STATEWIDE CORROSIVITY STUDY ON CORRUGATED STEEL CULVERT PIPE

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prepared by
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Statewide Corrosivity Study
on
Corrugated Steel Culvert Pipe

NTL
ENGINEERING &
GEOSCIENCE, INC.

Prepared for the
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September, 2001
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16. Abstract

NTL Engineering & Geoscience was requested to conduct a statewide research project and provide information and recommendations to assist the Montana Department of Transportation (MDT) with design of metal culverts. Under current sampling, testing, and analysis methods, MDT has experienced numerous failures within the design life of metal culverts. NTL has identified some factors we believe to be a part of the discrepancy between design and in-service pipe life. This report provides details of our research project, and provides recommendations based on data and analysis.

Selection criteria for buried metal culverts varies widely between state agencies and private consultants primarily since a standard methodology for identifying environments corrosive to metal culverts, assessing corrosion potential, and selecting materials that will perform in accordance with design criteria have not been clearly defined in standard engineering literature. Although fundamental to design, these tasks are often difficult to perform and are subject to debate and variation within the design community. Corrosivity is dependent upon many variables and the interaction of soil with metal is likewise complex and multi-variant. Our research has focused on observed, in-place culvert conditions and selective testing of soil samples from these locations. Resistivity and pH were selected as the main indicators of culvert corrosion for this research.

Although resistivity is a standard measure of soil corrosivity, numerous methods of preparing soils and measuring soil resistivity are accepted in practice with data then applied in a fairly generic manner to a relatively "standard" scale for assessing soil corrosion potential. NTL has performed corrosivity analysis based on the current MDT procedures for resistivity testing and pH along with other published test methods to evaluate the current MDT testing and analysis methods for selected sites in the various Districts.

Our research has attempted to begin the framework for a more consistent and applicable methodology for corrosion assessment for the MDT. We recommend, in this regard, that the AASHTO T288 Minimum Soil Resistivity test method be adopted as the basis for resistivity determination. It is further recommended that resistivity testing address the soil conditions expected to exist for backfill, foundation, and the adjacent drainageway as part of a culvert site investigation.

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Abstract

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Introduction

Current Montana Department of Transportation (MDT) standards for design of culverts are based on a 75 year service life. Although the state of practice for pipe design and selection has changed during the last 75 years, numerous premature failures have been identified in metal culverts by MDT District Offices and Hydraulics Section, which have cost the state considerable amounts of money to replace or repair. NTL Engineering, in cooperation with MDT, has conducted a statewide research project to address some of the factors affecting culvert/soil interaction and prediction of pipe life.

Corrosion of buried metal structures is a complex process that is not easily defined or quantified. The task for engineers or designers whose job is to build systems in which metal will be in contact with a corrosive environment can be summarized as follows:

- identify corrosive environments
- assess the corrosion potential
- select or design a material system that will provide the desired life and performance required for the system based on corrosivity analysis

NTL Engineering has addressed these tasks in our research and this report presents recommendations for corrosion assessment.

Soil sampling was conducted by MDT District personnel from 29 independent locations to provide a range of typical soil conditions encountered in the state. Sampling procedures included in Appendix A were developed by NTL and were presented to MDT personnel in charge of the sampling. The procedures and standardized sampling forms were used to provide a consistent selection and sampling protocol for collection of samples to be used for this research. An additional two sites were sampled by our engineer as a more detailed case study of two severely corroded culvert locations.

Testing of selected corrosivity indicators and soil index properties was conducted by MDT and NTL. Corrosivity testing included current MDT "in-house" tests and other published tests relevant to corrosion assessment. Quality control testing was performed by the Montana State University (MSU) Soil Testing Laboratory.

Analysis of corrosion potential was conducted using test data and current MDT pipe selection criteria. Individual corrosivity test procedures were then compared based on correlations between observed culvert condition and calculation of culvert life expectancy.

Background

Corrosion is a generalized term referring to the degradation of metal by reaction with the surrounding environment, but does not include mechanical degradation such as abrasion or damage due to impact or wearing forces. Corrosion is a natural and fundamental change driven by entropy theory: materials naturally trend toward a state of maximum disorder. Metallic elements exposed to a corrosive environment will therefore undergo oxidation, trending toward a more simple molecular structure.

Corrosivity is the measure or ability of the environment to react with metal such that corrosion occurs. Numerous factors and combinations of singular factors contribute to the corrosion process; analysis of no singular parameter influencing corrosivity can adequately predict the rate or extent of corrosion. To understand the general corrosion process and factors affecting corrosion of buried metal, the following summary is provided.

Corrosion Process

Corrosion is most commonly driven by electrochemical reactions (Bradford, 2000). In the corrosion process, a chemical reaction causes the release of electrons (driving the electrical reaction) at the anode site which flow through the metal to the cathode site where they are absorbed in another chemical reaction. At the anode site, metals are dislodged from the culvert and electrons are released leaving a metal ion in the surrounding soil moisture or other electrolyte solution:

$$Fe\ (iron) \rightarrow Fe^{2+}(aqueous) + 2e^-$$

The released electrons pass through the medium of least resistance (usually the pipe) and react with free oxygen at the cathode site. If conditions at the cathode site are acidic, the reaction will proceed as follows:

$$O_2 + 4H^{2+} + 4e^- \rightarrow 2H_2O$$

If conditions at the cathode site are neutral or basic (alkaline), the reaction becomes:

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The ionic solution containing the Fe^{2+} ions may further react to form Fe_2O_3 (rust), which may coat the surface of the metal, retarding the corrosion rate. Other reactions may occur in oxygen deprived mediums, or if other metals are present. Typically, localized areas on the culvert surface will serve as the anode and the much larger portion of the culvert will provide a surface for the much slower cathodic reaction which creates a relatively fast and localized corrosion cell.

Electrochemical corrosion cells can be divided into three general categories (Gilmor et. al. 1989).

- ***Galvanic Cells***
  Galvanic cells are formed when two dissimilar metals are in contact with an electrolyte; such is the case of a galvanized culvert with welded, cut, or damaged sections where the coating is reduced or eliminated leaving portions of steel and galvanization exposed to the soil or other medium. In this example, zinc ions will become detached from the coating and will loose electrons causing a current to flow and reactions similar to those shown above to occur.

- ***Concentration Cells***
  In contrast with galvanic cells, concentration cells are formed with nearly similar metals in contact with a nonhomogeneous electrolyte. A new culvert section with no major flaws in coating may be subjected to corrosion if the backfill soils are dissimilar. If some clay pockets were included in a predominantly sand or silt backfill and were placed in contact with the culvert, the culvert area in contact with the clay would become the anode and the larger portion of the culvert in contact with the sand or silt backfill would become the cathode, thereby causing a concentrated, discrete zone of corrosion. Likewise, layered systems such as a culvert placed in a trench on native soil, and backfilled with dissimilar soil may produce a concentration cell. Nonhomogeneous soils are commonplace and non-homogeneity can occur by virtue of varying soil types or any number of factors including varying moisture contents, oxygen levels, pH, etc.

- ***Electrolyte Cells***
  Electrolytic cells are driven by an external source of electrical energy (stray current) and are therefore not as common in culvert corrosion as concentration cells and galvanic cells in creating a corrosive environment.

Other corrosion cells include biochemical, stress/fatigue, and crevice (Gilmor et. al. 1989). These conditions are not as common, but are possible causes of culvert corrosion.

Factors Affecting Corrosion

Corrosion cells can develop under various conditions and many factors affect the extent and rate of reactions. The primary environmental factors are electrical conductivity (resistivity), moisture content, pH, aeration, and the presence of microbes (Bradford, 2000). However, some additional factors that influence corrosion are:

- Soil chemistry (mineralogy)
- Texture, structure, and homogeneity
- *In situ* soil density
- Clay content/composition

- Buffering capacity
- Soluble salt content
- Cation exchange capacity (CEC)
- Differences in soil potential

Soil conditions are rarely homogeneous and are nearly always in flux, particularly in drainages. By virtue of their purpose for carrying water for either storm drainage or routing of an existing waterway, culverts are commonly subjected to large variations in soil moisture, oxygen content, and soil chemistry. Therefore, by design, culverts are a likely candidate for corrosion. Some of the major factors contributing to a corrosive environment are further discussed in the following paragraphs:

- ***Resistivity***

  Resistivity is probably the most commonly used indicator of corrosivity and is derived from the resistance of current flow through the soil medium. Resistance is a material property dependent on dimension, material composition, and temperature. The dimensional units of resistance are $[\mu\ l\ t^{-1}]$ where μ=the magnetic permeability of a vacuum, l=length, and t=time: the practical unit of resistance is the ohm. Resistivity is a proportional quantity equal to the resistance that a known volume of a substance offers to the passage of electricity and is defined by the following equation:

  $$\rho = R\,\frac{A}{l}$$

  where ρ=resistivity, R=resistance, A=area, and l=length. Typically, resistivity is recorded in units of ohm·cm.

  Resistivity can be measured *in situ* or in the laboratory from samples collected from the field. Laboratory resistivity measurements can be accomplished by either remolding prepared soil samples into a box with integrated electrodes of known area and spacing, and recording the soil resistivity directly with a soil resistivity meter, or by preparing or extracting an aqueous solution from a soil/water dilution and reading the electrical conductivity (EC) of the liquid. *In situ* measurements are commonly performed by driving conductive electrodes into the soil at a known spacing or area. By applying a known voltage potential to the outer electrodes and measuring the current flow at the inner electrodes, a bulk or average resistance value can be calculated. Electrode shapes, spacings, and configurations may be varied for application; however, the Wenner 4-pin configuration is typically used for engineering purposes. Because this test provides an average resistivity value, all components of the soil are averaged into the final resistivity value. The presence of cobbles/boulders, voids, frozen earth, and the moisture content at the time of testing will influence the resistivity value. Therefore, a few measurements taken over a short time period may not provide an accurate design parameter. To provide confidence in the test results, many readings taken at different seasonal soil-moisture conditions must be provided for accurate design parameter determination. Because this research project could not incorporate seasonal readings, laboratory methods were chosen for resistivity determination.

There are many testing apparatuses and test methods for arriving at a resistivity value: laboratory test methods used in this project are discussed subsequently in more detail. In addition to a variety of test methods, many factors influence the determination of resistivity. Moisture content, density, temperature, and measured constituents all have a substantial impact on the resistivity value and are also discussed subsequently.

Resistivity is an important factor in assessing corrosion potential. The information obtained from resistivity measurements is typically interpreted in a general sense: low resistivity values indicate low impedance and high current flow, whereas high resistivity values indicate high resistance to the passage of current. However, some corrosion assessments use resistivity values directly in mathematical relationships to predict metal loss or pipe life. Figure 1 suggests one of several possible variations (depending upon author/publication) for general assessment of corrosion potential based on soil resistivity:

Resistivity Range ohm-cm	**Steel Corrodibility**	**Years to Penetrate Sheet Steel**
<500	very severe	1-5
500-1,000	severe	5-10
1,000-2,000	severe to moderate	10-15
2,000-5,000	moderate to slight	15-20
5,000-10,000	slight	>20
10,000-1,000,000	slight to none	

Figure 1 **Corrosion Assessment Table reproduced from *Practical Handbook of Corrosion Control in Soils* (Bradford, 2000)**

Depending on the source, the break in resistivity values between a corrosive and moderately corrosive environment varies considerably. For example, the break between a corrosive and a mildly corrosive condition occurs at approximately 2,000 ohm·cm as shown in the table above as compared to 5,000 ohm·cm from a scale published by the Cast Iron Pipe Research Association (Corrosion Potential 1970). In the 1940's, a resistivity threshold of 10,000 ohm·cm was accepted for design; however, studies within the last decade have shown that corrosion due to bacteria, dissimilar metals, oxygen concentration cells, and other factors can create a corrosive environment even near the 10,000 ohm·cm threshold (Fitzgerald, 1993). Due to the variability of methods and scales, interpretation of resistivity is typically selected and adapted by local practice or experience.

- *pH*
  Although resistivity is generally considered a good indicator of corrosive potential, in acidic soils, pH also has a significant effect (Bradford, 2000). Acidity can have multiple

effects on the soil/metal interaction. By increasing the free H^+ concentration, corrosion reactions may be accelerated, and general soil chemistry and biological factors may be altered thereby affecting soil corrosivity. Measurements of soil acidity can be determined as active, exchangeable, or hydrolyzing. Typically, some dilution of soil and water are collected from a site and a standard pH meter is used to obtain acidity data.

- ***Moisture Content, Drainage, and Aeration***
  Moisture content, drainage, and aeration are complex parameters that can influence the corrosivity of a particular environment. Due to the nature of culverts, moisture content and aeration are likely to vary along the length of the culvert and also will vary with seasonal water flow and peak drainage demands. Water flow can carry ions from surrounding soils through a seemingly inert soil backfill; for example, a sand material with a high resistivity used as a pipe backfill can become a corrosive environment due to transport of minerals through groundwater flow. Likewise, the homogeneity of a soil backfill may be altered by varying fluid flow and differences in moisture content and aeration within the influence area of the pipe. Anodic conditions can develop near the bottom of a culvert resting on moist or saturated, poorly aerated native soil when the backfill near the invert is aerated and less moist.

  It is suggested that the corrosivity of an environment becomes significantly less when the ratio of moisture to porosity is less than 20 percent (dry conditions) or greater than 80 percent (near saturation) (Bradford, 2000). However, soil resistivity is also dependent upon moisture content; resistivity generally decreases with increasing moisture content and increasing concentration of dissolved ions in the soil moisture. Therefore, even if soils become saturated and less oxygen is available, the bulk soil resistivity may become lower and lead to corrosive conditions. These conditions are difficult to assess and are likely to vary considerably around a culvert section subjected to seasonable changes.

  Biological corrosion may also be enhanced in moist, poorly drained soil conditions that can occur in pipe backfills near the center of the culvert section. These particular conditions provide a suitable environment for sulfate-reducing bacteria and other, anaerobic bacterial colonies. Redox potential is an indicator of possible environments for growth of anaerobic bacteria. Low and negative redox potentials may be indicative of this type of corrosive environment.

- ***Soil Chemistry/Composition***
  Textural assessment of soils is often used as a guideline for identifying potential corrosive environments. Clay and organic soils are typically more corrosive than granular soils. Also, disturbed soils are likely to be more corrosive than undisturbed, native soils. Soil chemistry is also used in corrosion analysis. High concentrations of calcium and magnesium carbonate may reduce corrosion potential by increasing pH and creating a protective film or precipitate on the metal surface (Bradford, 2000). High chloride and sulfate concentrations typically indicate more corrosive environments.

It should be stressed that the corrosivity of an environment is based on multiple, independent (and interdependent) variables and their interaction. No single parameter dominates the corrosion process, and therefore a combination of individual indicators is needed to accurately evaluate the corrosive potential of a particular environment.

Corrosion Assessment

The inherent complexity of soil corrosion creates great difficulties in estimating a reasonably valid service life prediction for a given site. No single corrosion contributing factor can be utilized to assess corrosion potential of a metal pipe/soil system. At the present, corrosion assessment is typically based on experience; no singular, standardized methodology is used in highway departments or private consulting firms.

A vast collection of current literature on corrosion of steel piling and bridge safety, rehabilitation and replacement can be obtained in technical journals, design manuals, and other research oriented papers; however, few papers relating to the corrosion of steel culvert sections have been published. Corrosion of culverts has typically received less attention than bridges, primarily due to the significantly lower budget and profile (Dively 1992). Nevertheless, premature corrosion of culvert sections may present safety risks and certainly increases maintenance costs and, in some cases, requires replacement before the required service life.

Different sources site varying methods of assessing corrosion potential. These diverse methods consider different parameters including chart solutions, numerical methods, statistical correlations, and general "rules of thumb". Some of the methods are described below:

- ***Chart Solutions***
  Graphical chart solutions typically relating soil resistivity, pH, and steel gage have been published by the Transportation Research Board (NTL, 1978), the American Iron and Steel Institute (AISA, 1994), and the California Department of Transportation (NTL,1972). These charts contain resistivity on a log scale, pH as turning lines and pipe life on an arithmetic scale, with a multiplier to account for gage thickness. The Utah Department of Transportation also published a graphical chart solution (Leatham,1977) relating soluble salts, pH, and resistivity to life expectancy scales for different pipe classes (coatings).

- ***Statistical Correlations***
  In 1991, Corpro Companies, Inc. prepared a report entitled "Condition and Corrosion Survey on Corrugated Steel Storm Sewer and Culvert Pipe" for the National Corrugated Steel Pipe Association (Bushman et al., 1991). This report included development of a spreadsheet that would predict an average service life (which is defined in their work as the time to first perforation multiplied by a factor of two) for a steel section with given pH, resistivity, moisture content, and chloride ion concentration. The spreadsheet reportedly uses a statistical relationship based on a population of data collected by

Corpro and others. Neither the spreadsheet, mathematical manipulation, or other information was made available to NTL upon our request to the authors, Corpro and Warren Rogers Associates, Inc.

- ***General "Rules of Thumb"***
  Numerous rating scales can be found in literature relating singular parameters such as resistivity to a general corrosion category. An example of this treatment is shown in the section Factors Affecting Corrosion of this paper. More complex rating systems requiring input from several contributing factors are available through such sources as the METALogic website (Bogaerts, 1988) and the publication *Practical Handbook of Corrosion Control in Soils* (Bradford, 2000). These rating systems assign point values to factors such as resistivity, pH, sulfides, redox potential, and moisture content. The points are totaled and applied to a scale that rates the relative corrosivity of the environment.

- ***Selected Department of Transportation Methods***
  The Wyoming Department of Transportation uses the Caltrans method of resistivity testing and uses galvanized steel culverts in all areas with resistivity values greater than 1000 ohm·cm and pH greater than 6 (Branson et al., 2000). The culverts are expected to have a minimum design life of 25 years. If resistivity values of less than 1000 ohm·cm, or if pH values are lower than 6, the Department considers concrete pipe or in some cases, alternate pipe coatings.

  The Idaho Department of Transportation uses the same resistivity criteria as the Wyoming Department of Transportation; however, design service life is expected to be 75 years (Stanley, 2000). The Idaho Materials Bureau reports several pipe failures not meeting the desired 75 year service life.

  The Montana Department of Transportation uses a modified AISI algorithm for estimating the average service life of culvert sections (MDT, 1996). This method consists of a mathematical solution for pipe life based on resistivity alone for pH values greater than 7.3, and resistivity and pH for lower pH values. Resistivity values are currently determined from a 1:2 soil and water dilution. The average service life is then multiplied by a specified factor to correct for varying steel gages and pipe coatings. These equation solutions are limited by a set of culvert service life guidelines outlined in the MDT Culvert Design Manual (MDT, 1996).

Statewide Corrosivity Research Project

Due to the frequently observed inadequate service life of some metal culvert installations (designed under the current MDT culvert selection procedures) and the costs of repairing or replacing these culverts, MDT has been searching for improvements to their current corrosion design methodology. NTL has, therefore, been selected to conduct research to evaluate culvert selection methods as a function of observed culvert conditions and testing as applicable to a number of installations across the state. The scope and intent of this research has been discussed previously, but generally was intended to provide recommendations on soil sampling techniques, corrosion assessment testing, and design philosophy for metal culverts.

Sampling

For the purpose of collecting a wide range of soil samples from culvert areas throughout the state, the services of the five MDT District Offices was sought. During the sampling phase of this research, each MDT District Office collected samples based on a selection criteria and sampling procedure prepared by NTL. The site selection and sampling procedures are included in Appendix A and are briefly summarized in the following paragraphs:

- ***Test Site Selection***
  The intent of this project was to collect samples encompassing a wide range of soil conditions through a statewide sampling program; therefore, each District was encouraged to select suitable sample locations generally targeting the following criteria:

  Areas of Poor Culvert Performance
  These areas were defined as having historically documented poor culvert performance relating to corrosion of corrugated steel culvert pipes. The intent of selecting these areas was to collect soil samples from in-place culverts that have or were in the process of reaching the end of their serviceable life, preferably before the expected (designed) service life.

  Areas of Fair to Good Culvert Performance
  These locations were to be selected from areas that had long-term historical data indicating a generally low corrosive environment for the purpose of including a range of corrosive to non-corrosive environments.

  Historically Identified "Hot" Areas
  This category was added in the event that a particular District could not identify prematurely corroded culverts, but had identified certain areas as potentially highly corrosive environments. These areas would likely include buried metal installations (ie. signposts, driven piling, etc.) that have shown signs of corrosion although no culvert sections may be present.

Areas of Proposed New Construction/Borrow

This category was also included to provide samples from a realignment/rehabilitation construction project currently in planning or progress. This type of area would likely include historical data from existing culverts.

Locations meeting the requirements of the first two culvert performance criteria ("poor" and "fair to good") were to be given high priority in test site selection. However, other locations of particular interest to the districts could also be considered based on collaborative review of applicability by MDT and NTL.

Upon selection of appropriate test sites, a Sample Log sheet was completed by District personnel for each test location. These log sheets contained information on general site conditions, culvert specifications/condition, sampling locations/descriptions, and additional site specific information observed during sampling. Log sheets submitted by the District Offices are included in Appendix B. A summary of site locations and culvert information (as reported by MDT) is given below (Figure 2)

MDT District	MDT Site Identification	County	Highway	Milepost/ Station	Culvert Type	Condition	Coating	Length (ft)	Diameter (in)	Age (yr)
1	D1-S1	Missoula	US 93	71	CSP	Fair	asphalt	120	108 x 60	20
1	D1-S2	Missoula	MT 200	7.7	CSP	Good	blakclad	60	24	15
1	D1-S3	Ravalli	US 93	42.1	CSP	Good	Bituminous	300	54	20
1	D1-S4	Sanders	MT 35	13.1	CSP	Good	galvanized	50	24	20
1	D1-S5	Sanders	MT 28	12.9	CSP	Good	galvanized	80	36	25
1	D1-S6	Lake	MT 212	5.7	CSP	Fair	galvanized	100	24	20
1	D1-S7	Lake	MT 5	93	CSP	Fair	galvanized	45	108 x 72	30
1	1	Lincoln	US 2	76	CSP	Good	none	92.8	24	3
1	2	Lincoln	US 93	185.5	CSP	Good	none	52	24	15
1	3	Lincoln	US 93	163.8	CSP	Good	none	150	24	9
1	4	Flathead	MT 40	2.2	CSP	Good	none	152	24	20
1	1 (5)	Sanders	MT 28	20.8	CMP	Fair	none	120	120	48
1	1 (6)	Flathead	MT 82	1.4	CMP	Good	none	54	24	15
1	1 (7)	Flathead	MT 83	87.25	CMP	Good	none	130	72	20
1	1 (8)	Flathead	JCT 35	45	CMP	Good	none	100	48	5
2	D2, S1	Madison	MT 41	45	CSP	Poor	galvanized	48	24	64
2	D2, S2	Madison	MT 41	50.3	CSP	Fair	galvanized	56	69 x 48	64
2	D2, S3	Meagher	US 89	40.1	CSP	Poor	galvanized	58	18	70
2	D2, S4	Meagher	US 89	45.7	CSP	Poor	galvanized	44	24	70
3	Site 1	Teton	I 15	303	CSP	Poor	galvanized	200	30	30
3	Site 2	Chouteau	R 22B	34.2	CSP	Good	epoxy	194	36	10
3	Site 3	Teton	I 15	301.4	CSP	Good	galvanized	75	12	30
4	D4,S1	Carter	MT 323	793+39.44	CSP	Poor	galvanized	176	40	23
4	D4,S2	Valley	MT 2	580.7	CMP	Poor	galvanized	74	30	30
4	D4,S3	Prairie	I 94	174.8	CSAP	Poor	galvanized	80	27	?
4	D4,S4	Prairie	I 94	556+29.66	CSP	Poor	galvanized	282	60	?
5	Site 1	Yellowstone	I90	485.54	SSPPA	Good	black mastic	222	128 x 83	28
5	Site 2	Petroleum	MT 200	147.95	SSPPA	Poor	galvanized	164	138	46
5	Site 3	Carbon	MT 310	35.7	CSP	Fair	galvanized	116	72	32
5	Site 4	Carbon	MT 78	19.8	CSP	Good	galvanized	64	78 x 70	41

Figure 2 **Summary of Site Locations and General Culvert Information**

Collection of at least 16 soil samples from approximately 4 different site locations was requested from each District Office. Specific sampling techniques and sample location selection criteria were outlined in our Sampling Procedure documentation provided in Appendix A. It was required that soil samples be representative of the environment in question and natural moisture content at the time of sampling be preserved by prompt collection and sealing of sample bags. Additional sampling included water samples and culvert coupons in selected locations. Photographs were included for most test locations. Representative photographs are included in Appendix C.

Testing

For this research project, resistivity, pH, sulfate, and chloride testing was performed to assess corrosion potential. Although several other parameters may be used in the evaluation of corrosion potential, these four common parameters were selected as practical, necessary parameters for corrosion assessment. Published methods including AASHTO T288 (American Association of State Highways and Transportation Officials, 1998), ASTM G57 (American Society for Testing and Materials, 1995), and Caltrans 643-C (State of California, Department of Public Works, 1972) were considered for the determination of soil resistivity. Results of previous research conducted by NTL suggests the AASHTO test method is the most reasonable and widely used of the published methods currently used in practice. The Caltrans method is similar to the AASHTO T288 method, however, it does not specify a seasoning or equilibration time. The ASTM G57 method for soil box testing uses a 24 hour minimum recommended seasoning time; however, this method tests only one moisture content at a nearly saturated condition rather than testing several points to establish the minimum resistivity. The AASHTO T288 treatment was therefore chosen for this project, since an equilibration time is specified for solute transport to occur and the lowest margin of error in terms of moisture content and density variations occurs near saturation where the minimum resistivity is often found.

The bulk soil samples recovered during the field investigation were transported to our laboratory where they were carefully inventoried and given individual identification numbers. The samples were thoroughly mixed and single-point, as-received resistivity and moisture content testing was performed. The samples were then air dried, re-mixed, and mechanically split into several smaller portions for additional laboratory testing. Atterberg limits (ASTM D4318), particle-size distribution (ASTM D422 and D1140), and minimum resistivity (AASHTO T288) testing was performed on all samples. Where applicable, additional resistivity testing was conducted with water collected from the particular site. Individual samples were also split and shipped to the MDT Materials Laboratory in Helena and to the MSU Soil Testing Laboratory in Bozeman. The MDT Materials Laboratory ran their own in-house corrosivity test battery including 1:2 dilution conductivity, pH, marble pH, sulfate, and chloride testing (Buell et al., 2001). Additional conductivity testing (1:1 dilution and saturated paste) and water sample conductivity testing was also conducted by the MDT (Buell et al., 2001). Test results are provided in tabular form in Figures 13 to 19 of Appendix D. A brief description of the testing is provided in the subsequent paragraphs.

The MSU Soils Testing Laboratory (MSU) located in Bozeman, Montana was chosen to provide quality control testing for NTL and the MDT Materials Laboratory. Approximately 15 percent of the samples tested for this study were sent to the MSU laboratory for conductivity, resistivity, pH, sulfate, and chloride testing (Gavlac et al., 1994 and Diamond, 1994).

- ***Soil Box Resistivity Testing***

  As-Received Resistivity Testing
  Upon receiving the samples from each of the District Offices, the samples were mixed at field moisture and compacted into the soil box to obtain an as-received resistivity value prior to processing and splitting for other testing. Soil samples containing gravel were screened over a No. 4 sieve, whereas sand and clay soils were mixed and tested with no further processing. The purpose of obtaining an as-received resistivity value was to collect a "snapshot" of the sample resistivity at natural moisture content with reduced disturbance created by mixing and drying.

  AASHTO T288 Testing
  Once the as-received resistivity testing was complete, the samples were screened to remove particles retained on a No. 10 sieve and air dried to prepare the samples for AASHTO T288 testing. Approximately 1500 grams of air-dried soil was then placed in a plastic beaker, combined with 150 grams of distilled water, and allowed to season overnight. The seasoned sample was then placed, with moderate finger pressure, into the soil box and the resistivity recorded. The soil from the box was then re-mixed with the rest of the sample and an additional 100 grams of water added to the sample. The AASHTO T288 test method requires repeated testing of the sample with cumulative, incremental water addition until a minimum resistivity has been obtained.

  When plotted against moisture content, the AASHTO T288 resistivity points produce a generally smooth curve sweeping through a resistivity range that may span several orders of magnitude. This curve typically has a steep negative slope in the range of possible field moisture conditions, but levels off near saturation. Beyond saturation, the resistivity increases slightly and is presumed to reverse curvature and reach an asymptotic value of the characteristic resistivity of pure, distilled water as the soil is diluted to a supersaturated solid suspension. Small changes in moisture content for relatively dry soil samples will produce large changes in resistivity; however, small changes in moisture content for samples near saturation will produce smaller changes in resistivity.

  The resistivity reading for each moisture addition is also a function of soil density. At a given moisture content, the resistivity of a sample can be varied by changing the amount of soil placed in the soil box. For samples with a moisture content below saturation, resistivity will decrease with increased density. The decrease in resistivity is not linear and will change more rapidly between a loose and medium dense condition than between a medium dense to dense condition. The "moderate finger pressure" specified by

AASHTO T288 is somewhat subjective and is dependent on the operators interpretation; however, near saturation where the minimum resistivity is typically reached, relative density makes very little difference as more of the pore space is occupied by water and cannot be compressed to a higher density without expelling water.

- ***Analytical Resistivity Testing***

  Saturated Paste Conductivity (Resistivity)
  A saturated paste conductivity test utilizes a conductivity probe rather than a soil box to arrive at a resistivity value. Soil is prepared by placing approximately 250 to 500 grams of air dried soil into a beaker and adding water to the soil until three criteria are met: a light "sheen" of water should glaze the surface when shaken vigorously from side to side, the soil should retain near vertical walls with slight collapse when a small soil spatula is struck through the soil, and a fraction of soil placed on the side of the blade should "flow" from the blade when inclined from the horizontal plane. Once these criteria are met, the soil/water paste is allowed to sit for 24 hours and the water is extracted through a high flow rate filter paper using a Buschner funnel attached to a vacuum chamber. Electrical conductivity (E.C.) is measured from the extract and can be readily converted to resistivity. Alternately, the electrical conductivity probe can be inserted directly into the soil paste without extraction to obtain a conductivity. The procedure for preparing a saturated paste is described in many soil testing manuals such as the *Methods of Soil Analysis* (Page et al., 1982).

  Soil/Water Dilution (1:1, 1:2, 1:3, etc.) Conductivity (Resistivity)
  For this type of test one part of air-dried soil is combined with one or more parts water to reach the desired dilution factor. The proportions of materials (water and soil) are typically measured by weight, however, some test procedures (such as the current MDT method) are measured by volume. The mixture is then shaken for a given time period (typically 30 minutes), allowed to settle, and electrical conductivity is measured on the solution directly with or without filtration. The resulting conductivity value is likewise converted to resistivity.

- ***pH, Sulfate, and Chloride Testing***

  Soil acidity/basicity can be measured on soil water extractions or dilutions and may provide a measure of active, hydrolyzing, or exchangeable acidity. Soil is usually prepared as a saturated paste or dilution and measurements taken with a glass/calomel electrode. Exchangeable acidity (more commonly referred to as total acidity) is probably the most common measurement; however, slightly lower pH readings may be obtained since total acidity also measures hydrogen atoms that are loosely bonded to metallic cations. Exchangeable acidity testing was conducted by MDT and MSU.

Sulfate and chloride concentrations may also be obtained by several different methods using different extraction mediums and concentrations with different detection methods. For corrosivity analysis ASTM and AASHTO procedures are commonly used for the determination of chloride and sulfate concentration.

Discussion of Testing, Analysis, and Results

Complete results of the index property, resistivity, sulfate, chloride, pH, and quality control testing are provided in Appendix D and Appendix F. Discussions regarding the quality of resistivity and sulfate/chloride/pH testing is provided in the subsequent sections.

Resistivity Testing

All four of the resistivity test methods conducted for this study were found to provide a different resistivity value for the same sample. For comparison purposes, the following graph (Figure 3) shows the analytical test results (as reported by MDT) plotted against the minimum resistivity as determined by NTL.

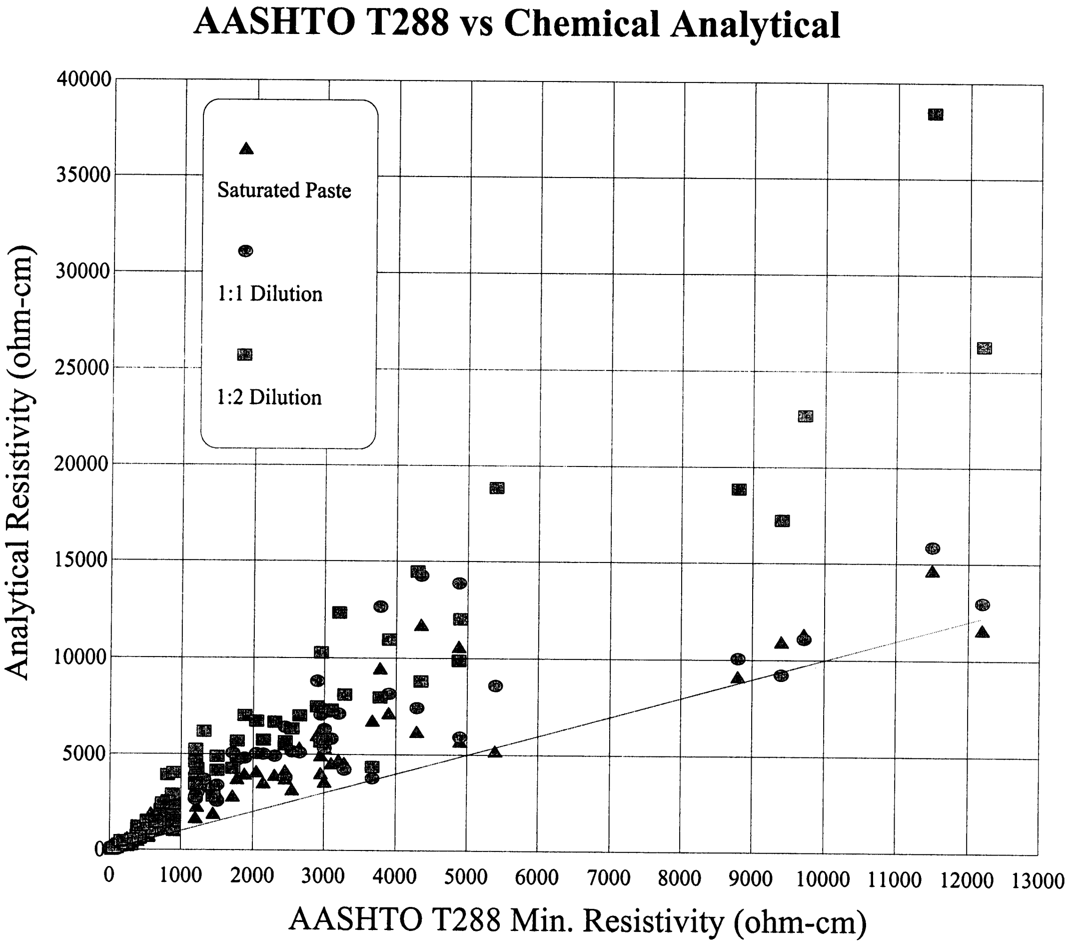

Figure 3 **Comparison of Resistivity Test Data**

The data markers, presented as triangles, circles, and squares, show the resistivity (on the y-axis) obtained by saturated paste, 1:1 dilution, and 1:2 dilution test methods respectively; therefore, each sample is represented by a vertical set of three data markers. Each vertical set of data markers is plotted against the corresponding AASHTO T288 minimum resistivity for that sample. The line represents the AASHTO T288 minimum resistivity on the y-axis. For example, sample D1-S5 had an AASHTO T288 minimum resistivity of 8,800 ohm·cm, a saturated paste resistivity of 9,174 ohm·cm, a 1:1 dilution resistivity of 10,101 ohm·cm, and a 1:2 resistivity of 18,867 ohm·cm. From 8,800 on the x-axis (minimum resistivity) the data set for each of the analytical resistivity tests can be found in a vertical projection above the x-axis at their corresponding resistivity values on the y-axis. For the majority of the samples, the AASHTO T288 minimum resistivity found the lowest resistivity of the methods used for resistivity testing.

To further illustrate the variability of test results for relatively low resistivity soil samples tested by the MDT procedures and AASHTO T288, Figure 3 has been reproduced below (Figure 4) and re-scaled to show only samples with minimum soil resistivity (as determined by AASHTO T288) of 2,750 ohm·cm or less. Each shaded, square marker on this graph corresponds to a single sample whose AASHTO T288 minimum resistivity is obtained from the vertical projection to the x-axis and whose MDT 1:2 resistivity is obtained from a horizontal projection to the y-axis. For example, two of the samples had AASHTO T288 minimum resistivity values of approximately 1,500 ohm·cm and the same samples had MDT 1:2 resistivity values of approximately 4,000 and 5,000 ohm·cm. In view of the obvious variability in resistivity values that are obtained for the same sample using the different methods, it is understandable why there exists difficulty in relating resistivity to corrosivity using the same analysis method.

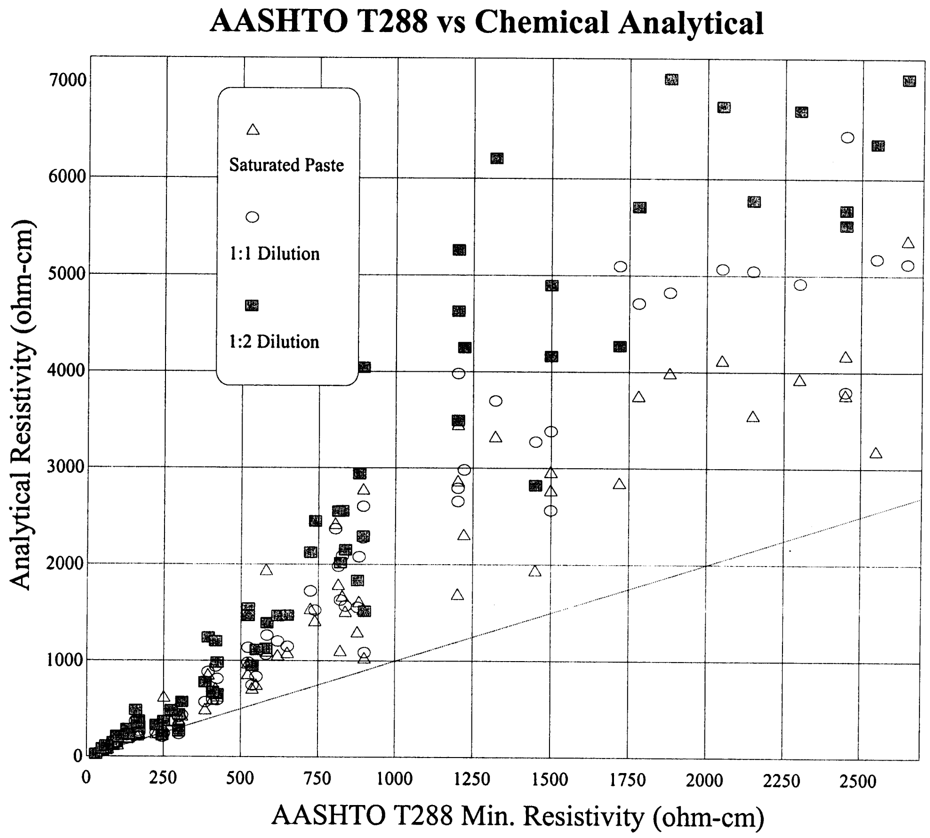

Figure 4 **Comparison of Resistivity Test Data for AASHTO T288 Resistivity Values Less than 2,750 ohm·cm**

The major differences in the analytical conductivity testing methods employed for this project are the amount of water added to the soil and the equilibration time. Saturated paste moisture contents vary with soil texture--that is, fine-grained soils will have a higher gravimetric moisture content than coarse-grained sand soils. Dilution methods (1:1 and 1:2) are typically prepared by adding one or two parts of water to one part of soil (by weight); therefore, the gravimetric water contents are equal for all soil textures. In the case of dilution methods prepared on a volumetric basis, however, gravimetric water contents will vary in relation to the specific bulk density of the soil and will therefore will vary slightly for different soil textures. At moisture contents well above saturation, conductivity will generally decrease, and resistivity will increase as more water is added (approaching 1:1 and 1:2 dilution moisture contents). Therefore, for the analytical tests, the saturated paste should give the lowest resistivity followed by the 1:1 dilution with a higher resistivity and 1:2 with the highest resistivity. This trend of increasing resistivity can generally be seen in Figures 3 and 4 as square markers are typically higher than circle markers which, in turn, are higher than triangular markers. The conductivity/resistivity data submitted by MDT generally follows this pattern; however, approximately 10 percent of the 1:1 dilution resistivity results were higher than the 1:2 dilution results and 28 percent of the saturated paste resistivity values were higher than the 1:1 dilution resistivity values. Therefore, some fundamental inconsistency may be present with the currently used test method.

Quality control tests were performed by MSU to evaluate reliability and reproducibility for the testing methods used for the study. Quality control samples were split from the same mixed sample as were sent to MDT for testing, and should therefore be expected to produce similar results independent of the individual laboratory equipment and laboratory technician. A graphical comparison of test results from the MDT and the MSU test results for the quality control samples is provided in Figure 5. The triangular, circular, and square markers denote a single quality control sample tested by MSU and MDT by saturated paste, 1:1 dilution, and 1:2 dilution test methods respectively. Each marker corresponds to MSU determined resistivity on the y-axis and MDT determined resistivity on the x-axis for the same sample. The solid line represents complete agreement/correlation between MSU and MDT.

It should be noted that MSU conducted the 1:1 and 1:2 dilution testing on a gravimetric basis and the MDT conducted 1:1 and 1:2 dilution testing based on volumetric methods. Therefore, some subtle differences between the two testing lab results of the 1:1 dilution and 1:2 dilution tests between the MDT and MSU is to be expected due to the difference in gravimetric moisture contents of the soil/water specimens. The saturated paste testing, however, should be similar as the methods for these tests varied to a lesser degree between the MDT and MSU laboratories. Testing procedures for all MDT and MSU tests have been documented and may be obtained from MDT or NTL Engineering & Geoscience.

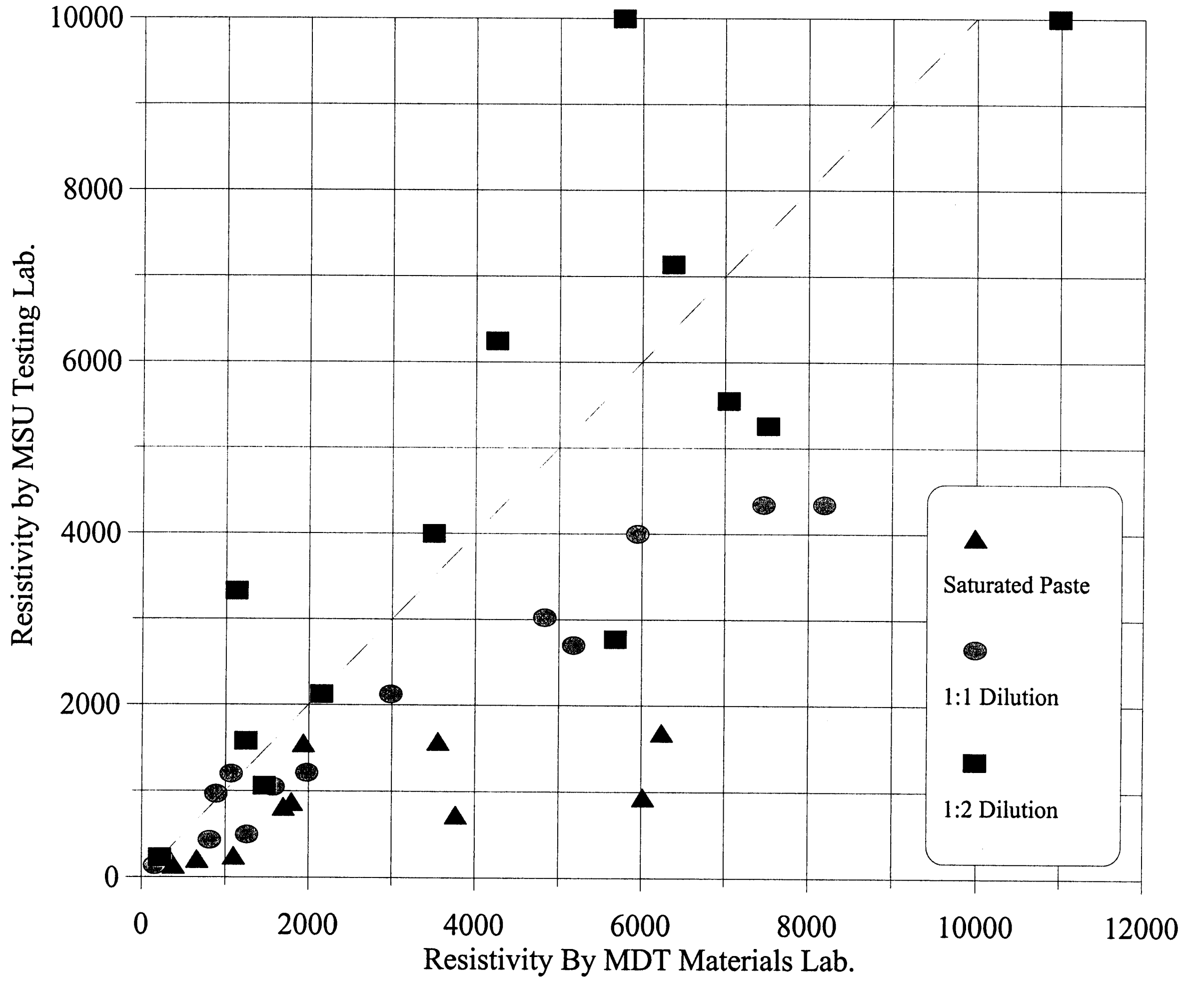

Figure 5 **Comparative Quality Control Data**

Since the two sets of data are largely scattered, duplicate quality control samples were resubmitted to each laboratory to show the expected reproducibility for each laboratory independently. The comparison table (Figure 6) shows the average maximum error and the maximum standard error between the data submitted by MDT and MSU and also shows the errors for the comparison samples tested twice by each laboratory. An effort was made to correlate the MSU gravimetric test results with MDT volumetric test results for the 1:1 and 1:2 dilution testing by applying a constant factor equal to an assumed bulk density for each of the sample results. Bulk densities of 0.9 to 1.5 were assumed for the range of textural classifications. This correlation correction did not significantly alter the average or maximum standard error shown in Figure 6.

	MDT vs MSU			**MDT vs MDT**			**MSU vs MSU**		
	paste	1:1	1:2	paste	1:1	1:2	paste	1:1	1:2
Avg Max Std Err (%)	227.1	56.3	49.2	17.6	17.7	38.5	24.1	5.6	28.1
Max Std Err (%)	538.6	153.2	194.7	65.2	66.8	342.0	78.1	8.7	66.3

Figure 6 **Standard Error of Chemical Analytical Resistivity Test Data**

Due to the variability of test results, the errors were calculated by dividing the absolute value of the difference between the two results by the average of the results. Average standard errors of these magnitudes are substantially higher than would be expected since testing procedures were nearly identical for the duplicate testing and may indicate that there are inherent problems with the test procedure. Errors could also be attributed to machine calibrations, temperature corrections, or laboratory technique. For resistivity values greater than about 5,000 ohm·cm, a difference in resistivity values of about 40 percent would not likely change the pipe selection in an analysis because soils with resistivity values greater than 3,000 ohm·cm are typically not considered corrosive to plain, galvanized steel. However, below 5,000 ohm·cm and particularly near 2,500 ohm·cm, a difference in results even as low as 10 percent can potentially lead to erroneous design conclusions and the designer may select a pipe that will not perform as required for the actual conditions. As can be seen from Figure 6, the average maximum standard error is substantially greater than 10 percent.

As a further check of possible equipment error, four standardized solutions of potassium chloride (with known conductivity properties ranging from 8,974 μS (111 ohm·cm) to 84 μS (11,905 ohm·cm)) were purchased from Fischer Scientific. These standard solutions were sent to MDT and MSU and each laboratory ran conductivity testing on the samples. Both laboratories submitted fairly consistent resistivity results with an average standard error of 7.5 percent. Since the standards were aqueous solutions and the error was much less as compared to the resistivity of the soil samples, it is likely that the abnormal standard error percentages described above may be more closely attributable to sample preparation than equipment error.

Quality control testing for the AASHTO T288 Resistivity was also conducted by MSU. Eight samples were shipped to MSU along with the NTL soil resistivity meter and soil box. Figure 7 shows the AASHTO T288 minimum resistivity as determined by NTL versus the AASHTO T288 minimum resistivity reported by the MSU. Since NTL equipment was used for the quality control testing, the results are not a comparison of different soil boxes or meters, but rather are a check on sample preparation, machine calibration, and individual technician technique.

Quality control testing for all three laboratories indicates that the AASHTO T288 test method is more repeatable between independent laboratories than the analytical resistivity methods. The average maximum standard error and the maximum standard error calculated from the soil box quality control samples were approximately 7 and 25 percent respectively; substantially lower than the error calculated for the 1:2 conductivity testing. Since MSU had not had any experience with soil box resistivity testing, it appears that a laboratory with little or no experience with this testing method and/or equipment can utilize the AASHTO T288 test method (and required equipment) with reasonable confidence and accuracy.

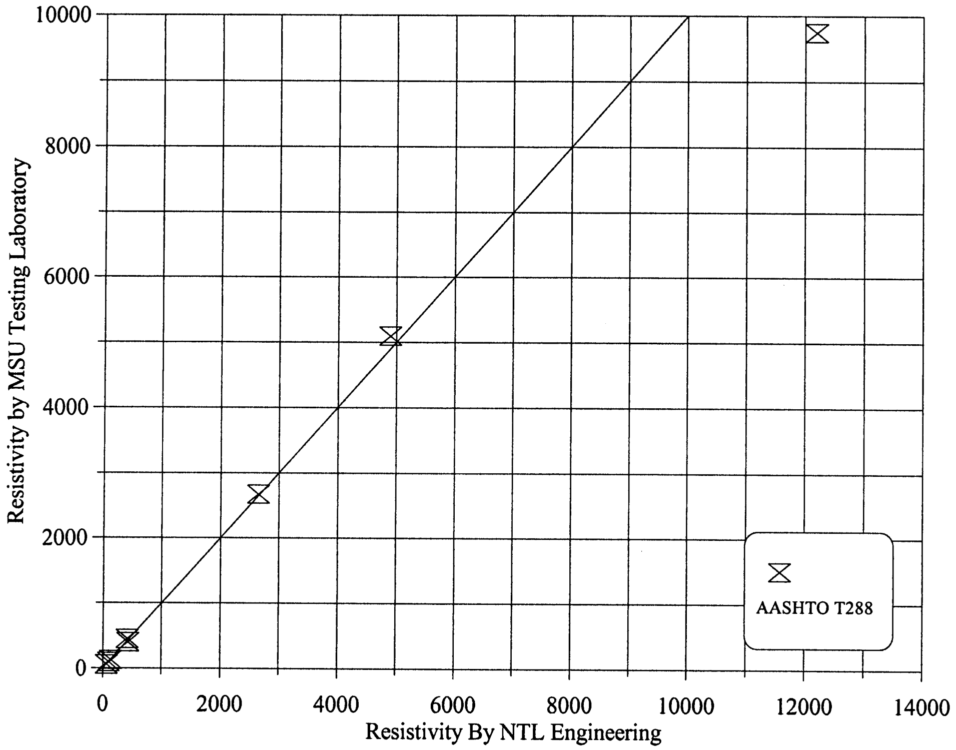

Figure 7 **Quality Control Testing for AASHTO T288 Soil Box Resistivity Testing**

pH, Sulfate, and Chloride Testing

Exchangeable acidity measurements from MDT and MSU prepared from saturated paste, 1:1, and 1:2 dilutions were comparable in magnitude and did not appear to vary enough to change pipe life predictions to a large degree. The methods used by MDT appear to be practical and sufficient for corrosivity determination.

Sulfate and chloride test results from MDT and MSU showed more variance than the resistivity testing. The difference between values for these parameters were such that no correlation or explanation can be given as to the factors affecting magnitude nor potential causes for the differences in values reported by each laboratory. For consistency and credibility, the ASTM and AASHTO procedures should be used for determination of chloride and sulfate concentration.

Culvert Life Predictions

Culvert conditions at each test site were recorded by MDT District personnel during the sampling phase, and where possible, specific information about pipe coatings and age were noted. Using this information and resistivity test data measured by current MDT and AASHTO T288 test methods, Figure 8 has been produced to relate existing pipe condition with each resistivity test method.

		AASHTO T288			MDT 1:2		
Culvert Condition	Resistivity Range (ohm·cm)	Culvert Age Range (years)			Culvert Age Range (years)		
		0-25	25-50	50+	0-25	25-50	50+
good	<2500	3	6	0	2	1	0
	>2500	9	4	0	10	9	0
fair	<2500	0	4	0	0	1	0
	>2500	3	2	3	3	5	3
poor	<2500	9	31	11	7	28	7
	>2500	0	0	1	2	3	5

Figure 8 **Number of Resistivity Tests Within a Given Resistivity Range for a Specified Culvert Condition**

In general, one would expect poor pipe conditions in nearly all age ranges for low resistivity values (less than 2500 ohm·cm) and good culvert conditions for high resistivity values (greater than 2500 ohm·cm); although some divergence could be expected for very young culverts in a resistivity range of less than 2500 ohm·cm and very old culverts in a resistivity range of greater than 2500 ohm·cm. For the poor culvert condition shown above, 51 of the samples had a resistivity of less than 2500 ohm·cm and only 1 of the samples (greater than 50 years old) exceeded that value as determined by the AASHTO T288 test method. Comparing these with the MDT 1:2 resistivity test method, only 42 samples had a resistivity less than 2500 ohm·cm and 10 samples from all age ranges exceeded 2500 ohm·cm. Five of the samples tested from poor culvert conditions less than 50 years of age had MDT 1:2 resistivity values greater than 2500 ohm·cm which would indicate that galvanized steel culverts should provide acceptable service lives by current MDT design procedures, whereas none of the AASHTO T288 procedure would rate any of the five acceptable for galvanized steel. Grouping by resistivity range, culvert conditions listed as fair were similar for the two methods. For culverts listed in good condition, the number of samples with AASHTO T288 resistivity values less than and greater than 2500 ohm·cm were 9 and 13 respectively, while the MDT 1:2 resistivity results were counted at 3 and 19 respectively. By inspection it would appear that the 1:2 method correlates better than AASHTO T288 for culverts classified as maintaining a good condition; however, 6 of the 9 samples with AASHTO T288 resistivity values less than 2500 ohm·cm were coated with epoxy or black mastic. It therefore appears that the coating is of clear benefit since the 6 samples taken from coated culvert pipes that were in good condition had resistivity values of less than 2500 ohm·cm. From analysis of data taken from the table, the AASHTO T288 test method appears to show a stronger, single-variant relative prediction correlation to observed pipe condition than the 1:2 dilution method currently used by the MDT.

The process of corrosion, however, is not driven by a single parameter and therefore analysis procedures have been expanded to account for more than one measured soil property. Soil pH is a widely used corrosion indicator and is incorporated in the current MDT design life analysis. To account for the effects of soil pH in the corrosivity analysis, the current design procedure used by MDT was used to give a predicted pipe life for further comparison of the resistivity test methods. The MDT design procedure consists of calculating a design service life from equations published by AISI, and presented in the MDT Design Manual (MDT, 1996), and using resistivity thresholds and pH ranges to specify acceptance of steel pipe and select steel coatings. For each sample and set of resistivity values (1:2 and AASHTO T288), pipe life estimates were calculated from the AISI equations:

$$\textbf{Service Life (years)} = 2.94\,R^{0.41} \quad \textbf{— for soil with a pH} \geq 7.3$$

or

$$\textbf{Service Life (years)} = 27.58\,[\log_{10} R - \log_{10}(2160-(2490\log_{10} \text{pH})) \quad \textbf{— for soil with a pH} < 7.3$$

where R is the resistivity value in ohm·cm and pH is the value of the soil pH reading. Pipe selections were based on use of steel culverts with galvanized, bituminous, or polymeric coating since these were the only types of culverts at the test locations. Figure 20 of Appendix E shows tabulated results of the MDT design criteria analysis for each sample with pipe recommendations, estimated life, and percentage of life used based on pH results by the MDT laboratory and resistivity results from the AASHTO T-288 and 1:2 dilution test results. Where "no steel" appears in the recommendations column, the design criteria does not allow galvanized, bituminous, or polymeric coated steel pipe. The last column shows where pipe selection recommendations differ between the AASHTO T288 and 1:2 resistivity values used for pipe coating prediction.

By using resistivity data from MDT measured 1:2 dilution (the current MDT practice) and AASHTO T288, the analysis returned two independent service life predictions and pipe type selection for each soil sample. Of the 87 test samples, 37 percent of the recommendations differed depending upon the method used for determining resistivity. A comparison summary of some of the results is given in Figure 9.

Comparison Parameter	**AASHTO T288**	**MDT 1:2**
number of test samples	87	87
recommendations different than in place pipe	69	58
recommendations:		
no steel	32	25
bituminous/polymeric	22	15
fiber-bonded	8	4
galvanized	25	43

Figure 9 **Comparison of Pipe Recommendations Using AASHTO T288 and MDT 1:2 Resistivity Results**

The differences in recommended culvert treatments for in-place galvanized steel culverts are further categorized in Figures 10 and 11 according to the condition rating assigned by the MDT District personnel who conducted sampling for the study. Figures 10 and 11 show analysis based on AASHTO T288 minimum resistivity and MDT 1:2 resistivity respectively for all galvanized steel culvert sites with known culvert age. Each figure shows the number of samples (tested by AASHTO T288 or MDT 1:2) for each culvert condition/age and the resulting pipe selection recommendation per current MDT resistivity criteria. For example using the AASHTO T288 test method and the MDT criteria for coating selection, the testing of 9 samples would recommend galvanized steel culverts based on analysis from samples taken from good culverts that are in the range of 0 to 25 years old.

In-Place, Galvanized Steel Culvert Condition	**Culvert Age Range (yrs.)**	**Recommended Treatment by AASHTO T288**			
		galvanized	*bitum/poly*	*fiber-bonded*	*no steel*
good	0-25	9			
	25-50	4	2		
	50+				
fair	0-25	1			
	25-50	2	3	1	
	50+	3			
poor	0-25			1	2
	25-50		5	2	24
	50+	2	5	2	3

Figure 10 **Recommended Culvert Treatments Based on AASHTO T288 Resistivity Versus In-Place Culvert Condition for Galvanized Steel Culverts**

In-Place, Galvanized Steel Culvert Condition	**Culvert Age Range (yrs.)**	**Recommended Treatment by MDT1:2**			
		galvanized	*bitum/poly*	*fiber-bonded*	*no steel*
good	0-25	9			
	25-50	6			
	50+				
fair	0-25	1			
	25-50	5	1		
	50+	3			
poor	0-25		1		2
	25-50	5	2	4	20
	50+	5	6		1

Figure 11 **Recommended Culvert Treatments Based on MDT 1:2 Resistivity Versus In-Place Culvert Condition for Galvanized Steel Culverts**

For the good culvert condition sites, nearly all of the samples indicate galvanized steel to be reliably specified. In the few instances where coatings were specified by analysis using the AASHTO T288 minimum resistivity, and coated culverts are currently in service, they were given a good to fair rating. There were two test samples from an epoxy coated culvert where, based on design criteria and AASHTO T288 minimum resistivity, no steel should be used; however, the 10 year old culverts appear to be in good condition.

In the fair condition category, all of the samples tested by both AASHTO T288 and MDT 1:2 indicate galvanized or coated steel pipe is suitable for use. From the above figures, the AASHTO T288 soil box test method and the MDT criteria appear to correlate reasonably well with observed culvert conditions.

Most importantly, of the culvert test sites where culvert condition was classified as poor, all pipes in service were galvanized. From the Figures above, the MDT criteria using AASHTO T288 minimum resistivity values shows that none of these sites in which the culvert has been in service for less than 50 years are suitable for galvanized steel; whereas MDT criteria using MDT 1:2 resistivity values shows that 5 of the samples show galvanized culverts to be suitable. Additionally, 29 of the samples tested by AASHTO T288 do not meet specifications for any steel (coated or non-coated) as compared with the 23 samples unsuitable for steel as predicted by MDT 1:2.

Case Study

Additional in-depth sampling was conducted at the site of two large steel culverts in District 5, which are corroded and in very poor condition. The purpose of this case study was to obtain a more in-depth look at one particular corrosive environment by applying the proposed analysis and testing methods in an in-depth manner to a particular site.

Introduction

Sampling was conducted near two, 138 inch diameter by 164 foot long galvanized steel plate culverts located on Highway 200, approximately 13 miles east of Winnett. The two culverts selected for case study show advanced signs of soil side corrosion particularly in the upper two-thirds of the culvert section. Numerous perforations ranging in size from 1 inch to more than 6 inches are evident in the troughs of the corrugations along the top of the culvert and equally large and numerous holes on the culvert sides. The east culvert has experienced some loss of structural integrity as evident by noticeable "bowing", elliptical deformation and buckling near the north invert. On nearly each of the corroded holes, white salt precipitates have collected and built up to thicknesses of approximately ¼-inch.

The culverts were originally designed for watershed drainage and stock crossing and are located in moderately deep coulees. The steel culverts were installed with 25 to 35+ feet of embankment cover and are assumed to be 8 gage (0.168") galvanized steel. Some nominal amount of sedimentation (less than 2 feet) has collected in the pipes. Sedimentation and the deformed condition of the pipe causes sustained water retention even when the upslope drainage is not flowing through the sections. The embankment appears to have been built from weathered clay shale presumably borrowed from the immediate vicinity. Asphalt invert aprons were placed on the slopes near the inverts. Due to the advanced signs of distress, the culverts were scheduled for grouted insert repair in the fall of 2000.

Sampling

Numerous samples were taken from the culvert embankment and sedimentation collected in the culvert bottom to provide soil information for the study. Additional soil samples were obtained from the native, undisturbed slopes and drainages (upslope of the culvert) to provide quasi-baseline data from the drainage that may represent soil conditions prior to the installation of the culverts. A 4-inch hand auger was used to collect soil samples from selected locations within the embankment and native soil profiles.

A series of samples were taken laterally through a buckle in the east pipe and obtained vertically through the embankment slope above the invert aprons to the top of the culvert section to provide profile information surrounding each pipe. Water samples were taken from the stagnant pool inside the culvert sections.

Testing

All soil samples were tested for resistivity (as-received, AASHTO T288, and MDT 1:2), pH, sulfate, and chloride. AASHTO minimum resistivity values ranged from 63 to 1500 ohm·cm and pH values were slightly basic and in the range of 7.4 to 8.8. An Inductively Coupled Plasma (ICP) Spectrophotometry scan of the salt materials collected from the culvert was also conducted by MSU to determine a non-quantitative composition of the material.

Results

Figure 12 shows a schematic diagram of the sampling positions and select test results for each of the tested culvert sites. Data shown on Figure 12 consists of as-received resistivity, AASHTO T288 minimum resistivity, and *in situ* moisture content testing as shown on the legend.

Samples taken from the streambed on the upslope side of the culvert and from the bank of the drainage show as-received resistivity values in the range of 100 to 1500 ohm·cm. A sample of the salts collected on the natural slope had a minimum resistivity of 32 ohm·cm. Based on the AASHTO T288 minimum resistivity test results of natural features and current MDT culvert selection criteria, an estimated pipe life of 19 to 59 years could be expected for a galvanized steel pipe. To obtain the MDT standard 75 year life, MDT pipe selection criteria recommends bituminous or polymeric coated steel pipe for the samples tested with a resistivity of 1500 ohm·cm and does not allow for the use of steel pipe for the sample tested at 100 ohm·cm. The in-place culvert; however, is galvanized steel and is approximately 46 years old, slightly more than half of the expected design life. Based on the conditions of the culverts, it is apparent that the culverts are at the end of their useful service life.

Samples taken from the embankment material show a distinct pattern of decreasing resistivity and increasing moisture content with depth in the embankment. For example, on the south invert of the west culvert, the as-received resistivity and minimum resistivity decreased incrementally from 7000 to 1050 and 425 to 165 ohm·cm, respectively, from the surface to the top of the culvert, on the side of the embankment. Similarly, a pattern of decreasing resistivity and increasing moisture content occurs laterally in the embankment toward the culvert section. A moisture content, as-received resistivity, and minimum resistivity contour map constructed on a cross section of the embankment perpendicular to the pipe would show a zone of high moisture content and low resistivity near the pipe with a gradual decrease in moisture content and increase in resistivity radiating outward from the pipe. Ironically, the most corrosive environment occurs around the culvert pipe.

Case Study--Pipes East of Winnett

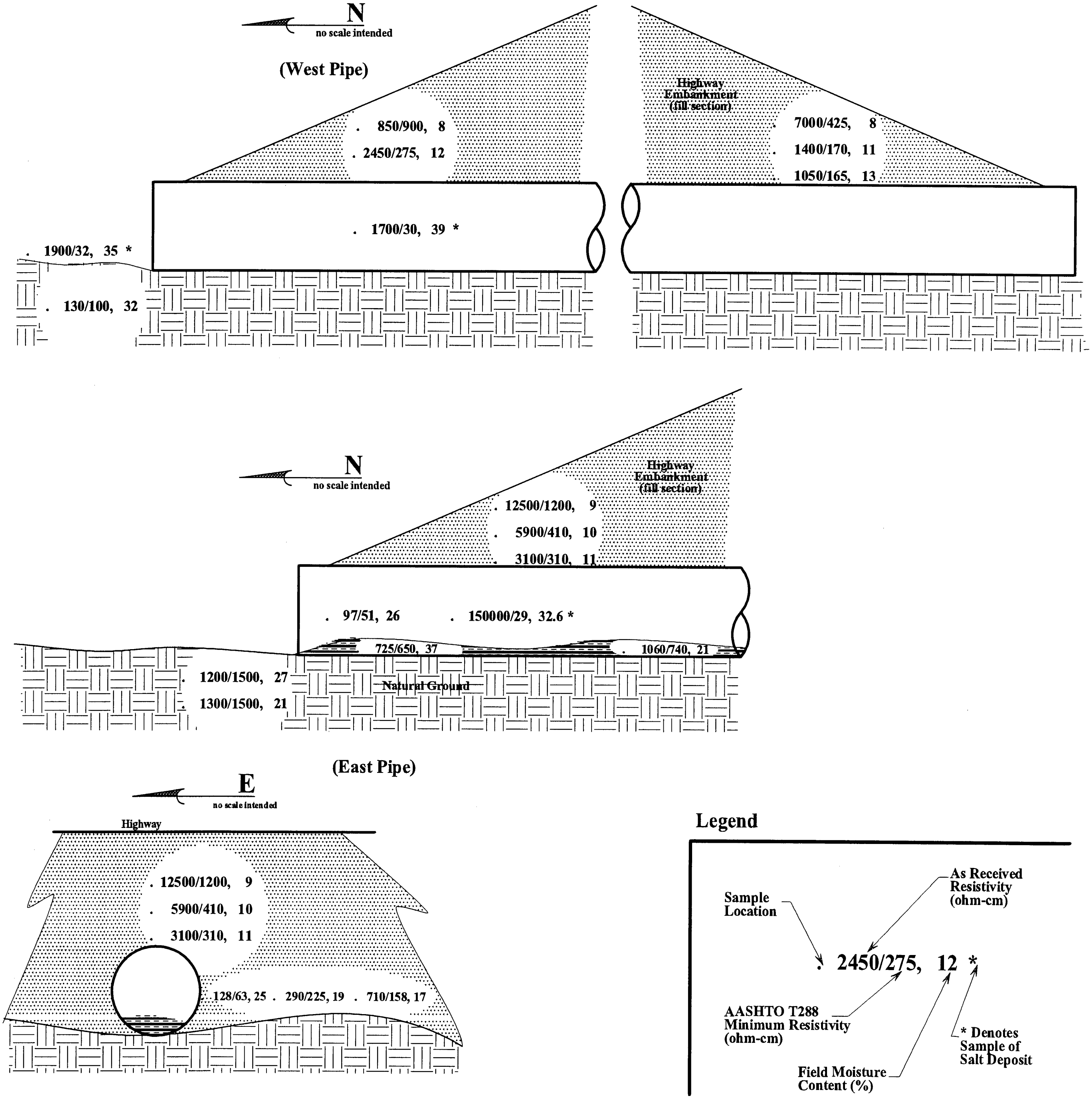

Figure 12 Case study culvert profiles

Assuming that the material used in the embankment was relatively homogeneous and consisted predominantly of soil with a minimum resistivity of approximately 1500 ohm·cm, a change in the physical corrosivity of the soil has taken place over time. Our research has shown that disturbing the natural soil structure by excavation and recompaction can change the minimum resistivity; therefore, it is likely that the action of breaking up the shale used in the embankment exposed more surface area from which minerals may be extracted from the soil and that a more porous medium was created by the embankment construction process. We further suspect that surface moisture and water from the drainage entered the embankment on the sides and transported dissolved salt materials to the pipe which acts as an impermeable zone and impedes the flow of moisture. This moisture, rich in salt minerals and supporting a high cation exchange capacity collects near the culvert surface. By this action, the soil environment directly in contact with the culvert became more corrosive than the original, undisturbed soil testing might have indicated. Minimum soil resistivity values of 350 to 50 ohm·cm and moisture contents of 11 to 26 percent were obtained at the soil/culvert interface. These data, analyzed by the AISI equations for pipe life indicate average service lives of approximately 15 to 29 years.

