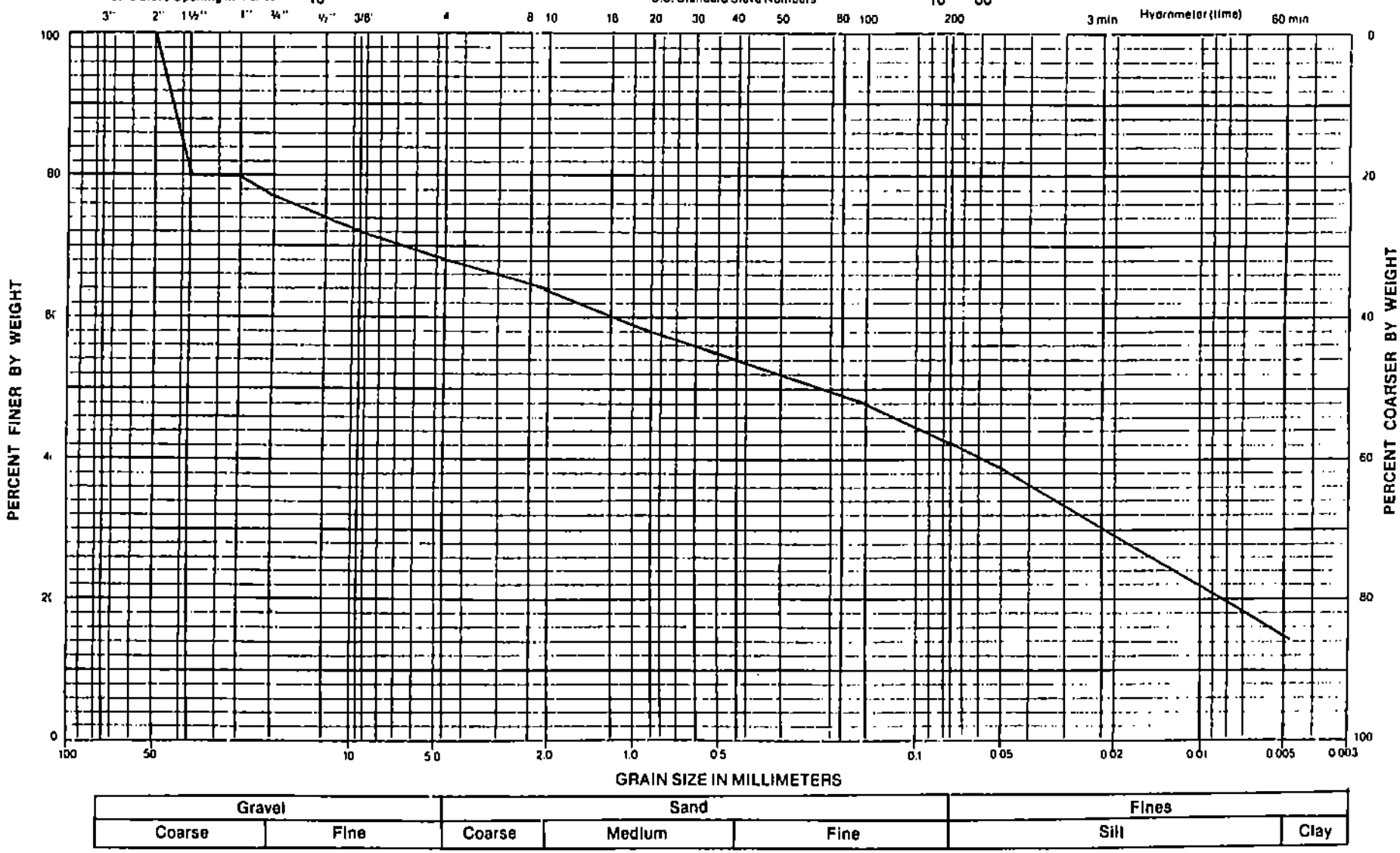
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-12, SPT-1, 4.0' - 5.5'

Classification Poorly-Graded GRAVEL With Sand (GP)

Moisture Content 7 %

Liquid Limit Granular %

Sample No. 40650

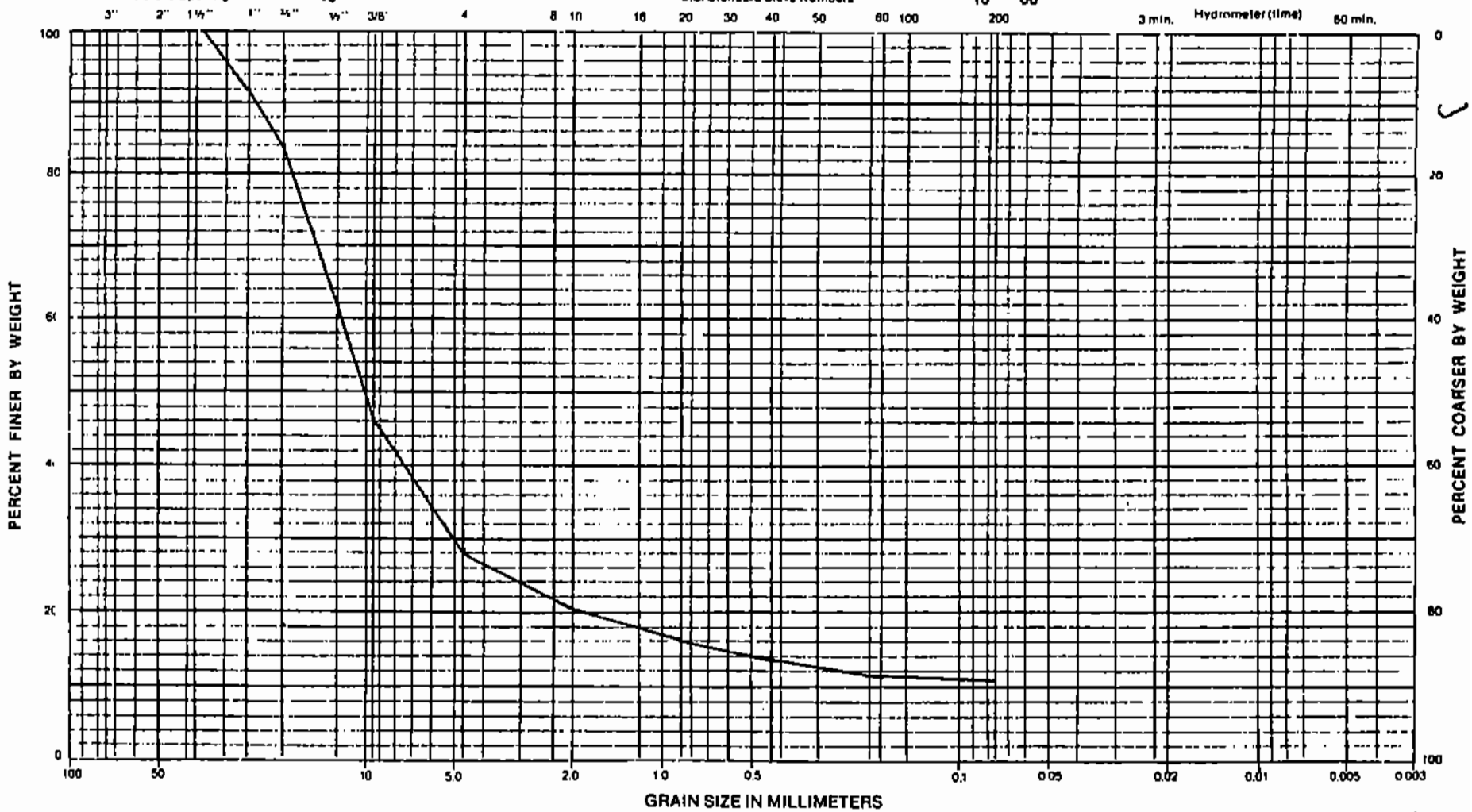
Job No. 88-152-2

Date 12/06/89

Plasticity Index Non-Plastic %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-13, SPT-1, 5.0' - 6.5'

Classification Silty GRAVEL with Sand (GM)

Sample No. 40666

Job No. 88-152-2

Date 12/06/89

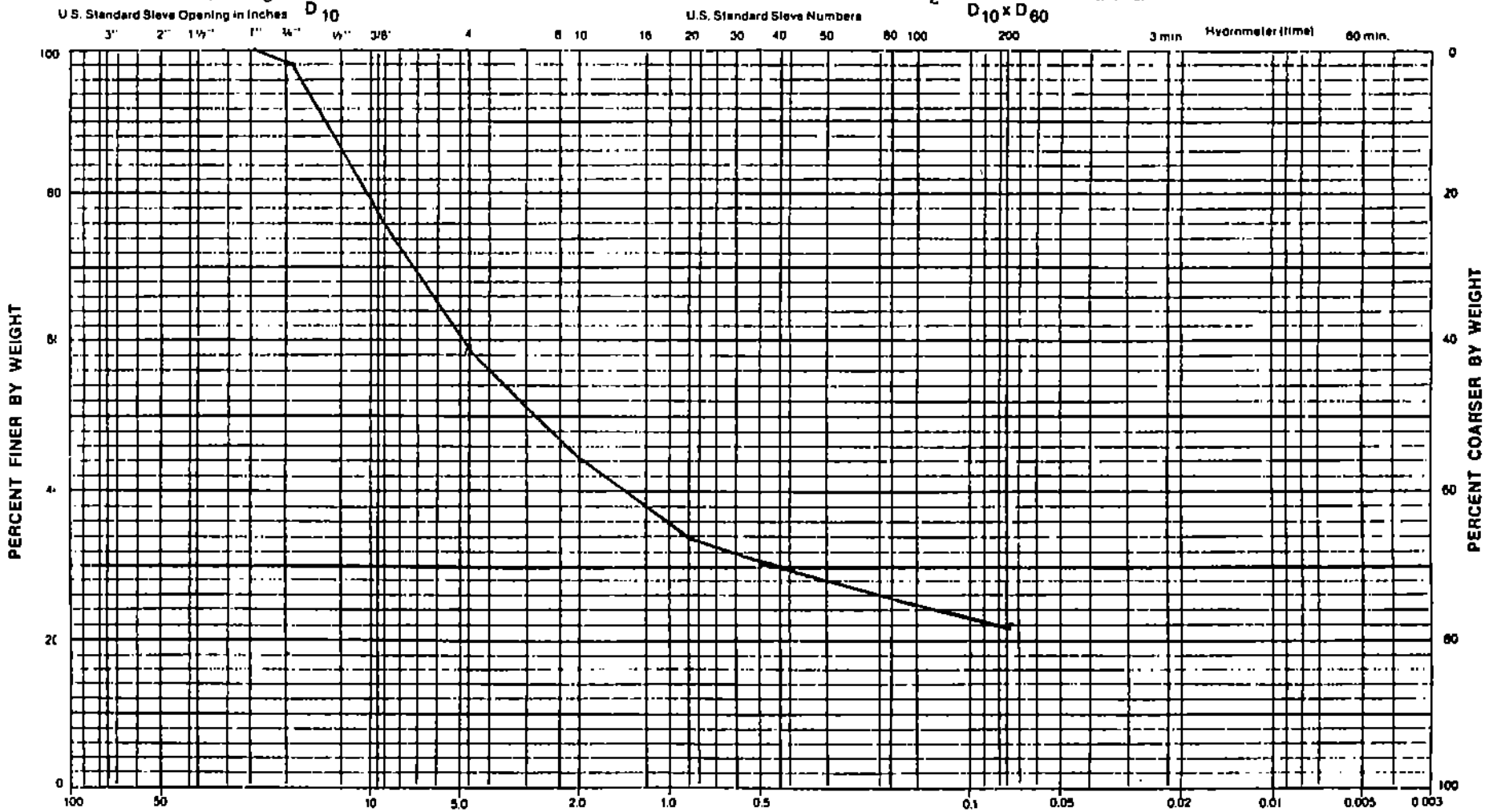
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/88) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-13, SPT-2, 10.0' - 11.5'

Classification Silty Clayey SAND with Gravel (SC-SM)

Sample No. 40667

Job No. 88-152-2

Date 12/06/89

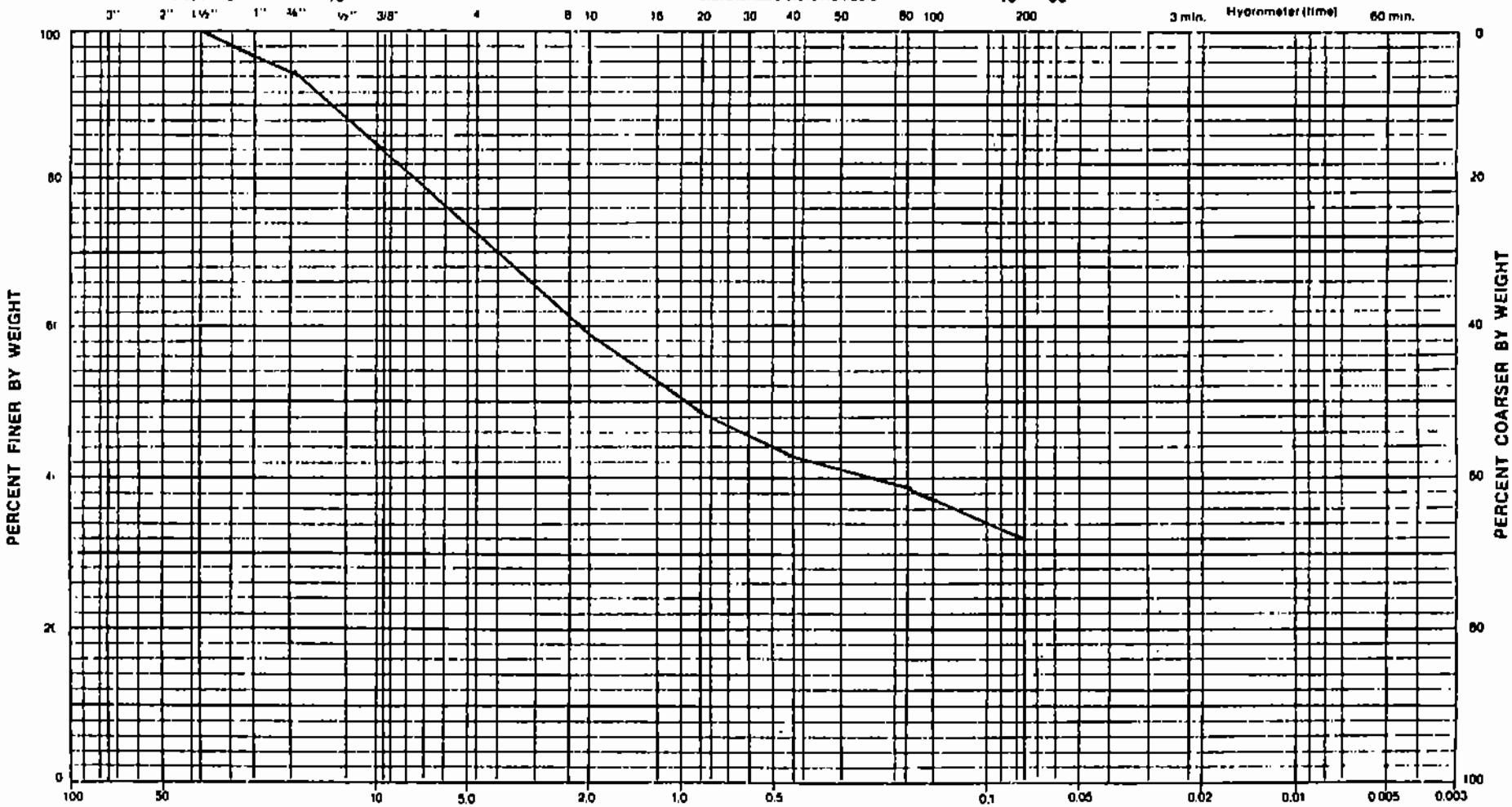
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-13, S-1, 14.5' - 15.0'

Classification Silty Clayey SAND with Gravel (SC-SM)

Sample No. 40953

Job No. 88-152-2

Date 12/18/89

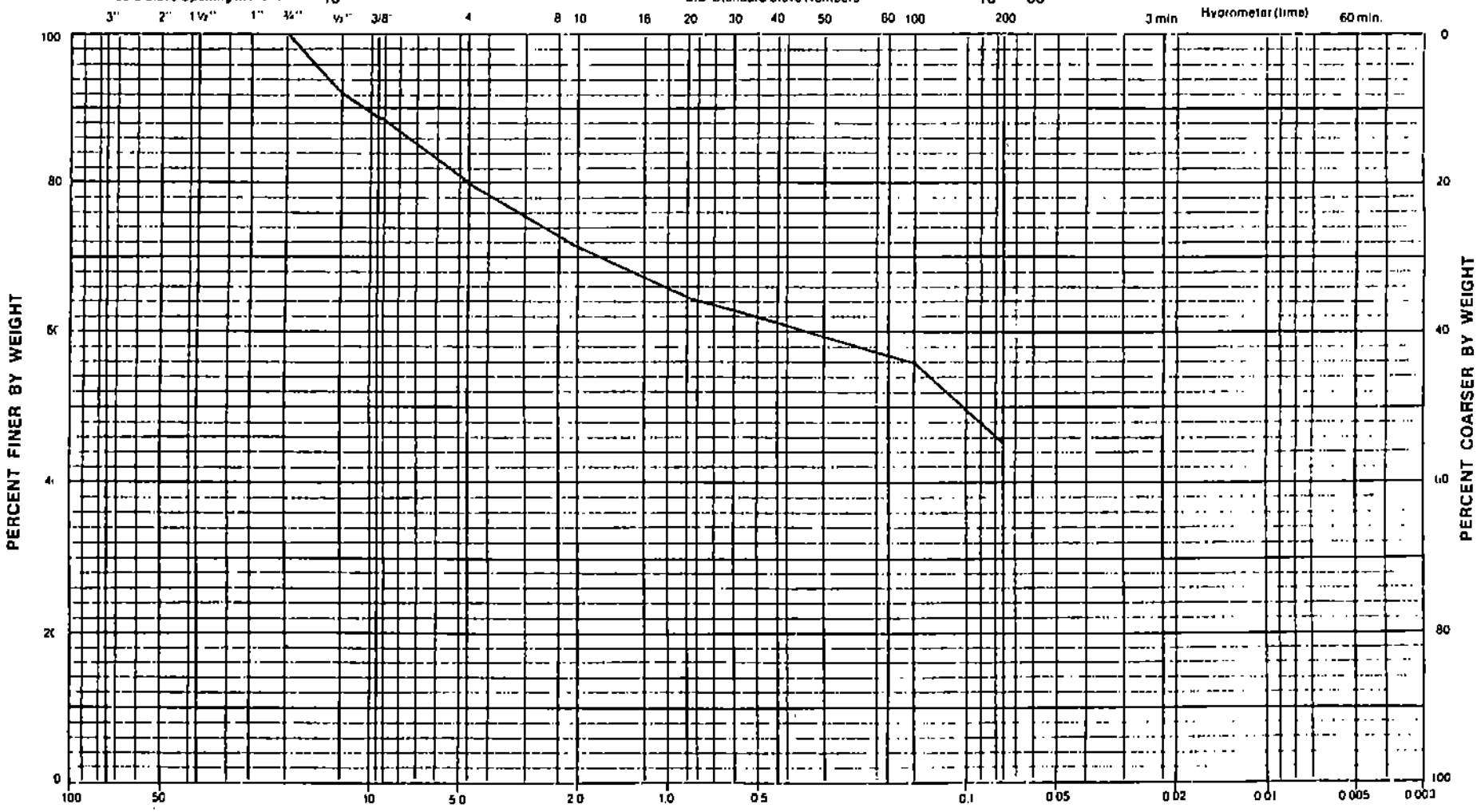
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-17, SPT-1, 4.5' - 6.0'

Classification Gravelly Lean CLAY with Sand (CL)

Sample No. 40642

Job No. 88-152-2

Date 12/06/89

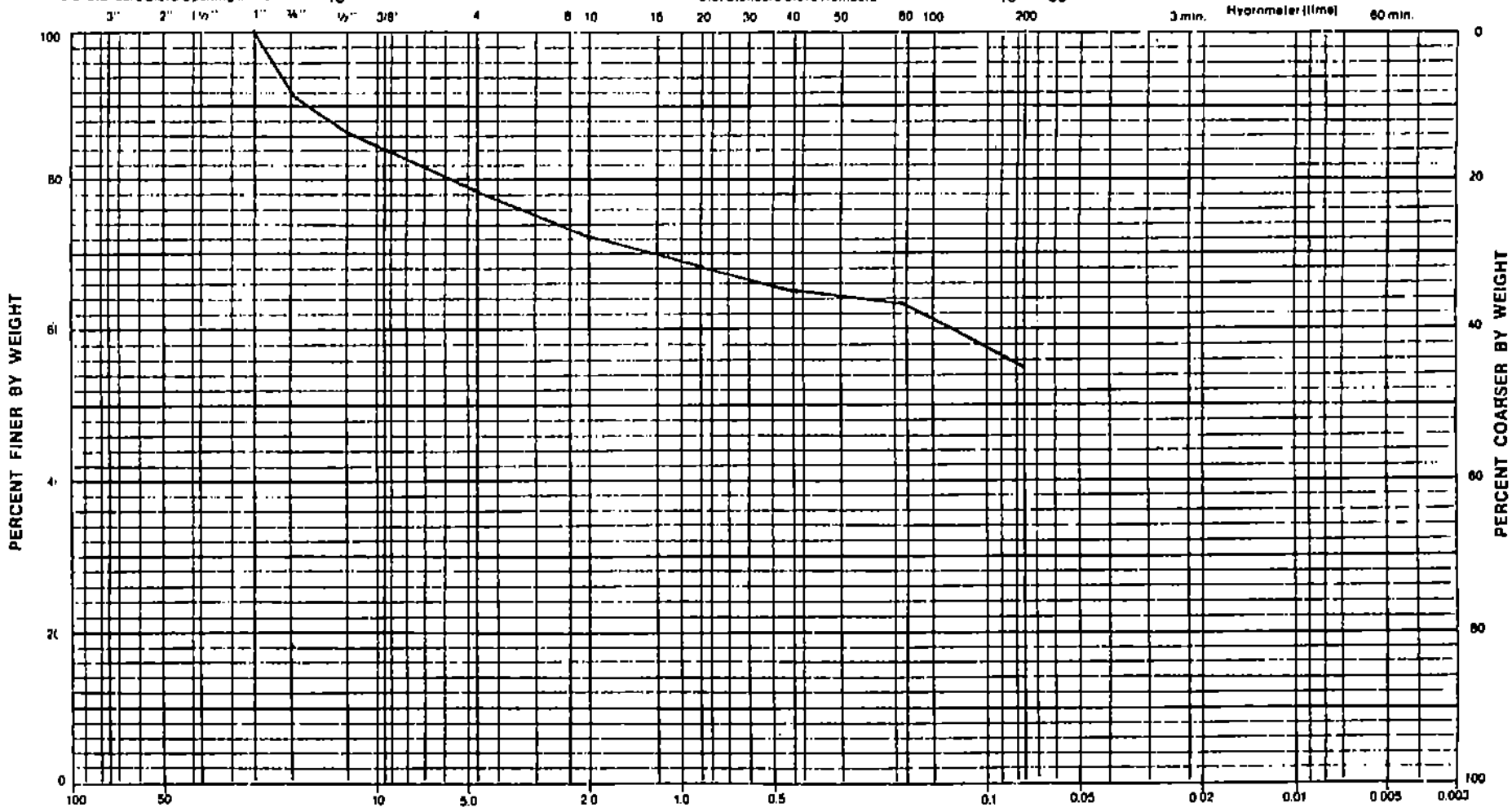
Moisture Content 9 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-18, S-1, 34.5' - 35.0'