Once the steel becomes perforated, small quantities of seepage have access to the interior of the culvert where the water is evaporated and salts collect on the surface. The drier interior conditions of the culvert cause a substantial buildup of salt concentrations in the soil behind the culvert and on the interior of the culvert around the perforations. These salts can be re-dissolved in times of higher moisture availability and cause a localized region with extremely corrosive soil conditions. Salts collected from the interior of the pipes and from the natural drainage up slope of the culvert had a minimum resistivity of approximately 30 ohm·cm which relates to an average service live of approximately 12 years. A non-quantitative ICP scan of 36 common elements was run on the salt material collected from the interior of the culvert. The initial extraction was conducted from a 1:1 dilution of soil and 5 percent nitric acid. After extraction, substantial precipitates began to form from elements which could not be held in the acid solution; therefore, the sample was further diluted 1:3 in nitric acid to suppress further precipitation. This scan found high concentrations of iron, potassium, magnesium, sodium, sulfur, and zinc; and, lower concentrations of calcium, magnesium, and molybdenum. This scan indicates that the salts were probably sodium chloride or potassium chloride. The presence of high concentrations of zinc, magnesium, and iron indicate that substantial metal ions have been transported with the evaporitic salts.

It is possible that a polymeric coated pipe, installed with no damage to the coating could have increased the service life of these culverts. At this point, there is data to suggest that some benefit would have been obtained by installing coated pipes. However, quantifying added life is difficult since various construction and other environmental factors influence coating success.

Conclusions and Recommendations

The following summary of conclusions and recommendations have been based on analysis of this research project and our related experience. Long-term monitoring of corrosion rates and soil conditions and case studies of coated pipe installations could not be accomplished within the framework of this research; therefore, recommendations relating to analysis and selection of pipe materials has been limited to generalized guidelines based on observations of installations used for this study. The Transportation Research Board and the NCHRP are currently conducting a study of corrosivity and may introduce new information useful in refining the culvert selection procedure.

Culvert Site Investigation and Soil Sampling

Obtaining appropriate samples is a fundamental and crucial phase in corrosion assessment for a proposed culvert site. For some projects, non-homogeneity of the soil conditions may cause significant variations in each of the corrosivity indicators; therefore, frequent and representative sampling must be conducted to generate sufficient and accurate test data.

Care must be taken to target areas and, more specifically, soils within areas which will have the largest effect on the culvert performance. Highly organic topsoil material may provide erroneously low resistivity values for a culvert site which will be stripped of all organic material and the culvert placed in a higher resistive environment. The reverse may also be true of a high resistivity soil whose structure or environment may be altered by construction such that corrosivity is increased. Therefore, culvert elevations, soil conditions, environmental conditions, and historical data must all be taken into account before sampling is conducted.

Sampling of imported backfill soil alone is not sufficient to provide an adequate representation of soil conditions surrounding the culvert. Changes in moisture conditions, chemical transfer, and bacterial growth are likely to occur within the backfill zone and what once was a non-corrosive, backfill soil may become a corrosive environment. The natural ground from the area in which the culvert is to be placed must also be included in a corrosivity analysis.

Sampling procedures may vary depending upon site conditions; however, at a minimum it is recommended that the following general steps be included as the basis for a sampling procedure:

- ***Historical Review***
  Areas having historically documented poor culvert performance may be identified by Soil Survey Reports generated by the District Office. If these reports are not available, visual inspection of culverts in the proposed site area should be performed. Culvert sections with abrasion or other physical deterioration should not necessarily be considered poor from a corrosivity standpoint.

- ***Site Reconnaissance***
  Site conditions should be recorded for each new job prior to field investigation. Visual indicators may be present that would suggest the possible corrosivity of the area. Sites with marshy conditions or high concentrations of organic material may indicate corrosive conditions. Other corrosive environmental indicators may include the presence of moderately to highly plastic, near-surface clay soils, saline seepage, or on-site corroded metals (signs, bridge decks, wire retaining walls, etc.). If such areas exist, these areas should be targeted for sampling to provide corrosivity data.

- ***Field Investigation***
  Specific areas should be targeted for sampling in the Site Reconnaissance Phase of the project. This information and preliminary culvert elevations should be used to select depths of soil sampling. It would be advantageous to obtain samples from the drainage and sideslopes, upstream of the expected culvert location. Potential borrow sources should also be sampled. The AASHTO T288 test method suggests collecting water samples from the site or local drainage for testing.

Testing Method

Our data shows that the AASHTO T288 minimum resistivity test provides better performance correlation with the current MDT corrosion criteria and observed culvert conditions than the 1:2 dilution, electrical conductivity test currently used by the MDT. An NCHRP/TRB research project is currently in progress to review existing test methods and develop new testing procedures if warranted. Based on the results of this study, the standard for soil resistivity may change, but until such time, it is our recommendation that the MDT begin to use the AASHTO T288 test method as the standard means of determining soil resistivity for corrosivity analysis.

The AASHTO T288 test method includes sample handling recommendations, processing information, and test procedure instructions. This test should be performed with room-temperature, distilled water, unless water samples are available from the site. Our limited research suggests that if the resistivity of an on-site water sample is less than the minimum resistivity of the soil to be tested, a minimum resistivity will not be reached until a large quantity of on-site water has been added. If this condition exists, the minimum soil resistivity as determined by AASHTO T288 will approach the resistivity of the water sample. If the on-site water sample has a higher resistivity than the soil, the minimum soil resistivity will be similar to the minimum resistivity using distilled water.

In some cases, it may be deemed prudent to supplement the test procedure for more in-depth analysis of critical structures. For example, with the culverts east of Winnett used in our case study, the density of the shale material to be used for the embankment backfill was likely known prior to construction. A check on the AASHTO minimum resistivity test may be performed by compacting the proposed backfill material into the soil box at the same dry density as would be obtained in the field. Subsequent to compacting the sample into the soil box at the prescribed dry density, the box could be submerged in a water bath of water collected from the site to fully saturate the sample, and the saturated sample could be connected to a soil meter to provide a single point resistivity. This should be the worst case scenario for resistivity conditions of the backfill under saturated conditions immediately after construction. As seen from analysis of this case study, it would not necessarily be prudent to use this one-point value as the controlling resistivity for design as the soil conditions change over the life of the structure. Two additional, site-specific tests would be beneficial to more thoroughly define site conditions. The first of these would involve testing of the surface material from a nearby slope that was observed to have saline seep conditions. The salts that are present in the slope are liable to be present in the embankment and will potentially migrate to the pipe; therefore, this resistivity value (obtained from an AASHTO T288 test) should be considered a long-term minimum value with a high probability of occurrence. The second test would be for the native soil upon which the culvert will be founded. This material could be sampled in much the same way as an undisturbed sample is collected for other geotechnical testing, by pushing a thin-walled steel tube into the soil and retrieving the contents. This sample could be trimmed to fit the soil box area and pressed into the soil box. The sample should then be saturated to model the worst case condition for the native material and a single point resistivity value taken from the material.

These additional resistivity tests should be viewed in conjunction with the AASHTO T288 test data to provide confidence in culvert material selection and should not be used without the AASHTO T288 data unless future research suggests a method with higher correlation to pipe life. We feel that the alternate tests could be used in conjunction with AASHTO T288 to provide a more representative, long-term model of soil conditions. From the case study data, the initial conditions in the culvert environment may be reasonably modeled by the single point resistivity of the undisturbed base material along with the AASHTO T288 minimum resistivity and single point resistivity determined for the saturated backfill at a known density. These conditions are likely to change over time and in this case, the controlling resistivity may approach the AASHTO T288 resistivity determined from the saline seep identified upslope in the drainageway.

MDT should also integrate the specifications for sampling, testing and analysis methods into the consultant design project requirements. Due to the multiple variations in test methods and the potentially large variation in results, the specifications should, at a minimum, define the testing procedures to be used for resistivity, pH, sulfate, and chloride.

Analysis and Selection of Materials

As with other geotechnical testing (moisture density, R-value, shear strength, etc.), the minimum resistivity, pH, sulfate, and chloride testing only provides an indication of corrosion potential on the sample tested in the laboratory and may not represent all actual field conditions or identify the most critical area. The results of these tests are dependent upon the quality and extent of sampling for the project. For some projects, non-homogeneity of the soil conditions may cause significant variations in each of these parameters; therefore, frequent sampling and sufficient test data must be generated to provide confidence in the data used for analysis.

Our research was limited to observations of primarily galvanized culvert conditions and sampling at a single season in the life of the culvert. Since corrosion is a progressive process, it would require long-term monitoring of numerous test sites involving culverts with varying coatings and soil conditions to completely assess the current MDT procedure for estimating pipe life. Correlations between the AASHTO T288 minimum resistivity, pH, and current MDT culvert selection criteria for estimating pipe life and recommending appropriate culvert coating appear to be reasonably consistent with the culvert performance conditions categorized by this study. However, additional research as described in the subsequent section should be conducted if a refined selection procedure is to be adopted.

Discussion of Future Research

It is strongly recommended that a database of corrosion indicators be constructed from all data collected in the future. A tabulated collection of soil resistivity, pH, chloride concentration, sulfate concentration, sampling depth, soil type, location, and other pertinent data should be stored for future reference. It is also recommended that these data be superimposed on to a statewide USGS soil survey map. With years of data collection, resistivity (and other corrosion indicators) contours could be constructed on these maps to outline general zones of corrosion potential. Each of these zones could be classified by a certain corrosion potential (high, moderate, low, or finer corrosive potential divisions) which could have standard culvert pipe treatments. This generalized area map would not preclude site testing, but could offer pre-investigation information from which to base a preliminary design. The map could also reduce testing frequency. For example, if a culvert is needed in an area of high corrosive potential, and preliminary centerline soil survey data shows high corrosive potential, additional testing during the geotechnical field investigation would not be necessary unless further quantification was desired. Likewise, areas of moderate concern could be sampled more heavily to optimize pipe selection economics with corrosion risk. These corrosivity maps would likely be general at first and limited to a statewide scale with conservative treatments; however, as the database grows, the contours could be tightened and eventually transferred to county maps and may be correlated with soil series mapping for more accurate preliminary planning.

In areas where soil conditions are questionable, or if analysis shows galvanized steel acceptable in an area where historical information suggests otherwise, instrumentation could be installed to monitor the corrosion rate and allow time to implement alternative measures such as cathodic protection before a culvert failure. This type of "early warning" system could allow for less expensive, galvanized steel culverts to be used with some additional confidence that high expenditures of premature replacement could be avoided. This monitoring/early warning system would likely consist of zinc, carbon steel, and galvanized steel coupons installed adjacent to the culvert at varying locations. These coupons would be "hard wired" to an enclosed panel or accessible housing, one would allow for periodic, real-time corrosion rate determination and provide a non-destructive means to monitor the culvert condition. If an analysis of the projected culvert life based on the measured corrosion rates indicates a high potential for premature failure, sacrificial anodes could be installed and connected to the culvert to potentially increase the service life at a fraction of the cost of replacement of a failed culvert. Data collected from these monitoring sites could also be used to “fine tune” culvert corrosion analysis and provide correlations between soil conditions, pipe materials, and pipe life. Initially, a corrosion engineer or specialist would be required to establish the monitoring installation procedure and provide technical assistance; however, this type of monitoring program could potentially become routine with reduced expense and time expenditure.

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APPENDICES

Appendix A

Corrosivity Study Sampling Procedures

NTL
ENGINEERING &
GEOSCIENCE, INC.
1505 14th St. SW - Great Falls, MT 59403-3269 - (406) 453-5400 - Fax (406) 761-6655

February 10, 2000

Attention: District Materials Supervisors

Subject: Statewide Corrosivity Study

NTL Engineering & Geoscience of Great Falls, Montana, in conjunction with the Montana Department of Transportation is conducting a statewide research program to study soil resistivity and the corrosive affects of soils on steel culverts and other buried metals. During the sampling phase of this research, the services of each Montana Department of Transportation District Offices will be sought to collect samples from select locations for testing. The District offices include:

- Great Falls
- Billings
- Glendive
- Butte
- Missoula

This letter details selection criteria for appropriate test sites, required materials, sampling procedures, and sample handling instructions. It is imperative that each of the district representatives in charge of the sampling contact the NTL Engineering Project Engineer prior to sampling to discuss prospective locations and clarify instructions presented herein.

Test Site Selection

The intent of this project is to collect samples encompassing a wide range of soil conditions through a statewide sampling program; therefore, it is desirable to consider each district in its entirety for suitable sample locations. In general, target areas should include a range of conditions outlined by the following criteria:

- **Areas of "poor" steel culvert performance**
  Areas having historically documented poor steel culvert performance may be identified by Soil Survey Reports in which steel culverts and drainages have been inspected and documented. If

these reports are not available, visual inspection of suspect areas should be performed. Steel culvert sections with abrasion or other physical deterioration should not be considered as poor from a corrosivity standpoint. If areas have been previously identified as needing replacement or insert repair, metallic coupon samples may be requested along with soil samples. The following criteria should be used as a general guideline to assess steel culvert condition:

> ***Non-Corroded*** culverts should be defined as having no evidence of surface rust or pitting on the entire culvert area. The culvert coating (galvanization, aluminization etc.) should be intact on the circumferential area. Non-corroded culverts should be given the designation "good" on the field Sampling Log form (attached).
>
> ***Moderately Corroded*** culverts have some surface rust, pitting, and holes penetrating through the culvert. Corrosion induced perforations for this category should be less than 1-inch in diameter. Moderately corroded culverts should be assigned a designation of "fair".
>
> ***Severely Corroded*** culverts have "large scale" perforations or a high density of small holes. A large portion of the culvert area exhibits corrosion deterioration. The designation "poor" should be assigned to severely corroded culverts.

Some steel culverts may exhibit a combination of the aforementioned designations. These locations should be described in detail in relation to recovered soil samples. A combination of the designations may be used (ie. fair to poor); however, detailed descriptions of the culvert will be necessary. Since this rating is designed to target corrosion, the affects of abrasion are not to be used as indicators of culvert condition. Abrasion can cause pitting, scouring, and rusting of the culvert base; these conditions are not to be considered in the above rating for culvert performance.

- **Areas of "fair to good" steel culvert performance**
  These locations may also be identified by Soil Survey Reports or by visual inspections conducted specifically for this project. These areas should be selected from areas that have long-term historical data offering information of the low corrosive environment. The previously described definitions of "fair" and "good" should be used as a general guideline for selection and description.

- **Historically identified "hot" areas**
  Some districts may have certain areas identified as potentially highly corrosive environments, although no steel culvert sections may be present. Such areas would likely be characterized by the presence of moderately to highly plastic, near-surface clay soils. Indicators such as saline seepage or corroded metals (signs, bridge decks, wire retaining walls, etc.) should be considered. If such areas exist, these areas should be targeted for sampling to provide high corrosivity potential data.

Culvert locations meeting the first two culvert performance criteria ("poor" and "fair to good") should be given high priority in test site selection; however, it is desired that all of these specific areas be sampled from each district. Special district conditions may include other possible sampling areas or conditions. If any special areas are identified within a district, the District Supervisor should contact our Project Engineer prior to sampling.

Required Materials

Upon selection of appropriate test sites by district personnel and after discussion of test site selections with our engineer, detailed soil surveys of the locations should be conducted. All such soil surveys should be performed by the District Materials Supervisor. A Sampling Log sheet is attached for use in recording pertinent data and maintaining consistency in field observations. A Sample Log sheet should be completed for each test location; spaces are provided for multiple samples at each location. The NTL Engineering Project Engineer will be available for discussion and coordinating the scoping and development of each site and to provide sampling recommendations. The soil survey includes planning for an appropriate combination of borings and/or excavations; examination of cutslopes, drainages, topography, and surface water conditions; photographs of the culverts, test locations, excavations, surrounding area; along with obtaining the recoverable materials. The survey must be sufficiently detailed to locate the test site on USGS quadrangle maps or MDT project maps, identify the sample location, and describe all pertinent conditions relative to the test site. The completed soil survey should then be submitted to our engineer in a the form of a written report and sample log sheets (attached) containing all visual observations related to the survey; all information should be clear, concise, and include all pertinent data as outlined below:

- **General**
  This section should include a written description of the test location including plan views, maps, and photographs as needed for location and clarity. A unique descriptive identification number should be assigned to all samples and materials. Detailed descriptions including historical data from steel culverts at the site should be included if available. Descriptions of sample collection including depth and relative locations are required for each sample.

- **Geology and Physiography**
  Pertinent topographic features including drainages, `cutslopes, vegetation, saline deposits, and surficial geology should be included, along with any known construction history.

- **Soils**
  Where applicable, a summary of soil profile, sampling location, and sample limits should accompany all samples recovered for testing. Boring/excavation logs (entered on the attached Sample Log) should indicate visual classification of soils by the Unified Classification System with visual observations of *in situ* moisture and density conditions.

- **Drainage and Water Conditions**
  At steel culvert locations, the report should include drainage and water conditions at the time of sampling and during operation. Approximate high water levels should be identified based on observed culvert conditions.

- **Materials**
  Soil, water, and steel culvert coupon materials should be properly labeled and listed in the report. These listings should include a brief visual description of the sample location.

- **Special Features**
  Any special features such as corroded signposts, bridge decking, saline seepage or other anomalies observed on the site should be noted.

Sampling

A minimum of 16 soil samples should be submitted from each district office. Water samples and steel culvert coupons may also be required based on availability. The sample sites should be geographically separated to the extent possible within the district area and should be selected in accordance with the materials criteria. At each testing location, a visual description of the site and photographs should be recorded as outlined in the ***Required Materials*** section.

Soil samples should be representative of the stratum in question and natural moisture content at the time of sampling should be preserved by prompt collection and sealing of sample bags. Sample location and prudent sampling techniques will be critical in obtaining suitable samples. The following sections detail sample requirements and specific procedures for materials sampling and handling.

Sample Requirements/Handling

Soil samples taken at any location shall meet the following criteria:

Predominant Material Type	**Minimum Weight of Sample Required** **grams (pounds)**
Clay	4500 (9.9)
Sand	6500 (14.3)
Gravel	9000 (19.8)

All pertinent locations and sampling information for each site should be recorded on the attached Sample Logs. The field crew manager shall be responsible for ensuring that sufficient detail is recorded on the field logs. The field logs shall contain sufficient information such that all field activity can be reconstructed by an outside party. At a minimum, all entries shall include:

- project name.
- date and time of start and finish of sample collection.
- weather conditions during sampling.
- description of the site including geology, physiography, topography, and special features or conditions of the area.
- location of sample site (milepost, station etc.) including photographs and map references
- stratigraphic details of all excavations/borings
- sampling equipment/method used for sample collection
- details of sampling work, particularly any deviations from the outlined procedures
- field observations
- types and number of samples including sample identification numbers and photographical references
- field and laboratory measurements as applicable (temperature, field density, moisture content)

All samples are to be promptly shipped to NTL Engineering and Geoscience at the given address. Samples are to be properly labeled and referenced to field logs. Water samples shall be placed in standard canning jars or approved plastic or glass bottles; soil samples are to be sealed in ziplock bags. Field logs should accompany samples and should also be placed in waterproof bags. Samples should be shipped in rigid, insulated boxes or coolers. Cardboard boxes with samples packed in Styrofoam or plastic bubble wrap are acceptable. All coolers will be returned to the origin address if so requested.

Example Sampling Procedures

The following procedures outline the general steps required for sample collection and documentation. Any deviation from these procedures should be recorded and reported to our Project Engineer.

Case 1 (Moderately to Severely Corroded Steel Culvert)

1. Photograph general location including views of the drainage paths near the invert for the upstream and downstream sides.

2. Record visual descriptions of general site geology, physiography, topography, culvert condition, culvert history, and special features or conditions of the area.

3. Collect a sample of the backfill through a corroded perforation in the pipe-or-by drilling through the roadway and subgrade to the elevation of the corroded pipe section. If

drilling is required, the sample elevation and location should be within 1.0 feet of the corroded portion of the culvert.

4. If the bottom of the culvert shows signs of corrosion (not abrasion) and soil materials have collected in the bottom of the culvert, collect a sample of material from within the culvert.

5. With excavation or drilling equipment, collect a sample of the native soil adjacent to the roadway in the upslope portion of the drainage. This sample should not include topsoil or other surficial materials and should be within 1.0± feet of the culvert elevation and within a lateral distance of approximately 10.0± feet of the culvert inlet.

6. Prepare a log of boring or excavation for each sample collection (sample attached).

7. If water is present in the culvert, collect a water sample to be submitted to our office with the soil samples.

8. Assign each sample a unique sample description number. Each sample number should be documented on a boring/excavation log or on a field report explaining where the sample was taken along with a visual classification of the soil. The sample numbers must be cross-referenced to a roadway stationing or mile post and offset. Begin each sample with a hyphenated, numeric prefix corresponding to the district zone number (ex. D1-S1-SS1 ==> District 1, Site 1, Soil Sample 1).

9. Each soil sample should sealed in 1-gallon Ziplock bag(s) immediately after exhumation and placed in an insulated box or cooler for storage and transport.

10. Photograph test pits, borings, or openings in the culvert subsequent to sampling. These photographs should show the exact location of the sample.

11. Backfill any excavations or borings and patch any asphalt or concrete disturbed for sample collection.

Case 2 (Non-Corroded Steel Culvert)

1. Photograph general location including views of the drainage paths near the invert for the upstream and downstream sides.

2. Record visual descriptions of general site geology, physiography, topography, culvert condition, culvert history, and special features or conditions of the area.

3. Collect a sample of the backfill near the edge of the roadway or from a boring extended to the elevation of the culvert within 1.0 feet (laterally) of the culvert location.

4. With excavation or drilling equipment, collect a sample of the native soil adjacent to the roadway in the upstream portion of the drainage. This sample should not include topsoil or other surficial materials and should be within 1.0± feet of the culvert elevation and within approximately 10.0± feet of the culvert inlet.

5. Prepare a log of boring or excavation for each sample collection (sample attached).

6. If water is present in the culvert, collect a water sample to be submitted to our office with the soil samples.

7. Assign each sample a unique sample description number. Each sample number should be documented on a boring/excavation log or on a field report explaining where the sample was taken along with a visual classification of the soil. The sample numbers must be cross-referenced to a roadway stationing or mile post and offset. Begin each sample with a hyphenated, numeric prefix corresponding to the district zone number (ex. D1-S1-SS1 ==> District 1, Site 1, Soil Sample 1).

8. Each soil sample should sealed in 1-gallon Ziplock bag(s) immediately after exhumation and placed in an insulated box or cooler for storage and transport.

9. Photograph test pits, borings, or openings in the culvert subsequent to sampling. These photographs should show the exact location of the sample.

10. Backfill any excavations or borings and patch any asphalt or concrete disturbed for sample collection.

Case 3 (Historically "Hot" Areas)

1. Select location for testing based on observed corrosion indicators such as fine-grained, high-plasticity soils; localized saline seepage, or swampy, high organic content drainages.

2. Photograph general location including views of the surrounding area including drainage areas.

3. Record visual descriptions of general site geology, physiography, topography, and special features or conditions of the area.

4. With excavation or drilling equipment, collect a sample of the native soil below the topsoil zone. This sample should not include topsoil or other surficial materials and should be within 3.0± feet of the prevailing ground surface.

5. If standing water is present or if groundwater enters the boring/excavation, collect a water sample to be submitted to our office with the soil samples.

6. Prepare a log of boring or excavation for each sample collection.

7. Assign each sample a unique sample description number. Each sample number should be documented on a boring/excavation log or on a field report explaining where the sample was taken along with a visual classification of the soil. The sample numbers must be cross-referenced to a roadway stationing or mile post and offset. Begin each sample with a hyphenated, numeric prefix corresponding to the district zone number (ex. D1-S1-SS1 ==> District 1, Site 1, Soil Sample 1).

8. Each soil sample should sealed in 1-gallon Ziplock bag(s) immediately after exhumation and placed in an insulated box or cooler for storage and transport.

9. Photograph test pits or borings subsequent to sampling. These photographs should show the exact location of the sample.

10. Backfill any excavations or borings created for sample collection.

We appreciate your cooperation and involvement with this project. Please contact our office if you have any questions or concerns regarding this report.

Sincerely,

NTL Engineering & Geoscience, Inc.

Jon J. Hepfner, E.I.T.
Project Geotechnical Engineer

Outline for Phase II of the Montana State Resistivity Testing Project

Samples are to be collected by Montana Department of Transportation District offices for a statewide resistivity research program. The District offices include:

- Great Falls
- Billings
- Glendive
- Butte
- Missoula

I. Sampling

A. Target areas include

- areas of poor culvert performance
- areas of fair to good culvert performance
- historically identified "hot" areas
- areas of proposed new construction/borrow
- case study (to be performed by NTL Engineering & Geoscience)

B. Desired sampling materials

- backfill and native soil samples around culverts exhibiting signs of poor performance
- backfill and native soil samples around culverts exhibiting fair to good performance
- soil samples from prospective borrow areas
- native soil samples in areas of proposed new construction
- photographs/location maps for each sample location
- visual classification of the soil samples
- visual description of surrounding conditions (vegetation, ground/surface water, etc)
- brief soil log of the test pit (where applicable)
- water samples (where applicable)

C. Sampling requirements

- adequate sample size
- sealed, contained storage
- proper documentation
- prompt delivery

II. Testing

A. NTL Engineering & Geoscience

- minimum soil resistivity (AASHTO T288/Caltrans/ASTM G57)
- particle size distribution
- Atterberg Limits
- *in situ* moisture content/material classification

B. Montana Department of Transportation

- saturated paste pH and conductivity
- 1:1 dilution pH and conductivity
- 1:2 dilution pH and conductivity
- sulfate/chloride

C. Soil Testing Laboratory MSU-Bozeman

- quality control testing for NTL Engineering & Geoscience and the Montana Department of Transportation

NTL Engineering
& Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District:

Materials Supervisor:

County:

Highway/Milepost:

Station/Offset:

Sampling Date: (start)

Sampling Date: (finish)

Sample Location:

Project Team Members:

General

Site Description:

Sample Locations:

Weather Conditions:

Site Sketch

Location, Description, and Reference Number

☐ **Photographs**

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station:

Culvert Type:

Approximate Age:

Length:

Diameter:

Coating:

General Condition:

Photograph Number(s):

Location of Soil Samples:

Remarks/Comments:

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☐ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection
(particularly any deviation from outlined procedures)

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: ____________________
Materials Supervisor: ____________________
County: ____________________
Location: ____________________

Materials

	Sample Id. #		Code*	Sample Size	Photograph Reference
☐ Soil Sample		/			
☐ Soil Sample		/			
☐ Soil Sample		/			
☐ Soil Sample		/			
☐ Water Sample					
☐ Coupon Sample					

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: ____________________

Boring/Excavation Log

Field Engineer: ____________________

Boring/Excavation Location: ____________________

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

Information Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log information

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ Other samples (water, coupons, etc)

Appendix B

MDT Field Notes

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: Missoula

Materials Supervisor: R. W. Todd

County: Missoula

Highway/Milepost: 93/P-71

Station/Offset: 74+90, 60' Lt ℄

Sampling Date: (start) 3/9/2000

Sampling Date: (finish) 3/10/2000

Sample Location: Lt. Side PTW

Project Team Members: Don Hauge, MLT III 523-5840

General

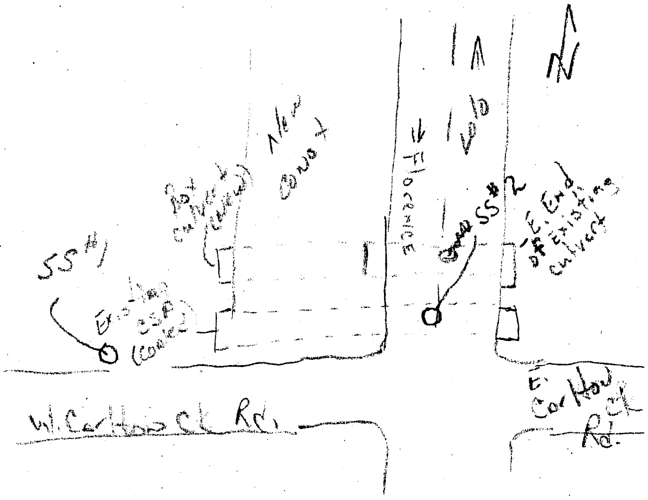
Site Description: Carlton Ck - West of PTW at area of pipe replacement. Slightly rolling terrain, fair to moderate ground cover (grasses, willows, cottonwood's). Location is South of Lolo, appr. 5 miles. Project is currently undergoing reconstruction (add 2 lanes)

Sample Locations: South side of stream channel Appr. 8' (2.4m) upstream of inlet (SS1)

SS#2 taken from sediment deposited inside of north pipe.

Weather Conditions: Partly Cloudy 40-45°F

Site Sketch



Location, Description, and Reference Number

☒ **Photographs** D1-S1 Photos 1 thru 12 - narrative on reverse

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions: Predominant soils are sandy gravel with some boulders and topsoil. Slope to inlet is almost flat. New construction has slope of 6:1

This set of culverts is being replaced with a single box concrete culvert. Section of old pipe retrieved for possible testing.

Culvert Inspection Report

Roadway Station: 74+80 +/-

Culvert Type: CSP Arch

Approximate Age: 20 +/- yrs

Length: 120' +/-

Diameter: 9' × 5' | 2.74m × 1.52m
8' × 5' | 2.44m × 1.52m

Coating: Asphalt Cto.

General Condition: Fair

Photograph Number(s):

Location of Soil Samples: Invert So. Side Bank

Remarks/Comments: Visual inspection shows pipe is in good condition. Some flaking and delamination of asphalt coating on lower third of pipe. Photos taken before and after sampling. Further inspection shows no rust through-outs some pitting at sediment line.

Sampling Equipment

☐ Backhoe

☐ Drill

☐ Hand Auger

☒ Shovel

☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Carlton Cr?

Page 2

MDT Materials District: Missoula
Materials Supervisor: Robert W. Todd

County: Missoula
Location: Carlton Ck
NH-STPE 7-2(25)78F Sta 75+80, Lt

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	D1-S1-SS1 /	D	9000 +/-	
☒ Soil Sample	D1-S1-SS2 /	Dx	4500 +/-	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel—9000g)	Gravel	Sand	Silt/Clay
	40% +4m	60% -4m	
	20% +4m +/-	80% +/-	
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Photos: 2-upstream, 2-outlet of south pipe, 2-outlet north pipe - 3 inside North pipe before sample (1-looking upstream) 1-after sampling from inside pipe
In-situ moisture SS1 = 19.0% SS2 = 14.3%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☒ Sampling equipment information/sampling methods
- ☒ Sampling methods
- ☐ Sampling material information
- Boring log information

Attachments

- ☒ Photographs of site
- ☐ Maps of project site
- ☒ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible]

NTL Engineering
& Geoscience
1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

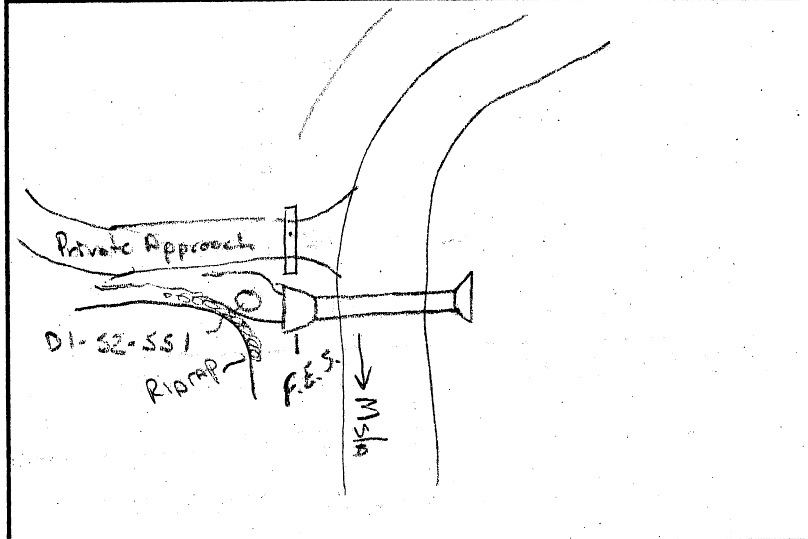
NTL Engineering Project Number 00-301

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Missoula
Highway/Milepost: 200 / 17.7+/-
Station/Offset: 2+60, 30'+/- Lt ℄
Sampling Date: (start) 3/16/00
Sampling Date: (finish) 3/16/00
Sample Location: 6' upstream of inlet.
Project Team Members: Don Hauge

General

Site Description: 2 pipes are present, Cross drain under Hwy is 24" "Blak-Clad" CSP, with F.E.S. Approach drain is 18" and appears to be plastic. At both pipes there is substantial build up of debris (Sanding material and trash). Location is east of Missoula on Hwy 200, approximately 12 miles. Area had major reconstruction in 1986-87

Site Sketch



Sample Locations: D1-S2-SS1 upslope from invert. approximately 6'.

Weather Conditions: Cloudy Skies, 35° F

☒ **Photographs**
☐ **Maps**

Location, Description, and Reference Number
Inlet 24" "Blak-Clad" pipe, Small Water flow
Outlet of appr drain, inlet (close up) appr drain. Rip-rap west side of channel.
D1-S2 Photos 1 thru 5

Geology, Physiology, Topography, and Special Features/Conditions: Mountainous terrain, Inlet channel has native grasses and knapweed in waterway. Coarse gravel and sand. Western side of channel is lined with rip-rap. (6" - 8" rock)

Culvert Inspection Report

Roadway Station: 2+60 (RF 24-1(8)8)
Culvert Type: C.S.P.
Approximate Age: 14-15 yrs
Length: 60' +/-
Diameter: 24"
Coating: "Blak-Clad"
General Condition: Good
Photograph Number(s):
Location of Soil Samples: 6' from inlet
Remarks/Comments: Pipe appears in very good condition - except for accumulation of debris.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd

County: Missoula
Location: 2760, MP 7.7+/-
RF 24-1(8)8 Rainbow Bend-W

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	DI- S2 - SS1 /	D		
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)

	Gravel	Sand	Silt/Clay
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: In-situ moisture 27.3%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

formation Checklist

Sampling site location and description (geology, topography, etc.)
Sampling equipment information/sampling methods
Sampling methods
Sampling material information
oring log in on

Attachments

☒ Photographs of site
☐ Maps of project site
☒ Adequate size soil samples
☒ Photographs of soil sample sites
☐ [illegible]

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Ravalli
Highway/Milepost: 93 / mp 42.1 +/-
Station/Offset: 90'+/- Lt ℄
Sampling Date: (start) 3/20/00
Sampling Date: (finish) 3/20/00
Sample Location: Upslope drainage
Project Team Members: Don Hauge MLTW

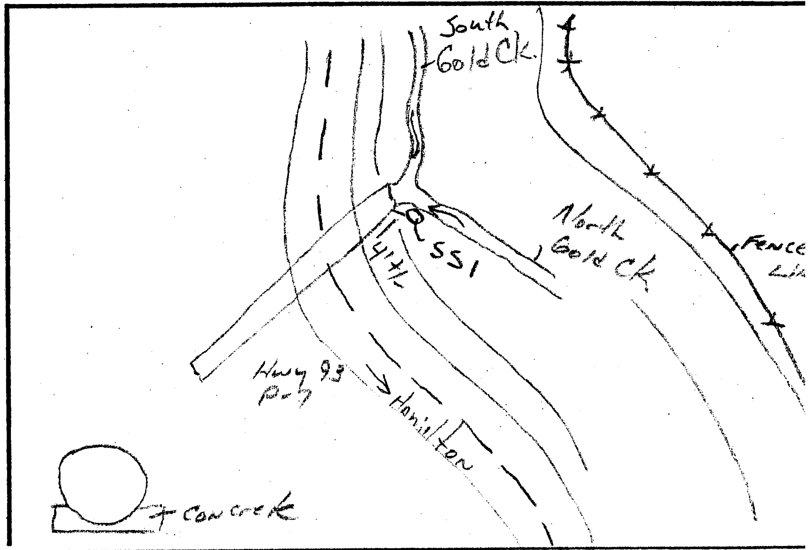
General

Site Description: Rolling terrain - pipe located at confluence of North and South Gold Ck. Both slopes have native grasses and willow-alder cover. This site is south of Hamilton appr. 6 miles. Roadway is 2-lane with wide shoulders. Water currently flowing

Sample Locations: 4'+/- northwest of pipe Taken at bank line

Weather Conditions: Clear 40°

Site Sketch



☒ **Photographs** — *Location, Description, and Reference Number:* D1-S3 Photos 1-6

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions: Stream beds are clean sand and gravel w/ stone present to 12"+/-" size, 40-50'+/- north of pipe, western bank is silt-bank shows some erosion from runoff. Pipe has concrete header at lower face. (See Sketch) (cut-off walls)

Culvert Inspection Report

Roadway Station: mp 42.1 +/-
Culvert Type: CSP
Approximate Age: 20 yrs
Length: 300'+/-
Diameter: 54"
Coating: Bituminous
General Condition: Good
Photograph Number(s):
Location of Soil Samples: 4' NW of invert

Remarks/Comments: Pipe is in relatively good condition - No rust through identified. Asphalt coating is wearing/falling off. Only rust noted is at seasonal water line. (abrasion) Pipe is at a skew to roadway, bottom of 35'-40' fill section

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

***Include Details of Sampling Equipment and Procedures/Methods of Sample Collection** (particularly any deviation*

Hand shovel on eastern side of N. Gold Ck. near invert

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Ravalli
Location: MP 42.1±

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	D1-S3-SS1 /	D	9000± gms	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	40-50% +4	50-60%	
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: In-situ moisture = 15.0%

Boring/Excavation Log

Field Engineer:
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
oring log in ion

Attachments

☒ Photographs of site
☐ Maps of project site
☒ Adequate size soil samples
☐ Photographs of soil sample sites
☐ mpl ater, co

**NTL Engineering
& Geoscience**

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

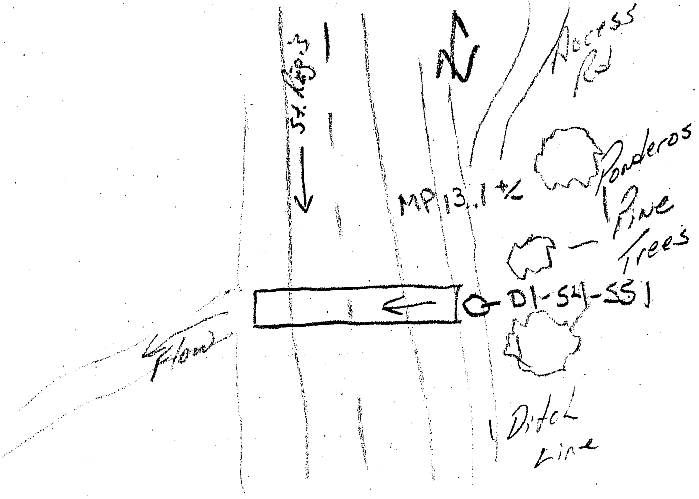
MDT Materials District: Missoula
Materials Supervisor: R. W. Todd
County: Sanders
Highway/Milepost: P35/ 13.1
Station/Offset: 60'± Rt ℄
Sampling Date: (start) 3/23/00
Sampling Date: (finish) 3/23/00
Sample Location:

Project Team Members: Don Hauge

General

Site Description: Cross Drain, Hwy 135 NB
No water flowing at present time.

Site Sketch



Sample Locations: 3' from invert

Weather Conditions: Ptly Cloudy, 40°

☒ **Photographs**

Location, Description, and Reference Number
2 - invert and inside of pipe
D1-S4

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions: Relatively flat, inside canyon, ½ mile due east of river. Surrounding terrain is very steep mountains with considerable talus slopes

Culvert Inspection Report

Roadway Station: MP 13.1±
Culvert Type: CSP
Approximate Age: 20+ yrs
Length: 50'
Diameter: 24"
Coating: None/Galvanized
General Condition: Good
Photograph Number(s):
Location of Soil Samples: 3'E of invert

Remarks/Comments: For apparent age of pipe, good condition, very little debris collection noted, Interior (or inspection) shows no serious rust - only from minor abrasion.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Mineral
Location: Hwy 135, MP 13.1

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	D1-54-SS1 /	D	6500	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	10	40	50
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Material has fair amount of silt.

In-situ moisture 17.5%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log information

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ [illegible]

NTL Engineering
& Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: Missoula

Materials Supervisor: R.W. Todd

County: Sanders

Highway/Milepost: P36 12.9+/-

Station/Offset: 10'+/- Lt ℄

Sampling Date: (start) 3/22/00

Sampling Date: (finish) 3/23/00

Sample Location: 5' upslope of invert

Project Team Members: Don Hauge

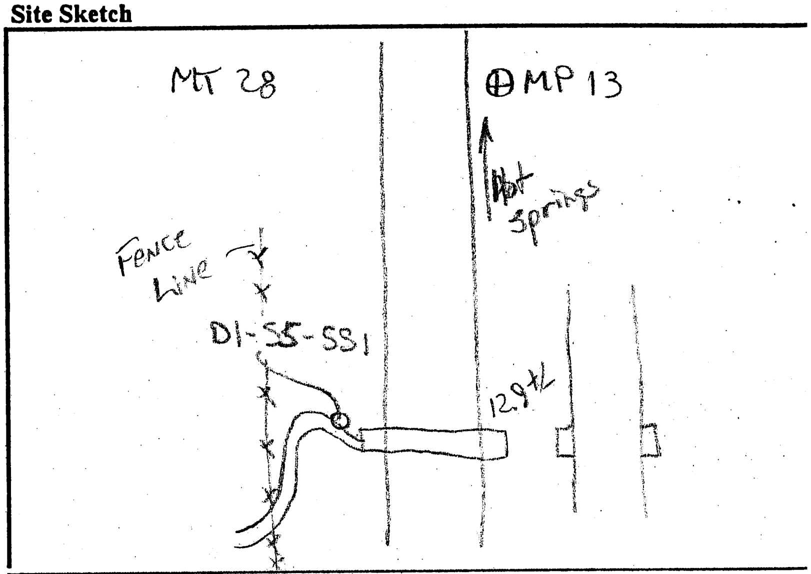
General

Site Description: Cross Drain carrying seasonal runoff, otherwise empty. Side slopes both ahead of and back of location shows some rock to 10"-12" range. Area of sample has thick pine needle coverage. Run-off water currently flowing.

Sample Locations: 5' upslope from invert.

Weather Conditions: Ptly Cldy 40°

Site Sketch



Location, Description, and Reference Number

☐ **Photographs**

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions: Rolling terrain, heavily wooded surroundings Glacial till - area shows angular and sub-angular rock with silty sand fines.

Culvert Inspection Report

Roadway Station: MP 12.9

Culvert Type: CSP

Approximate Age: 25+ yrs

Length: 80'

Diameter: 36"

Coating: Galvanized

General Condition: Good

Photograph Number(s):

Location of Soil Samples: See Above

Remarks/Comments: Only minor rust (abrasion) - Large amount of debris collection, but free flow of water (seasonal runoff)

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: ______________

Materials Supervisor: ______________

County: ______________

Location: ______________

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	D1-S5-SS1 /	D	6500g	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

	Gravel	Sand	Silt/Clay
For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	<10%	<30%	60%
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert

B -Backfill sample from a non-corroded culvert

C -Native soil sample near a corroded culvert

D -Native soil sample near a non-corroded culvert

Comments: ______________

In-situ moisture 30.5%

Boring/Excavation Log

Field Engineer: ______________

Boring/Excavation Location: ______________

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log information

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible]

NTL Engineering
& Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

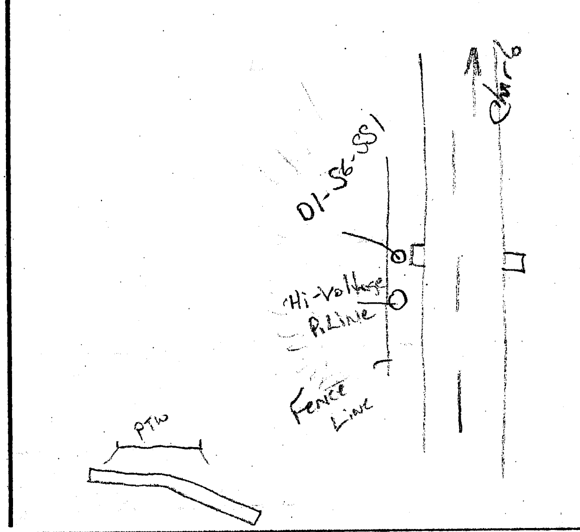
NTL Engineering Project Number 00-301

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Lake
Highway/Milepost: S212 MP 5.7+/-
Station/Offset: 45'+/- Lt ℄
Sampling Date: (start) 3/23/00
Sampling Date: (finish) 3/23/00
Sample Location: 3' from invert
Project Team Members: Don Hauge

General

Site Description: Rolling terrain, mostly bare slopes, grass cover, Located north by northeast of Nat'l Bison Range.
Pipe lays at moderate angle to roadway, with built in bend at approximate mid point. Outlet is 25-30' lower than invert end.

Site Sketch



Location, Description, and Reference Number

☐ **Photographs**

☐ **Maps**

Sample Locations: 3' upslope of invert

Weather Conditions: Ptly Cldy ±15°

Geology, Physiology, Topography, and Special Features/Conditions: Silt w/some gravels. Drain of agricultural land, which is predominant use of surrounding area.

Culvert Inspection Report

Roadway Station: MP 5.7+/-
Culvert Type: CSP
Approximate Age: 15-20 yrs
Length: 100'+/-
Diameter: 24"
Coating: Galvanized
General Condition: Fair
Photograph Number(s):
Location of Soil Samples: 3' upslope invert
Remarks/Comments: Minor abrasion rust can be seen, otherwise in fair to good condition.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Missoula
Materials Supervisor: [illegible] Todd

County: Lake
Location: S212 MP 5.7+/-

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	01-56-551 /	D	5500g	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
		<20%	80%+/-
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: IN-situ moisture = 17.1%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
oring log in ion

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ mpl ater, c

NTL Engineering & Geoscience
1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

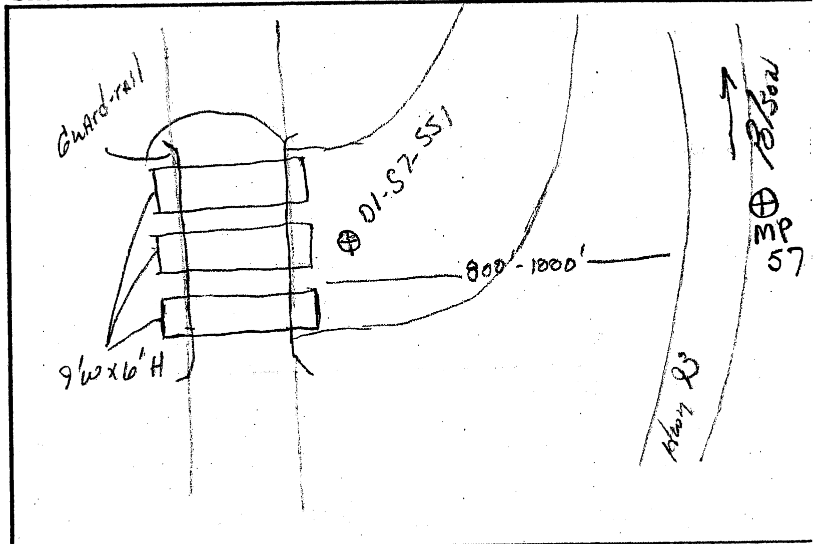
NTL Engineering Project Number 00-301

MDT Materials District: Missoula
Materials Supervisor: R.W. Todd
County: Lake
Highway/Milepost: P5 /93/
Station/Offset: 800'-1000' Lt
Sampling Date: (start) 3/31/00
Sampling Date: (finish) 3/31/00
Sample Location:
Project Team Members: Don Hauge

General

Site Description: Pablo Feeder Canal. Diversion canal for downstream irrigation use. Canal is approximately 40-45' wide.

Site Sketch



Sample Locations: 6' upstream of center pipe.

Location, Description, and Reference Number

☒ Photographs

☐ Maps

Weather Conditions: Clear 45°-50°

Geology, Physiology, Topography, and Special Features/Conditions: This location lies south of Flathead Lake in rolling terrain. Roadway carries fair amount of heavy truck traffic from gravel pit S[illegible] site to processing plant NE of site, as well as residential traffic. Canal banks are well covered with wetland grasses, shrubbery and willow/alder trees

Culvert Inspection Report

Roadway Station: W. of MP 57.0
Culvert Type: CSP
Approximate Age: 30yrs +/-
Length: 45'
Diameter: 6'H x 9'W
Coating: Galvanized
General Condition: Fair
Photograph Number(s):
Location of Soil Samples: 6' upstream

Remarks/Comments: Pipe(s) are in relatively fair condition. Considerable amount of rust (abrasion). Invert end of southern pipe is torn. All three show some bending inside and at invert (debris caused). Visual inspection of pipe(s) shows no rust through.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation...

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Missoula

Materials Supervisor: R.W. Todd

County: Lake

Location:

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	DK-57-551 /	D	9000+gms	
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel—9000g)	Gravel	Sand	Silt/Clay
	15%	85%	
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Canal bed is mostly sand with large rock (8"-10") as liner.
In-situ moisture = 3.7%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	Sample Depth to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- oring log in[illegible]on

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible] water, [illegible]

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL

Materials Supervisor: D. FRENCH

County: LINCOLN

Highway/Milepost: U.S. 2 / 75.95

Station/Offset: 65' LT ℄

Sampling Date: (start) 3-15-2000

Sampling Date: (finish) " " "

Sample Location: 1

Project Team Members: K. BECKSTROM & K. BIDWELL

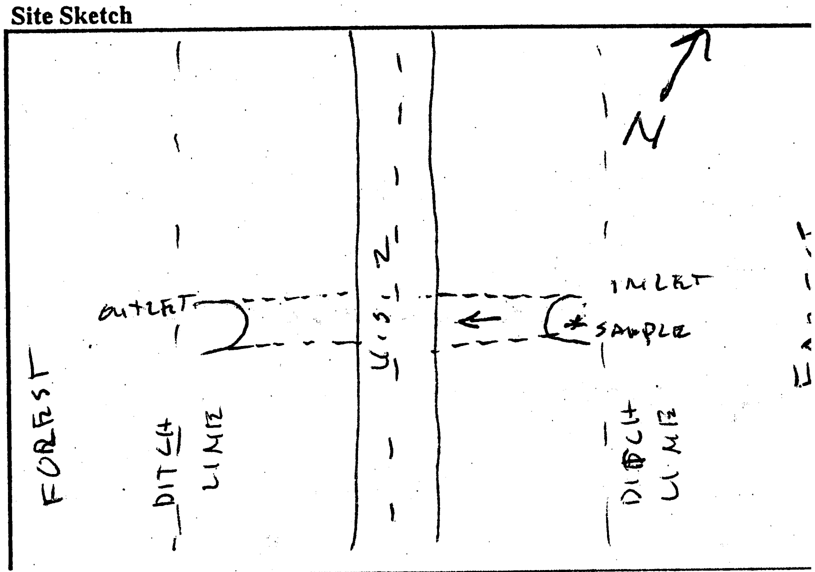
General

Site Description: U.S. 2 : M.P. 75.95 ROLLING HILLS; HEAVY PINE FOREST; NO FLOWING WATER

Sample Locations: FLOW LINE OF ~~OUT~~ INLET END OF PIPE; JUST IN FROM DITCH LINE; 2' BELOW FLOW LINE

Weather Conditions: LOW 30'S; PARTLY CLOUDY; LIGHT BREEZE

Site Sketch



Location, Description, and Reference Number

☒ Photographs — Location #1 photos 1-4

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:

Grassland, Forest and Rolling hills, Glacial Tertiary Valley sediment & morrainal gravels

Culvert Inspection Report

Roadway Station: M.P. 75.95

Culvert Type: C.S.P.

Approximate Age: 3 YEARS

Length: 92.8'

Diameter: 24"

Coating: NONE

General Condition: GOOD

Photograph Number(s): 1 – 4

Location of Soil Samples: See above

Remarks/Comments:

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviati

SOFT, PARTLY FROZEN GROUND - USED SHOVEL TO SAMPLE

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: LINCOLN
Location: U.S. 93 / M.P. 75.95

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	1 /	D		3
☐ Soil Sample	1A /	D		3
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0.05	0.05	99
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: 1½' BELOW FLOW LINE
INSITU MOISTURE = 34.2%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log information

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ [illegible]

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

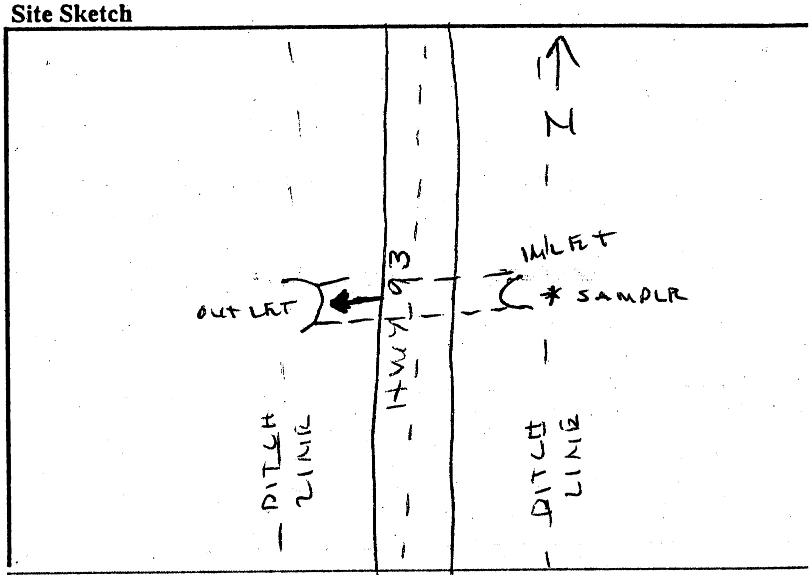
NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL
County: LINCOLN
Sampling Date: (start) 3/15/2000
Materials Supervisor: R. FRENCH
Highway/Milepost: US 93/185.5
Sampling Date: (finish) " " "
Station/Offset: 25' RT ℄
Sample Location: 2
Project Team Members: K. BECKSTROM K. BIDWELL

General

Site Description: FLAT GRASS LANDS, MINOR HILLS, NO WATER

Site Sketch



Sample Locations: 2' FROM INLET OF PIPE 1 1/2' ~~B~~ BELOW FLOW LINE

Location, Description, and Reference Number

☒ **Photographs** LOCATION #2 photos 5-8

☐ **Maps**

Weather Conditions: MOSTLY CLOUDY, UPPER 30'S, DRY, LIGHT WIND

Geology, Physiology, Topography, and Special Features/Conditions:
Rolling grassland, Tertiary valley fill.

Culvert Inspection Report

Roadway Station: M.P. 185.5
Length: 52'
General Condition: GOOD
Culvert Type: C.M.P.
Diameter: 24"
Photograph Number(s): 5 - 8
Approximate Age: 15 YEARS
Coating: NONE
Location of Soil Samples:
Remarks/Comments: OUTLET CRUSHED BUT NOT RUSTED

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☒ Other - PICK

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: LINCOLN
Location: U.S. 2 / M.P. 185.5

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	2	D		
☐ Soil Sample	2A	D		
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	94	5	1
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: INSITU MOISTURE = 14.3%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ oring log in[illegible]ion

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible] ater, co[illegible]

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL

Materials Supervisor: R. FRENCH

County: LINCOLN MP. 163.8

Highway/Milepost: U.S. 93

Station/Offset: 75' RT 4

Sampling Date: (start) 3-15-2000

Sampling Date: (finish) " " "

Sample Location: 3

Project Team Members: K. BECKSTROM, K. BIDWELL

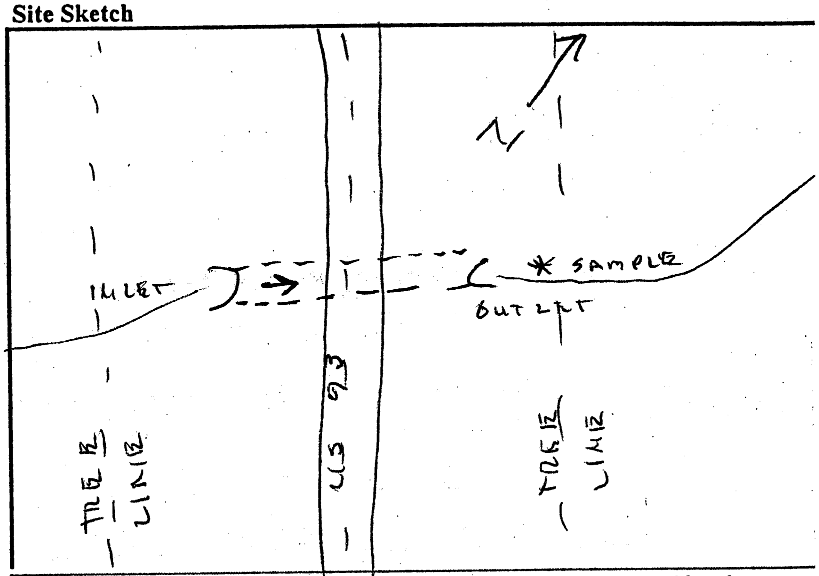
General

Site Description: SMALL ROLLING HEAVILY FORESTED HILLS. SMALL SPRING CROSSES ROAD, SLIGHLT RISE AT INLET SIDE, DESCENT AT OUTLET SIDE

Sample Locations: 2 FEET DOWNHILL FROM OUTLET 2' BELOW FLOW LINE

Weather Conditions: UPPER 30'S, MOSTLY CLOUDY SLIGHT BREEZE

Site Sketch



☒ Photographs

Location, Description, and Reference Number

Location #3 photos 9-12

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:

Rolling forested hills

Culvert Inspection Report

Roadway Station:

Culvert Type: C.M.P

Approximate Age: 9 YEARS

Length: 150'

Diameter: 24'

Coating: NONE

General Condition: GOOD

Photograph Number(s): 9-12

Location of Soil Samples: 2' below flowline (OUTLET)

Remarks/Comments: FETS SLIGHLY COLORED FROM HEAVY VEGETATION GROWING OVER THEM

Sampling Equipment

☐ Backhoe

☐ Drill

☐ Hand Auger

☒ Shovel

☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL

Materials Supervisor: R. FRENCH

County: LINCOLN

Location: U.S. 93 / M.P. 163.8

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	3	/ D		
☐ Soil Sample	3A	/ D		
☐ Soil Sample		/		
☐ Soil Sample		/		
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0.5	0.5	99
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert

B -Backfill sample from a non-corroded culvert

C -Native soil sample near a corroded culvert

D -Native soil sample near a non-corroded culvert

Comments: insitu moisture = 54.7%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log information

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible] ter, co [illegible]

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL

Materials Supervisor: R. FRENCH

County: FLATHEAD

Highway/Milepost: MT 40@2.2

Station/Offset: 76' RT ℄

Sampling Date: (start) 3-15-2000

Sampling Date: (finish) " " "

Sample Location: 4

Project Team Members: K. BECKSTROM, K. BIDWELL

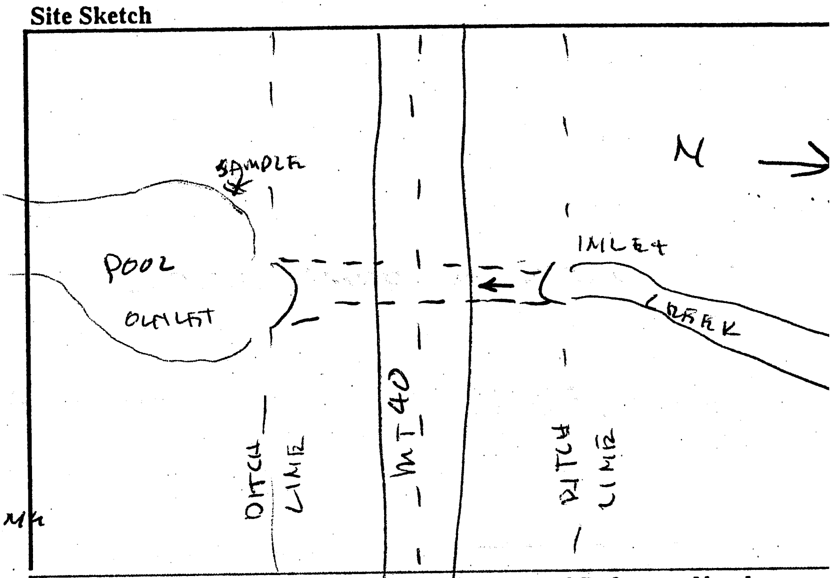
General

Site Description: GENERALLY FLAT; MIXED GRASSLAND & FOREST 0.3 MILE EAST ~~[illegible]~~ WHITEFISH RIVER; SMALL CREEK

Sample Locations: 2' BELOW FLOW LINE 10 FEET SW OF PIPE; OUTLET END HAS POOL AT IT; ALSO HAS SMALL WILLOW TREES GROWING NEXT TO PIPE

Weather Conditions: MOSTLY CLOUDY; LOW 40'S, DRY

Site Sketch



Location, Description, and Reference Number

☒ Photographs — LOCATION #4 PHOTOS 13-16

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: MP 2.2

Culvert Type: C.M.P.

Approximate Age: 20 YEARS

Length: 152'

Diameter: 24"

Coating: NONE

General Condition: GOOD

Photograph Number(s): 13-16

Location of Soil Samples: See above

Remarks/Comments: VEGETATION GROWN CLOSE & PIPE FULL OF WATER; HARD TO SEE; FETS IN GOOD CONDITION

Sampling Equipment

- ☐ Backhoe
- ☐ Drill
- ☐ Hand Auger
- ☒ Shovel
- ☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

4

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL

Materials Supervisor: R. FIZEACH

County: FLATHEAD

Location: MT 40 / M.P. 2.2

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	4	D		
☐ Soil Sample	4A	D		
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0	0.5	99.5
		0	
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: INSITU MOISTURE: 35.0%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log information

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ [illegible]

NTL Engineering
& Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: SANDERS
Highway/Milepost: HWY28/20.8
Station/Offset: 58' RT ℄
Sampling Date: (start) 3/16/2000
Sampling Date: (finish) " " "
Sample Location: 5
Project Team Members: K. BECKSTROM, K. BIDWELL

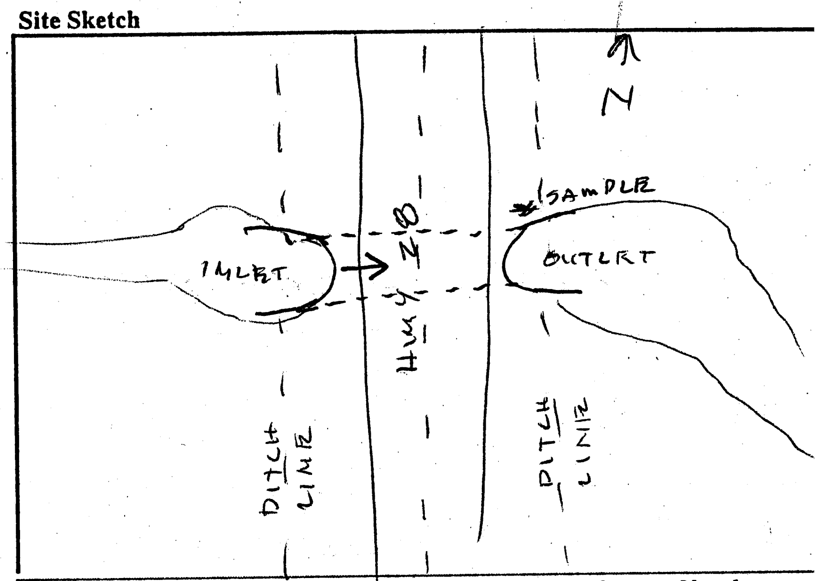
General

Site Description: SMALL & SLOW FLOWING CREEK IN GENTLY ROLLING GRASS LANDS.

Sample Locations: BESIDE PIPE, 4' BACK FROM OUTLET 3' BELOW FLOW LINE

Weather Conditions: LOW 30'S, SLIGHT BREEZE, OVERCAST, DRY

Site Sketch



Location, Description, and Reference Number

☒ Photographs location #5 photos 17-20

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:
flat grassland

Culvert Inspection Report

Roadway Station: M.P. 20.8
Culvert Type: C.M.P.
Approximate Age: 20+ YEARS
Length: 120'
Diameter: 48"
Coating: NONE
General Condition: FAIR
Photograph Number(s): 17-20
Location of Soil Samples: See above

Remarks/Comments: ~~TEE~~ SLIGHT RUST AT WATER LINE & BELOW, SOME RUST ON TOP

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: SANDERS
Location: 5

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	1	C		
☐ Soil Sample	1A	C		
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0	0	100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: INSITU MOISTURE = 55.7%

Boring/Excavation Log

Field Engineer:
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log information

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ [illegible]

NTL Engineering
& Geoscience
1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: FLATHEAD
Highway/Milepost: 82 / 1.4
Station/Offset: 27' RT ℄
Sampling Date: (start) 3-16-2000
Sampling Date: (finish) " " "
Sample Location: 6
Project Team Members: K. BECKSTROM & K. BIDWELL

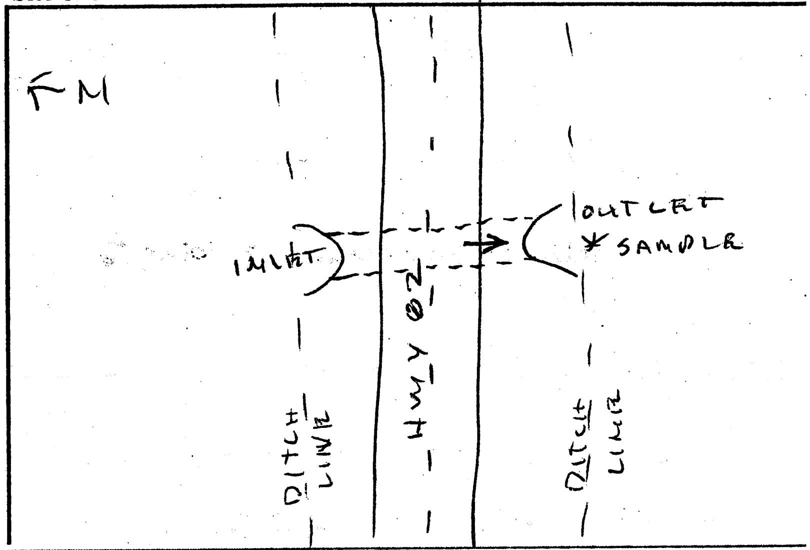
General

Site Description: GENTLY ROLLING FIELDS, ABOUT 1 MILE N OF LAKE SHORE, NO FREE WATER

Sample Locations: ON FLOW LINE; 2' DEEP

Weather Conditions: LIGHT WIND, MID 30'S, OVERCAST, DRY

Site Sketch



Location, Description, and Reference Number

☒ Photographs — Location #6 photos 21-24

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: M.P. 1.4
Culvert Type: C.M.P.
Approximate Age: 15 YEARS
Length: 54'
Diameter: 24"
Coating: NONE
General Condition: GOOD
Photograph Number(s): 21-24
Location of Soil Samples: see above

Remarks/Comments: INLET CRUSHED SLIGHTLY; VERY LITTLE RUST ON CRUSHED INLET, NONE ON REST OF PIPE

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☒ Other PICK

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: FLATHEAD
Location: # 5

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	1	D		
☐ Soil Sample	1A	D		
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

	Gravel	Sand	Silt/Clay
For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	0.5	5	94.5
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: insitu moisture = 24.5%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	Sample Depth to	Sample Number	Remarks

nformation Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log in[illegible]on

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible] sampl[illegible] water, co[illegible]

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL

Materials Supervisor: R. FRENCH

County: FLATHEAD

Highway/Milepost: 93/M.P. 87.25

Station/Offset: 65' LT ℄

Sampling Date: (start) 3/16/2000

Sampling Date: (finish) " " "

Sample Location: 7

Project Team Members:

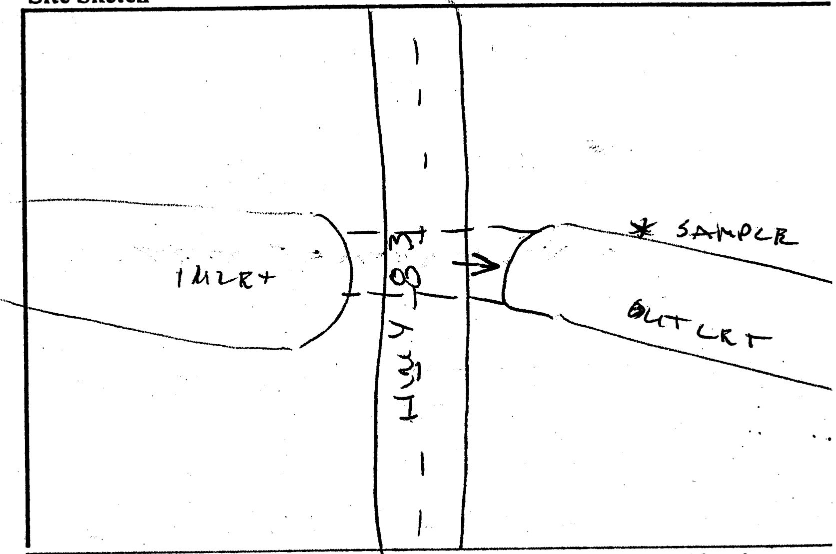
General

Site Description: FAST FLOWING CREEK, FLAT GRASS LANDS & FIELDS, SOME PINE WOODS, BOTTOM & SIDES OF CREEK ARE MOSTLY 6 - 12" ROCK.

Sample Locations: 15' FROM OUTLET IN BANK 1' BELOW FLOW LINE

Weather Conditions: MID 30'S, OVERCAST CALM, DRY

Site Sketch



Location, Description, and Reference Number

☒ Photographs — Location #7 photos 25-29

☐ Maps

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: M.P. 87.25

Culvert Type: C.M.P.

Approximate Age: 20 YEARS

Length: 130'

Diameter: 6 FOOT

Coating: NONE

General Condition: GOOD

Photograph Number(s): 25-29

Location of Soil Samples: See above

Remarks/Comments: SOME SURFACE RUST ON WATERLINE & BELOW

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: FLATHEAD
Location: 7

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	1	D		
☐ Soil Sample	1A	D		
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel–9000g)	Gravel	Sand	Silt/Clay
	0	0	1000
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: INSITU MOISTURE = 22.3%

Boring/Excavation Log

Field Engineer:
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

-] Sampling site location and description (geology, topography, etc.)
-] Sampling equipment information/sampling methods
-] Sampling methods
-] Sampling material information
-] Boring log information

Attachments

- ☐ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☐ Photographs of soil sample sites
- ☐ [illegible] ple [illegible] ater, co[illegible]

NTL Engineering & Geoscience
1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

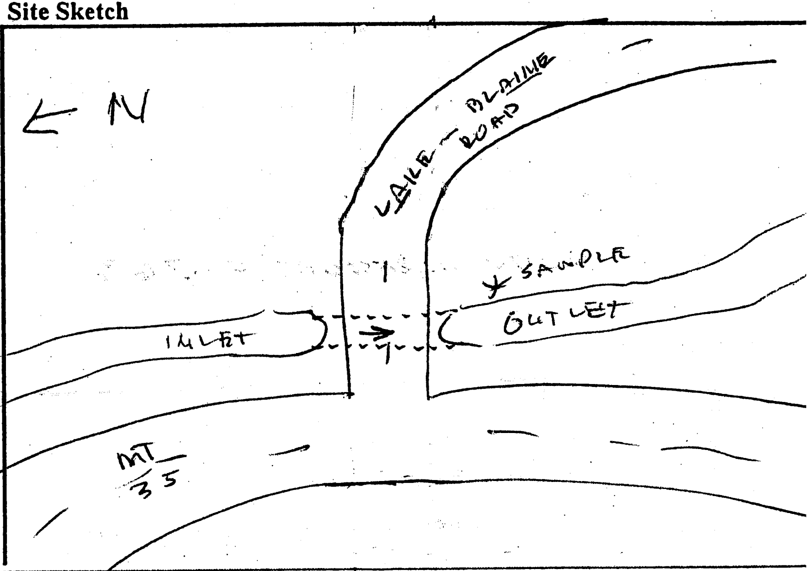
NTL Engineering Project Number 00-301

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: FLATHEAD M.P 45.0
Highway/Milepost: JCT Hwy 35 :: Lake Blaine Rd
Station/Offset: 30' RT ℄
Sampling Date: (start) 3/16/2000
Sampling Date: (finish) " " "
Sample Location: 8
Project Team Members:

General

Site Description: PIPE ON LK BLAINE ROAD 75' FROM PTW OF HWY 35 AT M.P. 44.8 MODERATE FLOW CREEK

Site Sketch



Sample Locations: 10' FROM OUTLET ON BANK. PIPE RIPRAPED, ALSO BANK FOR 3', 2' BELOW FLOW LINE

Location, Description, and Reference Number

☒ Photographs LOCATION#8 PHOTOS# 30-33

☐ Maps

Weather Conditions: 30° BLOWING SNOW

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: JCT. Hwy 35 and M.P. 45.0 Lake Blaine Rd.
Length: 100'
General Condition: GOOD
Culvert Type: C.M.P.
Diameter: 48"
Photograph Number(s): 30-33
Approximate Age: 5 YEARS
Coating: NONE
Location of Soil Samples: see above

Remarks/Comments:

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation

8

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: KALISPELL
Materials Supervisor: R. FRENCH
County: FLATHEAD
Location: 8

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☐ Soil Sample	1 /	D		
☐ Soil Sample	1A /	D		
☐ Soil Sample	/			
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0	90	10
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: INSITU MOISTURE = 37.6%

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks

nformation Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
Boring log information

Attachments

☐ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☐ Photographs of soil sample sites
☐ [illegible]

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Stamp 2255
Same type add on as shown in stock inlet - not sampled

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MADISON
Highway/Milepost: MT. 41/44.95
Station/Offset: 39+95
Sampling Date: (start) 5/13/00
Sampling Date: (finish) 5/13/00
Sample Location: DRAINAGE - MP 44.95
Project Team Members: BILL GRMOLJEZ, DAN HARRINGTON

General

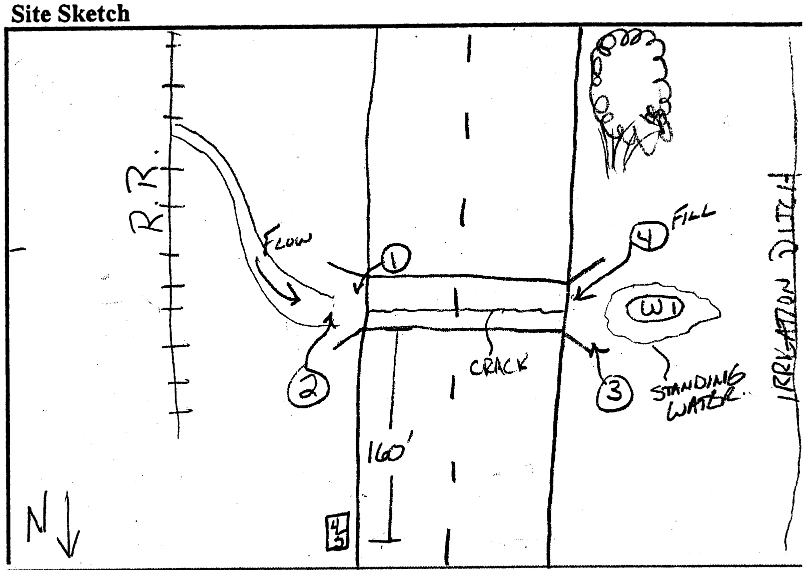
Site Description: THE PROJECT SITE WAS APPROXIMATELY 161' SOUTH of MILE MARKER 45 ON MT 41 BETWEEN SILVER STAR AND TWIN BRIDGES. THE STRETCH of HIGHWAY IS 2-LANES WITH MANY SMALL CULVERT SECTIONS.

Sample Locations: 4 SOIL SAMPLES, 1 WATER SAMPLE

- SOIL SAMPLE #1 - INLET END, PIPE BACKFILL, CORRODED CULVERT ≈ 14' Rt ℄
- SOIL SAMPLE #2 - INLET END, BOTTOM of CULVERT (ORIGINAL GROUND) ≈ 16' Rt ℄
- SOIL SAMPLE #3 - OUTLET END, PIPE BACKFILL, CORRODED CULVERT ≈ 14' Lt. ℄
- SOIL SAMPLE #4 - OUTLET END, FILL ON TOP of PIPE ≈ 13' Lt ℄ (EMBANKMENT)
- WATER SAMPLE #1 - OUTLET SIDE - STANDING WATER ≈ 17' LT. ℄

Weather Conditions: CLOUDY, TEMP ≈ 40° NO PRECIPITATION

Site Sketch



☒ **Photographs**

Location, Description, and Reference Number

SEE DISK #1

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: 39+95
Culvert Type: CMP
Approximate Age: 1935~1937
Length: 48.0'
Diameter: 24"
Coating: GALVANIZED
General Condition: POOR
Photograph Number(s): SEE DISK
Location of Soil Samples:

Remarks/Comments: PIPE IS SEVERELY CORRODED. 1"-2" DIAMETER HOLES CORRODED THROUGH BOTTOM HALF of CULVERT. APPROXIMATELY 1" of MATERIAL IN BOTTOM of PIPE. SOME ABRASION DETERIORATION, BUT MOSTLY CORROSION DAMAGE.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☒ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation fro

SAMPLES, D2-S1-SS1 ~ SS4, WERE COLLECTED BY HAND SHOVELING

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MADISON
Location: MP 44.95

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D2-S1-SS1 /	C/A	8589.5	
☑ Soil Sample	D2-S1-SS2 /	C/A	5014.7	
☑ Soil Sample	D2-S1-SS3 /	C/A	5643.8	
☑ Soil Sample	D2-S1-SS4 /	A	15,338.5	
☑ Water Sample	D2-S1-W1			
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)

	Gravel	Sand	Silt/Clay
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments:

Boring/Excavation Log

Field Engineer: BILL GRMOLJEZ, DAN HARRINGTON
Boring/Excavation Location: MT-41, MP 44.95, STA. 39+95

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
0^{0}	ASPHALT					
0^{5}	FILL, BASE GRAVEL,		0^{5}		SS-4	A-1
?	BACKFILL, BASE GRAVEL, PIT RUN		~		SS-4	
3^{0}	EMBANKMENT FILL			$3.^{0}$	SS-4	OUTLET
	PIPE BACKFILL, BLACK SILTY CLAY NATIVE SOIL		3.0 ~		SS-1	A-6, A-7 INLET
$5.^{0}$	PIPE BACKFILL, BLACK SILTY CLAY NATIVE SOIL			$5.^{0}$	SS-3	A-6, A-7 OUTLET
6^{0}	PIPE BED, ORIGINAL GROUND, NATIVE SOIL BLACK SILTY CLAY (SATURATED)		5^{0} ~	6^{0}	SS-2	A-6, A-7 INLET

Information Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☑ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☑ B[illegible]ing log inform

Attachments

- ☑ Photographs of site
- ☐ Maps of project site
- ☑ Adequate size soil samples
- ☑ Photographs of soil sample sites
- ☑ Oth[illegible], coupons, etc)

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Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: BUTTE (D-2)

Materials Supervisor: BILL GRMOLJEZ

County: MADISON

Highway/Milepost: MT. 41/50.29

Station/Offset: 27+34

Sampling Date: (start) 5/13/00

Sampling Date: (finish) 5/13/00

Sample Location: M.P. 50.29, STOCKPASS

Project Team Members: BILL GRMOLJEZ, DAN HARRINGTON

General

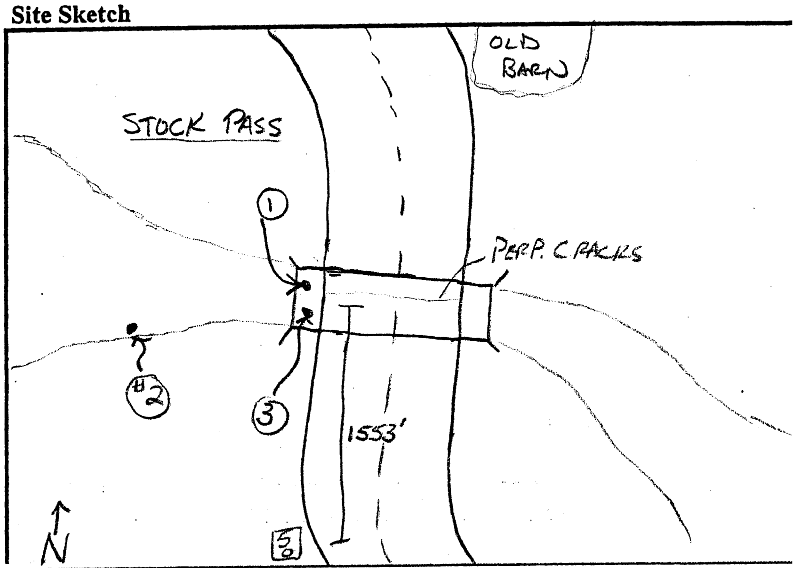
Site Description: THE PROJECT SITE WAS APPROXIMATELY 1553 ft. NORTH of MILE MARKER 50 ON MT 41 BETWEEN SILVER STAR AND TWIN BRIDGES THE STRETCH of HIGHWAY IS 2-LANES WITH MANY SMALL CULVERT SECTIONS

Sample Locations: 3 SOIL SAMPLES

- SOIL SAMPLE #1 - INLET END, BOTTOM of CULVERT ≈ 26' Lt ℄
- SOIL SAMPLE #2 - INLET END. DITCH ≈ 43' Lt ℄
- SOIL SAMPLE #3 - INLET END, BACK FILL AND EMBANKMENT. ≈ 25' Lt ℄

Weather Conditions: CLOUDY, TEMP ≈ 40° NO PRECIPITATION

Site Sketch



Location, Description, and Reference Number

☒ **Photographs** SEE DISK #2, DISK #3

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: 27+34

Culvert Type: CMP

Approximate Age: 1936 (ADD-ON 1975)

Length: 56'

Diameter: 69"x48"

Coating: GALVANIZED

General Condition: (FAIR) SLIGHTLY CORRODED

Photograph Number(s): SEE DISK

Location of Soil Samples:

Remarks/Comments: PIPE IS SLIGHTLY CORRODED. PIPE IS RUSTING ON THE OUTSIDE of THE PIPE APPROXIMATELY 10" of MATERIAL IN BOTTOM of PIPE.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☒ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation fro

SAMPLES D2-S2, SS1-SS3, WERE COLLECTED BY HAND SHOVELING.

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MADISON
Location: MP 50.29

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D2,S-2,SS-1 /	C	6826	
☑ Soil Sample	D-2,S-2,SS-2 /	C	7054	
☑ Soil Sample	D2,S-2,SS-3 /	A	13894	
☐ Soil Sample	/			
☐ Water Sample				
☐ Coupon Sample				

	Gravel	Sand	Silt/Clay
For soil samples, enter			
the estimated percent of			
material for each grain			
size. Collect a minimum			
sample size corresponding			
to the primary constituent			
(ie. gravel--9000g)			
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: D2, S-2, SS-1 SOIL SAMPLE TAKEN FROM INSIDE CULVERT.

Boring/Excavation Log

Field Engineer: BILL GRMOLJEZ, DAN HARRINGTON
Boring/Excavation Location: MT-41, MP 50.29 STA. 27+34

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
0^{0}	ASPHALT					
0^{5}	FILL, BASE GRAVEL,		0^{5}			
$1^{?9}$	EMBANKMENT FILL		2	1^{9}	SS-3	A-1 INLET
	EMBANKMENT FILL,					
6^{9}	EMBANKMENT FILL				SS-3	
6^{0}	INSIDE PIPE, NATIVE SOIL		6^{0} ~	6^{9}	SS-1	A-2 INLET
7^{3}	DITCH, NATIVE SOIL SAND SILTY GRAVELL		6^{9} ~	7^{3}	SS-2	A-1 INLET

Information Checklist

☐ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log inform

Attachments

☒ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☐ Photographs of soil sample sites
☐ Oth [illegible], coupons, etc)

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1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: BUTTE (D-2)

Materials Supervisor: BILL GRMOLJEZ

County: MEAGHER

Highway/Milepost: US 89, MP 40.09

Station/Offset: 883+01

Sampling Date: (start) 5/20/00

Sampling Date: (finish) 5/20/00

Sample Location: MP 40.09

Project Team Members: BILL GRMOLJEZ, DAN HARRINGTON

General

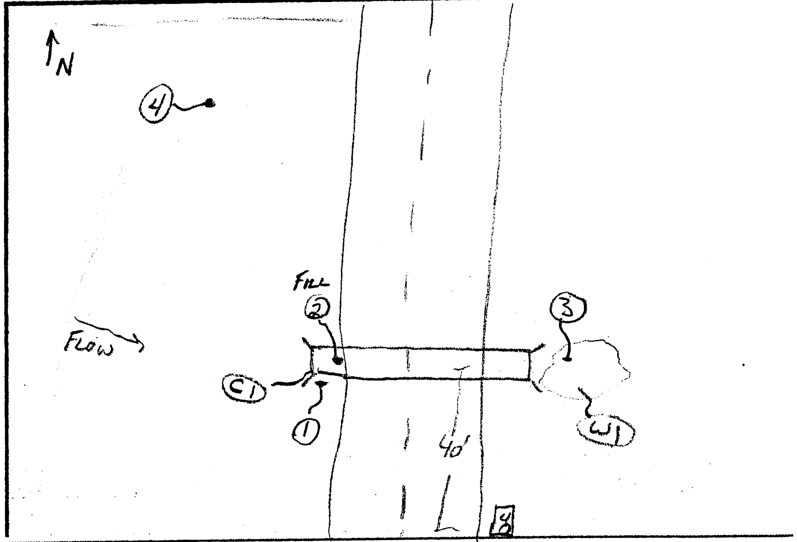
Site Description: THE PROJECT SITE WAS APPROXIMATELY 485 ft. NORTH of MILE MARKER 40 ON US 89, SOUTH of RINGLING. THE STRETCH of HIGHWAY IS 2-LANES WITH MANY SMALL CULVERT SECTIONS

Sample Locations: 4 SOIL SAMPLES, 1 WATER, 1 CULVERT

- SS-#1, INLET, PIPEBED, CORRODED CULVERT ≈ 29' Lt ℄
- SS-#2, INLET, EMBANKMENT (TOP of PIPE) ≈ 14' Lt ℄
- SS-#3, OUTLET, BOTTOM of DITCH (ORIGINAL GROUND) ≈ 33' Rt ℄
- SS-#4, INLET BANK of DITCH 50' NORTH of PIPE (ORIGINAL GROUND) ≈ 45' Lt ℄
- W-#1, OUTLET, STANDING WATER ≈ 32' Rt ℄
- C-#1, INLET, PIECE of CORRODED PIPE ≈ 28' Lt ℄
-

Weather Conditions: PARTLY CLOUDY, TEMP ≈ 50° NO PRECIPITATION.

Site Sketch



☒ **Photographs**

Location, Description, and Reference Number

SEE DISK #4

☐ **Maps**

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: 883+01

Culvert Type: CMP

Approximate Age: 1930

Length: 58'

Diameter: 18"

Coating: GALVANIZED

General Condition: POOR

Photograph Number(s): SEE DISK #4

Location of Soil Samples:

Remarks/Comments: PIPE IS SEVERELY CORRODED.

Sampling Equipment

☐ Backhoe

☐ Drill

☐ Hand Auger

☒ Shovel

☒ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation fro

SAMPLES D-2, S-1, SS1-SS-4, WERE COLLECTED BY HAND SHOVELING

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MEAGHER
Location: MP. 40.09

Materials

	Sample #		Code*	Sample Size	Photograph Reference
☑ Soil Sample	D2-S3-SS1	/	C/A	6035.8	
☑ Soil Sample	D2-S3-SS2	/	C/A	11,825.9	
☑ Soil Sample	D2-S3-SS3	/	C	5013.7	
☑ Soil Sample	D2-S3-SS4	/	C	5096.4	
☑ Water Sample	D2-S3-W1				
☑ Coupon Sample	D2-S3-C1				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments:

Boring/Excavation Log

Field Engineer: BILL GRMOLJEZ, DAN HARRINGTON
Boring/Excavation Location: US 89, MP 40.09

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
$0.^{0}$	ASPHALT					
0^{5}	BASE SURFACING GRAVEL		0^{5}	~		A-1
2^{0}	EMBANKMENT FILL			2^{0}		
?			2^{0} ~		SS-2	INLET A-2
4'	TOP OF PIPE			4'		
?			4'			TOP OF PIPE
5^{6}	BOTTOM OF PIPE			5^{6}		
5^{7}	PIPE BED, NATIVE SOIL, SILTY CLAY		5^{7}		SS-1	INLET A-7
?	NATIVE SOIL, DITCH DRAIN, CLAY		~		SS-4	A-7 INLET
6^{8}	PIPE BED, NATIVE SOIL, SILTY CLAY			6^{8}	SS-3	A-7 OUTLET

Information Checklist

☐ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☑ [illegible]ing log in[illegible]

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☑ Oth[illegible], coupons, etc)

NTL Engineering
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Statewide Corrosivity Study--Sample Log

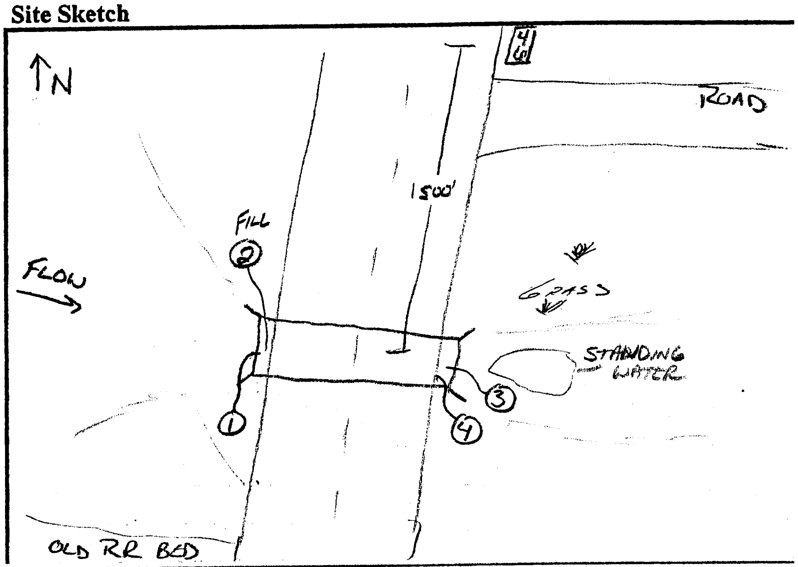
NTL Engineering Project Number 00-301

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MEAGHER
Highway/Milepost: US 89, MP 45.72
Station/Offset: 118+13
Sampling Date: (start) 5/20/00
Sampling Date: (finish) 5/20/00
Sample Location: MP 45.72
Project Team Members: BILL GRMOLJEZ, DAN HARRINGTON

General

Site Description: THE PROJECT SITE WAS APPROXIMATELY 1500' SOUTH OF MILE MARKER 46 ON US 89 JUST NORTH OF RINGLING. THE STRETCH OF HIGHWAY IS 2-LANES WITH MANY SMALL CULVERT SECTIONS.

Site Sketch



Sample Locations: 4 SOIL SAMPLES
- SS1, INLET, PIPE BED, CORRODED CULVERT ≈ 22' Lt ℄
- SS2, INLET, PIPE BACKFILL, CORRODED CULVERT ≈ 18' Lt ℄
- SS3, OUTLET, PIPE BED, CORRODED CULVERT ≈ 22' Rt ℄
- SS4, OUTLET, SURFACING MATERIAL, ≈ 19' Rt ℄

☒ Photographs

Location, Description, and Reference Number

SEE DISK #5

☐ Maps

Weather Conditions: PARTLY CLOUDY, TEMP ≈50° NO PRECIPITATION

Geology, Physiology, Topography, and Special Features/Conditions:

Culvert Inspection Report

Roadway Station: 118+13
Culvert Type: CMP
Approximate Age: 1930
Length: 44'
Diameter: 24"
Coating: GALVANIZED
General Condition: POOR
Photograph Number(s): DISK #5
Location of Soil Samples:

Remarks/Comments: PIPE IS SEVERELY CORRODED. 1/2" ~ 3" DIAMETER HOLES CORRODED THROUGH BOTTOM HALF OF CULVERT. ALL OF THE DETERIORATION WAS CAUSED BY CORROSION.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☒ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation fro

SAMPLES, D2-54-SS1~SS4, WERE COLLECTED BY HAND SHOVELING.

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BUTTE (D-2)
Materials Supervisor: BILL GRMOLJEZ
County: MEAGHER
Location: MP. 45.72

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D2-S4-SS1 /	C/A	11,075.4	
☑ Soil Sample	D2-S4-SS2 /	A	10,374.2	
☑ Soil Sample	D2-S4-SS3 /	C/A	6007.7	
☑ Soil Sample	D2-S4-SS4 /	A	14,027.0	
☐ Water Sample				
☐ Coupon Sample				

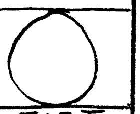
For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments:

Boring/Excavation Log

Field Engineer: BILL GRMOLJEZ
Boring/Excavation Location: US 89, MP 45.72

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
0^0	ASPHALT					
0^5	BASE, SURFACING GRAVEL, A-1 SANDY GRAVEL		0^5			
}			}		S4, SS4	A-1 OUTLET END.
2.0	FILL, EMBANKMENT, A-4 SANDY GRAVELY CLAY			2^0		
}			2^0		S4, SS2	A-4 INLET END
}			}			
4.7	TOP OF PIPE		}			
}				4.7		
}			4^7			
6.7	BOTTOM OF PIPE		}	6 7		
}	PIPE BED, NATIVE SOIL, A-7 CLAY		6^7		S4, SS3	OUTLET A-7
8.0				8^0	S4, SS1	INLET A-7

Information Checklist

☐ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☑ Boring log information

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☑ Oth[illegible], coupons, etc)

NTL Engineering
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1505 14th St SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: Great Falls

Materials Supervisor: J. Blossom

County: Teton

Highway/Milepost: I-15

Station/Offset: 303.168 ℄ 92+21

Sampling Date: (start) 07-6-00

Sampling Date: (finish) 07-6-00

Sample Location: Culvert Backfill, Backslope And inlet Drainage

Project Team Members: Kirby, Moffitt, Conwell

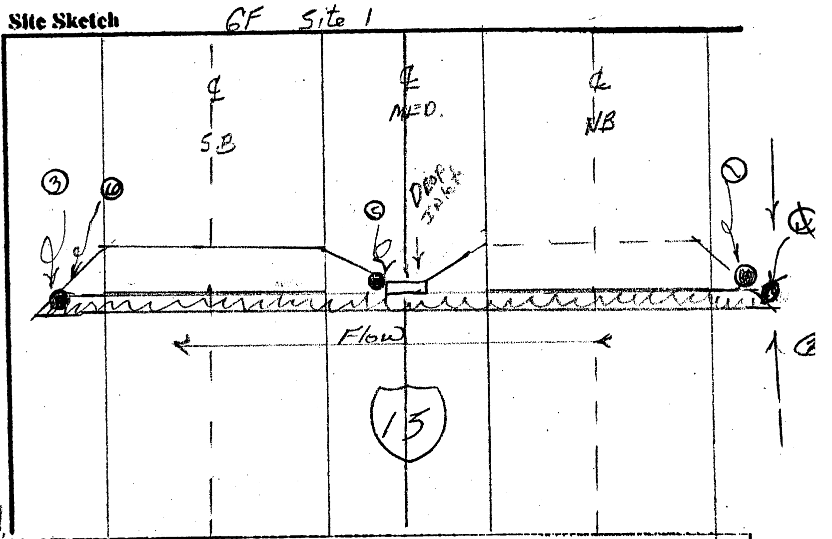
General

Site Description: The Project site is 882 ft ± North of M.P. 303 on I 15 Between Power and Dutton. This is 4 lane Interstate

Sample Locations: 5 Soil Sample, 1 Water Sample. & 1-corroded Pipe Mat'L.
Soil Sample #1 - Backfill Mat'L
Depth = 0.6' - 3.7' North side Culvert, 92.5 Rt ℄ Med.
Soil Sample #2 - Native Mat'L at 118 Rt ℄ Med.
Soil Sample #3 - Backfill mat'L - Thru. hole in Culvert.
Sample 4 - Water sample 98 Rt inlet end.
Sample 5 - Backfill mat'L 2' Lt mod. Corr.
Sample 6 - Corroded MAT'L.

Weather Conditions: Cloudy +65°

Site Sketch GF Site 1



☐ **Photographs**
Site 1 GF

☐ ~~**Maps**~~

Location, Description, and Reference Number
Gt Falls Site #1 Phot. 1 - Thru. 7
Phot. 1 & 2 - Backfill mat'L 92.5 Rt Sample #1
Phot #3 Native Mat'L and Drain Area
Phot. #4 - Backfill mat'L - Thru. Hole
Phot. #5 & 6 Sample #5 - Backfill at Mod. Corrosion.
Phot. #7 - Severely Corroded & Water Sample

Geology, Physiology, Topography, and Special Features/Conditions: Grey, Blue Clay on Cut Backslopes. Native grass Lt & Rt, with Rolling Hills.

Culvert Inspection Report

Roadway Station: 92+27 ±

Culvert Type: CMP Drain

Approximate Age: 30 year ±

Length: 200'

Diameter: 30"

Coating: Galvanize

General Condition: Poor

Photograph Number(s): GF site 1 - Phot 1-7

Location of Soil Samples: Backfill & Native Mat'L.

Remarks/Comments: Culvert corroded Severely Lt & Rt of ℄ on the Bottom ½ of Culvert. Moderate Corrosion in Center of Culvert. Holes through culvert Lt & Rt.

Sampling Equipment

☐ Backhoe
☐ Drill
☒ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation from outlined procedures) Backfill & Native Samples collected by Shovel & Hand Auger Sample #1, 2, & 5
Sample #3 Collected Through hole in culvert.

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Great Falls
Materials Supervisor: Jim Blossom
County: TETON
Location: 92+24 MP 303.168 I 15

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☒ Soil Sample	GF site 1-S1	A	—	P 1&2
☒ Soil Sample	GF site 1-S2	C	—	P 3
☒ Soil Sample	GF site 1-S3	A	-	P 4
☒ Soil Sample	GF site 1-S5	A		P 5&6
☒ Water Sample	GF site 1-S4			P 7
☒ Coupon Sample	GF site - S6			P 4

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
			100
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

- * A -Backfill sample from a corroded culvert
  B -Backfill sample from a non-corroded culvert
- C -Native soil sample near a corroded culvert
  D -Native soil sample near a non-corroded culvert

Comments: GF site 1- Sample #3 soil Taken From inside culvert

Boring/Excavation Log

Field Engineer: C Kiely
Boring/Excavation Location: 92.5' Rt 118' Rt, 7.0 Lt

Depth	ASTM Visual Classification and Description		Sample Depth from	Sample Depth to	Sample Number	Remarks
	Topsoil & Organic Mat'L		0	0.6		GF site #1
2.0'	Backfill mat'L Northside Culvert Clay 92.5 Rt		0.6	3.7	1	
	moisture sample seperate					
	Topsoil & Organic Mat'L		0	0.6		
1.5	Native Mat'L (Clay) 118' Rt		0.6	-2.0	2	
	moisture sample seperate					
	Backfill Mat'L. From inside Culvert (Clay)	22.1	—	—	3	
	98' Rt					
	Topsoil & Organic Mat'L 7.0' Lt		0	0.6		
2.0	Backfill mat'L from Moderate Corrosive Area		0.6	2.5'	4	
	moisture sample seperate					

Information Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log information

Attachments

- ☒ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☒ Photographs of soil sample sites
- ☒ Other samples ([✓ water], [✓ coupons], etc)

NTL Engineering
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Statewide Corrosivity Study--Sample Log

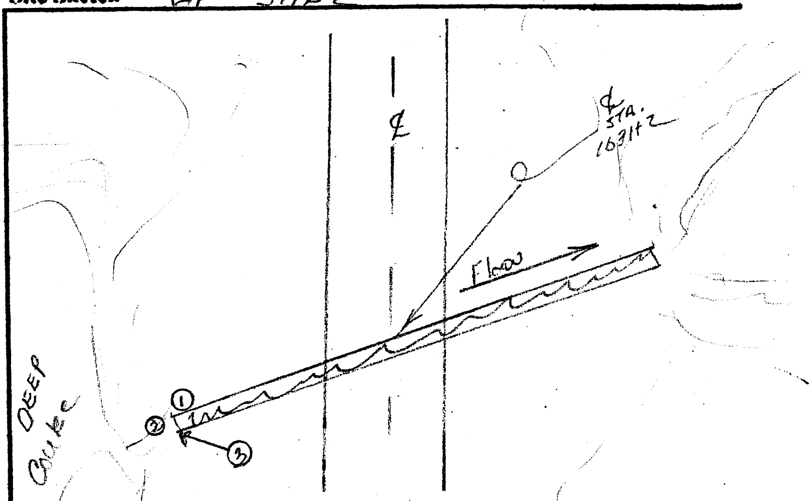
NTL Engineering Project Number 00-301

MDT Materials District: Great Falls
Materials Supervisor: J. Blossom
County: Chouteau
Highway/Milepost: 34.224
Station/Offset: 1031+20
Sampling Date: (start) 7-6-00
Sampling Date: (finish) 7-6-00
Sample Location: Culvert Backfill, upslope Drainage
Project Team Members: Kirby, Moffitt, Conwell

General

Site Description: Project site 2 is at MP. 34.224, sta 1031+20 on 2 Lane Highway Route 228 between Highwood & Fort Benton.

Site Sketch GF SITE 2



Sample Locations: 2 Soil Samples - 1-water sample.
Soil Sample #1 - Backfill mat' from north side
Soil Sample #2 Native mat'L from inlet side

WATER Sample from inlet End of Culvert, (91' Lt)

Weather Conditions: MY Cloudy & +75°

☒ **Photographs**

☒ ~~**Maps**~~

Location, Description, and Reference Number
GtFalls Site #2 Phot. 1 - Thru. 6
Phot #1 Backfill Mat'L - Sample #1
Phot #2 - Native Mat'L Sample #2
Phot - 3 - inlet End of Culvert
Phot 4,5 & 6 inlet Drainage

Geology, Physiology, Topography, and Special Features/Conditions: Culvert is Placed in wet area in Deep Coulee to inlet side, with cultivated Farm Areas Lt & Rt. Day Before Sampling, Rain storm went Through area. Culvert has about 36" Cover Mat'L. Culvert in Good Shape.

Culvert Inspection Report

Roadway Station: 1031+20
Culvert Type: CMP Drain
Approximate Age: 10 years+
Length: 194'
Diameter: 36"
Coating: Epoxy
General Condition: Very Good
Photograph Number(s): Great Falls site #2 1-
Location of Soil Samples: Backfill mat'L 88' Lt & Native Mat'L 91' Lt
Remarks/Comments: culvert is in very good shape through-out.

Sampling Equipment

☐ Backhoe
☐ Drill
☒ Hand Auger
☒ Shovel
☐ Other

***Include Details of Sampling Equipment and Procedures/Methods of Sample Collection** (particularly any deviation from outlined procedures)*: Backfill samples & Native samples collected with Hand Auger & Shovel.

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Great Falls
Materials Supervisor: J. Blosson
County: Chouteau
Location: mp 34.224 sec 228
℄ sta 1031+20

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	GF Site2-S1	B		PHot 1
☑ Soil Sample	GF Site2-S2	D		
☐ Soil Sample				
☐ Soil Sample				
☑ Water Sample	GF Site2-S3			
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

- * A -Backfill sample from a corroded culvert
- B -Backfill sample from a non-corroded culvert
- C -Native soil sample near a corroded culvert
- D -Native soil sample near a non-corroded culvert

Comments: GF Site #2 is in Good shape

Boring/Excavation Log

Field Engineer: C. Kiely
Boring/Excavation Location: 88' Lt ℄ 102 Lt

Depth	ASTM Visual Classification and Description	Sample Depth from	Sample Depth to	Sample Number	Remarks
0	Topsoil & Organic Mat'L	0	0.5		Site #2
2.0	Backfill Mat'L. 88' Lt ℄	0.5	3.5	1	
	moisture sample seperate				
0	Topsoil & Organic Mat'L.	0	0.5		
1.5	Native Mat'L. 102' Lt ℄	0.5	2.0	2	
	moisture sample seperate.				

Information Checklist

- ☐ Sampling site location and description (geology, topography, etc.)
- ☐ Sampling equipment information/sampling methods
- ☐ Sampling methods
- ☐ Sampling material information
- ☐ Boring log information

Attachments

- ☒ Photographs of site
- ☐ Maps of project site
- ☐ Adequate size soil samples
- ☒ Photographs of soil sample sites
- ☒ Other samples([✓ water] coupons, etc)

NTL Engineering
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Statewide Corrosivity Study--Sample Log

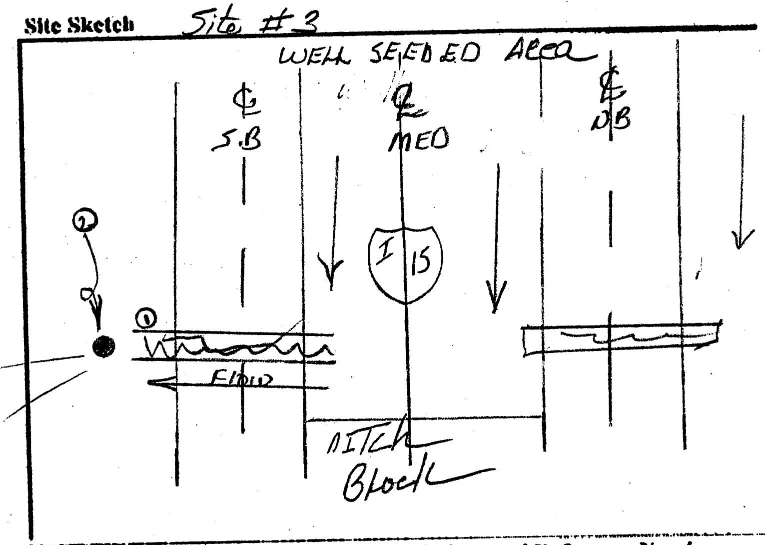
NTL Engineering Project Number 00-301

MDT Materials District: Great Falls
Materials Supervisor: J Blossom
County: Teton
Highway/Milepost: 301.41
Station/Offset: 2+74
Sampling Date: (start) 7-7-00
Sampling Date: (finish) 7-7-00
Sample Location: Culveet Backfill & down slope Drainage
Project Team Members: Kleby, Moffitt, Caswell

General

Site Description: The Project site #3 is on I 15 M.P. 301.41 South Bound Lane; Between Vaughn & Power

Site Sketch Site #3



Sample Locations: 2 Soil Sample - No Water sample
Soil Sample #1- Backfill Mat'L on Northside culvert

Soil Sample #2 Mat'L inside Culvert.

Weather Conditions: Ptly Cloudy +75°

☐ **Photographs**

~~☒ Maps~~

Location, Description, and Reference Number
Great Fall site #3
Phot #1 Sample #1 Back Fil Mat'L- & Sample #2- Mat'L inside culvert
Phot #2- Drainage area

Geology, Physiology, Topography, and Special Features/Conditions: Cultivated Faem Lt & Rt of Area - Reall Level Area. About 0.2' mat'L in Culvert

Culvert Inspection Report

Roadway Station: 2+74
Culvert Type: CMP Drain
Approximate Age: 30 years ±
Length: 75'
Diameter: 24"
Coating: Galvanise
General Condition: Good
Photograph Number(s): Great Falls site 3 1&2
Location of Soil Samples: Backfill mat'L & 40' Rt
Mat'L inside Pipe 39' ℄

Remarks/Comments:

Sampling Equipment

☐ Backhoe
☐ Drill
☒ Hand Auger
☒ Shovel
☒ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation from outlined procedures) Both Samples with Hand Auger & Shovel,

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Great Falls
Materials Supervisor: J. Blossom

County: Teton
Location: MP: 301.41 I-15
Site 2174

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	GF Site3 S-1		B	
☑ Soil Sample	GF Site 3 S-2		B (inside Pipe)	
☐ Soil Sample				
☐ Soil Sample				
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (Ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

- A -Backfill sample from a corroded culvert
  B -Backfill sample from a non-corroded culvert

C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Sample From outlet side, and sample #2 From inside Culvert

Boring/Excavation Log

Field Engineer: C. Kirby

Boring/Excavation Location: Backfill 40'Rt inside pipe at 39'Rt

Depth	ASTM Visual Classification and Description		Sample Depth from	Sample Depth to	Sample Number	Remarks
0	Topsoil & Organic Mat'L		0	0.5		Site #3
1.5	Backfill Mat'L alone side North Side culvert 40' Rt (moisture sample seperate)		0.5	2.0'	1	
—	Mat'L inside Culvert on outlet End at 39' Rt (Moisture sample seperate)		Flowline		2	

Information Checklist

☐ Sampling site location and description (geology, topography, etc.)
☐ Sampling equipment information/sampling methods
☐ Sampling methods
☐ Sampling material information
☐ Boring log information

Attachments

☒ Photographs of site
☐ Maps of project site
☐ Adequate size soil samples
☒ Photographs of soil sample sites
☐ Other samples (water, coupons, etc)

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Statewide Corrosivity Study--Sample Log

HUD-PLD-STPS 323-1(NP)21
Project # 34 km S of Ekalaka-S

NTL Engineering Project Number 00-301

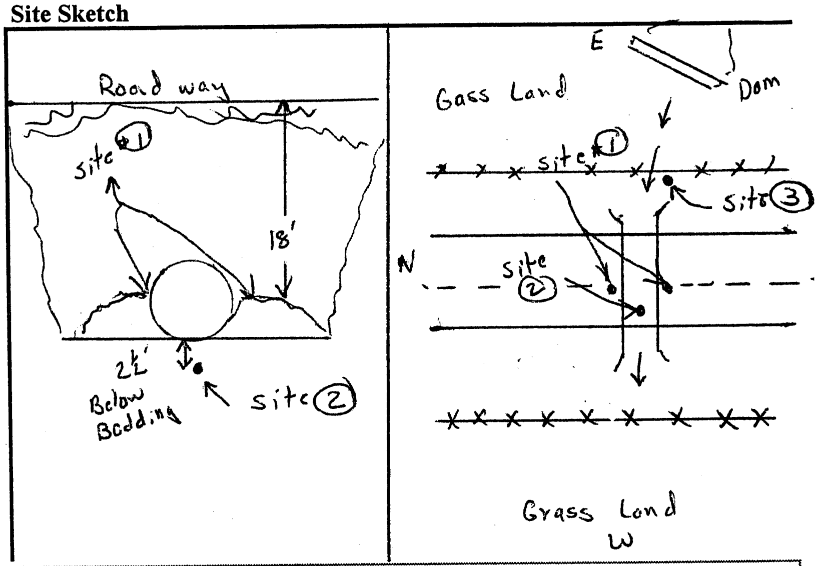
MDT Materials District: Glendive
Materials Supervisor: R. Warner
County: Carter
Highway/Milepost: — MT 323
Station/Offset: 793+39.44 Metric
Sampling Date: (start) 4-24-00
Sampling Date: (finish) 4-24-00
Sample Location: Below Culvert / side of Culvert Drainage
Project Team Members: R. Warner, A. Goroski

General

Site Description: This project site is Apx 21 miles South of Ekalaka on Highway 323, There are no mile markers on this project. This project is a complete reconstruct remove old culverts and replace with Concrete pipe. The highway is a two lane with several culvert Locations see attached culvert inspection report.

Sample Locations: 3 Sample Locations
Sample #1 Taken from 18' deep cut 2½' below pipe ~~back f~~. bedding. 26' Lt of ℄
Sample #2 taken Next to Culvert both Left and right sides. 26' Lt of ℄
Sample #3 taken upstream on drainage 130' Rt of ℄ 1'-2' Below top soil.

Site Sketch



☑ **Photographs**

Location, Description, and Reference Number
Glen-Site 1-3 Samples taken
4-5 Road Way and general area

☐ **Maps**

Weather Conditions: Partly Cloudy 45° slight Mist.

Geology, Physiology, Topography, and Special Features/Conditions: The general area is fatty clay with some silty Clayey possible touch of Benin'nt mixed in. The srounding area is Native grass land used for grazing. There is a small dam on the upstream side. The land is mostly flat some small hills

Culvert Inspection Report

Roadway Station: 793+39.44
Culvert Type: CSP
Approximate Age: 23 + years
Length: 53.6 m
Diameter: 1219
Coating: galvanized
General Condition: Poor
Photograph Number(s): Site 1 - 1-5
Location of Soil Samples: Bacfill, Below Bedding Native

Remarks/Comments: Corrosion on sidewalls starting appx. 3.0 m in and going for 3.0 m on both ends. erosion at outlet end of pipe

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☑ Other Scoop

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation from outlined procedures) All Samples take with Shovl. & Scoop

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Glendive
Materials Supervisor: R. Warner
County: Carter
Location: Highway 323

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D-4-S1-S1 /	A	19#	P1
☑ Soil Sample	D4-S1-S2 /	A	21#	P2-3-4
☑ Soil Sample	D-4-S1S3 /	C	15#	P5
☐ Soil Sample	/			
☐ Water Sample				
☑ Coupon Sample	D-4-S1			

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Contractor Had dug this culvert out and will replace with concrete Pipe Moisture Samples done at Glendive Dist Lab (see attached) Moisture Report.

Boring/Excavation Log

Field Engineer:
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
	No Boring done at this site					
	contractor dug out.					

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☐ Boring log information

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☑ Other samples (water, [✓ coupons], etc)

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Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

NH 1-9(26)573 PE
Oswego East & West

MDT Materials District: Glendive D-4
Materials Supervisor: R. Warner
County: VALLEY
Highway/Milepost: MT 2 MP 580.7
Station/Offset: 1308+38
Sampling Date: (start) 5-26-00
Sampling Date: (finish) 5-26-00
Sample Location: Inside Culvert, Outside Back, Drainage
Project Team Members: R. Warner D. Brownlee

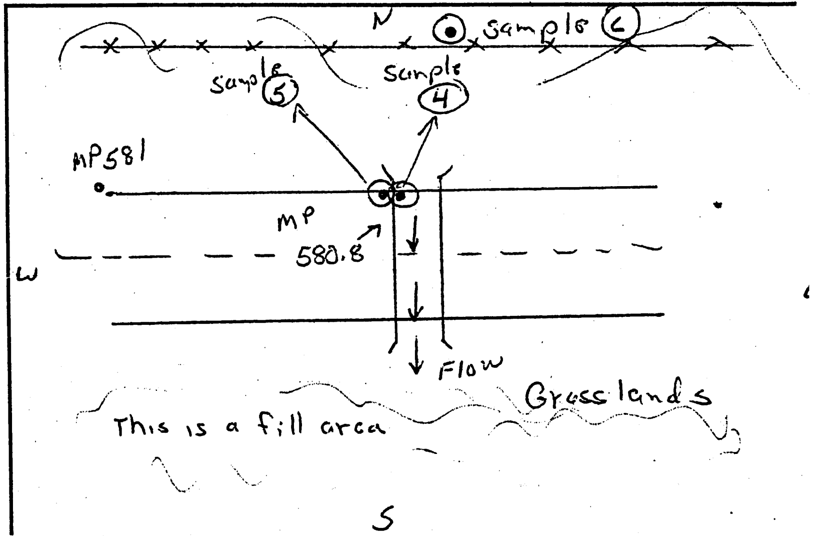
General

Site Description: This Project site is on Highway 2 in the North portion of District. The site is apx at MP 580.7 2 mile West of Oswego. The highway is a 2 Lane road with rollign Hills to the North ad Grosslands to South. It is Fhirly Flat. This area has quiet a few culverts. See Attached Culvert Inspection report.

Sample Locations: 3 sample Locations
Sample ④: Taken Through Hole in culvert apxx 2' in on the North end at west side of culvert. 27' Lt ℄.
Sample ⑤ Taken outside culvert 27' Lt ℄, 1½' Below top soil.
Sample ⑥ Taken 100' Lt of ℄ upstream ½' To 2.0' Below topsoil.

Weather Conditions: 70° Windy Partly cloudy.

Site Sketch



☑ Photographs
☐ Maps

Location, Description, and Reference Number
Site ~~8~~: ⑥ Hole in Pipe ⑦ North end of Pipe. ⑧ Looking up drainage ⑨ West bound Lookin west Top of Road ⑩ Looking south of Drainage ⑪ North end of culvert. ⑫ Looking East Roadway.

Geology, Physiology, Topography, and Special Features/Conditions: The general area is Fatty clayey The surrounding area is Native grass land used for grazing. the rolling hills to North are bare of vegetation because of the heavy clay area.

Culvert Inspection Report

Roadway Station: 1308+38
Culvert Type: CMP
Approximate Age: 30+ years
Length: 74'
Diameter: 30"
Coating: galvanized
General Condition: Poor
Photograph Number(s): 6-12
Location of Soil Samples: Hole in Culvert outside N. End, 100' up Dr
Remarks/Comments: This culvert is Rusted out Througout.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☑ Other
Scoop

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection ***(particularly any deviation from outlined procedures)*** All Samples taken with Shovel & Scoop.

MAY 09 2000

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Glendive
Materials Supervisor: R. Warner
County: Valley
Location: Highway 2

Materials

	Sample Id. #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D-4 - S 2-S4/	A	10#	
☑ Soil Sample	D-4- S 2-S5/	A	7#	
☑ Soil Sample	D4 - S2-S6/	C	19#	
☐ Soil Sample	/			
☐ Water Sample				
☑ Coupon Sample	D4-S2			

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Moisture ran in the District Lab (see attached)

Boring/Excavation Log

Field Engineer:
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
	No Boring done at this site					
	Sample done with Shovel and Scoop					

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☐ Boring log information

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☐ Other samples (water, coupons, etc)

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Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

Im 94-5(29)170 PE
Powder River-East

MDT Materials District: Glendive
Materials Supervisor: R. Warner
County: Prairie
Highway/Milepost: I94, MP 174.8
Station/Offset: 421+61.46 M
Sampling Date: (start) 5-4-00
Sampling Date: (finish) 5-4-00
Sample Location: In Culvert, Outside edge Drainage
Project Team Members: R. Warner M. Stroh

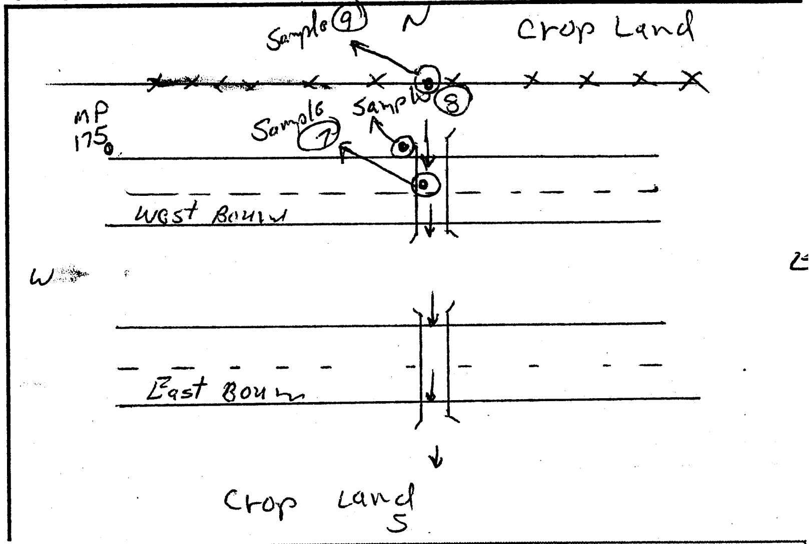
General

Site Description: This Project site is on I 94 Apx 1 mile West of Terry at station 421+61.46. This is a 4 Lane Interstat Highway Samples were taken on the West bound Lanes. There are crop Land both North and South of Roadway. There is irrigation ditche in general area. There are numerous culverts in this area see Culvert report.

Sample Locations: 3 sample Locations
Sample 7 Taken through hole in culvert
Sample 8 Taken on West side, North end inlet end.
Sample 9 taken 10.5 M North of Culvert Inlet end. 1½-2' Below top soil.

Weather Conditions: 75° Clear and sunny

Site Sketch



☑ Photographs
☐ Maps

Location, Description, and Reference Number
Site 3: Photo 1,2 Hole in culvert
P3 Facing N end of culvert
P4 edge of Road Facing N showing Drainage
P5 on shoulder facing South showing E W Bound Lanes

Geology, Physiology, Topography, and Special Features/Conditions: The general area is silty materal The surounding area is mostly crop Land irrigated, Flat on the most part.

Culvert Inspection Report

Roadway Station: 421+61.46 m
Culvert Type: CSAP
Approximate Age: ?
Length: 24.4 m
Diameter: 1092 S x 686 R mm
Coating: galvinazed
General Condition: WB POOR
Photograph Number(s): 1-6
Location of Soil Samples: Hole in Culvert North End, West side int · Drainage
Remarks/Comments: See Culvert inspection report.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☑ Other scoop

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation from [illegible]edure

Shovel, Scoop, Post hole digger.

MAY 09 2000

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Glendive
Materials Supervisor: R. Warner
County: Prairie
Location: I94

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D4-S3-S7 /	A	14#	1,2
☑ Soil Sample	D4-S3-S8 /	A	13#	3,4
☑ Soil Sample	D4-S3-S9 /	C	13#	3,5
☐ Soil Sample	/			
☐ Water Sample				
☑ Coupon Sample	D4-63			

	Gravel	Sand	Silt/Clay
For soil samples, enter			
the estimated percent of			100
material for each grain			100
size. Collect a minimum			100
sample size corresponding			
to the primary constituent			
(ie. gravel--9000g)			
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Moisture ran in District lab Glendive (see attached)

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
	No Boring done at this					
	site Samples taken with					
	shovel & Scoop					

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☐ Boring log information

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☐ O[illegible] (water, coupons

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1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

IM94-5(29)170 PE
Powder River - East

MDT Materials District: Glendive D4
Materials Supervisor: R. Warner
County: Prairie
Highway/Milepost:
Station/Offset: 556+29.66
Sampling Date: (start) 5-4-00
Sampling Date: (finish) 5-4-00
Sample Location: In Culvert outside edge Drainage
Project Team Members: R. Warner, M. Stroh

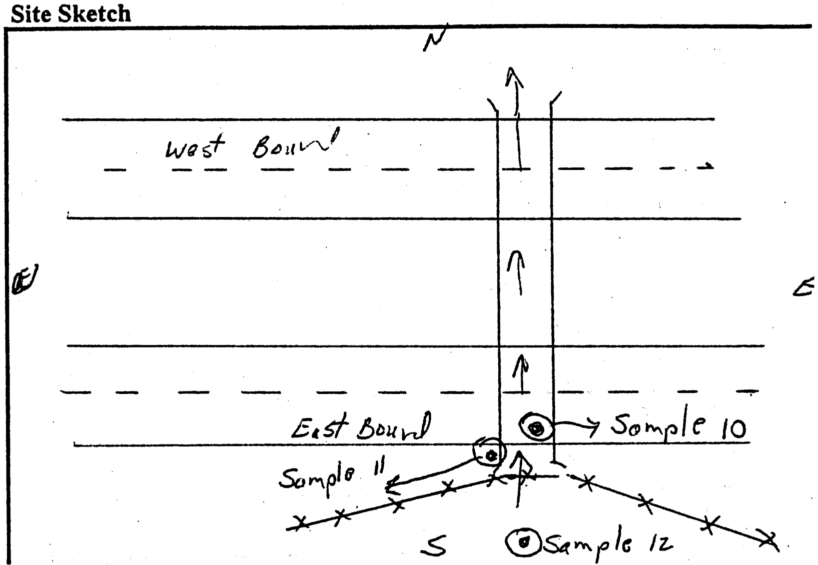
General

Site Description: This Project site is on I94 Between Fallon & Terry at station 556+26.66. This is a 4 Lane interstate. The samples were taken on The East Bound Lane. On the North side is crop land and on the South is Hills, and Railroad. Very Steep drainage at this area.
This Location is a deep Fill area 20'-25'

Sample Locations: 3 samples Locations
Sample 10, 10A, 10B, Taken through Hole in culvert.
Sample 11, Taken outside south end, inlet end of culvert upper left side,
Sample 12, Taken up the drainage 30'.
1 wtr. sample was Taken at this Location
1 Cupon was also taken

Weather Conditions: Sunny and warm 75°.

Site Sketch



☑ **Photographs**
☐ **Maps**

Location, Description, and Reference Number
Photo #1 - Shows hole in Culvert in Bottom where Sample 10 was secured
Photo #2 Facing N The inlet end 10' out.
Photo #3 Facing South Looking up Stre

Geology, Physiology, Topography, and Special Features/Conditions:
The area to the south (inlet end) is big hills with Steep cuts and valleys real rough traina. There is a railroad track running parrelle to the highway The North side is crop land dropping off Into the Yellowstone River.

Culvert Inspection Report

Roadway Station: 556+29.66
Culvert Type: CSP
Approximate Age: ?
Length: 86.0 m
Diameter: 1524 mm
Coating: galvinazed
General Condition: Poor
Photograph Number(s): 6, 7, 8,
Location of Soil Samples: Hole in Culvert outside edge Drainage
Remarks/Comments: See Culvert inspecton Report.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☑ Other
Scoop

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection *(particularly any deviation f... ined ... ures* Shovel, Scoop, Post hole digger

MAY 0 9 2000

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: Glendive D4
Materials Supervisor: R. Warner

County: Prairie
Location: I 94

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	D4-S4-S10 /	A	56 lbs	
☑ Soil Sample	D4-S4-S11 /	A	10.5 lbs	
☐ Soil Sample	D4-S4-S12 /	C	29 lbs	
☐ Soil Sample	/			
☑ Water Sample	D4-S4- S1			
☑ 1 Coupon Sample	D4-S4-S1			

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	100		
			100
	100		
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: Moisture ran in District Lab (see attached)

Boring/Excavation Log

Field Engineer:

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description		Sample Depth from	to	Sample Number	Remarks
	No Borings done at this					
	site.					
	Samples taken with Shovel					
	Post hole digger and scoop.					

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☐ [illegible]oring l[illegible] form[illegible]

Attachments

☑ Photographs of site
☐ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☐ (Other [illegible] c[illegible]s, etc)

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

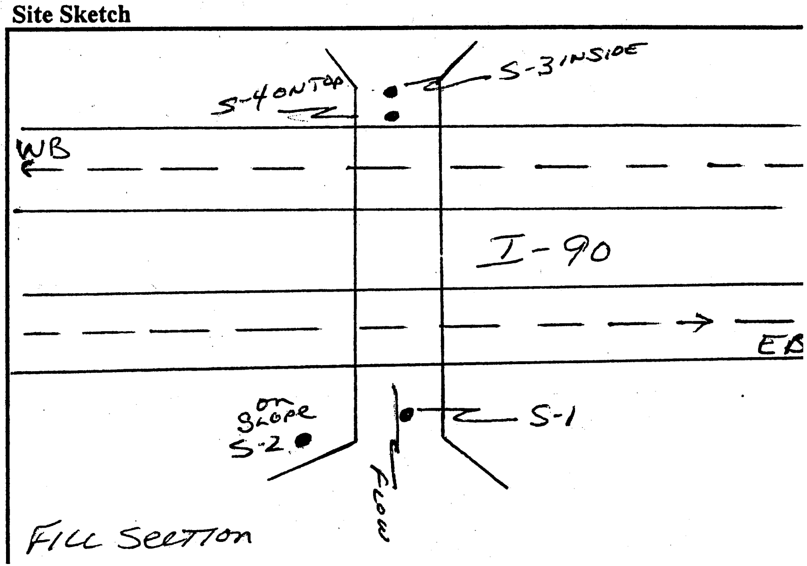
NTL Engineering Project Number 00-301

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: YELLOWSTONE
Highway/Milepost: I 90
Station/Offset: 1531+03
Sampling Date: (start) 4-27-00
Sampling Date: (finish) 4-27-00
Sample Location: DRAINAGE UPSLOPE BACKFILL
Project Team Members: J. JOHNSON B. HENNING

General

Site Description: SITE 1 ON I-90 BETWEEN BILLINGS + HARDIN AT MP 485.54 STA. 1531+03 4 LANE INTER STATE

Site Sketch



FILL SECTION

Sample Locations: 4 SAMPLES
S-1 OUTLET - SOIL FROM SLIGHTLY CORRODED CULVERT.
S-2 SOIL ON FILLSLOPE NEXT TO CULVERT
S-3 BOTTOM OF CULVERT INLET
S-4 FILL ON TOP OF PIPE

Weather Conditions:

Location, Description, and Reference Number

☑ Photographs BLG SITE 1 P-1 THROUGH P-8 SEE COMMENTS

☒ Maps 1-IG 90-9(26) 471 AS BUILTS

Geology, Physiology, Topography, and Special Features/Conditions: GENERALLY FLAT WITH ROLLING HILLS

Culvert Inspection Report

Roadway Station: 1531+03
Length: 222'
General Condition: GOOD
Culvert Type: SSPPA 12ga
Diameter: 10'8" x 6'11"
Photograph Number(s): P1 - P8
Approximate Age: INSTALL 72 28yr.
Coating: BLACK MASTIC ACROSS BOTTOM
Location of Soil Samples: INLET NATIVE BACKFILL

Remarks/Comments: PIPE HAS CORRODED BOLTS SEE P-5 MASTIC ON INSIDE BOTTOM + 2' UP SIDES. 4" MATERIAL THROUGHOUT BOTTOM. COULD NOT WALK THRU PIPE - WET/MUCKY 50' IN.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation fr rocedu

ALL HAND SHOVEL

MAY 03 2000

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: YELLOWSTONE
Location: I-90

Materials

	Sampl #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	BlgSITE1 S-1		7000	P-1
☑ Soil Sample	BLGSITE1 S-2		5000	P-4
☑ Soil Sample	BLGSITE1 S-3		6500	P-5
☑ Soil Sample	BlgSITE1 S-4		5700	P-8
☐ Water Sample				
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	0	20	80
	0	20	80
	20	20	60
	0	10	90
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: B1 SITE1 S-1, S-3 TAKEN FROM INSIDE CULVERT

Boring/Excavation Log

Field Engineer: J. JOHNSON

Boring/Excavation Location: 110'+/- RT CL 110'+/- LT CL

Depth	ASTM Visual Classification and Description	MOIST	Sample Depth from	to	Sample Number	Remarks
.25	SAND/SILTY SOIL OUTLET INSIDE CULVERT	3.2	0	.25	S-1	
.75	SANDY SOILS NEAR CULVERT	13.0	.50	.75	S-2	
.25	GRAVELLY SOIL INLET INSIDE CULVERT BOTTOM	10.4	0	.25	S-3	
.75	SOIL - SILTY CLAY ON TOP CULVERT	14.0	.50	.75	S-4	

Information Checklist

- ☑ Sampling site location and description (geology, topography, etc.)
- ☑ Sampling equipment information/sampling methods
- ☑ Sampling methods
- ☑ Sampling material information
- ☑ Boring log information

Attachments

- ☑ Photographs of site
- ☑ Maps of project site
- ☑ Adequate size soil samples
- ☑ Photographs of soil sample sites
- ☐ none s (water, coupon, etc)

NTL Engineering
& Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: PETROLEUM
Highway/Milepost: MT200/MP147.95
Station/Offset: 567+75M
Sampling Date: (start) 5-19-00
Sampling Date: (finish) 5-19-00
Sample Location: DRAINAGE/BACKFILL
Project Team Members: J. JOHNSON DMS, G. NESSAN LS2

General

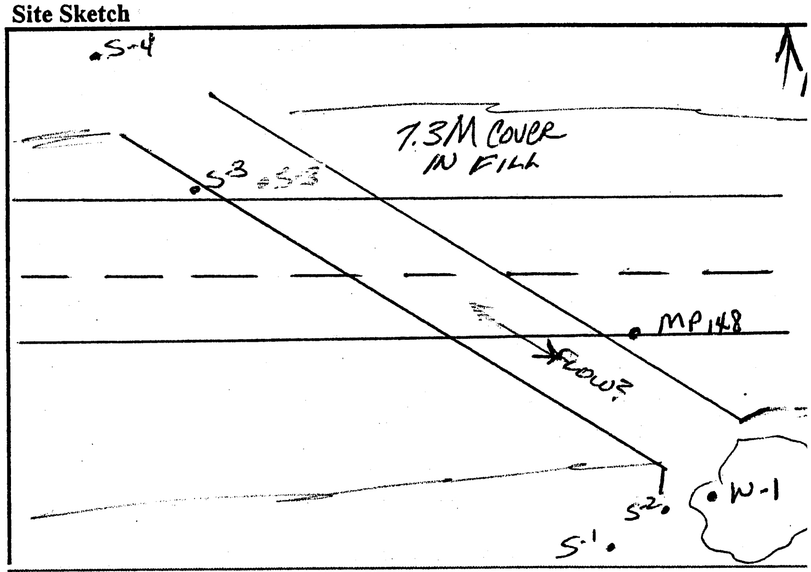
Site Description: PROJECT SITE IS ON MT 200(P57) AT MP 147.95 10+/- MI. E. OF WINNETT. STA 567.75 M

PIPE IS SCHEDULED FOR REPLACEMENT ON PROJECT NH57-4(10)148 LETTING JUNE 2000.

Sample Locations: S-1 OUTLET SO. END DRAINAGE -2', 10' LT. PIPE. S-2 OUTLET DRAINAGE -4', 5' LT. PIPE. W-1 OUTLET FROM PONDED SOURCE. S-3 BACKFILL, TOP OF PIPE INLET END (NORTH) S-4 DRAINAGE - INLET END 25' OUT.

Weather Conditions: PARTLY CLOUDY 70° WINDY.

Site Sketch



☑ **Photographs**

☐ **Maps**

Location, Description, and Reference Number

P1-P9 SAMPLE SITES DRAINAGE INTERIOR, BACKFILL, SEVERE CORROSION - SEE COMMENTS

Geology, Physiology, Topography, and Special Features/Conditions: GENERALLY FLAT/ROLLING WITH DEEP FILL SECTIONS. NATIVE GRASS - VERY DRY.