Classification Silty Clayey GRAVEL with Sand (GC-GM)

Sample No. 40955

Job No. 88-152-2

Date 12/18/89

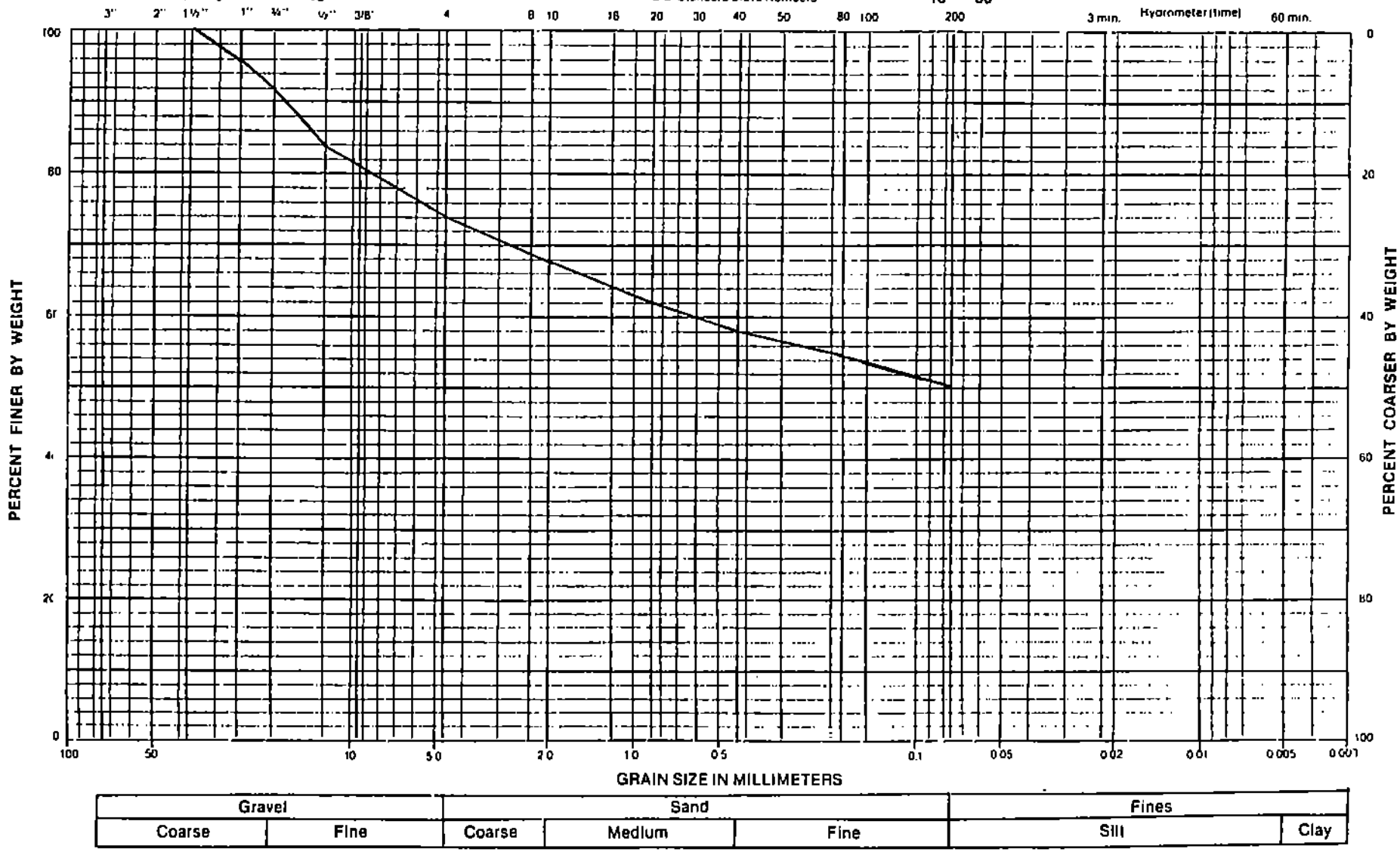
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-18, S-2, 48.0' - 48.5'

Classification Sandy Lean CLAY (CL)

Moisture Content -- %

Sample No. 40956

Job No. 88-152-2

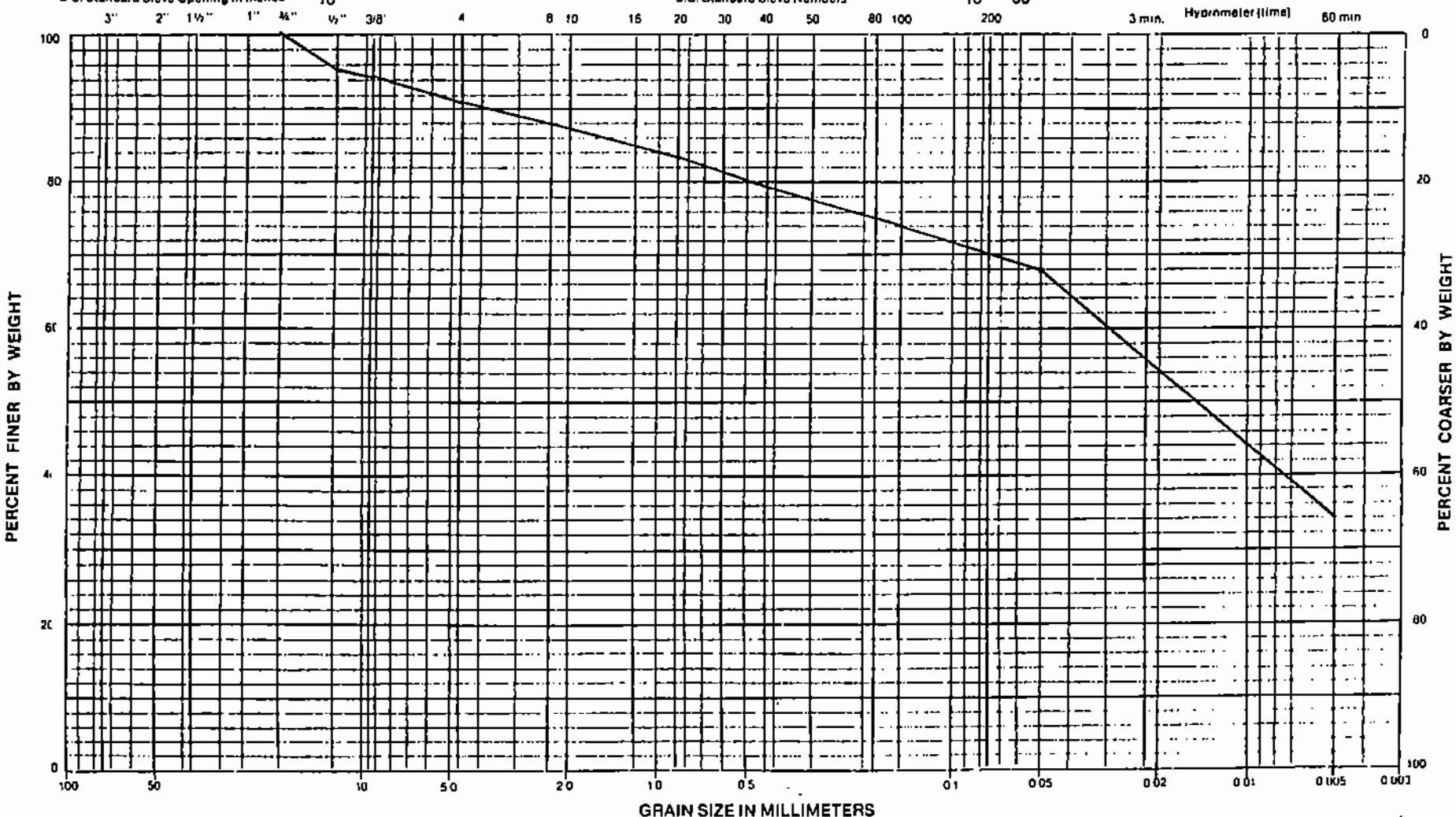
Date 12/18/89

Liquid Limit 30 %

Plasticity Index 11 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore - Tailings Impoundment

Sample No. SH 1

Location: DH 19 5' - 7'

Job No. 89-614

Classification Silt

Date December, 1989

Moisture Content 25.5 %

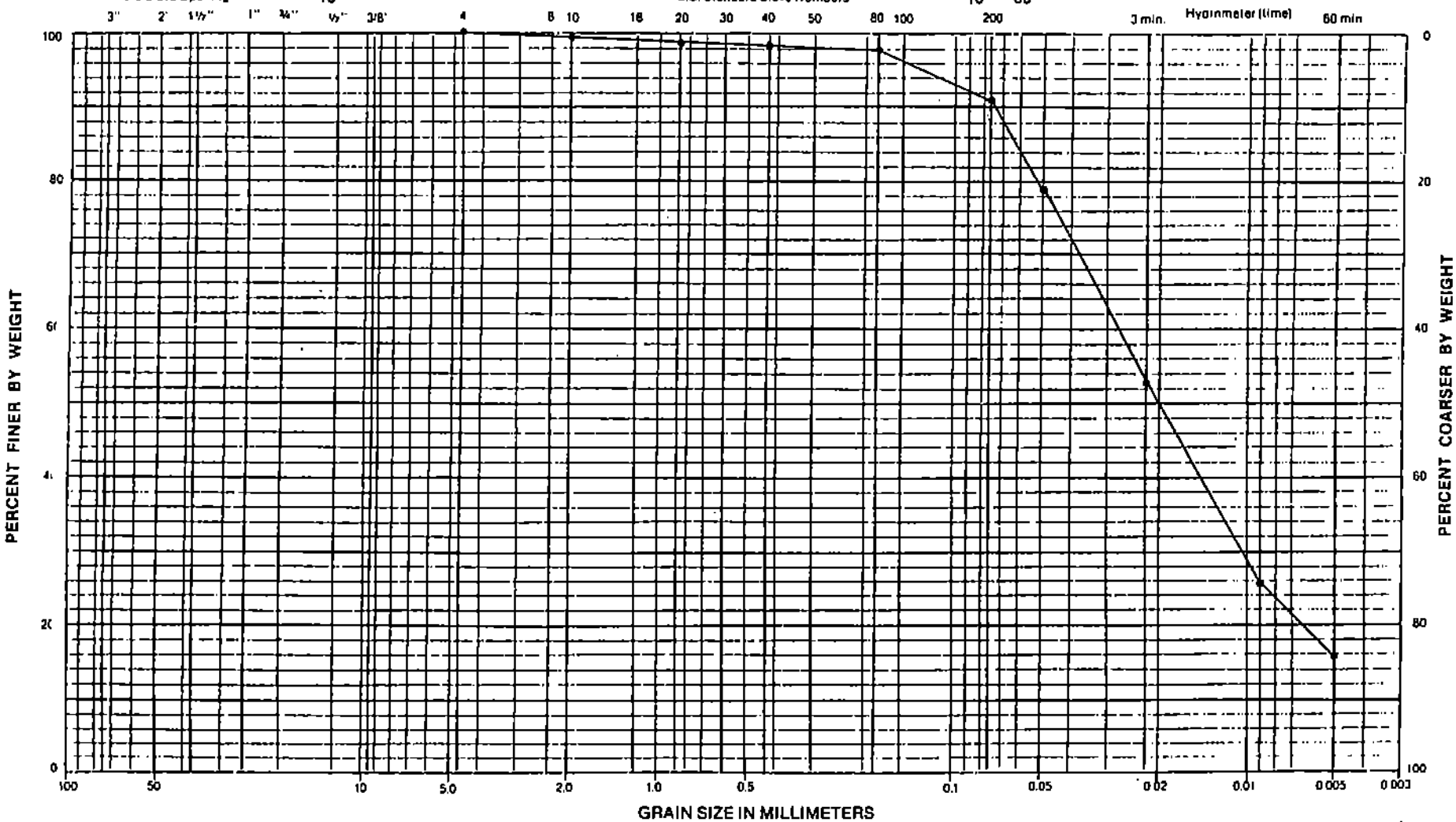
Liquid Limit - %

Plasticity Index - %

Dry unit weight 98.8 pcf

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = N/A

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-19, SPT-1, 20.0' - 21.0'

Classification Silty GRAVEL with Sand (GM)

Moisture Content -- %

Liquid Limit Granular %

Plasticity Index Non-Plastic%

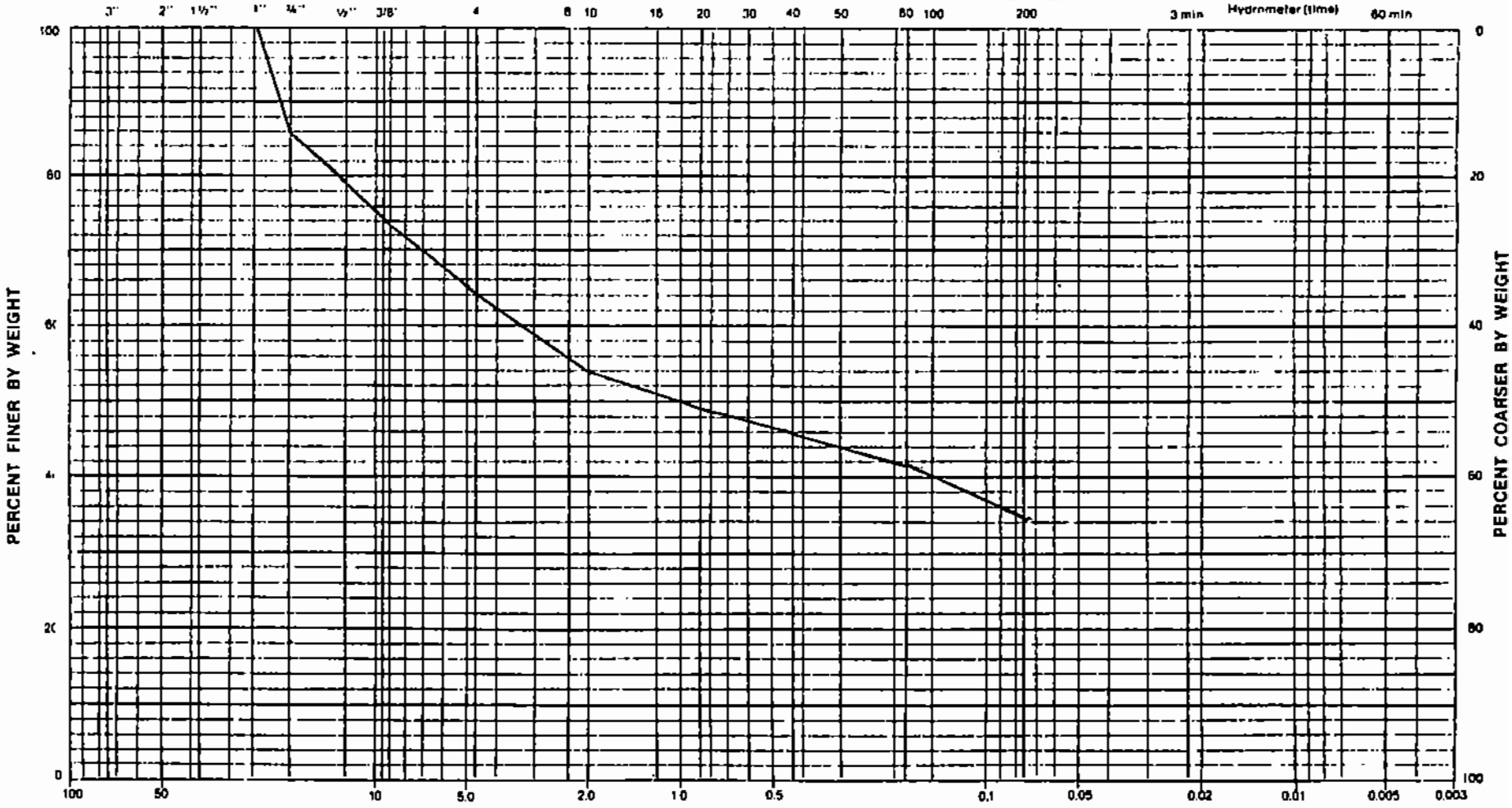
Sample No. 40681

Job No. 88-152-2

Date 12/06/89

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-108

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore - Tailings Impoundment

Location: DH 20 4.0 - 5.4'

Classification Silty sand

Sample No. SH 1

Job No. 89-614

Date December, 1989

Moisture Content 12.9 %

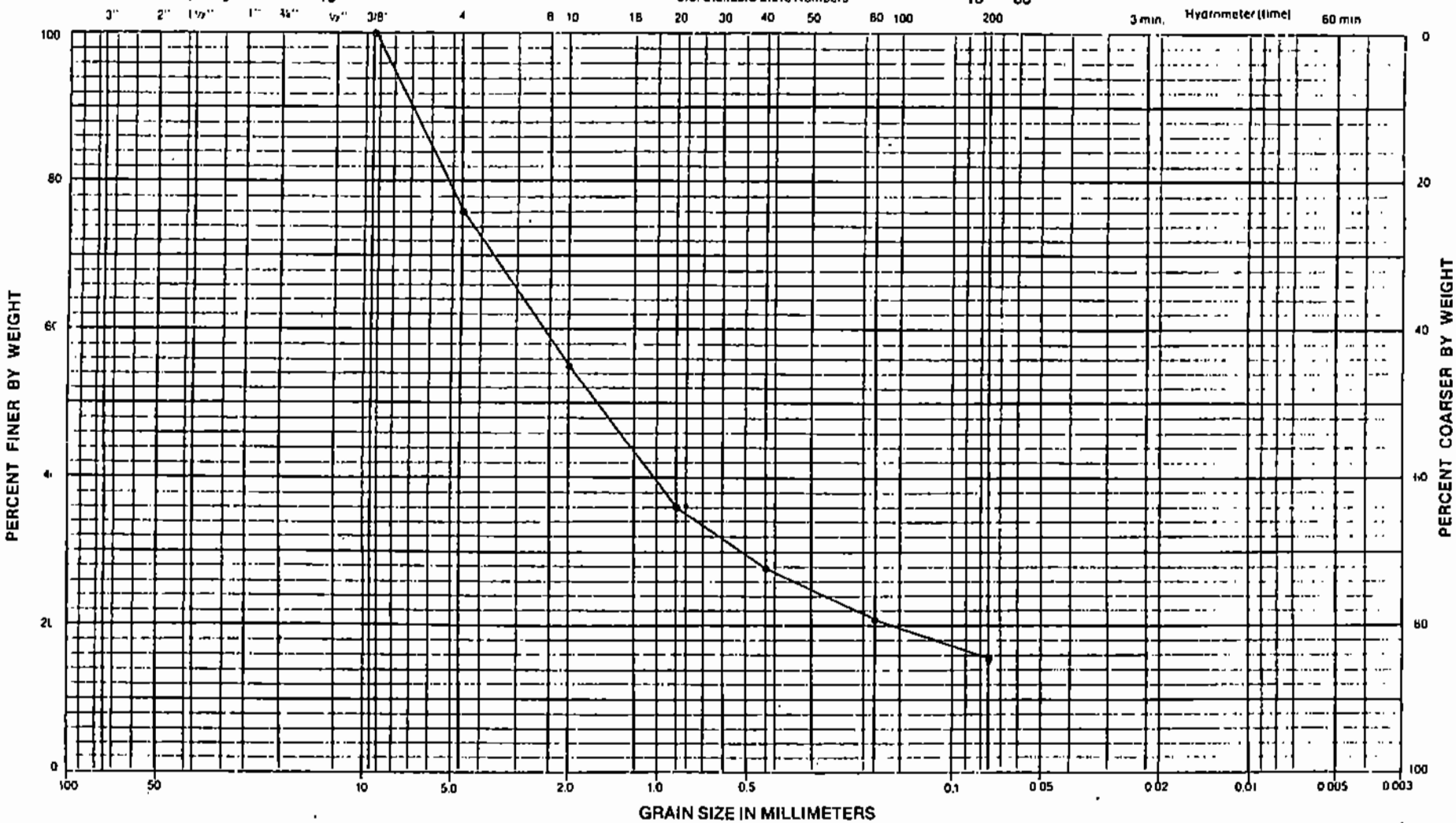
Dry unit weight 98.6 Pcf

Liquid Limit 27 %

Plasticity Index 3 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ N/A

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore Tailings Impoundment

Location: DH-20 8.0' to 10.0'

Classification _____

Sample No. _____

Job No. 89-614

Date February 1990

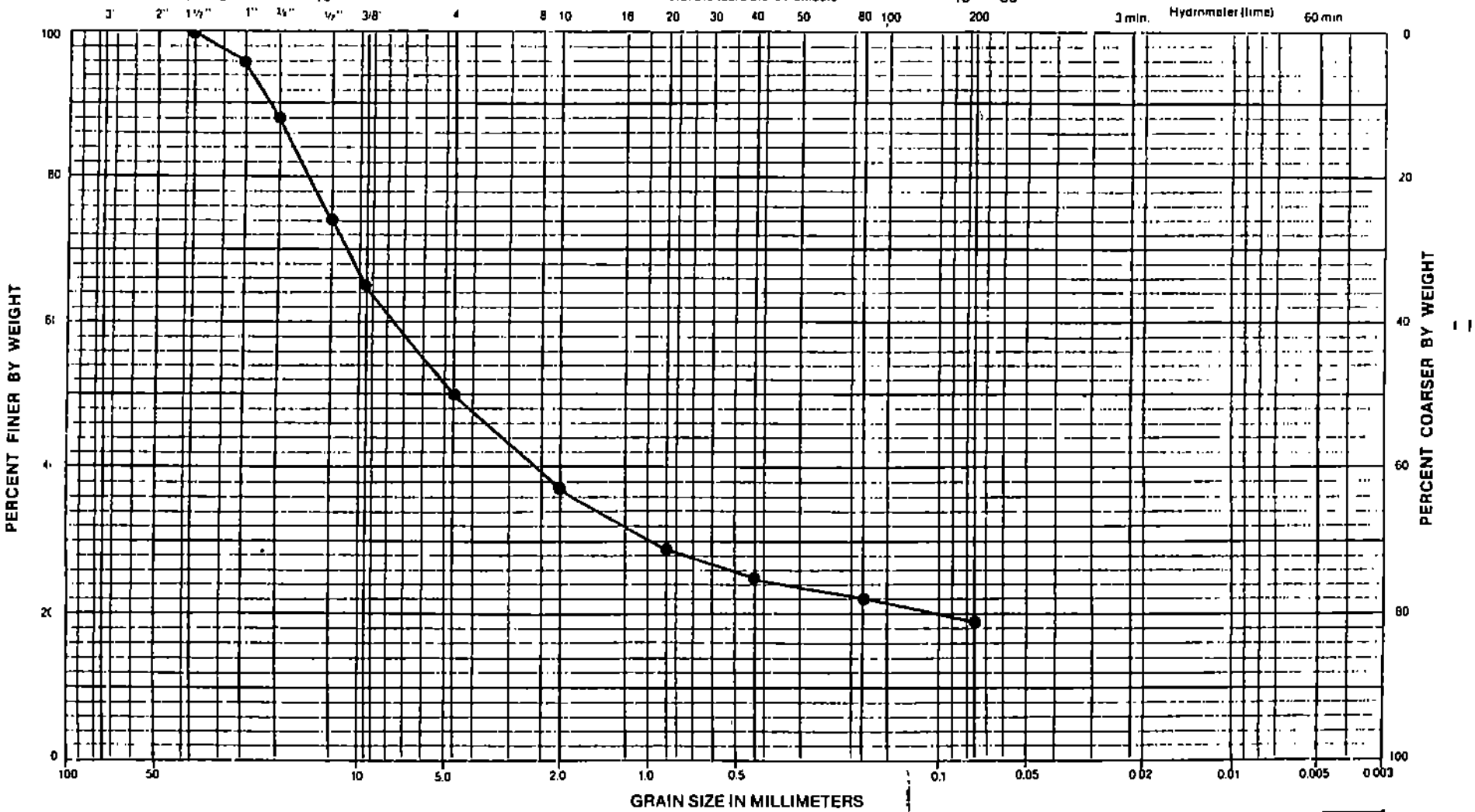
Moisture Content _____ %

Liquid Limit _____ %

Plasticity Index _____ %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ N/A