Culvert Inspection Report

Roadway Station: 567+75.1
Culvert Type: SSPPC
Approximate Age: 1954 = 46 yr.
Length: 50 m
Diameter: 3505 mm (138")
Coating: GALVANIZED
General Condition: POOR
Photograph Number(s): Blg Site 2 P1-P9
Location of Soil Samples: INLET DRAINAGE BACKFILL, OUTLET DRAINAGE

Remarks/Comments: PIPE IS CORRODED, HOLES IN AN AREA MID TO UPPER ON ONE SIDE - RUSTED 4' ACROSS BOTTOM - STANDING WATER 2/3 THROUGH. ALKALI SOILS SURROUNDING AREA. 7.32 m COVER

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☑ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (*particularly any deviation* rom [illegible] pr

SAMPLES ALL COLLECTED W/SHOVEL

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: PETROLEUM
Location: MT 200 MP 147.95

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	BlgSITE2S-1	C	3500g	P-1
☑ Soil Sample	BlgSITE2S-2	C	2500g	P-2
☑ Soil Sample	BlgSITE2S-3	A	6500g	P-5
☑ Soil Sample	BlgSITE2S4	C	3400g	P-9
☑ Water Sample	W-1		Qt.	P-3
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
			100
			100
	2	3	95
			100
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: W-1 WATER TAKEN FROM STANDING WATER

Boring/Excavation Log

Field Engineer: J. JOHNSON
Boring/Excavation Location:

Depth	ASTM Visual Classification and Description	MOIST CONT	Sample Depth from	to	Sample Number	Remarks
0.5'	NATIVE SOIL SPONGY VERY WET	31.4	0.5'	0.75'	BlSITE2S-1	
0.5	DRAINAGE SOIL Spongy very wet	29.8	0.5'	0.75'	BlgSITE2S-2	
0.5	BACKFILL - SILTY Some AGG. DAMP	10.0	0.5	0.70'	BlgSITE2S-3	
0.5	DRAINAGE - SPONGY DENSE WET SILT	43.4	0.5	0.75'	BlgSITE2S-4	

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☑ Boring log information

Attachments

☑ Photographs of site
☑ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☑ Other samples (water, coupons, etc.)

Statewide Corrosivity Study--Sample Log

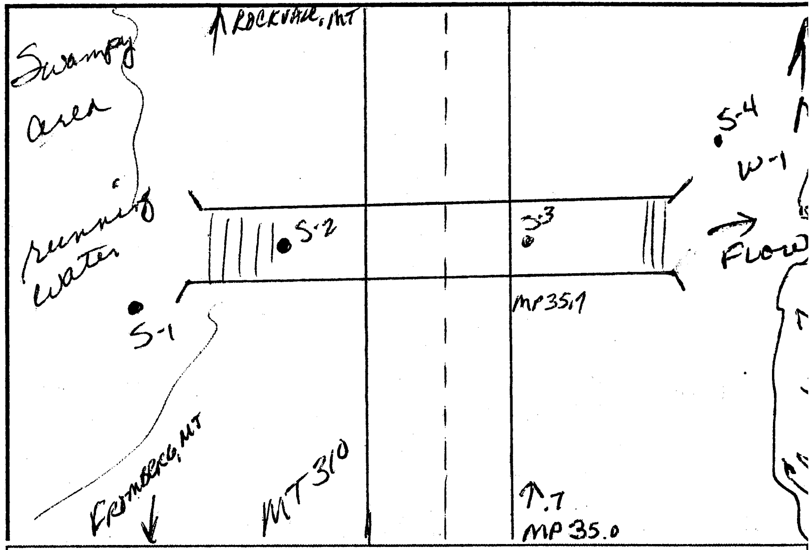
NTL Engineering Project Number 00-301

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: CARBON
Highway/Milepost: 310 / 35.7
Station/Offset: 474+86
Sampling Date: (start) 5-24-00
Sampling Date: (finish) 5-24-00
Sample Location: DRAINAGE/BACKFILL
Project Team Members: J. JOHNSON DMS, B. HENNING LS2

General

Site Description: HWY 310 BETWEEN FROMBERG + ROCKVALE, MT. GENERALLY FLAT - LOW LYING WITH SWAMPY AREAS RT + LT ℄ THROUGHOUT. PIPE IS AT MILEPOST 35.7 STA 474+86 ON NH4-1(14)34 P.E. FROMBERG-ROCKVALE.

Site Sketch



Sample Locations: S-1 NATURAL SOIL NEAR INLET - CORRODED PIPE.
S-2 BACKFILL TOP OF INLET - LT. CL.
S-3 BACKFILL TOP OF OUTLET RT. CL
S-4 DRAINAGE OUTLET RT. CL.

☑ **Photographs**

Location, Description, and Reference Number

GENERAL SITE P8-P10
SAMPLES / PIPE CONDITION
SEE COMMENTS

☐ **Maps**

Weather Conditions: PARTLY CLOUDY 65°F LT. WIND

Geology, Physiology, Topography, and Special Features/Conditions: GENERALLY FLAT W/ LOW LYING AREAS OF SWAMP RT + LT CL.

Culvert Inspection Report

Roadway Station: 474+86
Culvert Type: CSP
Approximate Age: 32 yrs.
Length: 116
Diameter: 72"
Coating: GALVANIZED
General Condition: FAIR
Photograph Number(s): P-1 THRU P-10
Location of Soil Samples: NATIVE DRAINAGE BACKFILL

Remarks/Comments:

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation from ou

ALL SHOVEL SAMPLES

RECEIVED
JUN 01 2000

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: CARBON
Location: Hwy 310 P-4 P-4
MP 35.7

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	Big Site3 S-1 /	C	4000g	P-1
☑ Soil Sample	Big Site3 S-2 /	A	6200g	P-3
☑ Soil Sample	Big Site3 S-3 /	A	6650g	P-4
☑ Soil Sample	Big Site3 S-4 /	C	6000g	P-5
☑ Water Sample	W-1		1gal	
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
		15	85
	15	15	70
	20	40	40
	10	90	
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments:

Boring/Excavation Log

Field Engineer: JANET JOHNSON

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description	MOIST CONT	Sample Depth from	to	Sample Number	Remarks
0.5	DARK SANDY SOIL - DENSE - MOIST DRAINAGE	29.4	0.5	1.0	SITE 3 S-1	
0.5	BACKFILL CLAYEY SAND W/GRAVEL	9.9	0.5	1.0	SITE 3 S-2	
0.5	BACKFILL CLAYEY SAND W/GRAVEL DRY	3.0	0.5	1.0	SITE 3 S-3	
0.5	DRAINAGE GRAVELLY SAND - WET GRANULAR	29.4	0.5	1.0	SITE 3 S-4	

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☑ Boring log information

Attachments

☑ Photographs of site
☑ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☑ (Other samples (water, coupons, etc)

NTL Engineering & Geoscience

1505 14th St. SW, Great Falls, MT 49403-3269

Statewide Corrosivity Study--Sample Log

NTL Engineering Project Number 00-301

MDT Materials District: BILLINGS

Materials Supervisor: J. JOHNSON

County: CARBON

Highway/Milepost: 78 / 19.8 +/-

Station/Offset: 1053+24 ℄

Sampling Date: (start) 6-1-00

Sampling Date: (finish) 6-1-00

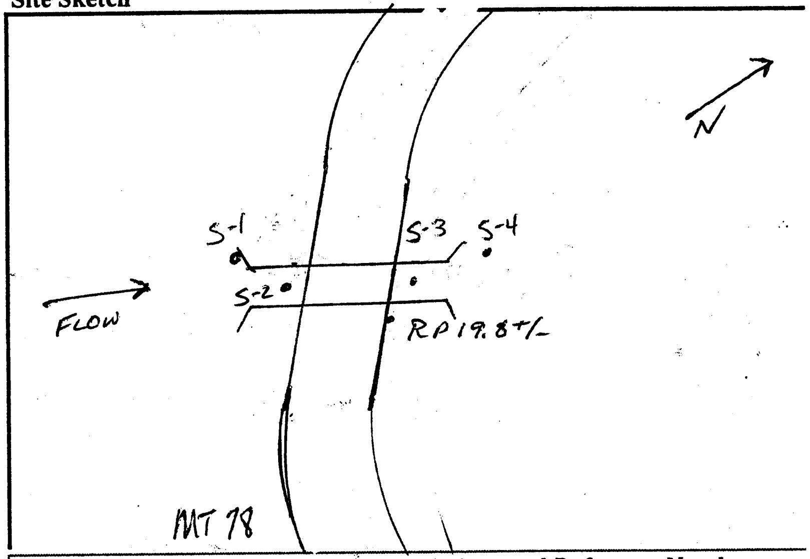
Sample Location: UPSLOPE, DRAINAGE BACKFILL

Project Team Members: J. JOHNSON B. HENNING

General

Site Description: HWY 78 NEAR TOWN OF ROSCOE, MT (20 MI. NE OF RED LODGE) 2 LANE RURAL. ON PROJECT STPP 78-1(4)19 ROSCOE - JCT. 419. CURRENTLY IN PRECONSTRUCTION PHASE.

Site Sketch



Sample Locations: S-1 - NATURAL UPSLOPE S-2 DRAINAGE INSIDE PIPE S-3 BACKFILL OVER PIPE. S-4 DRAINAGE/NATURAL SOIL OUTLET SIDE (RT. CL)

☒ **Photographs**

Location, Description, and Reference Number

P1 - P7 SEE REMARKS

☐ **Maps**

Weather Conditions: 70° PARTLY CLOUDY LT. WIND.

Geology, Physiology, Topography, and Special Features/Conditions: TOPO GENERALLY FLAT W/ ROLLING HILLS.

Culvert Inspection Report

Roadway Station: 1053+24

Culvert Type: CSP

Approximate Age: 1959? 41 yrs

Length: 64'

Diameter: 6'6" x 5'10"

Coating: GALVANIZED

General Condition: VERY GOOD

Photograph Number(s): P1 - P-7

Location of Soil Samples: UPSLOPE DRAINA BACKFILL

Remarks/Comments: PIPE HAS SLIGHT CORROSION ACROSS BOTTOM NOTE P-2 APPROX 8"-10" OF MATERIAL ON BOTTOM STOCKPASS.

Sampling Equipment

☐ Backhoe
☐ Drill
☐ Hand Auger
☒ Shovel
☐ Other

Include Details of Sampling Equipment and Procedures/Methods of Sample Collection (particularly any deviation ...lined proce

COLLECTED BY SHOVEL

Statewide Corrosivity Study--Sample Log

Page 2

MDT Materials District: BILLINGS
Materials Supervisor: J. JOHNSON
County: CARBON
Location: Hwy 78 MP 19.8+/-

Materials

	Sample #	Code*	Sample Size	Photograph Reference
☑ Soil Sample	BIg SITE 4 S-1 /	D	5800	P-1
☑ Soil Sample	BIg SITE 4 S-2 /	D	5600	P-2
☑ Soil Sample	BIg SITE 4 S-3 /	B	7800	P-4
☑ Soil Sample	BIg SITE 4 S-4 /	D	7600	P.5
☐ Water Sample	NA Dry			
☐ Coupon Sample				

For soil samples, enter the estimated percent of material for each grain size. Collect a minimum sample size corresponding to the primary constituent (ie. gravel--9000g)	Gravel	Sand	Silt/Clay
	5	25	70
	5	10	85
	20	30	50
	30	60	10
Minimum Sample Size	9000g (19.8 lb)	6500g (14.3 lb)	4500g (9.9 lb)

* A -Backfill sample from a corroded culvert
B -Backfill sample from a non-corroded culvert
C -Native soil sample near a corroded culvert
D -Native soil sample near a non-corroded culvert

Comments: BIg SITE 4 S-2 TAKEN INSIDE CULVERT

Boring/Excavation Log

Field Engineer: J.J.

Boring/Excavation Location:

Depth	ASTM Visual Classification and Description	MOIS CONT	Sample Depth from	to	Sample Number	Remarks
0.5'	NATIVE SOIL ON UPSLOPE	16.7	0.5'	0.75'	SITE 4 S-1	
0.4'	DRAINAGE MATERIAL INSIDE CULVERT MED DENSE MOIST	48.7	0.4'	0.6'	SITE 4 S-2	
0.5'	BACKFILL - GRAVELLY SOIL	11.2	0.4'	0.8'	SITE 4 S-3	
0.5'	NATIVE SOIL / DRAINAGE SANDY SOIL	15.8	0.5'	0.8'	SITE 4 S-4	

Information Checklist

☑ Sampling site location and description (geology, topography, etc.)
☑ Sampling equipment information/sampling methods
☑ Sampling methods
☑ Sampling material information
☑ Boring log information

Attachments

☑ Photographs of site
☑ Maps of project site
☑ Adequate size soil samples
☑ Photographs of soil sample sites
☐ Other samples ([illegible]ons, etc)

Appendix C

Photograph Log

Appendix D

Test Results Summary

District/ Location	Soil Classification				Atterberg Limits			Gradation		
	Unified		AASHTO	GI	LL	PL	PI	%Gravel	%Sand	%Silt/Clay
D1- S 1	Well Graded Gravel with Sand	GW	A-1-a	0	NP	NP	NP	74.5	24.0	1.5
D1- S 2	Poorly Graded Gravel with Silt and Sand	GP-GM	A-1-a	0	NP	NP	NP	57.4	35.5	7.1
D1- S 3	Silty Sand	SM	A-4	0	25	26	NP	7.6	44.5	47.9
D1- S 4	Poorly Graded Gravel with Sand	GP	A-1-a	0	NP	NP	NP	56.7	41.3	2.0
D1- S 5	Silty Sand with Gravel	SM	A-2-4	0	33	30	3	18.0	48.2	33.8
D1- S 6	Silty Sand with Gravel	SM	A-4	0	36	32	4	24.4	30.0	45.6
D1- S 7	Silt	ML	A-4	-5	30	24	6	0.1	10.1	89.8
D1- S 8	Poorly Graded Sand with Silt and Gravel	SP-SM	A-1-b	0	NP	NP	NP	25.4	69.0	5.6
D1- S 9	Silt	ML	A-4	0	25	25	NP	2.9	11.1	86.0
D1-S10	Silty Gravel with Sand	GM	A-1-b	0	49	47	3	61.6	22.3	16.1
D1-S11	Sandy Silt	ML	A-5	-7	42	32	10	8.5	22.2	69.3
D1-S12	Sandy Silt	ML	A-4	0	25	22	4	1.3	44.0	54.7
D1-S13	Lean Clay	CL	A-7-6	-22	42	21	21	0.2	4.1	95.7
D1-S14	Sandy Silty Clay	CL-ML	A-4	-1	28	22	6	2.6	41.9	55.5
D1-S15	Sandy Silt	ML	A-6	-5	38	27	11	8.0	31.4	60.6
D1-S16	Silty Sand	SM	A-2-4	0	NP	NP	NP	8.7	56.3	35.0
D2- S 1	Sandy Elastic Silt	MH	A-7-6	-11	50	29	22	12.6	30.3	57.1
D2- S 2	Sandy Lean Clay	CL	A-7-6	-12	41	14	27	1.4	41.4	57.2
D2- S 3	Sandy Lean Clay	CL	A-7-6	-19	46	16	30	1.9	27.8	70.3
D2- S 4	Poorly Graded Gravel with Silt and Sand	GP-GM	A-1-a	0	NP	NP	NP	53.5	40.6	5.9
D2- S 5	Poorly Graded Sand with Silt and Gravel	SP-SM	A-1-b	0	NP	NP	NP	21.9	70.7	7.4
D2- S 6	Silty Sand with Gravel	SM	A-1-b	0	NP	NP	NP	27.3	58.4	14.3
D2- S 7	Poorly Graded Sand with Silt and Gravel	SP-SM	A-1-b	0	NP	NP	NP	42.3	46.1	11.6
D2- S 8	Fat Clay with Sand	CH	A-7-6	-32	58	17	41	2.4	18.9	78.7
D2- S 9	Clayey Gravel with Sand	GC	A-2-6	0	33	16	17	54.3	28.6	17.1
D2-S10	Lean Clay with Sand	CL	A-7-6	-22	47	15	31	1.0	24.4	74.6
D2-S11	Fat Clay with Sand	CH	A-7-6	-34	56	17	39	0.3	15.4	84.3
D2-S12	Clayey Gravel with Sand	GC	A-2-7	-4	51	17	34	42.3	25.0	32.7
D2-S13	Clayey Sand with Gravel	SC	A-2-6	-1	37	20	17	22.2	53.7	24.1
D2-S14	Clayey Sand	SC	A-7-6	-7	41	15	25	8.2	44.9	46.9
D2-S15	Clayey Gravel with Sand	GC	A-2-6	0	26	14	12	44.8	38.6	16.6
D3- S 1	Sandy Lean Clay	CL	A-6	-10	39	20	19	7.9	29.3	62.8
D3- S 2	Sandy Lean Clay with Gravel	CL	A-7-6	-8	43	24	19	18.7	26.7	54.6
D3- S 3	Sandy Lean Clay	CL	A-6	-9	37	17	20	6.2	34.8	59.0
D3- S 5	Sandy Lean Clay	CL	A-6	-5	32	19	13	5.5	35.2	59.3
D3- S 7	Lean Clay	CL	A-7-6	-25	43	17	27	0.2	9.3	90.5
D3- S 8	Lean Clay with Sand	CL	A-6	-17	39	15	24	0.9	21.0	78.1
D3-S10	Lean Clay	CL	A-7-6	-29	48	15	33	0.2	12.9	86.9
D3-S11	Lean Clay with Sand	CL	A-7-6	-18	47	21	26	1.1	26.4	72.5
D4- S 1	Poorly Graded Sand	SP	A-7-6	-27	60	15	45	14.1	85.1	0.8
D4- S 2	Fat Clay with Sand	CH	A-7-6	-28	57	18	40	1.6	25.7	72.7
D4- S 3	Fat Clay	CH	A-7-6	-52	70	21	49	0.0	4.9	95.1
D4- S 4	Fat Clay	CH	A-7-6	-80	103	21	81	0.5	10.9	88.6
D4- S 5	Fat Clay with Gravel	CH	A-7-6	-51	78	18	60	9.6	9.2	81.2
D4- S 6	Fat Clay with Sand	CH	A-7-6	-42	71	21	50	0.3	19.8	79.9
D4- S 7	Sandy Lean Clay	CL	A-6	-13	37	15	22	0.5	29.3	70.2
D4- S 8	Lean Clay with Sand	CL	A-6	-16	36	14	23	0.1	20.5	79.4
D4- S 9	Sandy Lean Clay	CL	A-4	-3	29	21	8	0.0	34.2	65.8
D4-S10	Well Graded Gravel with Clay and Sand	GW-GC	A-2-4	0	27	19	9	63.4	29.3	7.3
D4-S11	Silty Clay with Sand	CL-ML	A-4	-3	26	21	5	1.1	18.9	80.0
D4-S12	Clayey Sand with Gravel	SC	A-2-6	-1	35	15	21	26.8	49.1	24.1
D5- S 1	Lean Clay with Sand	CL	A-6	-14	37	16	21	8.1	17.1	74.8
D5- S 2	Fat Clay	CH	A-7-6	-37	52	16	36	0.4	3.9	95.7
D5- S 3	Clayey Gravel with Sand	GC	A-7-6	-4	41	16	25	35.2	27.9	36.9
D5- S 4	Fat Clay	CH	A-7-6	-35	51	17	35	0.7	5.2	94.1
D5- S 5	Lean Clay with Sand	CL	A-6	-16	38	15	23	0.0	22.0	78.0
D5- S 6	Lean Clay	CL	A-6	-18	36	15	22	0.0	12.0	88.0
D5- S 7	Lean Clay with Sand	CL	A-6	-14	37	15	21	10.1	13.7	76.2
D5- S 8	Lean Clay	CL	A-7-6	-27	45	17	28	0.0	8.2	91.8
D5- S 9	Clayey Gravel with Sand	GC	A-7-6	-11	55	21	34	31.1	22.0	46.9
D5-S10	Sandy Lean Clay	CL	A-6	-7	35	19	16	0.0	39.2	60.8
D5-S11	Silty Sand with Gravel	SM	A-1-b	0	21	20	1	29.3	50.1	20.6
D5-S12	Silty Sand with Gravel	SM	A-1-b	0	26	23	3	31.6	53.8	14.6
D5-S13	Silty Sand with Gravel	SM	A-2-6	0	39	28	12	18.4	54.9	26.7
D5-S14	Silty Sand	SM	A-5	0	60	56	4	5.5	56.9	37.6
D5-S15	Clayey Gravel with Sand	GC	A-2-6	-1	32	19	14	35.9	32.7	31.4
D5-S16	Poorly Graded Gravel with Silt and Sand	GP-GM	A-1-b	0	41	40	1	49.8	39.2	11.0

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Soil Property Summary

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Figure 13

District/ Location	Soil Classification				Atterberg Limits			Gradation		
	Unified		AASHTO	GI	LL	PL	PI	%Gravel	%Sand	%Silt/Clay
D1- S 1	Well Graded Sand with Silt	SW-SM	A-1-b	0	NP	NP	NP	0.0	91.5	8.5
D1- S 2	Silty Sand	SM	A-2-4	0	NP	NP	NP	0.0	81.2	18.8
D1- S 3	Sandy Silt	ML	A-4	0	25	26	NP	0.0	43.1	56.9
D1- S 4	Well Graded Sand with Silt	SW-SM	A-1-b	0	NP	NP	NP	0.0	93.8	6.2
D1- S 5	Silty Sand	SM	A-4	0	33	30	3	0.0	50.6	49.4
D1- S 6	Sandy Silt	ML	A-4	-3	36	32	4	0.0	31.7	68.3
D1- S 7	Silt	ML	A-4	-5	30	24	6	0.0	9.8	90.2
D1- S 8	Poorly Graded Sand with Silt	SP-SM	A-2-4	0	NP	NP	NP	0.0	89.9	10.1
D1- S 9	Silt	ML	A-4	0	25	25	NP	0.0	9.1	90.9
D1-S10	Sandy Silt	ML	A-5	-3	49	47	3	0.0	40.3	59.7
D1-S11	Silt with Sand	ML	A-5	-9	42	32	10	0.0	20.8	79.2
D1-S12	Sandy Silt	ML	A-4	0	25	22	4	0.0	44.1	55.9
D1-S13	Lean Clay	CL	A-7-6	-22	42	21	21	0.0	3.9	96.1
D1-S14	Sandy Silty Clay	CL-ML	A-4	-2	28	22	6	0.0	41.5	58.5
D1-S15	Silt with Sand	ML	A-6	-7	38	27	11	0.0	28.7	71.3
D1-S16	Silty Sand	SM	A-2-4	0	NP	NP	NP	0.0	65.6	34.4
D2- S 1	Sandy Elastic Silt	MH	A-7-6	-15	50	29	22	0.0	30.9	69.1
D2- S 2	Sandy Lean Clay	CL	A-7-6	-12	41	14	27	0.0	41.0	59.0
D2- S 3	Lean Clay with Sand	CL	A-7-6	-20	46	16	30	0.0	27.6	72.4
D2- S 4	Silty Sand	SM	A-2-4	0	NP	NP	NP	0.0	84.4	15.6
D2- S 5	Well Graded Sand with Silt	SW-SM	A-2-4	0	NP	NP	NP	0.0	88.6	11.4
D2- S 6	Silty Sand	SM	A-2-4	0	NP	NP	NP	0.0	77.5	22.5
D2- S 7	Silty Sand	SM	A-2-4	0	NP	NP	NP	0.0	76.7	23.3
D2- S 8	Fat Clay with Sand	CH	A-7-6	-34	58	17	41	0.0	18.3	81.7
D2- S 9	Clayey Sand	SC	A-6	-4	33	16	17	0.0	53.2	46.8
D2-S10	Lean Clay with Sand	CL	A-7-6	-22	47	15	31	0.0	23.9	76.1
D2-S11	Fat Clay with Sand	CH	A-7-6	-34	56	17	39	0.0	15.2	84.8
D2-S12	Sandy Fat Clay	CH	A-7-6	-19	51	17	34	0.0	37.3	62.7
D2-S13	Clayey Sand	SC	A-6	-2	37	20	17	0.0	62.7	37.3
D2-S14	Sandy Lean Clay	CL	A-7-6	-10	41	15	25	0.0	45.4	54.6
D2-S15	Clayey Sand	SC	A-6	-1	26	14	12	0.0	61.7	38.3
D3- S 1	Lean Clay with Sand	CL	A-6	-14	39	20	19	0.0	21.9	78.1
D3- S 2	Lean Clay with Sand	CL	A-7-6	-15	43	24	19	0.0	21.8	78.2
D3- S 3	Sandy Lean Clay	CL	A-6	-11	37	17	20	0.0	32.3	67.7
D3- S 5	Sandy Lean Clay	CL	A-6	-7	32	19	13	0.0	30.9	69.1
D3- S 7	Lean Clay	CL	A-7-6	-25	43	17	27	0.0	8.9	91.1
D3- S 8	Lean Clay with Sand	CL	A-6	-18	39	15	24	0.0	20.7	79.3
D3-S10	Lean Clay	CL	A-7-6	-30	48	15	33	0.0	10.3	89.7
D3-S11	Lean Clay with Sand	CL	A-7-6	-19	47	21	26	0.0	25.2	74.8
D4- S 1	Clayey Sand	SC	A-7-6	-8	60	15	45	0.0	63.5	36.5
D4- S 2	Fat Clay with Sand	CH	A-7-6	-29	57	18	40	0.0	25.5	74.5
D4- S 3	Fat Clay	CH	A-7-6	-52	70	21	49	0.0	4.8	95.2
D4- S 4	Fat Clay	CH	A-7-6	-83	103	21	81	0.0	8.9	91.1
D4- S 5	Fat Clay	CH	A-7-6	-60	78	18	60	0.0	8.7	91.3
D4- S 6	Fat Clay with Sand	CH	A-7-6	-43	71	21	50	0.0	18.5	81.5
D4- S 7	Lean Clay with Sand	CL	A-6	-14	37	15	22	0.0	26.6	73.4
D4- S 8	Lean Clay with Sand	CL	A-6	-16	36	14	23	0.0	20.5	79.5
D4- S 9	Sandy Lean Clay	CL	A-4	-3	29	21	8	0.0	34.1	65.9
D4-S10	Clayey Sand	SC	A-2-4	0	27	19	9	0.0	74.8	25.2
D4-S11	Silty Clay with Sand	CL-ML	A-4	-3	26	21	5	0.0	18.8	81.2
D4-S12	Clayey Sand	SC	A-6	-3	35	15	21	0.0	62.1	37.9
D5- S 1	Lean Clay with Sand	CL	A-6	-17	37	16	21	0.0	15.5	84.5
D5- S 2	Fat Clay	CH	A-7-6	-37	52	16	36	0.0	3.5	96.5
D5- S 3	Sandy Lean Clay	CL	A-7-6	-15	41	16	25	0.0	30.0	70.0
D5- S 4	Fat Clay	CH	A-7-6	-36	51	17	35	0.0	4.6	95.4
D5- S 5	Lean Clay with Sand	CL	A-6	-16	38	15	23	0.0	22.0	78.0
D5- S 6	Lean Clay	CL	A-6	-18	36	15	22	0.0	11.4	88.6
D5- S 7	Lean Clay	CL	A-6	-17	37	15	21	0.0	14.3	85.7
D5- S 8	Lean Clay	CL	A-7-6	-27	45	17	28	0.0	8.1	91.9
D5- S 9	Sandy Fat Clay	CH	A-7-6	-23	55	21	34	0.0	30.4	69.6
D5-S10	Sandy Lean Clay	CL	A-6	-8	35	19	16	0.0	36.6	63.4
D5-S11	Silty Sand	SM	A-2-4	0	21	20	1	0.0	68.0	32.0
D5-S12	Silty Sand	SM	A-2-4	0	26	23	3	0.0	77.3	22.7
D5-S13	Silty Sand	SM	A-6	-1	39	28	12	0.0	64.1	35.9
D5-S14	Silty Sand	SM	A-5	0	60	56	4	0.0	58.7	41.3
D5-S15	Sandy Lean Clay	CL	A-6	-5	32	19	14	0.0	45.6	54.4
D5-S16	Silty Sand	SM	A-2-5	0	41	40	1	0.0	74.4	25.6

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Processed Soil Property Summary

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Figure 14

District/	Soil Classification				Atterberg Limits			Gradation		
Location	Unified		AASHTO	GI	LL	PL	PI	%Gravel	%Sand	%Silt/Clay
CS-EC, 1	Lean Clay with Sand	CL	A-7-6	(21)	44	19	25	0.0	16.3	83.7
CS-EC, 2	Lean Clay with Sand	CL	A-7-6	(21)	44	19	25	0.0	17.6	82.4
CS-EC, 3	Elastic Silt with Sand	MH	A-5	(17)	98	98	0	0.0	17.3	82.7
CS-EC, 4	Lean Clay	CL	A-6	(19)	40	18	22	0.0	13.5	86.5
CS-EC, 5	Lean Clay	CL	A-6	(16)	36	17	19	0.0	11.8	88.2
CS-EC, 6	Lean Clay	CL	A-7-6	(29)	44	16	29	0.0	2.8	97.2
CS-EC, 7	Lean Clay	CL	A-7-6	(32)	46	15	31	0.0	2.4	97.6
CS-EC, 8	Lean Clay	CL	A-7-6	(29)	44	15	29	0.0	3.6	96.4
CS-EC, 9	Lean Clay	CL	A-6	(13)	35	19	16	0.0	13.4	86.6
CS-EC,10	Lean Clay	CL	A-6	(23)	40	15	26	0.0	9.7	90.3
CS-EC,11	Lean Clay	CL	A-7-6	(29)	44	15	29	0.0	4.2	95.8
CS-EC,12	Lean Clay	CL	A-7-6	(28)	43	15	28	0.0	2.1	97.9
CS-WC, 1	Elastic Silt with Sand	MH	A-7-5	(16)	53	32	21	0.0	28.9	71.1
CS-WC, 2	Elastic Silt	MH	A-7-5	(17)	53	37	17	0.0	18.0	82.0
CS-WC, 3	Lean Clay	CL	A-7-6	(26)	43	14	29	0.0	9.9	90.1
CS-WC, 4	Lean Clay	CL	A-6	(18)	37	15	22	0.0	13.4	86.6
CS-WC, 5	Lean Clay with Sand	CL	A-7-6	(27)	47	15	32	0.0	15.6	84.4
CS-WC, 6	Lean Clay	CL	A-6	(22)	38	14	23	0.0	5.3	94.7
CS-WC, 7	Lean Clay	CL	A-6	(22)	38	15	23	0.0	4.3	95.7
CS-WC, 8	Lean Clay	CL	A-7-6	(25)	44	15	29	0.0	13.3	86.7

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Case Study Samples--Soil Property Summary

NTL Engineering and Geoscience
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Figure 15

Sample Number	Testing Date	pH		Marble pH		Conductivity			Resistivity			Sulfate	Chloride
		paste	1:2	paste	1:2	Paste	1:1	1:2	Paste	1:1	1:2		
						(mmhos/cm)	(mmhos/cm)	(mmhos/cm)	(ohm-cm)	(ohm-cm)	(ohm-cm)	(%)	(%)
D1-S1	05/24/00	7.1	7.8	7.3	7.6	0.091	0.108	0.058	10989	9259	17241	Trace	Trace
D1-S2	05/24/00	6.4	6.8	6.9	7.0	0.088	0.090	0.044	11363	11111	22727	Trace	Trace
D1-S3	05/24/00	6.5	6.6	7.0	7.0	0.160	0.134	0.069	6250	7462	14492	Trace	Trace
D1-S4	05/24/00	7.1	7.3	7.1	7.4	0.086	0.077	0.038	11627	12987	26315	Trace	Trace
D1-S5	05/24/00	6.2	6.4	6.7	6.9	0.109	0.099	0.053	9174	10101	18867	Trace	Trace
D1-S6	06/01/00	6.7	7.2	6.8	7.0	0.191	0.116	0.053	5236	8626	18868	Trace	Trace
D1-S7	06/01/00	7.7	7.8	7.6	7.7	0.210	0.140	0.081	4762	7143	12346	Trace	Trace
D1-S8	06/01/00	7.7	7.9	7.6	7.7	0.068	0.063	0.026	14706	15873	38462	Trace	Trace
D1-S9	06/01/00	7.7	7.9	7.6	7.4	0.174	0.168	0.083	5747	5952	12048	Trace	Trace
D1-S10	06/01/00	7.9	8.0	7.8	7.7	0.217	0.236	0.123	4608	4237	8130	Trace	Trace
D1-S11	06/06/00	7.4	7.6	7.2	7.3	0.265	0.263	0.176	3773	3802	5682	Trace	Trace
D1-S12	06/06/00	8.1	8.3	7.9	8.2	0.186	0.158	0.138	5376	6329	7246	Trace	Trace
D1-S13	06/06/00	8.0	8.4	7.9	8.2	0.250	0.207	0.142	4000	4831	7042	Trace	Trace
D1-S14	06/06/00	7.7	8.2	7.5	7.8	0.219	0.171	0.136	4566	5848	7353	Trace	Trace
D1-S15	06/06/00	7.1	7.2	7.1	7.3	0.139	0.122	0.091	7194	8197	10989	Trace	Trace
D1-S16	06/07/00	7.8	8.0	7.6	7.8	0.147	0.263	0.228	6802	3802	4385	Trace	Trace
D2-S1	07/12/00	9.0	9.4	8.8	9.3	1.506	1.224	1.017	664	817	983	0.105	0.011
D2-S2	07/12/00	8.0	8.3	7.9	8.3	0.647	0.579	0.470	1546	1727	2127	0.052	0.004
D2-S3	07/20/00	8.0	8.4	8.0	8.3	0.589	0.478	0.391	1678	2092	2557	0.088	0.01
D2-S4	07/20/00	8.1	8.5	8.0	8.2	0.105	0.079	0.125	9524	12658	8000	Trace	Trace
D2-S5	07/20/00	8.2	8.5	7.5	7.8	0.085	0.070	0.113	11765	14286	8850	Trace	Trace
D2-S6	07/20/00	8.0	8.4	7.9	7.9	0.166	0.113	0.133	6024	8850	7519	Trace	Trace
D2-S7	07/20/00	8.4	8.8	8.4	8.4	0.094	0.072	0.101	10638	13888	9901	Trace	Trace
D2-S8	07/24/00	8.7	9.5	8.7	9.3	1.155	1.126	0.803	866	888	1245	0.033	0.014
D2-S9	07/24/00	8.2	9.1	8.3	9.0	0.266	0.212	0.175	3759	4716	5714	0.018	Trace
D2-S10	07/24/00	8.1	8.7	8.1	8.7	1.148	1.014	0.647	871	986	1546	0.051	0.007
D2-S11	07/24/00	9.3	9.7	9.3	9.6	5.034	4.446	3.432	199	225	291	0.537	0.025
D2-S12	07/24/00	7.6	8.1	7.5	8.0	0.658	0.635	0.464	1519	1575	2155	0.04	Trace
D2-S13	07/28/00	7.5	7.8	7.6	7.8	0.350	0.196	0.234	2857	5102	4274	Trace	Trace
D2-S14	07/28/00	7.4	8.1	7.4	8.0	0.900	0.612	0.495	1111	1634	2020	0.062	Trace
D2-S15	07/28/00	8.0	8.5	8.0	8.4	0.239	0.155	0.181	4184	6452	5525	Trace	Trace
D3-S1	08/15/00	3.8	3.9	4.2	5.8	0.617	0.480	0.340	1621	2083	2941	0.2	Trace
D3-S2	08/15/00	3.3	3.4	6.4	5.9	0.904	0.790	0.716	1106	1266	1397	0.53	Trace
D3-S3	08/15/00	3.3	3.4	4.9	5.7	0.938	0.828	0.679	1066	1208	1473	0.53	Trace
D3-S5	08/15/00	4.4	4.5	6.0	6.1	0.254	0.203	0.149	3937	4926	6711	0.06	Trace
D3-S7	08/15/00	8.0	8.4	8.0	8.2	3.840	3.710	2.640	260	270	379	0.011	Trace
D3-S8	08/21/00	8.3	8.6	8.1	8.4	6.414	6.228	4.542	156	160	220	0.0171	Trace
D3-S10	08/21/00	7.9	8.3	7.9	8.2	0.555	0.504	0.392	1801	1984	2551	0.045	Trace
D3-S11	08/21/00	7.5	7.9	7.6	7.7	0.289	0.251	0.190	3460	3984	5263	0.01	Trace
D4-S1	06/07/00	7.8	8.0	7.7	7.9	2.622	4.122	3.762	381	243	266	1.34	0.002
D4-S2	06/07/00	7.7	7.9	7.6	7.8	3.060	4.710	4.362	327	212	229	1.3	0.001
D4-S3	06/07/00	8.0	8.4	7.8	8.1	0.516	0.934	0.884	1949	1070	1131	0.03	0.0015
D4-S4	06/07/00	9.1	9.1	8.9	8.9	1.584	4.068	2.664	631	246	375	0.214	0.018
D4-S5	07/06/00	7.9	8.1	7.8	7.9	2.510	2.380	2.250	398	420	444	1.01	Trace
D4-S6	07/06/00	5.3	5.5	6.4	6.6	1.990	1.740	1.280	503	575	781	0.44	Trace
D4-S7	07/06/00	7.8	8.0	7.8	8.0	1.390	1.330	1.050	719	752	952	0.23	Trace
D4-S8	07/06/00	8.0	8.8	8.0	8.5	0.300	0.270	0.161	3333	3704	6211	0.01	Trace
D4-S9	07/06/00	8.9	9.9	8.7	9.5	1.390	1.060	0.830	719	943	1205	0.06	Trace
D4-S10	07/12/00	9.0	10.0	8.7	9.6	0.648	0.439	0.436	1543	2278	2294	0.053	0.003
D4-S11	07/12/00	8.4	10.0	8.7	8.5	0.242	0.197	0.148	4132	5076	6756	0.019	0.003
D4-S12	07/12/00	8.6	9.7	8.3	9.1	1.018	0.876	0.680	982	1141	1471	0.071	0.003
D5-S1	07/28/00	6.9	7.9	6.9	7.6	0.587	0.376	0.286	1703	2660	3497	Trace	Trace
D5-S2	08/01/00	7.7	8.2	7.7	7.9	0.412	0.422	0.254	2427	2370	3937	0.014	0.009
D5-S3	08/01/00	7.8	8.0	7.6	7.9	0.765	0.642	0.544	1307	1558	1838	0.101	0.007
D5-S4	08/01/00	7.8	7.7	7.7	7.9	0.359	0.384	0.247	2786	2604	4048	0.012	0.014
D5-S5	08/01/00	8.4	8.7	8.3	8.5	4.848	5.148	4.254	206	194	235	1.163	0.014
D5-S6	08/01/00	8.5	8.8	8.5	8.7	7.992	7.734	6.612	125	129	151	1.858	0.029
D5-S7	08/08/00	7.7	8.3	7.6	8.1	0.432	0.335	0.235	2315	2985	4255	Trace	Trace
D5-S8	08/08/00	8.5	8.7	8.5	8.7	10.820	10.610	8.510	92	94	118	2.78	Trace
D5-S9	08/08/00	7.3	7.8	7.2	7.4	1.314	1.190	0.895	761	840	1118	0.188	Trace
D5-S10	08/08/00	7.8	8.2	7.8	7.9	0.281	0.198	0.173	3559	5051	5780	Trace	Trace
D5-S11	08/08/00	7.8	8.3	7.9	7.9	0.247	0.177	0.176	4049	5649	5682	Trace	Trace
D5-S12	08/14/00	7.4	8.1	7.3	7.6	0.513	0.305	0.354	1949	3278	2825	Trace	Trace
D5-S13	08/14/00	7.3	7.7	7.3	7.2	0.313	0.193	0.157	3194	5181	6369	Trace	Trace
D5-S14	08/14/00	7.2	7.3	7.3	7.3	0.186	0.195	0.142	5376	5128	7042	Trace	Trace
D5-S15	08/14/00	7.5	8.0	7.6	7.7	0.201	0.141	0.097	4975	7092	10309	Trace	Trace
D5-S16	08/14/00	7.4	7.5	7.3	7.0	0.278	0.187	0.172	3597	5347	5814	Trace	Trace
CS-W1	11/21/00	9.1	9.5	9.1	9.5	29.040	28.860	33.060	34	35	30	7.98	Trace
CS-W3	11/21/00	8.2	8.6	7.9	8.4	7.686	7.032	4.830	130	142	207	1.76	Trace
CS-W4	11/21/00	7.4	7.6	7.5	7.7	0.965	0.916	0.658	1036	1092	1520	0.26	Trace
CS-W5	11/21/00	7.7	8.0	7.8	0.0	2.688	2.652	2.046	372	377	489	0.72	Trace
CS-W6	11/21/00	7.7	7.9	7.8	7.9	1.578	1.674	1.524	634	597	656	0.53	Trace
CS-W7	11/28/00	8.0	8.1	8.0	8.1	4.170	4.010	3.190	240	249	313	0.86	Trace
CS-W8	11/28/00	8.1	8.4	8.1	8.4	4.510	4.290	2.810	222	233	356	0.098	Trace
CS-E1	11/28/00	7.8	0.0	8.0	8.1	14.220	14.580	11.760	70	69	85	5.12	Trace
CS-E2	11/28/00	8.8	9.0	8.6	8.9	12.360	12.300	8.400	81	81	119	3.8	Trace
CS-E4	11/28/00	7.5	8.0	7.4	7.6	0.360	0.390	0.240	2777	2564	4167	0.02	Trace
CS-E5	12/01/00	7.8	8.1	7.7	7.9	0.337	0.295	0.204	2967	3390	4902	0.05	Trace
CS-E6	12/01/00	7.9	8.3	7.8	8.2	0.348	0.358	0.216	2874	2793	4630	0.06	Trace
CS-E7	12/01/00	7.7	7.9	7.6	7.7	1.650	1.668	1.476	606	600	678	0.54	Trace
CS-E8	12/01/00	8.2	8.3	8.0	8.2	2.304	2.286	1.752	434	437	571	0.65	Trace
CS-E9	12/01/00	7.4	7.7	7.2	7.5	0.915	0.867	0.678	1093	1153	1475	0.15	Trace
CS-E10	12/05/00	8.0	8.3	8.0	8.2	0.703	0.653	0.408	1423	1531	2451	Trace	Trace
CS-E11	12/05/00	8.4	8.6	8.4	8.5	3.996	3.954	2.994	250	252	334	0.9	Trace
CS-E12	12/05/00	7.8	8.1	7.8	8.0	2.940	2.676	2.046	340	374	489	0.54	Trace

Project: Statewide Corrosivity Study
Montana

Job No.: 00-301
Date: 02/22/01

Montana Department of Transportation Test Results

NTL Engineering and Geoscience
Great Falls, Montana

Figure 16

NTL Sample Number	As-Recieved Resistivity Testing				AASHTO T288 Min. Resistivity Testing			AASHTO T288 Testing w/On-site Water	
	Resistivity (ohm-cm)	Moisture Content (%)	Wet Density (pcf)	Dry Density (pcf)	Min. Resistivity (ohm-cm)	Moisture Content (%)	Resistivity @ field MC (ohm-cm)	Water Resistivity (ohm-cm)	Minimum Resistivity (ohm-cm)
D1-S1	512000	4.8	110.7	105.7	9400	35.0	33343		
D1-S2	250000	15.8	114.8	99.2	9720	30.0	13380		10250
D1-S3	75000	23.8	125.8	101.6	4300	25.0	4445		
D1-S4	98500	11.9	128.6	114.9	12200	30.0	19461		
D1-S5	190000	21.4	131.4	108.2	8800	25.0	10038		5300
D1-S6	59500	16.3	79.6	68.4	5400	30.0	16182		4650
D1-S7	99000	46.7	98.6	67.2	3200	30.0	3433		
D1-S8	11000000	4.6	104.1	99.5	11500	40.0	34138		
D1-S9	34000	25.5	132.4	105.5	4900	25.0	4905		
D1-S10	69000	13.8	123.4	108.4	3280	75.0	30500		
D1-S11	16000	45.2	109.7	75.6	2450	40.0	2552		
D1-S12	21000	35.1	124.6	92.2	3000	25.0	3143	2150	2150
D1-S13	20000	38.0	123.3	89.3	1880	25.0	2104		1850
D1-S14	48500	22.2	116.1	95.0	3900	25.0	4179		
D1-S15	42000	29.3	128.7	99.5	3900	25.0	4055		3700
D1-S16	27000	35.7	120.2	88.6	3680	50.0	3850		
D2-S1	585	28.8	109.3	84.9	425	52.0	555	2080	418
D2-S2	1085	41.2	113.2	80.2	725	24.0	794	2080	712
D2-S3	870	39.2	112.0	80.4	828	31.0	896	2080	755
D2-S4	66000	24.3	113.1	91.1	3780	38.0	3973	2080	2080
D2-S5	21500	6.3	113.2	106.5	4350	31.0	10484		
D2-S6	7250	7.2	116.5	108.7	2900	24.0	5244		
D2-S7	9000	5.3	124.1	117.9	4880	17.0	6675		
D2-S8	450	30.8	121.9	93.2	395	24.0	405	945	368
D2-S9	3000	8.9	126.2	115.9	1780	17.0	2409	945	945
D2-S10	750	20.7	126.1	104.4	525	17.0	525	945	455
D2-S11	190	24.6	127.5	102.4	130	38.0	132	945	130
D2-S12	950	24.4	115.2	92.6	838	24.0	839		
D2-S13	2900	14.4	130.9	114.4	1720	24.0	2456		
D2-S14	870	34.1	118.5	88.4	822	31.0	825		
D2-S15	6950	4.6	118.5	113.3	2450	10.0	2411		
D3-S1	1580	18.1	132.6	112.2	882	101.0	1388	315	315
D3-S2	1045	18.9	128.2	107.8	585	115.0	1035	315	315
D3-S3	915	11.2	126.8	113.9	620	73.0	1983	315	315
D3-S5	3200	29.7	126.7	97.6	2300	24.0	2300		
D3-S7	228	24.1	125.4	101.0	168	66.0	208	315	315
D3-S8	120	27.3	121.3	95.3	98	66.0	113		
D3-S10	915	17.5	131.6	112.0	815	38.0	901		
D3-S11	1300	29.9	116.4	89.6	1200	24.0	1200		
D4-S1	1500	22.1	113.3	92.8	300	85.0	438		
D4-S2	5350	11.6	97.3	87.2	245	55.0	486		
D4-S3	570	27.6	123.3	96.6	582	20.0	627		
D4-S4	6450	13.3	180.1	158.9	250	30.0	1440		
D4-S5	330	28.2	122.1	95.2	300	55.0	341		
D4-S6	1800	22.4	97.9	80.0	385	40.0	464		
D4-S7	2020	15.2	112.3	97.5	538	40.0	956		
D4-S8	1620	18.1	128.2	108.6	1320	15.0	1332		
D4-S9	1250	12.3	107.6	95.8	420	30.0	816		
D4-S10	1032	11.6	131.9	118.1	895	25.0	1414	310	310
D4-S11	13000	6.7	94.2	88.3	2050	15.0	4182	310	310
D4-S12	36500	4.7	101.6	97.1	525	30.0	1254	310	310
D5-S1	4020000	2.9	90.3	87.8	1200	24.0	4248		
D5-S2	5150	13.2	98.8	87.3	805	24.0	1668		
D5-S3	1250	13.2	128.8	113.8	878	38.0	1777		
D5-S4	1580	18.7	118.1	99.5	895	24.0	1049		
D5-S5	140	31.4	120.9	92.0	135	52.0	152	290	115
D5-S6	91	29.2	122.9	95.1	85.5	52.0	95	290	82.5
D5-S7	2550	10.4	110.9	100.4	1220	17.0	2521	290	290
D5-S8	74	43.2	111.4	77.8	68.8	59.0	74	290	64.8
D5-S9	600	30.0	118.2	90.9	550	59.0	668		552
D5-S10	5250	8.4	109.1	100.7	2150	17.0	3172		1680
D5-S11	33000	2.9	106.8	103.7	2950	17.0	4256		1850
D5-S12	1220	25.9	121.3	96.4	1450	24.0	1450		1090
D5-S13	4600	16.1	113.4	97.7	2550	31.0	5241		
D5-S14	2700	52.6	101.9	66.8	2650	52.0	2650		
D5-S15	4800	10.0	125.0	113.6	2950	17.0	4794		
D5-S16	4150	12.2	116.9	104.2	3000	38.0	8309		
CS-W1	1700	29.9			30	70.0	79		
CS-W2	1900	34.5			32	95.0	116		
CS-W3	130	31.9			100	38.0	104		
CS-W4	850	8.2			900	35.0	4864		
CS-W5	2450	12.4			275	70.0	1601		
CS-W6	7000	7.9			425	65.0	3448		
CS-W7	1400	11.1			170	50.0	742		
CS-W8	1050	12.8			165	45.0	677		
CS-E1	97	25.8			51	66.0	78		
CS-E2	128	24.6			63	59.0	84		
CS-E3	150000	32.6			29	122.0	743		
CS-E4	1200	26.8			1500	24.0	1500		
CS-E5	1300	21.2			1500	17.0	1500		
CS-E6	12500	8.8			1200	24.0	3676		
CS-E7	5900	10.1			410	66.0	2228		
CS-E8	3100	11.0			310	73.0	2014		
CS-E9	725	36.9			650	45.0	706		
CS-E10	1060	21.4			740	24.0	805		
CS-E11	290	18.6			225	45.0	304		
CS-E12	710	16.8			158	66.0	238		

Project: Statewide Corrosivity Study
Montana

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Soil Box and AASTHO T288 Minimum Resistivity Test Results

NTL Engineering and Geoscience
Great Falls, Montana

Figure 17

Testing Conducted by the Montana Department of Transportation Materials Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (%)	Chloride (%)
D1-S3	**6.5**	6.6	**0.16**	**0.13**	0.07	**6250.0**	**7462.7**	14492.8	**Trace**	**Trace**
D1-S5	6.2	6.4	0.11	0.10	**0.05**	9174.3	10101.0	**18867.9**	Trace	Trace
D1-S9	7.7	**7.9**	0.17	**0.17**	0.08	5747.1	**5952.4**	12048.2	Trace	Trace
D1-S11	**7.4**	**7.6**	**0.27**	0.26	**0.18**	**3773.6**	3802.3	**5681.8**	**Trace**	**Trace**
D1-S13	8.0	8.4	0.25	**0.21**	**0.14**	4000.0	**4830.9**	**7042.3**	Trace	Trace
D1-S15	7.1	7.2	0.14	**0.12**	**0.09**	7194.2	**8196.7**	**10989.0**	Trace	Trace
D2-S1	**9.0**	9.4	**1.51**	**1.22**	1.02	**664.0**	**817.0**	983.3	**0.11**	**0.01**
D2-S6	8.0	**8.4**	**0.17**	0.11	**0.13**	**6024.1**	8849.6	**7518.8**	Trace	Trace
D2-S8	8.7	9.5	1.16	**1.13**	**0.80**	865.8	**888.1**	**1245.3**	**0.033**	**0.014**
D2-S12	7.6	**8.1**	0.66	**0.64**	**0.46**	1519.8	**1574.8**	**2155.2**	0.04	Trace
D3-S2	3.3	3.4	**0.90**	**0.79**	0.72	**1106.2**	**1265.8**	1396.6	0.53	Trace
D3-S8	8.3	8.6	6.41	**6.23**	**4.54**	155.9	**160.6**	**220.2**	**0.0171**	**Trace**
D3-S10	**7.9**	8.3	**0.56**	**0.50**	0.39	**1801.8**	**1984.1**	2551.0	**0.045**	**Trace**
D4-S1	**7.8**	8.0	**2.62**	**4.12**	3.76	**381.4**	**242.6**	265.8	**1.34**	**0.002**
D4-S3	**8.0**	8.4	**0.52**	**0.93**	**0.88**	**1938.0**	**1070.7**	**1131.2**	**0.03**	**0.0015**
D4-S12	8.6	**9.7**	1.02	0.88	**0.68**	982.3	1141.6	**1470.6**	0.071	0.003
D5-S1	6.9	7.9	**0.59**	0.38	**0.29**	**1703.6**	2659.6	**3496.5**	**Trace**	**Trace**
D5-S7	7.7	**8.3**	0.43	**0.34**	**0.24**	2314.8	**2985.1**	**4255.3**	**Trace**	**Trace**
D5-S10	**7.8**	8.2	**0.28**	0.20	**0.17**	**3558.7**	5050.5	**5780.3**	Trace	Trace
D5-S13	7.3	**7.7**	0.31	**0.19**	**0.16**	3194.9	**5181.3**	**6369.4**	Trace	Trace

Quality Control Testing Conducted by the Montana State University Soil Testing Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (ppm)	Chloride (ppm)
D1-S3	6.4		0.59	0.23		1694.9	4347.8		34	10.3
D1-S5					0.10			10000.0		
D1-S9		8.5		0.25			4000.0			
D1-S11	7.1	7.5	1.36		0.36	735.3		2777.8	25	127.4
D1-S13				0.33	0.18		3030.3	5555.6		
D1-S15				0.23	0.10		4347.8	10000.0		
D2-S1	8.6		4.59	2.26		217.9	442.5		672	604.7
D2-S6		8.7	1.06		0.19	943.4		5263.2		
D2-S8				1.03	0.63		970.9	1587.3	116	12.4
D2-S12		8.1		0.95	0.47		1052.6	2127.7		
D3-S2			3.88	2.00		257.7	500.0			
D3-S8				7.04	4.20		142.0	238.1	8401	68.6
D3-S10	7.8		1.13	0.82		885.0	1219.5		149	19.7
D4-S1	7.7		6.77	4.25		147.7	235.3		5439	79.6
D4-S3	7.8		0.64	0.83	0.30	1562.5	1204.8	3333.3	1887	6.1
D4-S12		9.7			0.94			1063.8		
D5-S1			1.21		0.25	826.4		4000.0	127	9.1
D5-S7		8.2		0.47	0.16		2127.7	6250.0	77	14.6
D5-S10	7.6		0.63		0.10	1587.3		10000.0		
D5-S13		7.3		0.37	0.14		2702.7	7142.9		

Project: Statewide Corrosivity Study
Montana

Job No.: 00-301
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Quality Control Testing Results

NTL Engineering and Geoscience
Great Falls, Montana

Figure 18

Testing Conducted by the Montana Department of Transportation Materials Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (%)	Chloride (%)
D1-S3	6.5	6.6	0.16	0.13	0.07	6250.0	7462.7	14492.8	Trace	Trace
D1-S5	6.2	6.4	0.11	0.10	0.05	9174.3	10101.0	18867.9	Trace	Trace
D1-S11	7.4	7.6	0.27	0.26	0.18	3773.6	3802.3	5681.8	Trace	Trace
D1-S15	7.1	7.2	0.14	0.12	0.09	7194.2	8196.7	10989.0	Trace	Trace
D2-S6	8.0	8.4	0.17	0.11	0.13	6024.1	8849.6	7518.8	Trace	Trace
D2-S12	7.6	8.1	0.66	0.64	0.46	1519.8	1574.8	2155.2	0.04	Trace
D3-S2	3.3	3.4	0.90	0.79	0.72	1106.2	1265.8	1396.6	0.53	Trace
D4-S3	8.0	8.4	0.52	0.93	0.88	1938.0	1070.7	1131.2	0.03	0.00
D4-S12	8.6	9.7	1.02	0.88	0.68	982.3	1141.6	1470.6	0.07	0.00
D5-S7	7.7	8.3	0.43	0.34	0.24	2314.8	2985.1	4255.3	Trace	Trace
D5-S10	7.8	8.2	0.28	0.20	0.17	3558.7	5050.5	5780.3	Trace	Trace
D5-S13	7.3	7.7	0.31	0.19	0.16	3194.9	5181.3	6369.4	Trace	Trace

DuplicateTesting Conducted by the Montana Department of Transportation Materials Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (%)	Chloride (%)
D1-S3	6.5	6.7	0.133	0.103	0.082	7,519	9,709	12,195	Trace	Trace
D1-S5	6.4	6.5	0.066	0.071	0.066	15,152	14,085	15,152	Trace	Trace
D1-S11	7.2	7.3	0.33	0.3	0.21	3,030	3,333	4,762	Trace	Trace
D1-S15	6.9	7.1	0.16	0.14	0.09	6,250	7,143	11,111	Trace	Trace
D2-S6	7.9	8.3	0.18	0.13	0.13	5,555	7,692	7,692	Trace	Trace
D2-S12	7.6	8	0.67	0.63	0.44	1,493	1,587	2,273	0.04	Trace
D3-S2	3.3	3.4	0.89	0.89	0.88	1,123	1,123	1,136	0.42	Trace
D4-S3	7.9	8.1	0.54	0.56	0.2	1,852	1,786	5,000	Trace	Trace
D4-S12	8.4	9.2	1.03	0.87	0.73	971	1,149	1,370	0.07	Trace
D5-S7	7.7	8.1	0.4	0.32	0.24	2,500	3,125	4,166	Trace	Trace
D5-S10	7.9	8	0.23	0.18	0.16	4,378	5,555	6,250	Trace	Trace
D5-S13	7.2	7.5	0.23	0.2	0.17	4,378	5,000	5,882	Trace	Trace

Testing Conducted by the Montana State University Soil Testing Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (ppm)	Chloride (ppm)
D1-S3	6.4		0.59	0.23		1694.9	4347.8		34	10.3
D1-S5					0.10			10000.0		
D1-S11	7.1	7.5	1.36		0.36	735.3		2777.8	25	127.4
D1-S15				0.23	0.10		4347.8	10000.0		
D2-S6		8.7	1.06		0.19	943.4		5263.2		
D2-S12		8.1		0.95	0.47		1052.6	2127.7		
D3-S2			3.88	2.00		257.7	500.0			
D4-S3	7.8		0.64	0.83	0.30	1562.5	1204.8	3333.3	1887	6.1
D4-S12		9.7			0.94			1063.8		
D5-S7		8.2		0.47	0.16		2127.7	6250.0	77	14.6
D5-S10	7.6		0.63		0.10	1587.3		10000.0		
D5-S13		7.3		0.37	0.14		2702.7	7142.9		

DuplicateTesting Conducted by the Montana Department of Transportation Materials Laboratory

Sample Number	pH paste	pH 1:2	Conductivity Paste (mmhos/cm)	Conductivity 1:1 (mmhos/cm)	Conductivity 1:2 (mmhos/cm)	Resistivity Paste (ohm-cm)	Resistivity 1:1 (ohm-cm)	Resistivity 1:2 (ohm-cm)	Sulfate (ppm)	Chloride (ppm)
D1-S3	6.3		0.66	0.22		1515.2	4545.5			
D1-S5		6.5			0.08			12500.0		
D1-S11		7.2	1.63		0.43	613.5		2325.6		
D1-S15		7.2		0.25	0.13		4000.0	7692.3		
D2-S6		8.4	1.17		0.18	854.7		5555.6		
D2-S12		8.2		1.03	0.59		970.9	1694.9		
D3-S2	1.4		4.14	1.88		241.5	531.9			
D4-S3		8.2	1.14		0.49	877.2		2040.8		
D4-S12		9.8			0.53			1886.8		
D5-S7		8.4		0.47	0.23		2127.7	4347.8		
D5-S10		8.1	0.75		0.13	1333.3		7692.3		
D5-S13		7.3		0.39	0.22		2564.1	4545.5		

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Duplicate Testing Results

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Figure 19

Appendix E

Supplementary Analysis Data

	Laboratory Testing			Culvert Information			AASHTO T288			MDT			
Sample Number	AASHTO Resistivity	pH	1:2 Resistivity	Condition	Age	Coating	Recommendation	Estimated Life	Percent Life Used	Recommendation	Estimated Life	Percent Life Used	Recommendations Comparison
D1-S1	9400	7.1	17241	fair	20	asphalt	galvanized	65	31	galvanized	73	28	same
D1-S2	9720	6.4	22727	fair	20	asphalt	galvanized	50	40	galvanized	60	33	same
D1-S3	4300	6.5	14492	good	15	blakclad	galvanized	41	36	galvanized	56	27	same
D1-S4	12200	7.1	26315	good	20	Bituminous	galvanized	68	29	galvanized	78	26	same
D1-S5	8800	6.2	18867	good	20	galvanized	galvanized	46	43	galvanized	55	36	same
D1-S6	5400	6.7	18868	good	25	galvanized	galvanized	47	53	galvanized	62	40	same
D1-S7	3200	7.7	12345.7	fair	20	galvanized	galvanized	80	25	galvanized	140	14	same
D1-S8	11500	7.7	38462	fair	30	galvanized	galvanized	136	22	galvanized	223	13	same
D1-S9	4900	7.7	12048.2	good	3	none	galvanized	96	3	galvanized	139	2	same
D1-S10	3280	7.9	8130	good	15	none	galvanized	81	18	galvanized	118	13	same
D1-S11	2450	7.4	5681.82	good	9	none	galvanized	72	12	galvanized	102	9	same
D1-S12	3000	8.1	7246	good	20	none	galvanized	78	26	galvanized	112	18	same
D1-S13	1880	8	7042	fair	48	none	bituminous/polymeric	65	74	galvanized	111	43	different
D1-S14	3100	7.7	7353	good	15	none	galvanized	79	19	galvanized	113	13	same
D1-S15	3900	7.1	10989	good	20	none	galvanized	55	37	galvanized	67	30	same
D1-S16	3680	7.8	4385	good	5	none	galvanized	85	6	galvanized	92	5	same
D2-S1	425	9	983	poor	64	galvanized	no steel	35	182	bituminous/polymeric	50	129	different
D2-S2	725	8	2127	poor	64	galvanized	fiber-bonded	44	146	bituminous/polymeric	68	94	different
D2-S3	828	8	2557	poor	64	galvanized	bituminous/polymeric	46	138	galvanized	73	87	different
D2-S4	3780	8.1	8000	poor	64	galvanized	galvanized	86	74	galvanized	117	55	same
D2-S5	4350	8.2	8850	fair	64	galvanized	galvanized	91	70	galvanized	122	52	same
D2-S6	2900	8	7519	fair	64	galvanized	galvanized	77	83	galvanized	114	56	same
D2-S7	4880	8.4	9901	fair	64	galvanized	galvanized	96	67	galvanized	128	50	same
D2-S8	395	8.7	1245	poor	70	galvanized	no steel	34	205	bituminous/polymeric	55	128	different
D2-S9	1780	8.2	5714	poor	70	galvanized	bituminous/polymeric	63	111	galvanized	102	69	different
D2-S10	525	8.1	1546	poor	70	galvanized	fiber-bonded	38	183	bituminous/polymeric	60	117	different
D2-S11	130	9.3	291	poor	70	galvanized	no steel	22	324	no steel	30	233	same
D2-S12	838	7.6	2155	poor	70	galvanized	bituminous/polymeric	46	151	bituminous/polymeric	68	102	same
D2-S13	1720	7.5	4274	poor	70	galvanized	bituminous/polymeric	62	112	galvanized	91	77	different
D2-S14	822	7.4	2020	poor	70	galvanized	bituminous/polymeric	46	152	bituminous/polymeric	67	105	same
D2-S15	2450	8	5525	poor	70	galvanized	galvanized	72	97	galvanized	101	70	same
D3-S1	882	3.8	2941	poor	30	galvanized	no steel	2	1204	no steel	17	177	same
D3-S2	585	3.3	1397	poor	30	galvanized	no steel	-5	-633	no steel	6	527	same
D3-S3	620	3.3	1473	poor	30	galvanized	no steel	-4	-742	no steel	6	475	same
D3-S5	2300	4.4	6711	poor	30	galvanized	no steel	17	177	no steel	30	101	same
D3-S7	168	8	379	good	10	epoxy	no steel	24	42	no steel	34	30	same
D3-S8	98	8.3	220	good	10	epoxy	no steel	19	52	no steel	27	37	same
D3-S10	815	7.9	2551	good	30	galvanized	bituminous/polymeric	46	65	galvanized	73	41	different
D3-S11	1200	7.5	5263	good	30	galvanized	bituminous/polymeric	54	56	galvanized	99	30	different
D4-S1	300	7.8	266	poor	23	galvanized	no steel	30	75	no steel	29	79	same
D4-S2	245	7.7	229	poor	23	galvanized	no steel	28	82	no steel	27	84	same
D4-S3	582	8	1131	poor	23	galvanized	fiber-bonded	40	58	bituminous/polymeric	53	44	different
D4-S4	250	9.1	375	poor	30	galvanized	no steel	28	106	no steel	33	90	same
D4-S5	300	7.9	444	poor	30	galvanized	no steel	30	98	no steel	36	84	same
D4-S6	385	5.3	781	poor	30	galvanized	no steel	1	3263	fiber-bonded	9	319	different
D4-S7	538	7.8	952	poor	?	galvanized	fiber-bonded	39	?	bituminous/polymeric	49	?	different
D4-S8	1320	8	6211	poor	?	galvanized	bituminous/polymeric	56	?	galvanized	106	?	different
D4-S9	420	8.9	1205	poor	?	galvanized	no steel	35	?	bituminous/polymeric	54	?	different
D4-S10	895	9	2294	poor	?	galvanized	bituminous/polymeric	48	?	bituminous/polymeric	70	?	same
D4-S11	2050	8.4	6756	poor	?	galvanized	bituminous/polymeric	67	?	galvanized	109	?	different
D4-S12	525	8.6	1471	poor	?	galvanized	fiber-bonded	38	?	bituminous/polymeric	58	?	different
D5-S1	1200	6.9	3497	good	28	black mastic	bituminous/polymeric	34	83	galvanized	47	60	different
D5-S2	805	7.7	3937	good	28	black mastic	bituminous/polymeric	46	61	galvanized	88	32	different
D5-S3	878	7.8	1838	good	28	black mastic	bituminous/polymeric	47	59	bituminous/polymeric	64	44	same
D5-S4	895	7.8	4048	good	28	black mastic	bituminous/polymeric	48	59	galvanized	89	32	different
D5-S5	135	8.4	235	poor	46	galvanized	no steel	22	209	no steel	28	167	same
D5-S6	85.5	8.5	151	poor	46	galvanized	no steel	18	253	no steel	23	200	same
D5-S7	1220	7.7	4255	poor	46	galvanized	bituminous/polymeric	54	85	galvanized	90	51	different
D5-S8	68.8	8.5	118	poor	46	galvanized	no steel	17	276	no steel	21	221	same
D5-S9	550	7.3	1118	fair	32	galvanized	fiber-bonded	48	67	bituminous/polymeric	56	57	different
D5-S10	2150	7.8	5780	fair	32	galvanized	bituminous/polymeric	68	47	galvanized	103	31	different
D5-S11	2950	7.8	5682	fair	32	galvanized	galvanized	78	41	galvanized	102	31	same
D5-S12	1450	7.4	2825	fair	32	galvanized	bituminous/polymeric	58	55	galvanized	76	42	different
D5-S13	2550	7.3	6369	good	41	galvanized	galvanized	66	62	galvanized	77	53	same
D5-S14	2650	7.2	7042	good	41	galvanized	galvanized	56	74	galvanized	67	61	same
D5-S15	2950	7.5	10309	good	41	galvanized	galvanized	78	53	galvanized	130	32	same
D5-S16	3000	7.4	5814	good	41	galvanized	galvanized	78	52	galvanized	103	40	same
CS-E1	51	7.8	85	poor	46	galvanized	no steel	15	312	no steel	18	253	same
CS-E2	62.5	8.8	119	poor	46	galvanized	no steel	16	287	no steel	21	221	same
CS-E3	29	9		poor	46	galvanized	no steel	12	393	no steel	12	383	same
CS-E4	1500	7.5	4167	poor	46	galvanized	bituminous/polymeric	59	78	galvanized	90	51	different
CS-E5	1500	7.8	4902	poor	46	galvanized	bituminous/polymeric	59	78	galvanized	96	48	different
CS-E6	1200	7.9	4630	poor	46	galvanized	bituminous/polymeric	54	85	galvanized	94	49	different
CS-E7	410	7.7	678	poor	46	galvanized	no steel	35	133	fiber-bonded	43	108	different
CS-E8	310	8.2	571	poor	46	galvanized	no steel	31	149	fiber-bonded	40	116	different
CS-E9	650	7.4	1475	poor	46	galvanized	fiber-bonded	42	110	bituminous/polymeric	59	79	different
CS-E10	740	8	2451	poor	46	galvanized	fiber-bonded	44	104	galvanized	72	64	different
CS-E11	225	8.4	334	poor	46	galvanized	no steel	27	170	no steel	32	144	same
CS-E12	158	7.8	489	poor	46	galvanized	no steel	23	196	no steel	37	124	same
CS-W1	30	9.1	30	poor	46	galvanized	no steel	12	388	no steel	12	388	same
CS-W2	31.5	9		poor	46	galvanized	no steel	12	380	no steel	12	383	same
CS-W3	100	8.2	207	poor	46	galvanized	no steel	19	237	no steel	26	176	same
CS-W4	900	7.4	1520	poor	46	galvanized	bituminous/polymeric	48	96	bituminous/polymeric	59	78	same
CS-W5	275	7.7	489	poor	46	galvanized	no steel	29	156	no steel	37	124	same
CS-W6	425	7.7	656	poor	46	galvanized	no steel	35	131	fiber-bonded	42	110	different
CS-W7	170	8	313	poor	46	galvanized	no steel	24	191	no steel	31	148	same
CS-W8	165	8.1	356	poor	46	galvanized	no steel	24	193	no steel	33	141	same

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Service Life Analysis and Coating Recommendations

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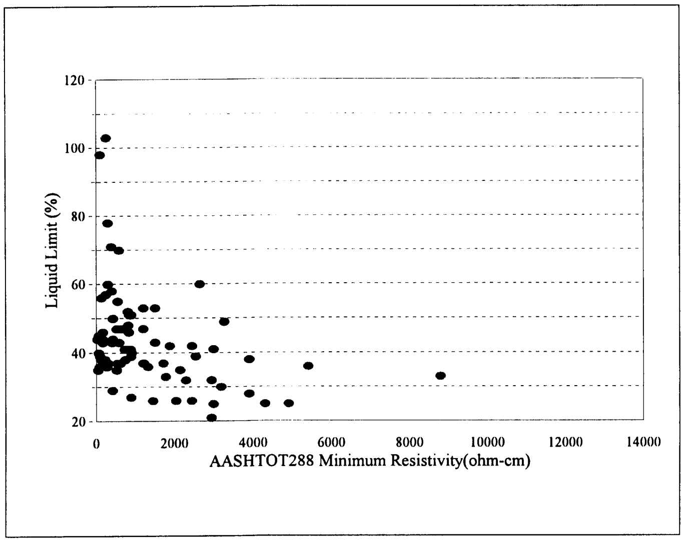
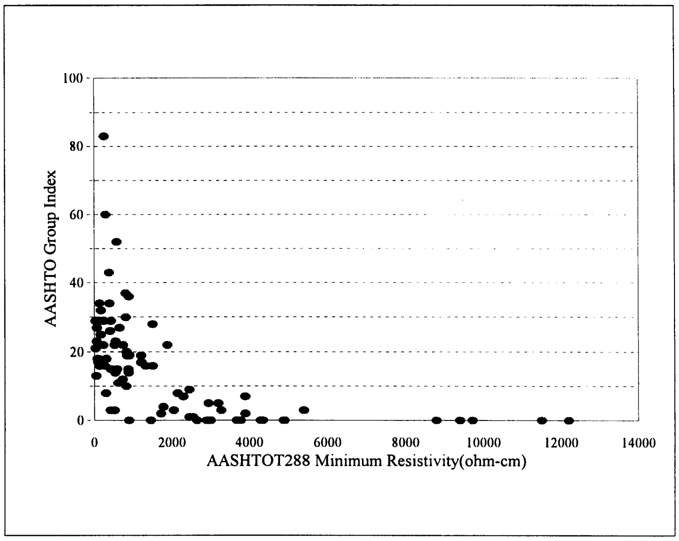
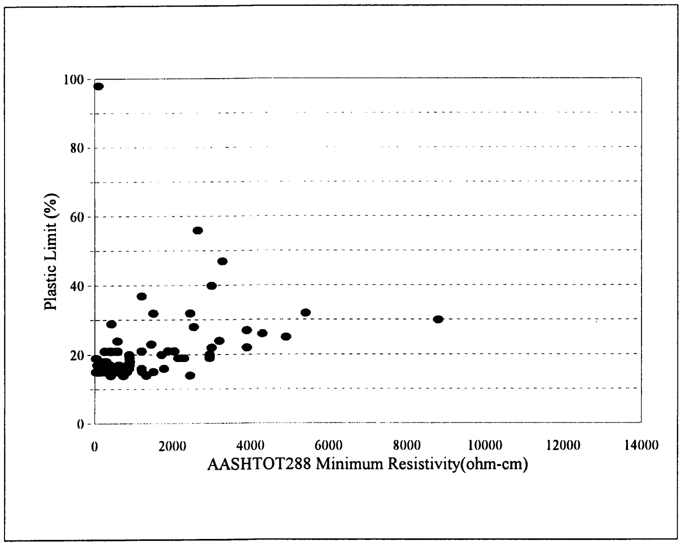
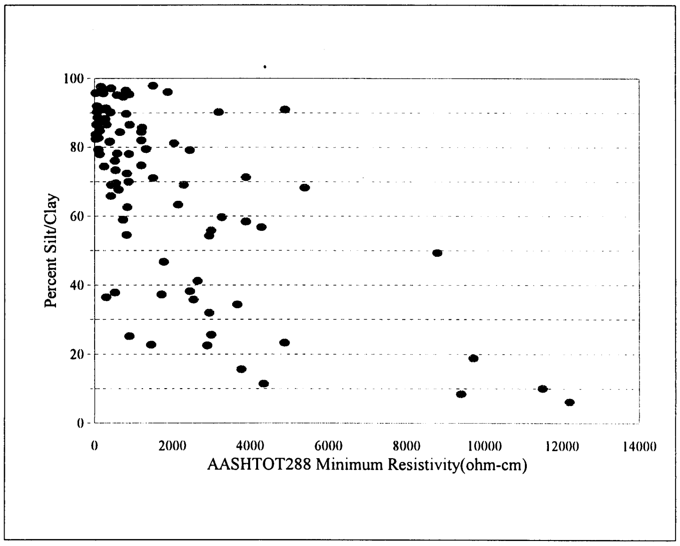
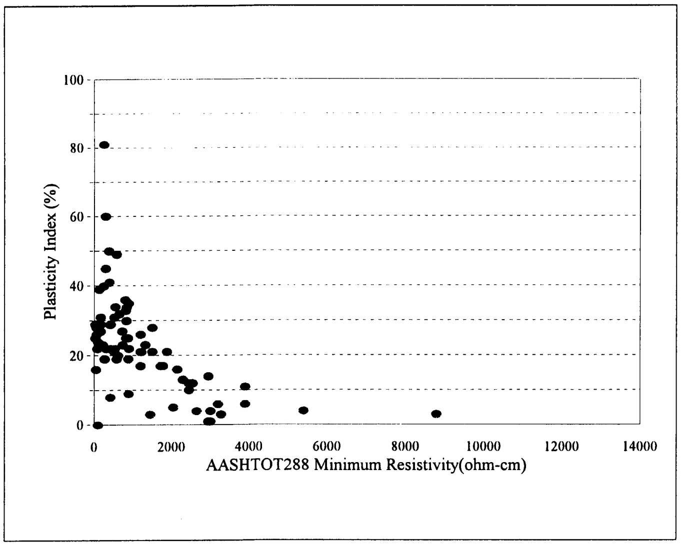
Figure 20

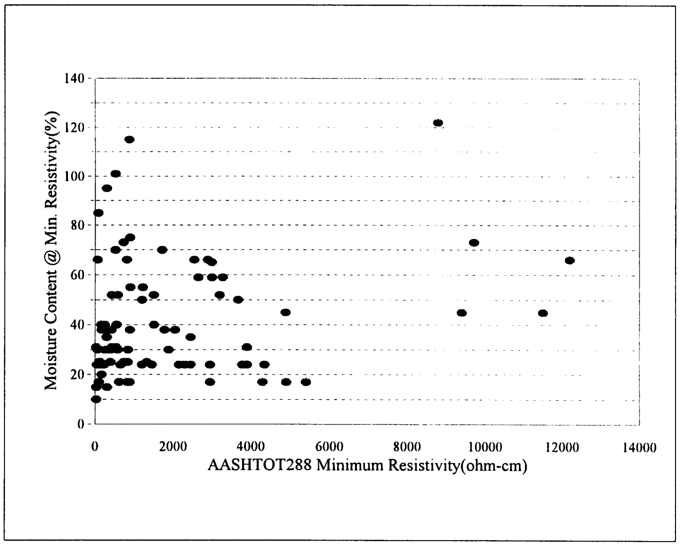












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AASTHO T288 Minimum Resistivity/Soil Property Correlations

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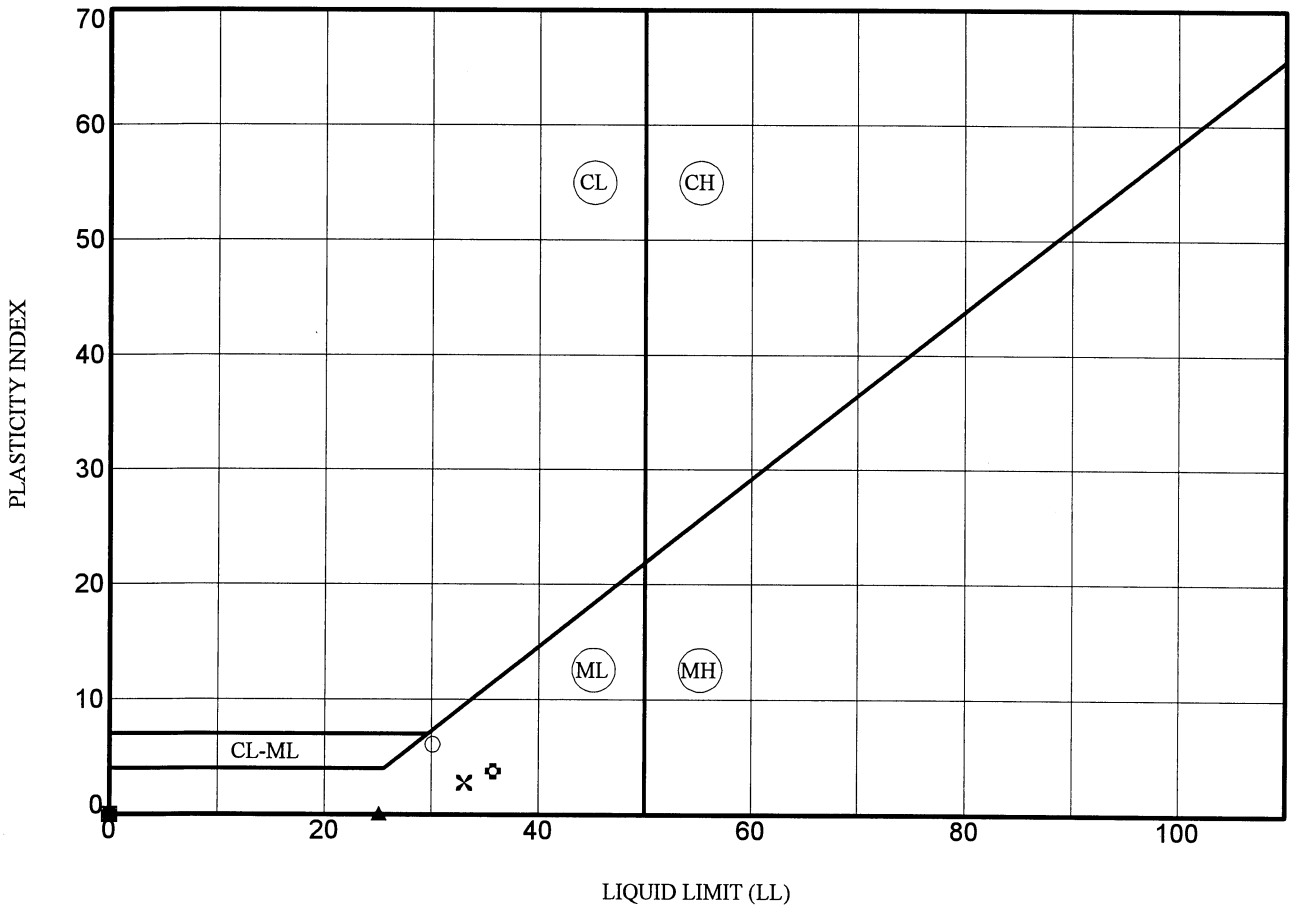
Figure 21

Appendix F

NTL Index Test Plates



Specimen Identification			LL	PL	PI	Fines	Classification
●	**D1**	**1.0**	**NP**	**NP**	**NP**	**1.5**	**Well-graded Gravel With Sand GW**
⊠	**D1**	**2.0**	**NP**	**NP**	**NP**	**7.1**	**Poorly Graded Gravel With Silt And Sand GP-GM**
▲	**D1**	**3.0**	**25**	**25**	**NP**	**47.9**	**Silty Sand SM**
★	**D1**	**4.0**	**NP**	**NP**	**NP**	**2.0**	**Poorly Graded Gravel With Sand GP**
✕	**D1**	**5.0**	**33**	**30**	**3**	**33.8**	**Silty Sand With Gravel SM**
✿	**D1**	**6.0**	**36**	**32**	**4**	**45.6**	**Silty Sand With Gravel SM**
○	**D1**	**7.0**	**30**	**24**	**6**	**89.8**	**Silt ML**
△	**D1**	**8.0**	**NP**	**NP**	**NP**	**5.6**	**Poorly Graded Sand With Silt And Gravel SP-SM**

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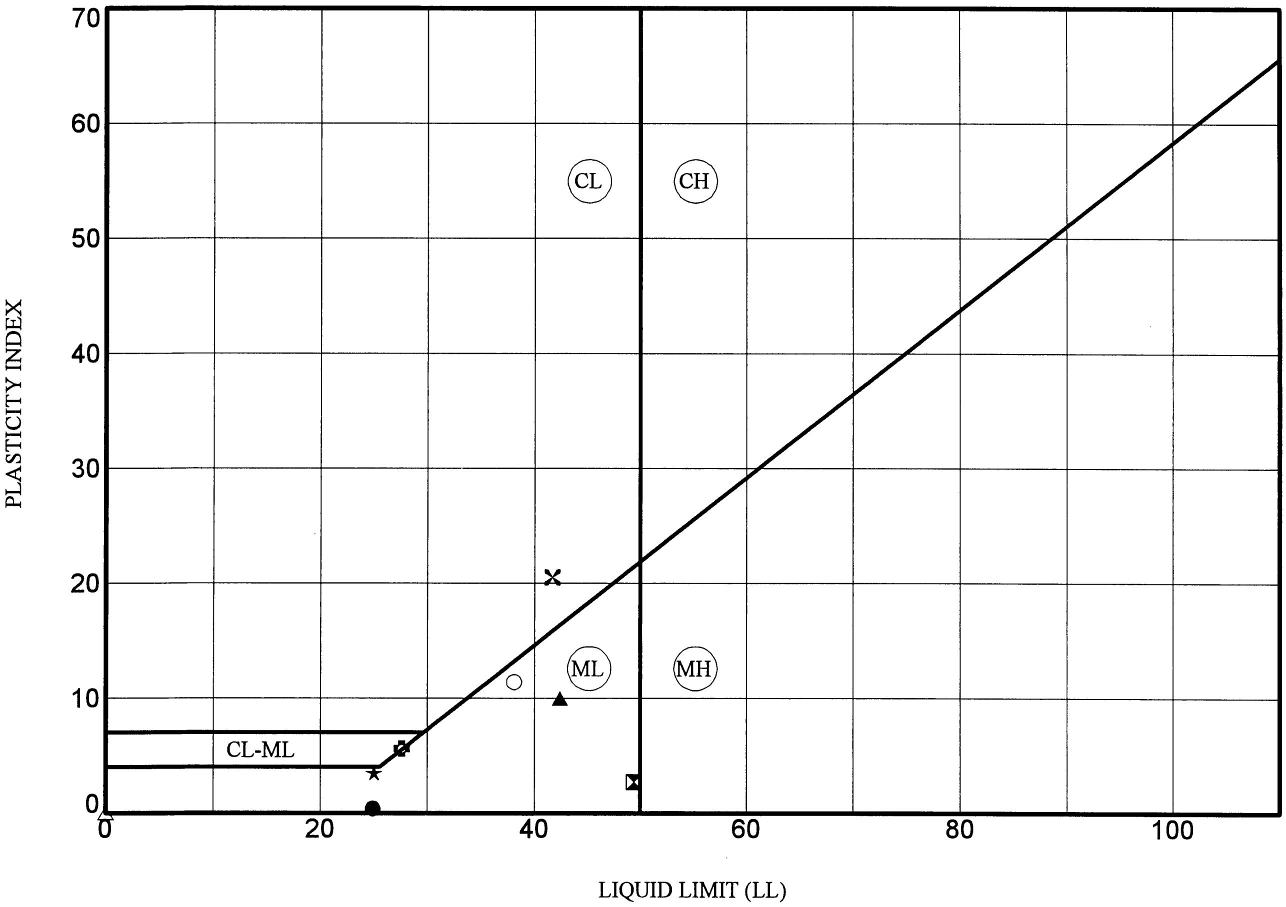
Plate No. 1



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D1**	**9.0**	**25**	**25**	**NP**	**86.0**	**Silt ML**
⧗	**D1**	**10.0**	**49**	**47**	**3**	**16.1**	**Silty Gravel With Sand GM**
▲	**D1**	**11.0**	**42**	**32**	**10**	**69.3**	**Sandy Silt ML**
★	**D1**	**12.0**	**25**	**22**	**4**	**54.7**	**Sandy Silt ML**
✕	**D1**	**13.0**	**42**	**21**	**21**	**95.7**	**Lean Clay CL**
✤	**D1**	**14.0**	**28**	**22**	**6**	**55.5**	**Sandy Silty Clay CL-ML**
○	**D1**	**15.0**	**38**	**27**	**11**	**60.6**	**Sandy Silt ML**
△	**D1**	**16.0**	**NP**	**NP**	**NP**	**35.0**	**Silty Sand SM**

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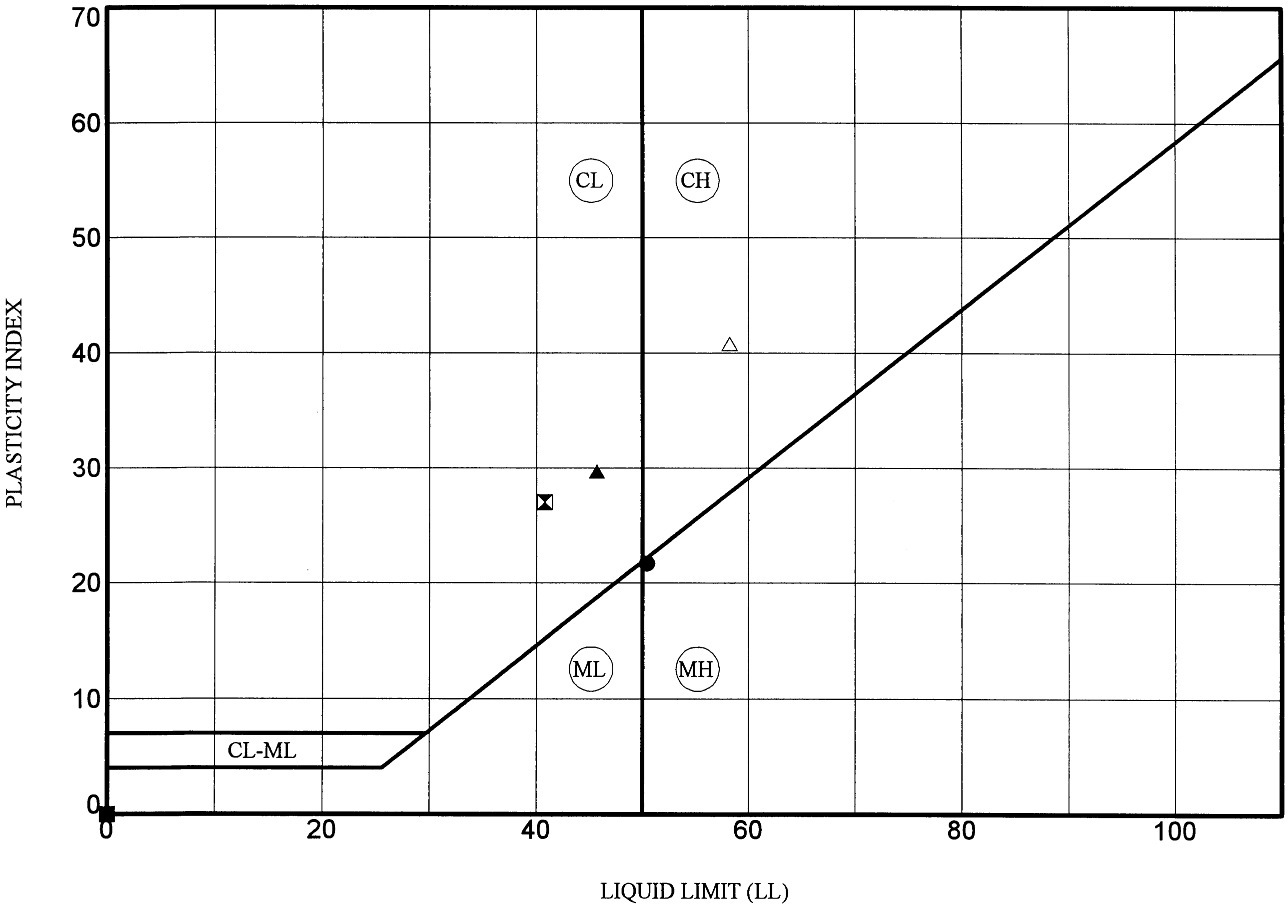
Plate No. 2



Specimen Identification			LL	PL	PI	Fines	Classification
●	**D2**	**1.0**	**50**	**29**	**22**	**57.1**	**Sandy Elastic Silt MH**
⧗	**D2**	**2.0**	**41**	**14**	**27**	**57.2**	**Sandy Lean Clay CL**
▲	**D2**	**3.0**	**46**	**16**	**30**	**70.3**	**Lean Clay With Sand CL**
★	**D2**	**4.0**	**NP**	**NP**	**NP**	**5.9**	**Poorly Graded Gravel With Silt And Sand GP-GM**
✕	**D2**	**5.0**	**NP**	**NP**	**NP**	**7.4**	**Poorly Graded Sand With Silt And Gravel SP-SM**
✿	**D2**	**6.0**	**NP**	**NP**	**NP**	**14.3**	**Silty Sand With Gravel SM**
○	**D2**	**7.0**	**NP**	**NP**	**NP**	**11.6**	**Poorly Graded Sand With Silt And Gravel SP-SM**
△	**D2**	**8.0**	**58**	**17**	**41**	**78.7**	**Fat Clay With Sand CH**

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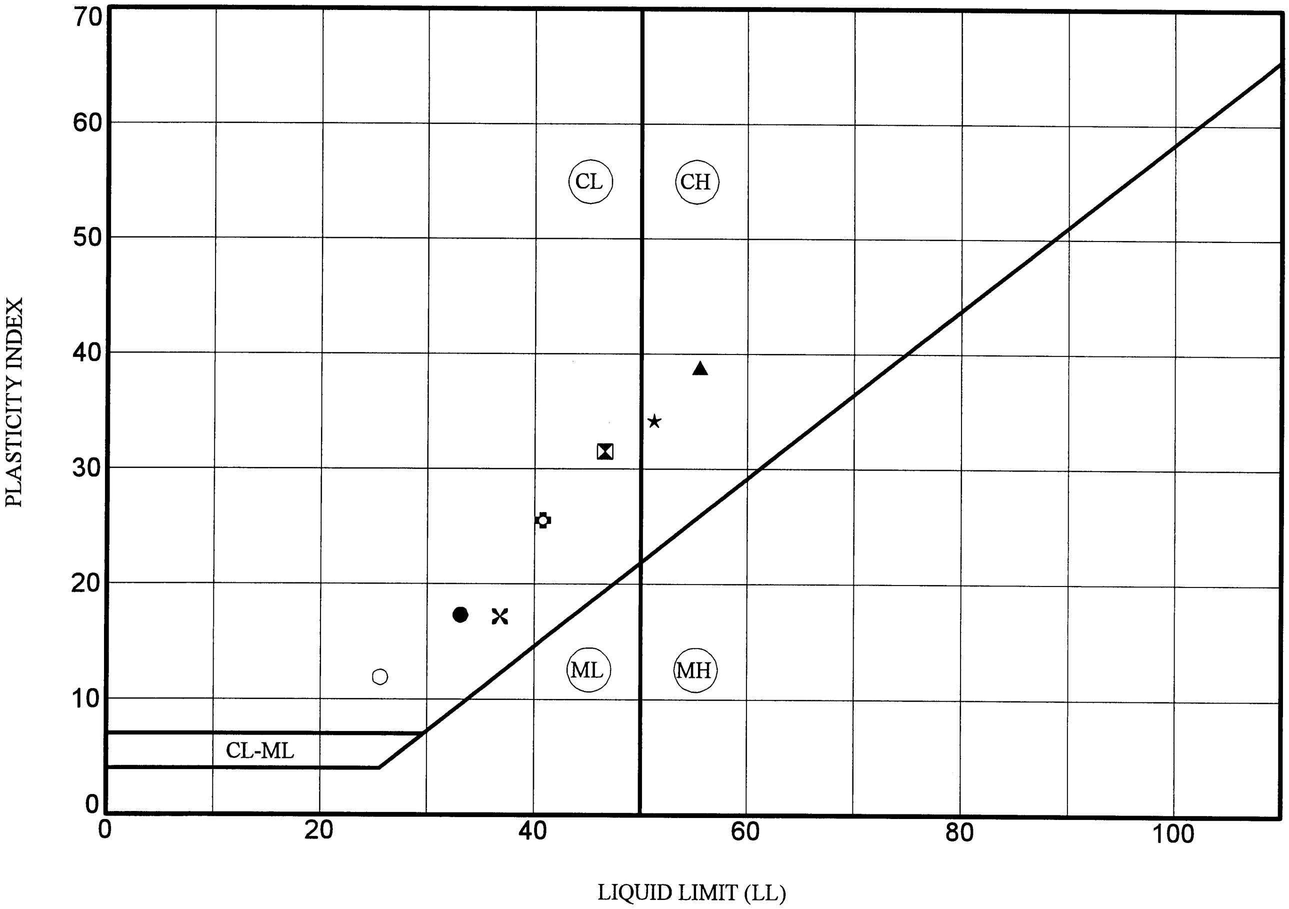
Plate No. 3



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D2**	**9.0**	**33**	**16**	**17**	**17.1**	**Clayey Gravel With Sand GC**
☒	**D2**	**10.0**	**47**	**15**	**32**	**74.6**	**Lean Clay With Sand CL**
▲	**D2**	**11.0**	**56**	**17**	**39**	**84.3**	**Fat Clay With Sand CH**
★	**D2**	**12.0**	**51**	**17**	**34**	**32.7**	**Clayey Gravel With Sand GC**
×	**D2**	**13.0**	**37**	**20**	**17**	**24.1**	**Clayey Sand With Gravel SC**
✿	**D2**	**14.0**	**41**	**15**	**26**	**46.9**	**Clayey Sand SC**
○	**D2**	**15.0**	**26**	**14**	**12**	**16.6**	**Clayey Gravel With Sand GC**

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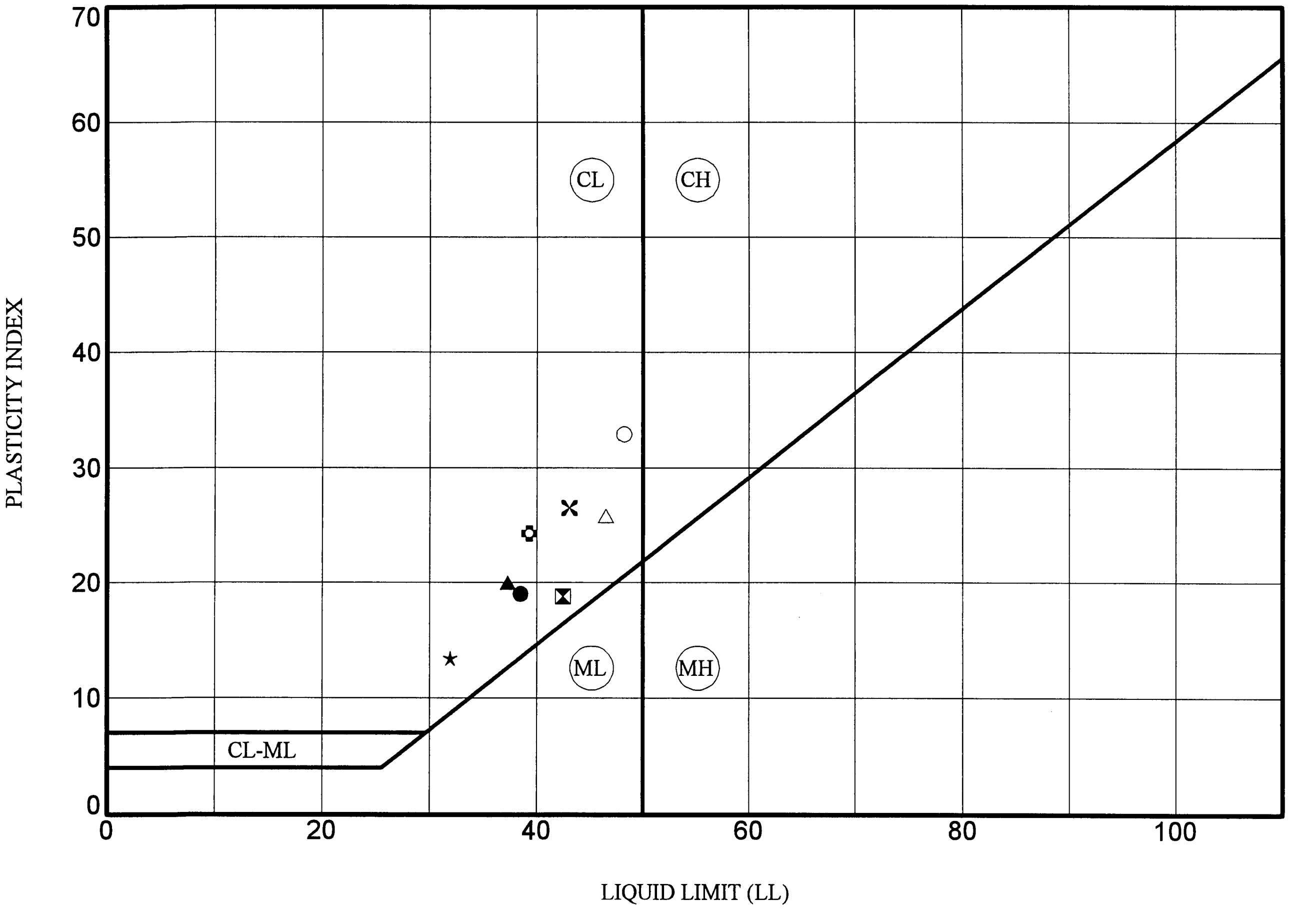
Plate No. 4



Specimen Identification			LL	PL	PI	Fines	Classification
●	**D3**	**1.0**	**39**	**20**	**19**	**62.8**	**Sandy Lean Clay CL**
⊠	**D3**	**2.0**	**43**	**24**	**19**	**54.6**	**Sandy Lean Clay With Gravel CL**
▲	**D3**	**3.0**	**37**	**17**	**20**	**59.0**	**Sandy Lean Clay CL**
★	**D3**	**5.0**	**32**	**19**	**13**	**59.3**	**Sandy Lean Clay CL**
✕	**D3**	**7.0**	**43**	**17**	**27**	**90.5**	**Lean Clay CL**
✤	**D3**	**8.0**	**39**	**15**	**24**	**78.1**	**Lean Clay With Sand CL**
○	**D3**	**10.0**	**48**	**15**	**33**	**86.9**	**Lean Clay CL**
△	**D3**	**11.0**	**47**	**21**	**26**	**72.5**	**Lean Clay With Sand CL**

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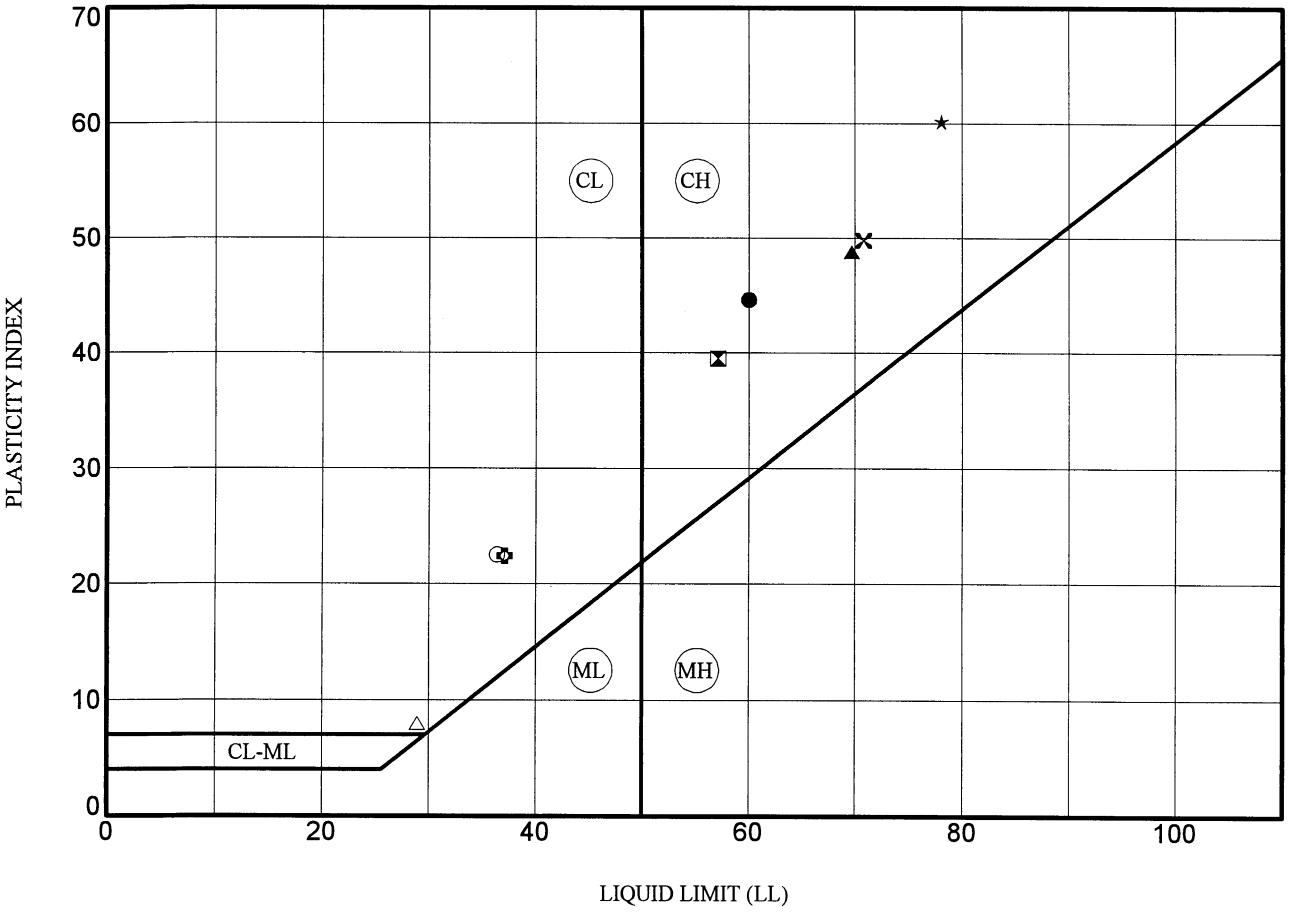
Plate No. 5



	Specimen Identification	LL	PL	PI	Fines	Classification
●	**D4 1.0**	**60**	**15**	**45**	**0.8**	**Poorly Graded Sand SP**
☒	**D4 2.0**	**57**	**18**	**40**	**72.7**	**Fat Clay With Sand CH**
▲	**D4 3.0**	**70**	**21**	**49**	**95.1**	**Fat Clay CH**
★	**D4 5.0**	**78**	**18**	**60**	**81.2**	**Fat Clay With Gravel CH**
✕	**D4 6.0**	**71**	**21**	**50**	**79.9**	**Fat Clay With Sand CH**
✿	**D4 7.0**	**37**	**15**	**22**	**70.2**	**Lean Clay With Sand CL**
○	**D4 8.0**	**36**	**14**	**23**	**79.4**	**Lean Clay With Sand CL**
△	**D4 9.0**	**29**	**21**	**8**	**65.8**	**Sandy Lean Clay CL**

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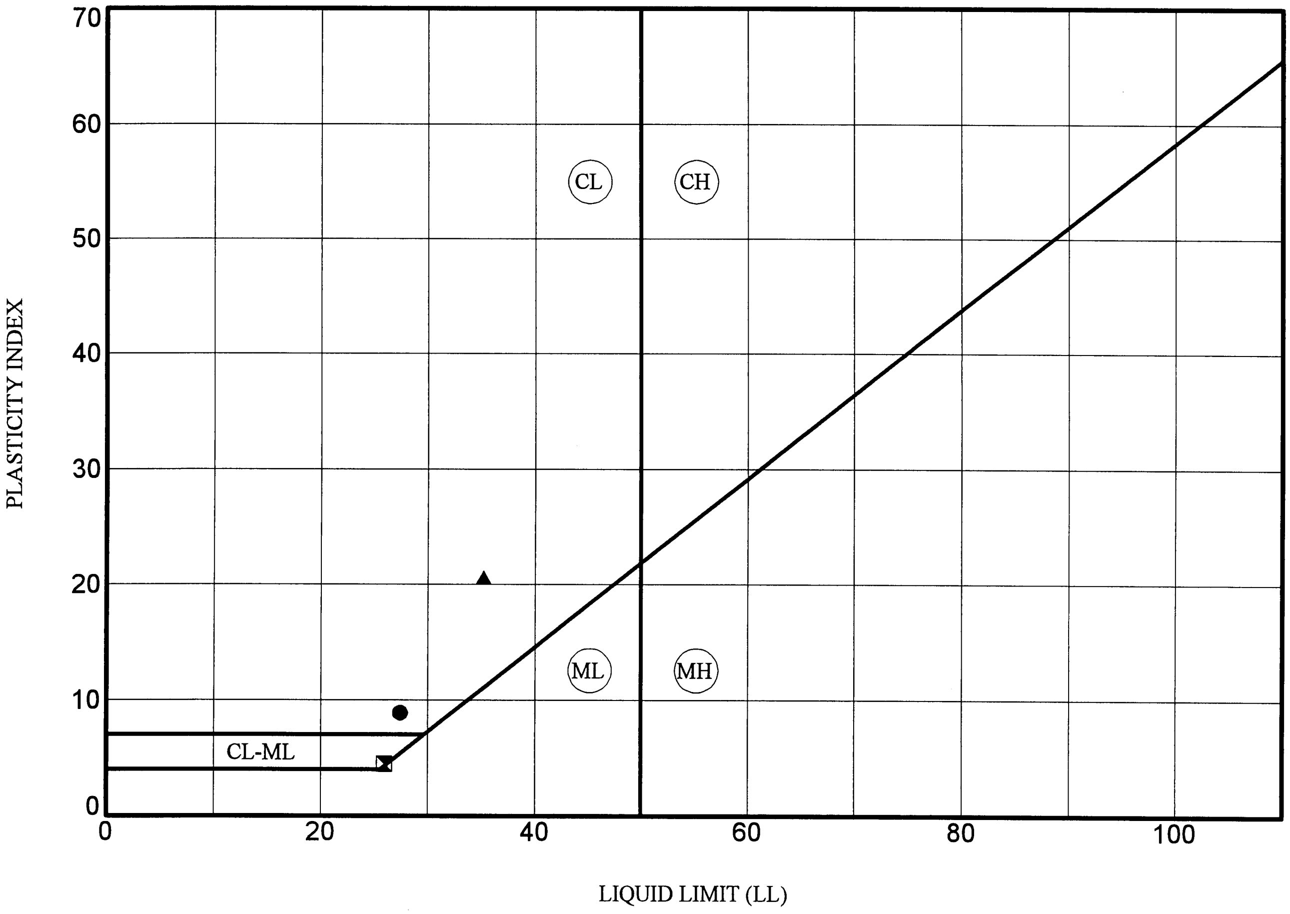
Plate No. 6



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D4**	**10.0**	**27**	**19**	**9**	**7.3**	**Well-graded Gravel With Clay And Sand GW-GC**
⧗	**D4**	**11.0**	**26**	**21**	**5**	**80.0**	**Silty Clay With Sand CL-ML**
▲	**D4**	**12.0**	**35**	**15**	**21**	**24.1**	**Clayey Sand With Gravel SC**

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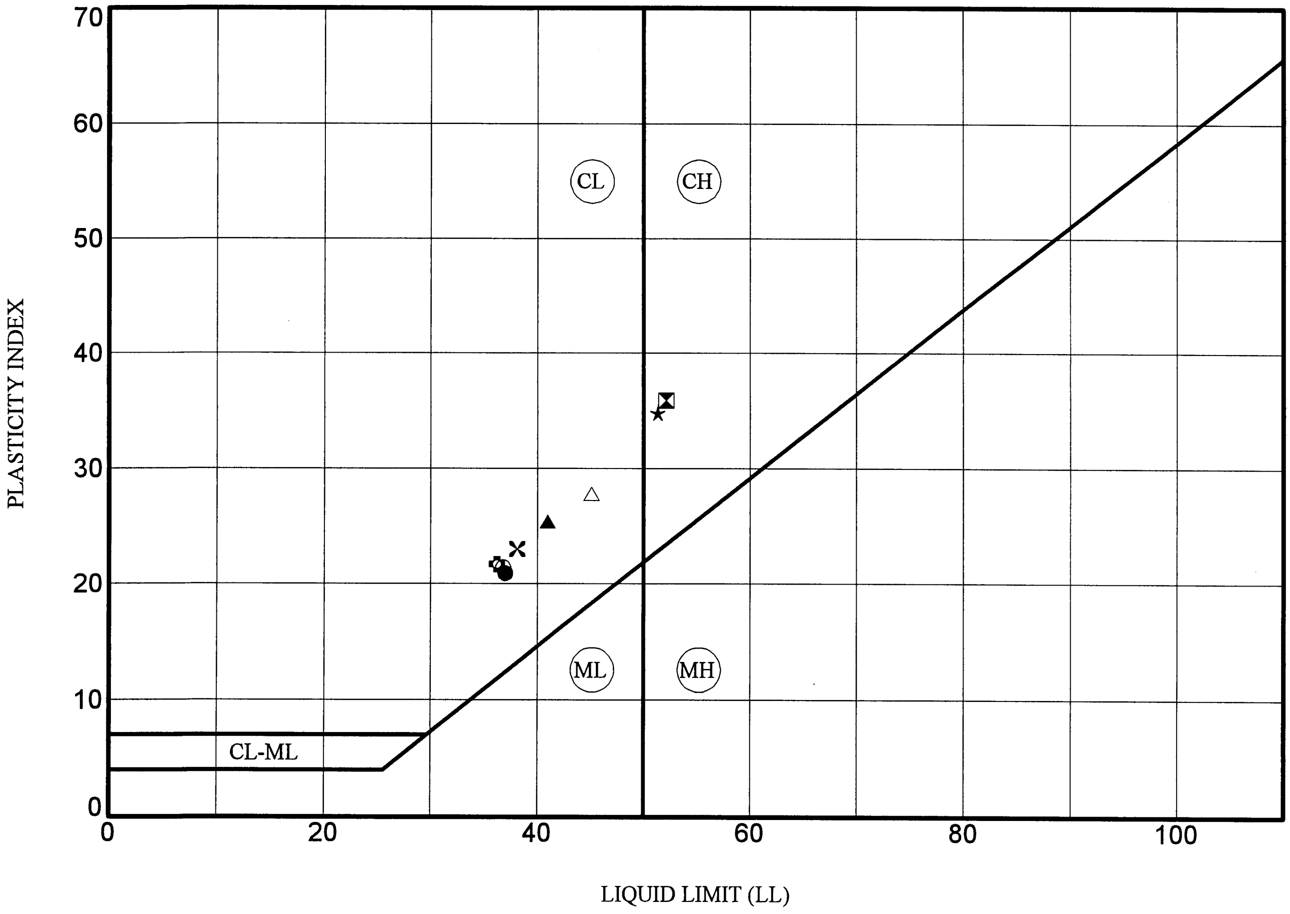
Plate No. 7



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D5**	**1.0**	**37**	**16**	**21**	**74.8**	**Lean Clay With Sand CL**
☒	**D5**	**2.0**	**52**	**16**	**36**	**95.7**	**Fat Clay CH**
▲	**D5**	**3.0**	**41**	**16**	**25**	**36.9**	**Clayey Gravel With Sand GC**
★	**D5**	**4.0**	**51**	**17**	**35**	**94.1**	**Fat Clay CH**
×	**D5**	**5.0**	**38**	**15**	**23**	**78.0**	**Lean Clay With Sand CL**
✤	**D5**	**6.0**	**36**	**15**	**22**	**88.0**	**Lean Clay CL**
○	**D5**	**7.0**	**37**	**15**	**21**	**76.2**	**Lean Clay With Sand CL**
△	**D5**	**8.0**	**45**	**17**	**28**	**91.8**	**Lean Clay CL**

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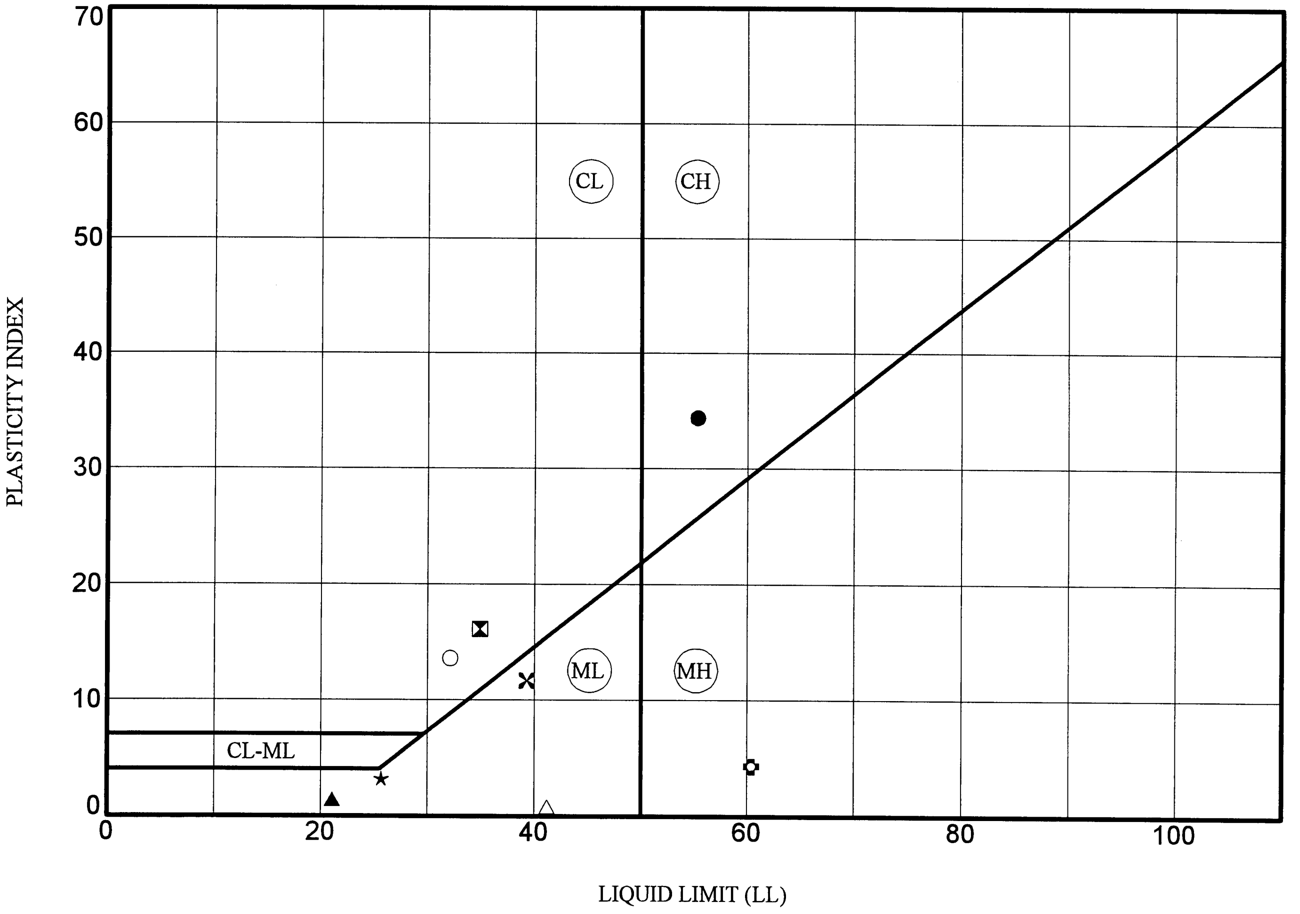

Specimen Identification			LL	PL	PI	Fines	Classification
●	**D5**	**9.0**	**55**	**21**	**34**	**46.9**	**Clayey Gravel With Sand GC**
⌧	**D5**	**10.0**	**35**	**19**	**16**	**60.8**	**Sandy Lean Clay CL**
▲	**D5**	**11.0**	**21**	**20**	**1**	**20.6**	**Silty Sand With Gravel SM**
★	**D5**	**12.0**	**26**	**23**	**3**	**14.6**	**Silty Sand With Gravel SM**
✕	**D5**	**13.0**	**39**	**28**	**12**	**26.7**	**Silty Sand With Gravel SM**
✿	**D5**	**14.0**	**60**	**56**	**4**	**37.6**	**Silty Sand SM**
○	**D5**	**15.0**	**32**	**19**	**14**	**31.4**	**Clayey Gravel With Sand GC**
△	**D5**	**16.0**	**41**	**40**	**1**	**11.0**	**Poorly Graded Gravel With Silt And Sand GP-GM**

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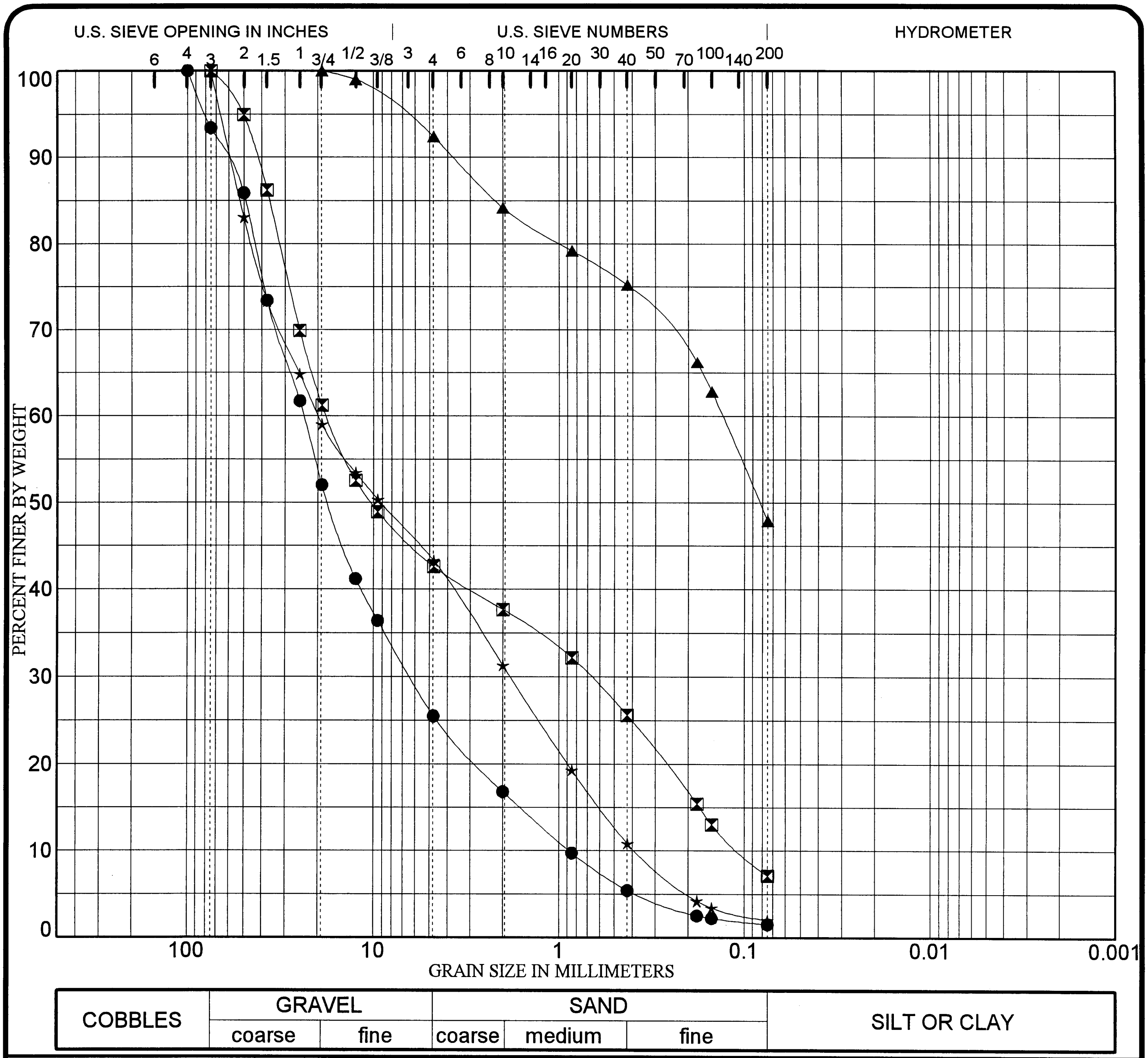

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	D1	1.0	**Well-graded Gravel With Sand GW**	1	NP	NP	NP	1.90	27.0
⊠	D1	2.0	**Poorly Graded Gravel With Silt And Sand GP-GM**	1	NP	NP	NP	0.24	170.1
▲	D1	3.0	**Silty Sand SM**	1	25	26	NP		
★	D1	4.0	**Poorly Graded Gravel With Sand GP**	1	NP	NP	NP	0.44	52.0

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	D1	1.0	100.00	23.83	6.324	0.8813	67.9	24.0	1.5	
⊠	D1	2.0	75.00	17.93	0.675	0.1054	57.4	35.5	7.1	
▲	D1	3.0	19.00	0.13			7.6	44.5	47.9	
★	D1	4.0	75.00	19.92	1.823	0.3830	56.7	41.3	2.0	

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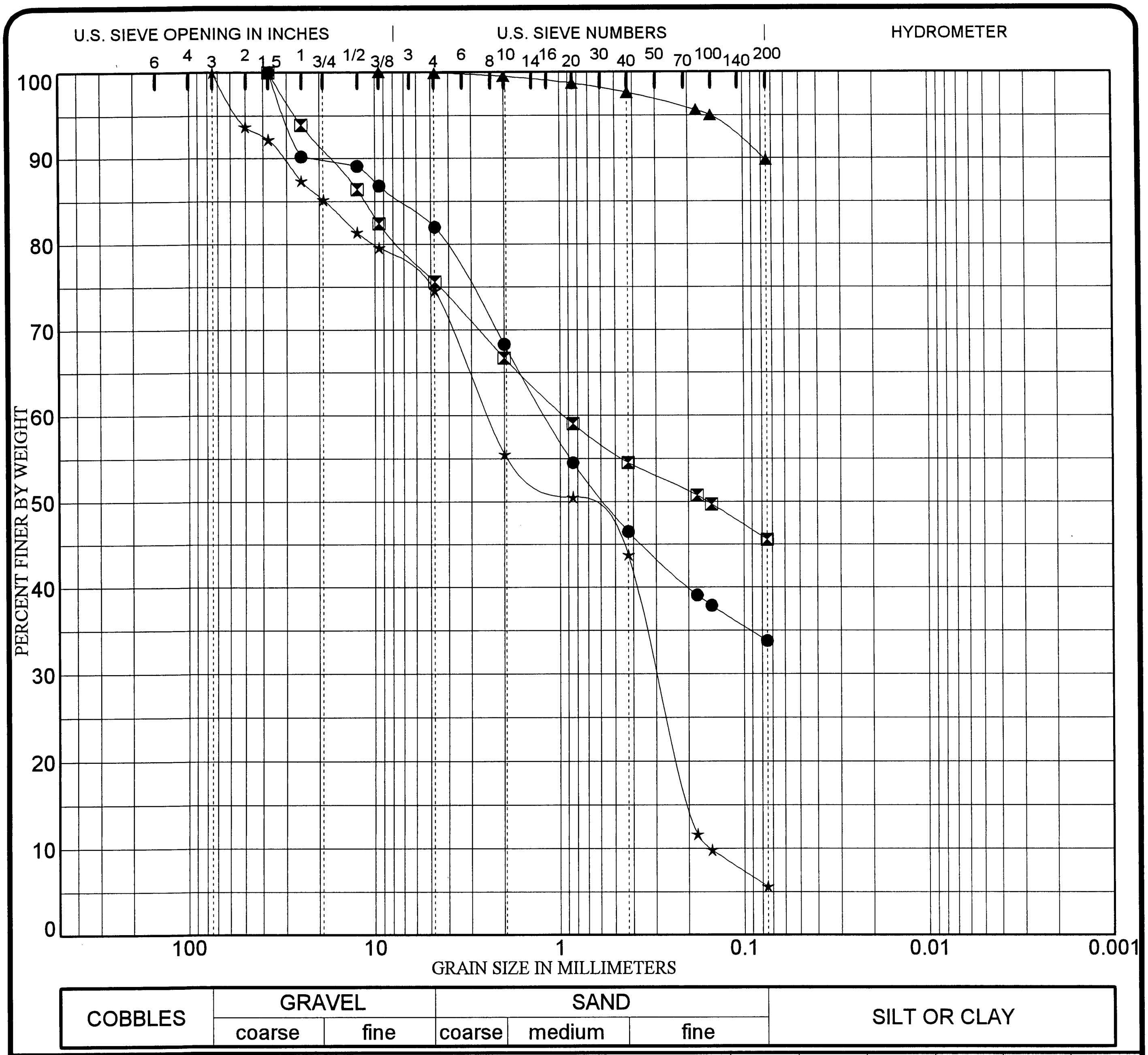

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**5.0**	**Silty Sand With Gravel SM**	**1**	**33**	**30**	**3**		
☒	**D1**	**6.0**	**Silty Sand With Gravel SM**	**1**	**36**	**32**	**4**		
▲	**D1**	**7.0**	**Silt ML**	**1**	**30**	**24**	**6**		
★	**D1**	**8.0**	**Poorly Graded Sand With Silt And Gravel SP-SM**	**1**	**NP**	**NP**	**NP**	**0.23**	**16.0**

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**5.0**	**37.50**	**1.20**			**18.0**	**48.2**	**33.8**	
☒	**D1**	**6.0**	**37.50**	**0.95**			**24.4**	**30.0**	**45.6**	
▲	**D1**	**7.0**	**9.50**				**0.1**	**10.1**	**89.8**	
★	**D1**	**8.0**	**75.00**	**2.45**	**0.294**	**0.1531**	**25.4**	**69.0**	**5.6**	

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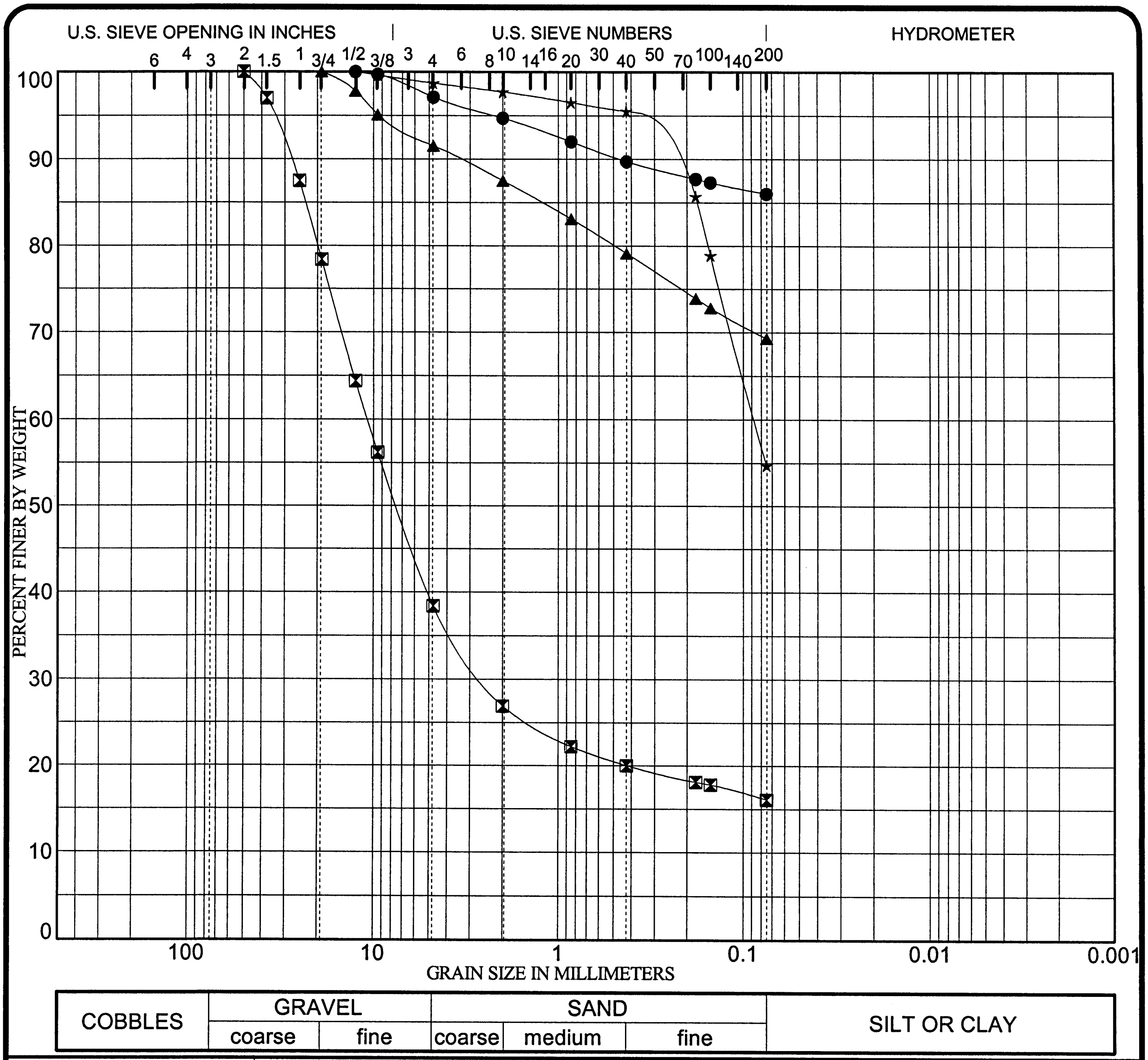

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**9.0**	**Silt ML**	**1**	**25**	**25**	**NP**		
⧗	**D1**	**10.0**	**Silty Gravel With Sand GM**	**1**	**49**	**47**	**3**		
▲	**D1**	**11.0**	**Sandy Silt ML**	**1**	**42**	**32**	**10**		
★	**D1**	**12.0**	**Sandy Silt ML**	**1**	**25**	**22**	**4**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**9.0**	**12.50**				**2.9**	**11.1**	**86.0**	
⧗	**D1**	**10.0**	**50.00**	**10.79**	**2.525**		**61.6**	**22.3**	**16.1**	
▲	**D1**	**11.0**	**19.00**				**8.5**	**22.2**	**69.3**	
★	**D1**	**12.0**	**12.50**	**0.09**			**1.3**	**44.0**	**54.7**	

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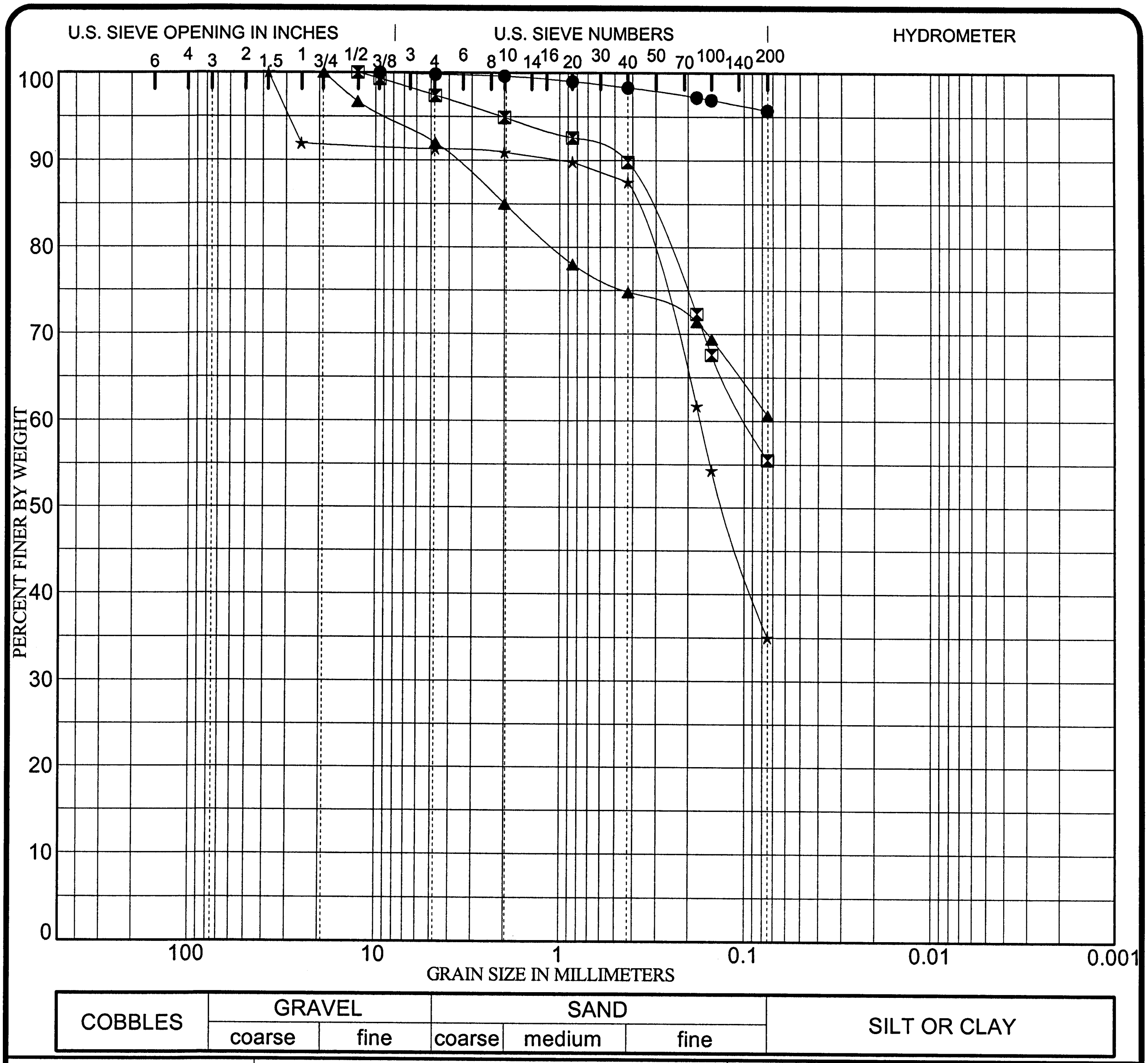

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**13.0**	**Lean Clay CL**	**1**	**42**	**21**	**21**		
☒	**D1**	**14.0**	**Sandy Silty Clay CL-ML**	**1**	**28**	**22**	**6**		
▲	**D1**	**15.0**	**Sandy Silt ML**	**1**	**38**	**27**	**11**		
★	**D1**	**16.0**	**Silty Sand SM**	**1**	**NP**	**NP**	**NP**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**13.0**	**9.50**				**0.2**	**4.1**	**95.7**	
☒	**D1**	**14.0**	**12.50**	**0.10**			**2.6**	**41.9**	**55.5**	
▲	**D1**	**15.0**	**19.00**				**8.0**	**31.4**	**60.6**	
★	**D1**	**16.0**	**37.50**	**0.17**			**8.7**	**56.3**	**35.0**	