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore - Tailings Impoundment

Location: DH 20 12' - 14'

Classification Silty Sand *

Sample No. SH 5

Job No. 89-614

Date December, 1989

Moisture Content 26.1 %

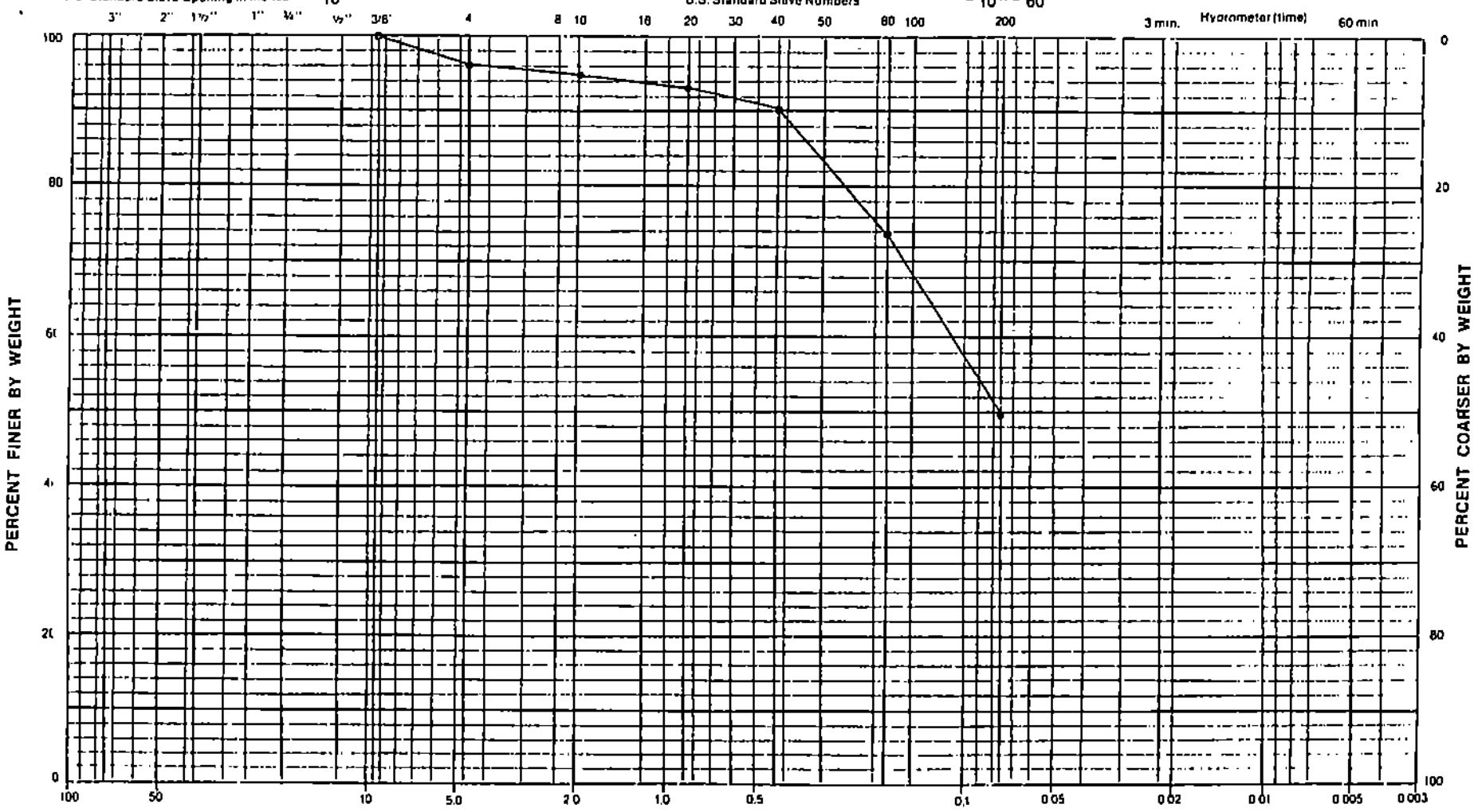
Liquid Limit - %

Plasticity Index - %

Dry unit weight 95.6 Pcf

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ N/A

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

* Classification not verified with Atterberg Limits

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montanore - Tailings Impoundment

Location: DH 20 16' - 18'

Classification Sandy Silt

Sample No. SH 7

Job No. 89-614

Date December, 1989

Moisture Content 26.0 %

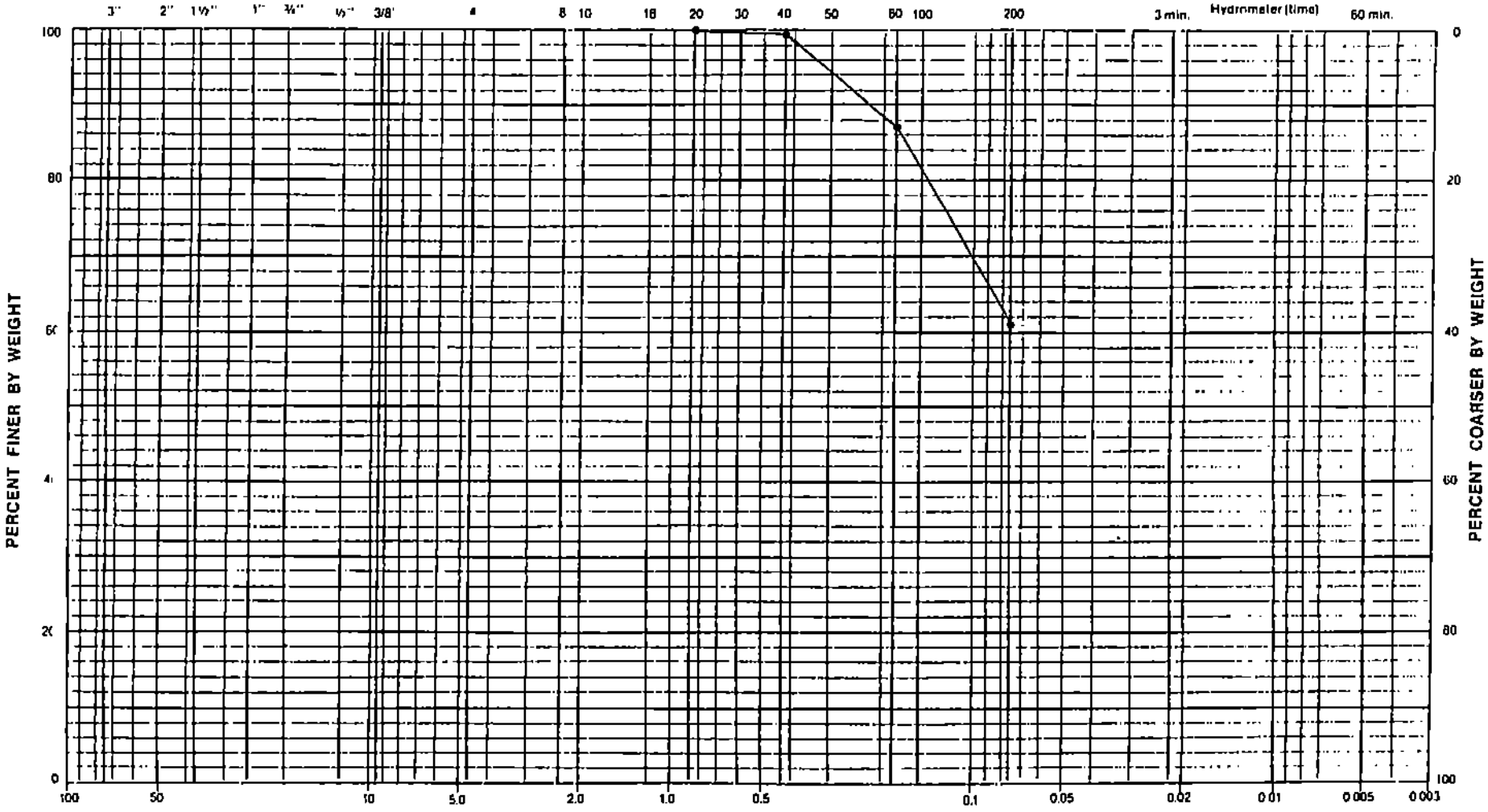
Liquid Limit Granular %

Plasticity Index Nonplastic %

Dry unit weight 94.7 Pcf

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ N/A

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ N/A



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-20, SPT-1, 25.0' - 26.5'

Classification Silty CLAY with Sand (CL-ML)

Sample No. 40682

Job No. 88-152-2

Date 12/06/89

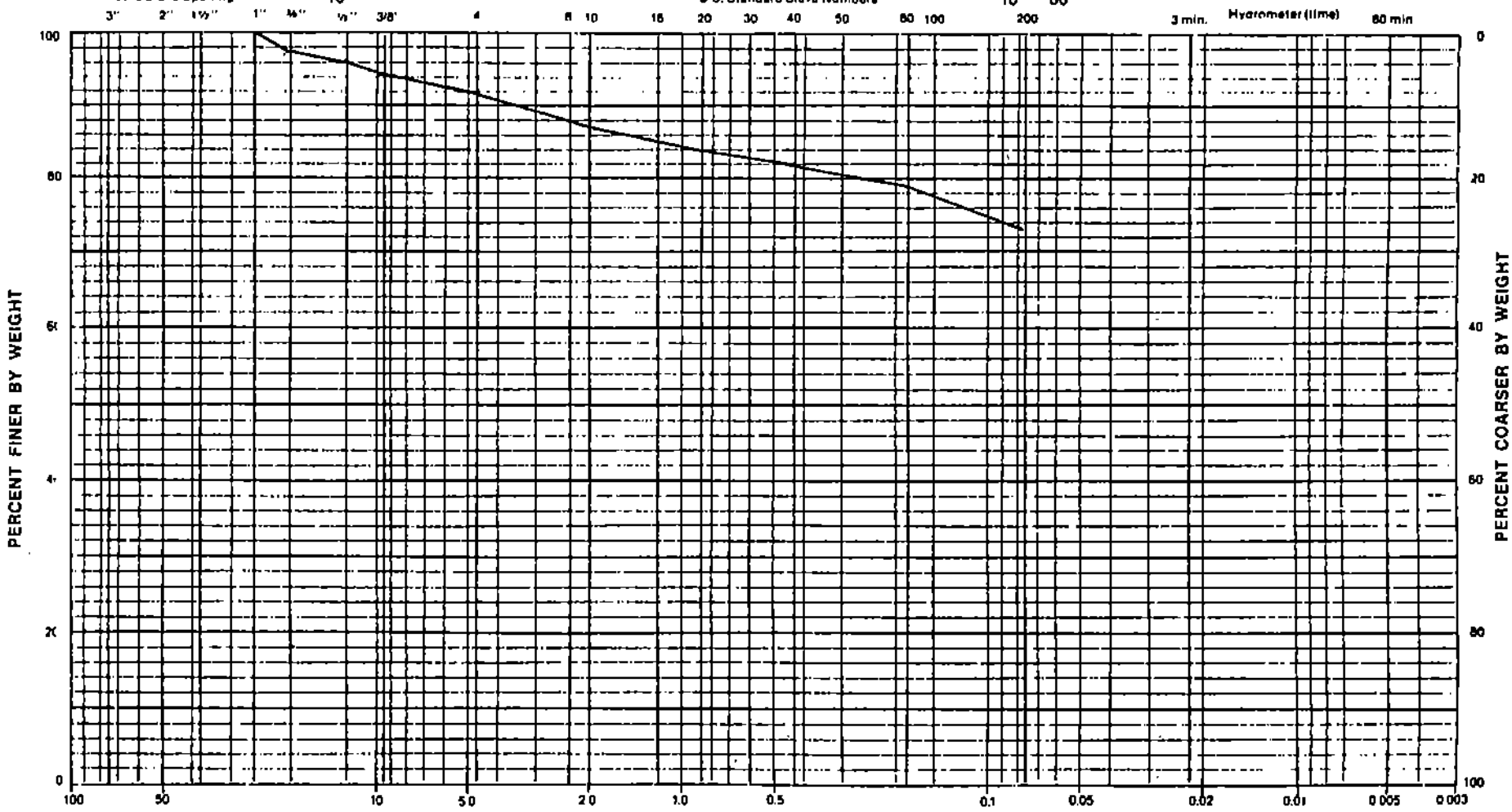
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: DH-20, S-1, 39.0' - 39.5'

Classification Sandy Lean CLAY (CL)

Moisture Content -- %

Liquid Limit 36 %

Sample No. 40957

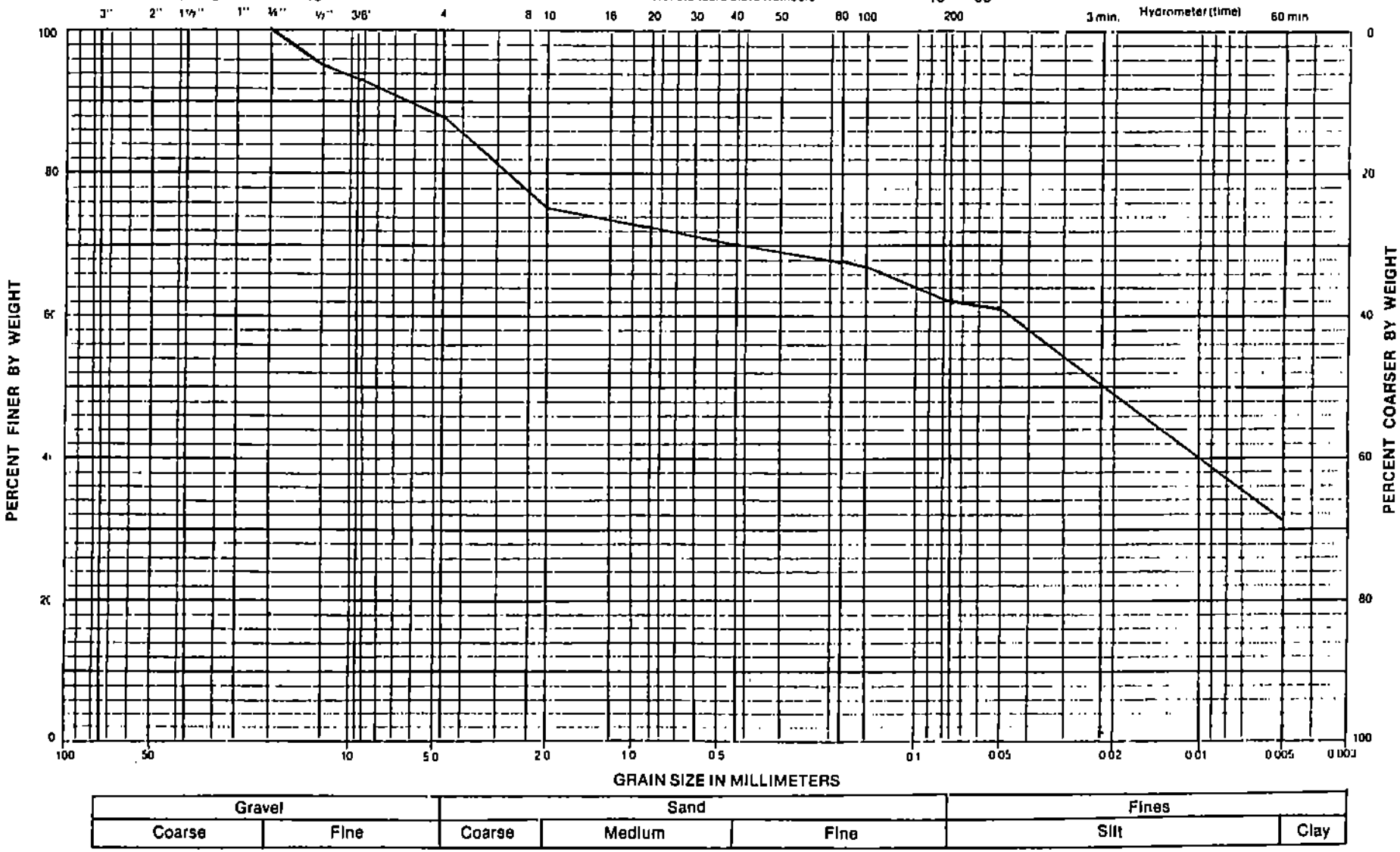
Job No. 88-152-2

Date 12/18/89

Plasticity Index 17 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

1988 TEST PIT GRAIN SIZE CURVES

Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: Little Cherry Site TP-102, S-2, 4.0'-8.0'

Classification Silty SAND w/Gravel (SM)

Moisture Content 12 %

Sample No. 32284

Job No. 88-152

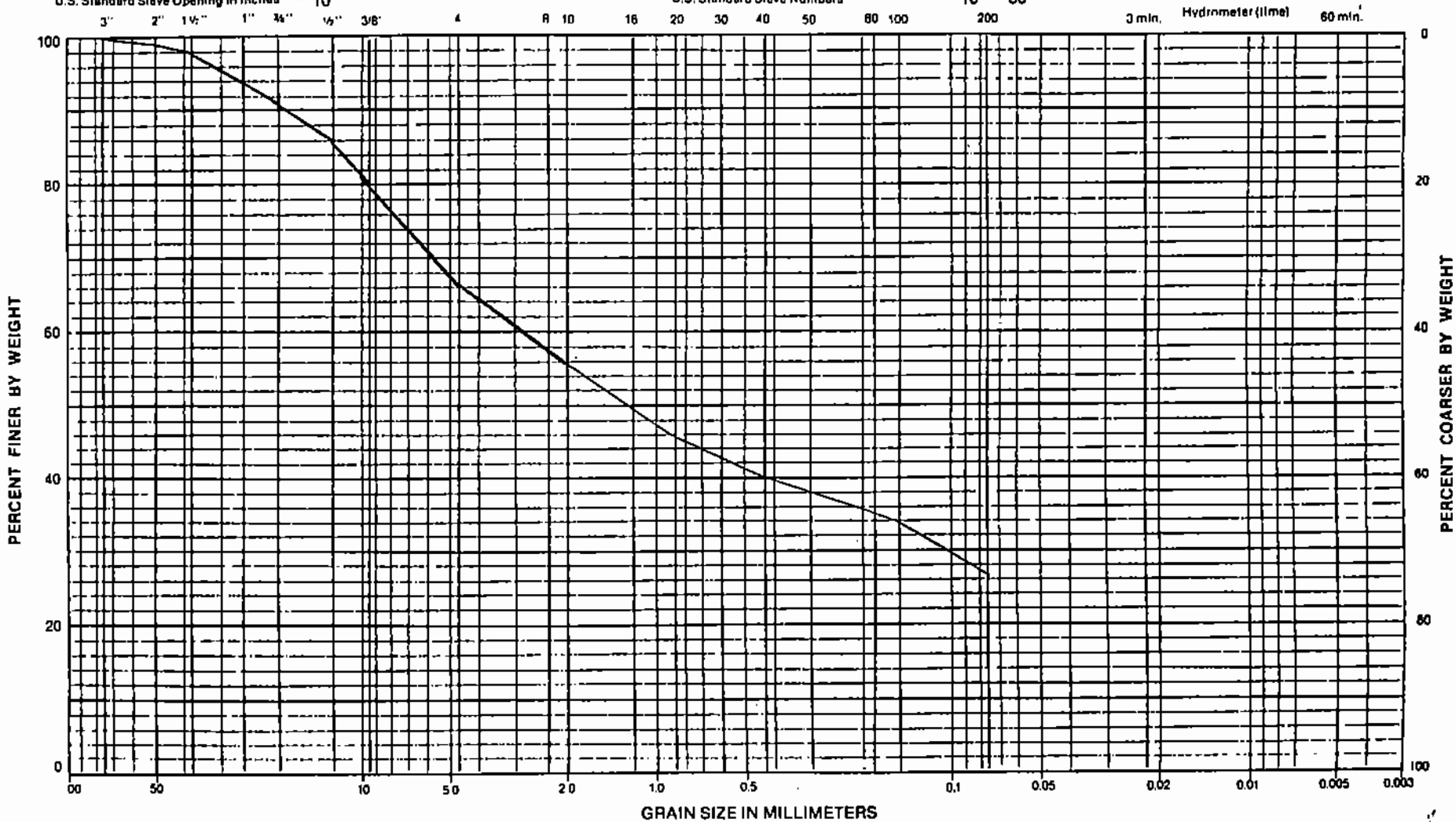
Date August 1988

Liquid Limit GNP %

Plasticity Index _____ %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: Little Cherry Site TP-103, S-1, 4.0'-11.0'

Classification: Sandy Silty CLAY (CL-ML)

Sample No. 32285

Job No. 88-152

Date August 1988

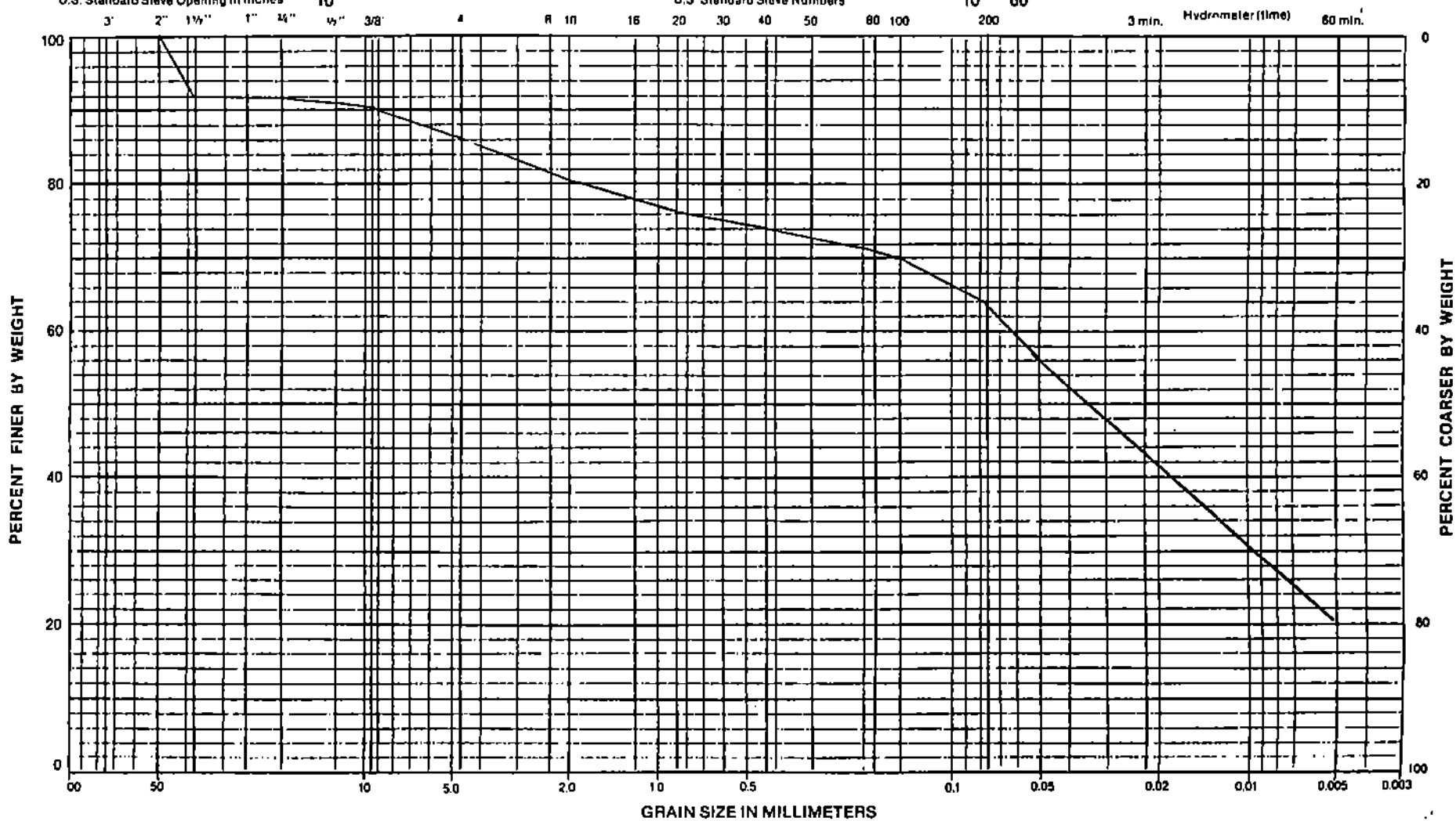
Moisture Content 2 %

Liquid Limit 21 %

Plasticity Index 4 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Sample No. 32286

Location: TP-105, S-1, 8.0'-14.0'

Job No. 88-152

Classification Poorly-Graded SAND w/Silt & Gravel (SP-SM)

Date August 1988

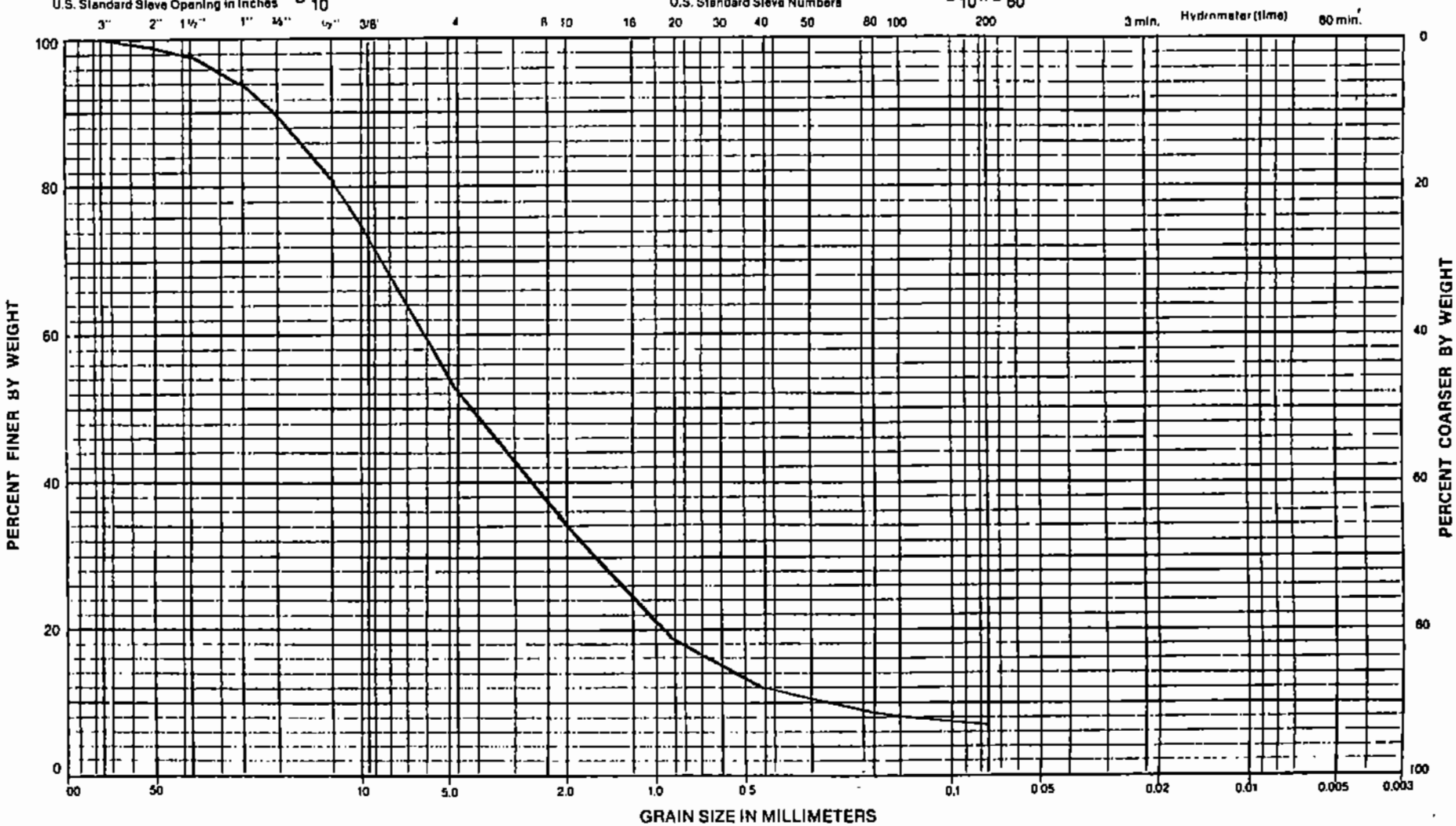
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ 20

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ 3.83



Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: TP-106, S-1, 6.0'-8.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 11 %

Sample No. 32287

Job No. 88-152

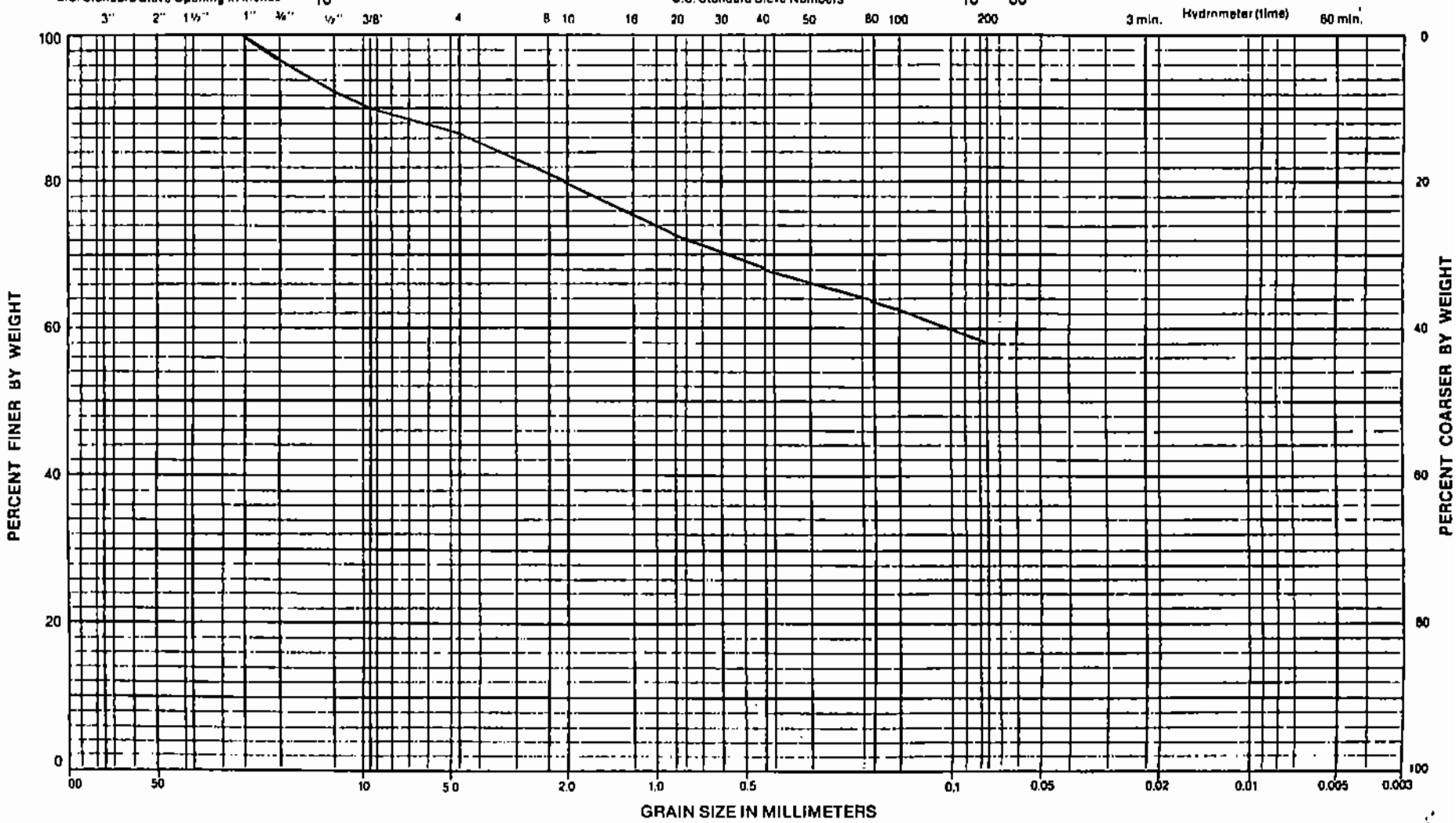
Date August 1988

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: TP-107, S-1, 8.0'-9.0'

Classification Sandy Silty CLAY w/Gravel (CL-ML)

Moisture Content 6 %

Sample No. 32288

Job No. 88-152

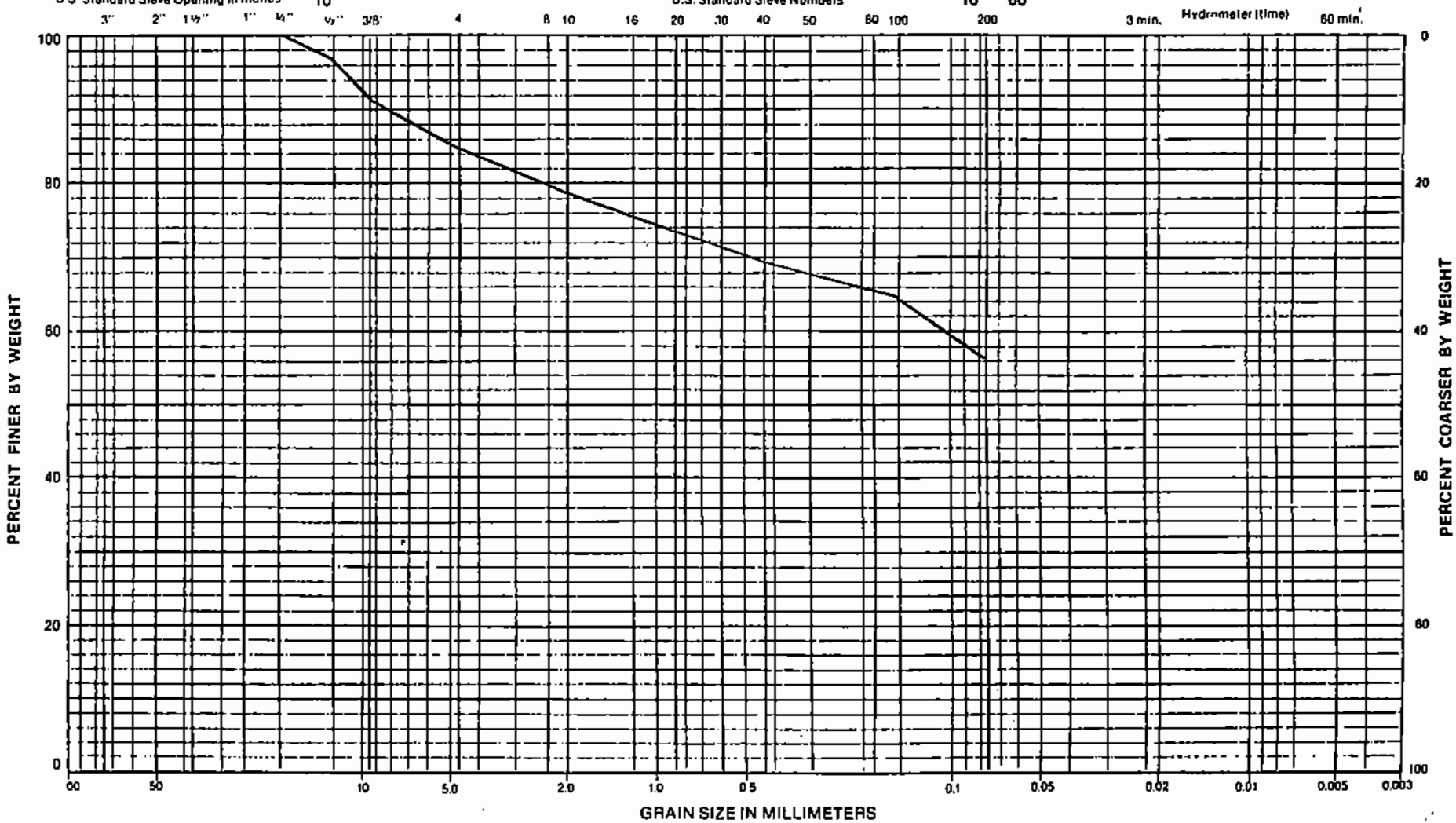
Date August 1988

Liquid Limit 20 %

Plasticity Index 6 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Sample No. 32290

Location: Little Cherry Site, TP-109, 8.0'-10.0', S-1

Job No. 88-152

Classification: Sandy SILT

Date: October 1988

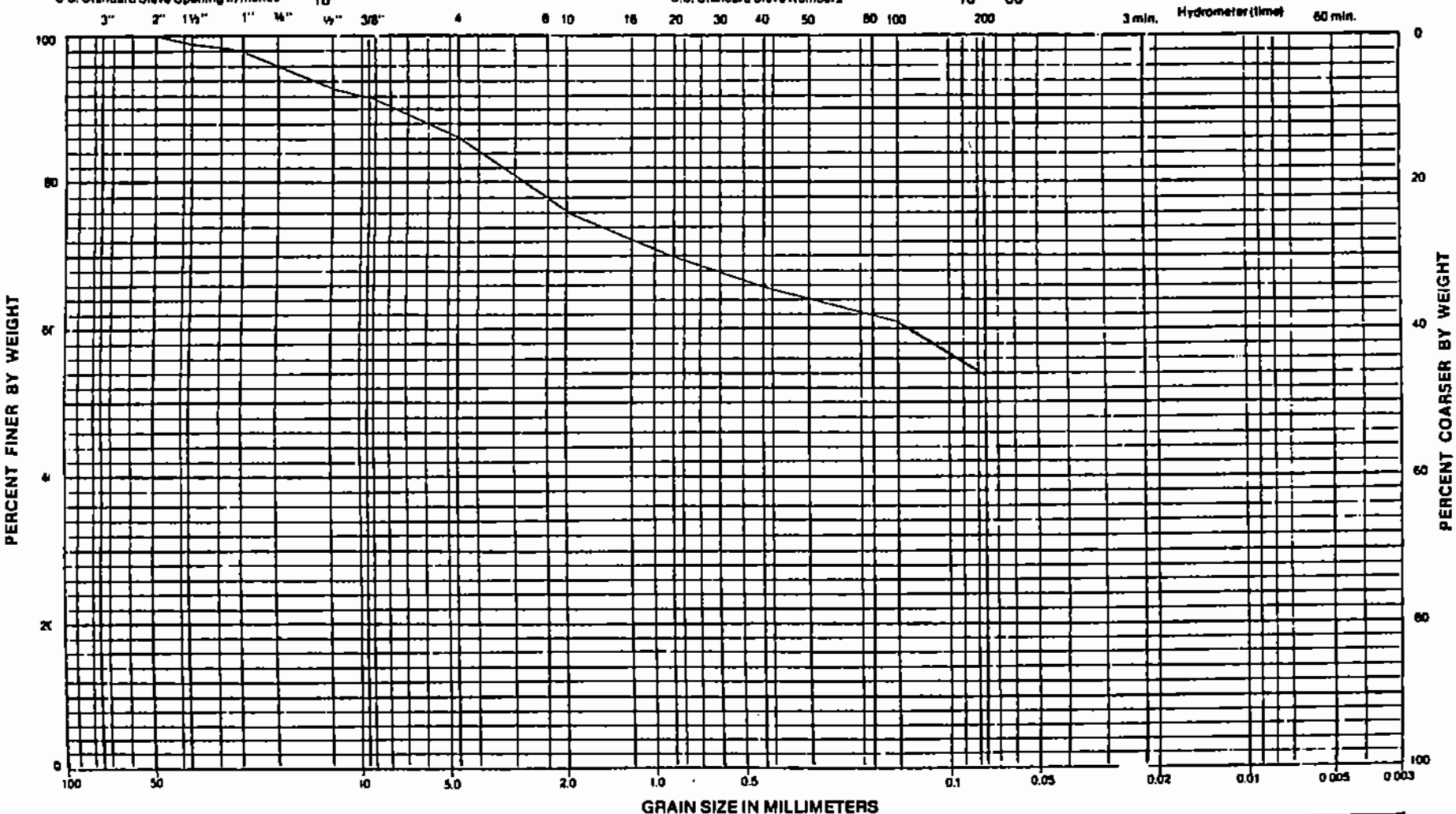
Moisture Content: 13 %

Liquid Limit: 20 %

Plasticity Index: 1 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

NET-105

1989 TEST PIT GRAIN SIZE CURVES

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-121, S-1, 6.0' - 9.0'

Classification Clayey GRAVEL with Sand (GC)

Moisture Content 10 %

Liquid Limit -- %

Sample No. 40752

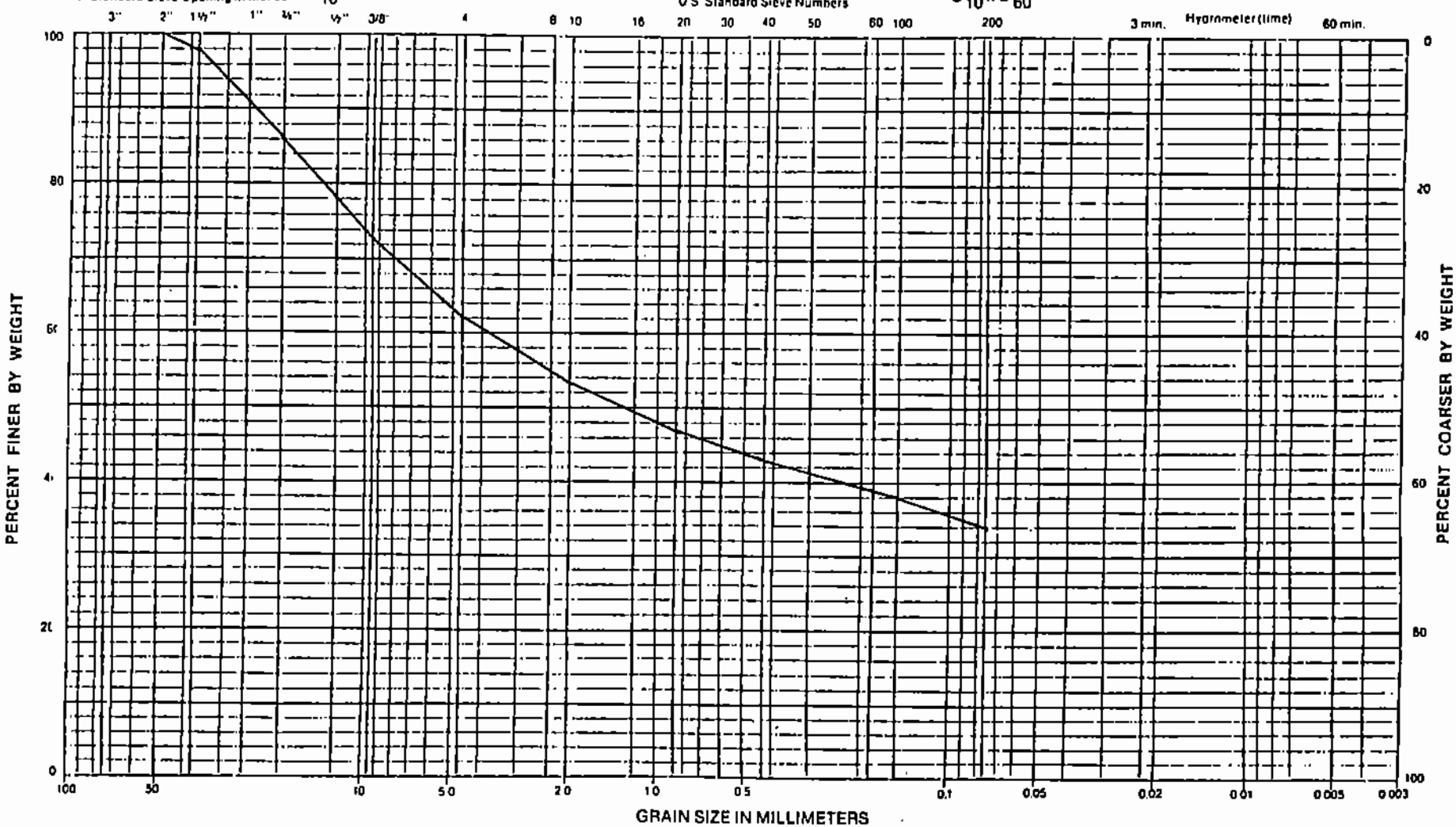
Job No. 88-152-2

Date 12/13/89

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-121, S-2, 9.0' - 12.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 19 %