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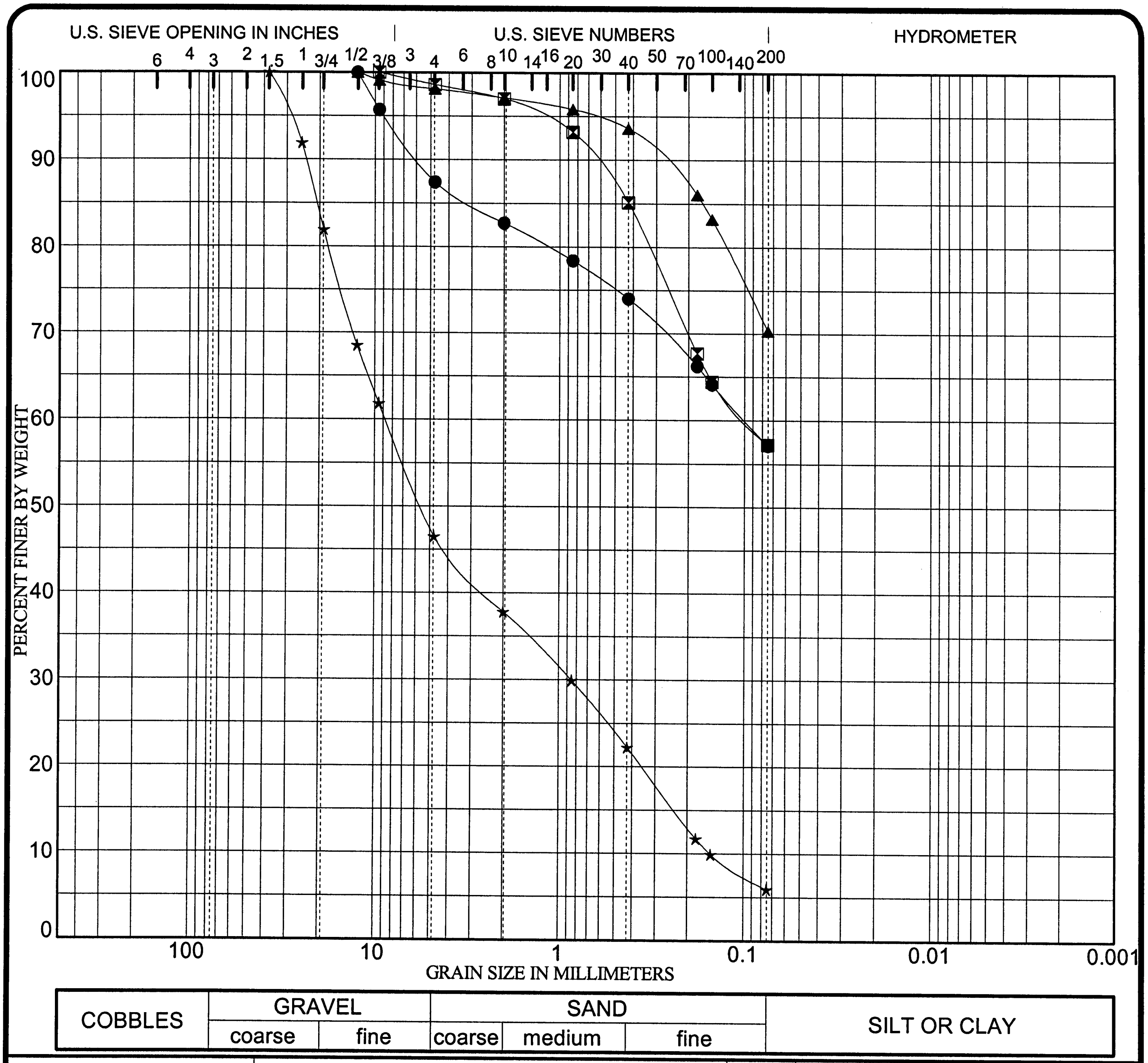
Plate No. 13



	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**1.0**	**Sandy Elastic Silt MH**		**50**	**29**	**22**		
☒	**D2**	**2.0**	**Sandy Lean Clay CL**		**41**	**14**	**27**		
▲	**D2**	**3.0**	**Lean Clay With Sand CL**		**46**	**16**	**30**		
★	**D2**	**4.0**	**Poorly Graded Gravel With Silt And Sand GP-GM**		**NP**	**NP**	**NP**	**0.56**	**57.8**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**1.0**	**12.50**	**0.10**			**12.6**	**30.3**	**57.1**	
☒	**D2**	**2.0**	**9.50**	**0.10**			**1.4**	**41.4**	**57.2**	
▲	**D2**	**3.0**	**12.50**				**1.9**	**27.8**	**70.3**	
★	**D2**	**4.0**	**37.50**	**8.76**	**0.859**	**0.1515**	**53.5**	**40.6**	**5.9**	

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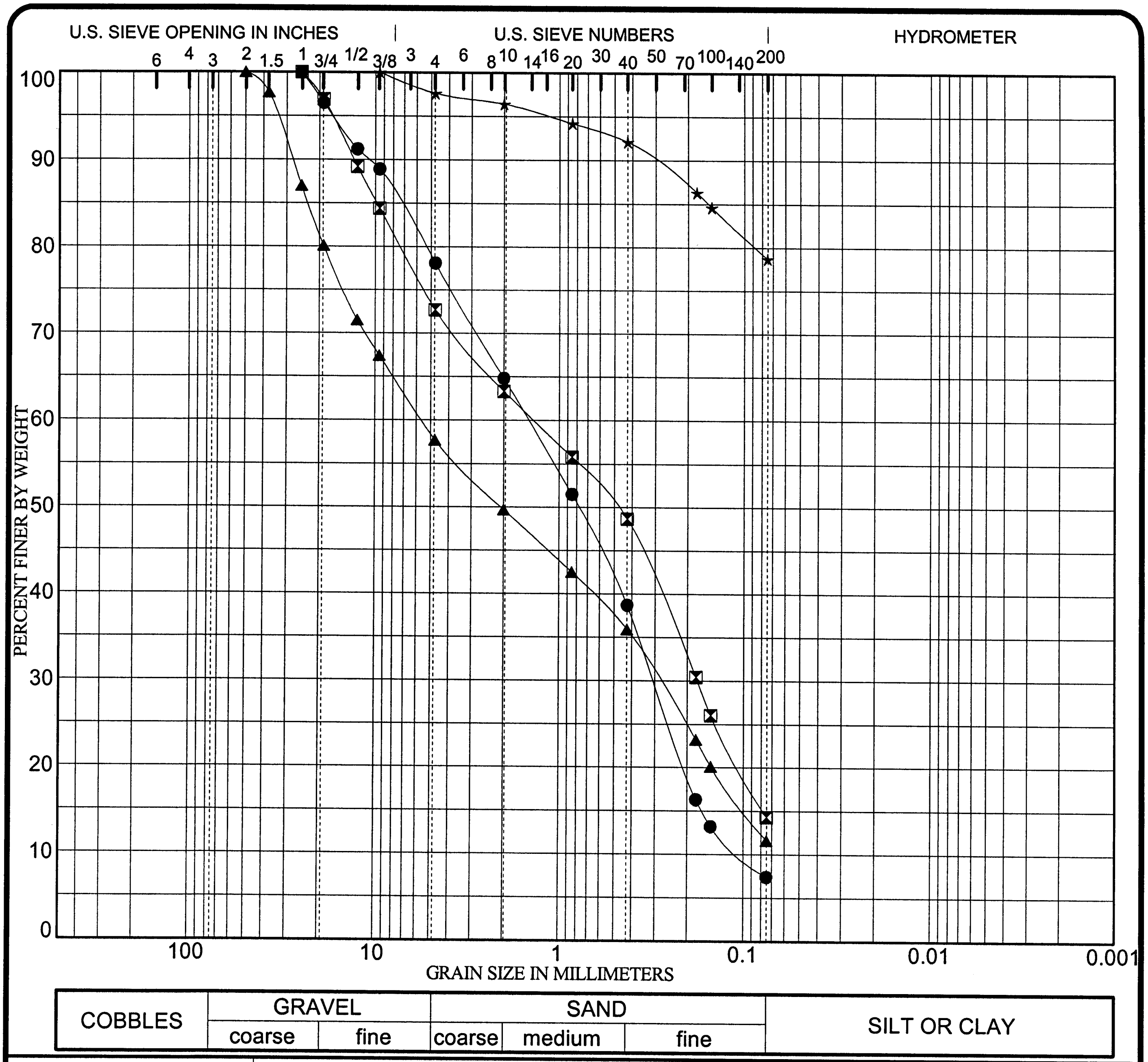
Plate No. 14



Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**5.0**	**Poorly Graded Sand With Silt And Gravel SP-SM**		**NP**	**NP**	**NP**	**0.62**	**14.4**
☒	**D2**	**6.0**	**Silty Sand With Gravel SM**		**NP**	**NP**	**NP**		
▲	**D2**	**7.0**	**Poorly Graded Sand With Silt And Gravel SP-SM**		**NP**	**NP**	**NP**	**0.22**	**85.1**
★	**D2**	**8.0**	**Fat Clay With Sand CH**		**58**	**17**	**41**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**5.0**	**25.00**	**1.47**	**0.304**	**0.1023**	**21.9**	**70.7**	**7.4**	
☒	**D2**	**6.0**	**25.00**	**1.37**	**0.177**		**27.3**	**58.4**	**14.3**	
▲	**D2**	**7.0**	**50.00**	**5.60**	**0.285**		**42.3**	**46.1**	**11.6**	
★	**D2**	**8.0**	**9.50**				**2.4**	**18.9**	**78.7**	

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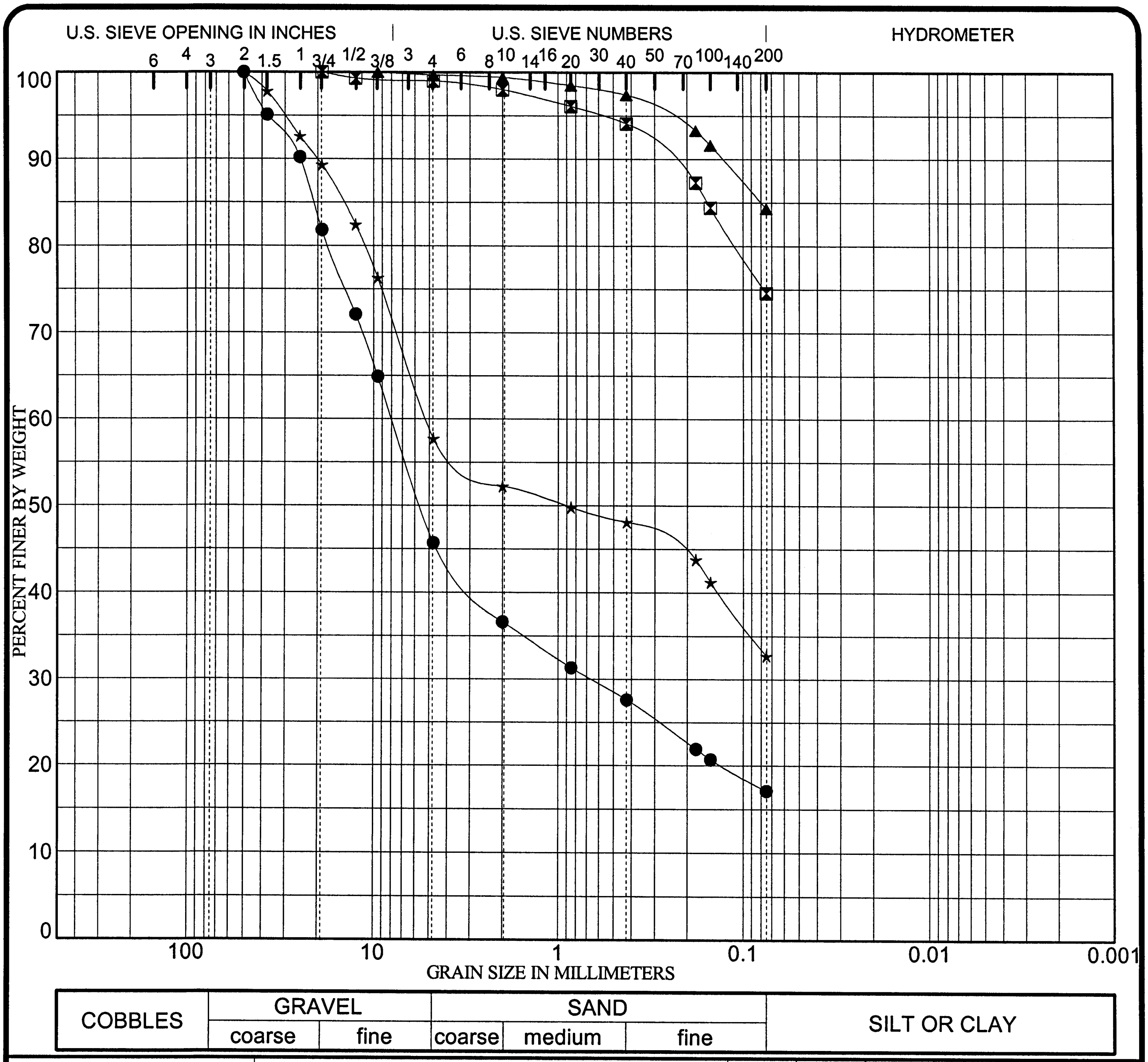

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**9.0**	**Clayey Gravel With Sand GC**		**33**	**16**	**17**		
☒	**D2**	**10.0**	**Lean Clay With Sand CL**		**47**	**15**	**32**		
▲	**D2**	**11.0**	**Fat Clay With Sand CH**		**56**	**17**	**39**		
★	**D2**	**12.0**	**Clayey Gravel With Sand GC**		**51**	**17**	**34**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**9.0**	**50.00**	**7.96**	**0.666**		**54.3**	**28.6**	**17.1**	
☒	**D2**	**10.0**	**19.00**				**1.0**	**24.4**	**74.6**	
▲	**D2**	**11.0**	**9.50**				**0.3**	**15.4**	**84.3**	
★	**D2**	**12.0**	**50.00**	**5.18**			**42.3**	**25.0**	**32.7**	

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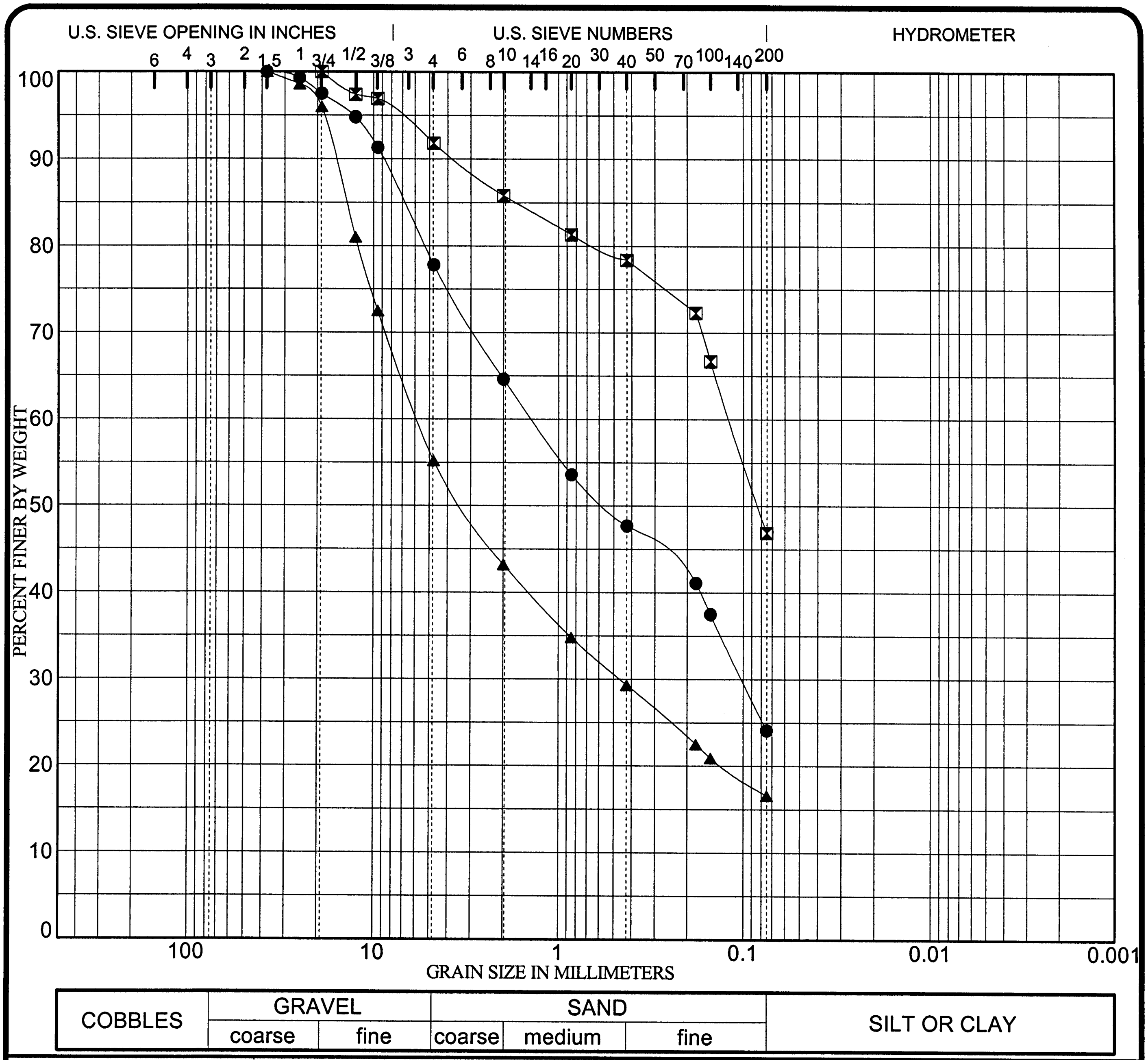
Plate No. 16



Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**13.0**	**Clayey Sand With Gravel SC**		**37**	**20**	**17**		
⊠	**D2**	**14.0**	**Clayey Sand SC**		**41**	**15**	**26**		
▲	**D2**	**15.0**	**Clayey Gravel With Sand GC**		**26**	**14**	**12**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**13.0**	**37.50**	**1.40**	**0.102**		**22.2**	**53.7**	**24.1**	
⊠	**D2**	**14.0**	**19.00**	**0.12**			**8.2**	**44.9**	**46.9**	
▲	**D2**	**15.0**	**37.50**	**5.76**	**0.464**		**44.8**	**38.6**	**16.6**	

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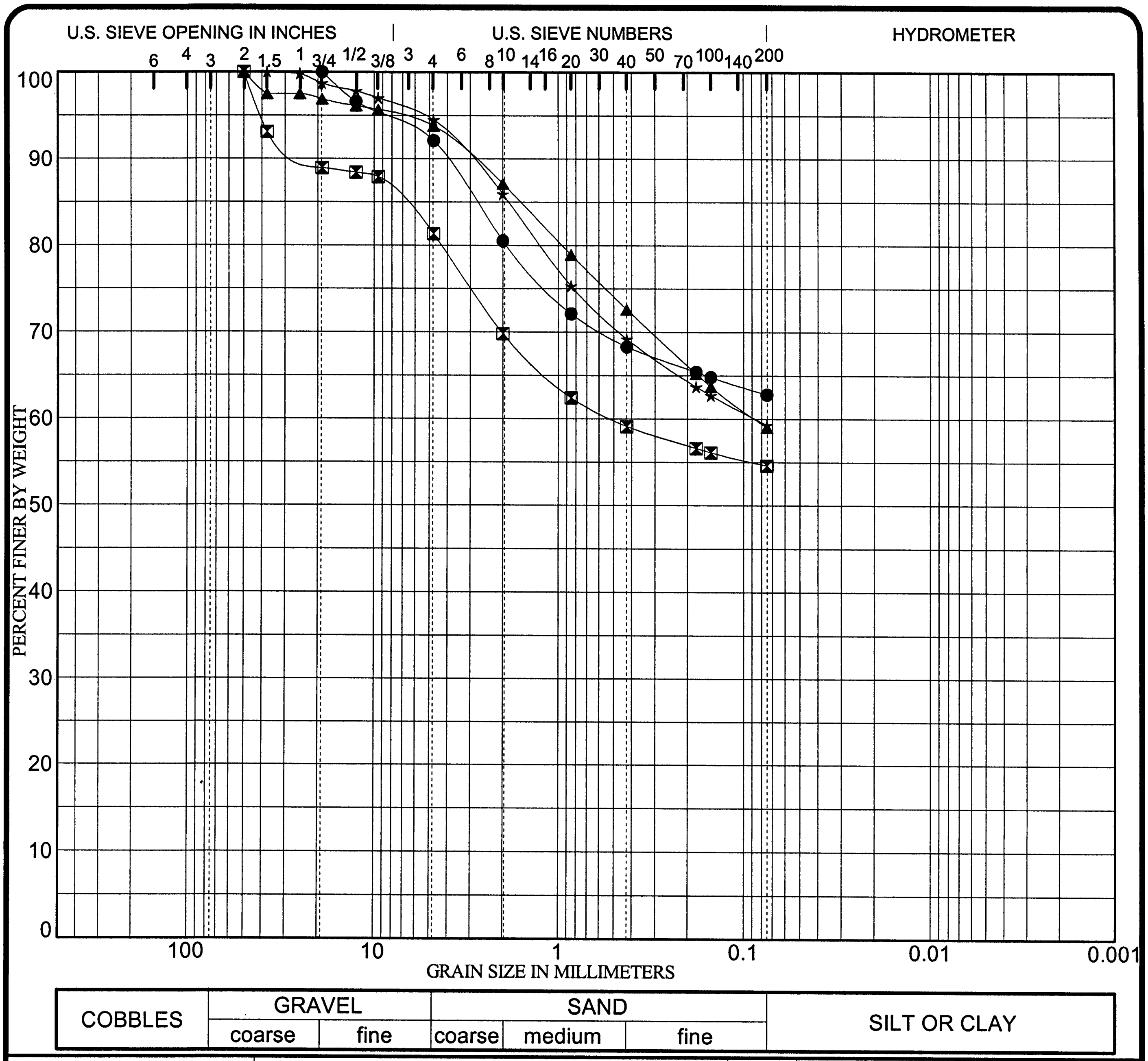

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D3**	**1.0**	**Sandy Lean Clay CL**		**39**	**20**	**19**		
⧗	**D3**	**2.0**	**Sandy Lean Clay With Gravel CL**		**43**	**24**	**19**		
▲	**D3**	**3.0**	**Sandy Lean Clay CL**		**37**	**17**	**20**		
★	**D3**	**5.0**	**Sandy Lean Clay CL**		**32**	**19**	**13**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D3**	**1.0**	**19.00**				**7.9**	**29.3**	**62.8**	
⧗	**D3**	**2.0**	**50.00**	**0.51**			**18.7**	**26.7**	**54.6**	
▲	**D3**	**3.0**	**50.00**	**0.09**			**6.2**	**34.8**	**59.0**	
★	**D3**	**5.0**	**37.50**	**0.09**			**5.5**	**35.2**	**59.3**	

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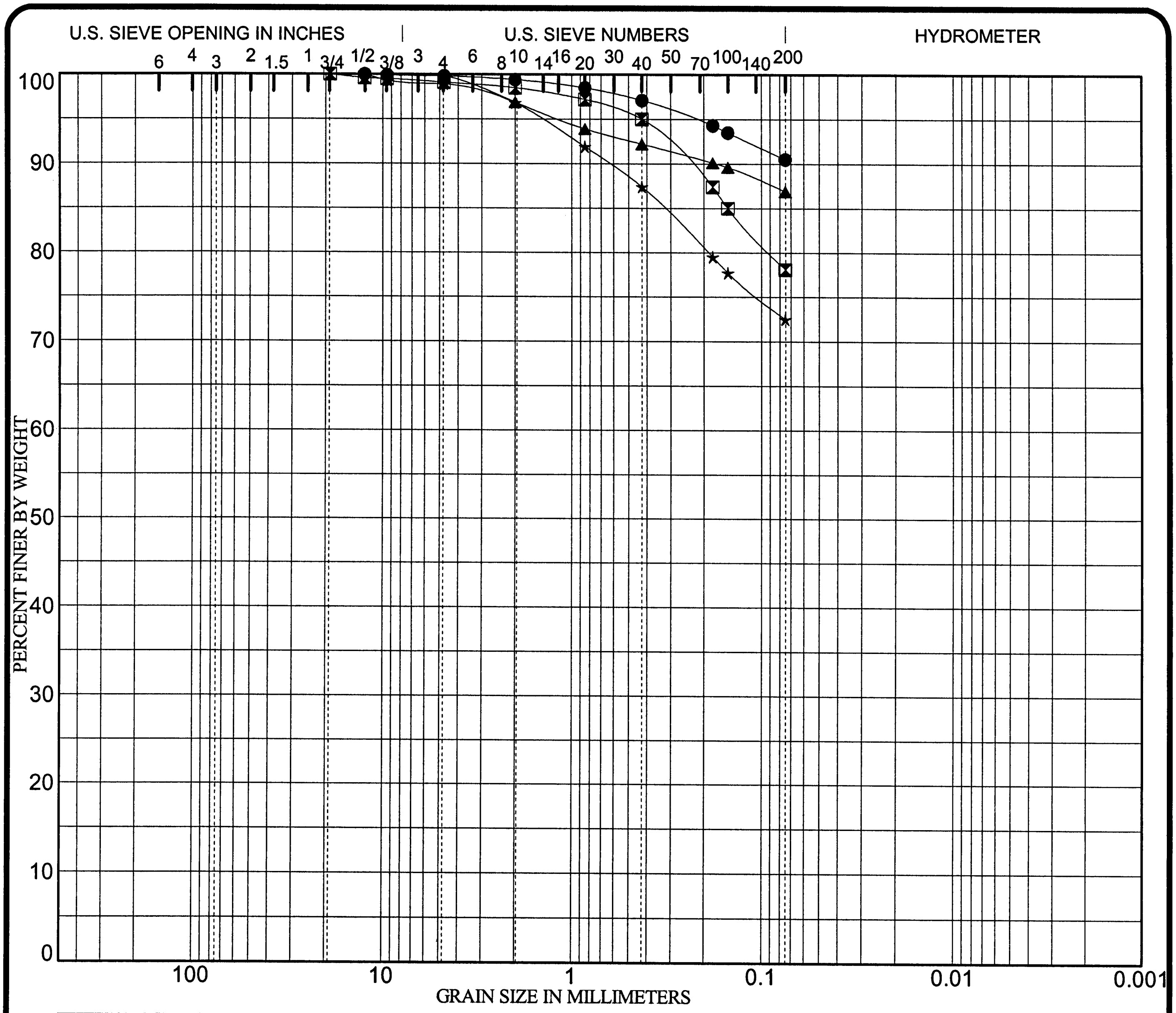

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D3**	**7.0**	**Lean Clay CL**		**43**	**17**	**27**		
⧗	**D3**	**8.0**	**Lean Clay With Sand CL**		**39**	**15**	**24**		
▲	**D3**	**10.0**	**Lean Clay CL**		**48**	**15**	**33**		
★	**D3**	**11.0**	**Lean Clay With Sand CL**		**47**	**21**	**26**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D3**	**7.0**	**12.50**				**0.2**	**9.3**	**90.5**	
⧗	**D3**	**8.0**	**19.00**				**0.9**	**21.0**	**78.1**	
▲	**D3**	**10.0**	**9.50**				**0.2**	**12.9**	**86.9**	
★	**D3**	**11.0**	**12.50**				**1.1**	**26.4**	**72.5**	

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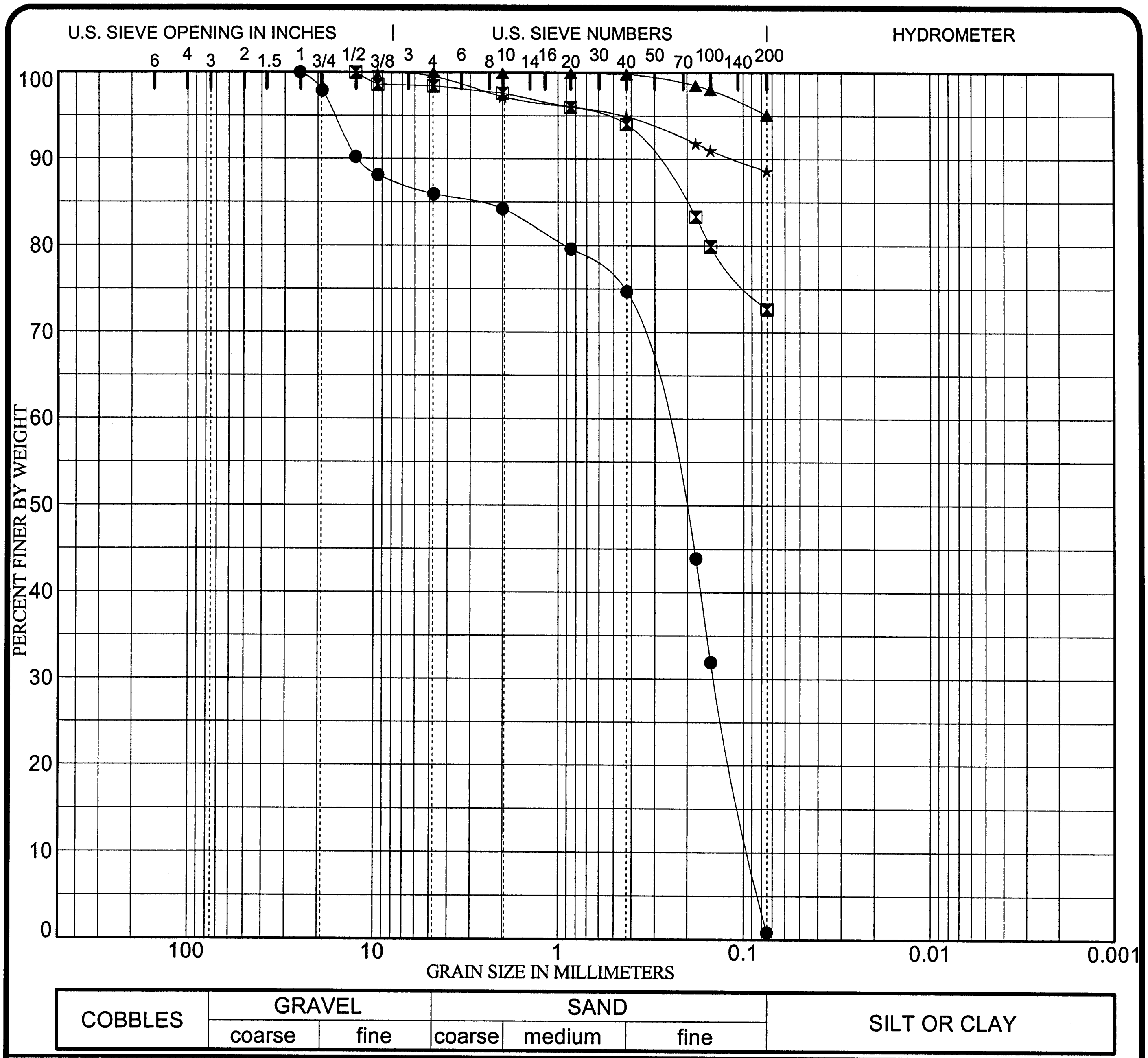
Plate No. 19



Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D4**	**1.0**	**Poorly Graded Sand SP**		**60**	**15**	**45**	**0.80**	**3.1**
☒	**D4**	**2.0**	**Fat Clay With Sand CH**		**57**	**18**	**40**		
▲	**D4**	**3.0**	**Fat Clay CH**		**70**	**21**	**49**		
★	**D4**	**4.0**	**Fat Clay CH**		**103**	**21**	**81**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D4**	**1.0**	**25.00**	**0.28**	**0.144**	**0.0921**	**14.1**	**85.1**	**0.8**	
☒	**D4**	**2.0**	**12.50**				**1.6**	**25.7**	**72.7**	
▲	**D4**	**3.0**	**4.75**				**0.0**	**4.9**	**95.1**	
★	**D4**	**4.0**	**9.50**				**0.5**	**10.9**	**88.6**	

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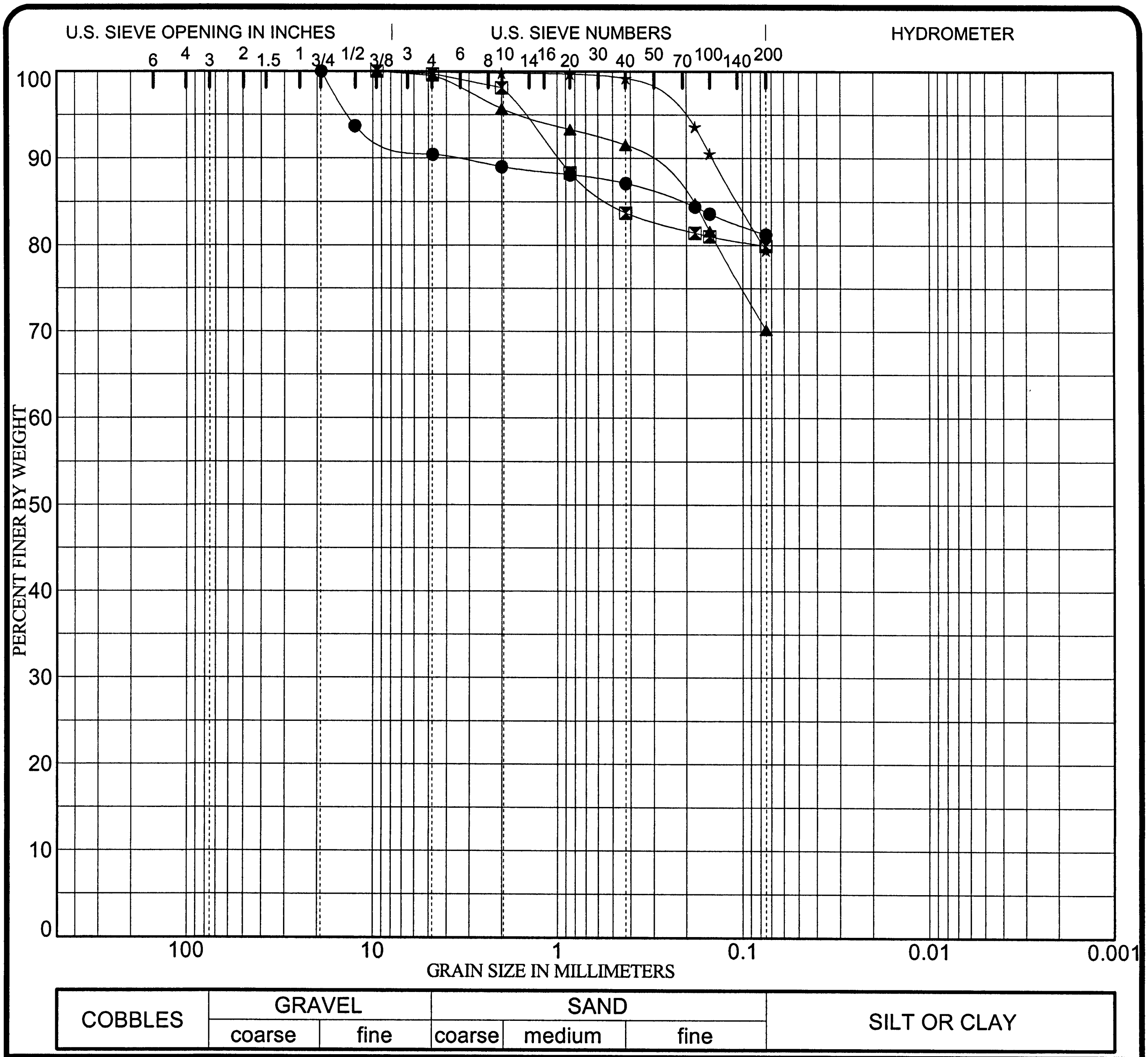
Plate No. 20



Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	D4	5.0	Fat Clay With Gravel CH		78	18	60		
⧗	D4	6.0	Fat Clay With Sand CH		71	21	50		
▲	D4	7.0	Lean Clay With Sand CL		37	15	22		
★	D4	8.0	Lean Clay With Sand CL		36	14	23		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	D4	5.0	19.00				9.6	9.2	81.2	
⧗	D4	6.0	9.50				0.3	19.8	79.9	
▲	D4	7.0	9.50				0.5	29.3	70.2	
★	D4	8.0	9.50				0.1	20.5	79.4	

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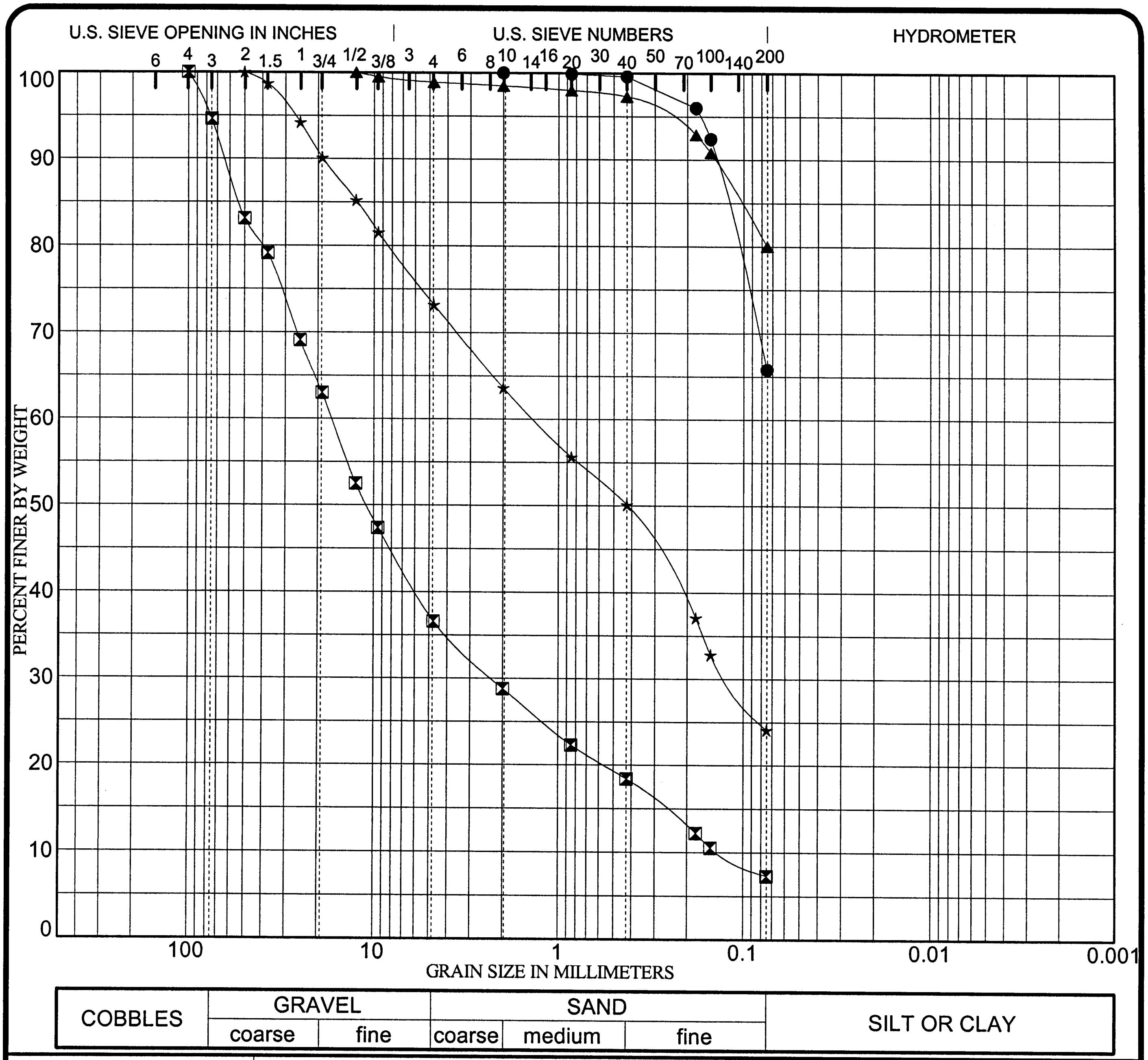

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	D4	9.0	Sandy Lean Clay CL		29	21	8		
☒	D4	10.0	Well-graded Gravel With Clay And Sand GW-GC		27	19	9	2.30	125.2
▲	D4	11.0	Silty Clay With Sand CL-ML		26	21	5		
★	D4	12.0	Clayey Sand With Gravel SC		35	15	21		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	D4	9.0	2.00				0.0	34.2	65.8	
☒	D4	10.0	100.00	16.86	2.285	0.1346	58.0	29.3	7.3	
▲	D4	11.0	12.50				1.1	18.9	80.0	
★	D4	12.0	50.00	1.36	0.120		26.8	49.1	24.1	

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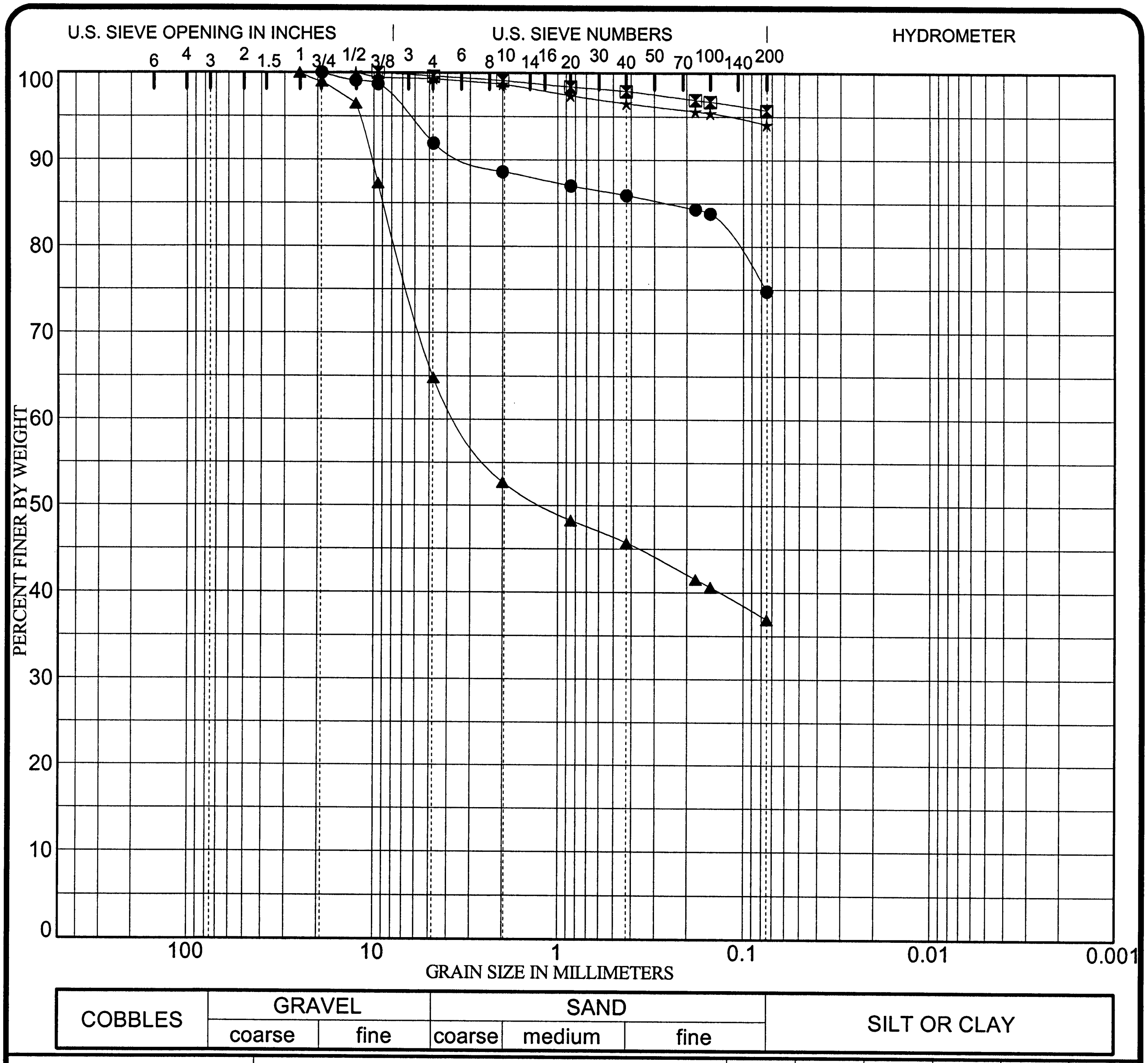

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D5**	**1.0**	**Lean Clay With Sand CL**		**37**	**16**	**21**		
☒	**D5**	**2.0**	**Fat Clay CH**		**52**	**16**	**36**		
▲	**D5**	**3.0**	**Clayey Gravel With Sand GC**		**41**	**16**	**25**		
★	**D5**	**4.0**	**Fat Clay CH**		**51**	**17**	**35**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D5**	**1.0**	**19.00**				**8.1**	**17.1**	**74.8**	
☒	**D5**	**2.0**	**9.50**				**0.4**	**3.9**	**95.7**	
▲	**D5**	**3.0**	**25.00**	**3.37**			**35.2**	**27.9**	**36.9**	
★	**D5**	**4.0**	**12.50**				**0.7**	**5.2**	**94.1**	

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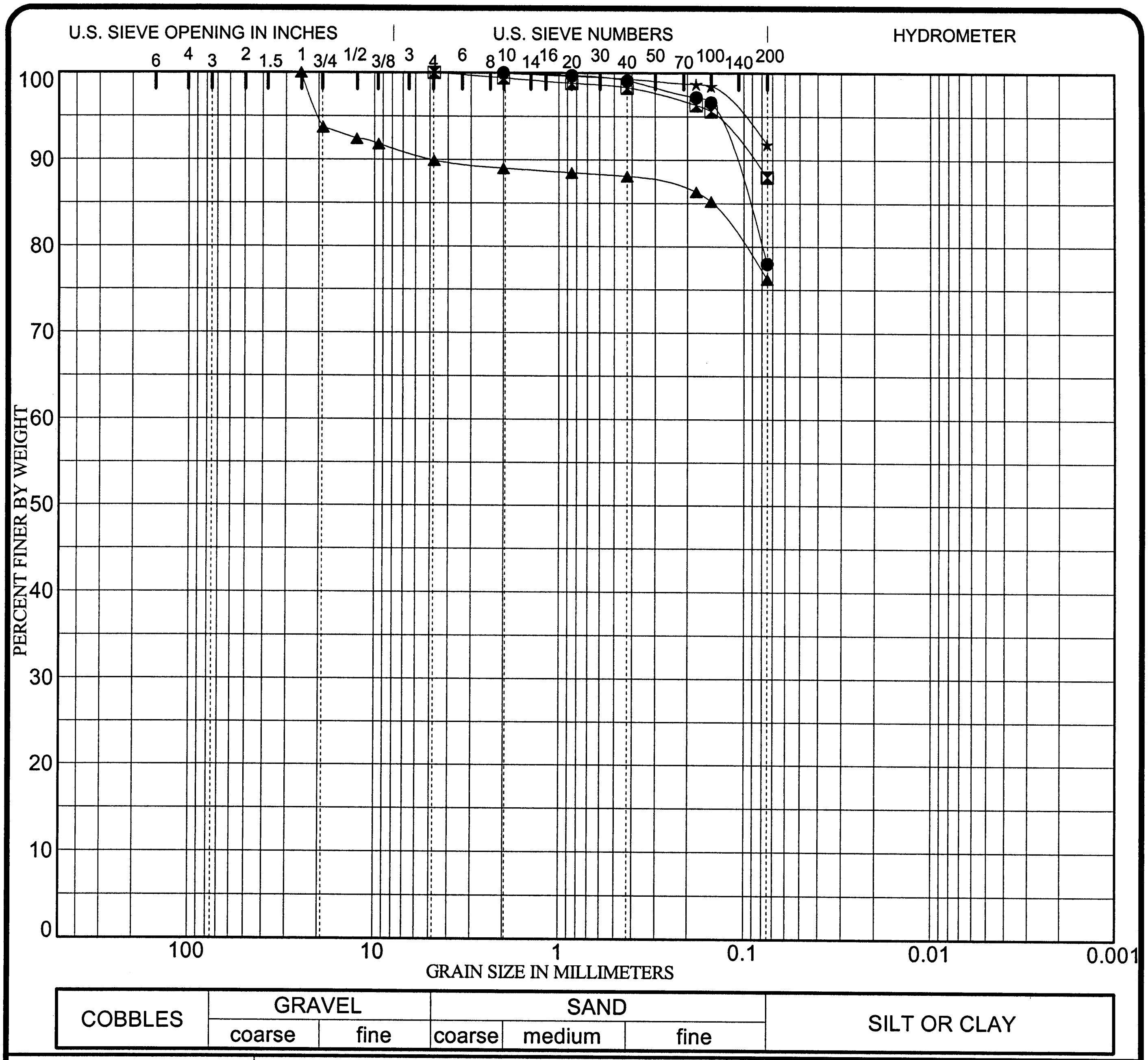

Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
● **D5 5.0**	**Lean Clay With Sand CL**		**38**	**15**	**23**		
⧗ **D5 6.0**	**Lean Clay CL**		**36**	**15**	**22**		
▲ **D5 7.0**	**Lean Clay With Sand CL**		**37**	**15**	**21**		
★ **D5 8.0**	**Lean Clay CL**		**45**	**17**	**28**		

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **D5 5.0**	**2.00**				**0.0**	**22.0**	**78.0**	
⧗ **D5 6.0**	**4.75**				**0.0**	**12.0**	**88.0**	
▲ **D5 7.0**	**25.00**				**10.1**	**13.7**	**76.2**	
★ **D5 8.0**	**4.75**				**0.0**	**8.2**	**91.8**	

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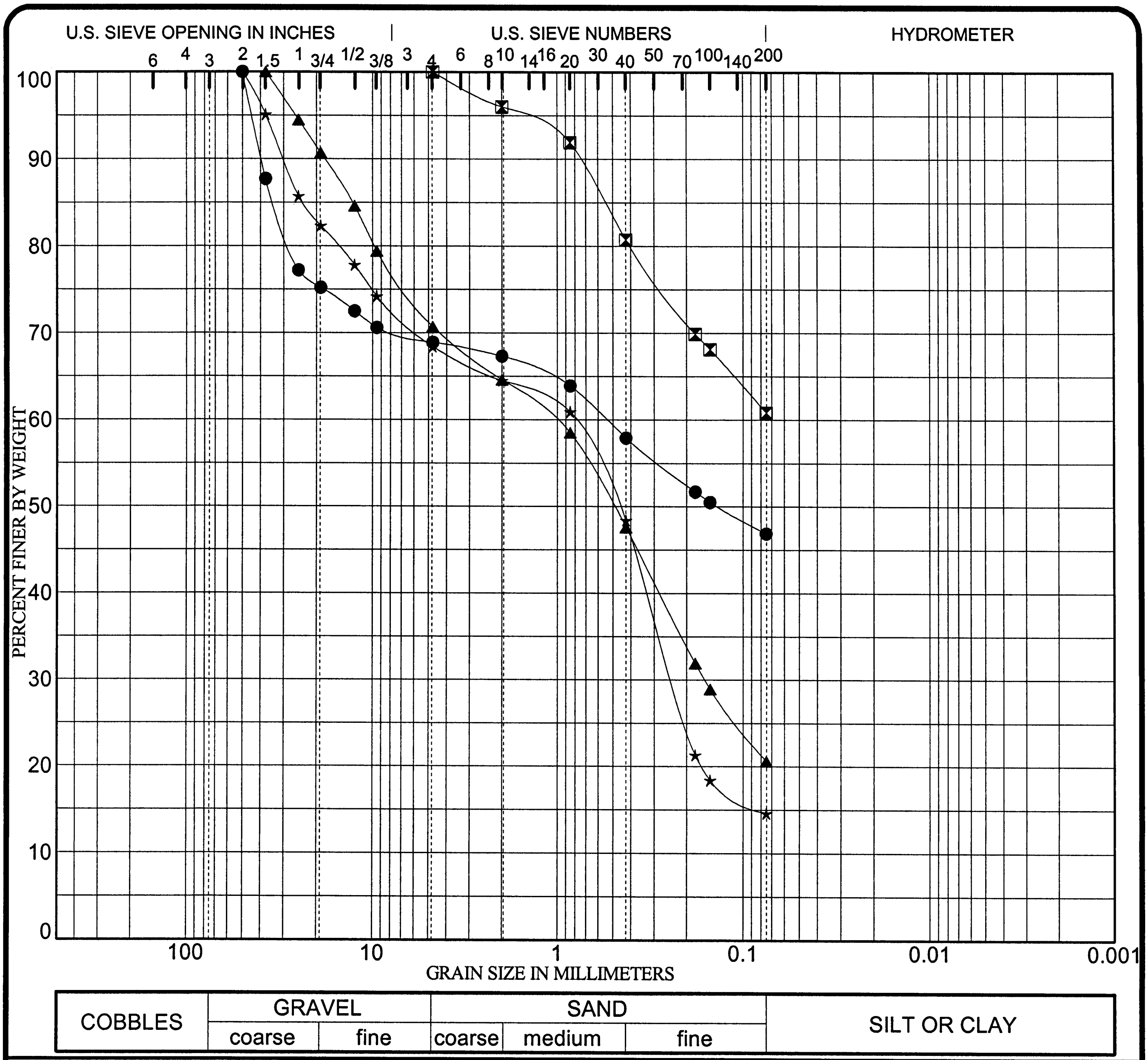

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D5**	**9.0**	**Clayey Gravel With Sand GC**		**55**	**21**	**34**		
☒	**D5**	**10.0**	**Sandy Lean Clay CL**		**35**	**19**	**16**		
▲	**D5**	**11.0**	**Silty Sand With Gravel SM**		**21**	**20**	**1**		
★	**D5**	**12.0**	**Silty Sand With Gravel SM**		**26**	**23**	**3**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D5**	**9.0**	**50.00**	**0.54**			**31.1**	**22.0**	**46.9**	
☒	**D5**	**10.0**	**4.75**				**0.0**	**39.2**	**60.8**	
▲	**D5**	**11.0**	**37.50**	**1.05**	**0.160**		**29.3**	**50.1**	**20.6**	
★	**D5**	**12.0**	**50.00**	**0.81**	**0.237**		**31.6**	**53.8**	**14.6**	

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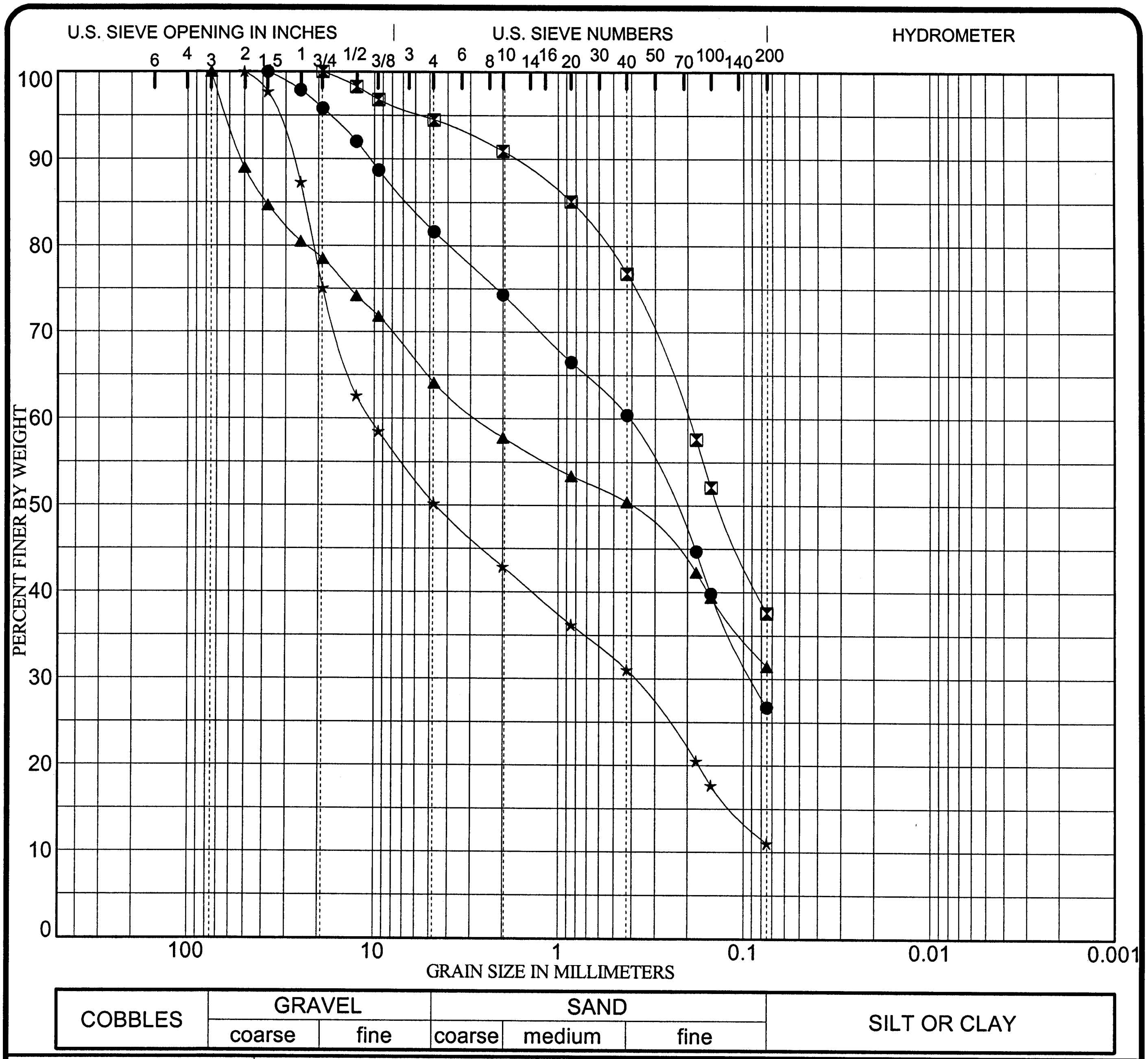

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D5**	**13.0**	**Silty Sand With Gravel SM**		**39**	**28**	**12**		
⊠	**D5**	**14.0**	**Silty Sand SM**		**60**	**56**	**4**		
▲	**D5**	**15.0**	**Clayey Gravel With Sand GC**		**32**	**19**	**14**		
★	**D5**	**16.0**	**Poorly Graded Gravel With Silt And Sand GP-GM**		**41**	**40**	**1**	**0.22**	**155.3**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D5**	**13.0**	**37.50**	**0.42**	**0.089**		**18.4**	**54.9**	**26.7**	
⊠	**D5**	**14.0**	**19.00**	**0.20**			**5.5**	**56.9**	**37.6**	
▲	**D5**	**15.0**	**75.00**	**2.71**			**35.9**	**32.7**	**31.4**	
★	**D5**	**16.0**	**50.00**	**10.50**	**0.392**		**49.8**	**39.2**	**11.0**	

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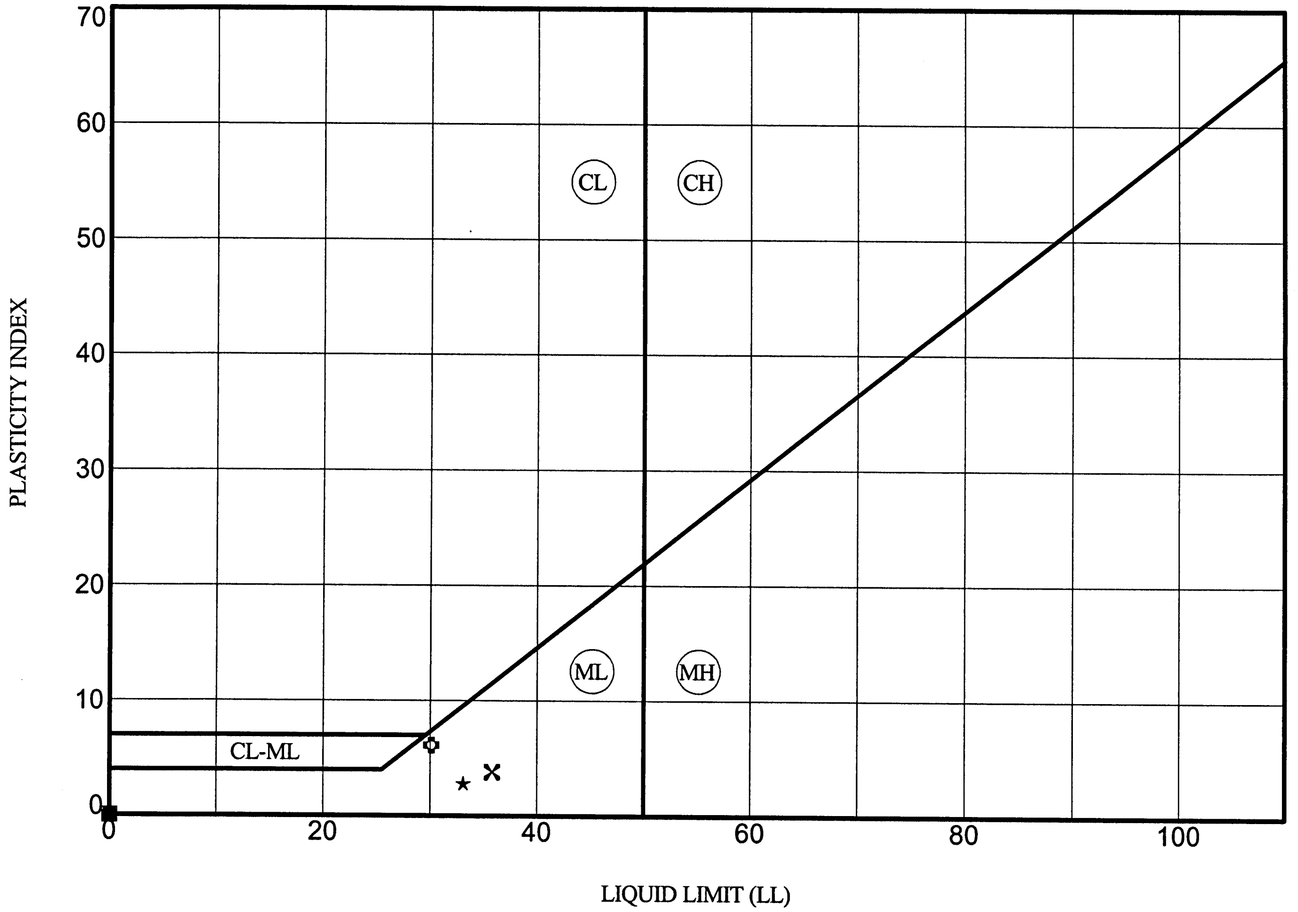

	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D1**	**1.0**	**NP**	**NP**	**NP**	**8.5**	**Well-graded Sand With Silt SW-SM**
⊠	**D1**	**2.0**	**NP**	**NP**	**NP**	**18.8**	**Silty Sand SM**
▲	**D1**	**4.0**	**NP**	**NP**	**NP**	**6.2**	**Well-graded Sand With Silt SW-SM**
★	**D1**	**5.0**	**33**	**30**	**3**	**49.4**	**Silty Sand SM**
×	**D1**	**6.0**	**36**	**32**	**4**	**68.3**	**Sandy Silt ML**
✿	**D1**	**7.0**	**30**	**24**	**6**	**90.2**	**Silt ML**
○	**D1**	**8.0**	**NP**	**NP**	**NP**	**10.1**	**Poorly Graded Sand With Silt SP-SM**

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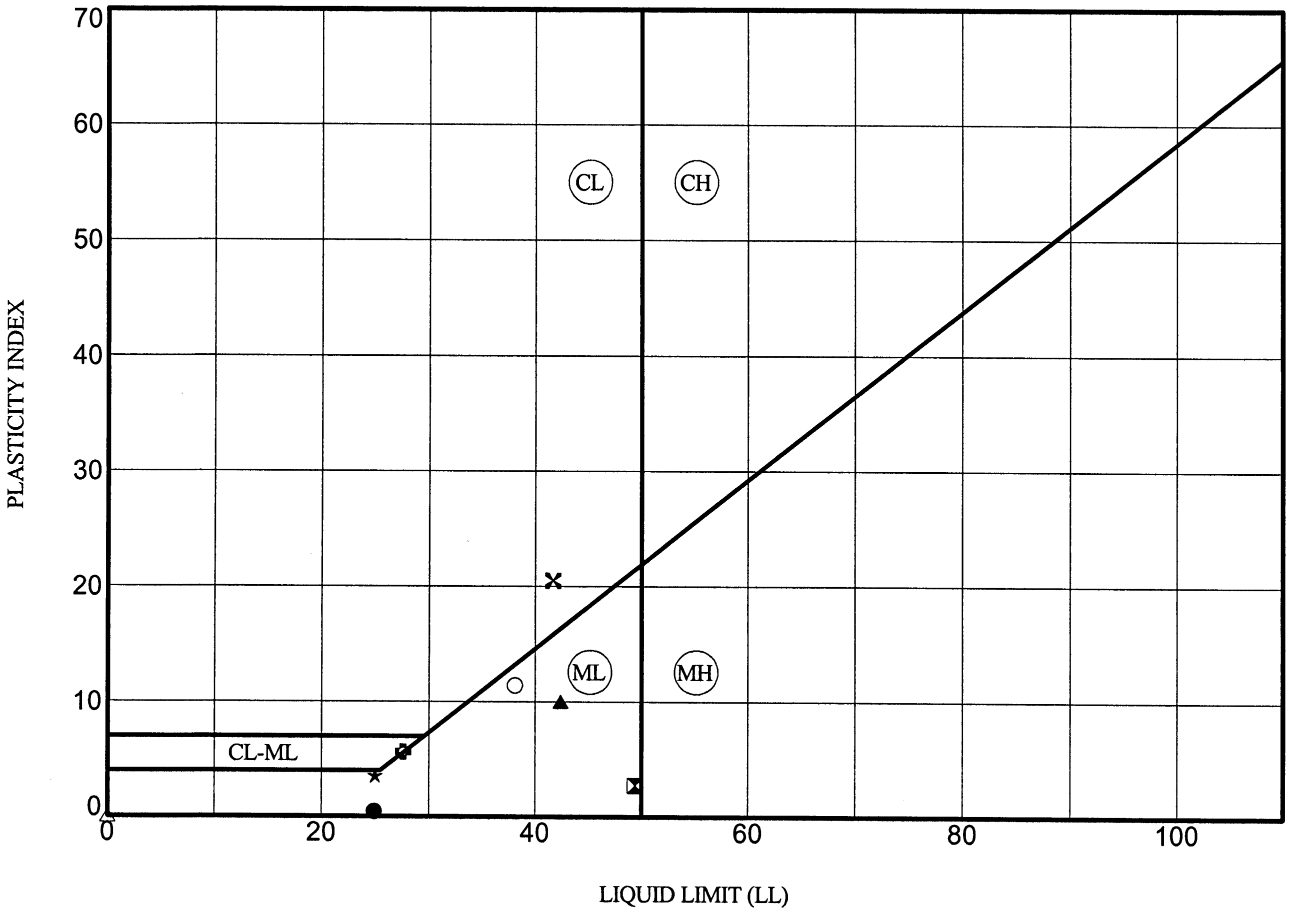

Specimen Identification			LL	PL	PI	Fines	Classification
●	D1	9.0	25	25	NP	90.9	Silt ML
⧗	D1	10.0	49	47	3	59.7	Sandy Silt ML
▲	D1	11.0	42	32	10	79.2	Silt With Sand ML
★	D1	12.0	25	22	4	55.9	Sandy Silt ML
✕	D1	13.0	42	21	21	96.1	Lean Clay CL
✿	D1	14.0	28	22	6	58.5	Sandy Silty Clay CL-ML
○	D1	15.0	38	27	11	71.3	Silt With Sand ML
△	D1	16.0	NP	NP	NP	34.4	Silty Sand SM