Sample No. 39452

Job No. 88-152-2

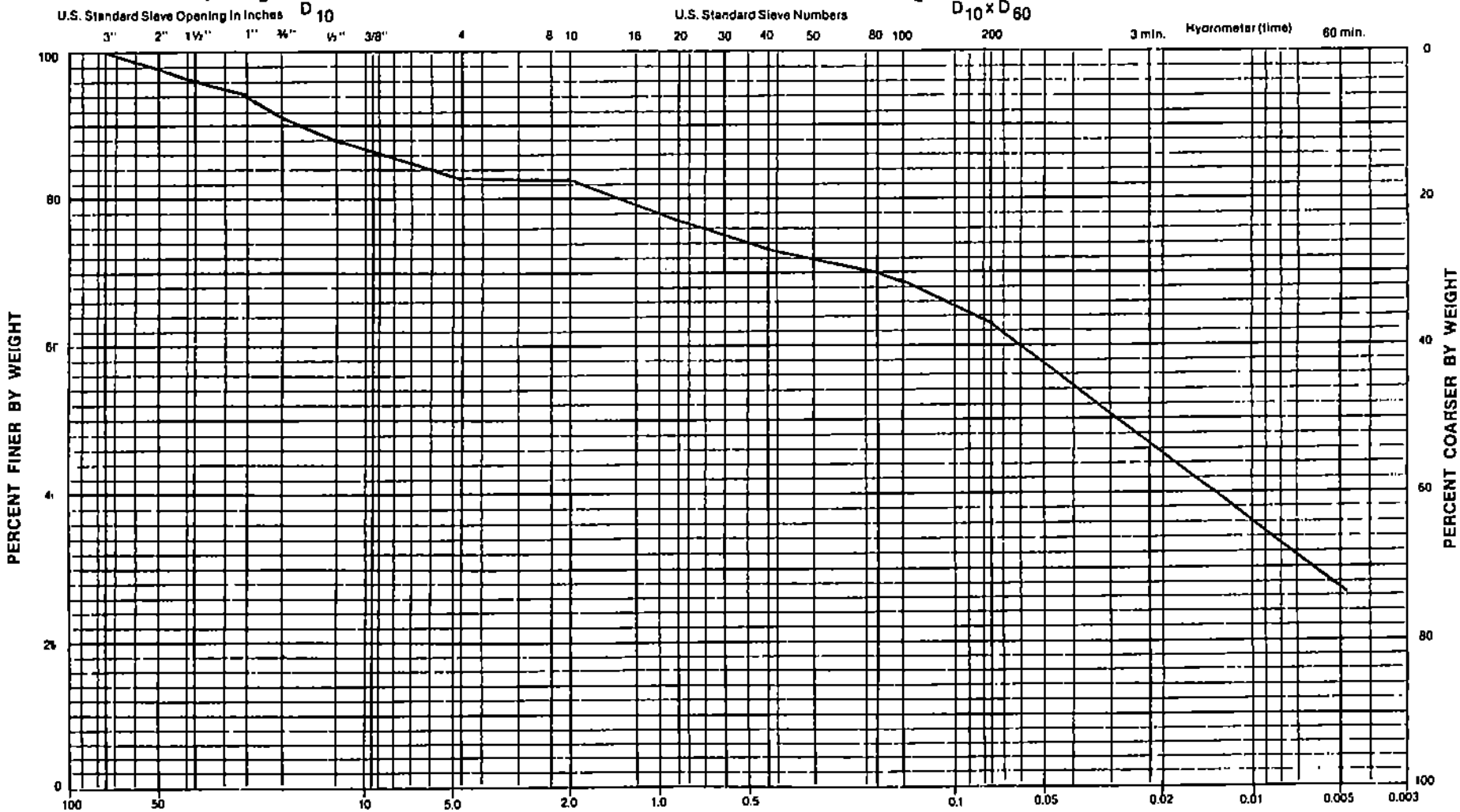
Date 12/04/89

Liquid Limit 24 %

Plasticity Index 11 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-122, S-1, 5.0' - 8.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 10 %

Liquid Limit -- %

Sample No. 40744

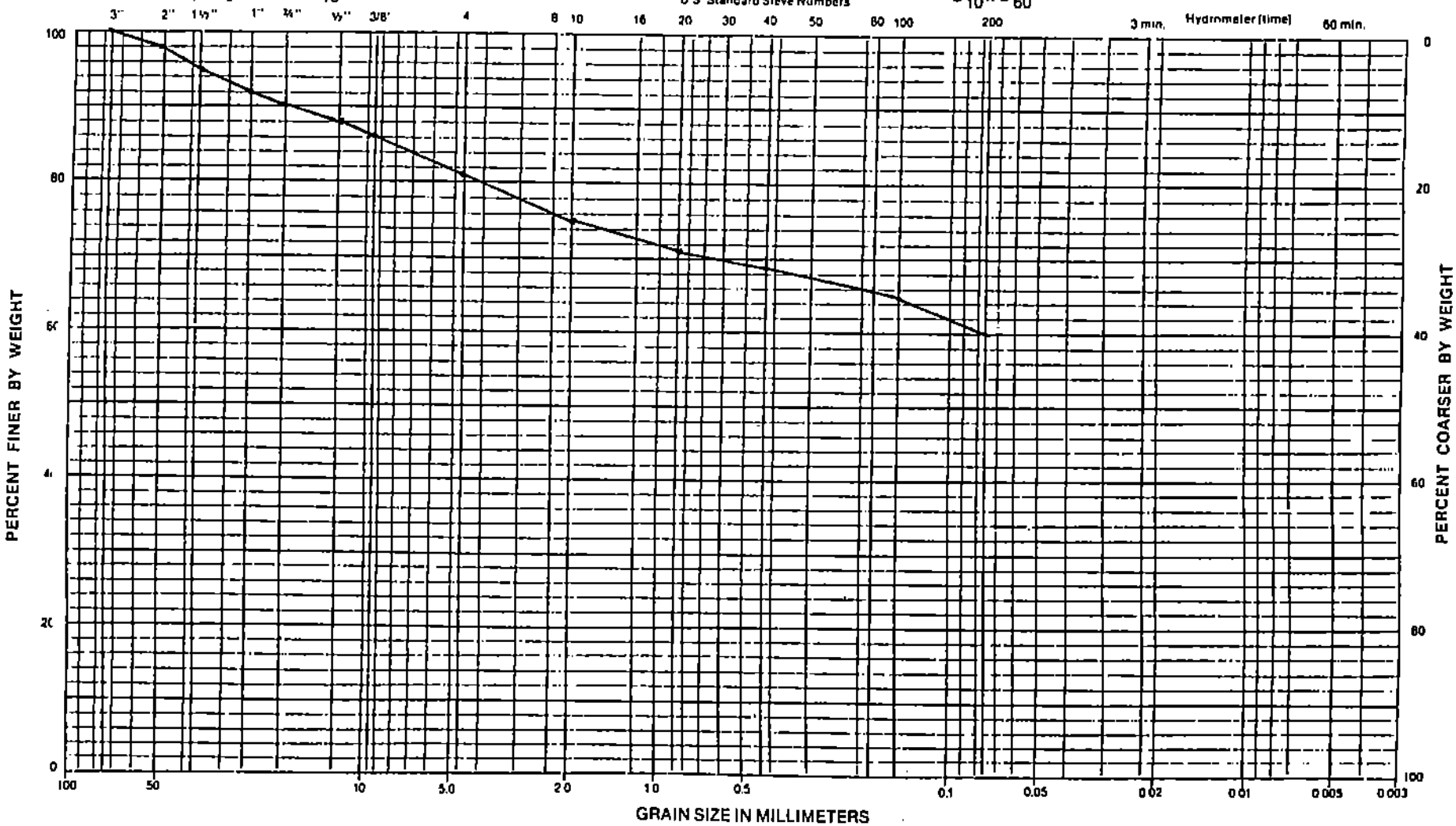
Job No. 88-152-2

Date 12/13/89

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-124, S-1, 6.0' - 8.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 34 %

Liquid Limit 33 %

Sample No. 40745

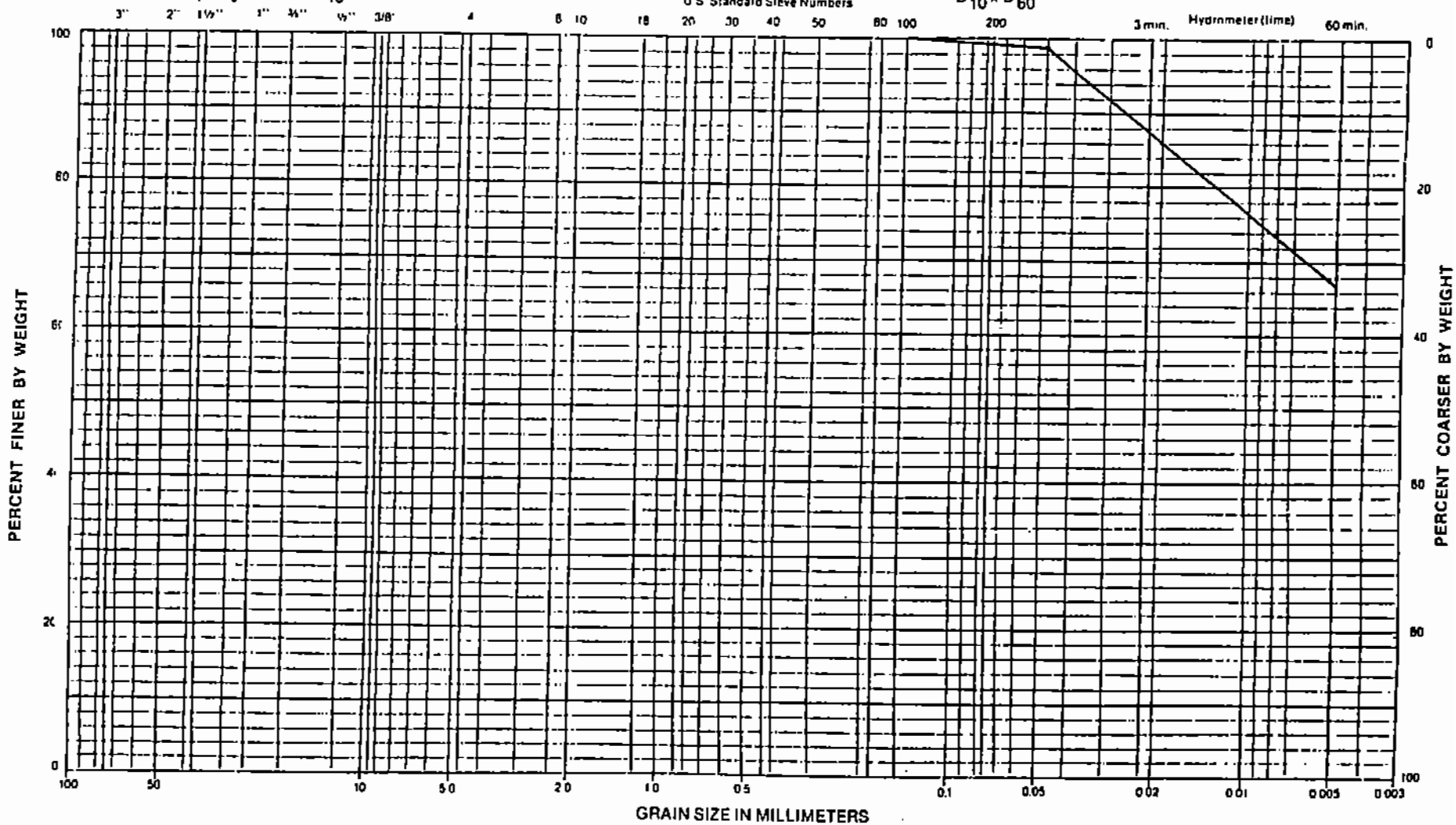
Job No. 88-152-2

Date 12/13/89

Plasticity Index 9 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-126, S-1, 4.0' - 6.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 13 %

Sample No. 40746

Job No. 88-152-2

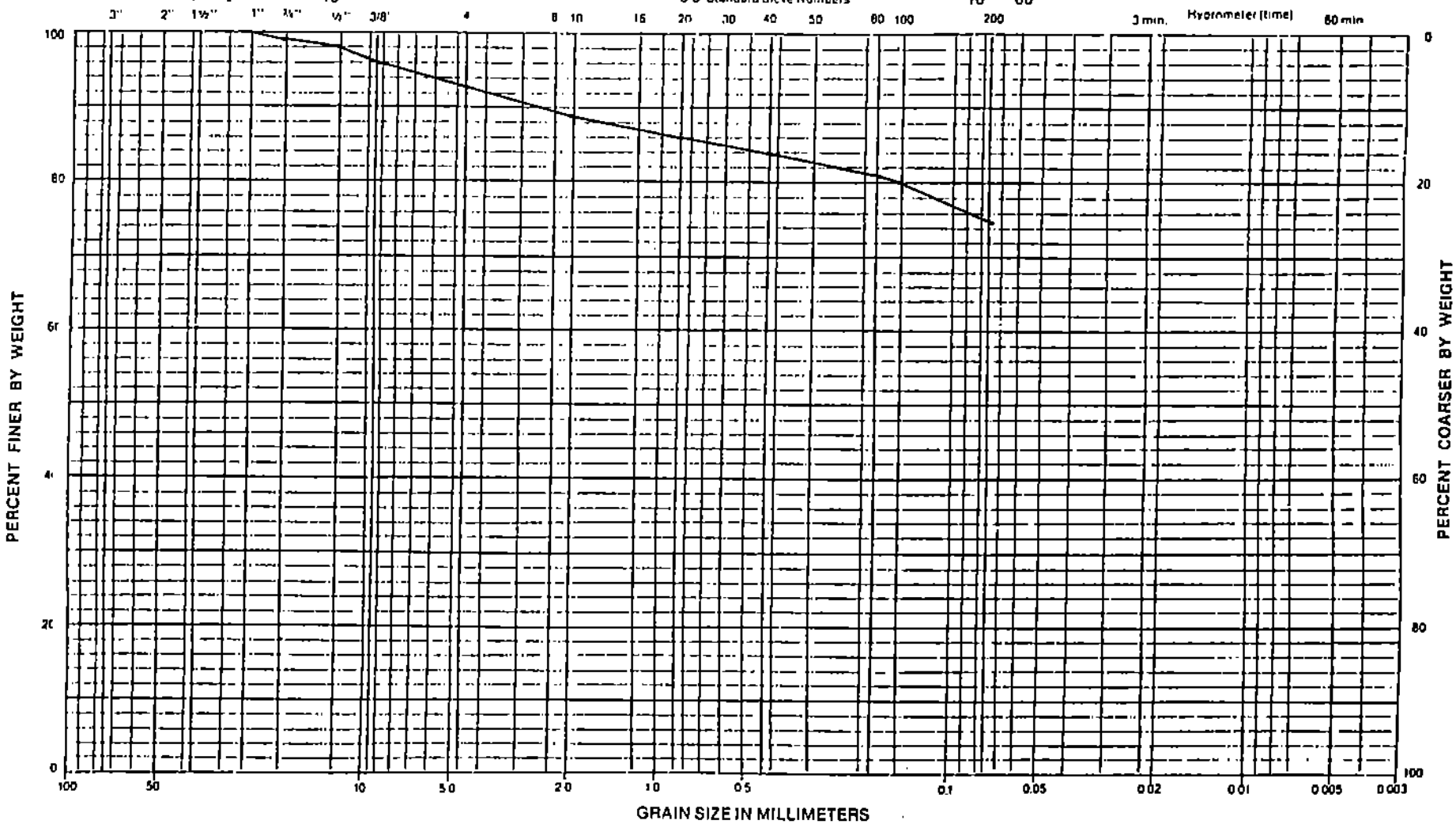
Date 12/13/89

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-127, S-1, 3.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 13 %

Liquid Limit 26 %

Sample No. 39454

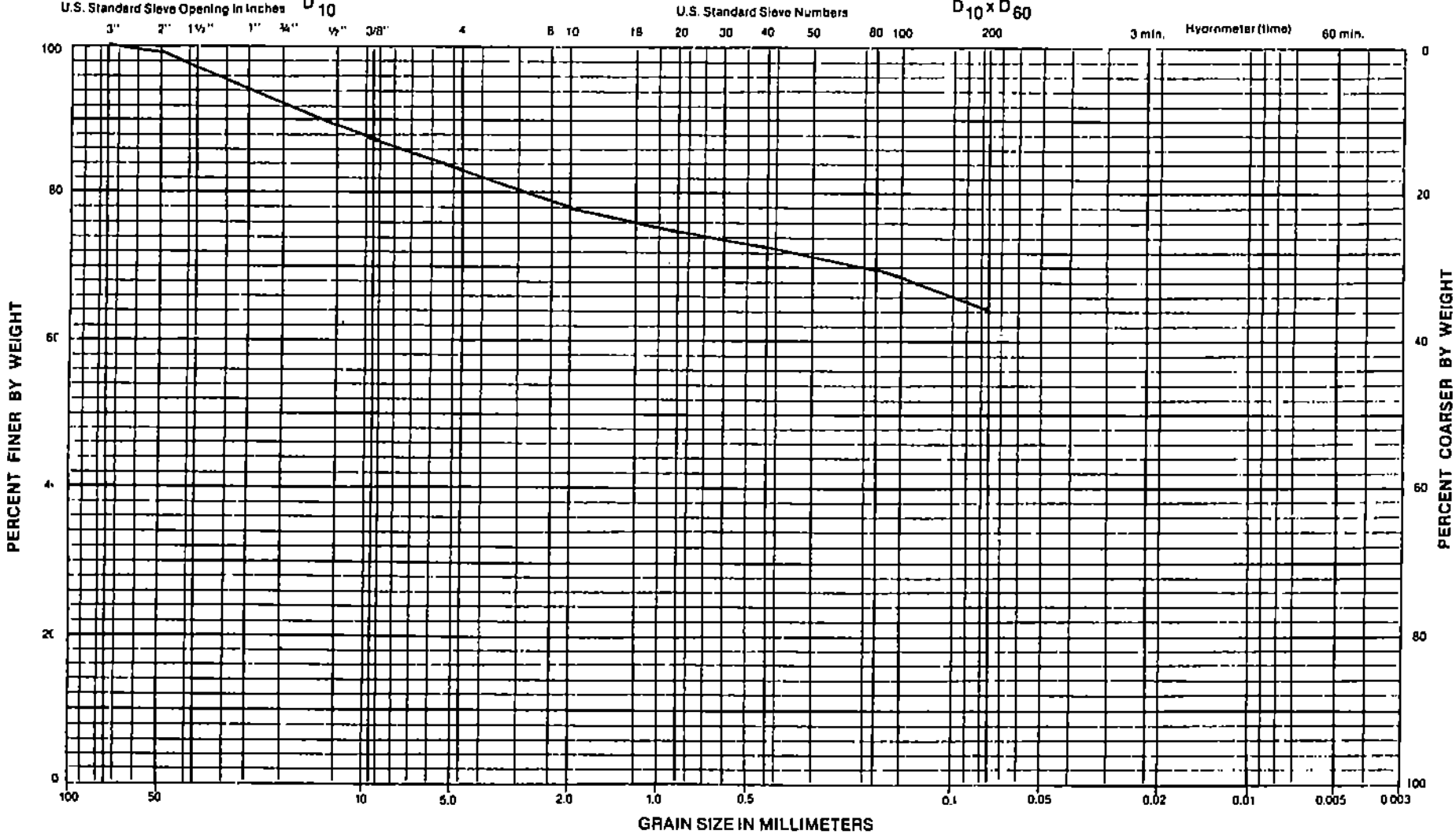
Job No. 88-152-2

Date 12/04/89

Plasticity Index 10 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-128, S-1, 3.0' - 5.0'

Classification Lean CLAY with Gravel (CL)

Moisture Content 20 %

Sample No. 39455

Job No. 88-152-2

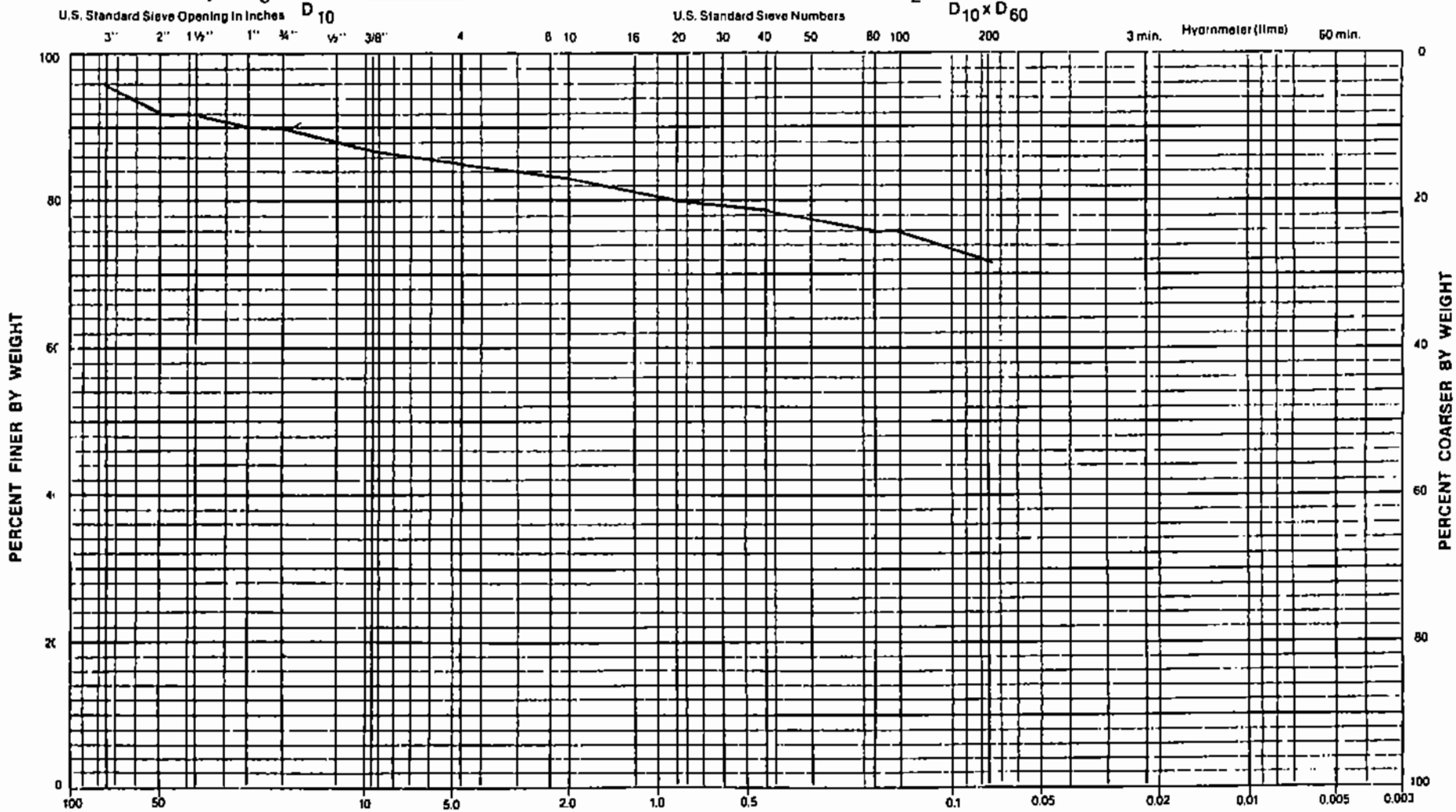
Date 12/04/89

Liquid Limit 26 %

Plasticity Index 10 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CN1-106

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-128, S-2, 11.0' - 14.0'

Classification Lean CLAY (CL)