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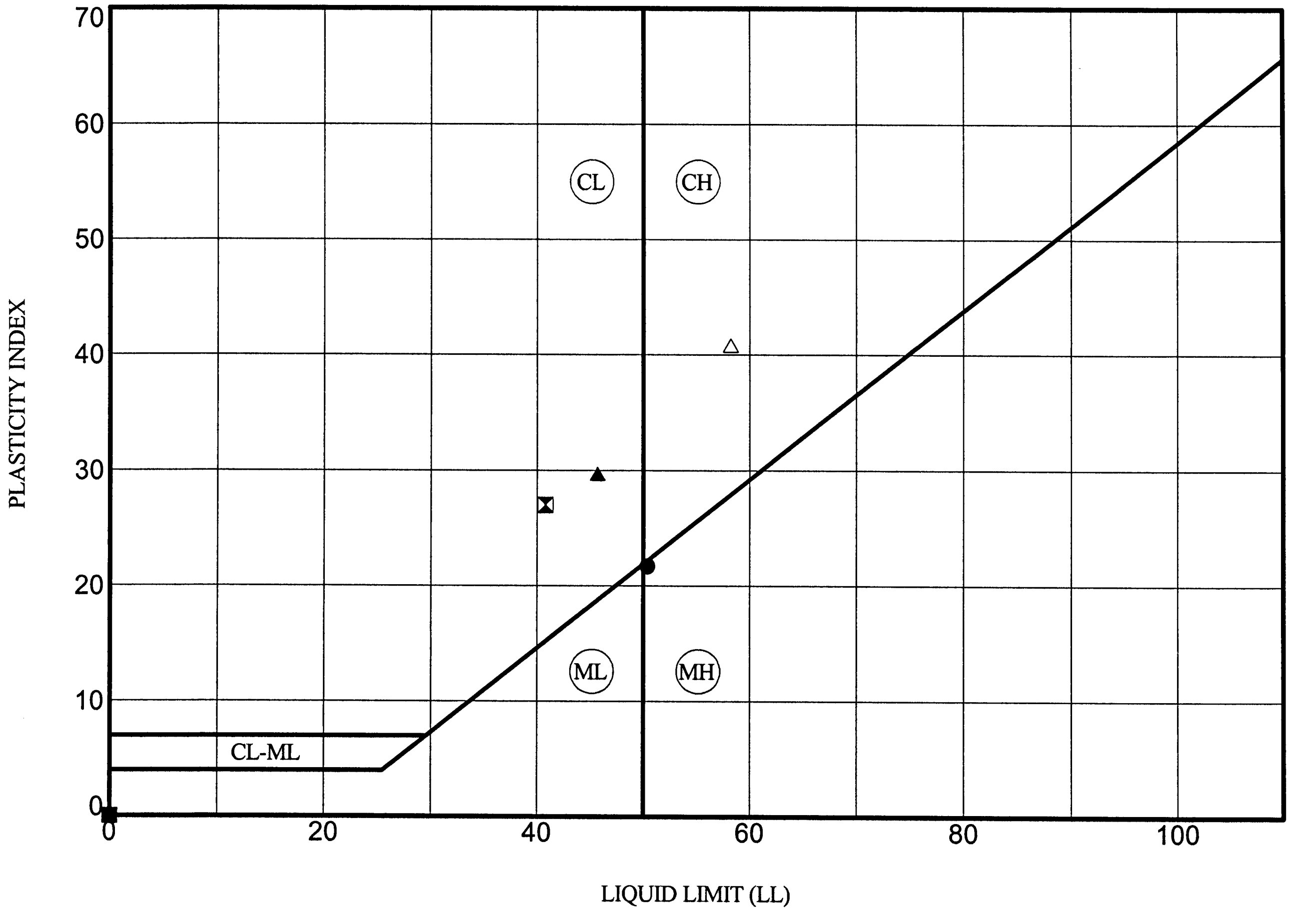
Plate No. 28



Specimen Identification			LL	PL	PI	Fines	Classification
●	D2	1.0	50	29	22	69.1	Sandy Elastic Silt MH
⧗	D2	2.0	41	14	27	59.0	Sandy Lean Clay CL
▲	D2	3.0	46	16	30	72.4	Lean Clay With Sand CL
★	D2	4.0	NP	NP	NP	15.6	Silty Sand SM
✕	D2	5.0	NP	NP	NP	11.4	Well-graded Sand With Silt SW-SM
✿	D2	6.0	NP	NP	NP	22.5	Silty Sand SM
○	D2	7.0	NP	NP	NP	23.3	Silty Sand SM
△	D2	8.0	58	17	41	81.7	Fat Clay With Sand CH

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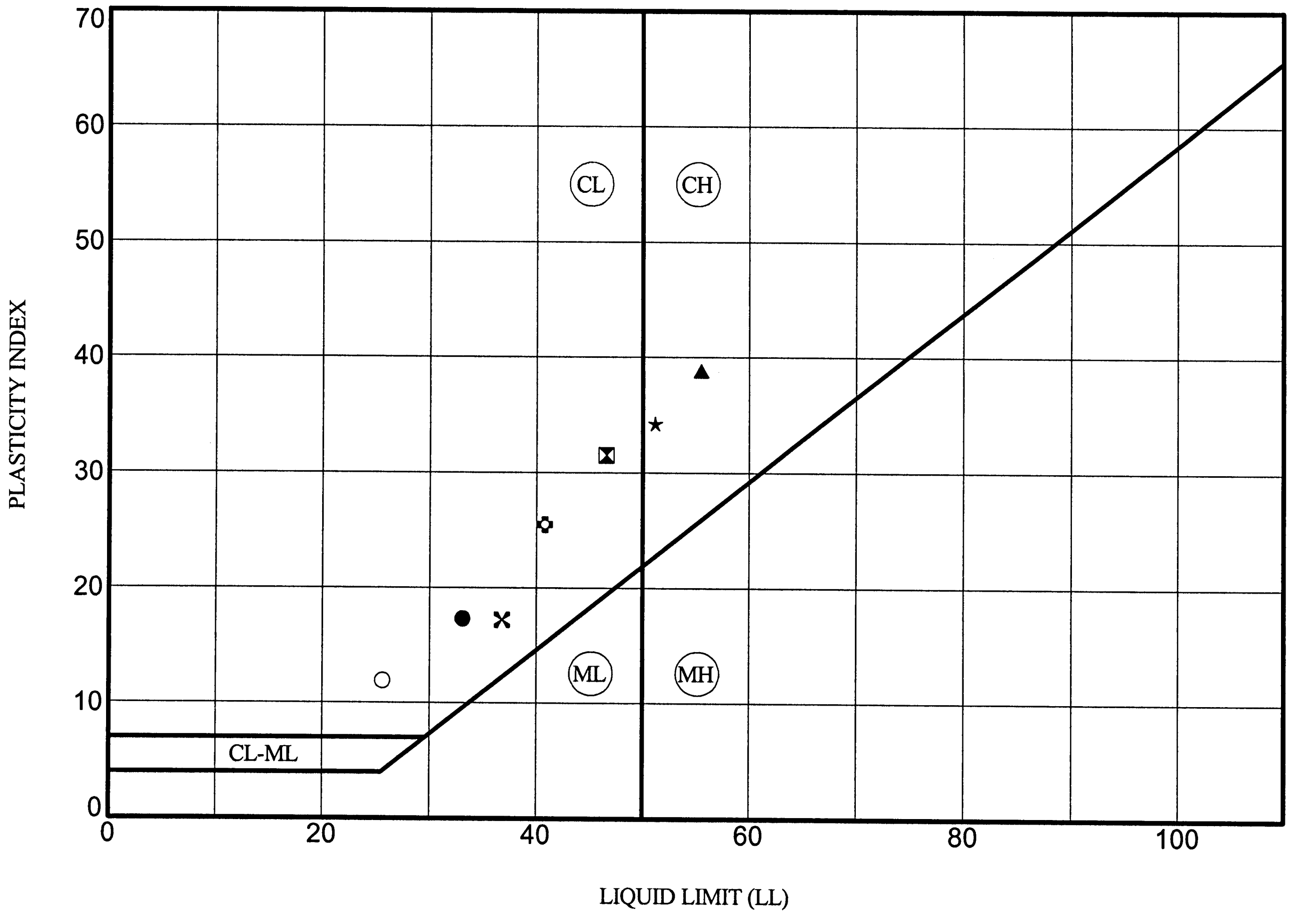

	Specimen Identification		LL	PL	PI	Fines	Classification
●	**D2**	**9.0**	**33**	**16**	**17**	**46.8**	**Clayey Sand SC**
⧗	**D2**	**10.0**	**47**	**15**	**32**	**76.1**	**Lean Clay With Sand CL**
▲	**D2**	**11.0**	**56**	**17**	**39**	**84.8**	**Fat Clay With Sand CH**
★	**D2**	**12.0**	**51**	**17**	**34**	**62.7**	**Sandy Fat Clay CH**
✕	**D2**	**13.0**	**37**	**20**	**17**	**37.3**	**Clayey Sand SC**
✿	**D2**	**14.0**	**41**	**15**	**26**	**54.6**	**Sandy Lean Clay CL**
○	**D2**	**15.0**	**26**	**14**	**12**	**38.3**	**Clayey Sand SC**

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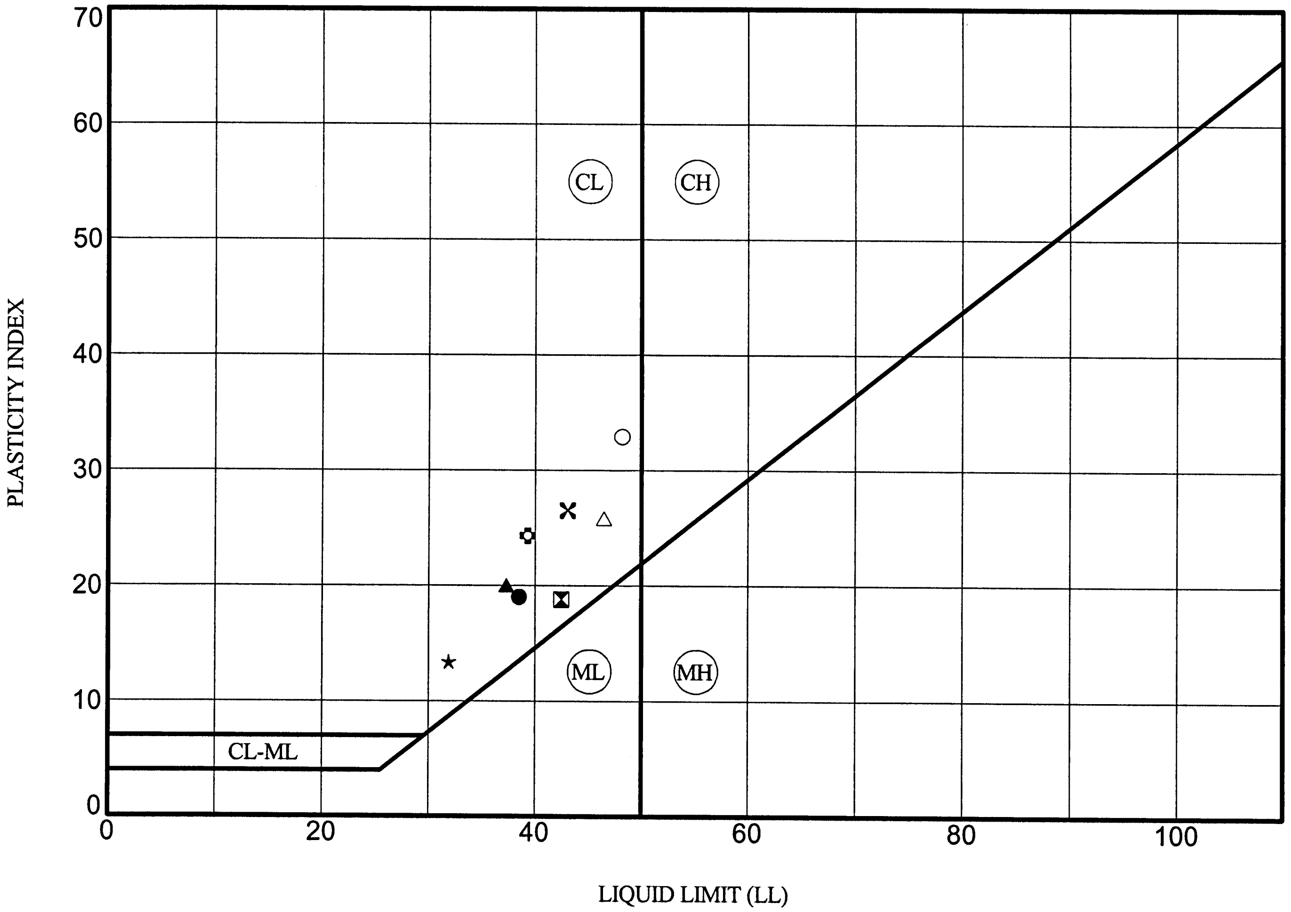

Specimen Identification			LL	PL	PI	Fines	Classification
●	**D3**	**1.0**	**39**	**20**	**19**	**78.1**	**Lean Clay With Sand CL**
⌛	**D3**	**2.0**	**43**	**24**	**19**	**78.2**	**Lean Clay With Sand CL**
▲	**D3**	**3.0**	**37**	**17**	**20**	**67.7**	**Sandy Lean Clay CL**
★	**D3**	**5.0**	**32**	**19**	**13**	**69.1**	**Sandy Lean Clay CL**
✕	**D3**	**7.0**	**43**	**17**	**27**	**91.1**	**Lean Clay CL**
✿	**D3**	**8.0**	**39**	**15**	**24**	**79.3**	**Lean Clay With Sand CL**
○	**D3**	**10.0**	**48**	**15**	**33**	**89.7**	**Lean Clay CL**
△	**D3**	**11.0**	**47**	**21**	**26**	**74.8**	**Lean Clay With Sand CL**

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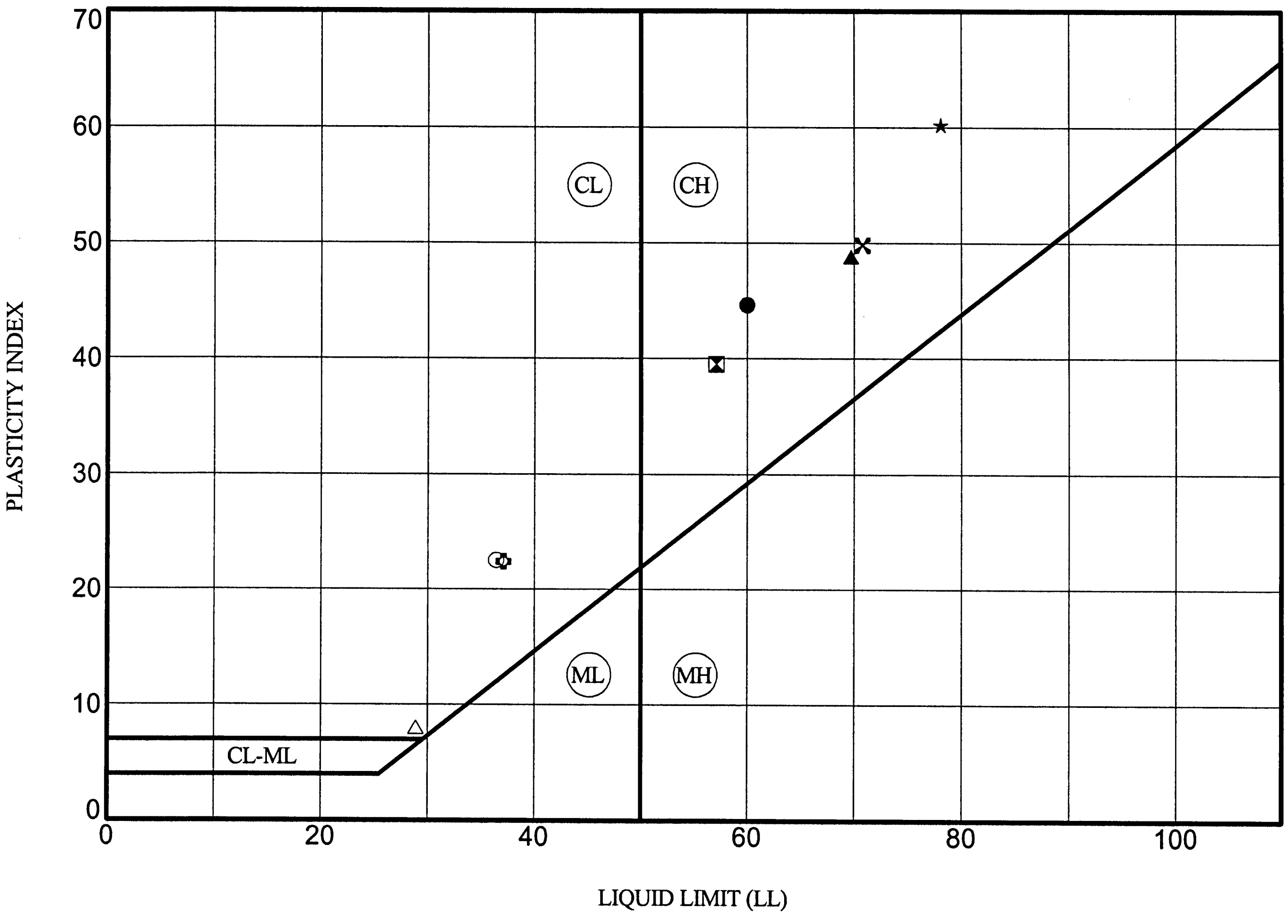

	Specimen Identification	LL	PL	PI	Fines	Classification
●	**D4 1.0**	**60**	**15**	**45**	**36.5**	**Clayey Sand SC**
⧗	**D4 2.0**	**57**	**18**	**40**	**74.5**	**Fat Clay With Sand CH**
▲	**D4 3.0**	**70**	**21**	**49**	**95.2**	**Fat Clay CH**
★	**D4 5.0**	**78**	**18**	**60**	**91.3**	**Fat Clay CH**
✕	**D4 6.0**	**71**	**21**	**50**	**81.5**	**Fat Clay With Sand CH**
✿	**D4 7.0**	**37**	**15**	**22**	**73.4**	**Lean Clay With Sand CL**
○	**D4 8.0**	**36**	**14**	**23**	**79.5**	**Lean Clay With Sand CL**
△	**D4 9.0**	**29**	**21**	**8**	**65.9**	**Sandy Lean Clay CL**

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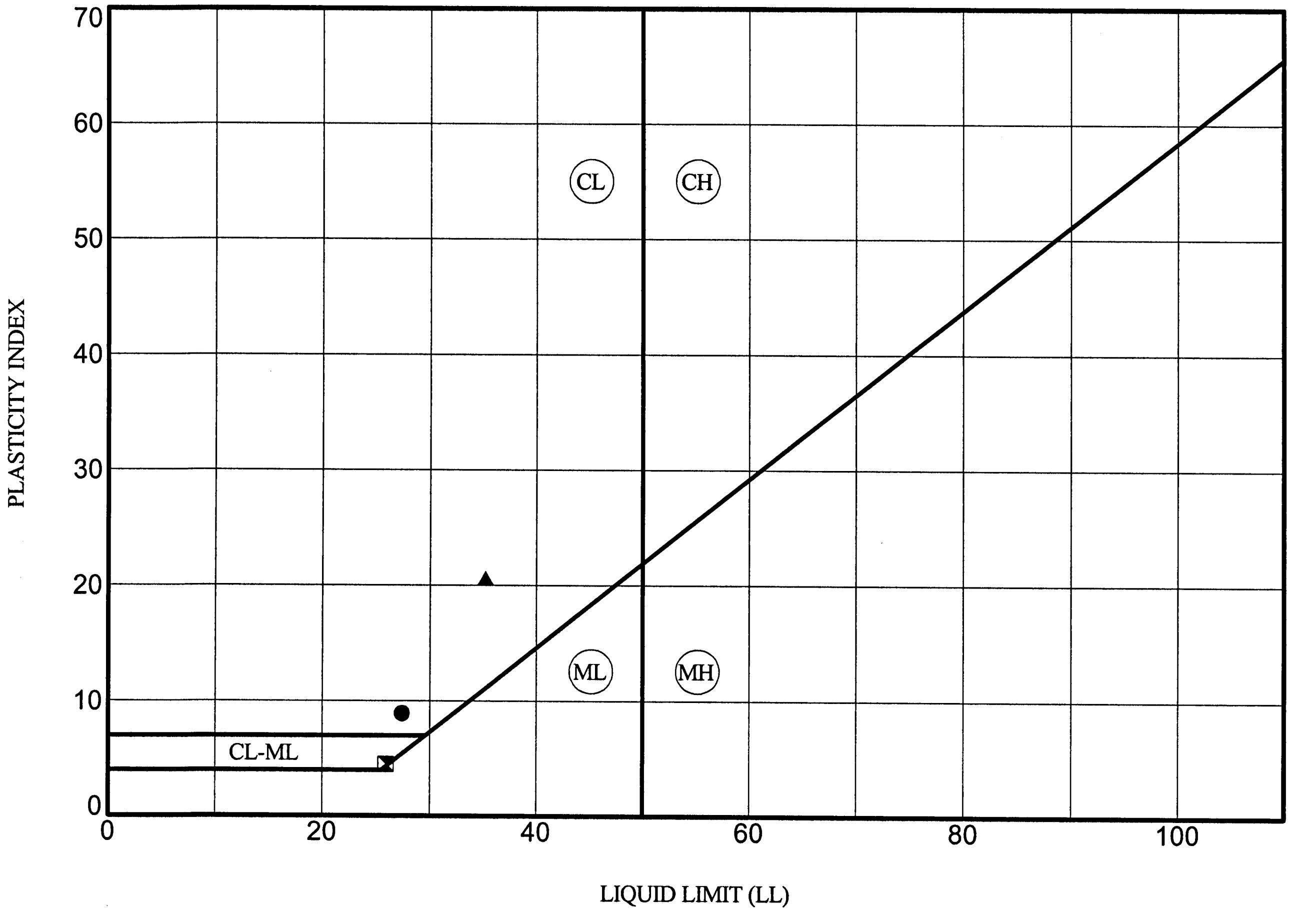

Specimen Identification		LL	PL	PI	Fines	Classification
●	**D4 10.0**	**27**	**19**	**9**	**25.2**	**Clayey Sand SC**
☒	**D4 11.0**	**26**	**21**	**5**	**81.2**	**Silty Clay With Sand CL-ML**
▲	**D4 12.0**	**35**	**15**	**21**	**37.9**	**Clayey Sand SC**

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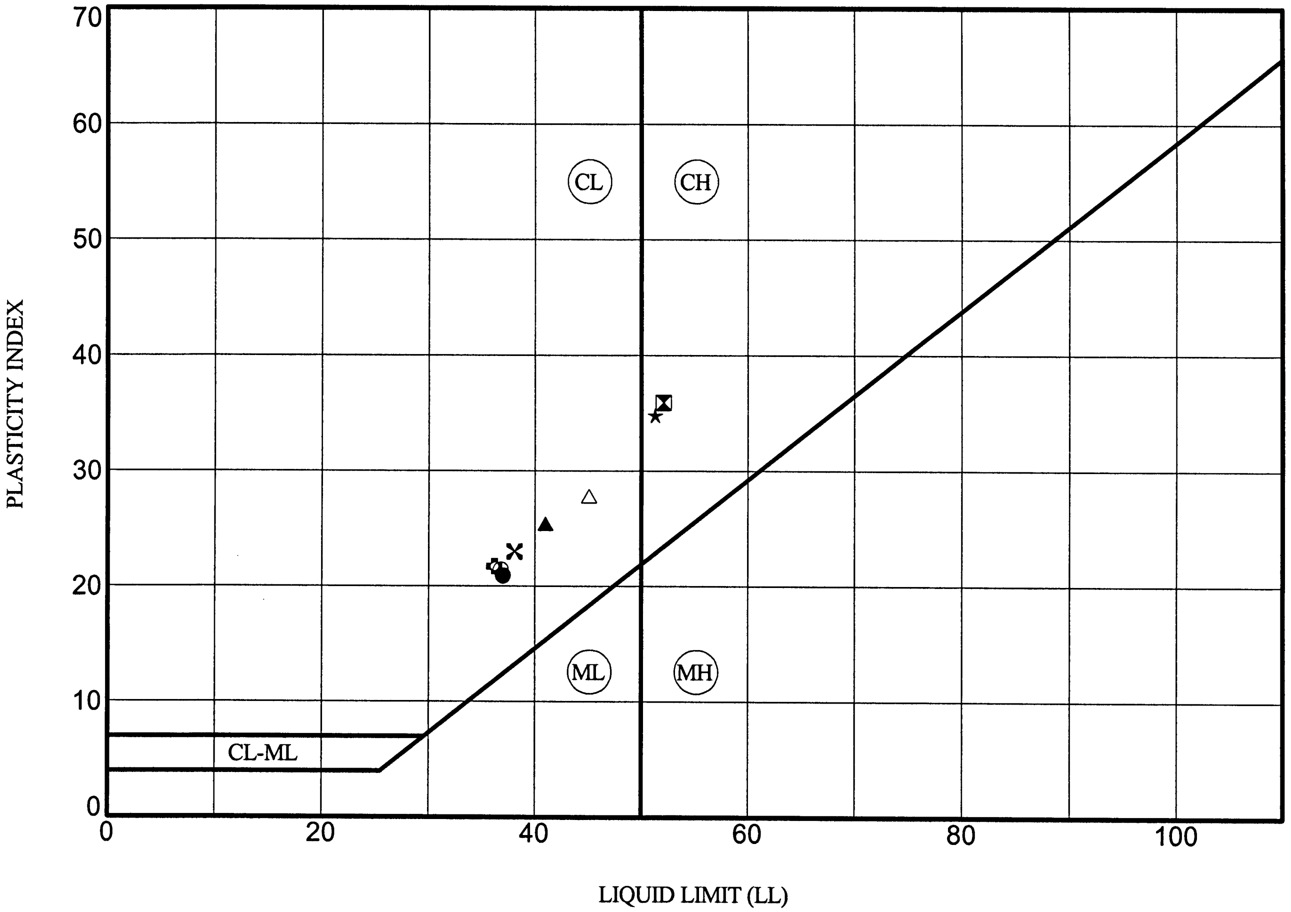

Specimen Identification			LL	PL	PI	Fines	Classification
●	**D5**	**1.0**	**37**	**16**	**21**	**84.5**	**Lean Clay With Sand CL**
⊠	**D5**	**2.0**	**52**	**16**	**36**	**96.5**	**Fat Clay CH**
▲	**D5**	**3.0**	**41**	**16**	**25**	**70.0**	**Sandy Lean Clay CL**
★	**D5**	**4.0**	**51**	**17**	**35**	**95.4**	**Fat Clay CH**
✕	**D5**	**5.0**	**38**	**15**	**23**	**78.0**	**Lean Clay With Sand CL**
✿	**D5**	**6.0**	**36**	**15**	**22**	**88.6**	**Lean Clay CL**
○	**D5**	**7.0**	**37**	**15**	**21**	**85.7**	**Lean Clay CL**
△	**D5**	**8.0**	**45**	**17**	**28**	**91.9**	**Lean Clay CL**

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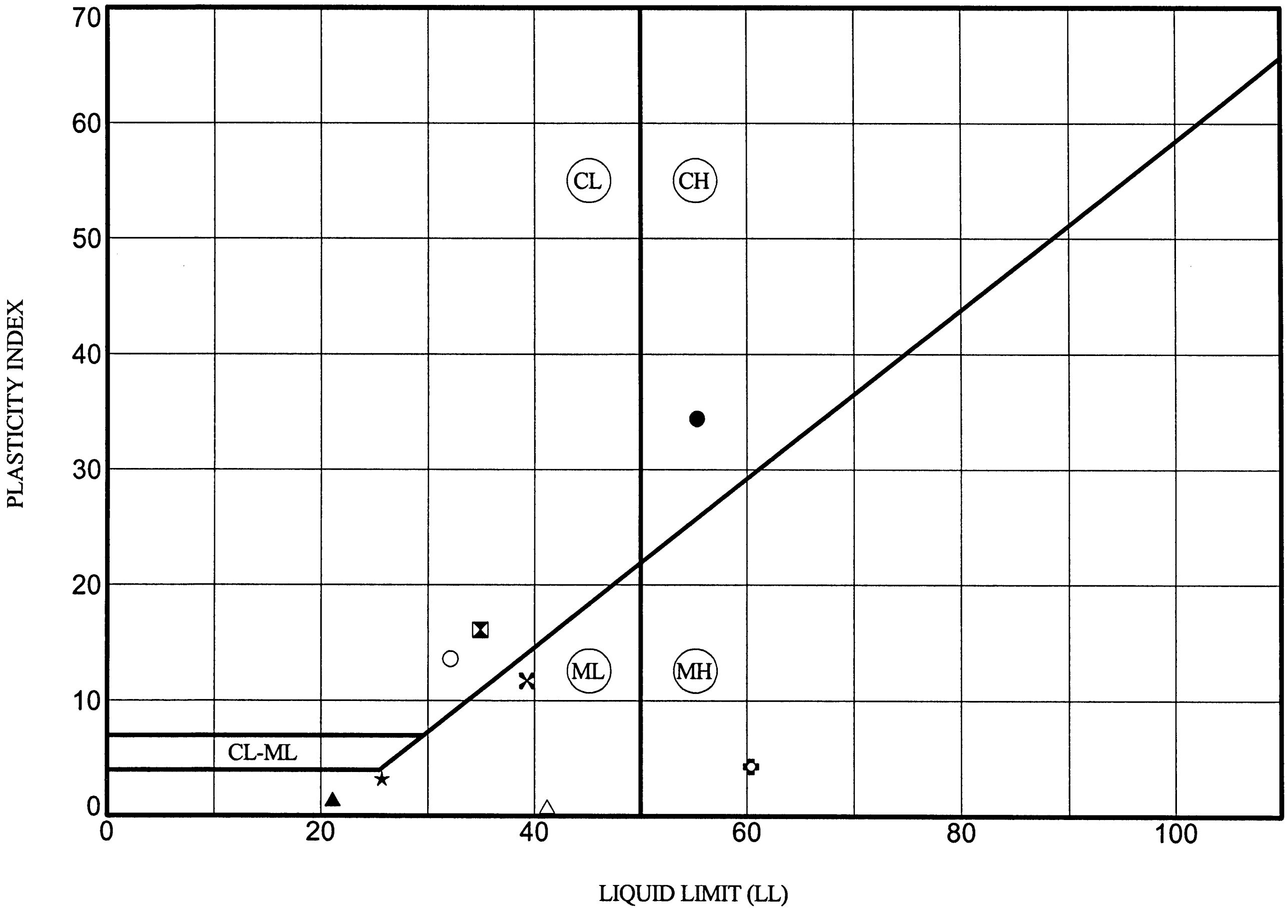

Specimen Identification			LL	PL	PI	Fines	Classification
●	**D5**	**9.0**	**55**	**21**	**34**	**69.6**	**Sandy Fat Clay CH**
☒	**D5**	**10.0**	**35**	**19**	**16**	**63.4**	**Sandy Lean Clay CL**
▲	**D5**	**11.0**	**21**	**20**	**1**	**32.0**	**Silty Sand SM**
★	**D5**	**12.0**	**26**	**23**	**3**	**22.7**	**Silty Sand SM**
✕	**D5**	**13.0**	**39**	**28**	**12**	**35.9**	**Silty Sand SM**
✤	**D5**	**14.0**	**60**	**56**	**4**	**41.3**	**Silty Sand SM**
○	**D5**	**15.0**	**32**	**19**	**14**	**54.4**	**Sandy Lean Clay CL**
△	**D5**	**16.0**	**41**	**40**	**1**	**25.6**	**Silty Sand SM**

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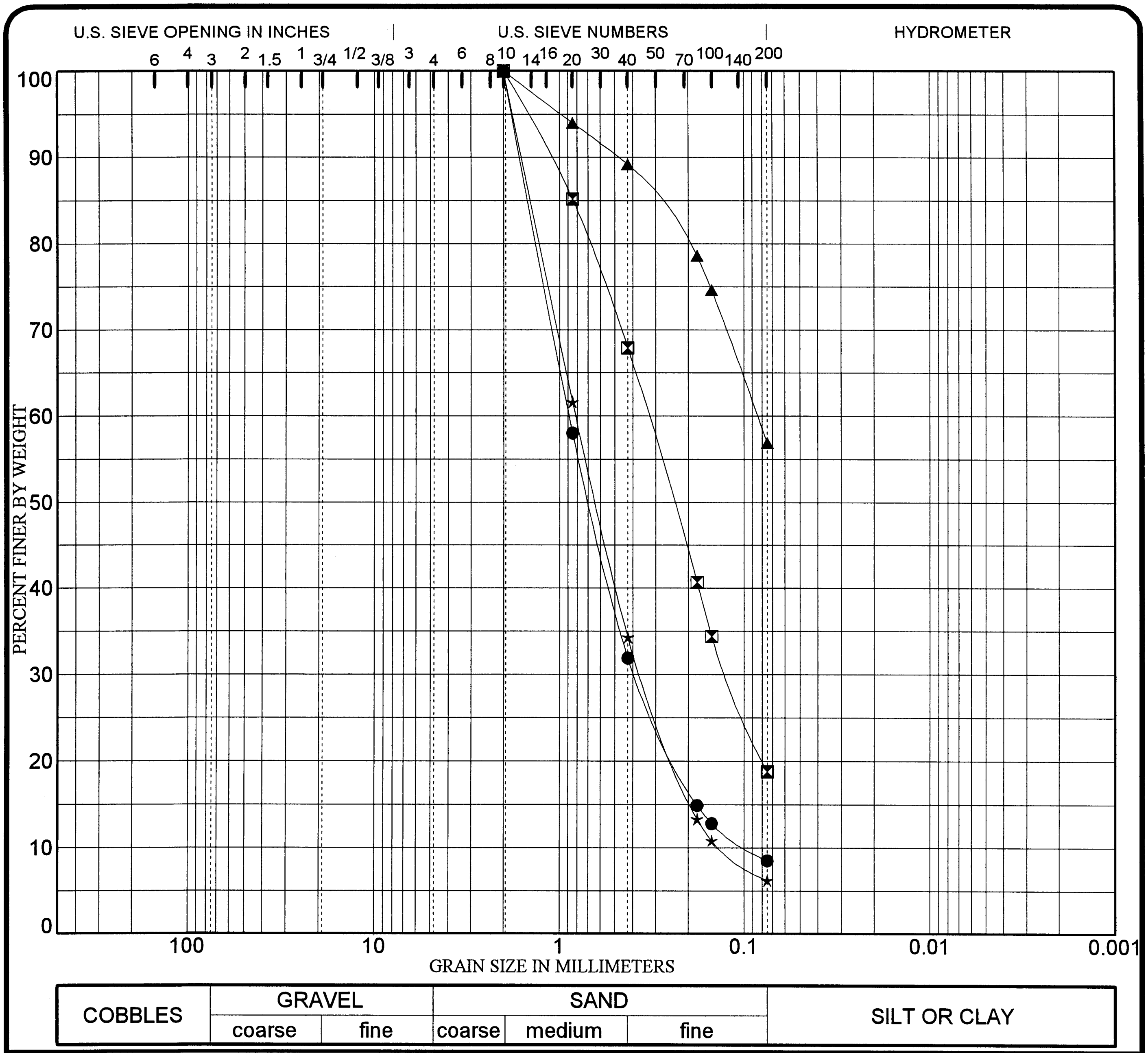

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**1.0**	**Well-graded Sand With Silt SW-SM**	**1**	**NP**	**NP**	**NP**	**1.76**	**9.3**
☒	**D1**	**2.0**	**Silty Sand SM**	**1**	**NP**	**NP**	**NP**		
▲	**D1**	**3.0**	**Sandy Silt ML**	**1**	**25**	**26**	**NP**		
★	**D1**	**4.0**	**Well-graded Sand With Silt SW-SM**	**1**	**NP**	**NP**	**NP**	**1.17**	**6.1**

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**1.0**	**2.00**	**0.89**	**0.386**	**0.0955**	**0.0**	**91.5**	**8.5**	
☒	**D1**	**2.0**	**2.00**	**0.33**	**0.123**		**0.0**	**81.2**	**18.8**	
▲	**D1**	**3.0**	**2.00**	**0.08**			**0.0**	**43.1**	**56.9**	
★	**D1**	**4.0**	**2.00**	**0.82**	**0.356**	**0.1330**	**0.0**	**93.8**	**6.2**	

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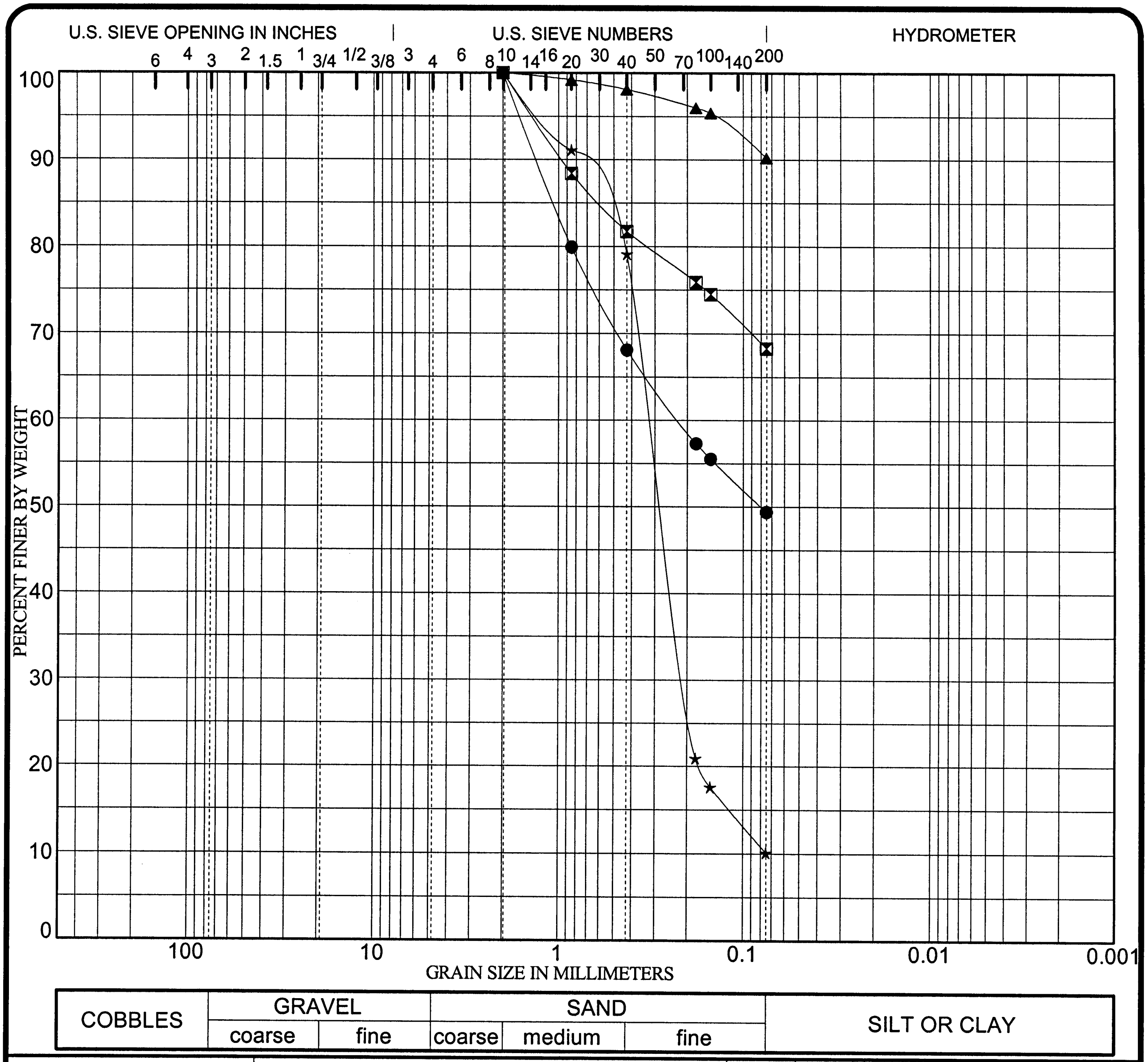

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**5.0**	**Silty Sand SM**	**1**	**33**	**30**	**3**		
☒	**D1**	**6.0**	**Sandy Silt ML**	**1**	**36**	**32**	**4**		
▲	**D1**	**7.0**	**Silt ML**	**1**	**30**	**24**	**6**		
★	**D1**	**8.0**	**Poorly Graded Sand With Silt SP-SM**	**1**	**NP**	**NP**	**NP**	**1.78**	**4.3**

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**5.0**	**2.00**	**0.22**			**0.0**	**50.6**	**49.4**	
☒	**D1**	**6.0**	**2.00**				**0.0**	**31.7**	**68.3**	
▲	**D1**	**7.0**	**2.00**				**0.0**	**9.8**	**90.2**	
★	**D1**	**8.0**	**2.00**	**0.32**	**0.206**		**0.0**	**89.9**	**10.1**	

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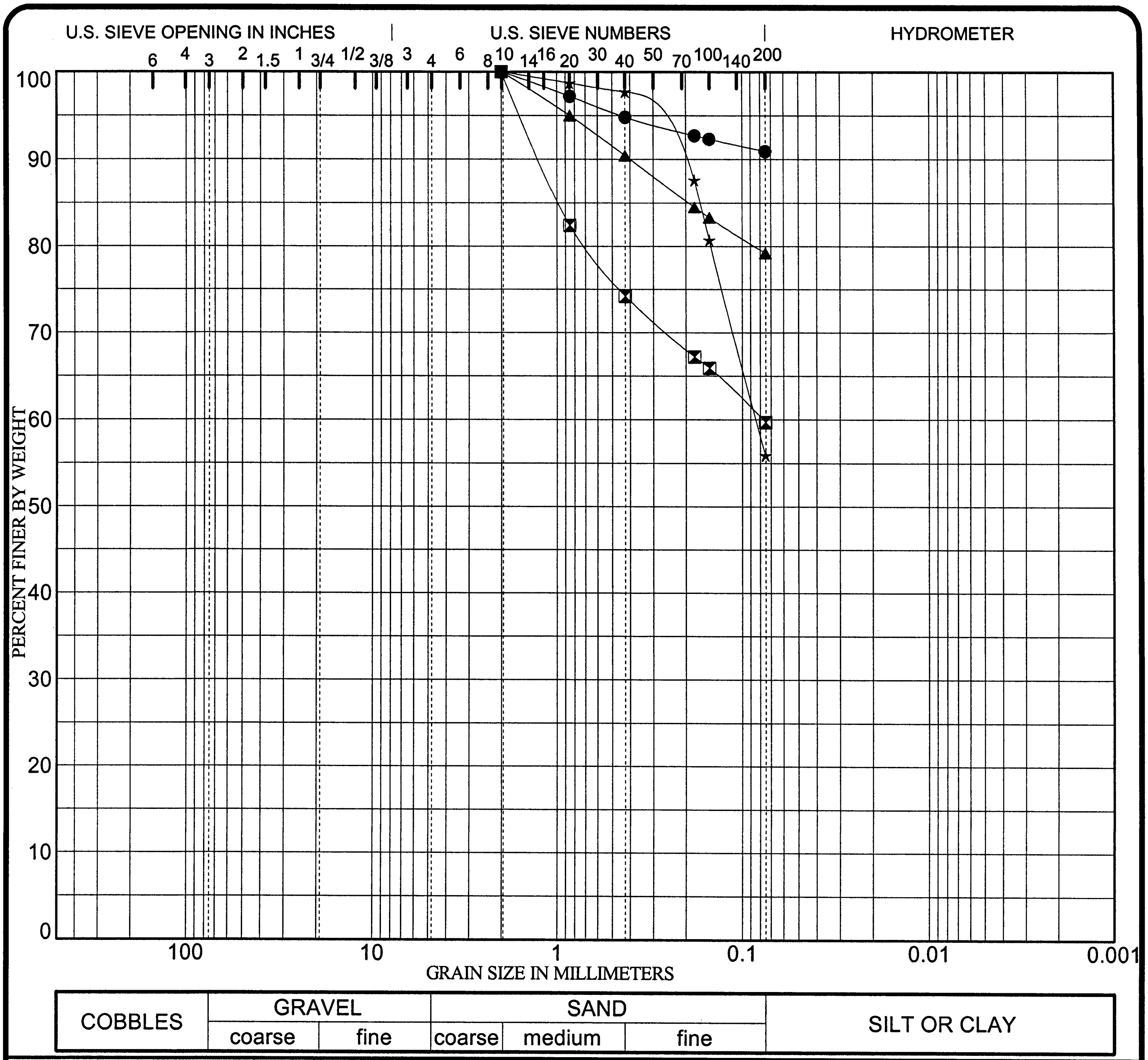

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**9.0**	**Silt ML**	**1**	**25**	**25**	**NP**		
☒	**D1**	**10.0**	**Sandy Silt ML**	**1**	**49**	**47**	**3**		
▲	**D1**	**11.0**	**Silt With Sand ML**	**1**	**42**	**32**	**10**		
★	**D1**	**12.0**	**Sandy Silt ML**	**1**	**25**	**22**	**4**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**9.0**	**2.00**				**0.0**	**9.1**	**90.9**	
☒	**D1**	**10.0**	**2.00**	**0.08**			**0.0**	**40.3**	**59.7**	
▲	**D1**	**11.0**	**2.00**				**0.0**	**20.8**	**79.2**	
★	**D1**	**12.0**	**2.00**	**0.08**			**0.0**	**44.1**	**55.9**	

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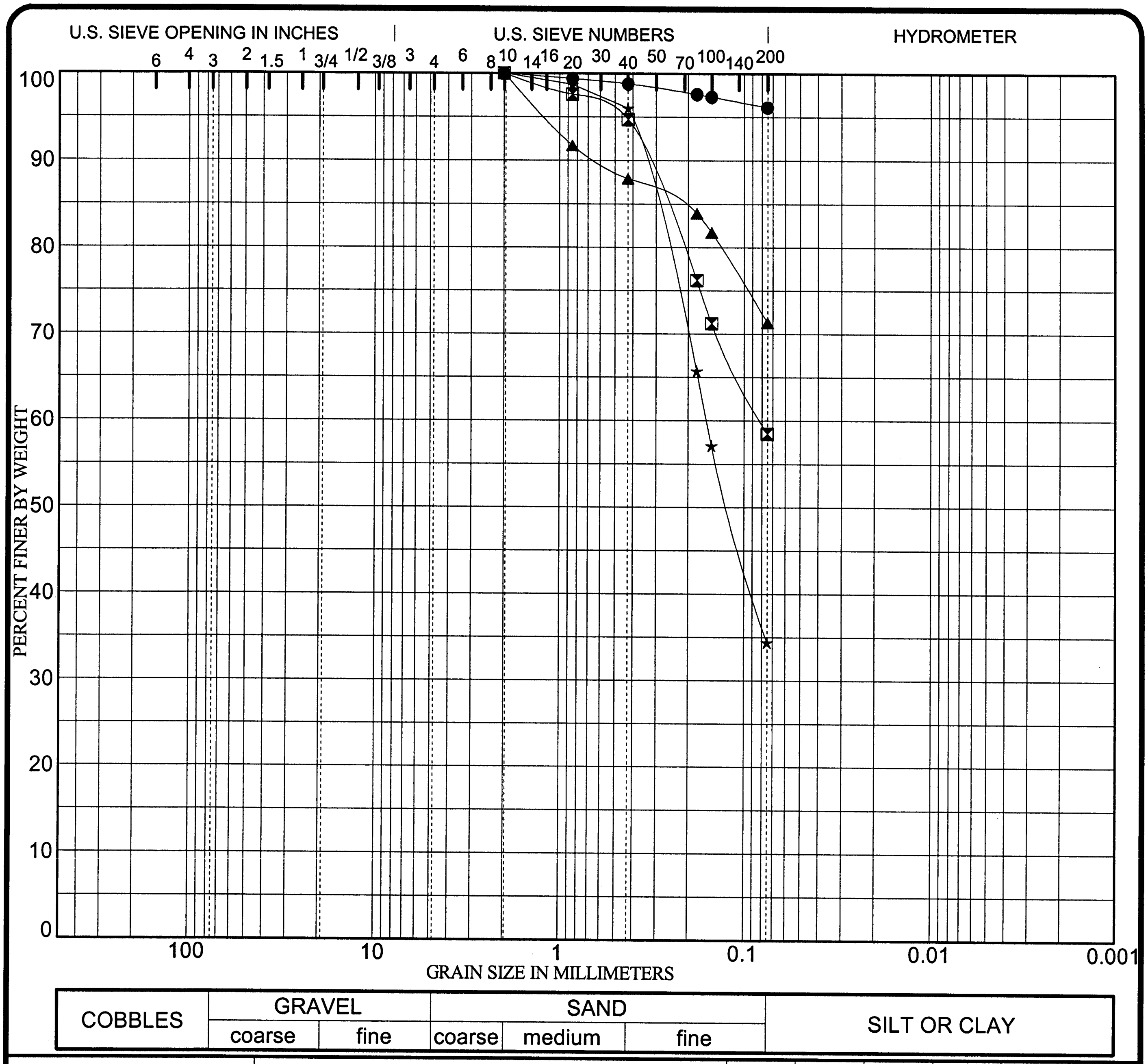

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D1**	**13.0**	**Lean Clay CL**	**1**	**42**	**21**	**21**		
☒	**D1**	**14.0**	**Sandy Silty Clay CL-ML**	**1**	**28**	**22**	**6**		
▲	**D1**	**15.0**	**Silt With Sand ML**	**1**	**38**	**27**	**11**		
★	**D1**	**16.0**	**Silty Sand SM**	**1**	**NP**	**NP**	**NP**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D1**	**13.0**	**2.00**				**0.0**	**3.9**	**96.1**	
☒	**D1**	**14.0**	**2.00**	**0.08**			**0.0**	**41.5**	**58.5**	
▲	**D1**	**15.0**	**2.00**				**0.0**	**28.7**	**71.3**	
★	**D1**	**16.0**	**2.00**	**0.16**			**0.0**	**65.6**	**34.4**	

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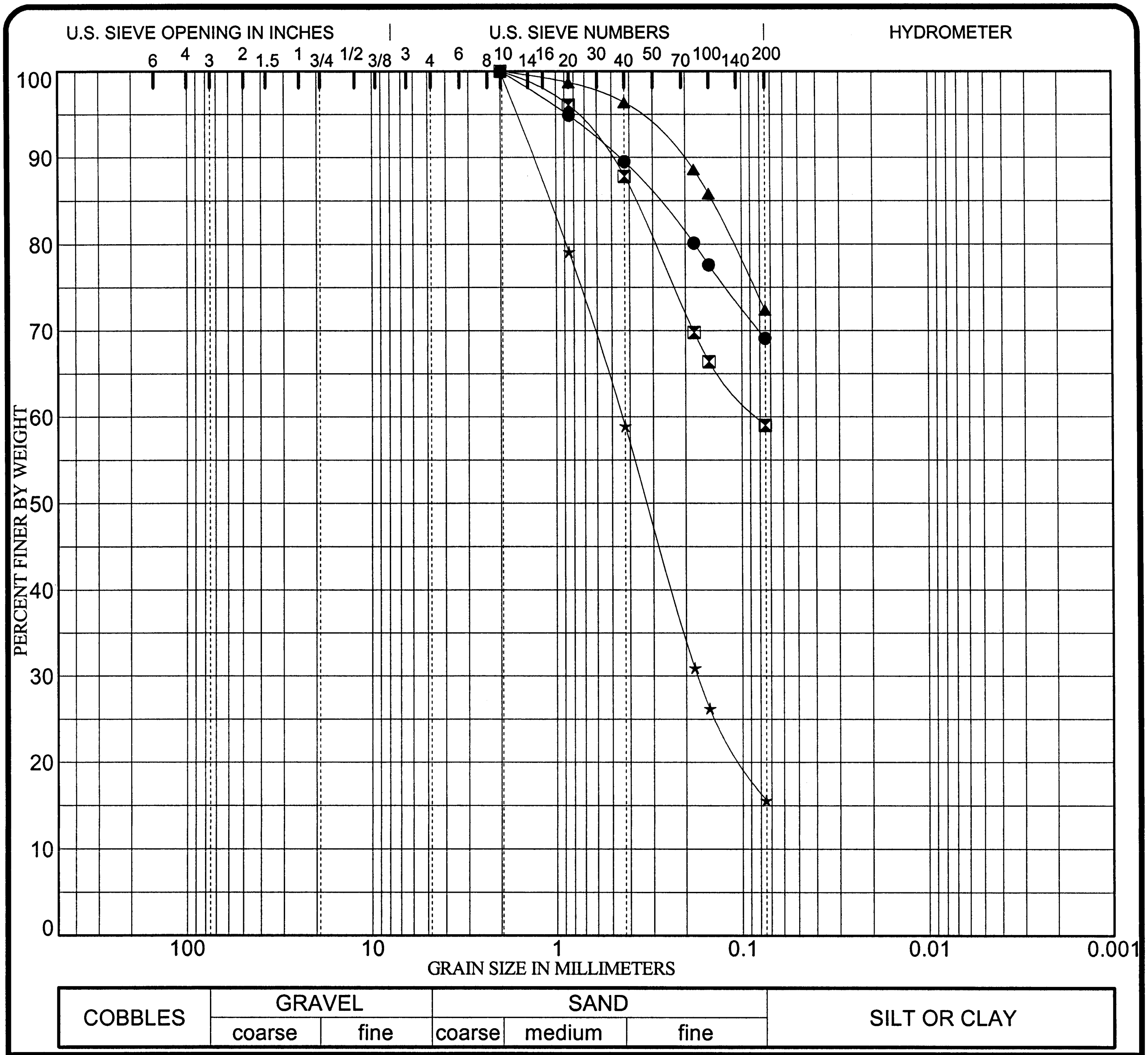

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**1.0**	**Sandy Elastic Silt MH**		**50**	**29**	**22**		
☒	**D2**	**2.0**	**Sandy Lean Clay CL**		**41**	**14**	**27**		
▲	**D2**	**3.0**	**Lean Clay With Sand CL**		**46**	**16**	**30**		
★	**D2**	**4.0**	**Silty Sand SM**		**NP**	**NP**	**NP**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**1.0**	**2.00**				**0.0**	**30.9**	**69.1**	
☒	**D2**	**2.0**	**2.00**	**0.08**			**0.0**	**41.0**	**59.0**	
▲	**D2**	**3.0**	**2.00**				**0.0**	**27.6**	**72.4**	
★	**D2**	**4.0**	**2.00**	**0.44**	**0.174**		**0.0**	**84.4**	**15.6**	

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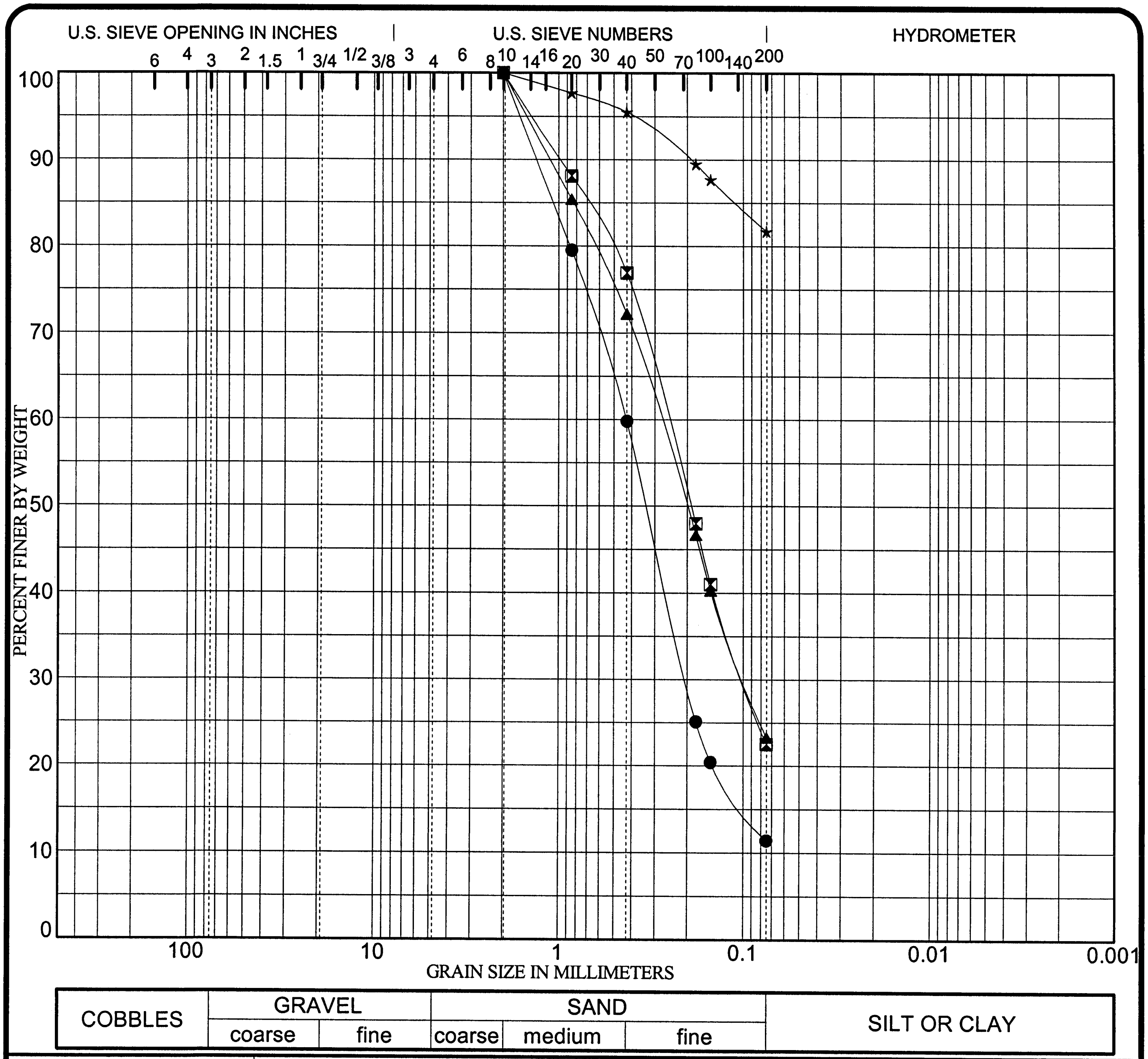

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**5.0**	**Well-graded Sand With Silt SW-SM**		**NP**	**NP**	**NP**	**1.43**	**6.4**
⧗	**D2**	**6.0**	**Silty Sand SM**		**NP**	**NP**	**NP**		
▲	**D2**	**7.0**	**Silty Sand SM**		**NP**	**NP**	**NP**		
★	**D2**	**8.0**	**Fat Clay With Sand CH**		**58**	**17**	**41**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**5.0**	**2.00**	**0.43**	**0.203**		**0.0**	**88.6**	**11.4**	
⧗	**D2**	**6.0**	**2.00**	**0.26**	**0.099**		**0.0**	**77.5**	**22.5**	
▲	**D2**	**7.0**	**2.00**	**0.28**	**0.099**		**0.0**	**76.7**	**23.3**	
★	**D2**	**8.0**	**2.00**				**0.0**	**18.3**	**81.7**	

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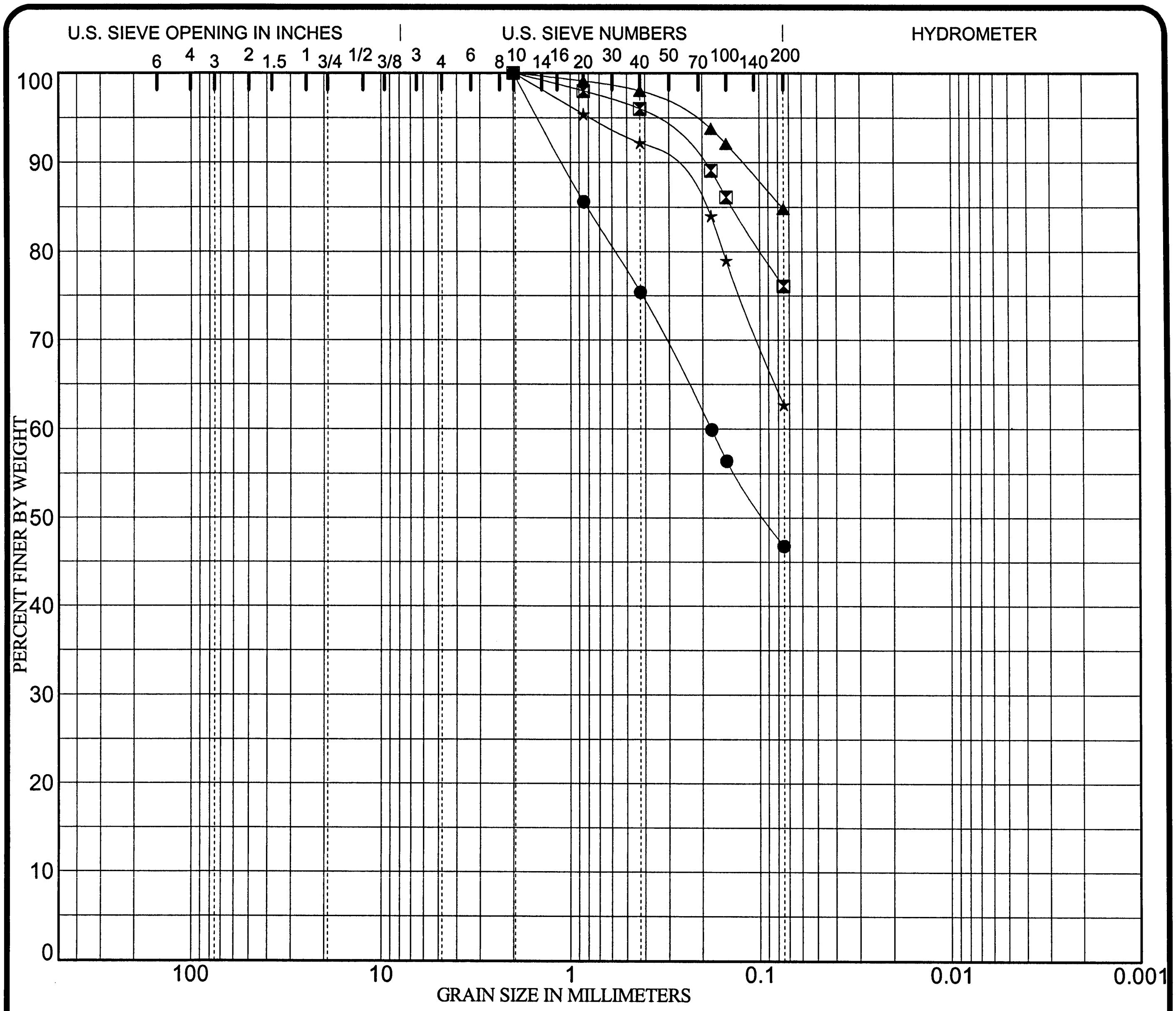

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**9.0**	**Clayey Sand SC**		**33**	**16**	**17**		
☒	**D2**	**10.0**	**Lean Clay With Sand CL**		**47**	**15**	**32**		
▲	**D2**	**11.0**	**Fat Clay With Sand CH**		**56**	**17**	**39**		
★	**D2**	**12.0**	**Sandy Fat Clay CH**		**51**	**17**	**34**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**9.0**	**2.00**	**0.18**			**0.0**	**53.2**	**46.8**	
☒	**D2**	**10.0**	**2.00**				**0.0**	**23.9**	**76.1**	
▲	**D2**	**11.0**	**2.00**				**0.0**	**15.2**	**84.8**	
★	**D2**	**12.0**	**2.00**				**0.0**	**37.3**	**62.7**	

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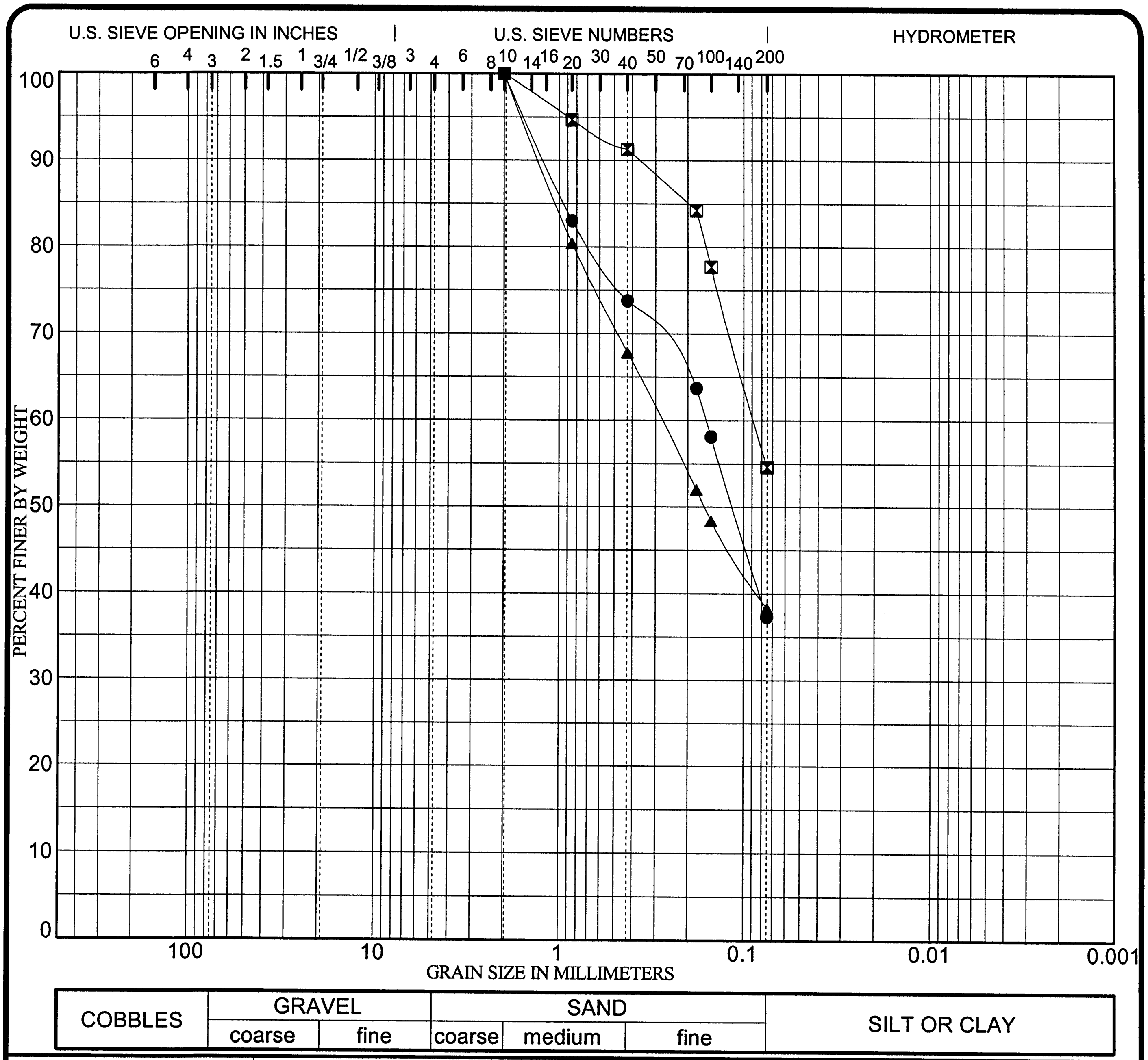

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**D2**	**13.0**	**Clayey Sand SC**		**37**	**20**	**17**		
☒	**D2**	**14.0**	**Sandy Lean Clay CL**		**41**	**15**	**26**		
▲	**D2**	**15.0**	**Clayey Sand SC**		**26**	**14**	**12**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D2**	**13.0**	**2.00**	**0.16**			**0.0**	**62.7**	**37.3**	
☒	**D2**	**14.0**	**2.00**	**0.09**			**0.0**	**45.4**	**54.6**	
▲	**D2**	**15.0**	**2.00**	**0.28**			**0.0**	**61.7**	**38.3**	