Moisture Content 27 %

Liquid Limit 41 %

Sample No. 39456

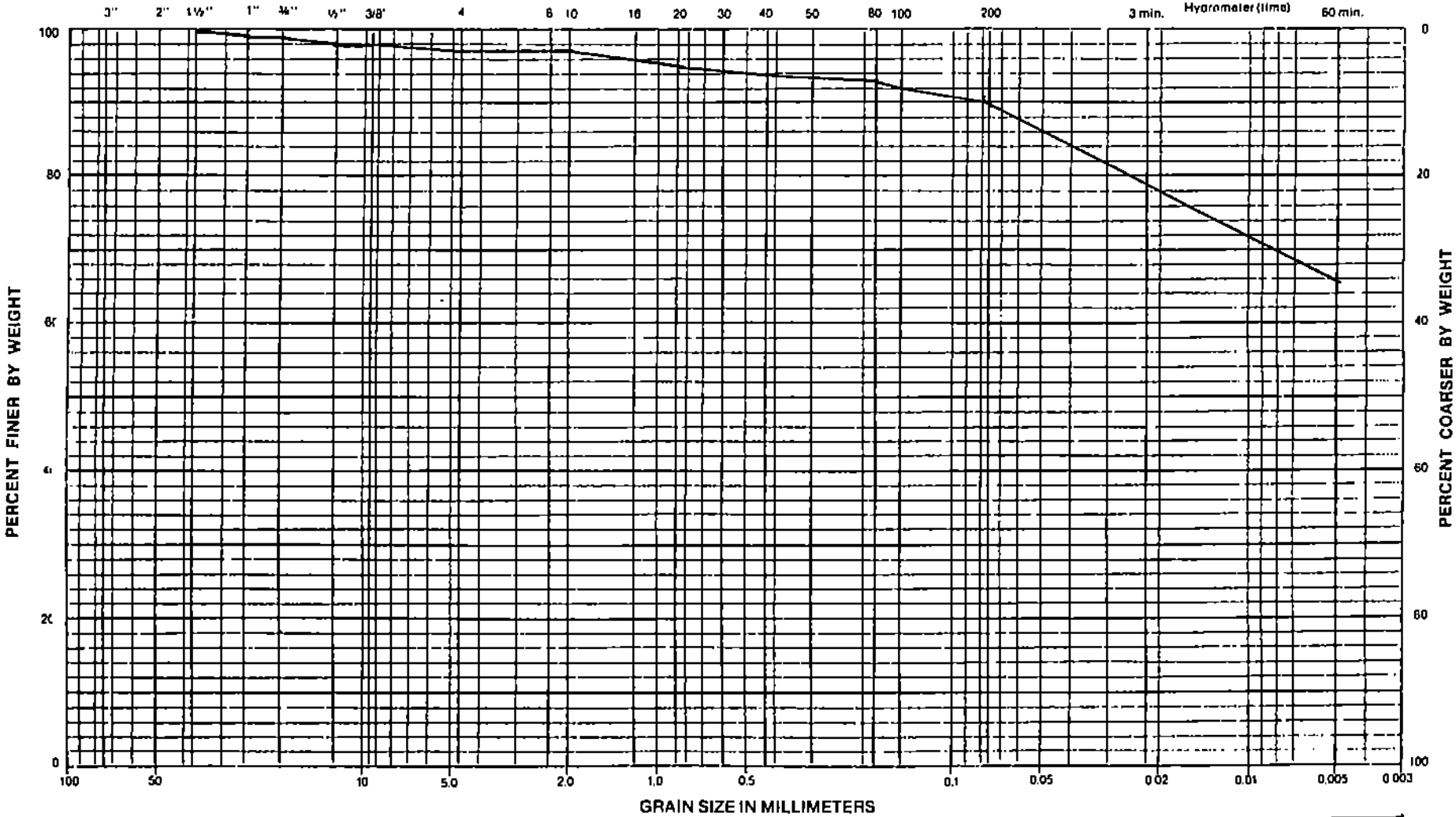
Job No. 88-152-2

Date 12/04/89

Plasticity Index 19 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-132, S-1, 3.0' - 7.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 11 %

Sample No. 39459

Job No. 88-152-2

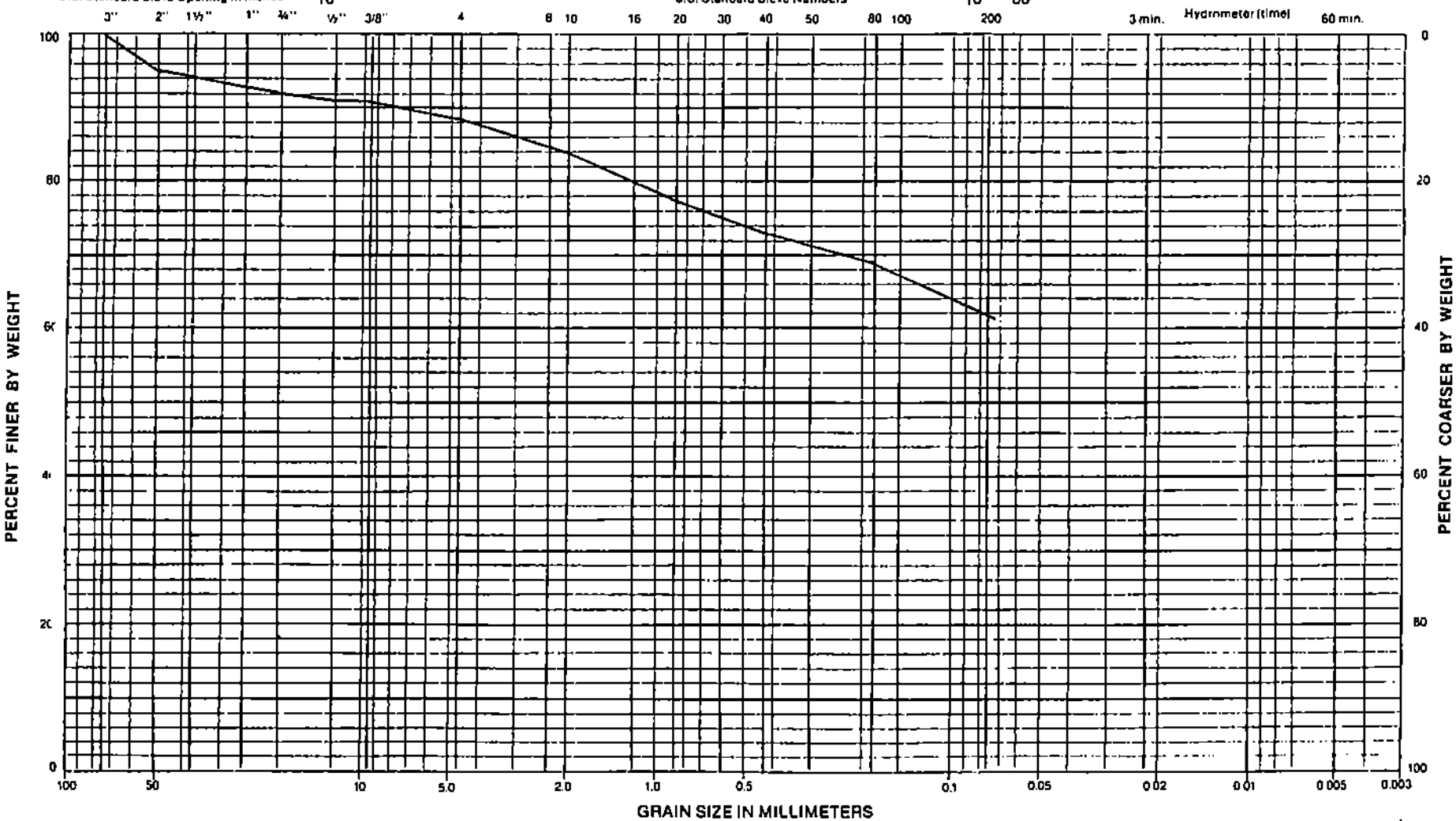
Date 12/04/89

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-133, S-1, 1.0' - 3.0'

Classification Silty GRAVEL with Sand (GM)

Moisture Content 8 %

Sample No. 40747

Job No. 88-152-2

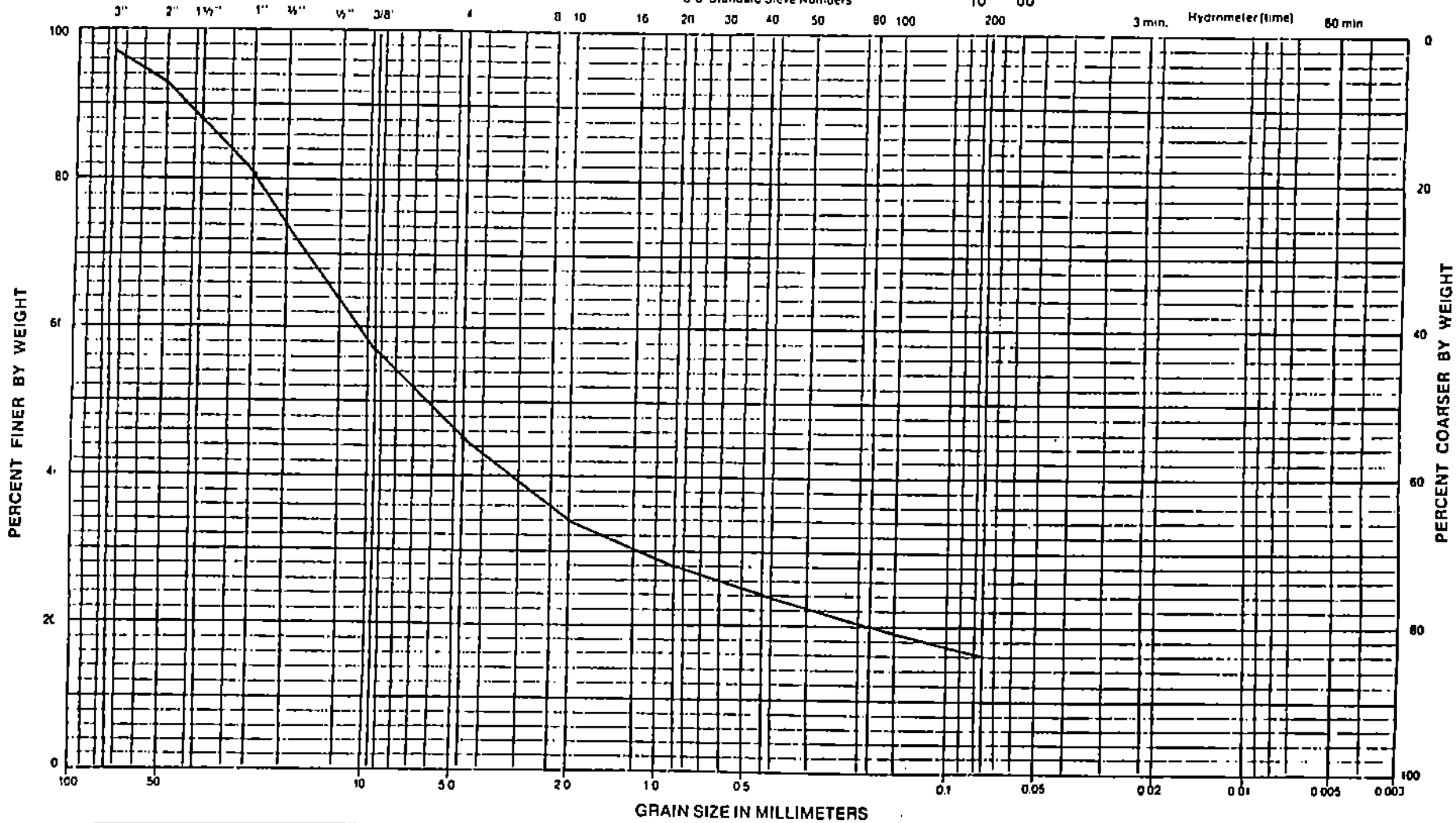
Date 12/13/89

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-134, S-2, 2.0' - 4.0'

Classification Clayey SAND with Gravel

Moisture Content 6 %

Liquid Limit -- %

Plasticity Index -- %

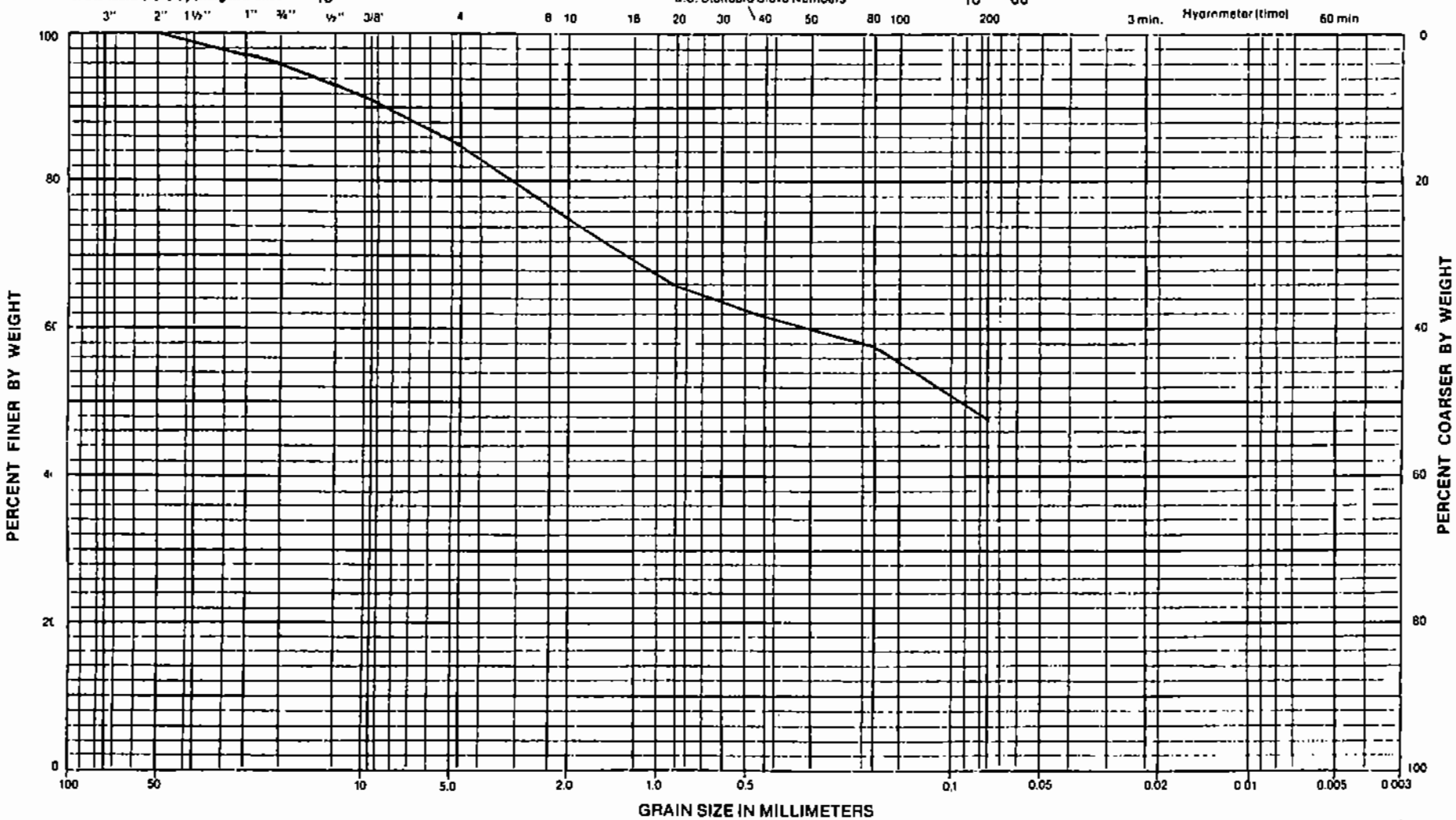
Sample No. 39461

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-135, S-1, 6.0' - 8.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 12 %

Liquid Limit -- %

Sample No. 40748

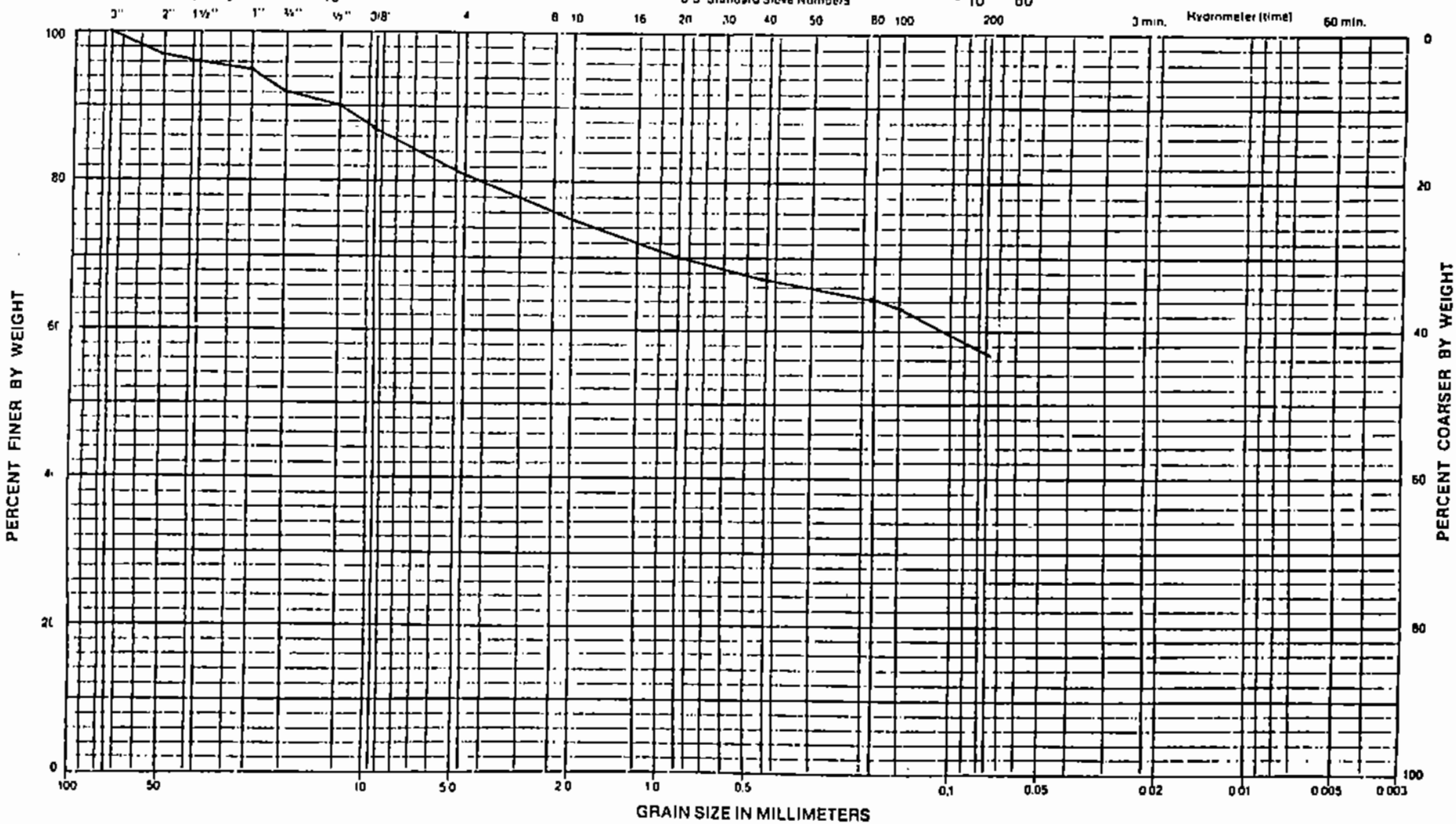
Job No. 88-152-2

Date 12/13/89

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-136, S-1, 2.0' - 4.0'

Classification Gravelly Lean CLAY with Sand (CL)

Sample No. 39463

Job No. 88-152-2

Date 12/04/89

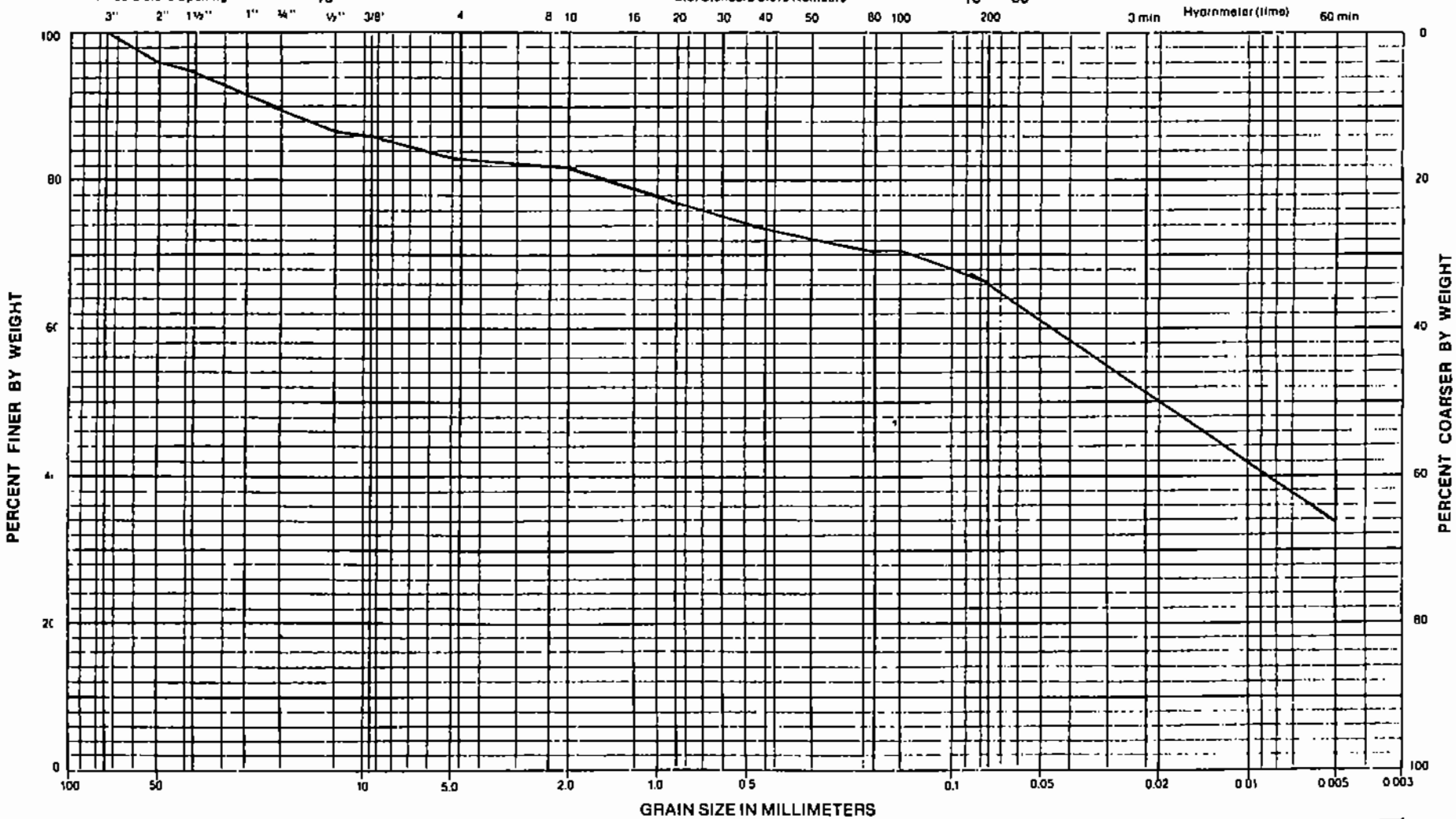
Moisture Content 22 %

Liquid Limit 42 %

Plasticity Index 22 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-138, S-1, 2.0' - 4.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 12 %

Sample No. 39464

Job No. 88-152-2

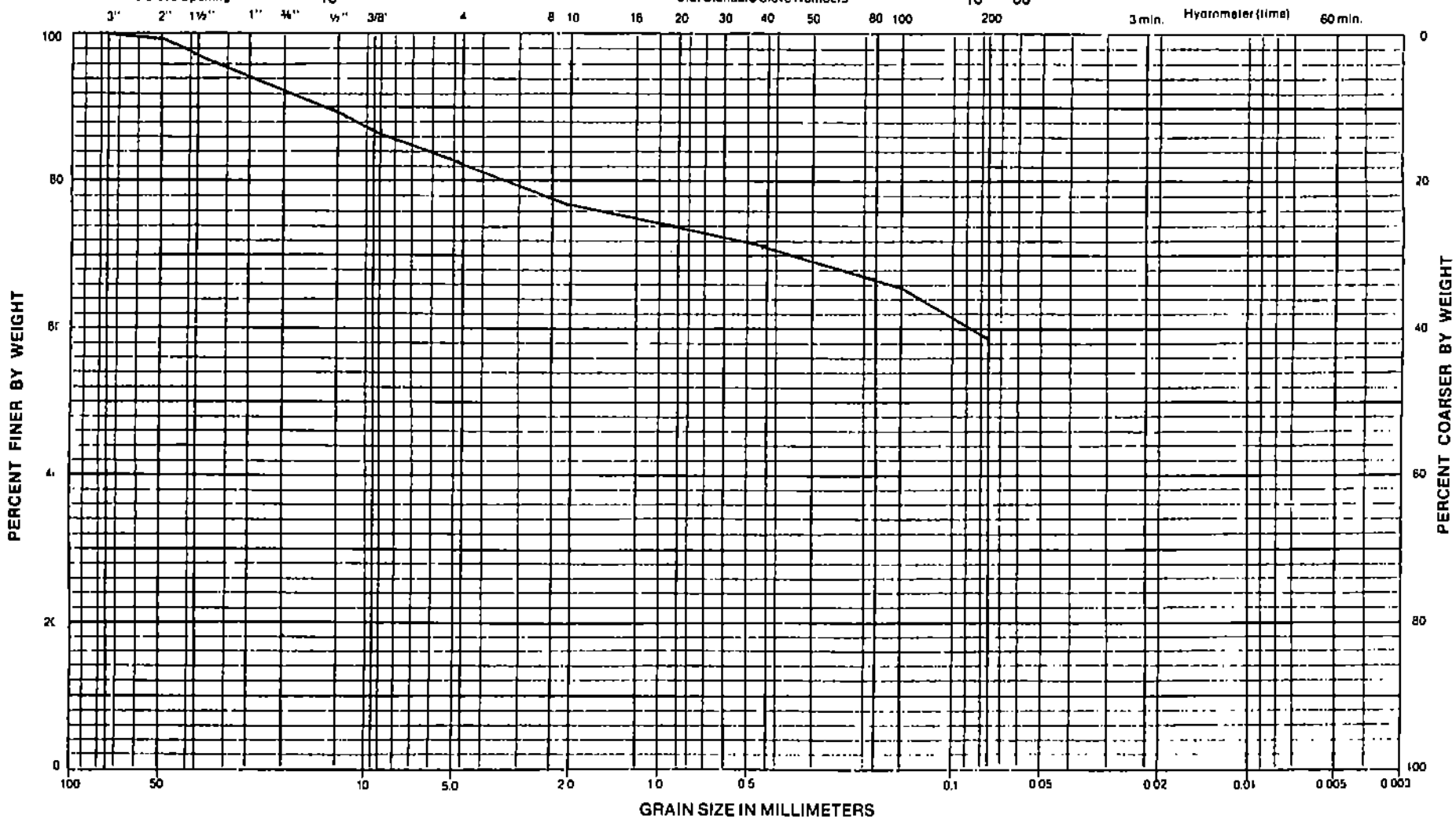
Date 12/04/89

Liquid Limit 25 %

Plasticity Index 9 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-140, S-1, 3.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 16 %

Liquid Limit -- %

Plasticity Index -- %

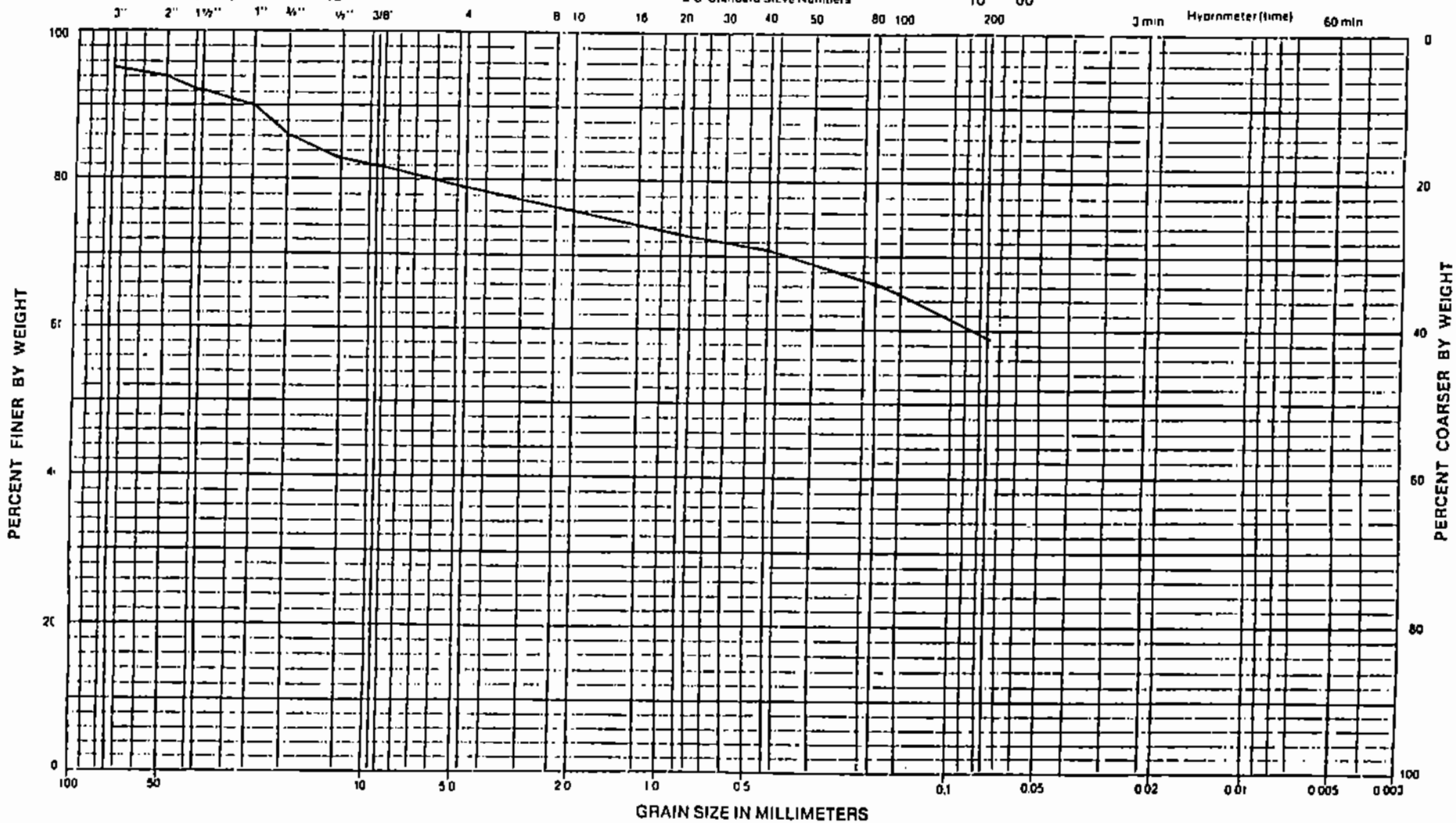
Sample No. 40749

Job No. 88-152-2

Date 12/13/89

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-142, S-1, 2.0' - 3.0'

Classification Sandy Lean CLAY with Gravel (CL)

Sample No. 39466

Job No. 88-152-2

Date 12/04/89

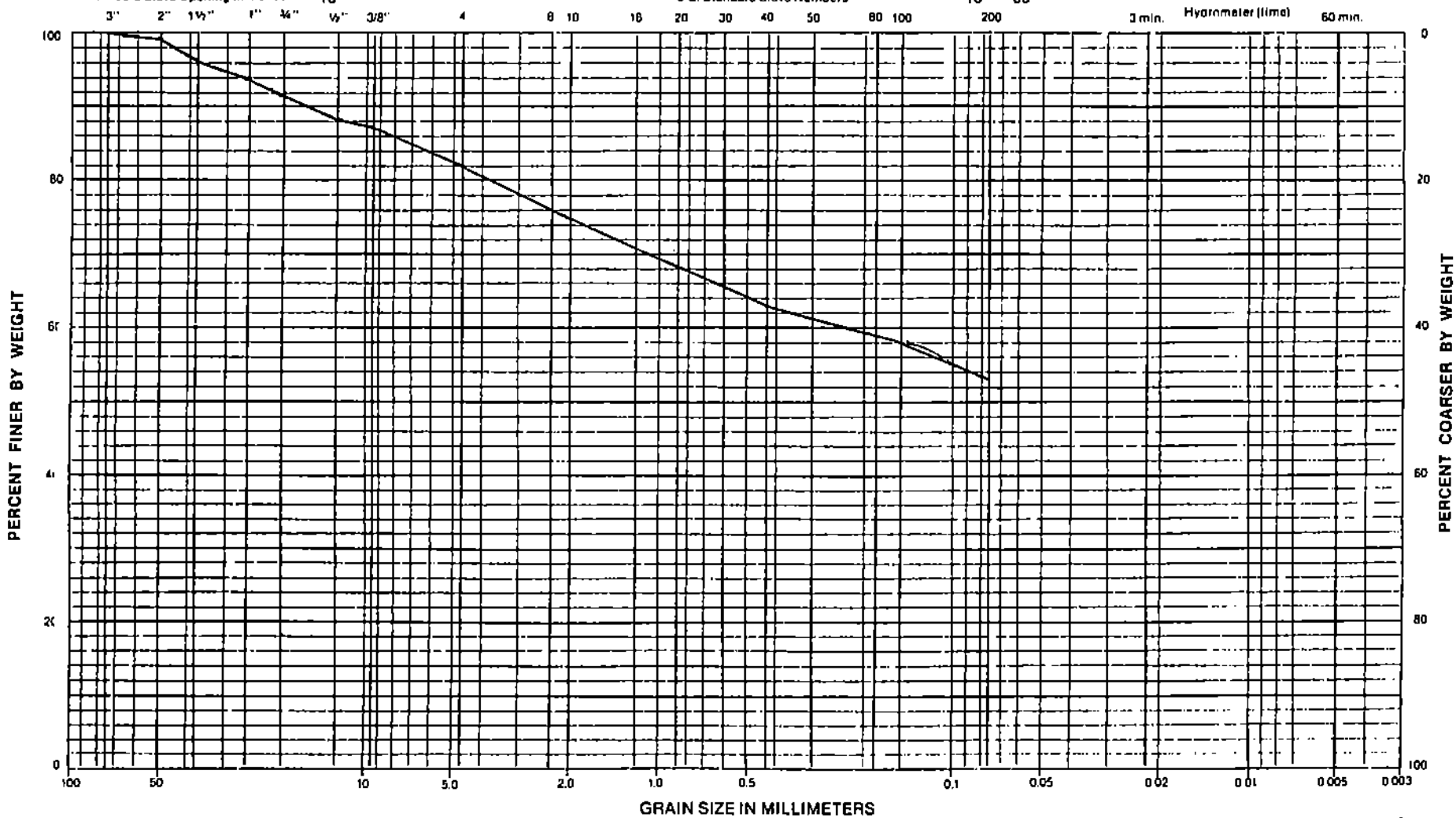
Moisture Content 10 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-143, S-1, 6.0' - 8.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 14 %

Sample No. 40750

Job No. 88-152-2

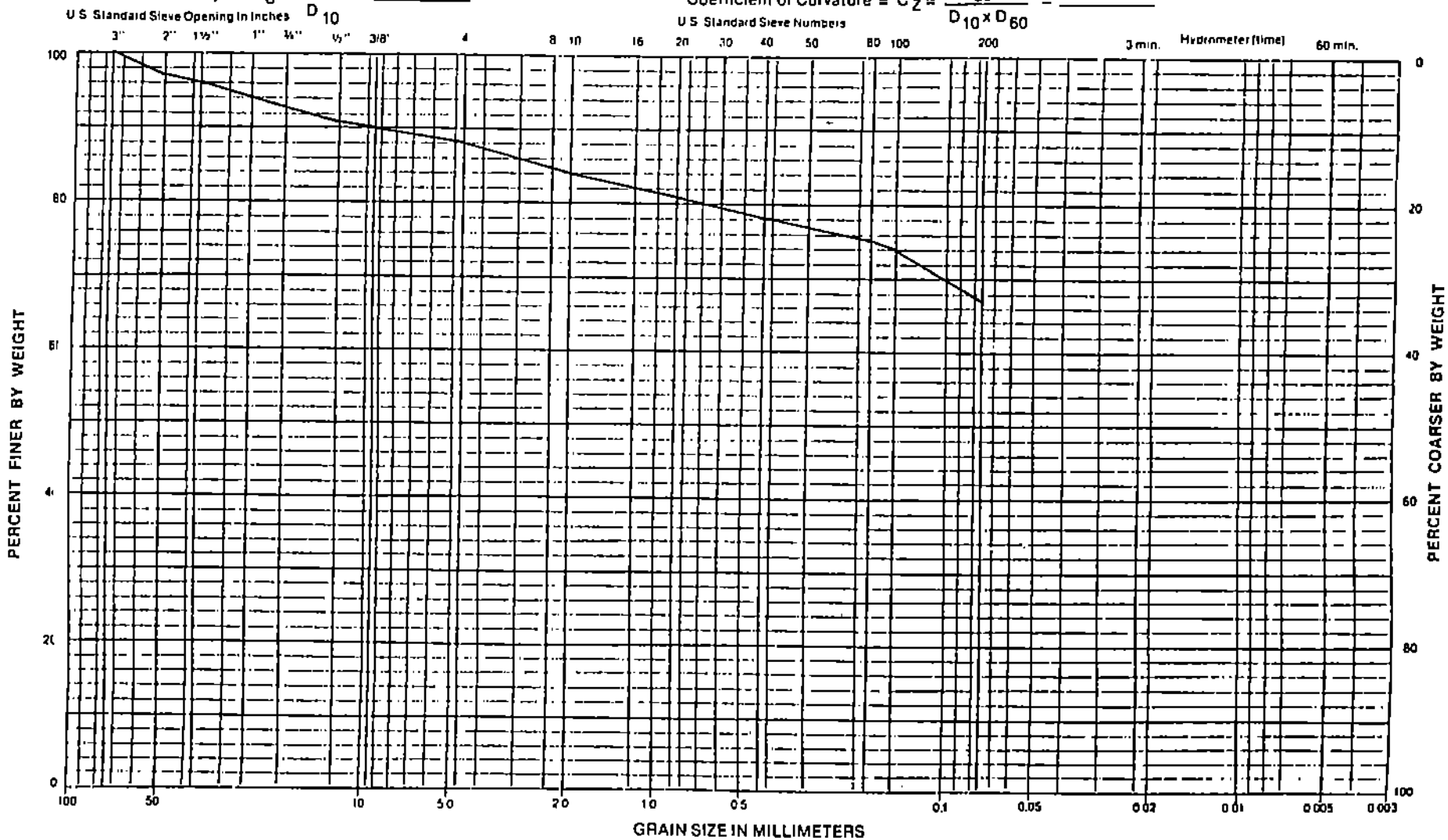
Date 12/13/89

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/88) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-144, S-1, 3.0' - 5.0'

Classification Gravelly Lean CLAY (CL)

Moisture Content 16 %

Liquid Limit 26 %

Sample No. 39467

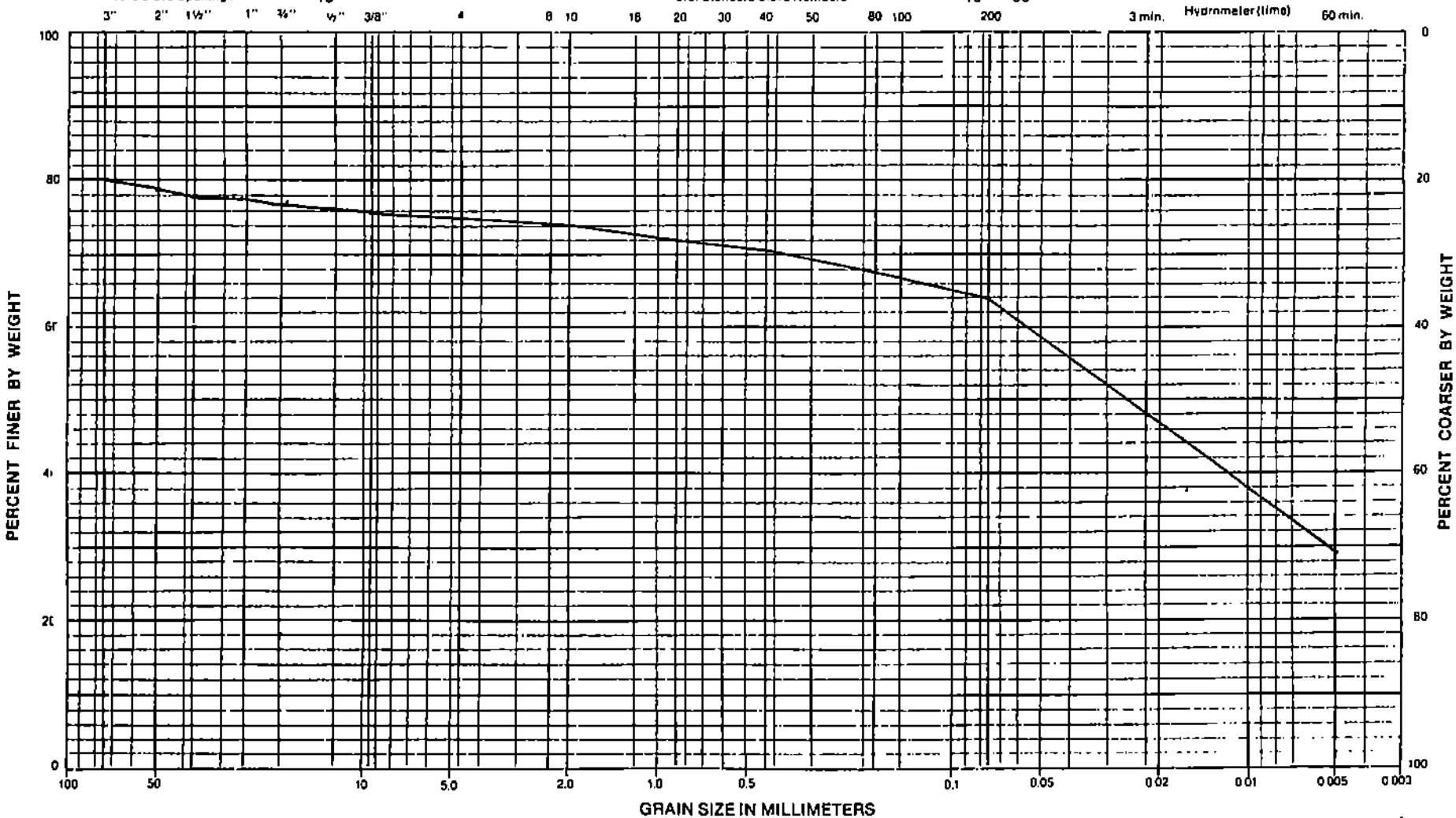
Job No. 88-152-2

Date 12/04/89

Plasticity Index 9 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: TP-145, S-2, 5.0' - 7.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 19 %

Liquid Limit 31 %

Sample No. 40751

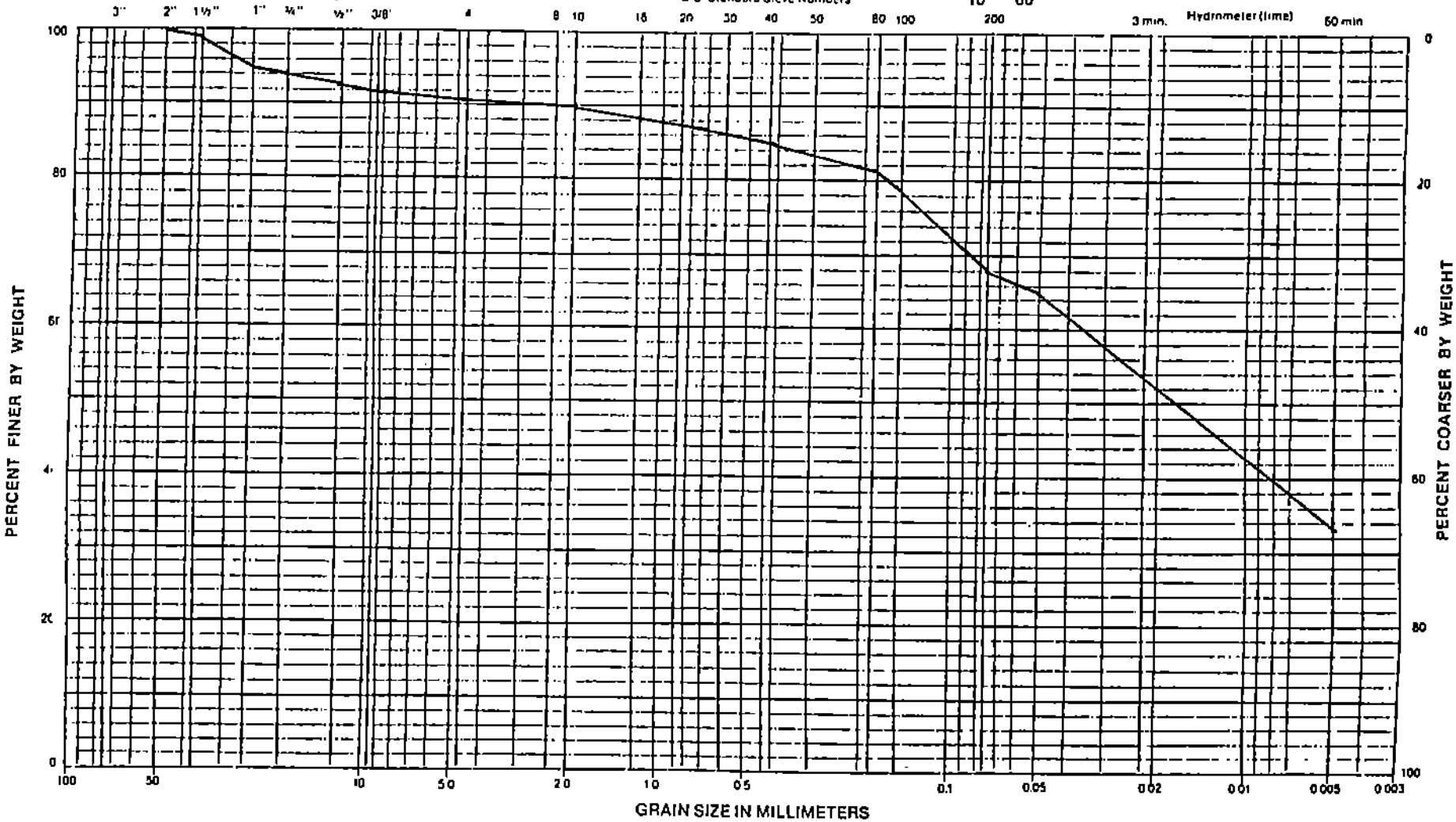
Job No. 88-152-2

Date 12/13/89

Plasticity Index 15 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-147, S-1, 1.0' - 3.0'

Classification Clayey GRAVEL with Sand (GC)

Moisture Content 9 %

Liquid Limit -- %

Plasticity Index -- %

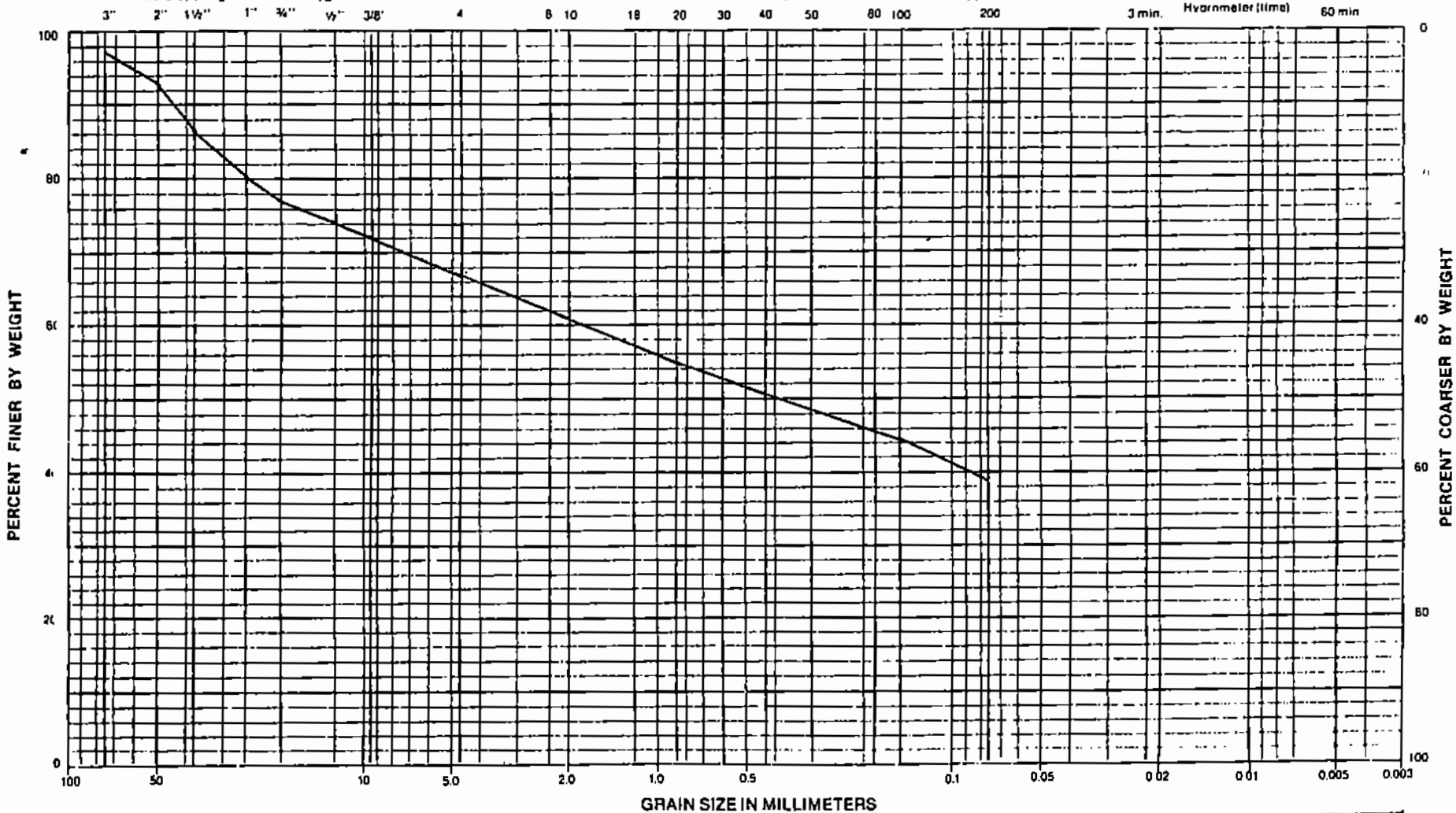
Sample No. 39468

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-2, S-1, 4.0' - 6.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content -- %

Liquid Limit 23 %

Sample No. 39442

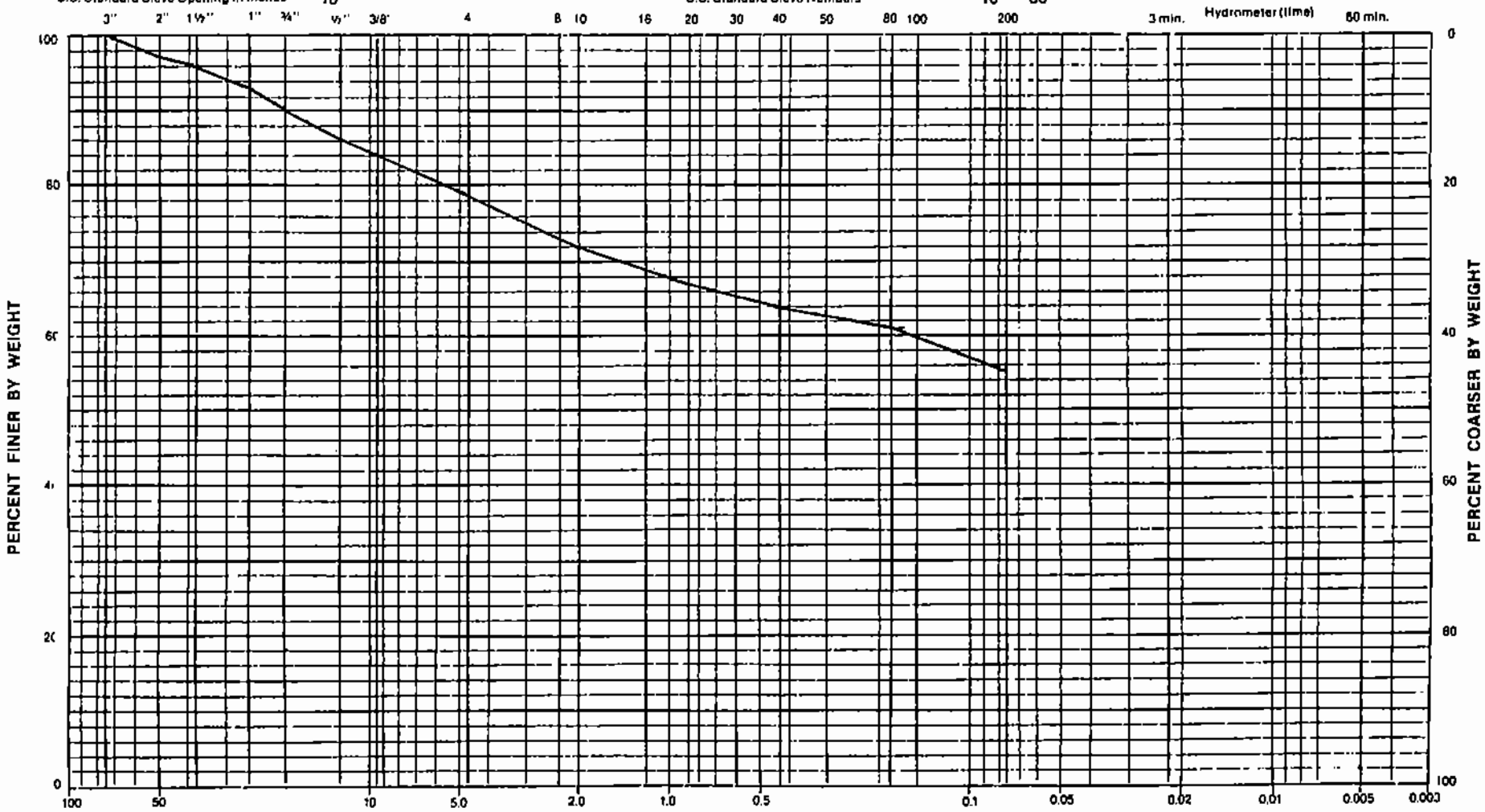
Job No. 88-152-2

Date 12/04/89

Plasticity Index 6 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-3, S-1, 4.0' - 6.0'

Classification Lean CLAY with Sand (CL)

Sample No. 39443

Job No. 88-152-2

Date 12/04/89

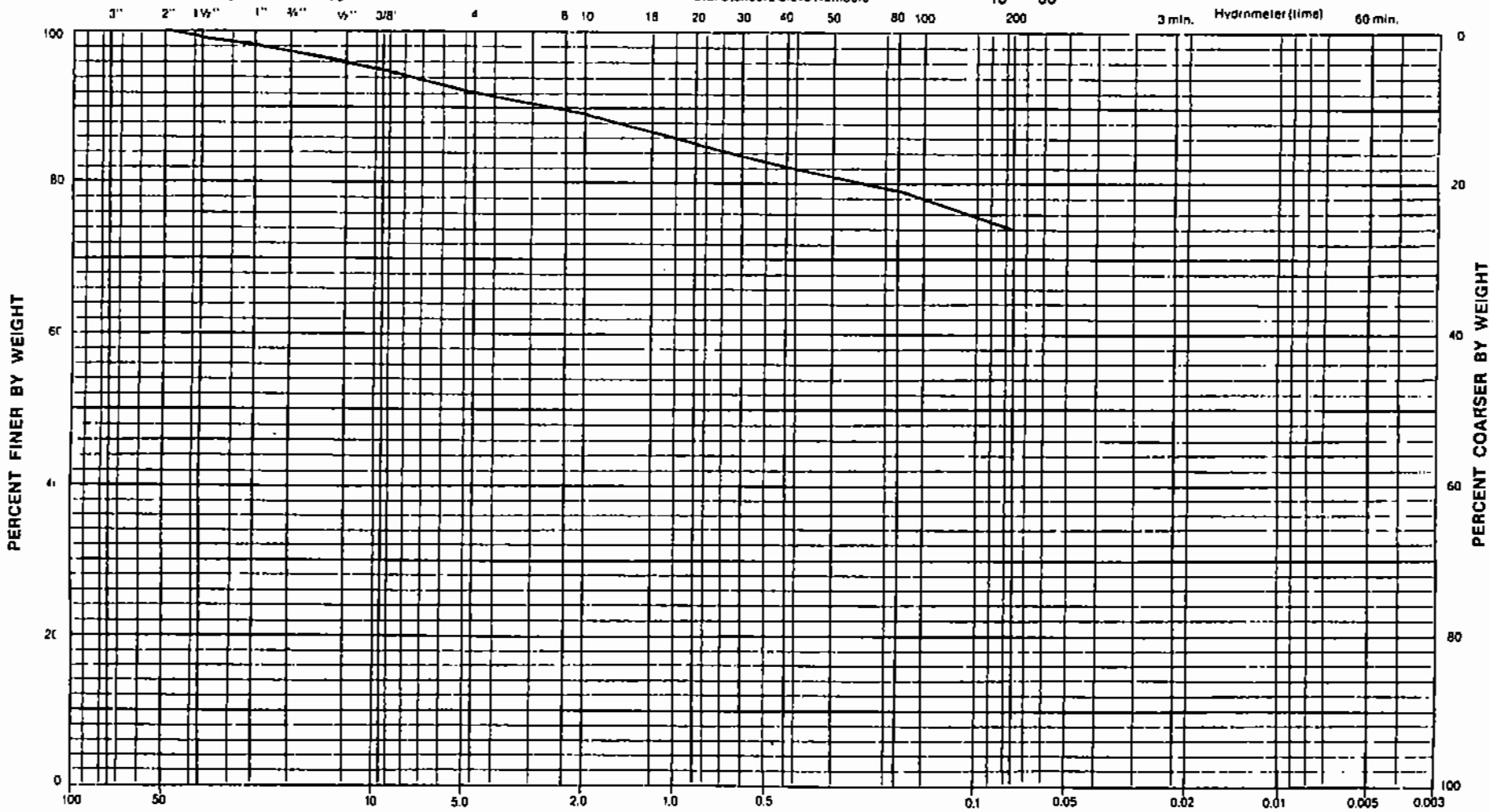
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-4, S-1, 4.0' - 6.0'

Classification Silty Clayey SAND with Gravel (SC-SM)

Moisture Content -- %

Liquid Limit Granular %

Sample No. 40716

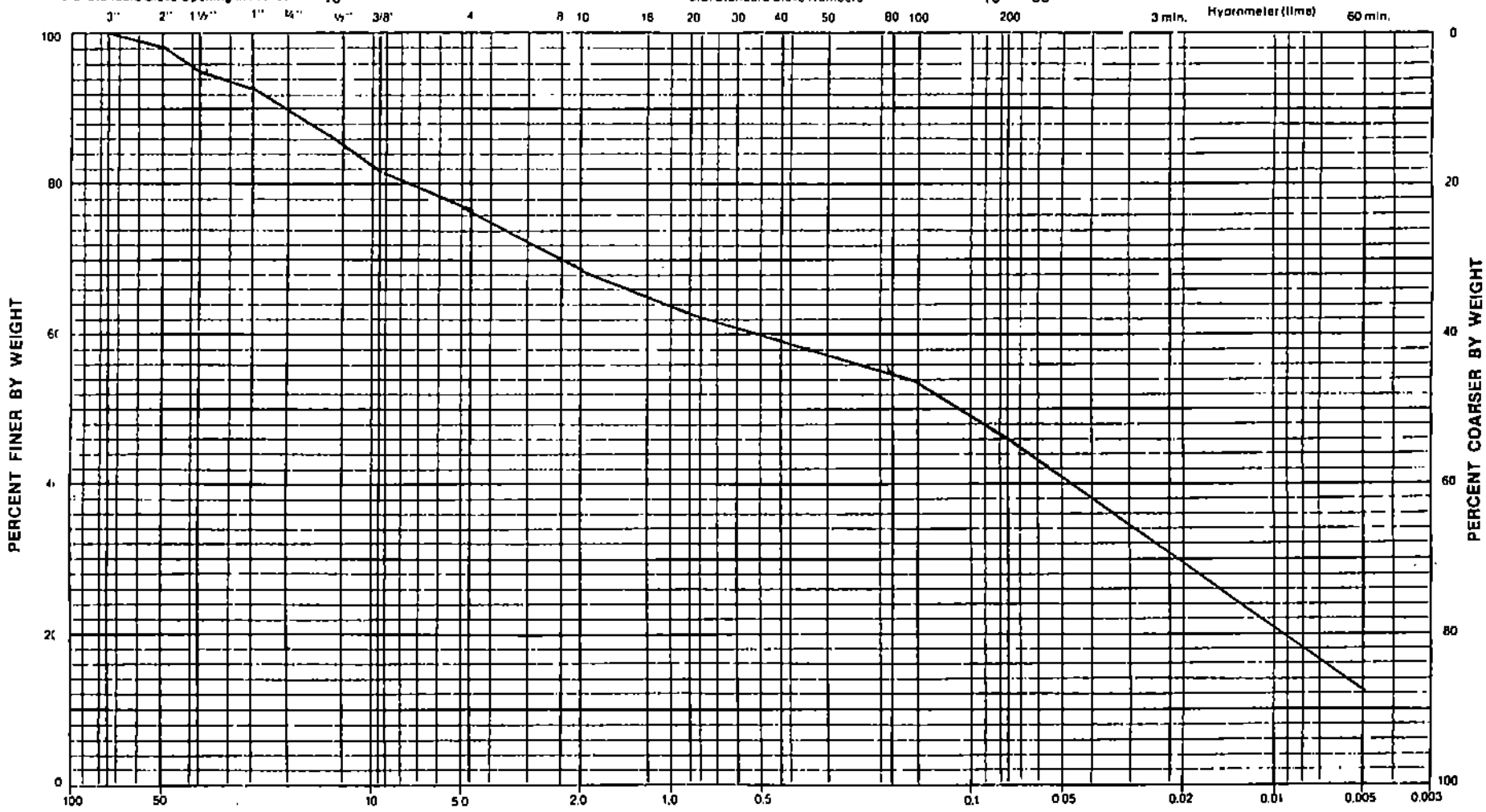
Job No. 88-152-2

Date 12/04/89

Plasticity Index Non-Plastic %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ .....

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-5, S-1, 4.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Sample No. 39444

Job No. 88-152-2

Date 12/04/89

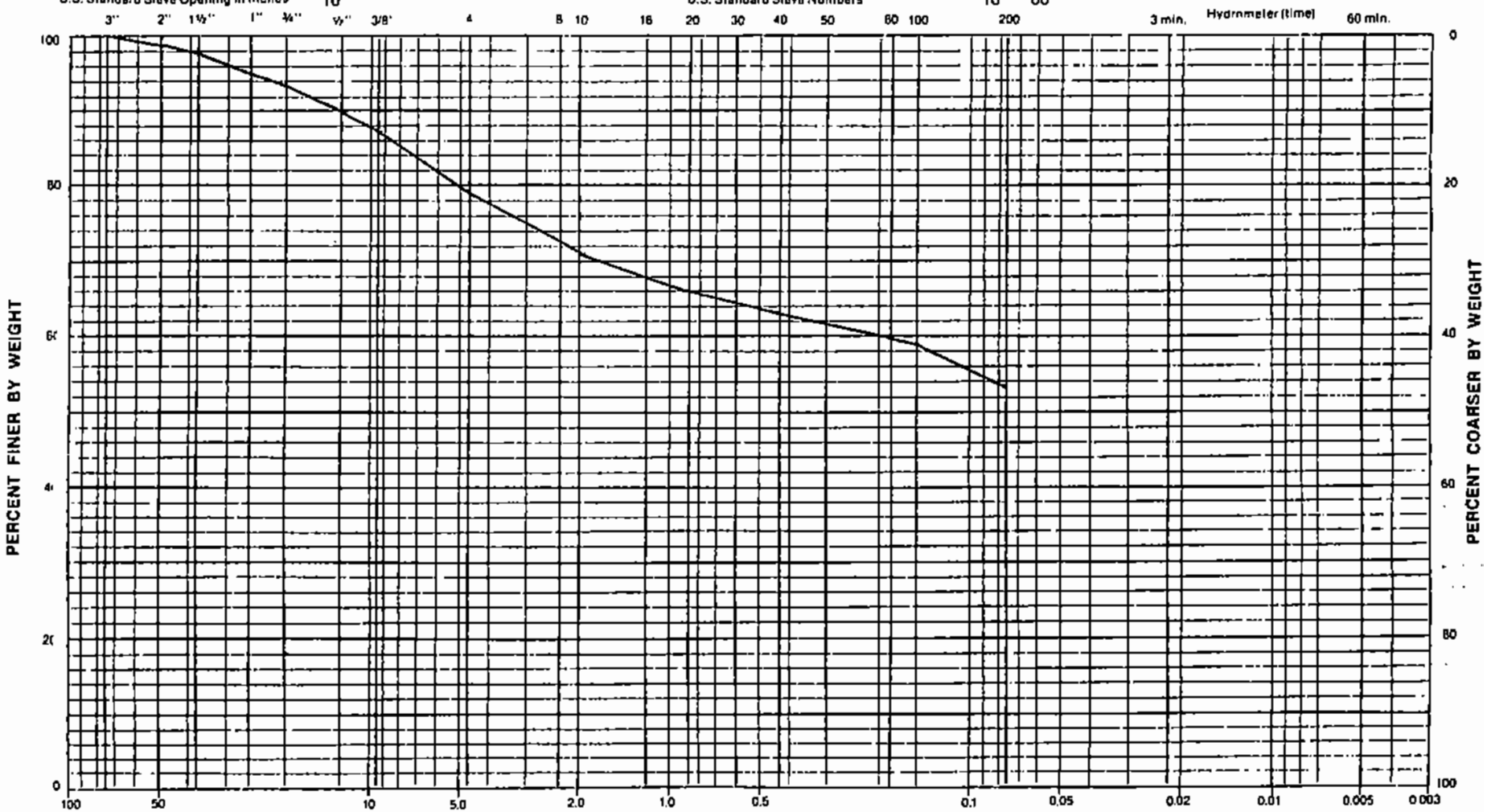
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-6, S-1, 4.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content -- %

Liquid Limit 30 %

Sample No. 39445

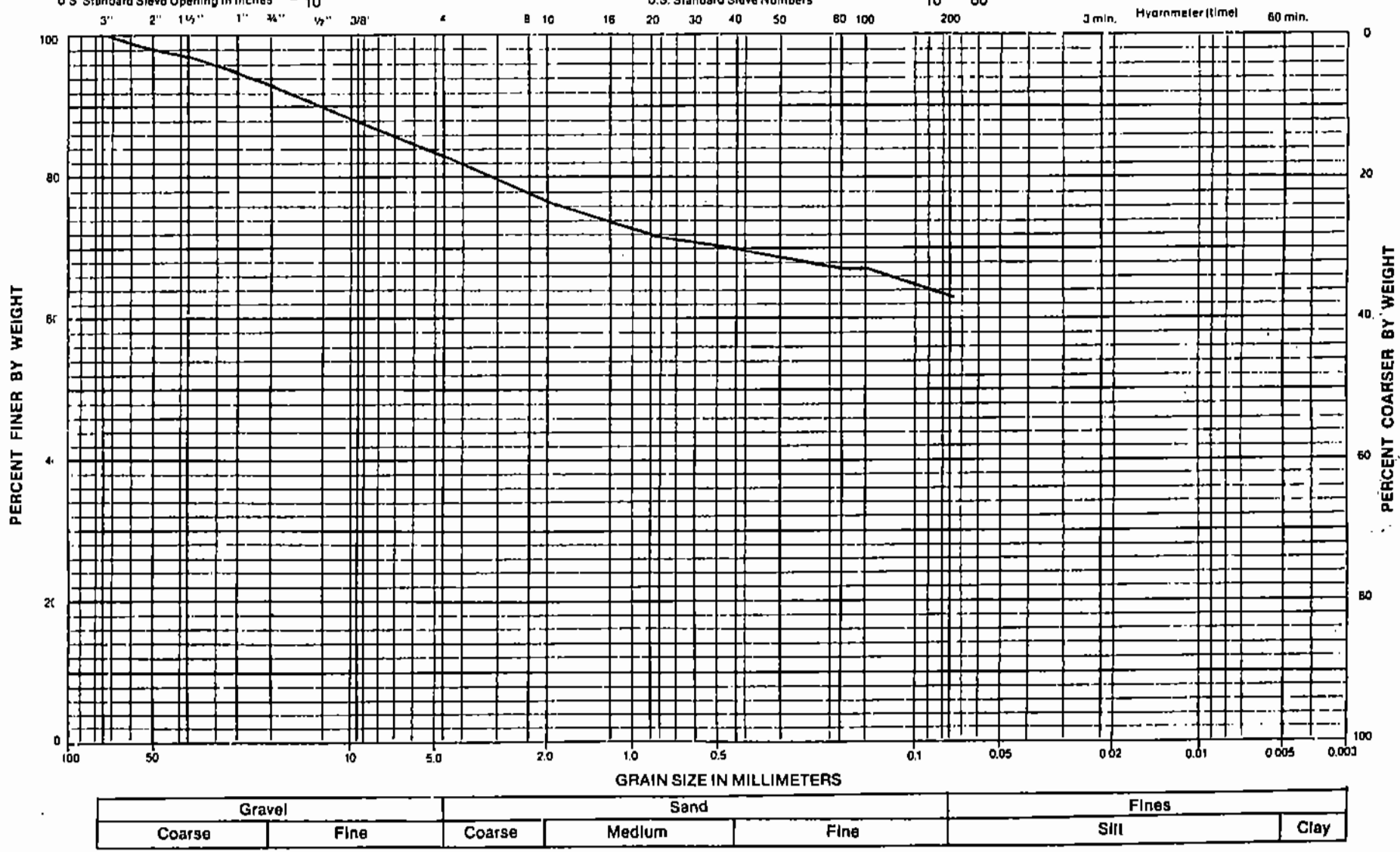
Job No. 88-152-2

Date 12/04/89

Plasticity Index 12 %

Coefficient of Uniformity $= C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature $= C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Gravel		Sand			Fines	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

(Rev. 1/89) CNI-105