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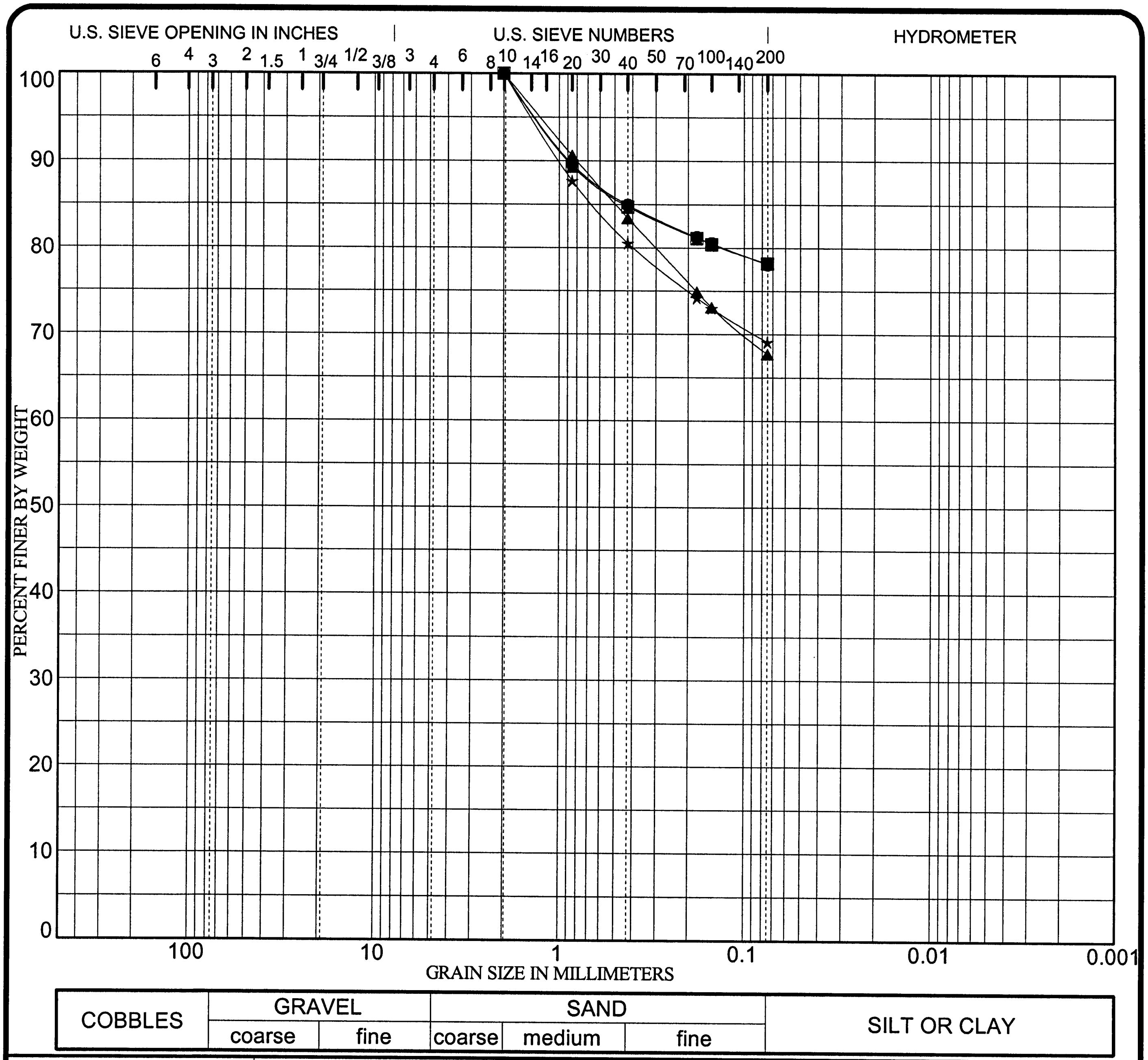

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D3**	**1.0**	**Lean Clay With Sand CL**		**39**	**20**	**19**		
☒	**D3**	**2.0**	**Lean Clay With Sand CL**		**43**	**24**	**19**		
▲	**D3**	**3.0**	**Sandy Lean Clay CL**		**37**	**17**	**20**		
★	**D3**	**5.0**	**Sandy Lean Clay CL**		**32**	**19**	**13**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D3**	**1.0**	**2.00**				**0.0**	**21.9**	**78.1**	
☒	**D3**	**2.0**	**2.00**				**0.0**	**21.8**	**78.2**	
▲	**D3**	**3.0**	**2.00**				**0.0**	**32.3**	**67.7**	
★	**D3**	**5.0**	**2.00**				**0.0**	**30.9**	**69.1**	

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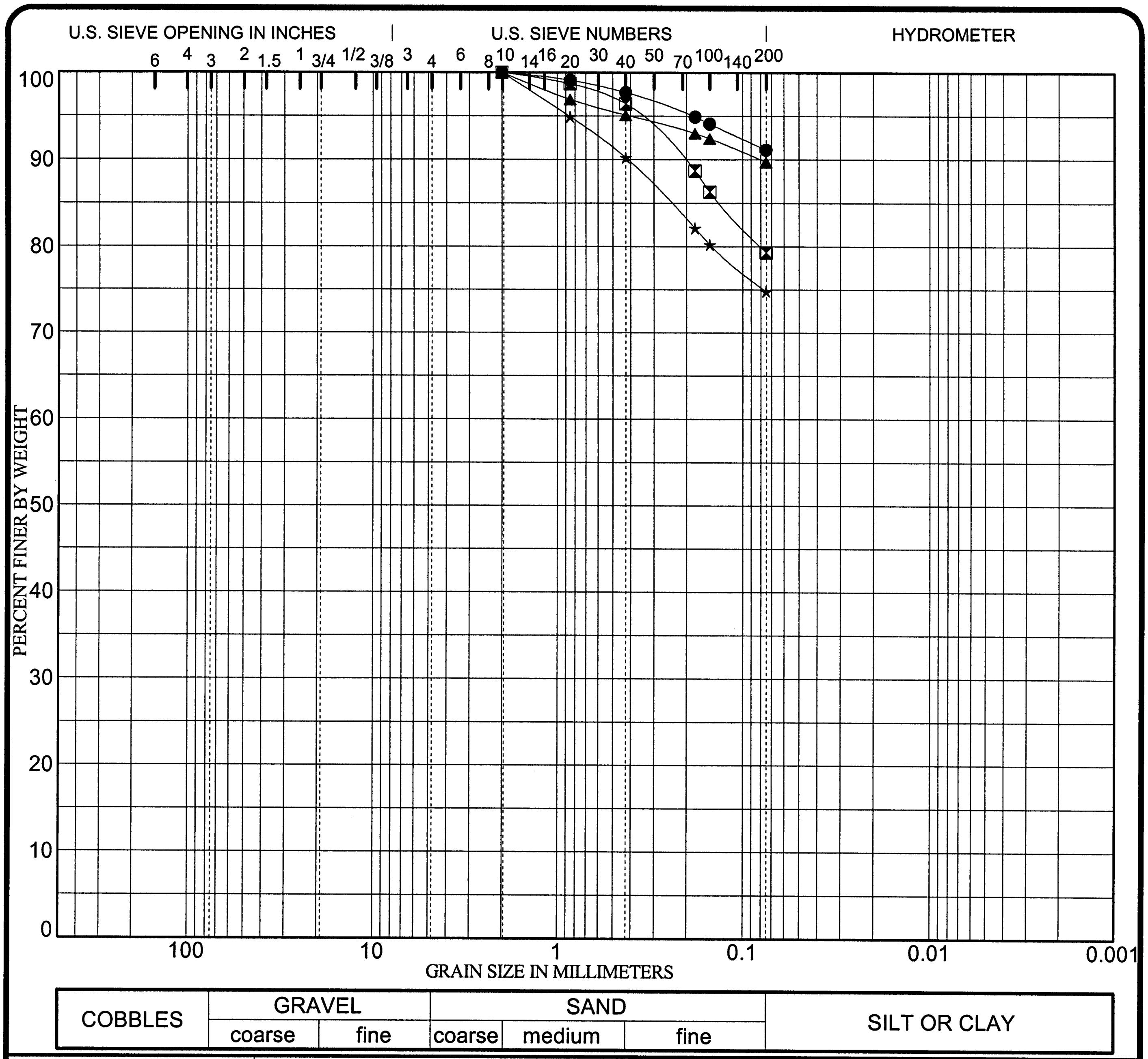

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D3**	**7.0**	**Lean Clay CL**		**43**	**17**	**27**		
☒	**D3**	**8.0**	**Lean Clay With Sand CL**		**39**	**15**	**24**		
▲	**D3**	**10.0**	**Lean Clay CL**		**48**	**15**	**33**		
★	**D3**	**11.0**	**Lean Clay With Sand CL**		**47**	**21**	**26**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D3**	**7.0**	**2.00**				**0.0**	**8.9**	**91.1**	
☒	**D3**	**8.0**	**2.00**				**0.0**	**20.7**	**79.3**	
▲	**D3**	**10.0**	**2.00**				**0.0**	**10.3**	**89.7**	
★	**D3**	**11.0**	**2.00**				**0.0**	**25.2**	**74.8**	

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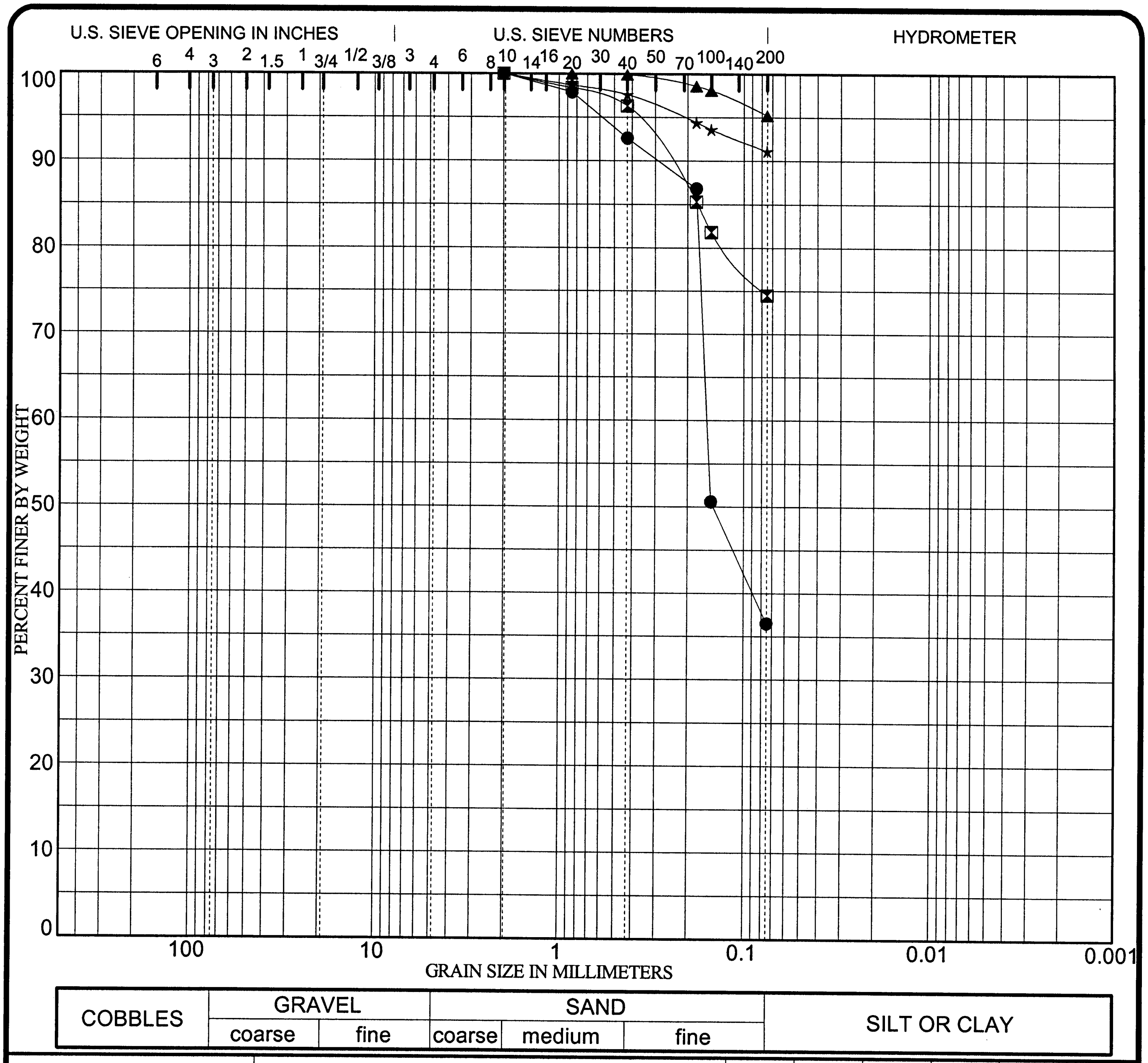

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	D4	1.0	Clayey Sand SC		60	15	45		
☒	D4	2.0	Fat Clay With Sand CH		57	18	40		
▲	D4	3.0	Fat Clay CH		70	21	49		
★	D4	4.0	Fat Clay CH		103	21	81		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	D4	1.0	2.00	0.16			0.0	63.5	36.5	
☒	D4	2.0	2.00				0.0	25.5	74.5	
▲	D4	3.0	0.85				0.0	4.8	95.2	
★	D4	4.0	2.00				0.0	8.9	91.1	

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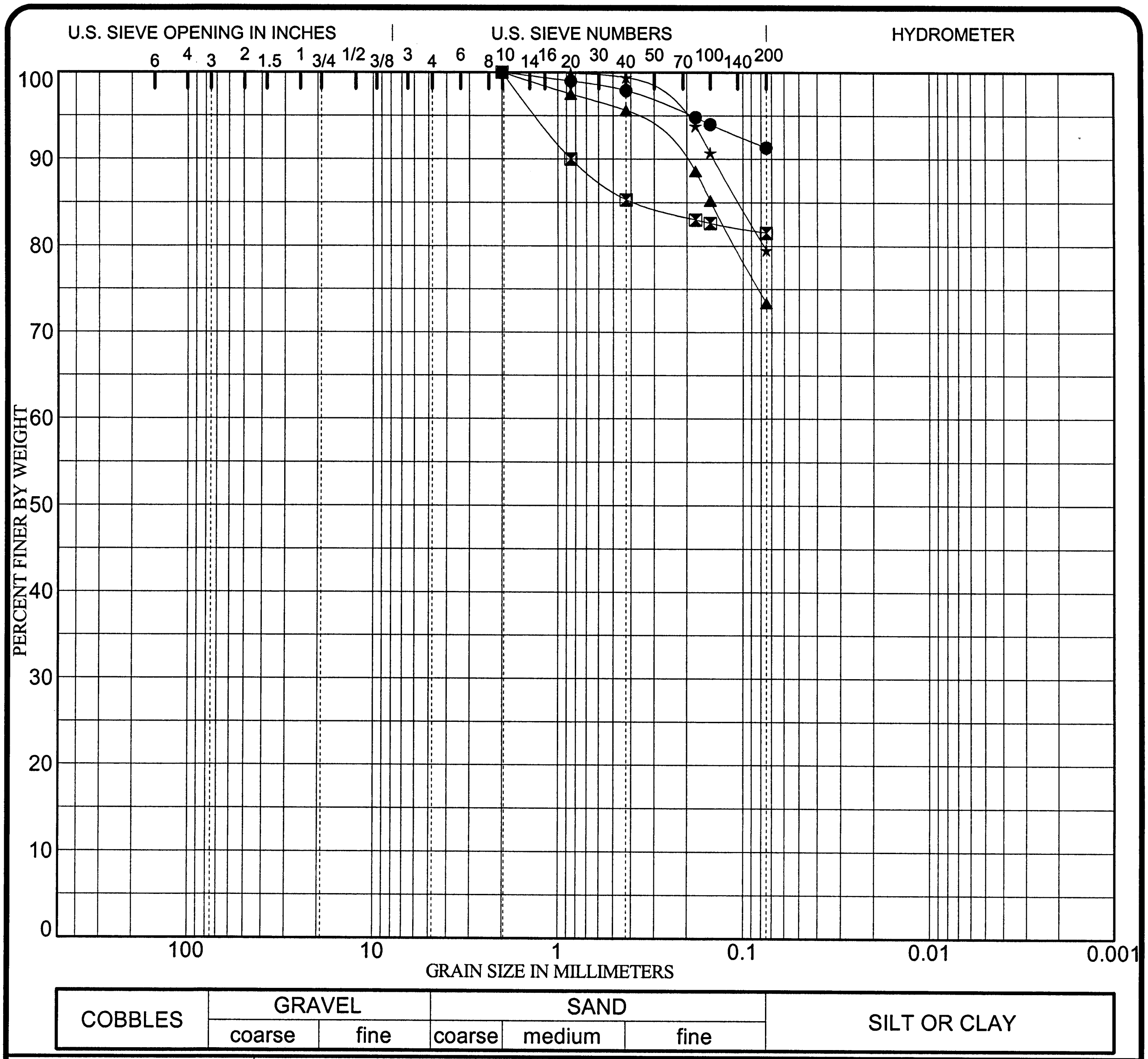

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D4**	**5.0**	**Fat Clay CH**		**78**	**18**	**60**		
⧗	**D4**	**6.0**	**Fat Clay With Sand CH**		**71**	**21**	**50**		
▲	**D4**	**7.0**	**Lean Clay With Sand CL**		**37**	**15**	**22**		
★	**D4**	**8.0**	**Lean Clay With Sand CL**		**36**	**14**	**23**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D4**	**5.0**	**2.00**				**0.0**	**8.7**	**91.3**	
⧗	**D4**	**6.0**	**2.00**				**0.0**	**18.5**	**81.5**	
▲	**D4**	**7.0**	**2.00**				**0.0**	**26.6**	**73.4**	
★	**D4**	**8.0**	**2.00**				**0.0**	**20.5**	**79.5**	

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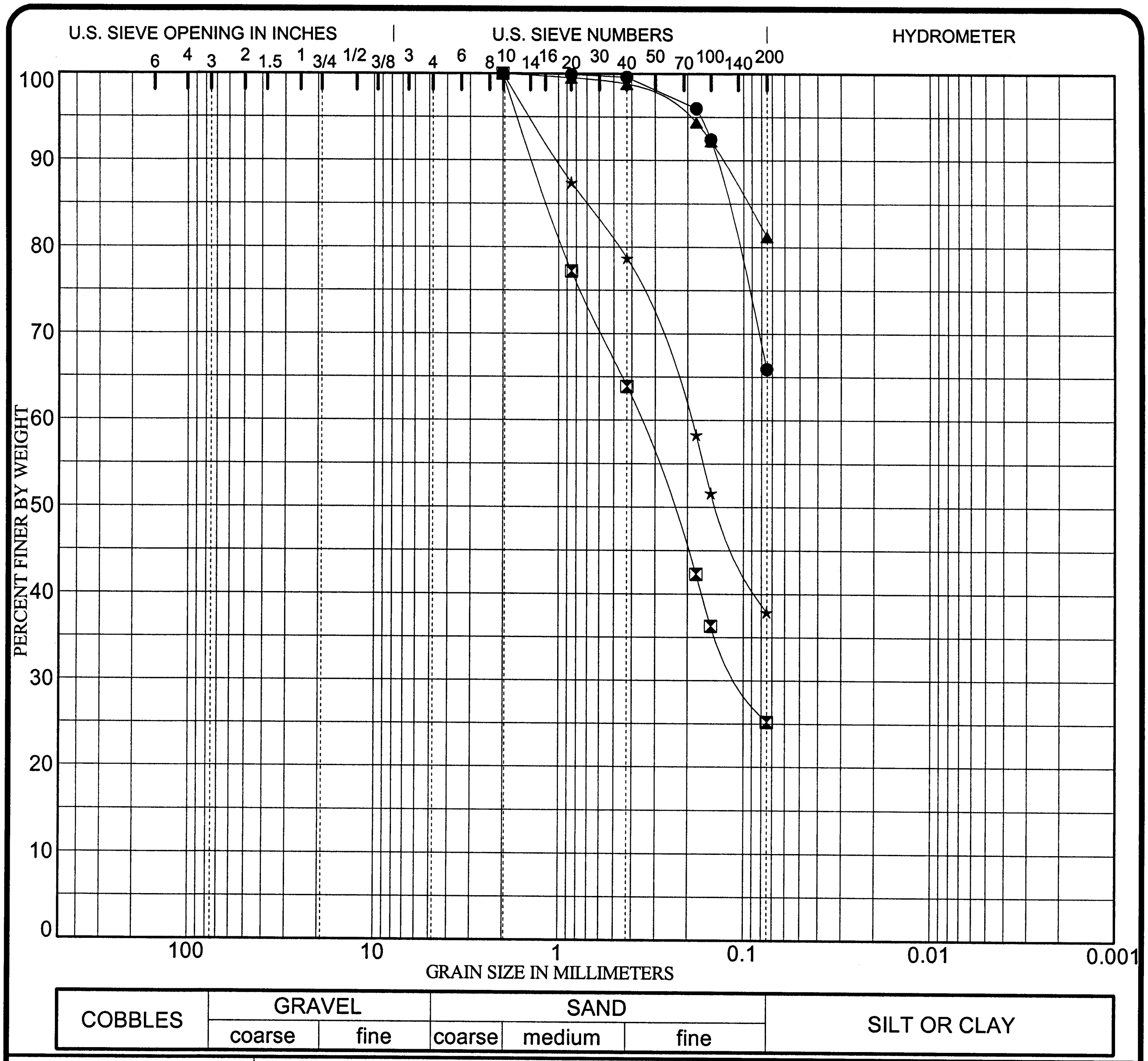

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D4**	**9.0**	**Sandy Lean Clay CL**		**29**	**21**	**8**		
☒	**D4**	**10.0**	**Clayey Sand SC**		**27**	**19**	**9**		
▲	**D4**	**11.0**	**Silty Clay With Sand CL-ML**		**26**	**21**	**5**		
★	**D4**	**12.0**	**Clayey Sand SC**		**35**	**15**	**21**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D4**	**9.0**	**2.00**				**0.0**	**34.1**	**65.9**	
☒	**D4**	**10.0**	**2.00**	**0.36**	**0.101**		**0.0**	**74.8**	**25.2**	
▲	**D4**	**11.0**	**2.00**				**0.0**	**18.8**	**81.2**	
★	**D4**	**12.0**	**2.00**	**0.19**			**0.0**	**62.1**	**37.9**	

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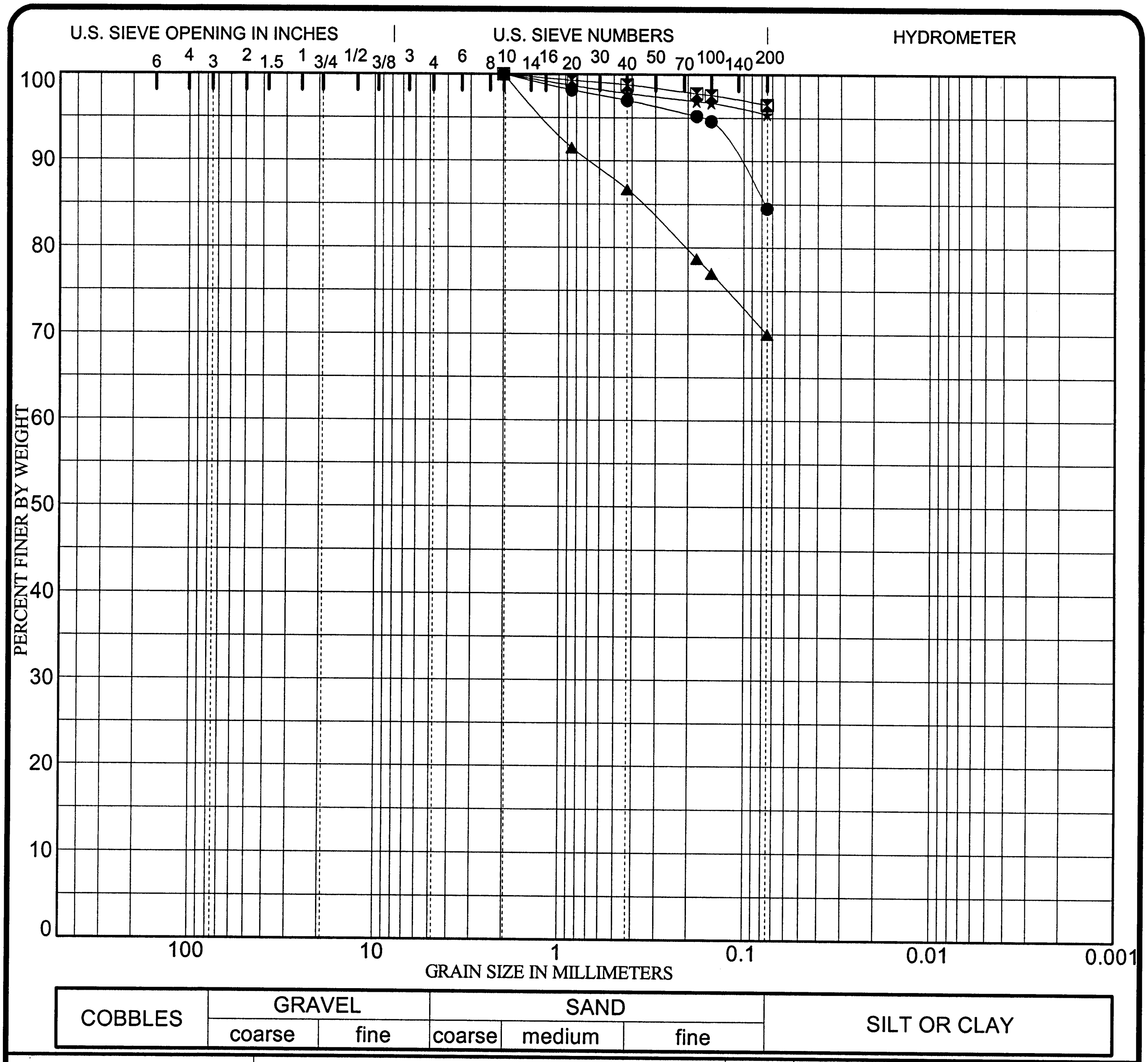

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	D5	1.0	Lean Clay With Sand CL		37	16	21		
⧗	D5	2.0	Fat Clay CH		52	16	36		
▲	D5	3.0	Sandy Lean Clay CL		41	16	25		
★	D5	4.0	Fat Clay CH		51	17	35		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	D5	1.0	2.00				0.0	15.5	84.5	
⧗	D5	2.0	2.00				0.0	3.5	96.5	
▲	D5	3.0	2.00				0.0	30.0	70.0	
★	D5	4.0	2.00				0.0	4.6	95.4	

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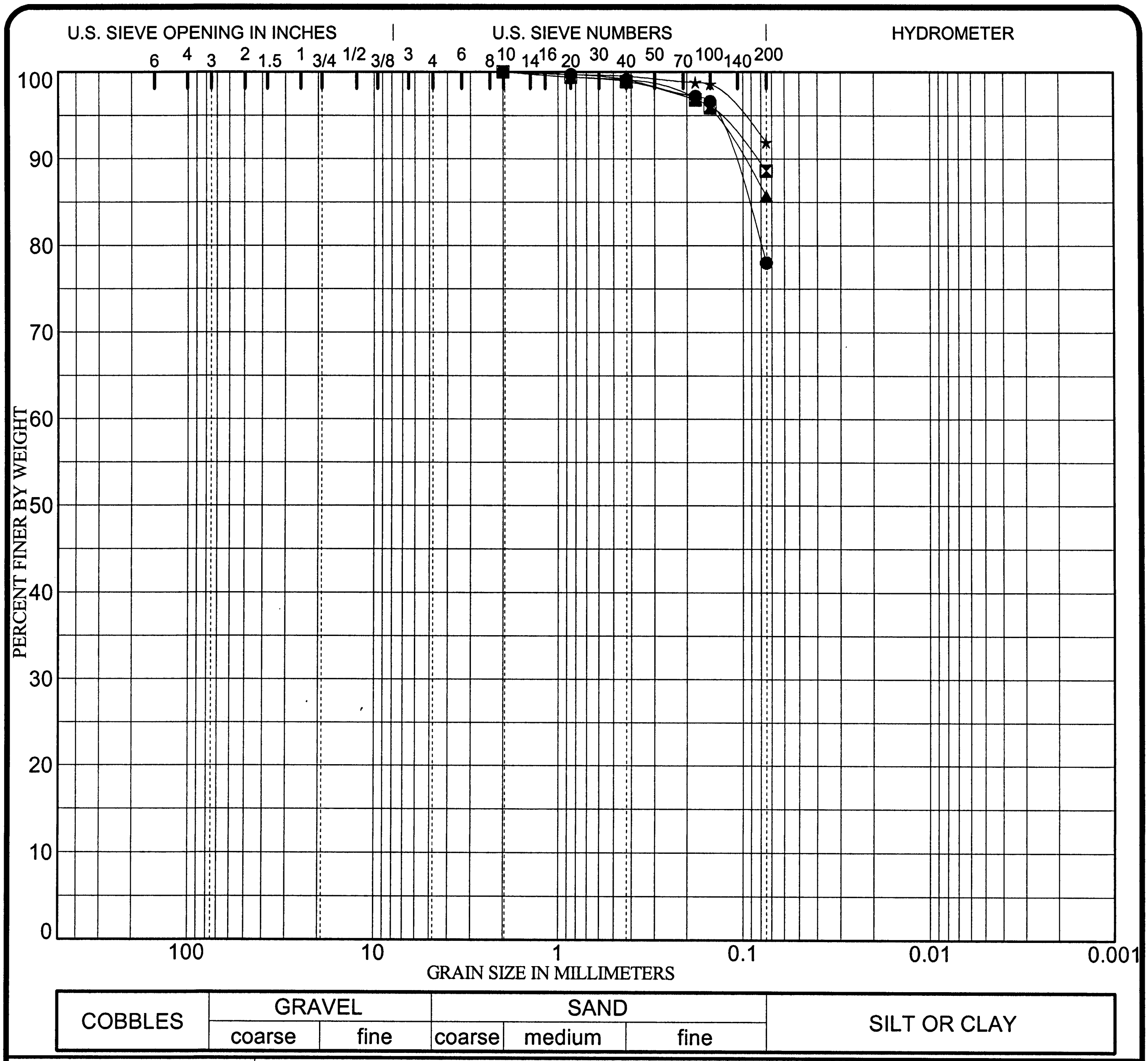

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D5**	**5.0**	**Lean Clay With Sand CL**		**38**	**15**	**23**		
⧗	**D5**	**6.0**	**Lean Clay CL**		**36**	**15**	**22**		
▲	**D5**	**7.0**	**Lean Clay CL**		**37**	**15**	**21**		
★	**D5**	**8.0**	**Lean Clay CL**		**45**	**17**	**28**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D5**	**5.0**	**2.00**				**0.0**	**22.0**	**78.0**	
⧗	**D5**	**6.0**	**2.00**				**0.0**	**11.4**	**88.6**	
▲	**D5**	**7.0**	**2.00**				**0.0**	**14.3**	**85.7**	
★	**D5**	**8.0**	**2.00**				**0.0**	**8.1**	**91.9**	

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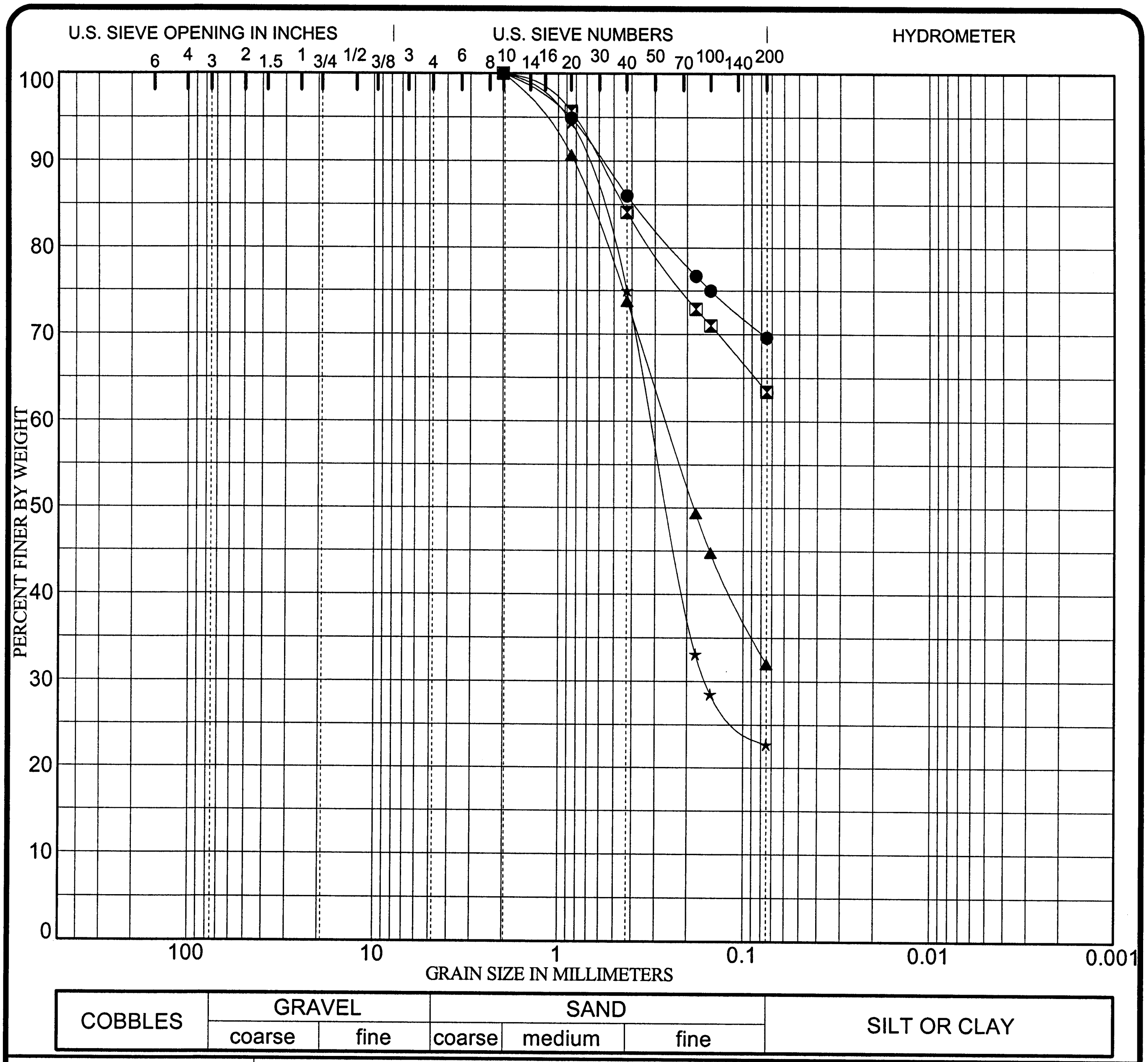

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**D5**	**9.0**	**Sandy Fat Clay CH**		**55**	**21**	**34**		
☒	**D5**	**10.0**	**Sandy Lean Clay CL**		**35**	**19**	**16**		
▲	**D5**	**11.0**	**Silty Sand SM**		**21**	**20**	**1**		
★	**D5**	**12.0**	**Silty Sand SM**		**26**	**23**	**3**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**D5**	**9.0**	**2.00**				**0.0**	**30.4**	**69.6**	
☒	**D5**	**10.0**	**2.00**				**0.0**	**36.6**	**63.4**	
▲	**D5**	**11.0**	**2.00**	**0.26**			**0.0**	**68.0**	**32.0**	
★	**D5**	**12.0**	**2.00**	**0.31**	**0.159**		**0.0**	**77.3**	**22.7**	

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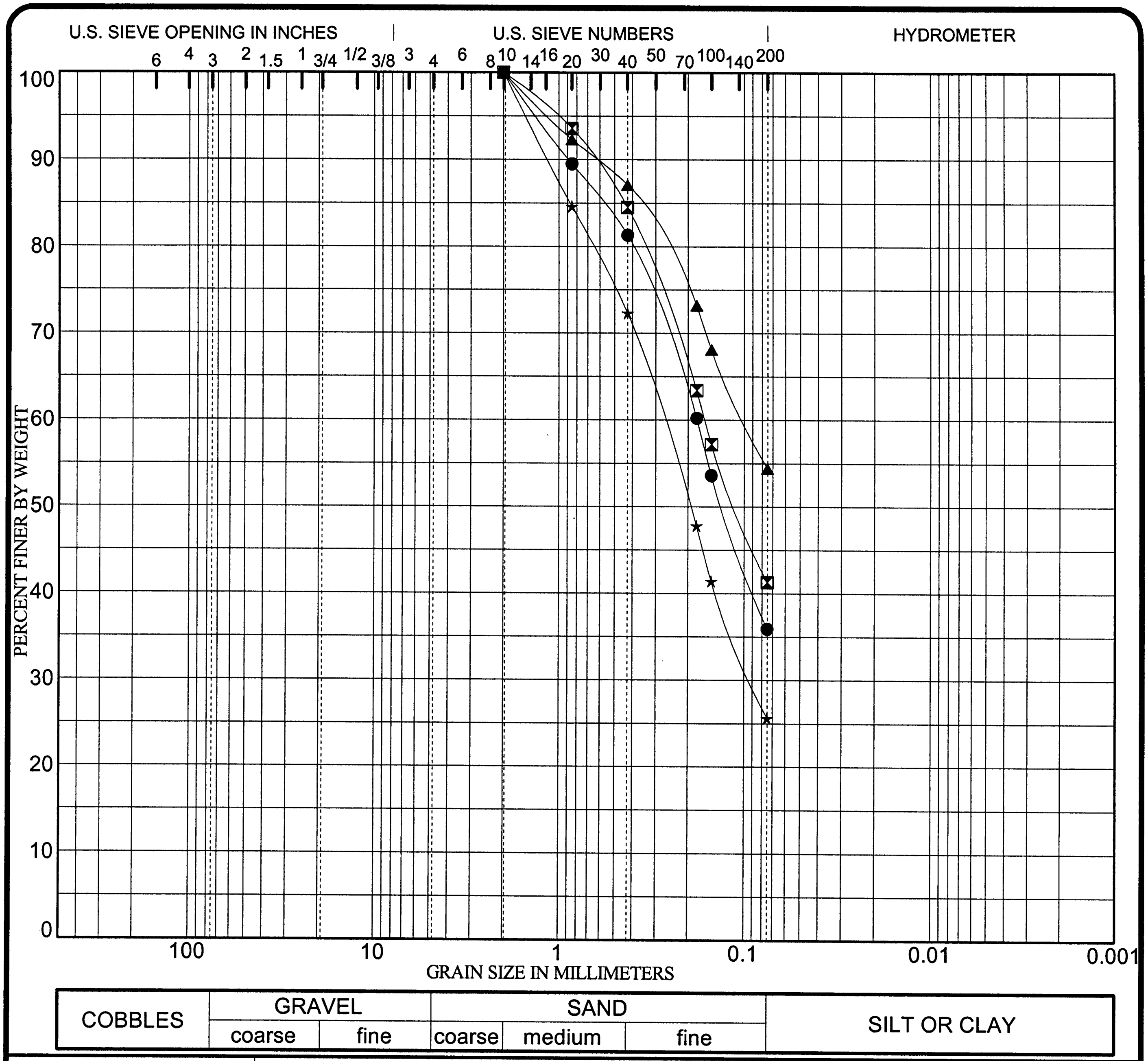

Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
● **D5**	**13.0**	**Silty Sand SM**		**39**	**28**	**12**		
⧗ **D5**	**14.0**	**Silty Sand SM**		**60**	**56**	**4**		
▲ **D5**	**15.0**	**Sandy Lean Clay CL**		**32**	**19**	**14**		
★ **D5**	**16.0**	**Silty Sand SM**		**41**	**40**	**1**		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **D5**	**13.0**	**2.00**	**0.18**			**0.0**	**64.1**	**35.9**	
⧗ **D5**	**14.0**	**2.00**	**0.16**			**0.0**	**58.7**	**41.3**	
▲ **D5**	**15.0**	**2.00**	**0.10**			**0.0**	**45.6**	**54.4**	
★ **D5**	**16.0**	**2.00**	**0.28**	**0.091**		**0.0**	**74.4**	**25.6**	

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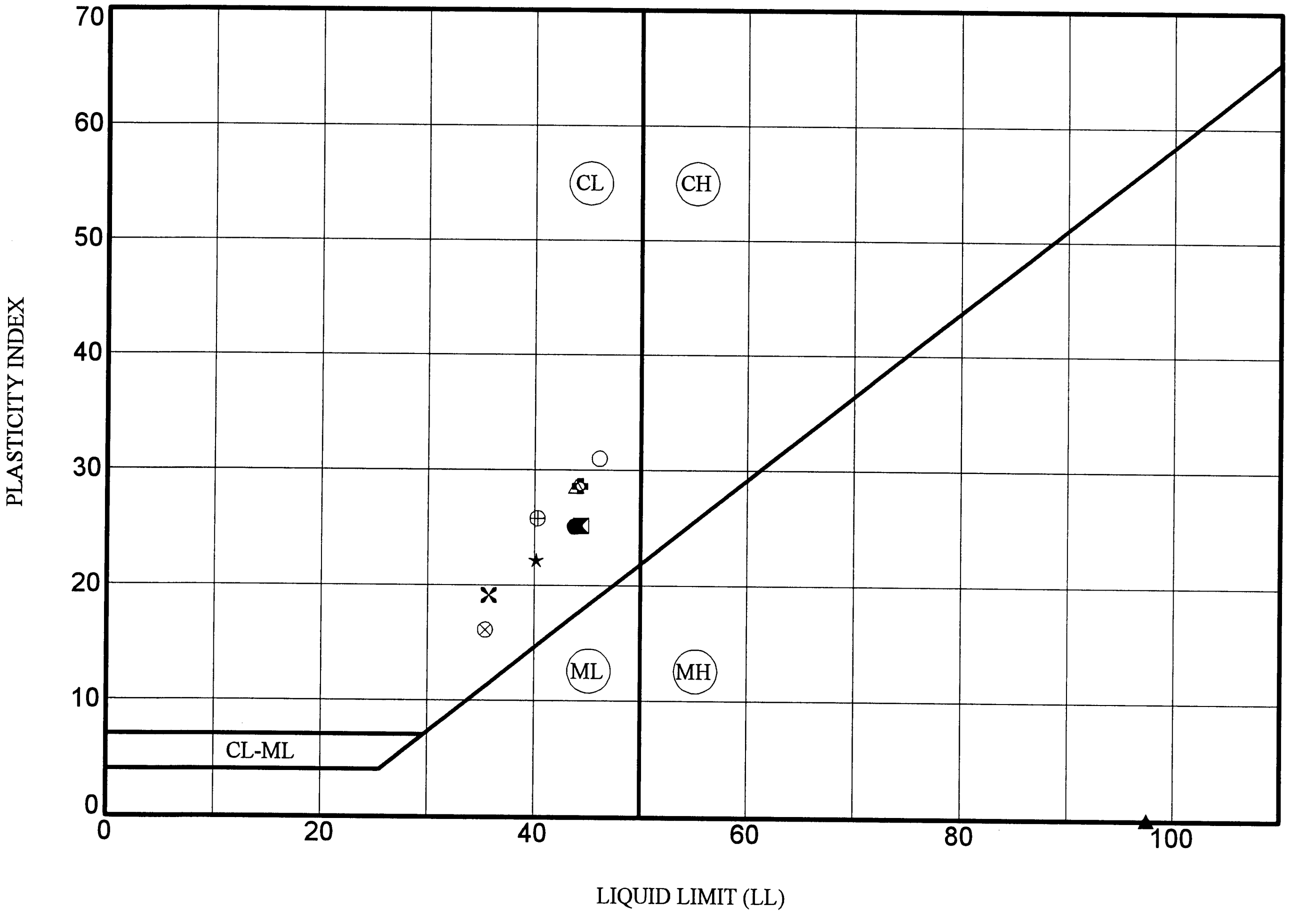
Plate No. 52



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**CS-EC**	**1.0**	**44**	**19**	**25**	**83.7**	**Lean Clay With Sand CL**
⧗	**CS-EC**	**2.0**	**44**	**19**	**25**	**82.4**	**Lean Clay With Sand CL**
▲	**CS-EC**	**3.0**	**98**	**97**	**NP**	**82.7**	**Elastic Silt With Sand MH**
★	**CS-EC**	**4.0**	**40**	**18**	**22**	**86.5**	**Lean Clay CL**
✕	**CS-EC**	**5.0**	**36**	**17**	**19**	**88.2**	**Lean Clay CL**
✿	**CS-EC**	**6.0**	**44**	**16**	**29**	**97.2**	**Lean Clay CL**
○	**CS-EC**	**7.0**	**46**	**15**	**31**	**97.6**	**Lean Clay CL**
△	**CS-EC**	**8.0**	**44**	**15**	**29**	**96.4**	**Lean Clay CL**
⊗	**CS-EC**	**9.0**	**35**	**19**	**16**	**86.6**	**Lean Clay CL**
⊕	**CS-EC**	**10.0**	**40**	**15**	**26**	**90.3**	**Lean Clay CL**

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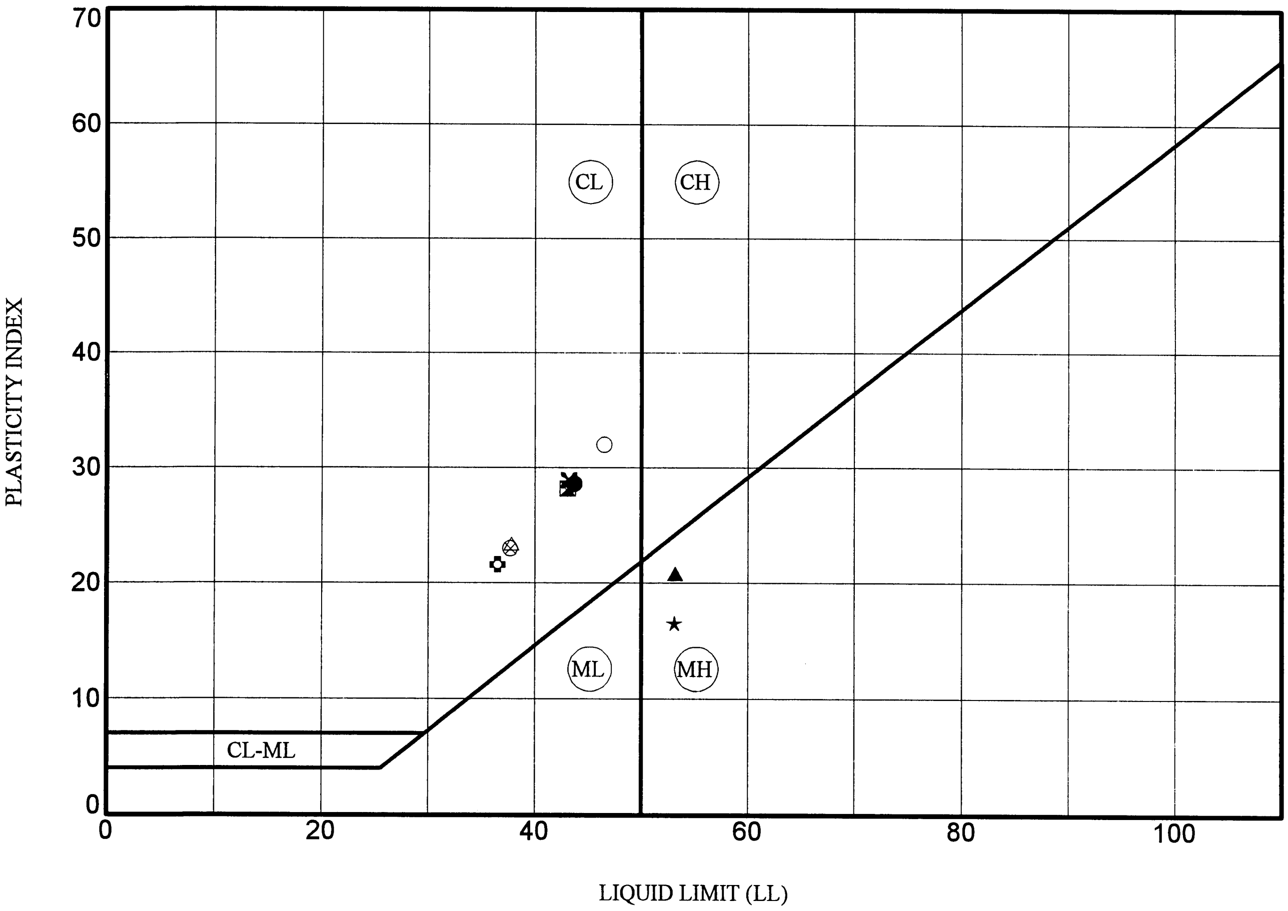

	Specimen Identification		LL	PL	PI	Fines	Classification
●	**CS-EC**	**11.0**	**44**	**15**	**29**	**95.8**	**Lean Clay CL**
⧗	**CS-EC**	**12.0**	**43**	**15**	**28**	**97.9**	**Lean Clay CL**
▲	**CS-WC**	**1.0**	**53**	**32**	**21**	**71.1**	**Elastic Silt With Sand MH**
★	**CS-WC**	**2.0**	**53**	**37**	**17**		**Elastic Silt MH**
✕	**CS-WC**	**3.0**	**43**	**14**	**29**	**90.1**	**Lean Clay CL**
✿	**CS-WC**	**4.0**	**37**	**15**	**22**	**86.6**	**Lean Clay CL**
○	**CS-WC**	**5.0**	**47**	**15**	**32**	**84.4**	**Lean Clay With Sand CL**
△	**CS-WC**	**6.0**	**38**	**14**	**23**	**94.7**	**Lean Clay CL**
⊗	**CS-WC**	**7.0**	**38**	**15**	**23**	**95.7**	**Lean Clay CL**
⊕	**CS-WC**	**8.0**	**44**	**15**	**29**	**86.7**	**Lean Clay CL**

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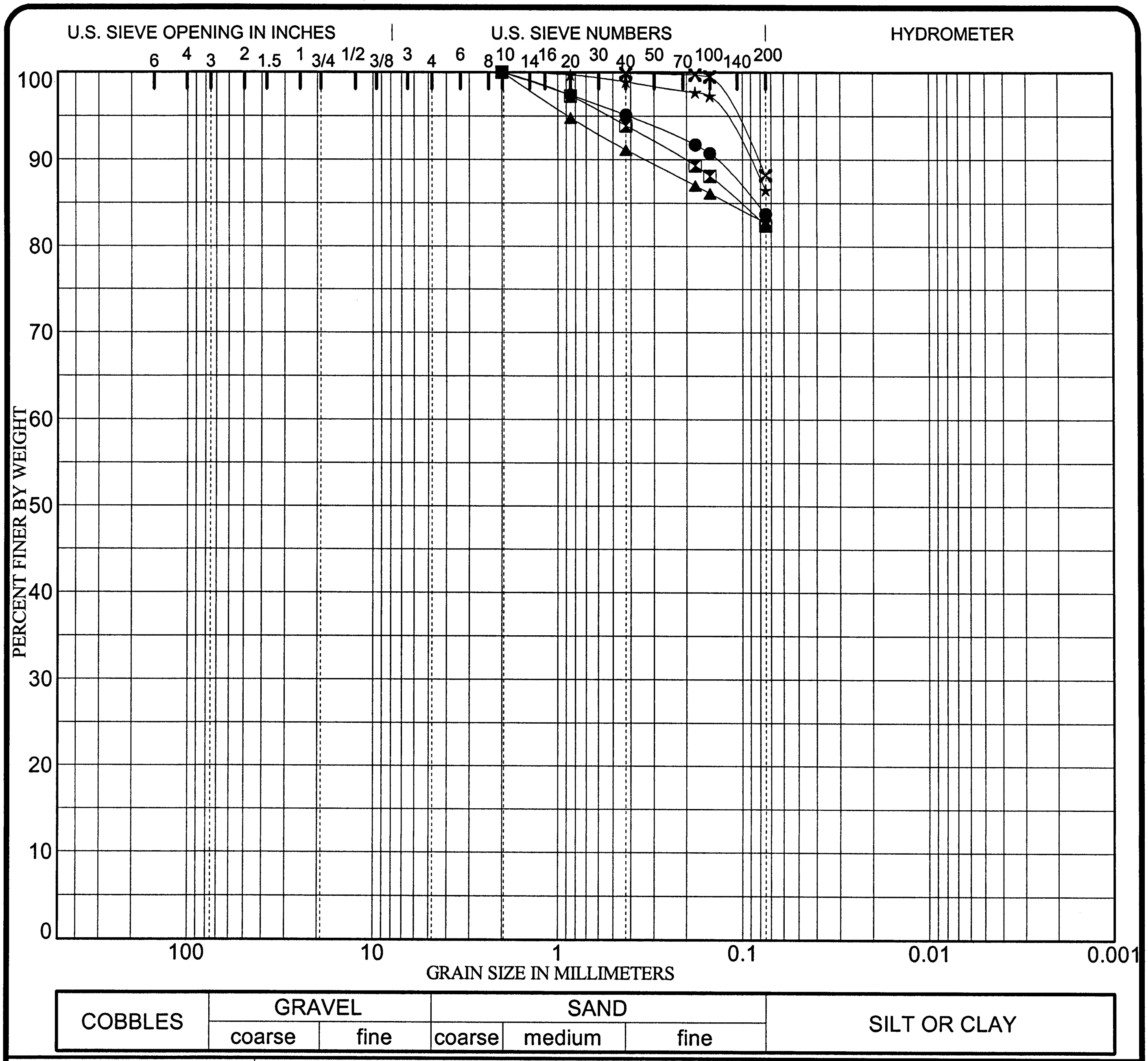

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**CS-EC**	**1.0**	**Lean Clay With Sand CL**		**44**	**19**	**25**		
⧗	**CS-EC**	**2.0**	**Lean Clay With Sand CL**		**44**	**19**	**25**		
▲	**CS-EC**	**3.0**	**Elastic Silt With Sand MH**		**98**	**97**	**NP**		
★	**CS-EC**	**4.0**	**Lean Clay CL**		**40**	**18**	**22**		
✕	**CS-EC**	**5.0**	**Lean Clay CL**		**36**	**17**	**19**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**CS-EC**	**1.0**	**2.00**				**0.0**	**16.3**	**83.7**	
⧗	**CS-EC**	**2.0**	**2.00**				**0.0**	**17.6**	**82.4**	
▲	**CS-EC**	**3.0**	**2.00**				**0.0**	**17.3**	**82.7**	
★	**CS-EC**	**4.0**	**2.00**				**0.0**	**13.5**	**86.5**	
✕	**CS-EC**	**5.0**	**2.00**				**0.0**	**11.8**	**88.2**	

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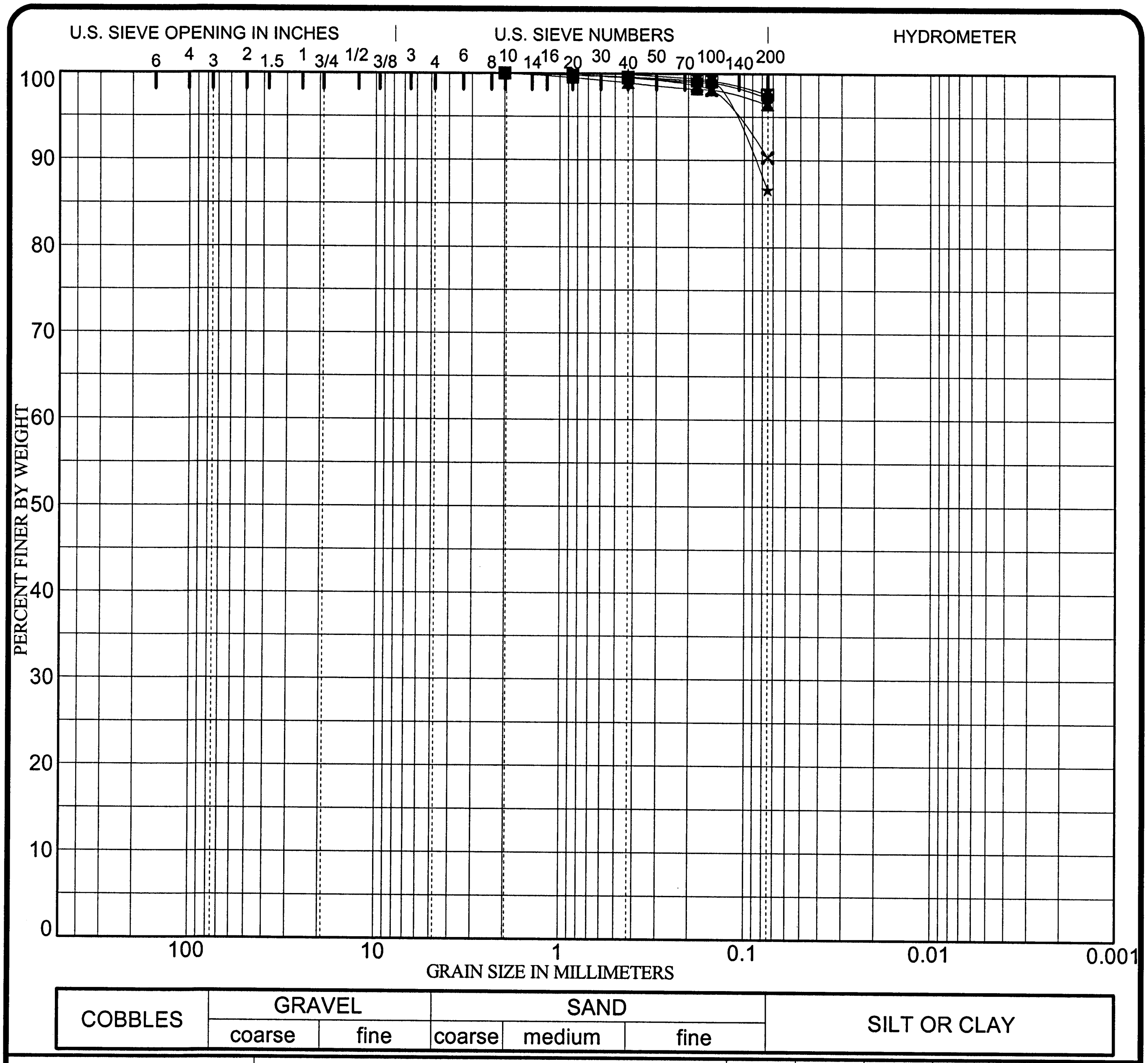

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**CS-EC**	**6.0**	**Lean Clay CL**		**44**	**16**	**29**		
☒	**CS-EC**	**7.0**	**Lean Clay CL**		**46**	**15**	**31**		
▲	**CS-EC**	**8.0**	**Lean Clay CL**		**44**	**15**	**29**		
★	**CS-EC**	**9.0**	**Lean Clay CL**		**35**	**19**	**16**		
✕	**CS-EC**	**10.0**	**Lean Clay CL**		**40**	**15**	**26**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**CS-EC**	**6.0**	**2.00**				**0.0**	**2.8**	**97.2**	
☒	**CS-EC**	**7.0**	**2.00**				**0.0**	**2.4**	**97.6**	
▲	**CS-EC**	**8.0**	**2.00**				**0.0**	**3.6**	**96.4**	
★	**CS-EC**	**9.0**	**0.85**				**0.0**	**13.4**	**86.6**	
✕	**CS-EC**	**10.0**	**2.00**				**0.0**	**9.7**	**90.3**	

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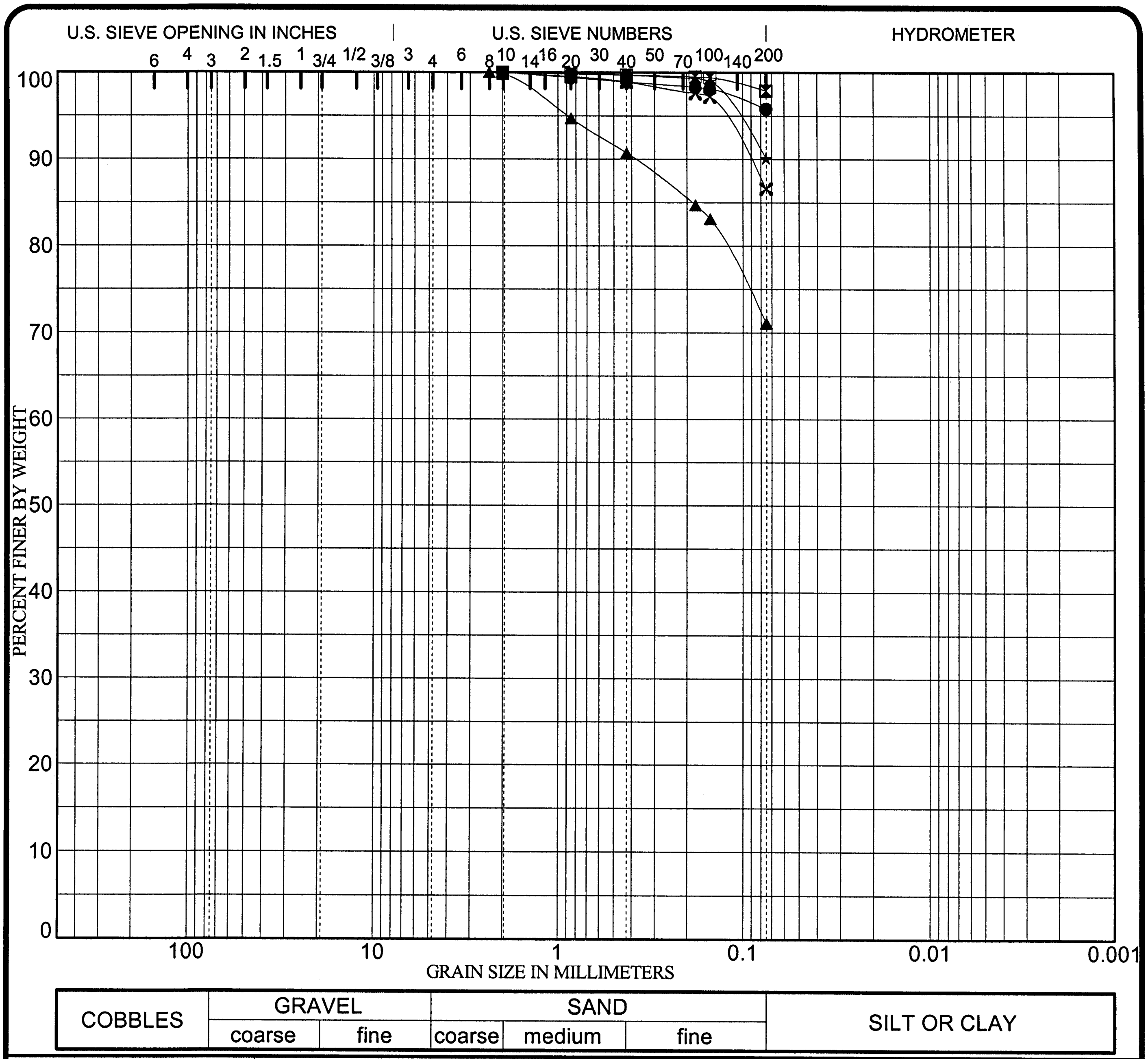

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**CS-EC**	**11.0**	**Lean Clay CL**		**44**	**15**	**29**		
⧗	**CS-EC**	**12.0**	**Lean Clay CL**		**43**	**15**	**28**		
▲	**CS-WC**	**1.0**	**Elastic Silt With Sand MH**		**53**	**32**	**21**		
★	**CS-WC**	**3.0**	**Lean Clay CL**		**43**	**14**	**29**		
✕	**CS-WC**	**4.0**	**Lean Clay CL**		**37**	**15**	**22**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**CS-EC**	**11.0**	**2.00**				**0.0**	**4.2**	**95.8**	
⧗	**CS-EC**	**12.0**	**2.00**				**0.0**	**2.1**	**97.9**	
▲	**CS-WC**	**1.0**	**2.36**				**0.0**	**28.9**	**71.1**	
★	**CS-WC**	**3.0**	**2.00**				**0.0**	**9.9**	**90.1**	
✕	**CS-WC**	**4.0**	**2.00**				**0.0**	**13.4**	**86.6**	

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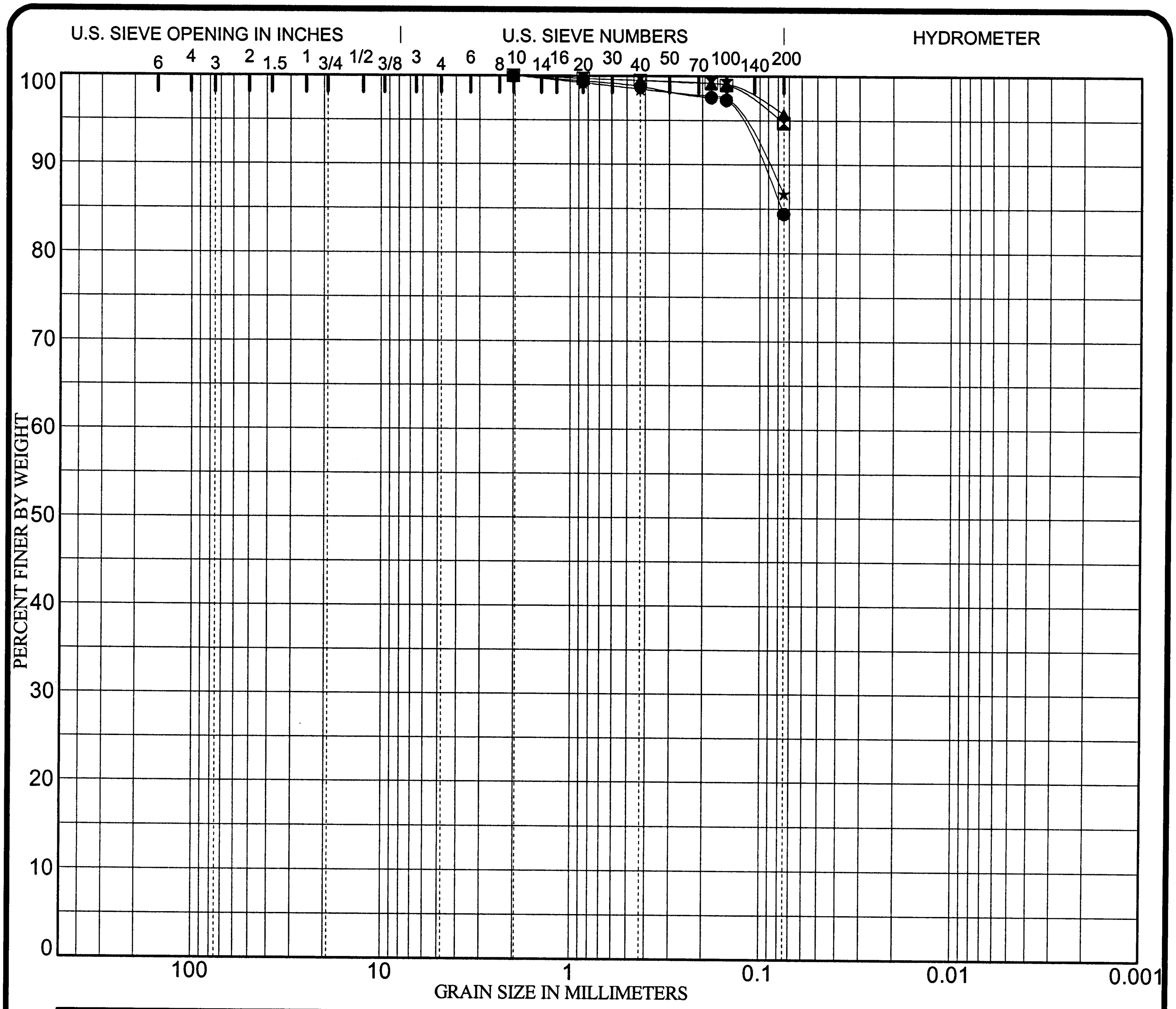

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	CS-WC	5.0	Lean Clay With Sand CL		47	15	32		
⧗	CS-WC	6.0	Lean Clay CL		38	14	23		
▲	CS-WC	7.0	Lean Clay CL		38	15	23		
★	CS-WC	8.0	Lean Clay CL		44	15	29		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	CS-WC	5.0	2.00				0.0	15.6	84.4	
⧗	CS-WC	6.0	2.00				0.0	5.3	94.7	
▲	CS-WC	7.0	2.00				0.0	4.3	95.7	
★	CS-WC	8.0	2.00				0.0	13.3	86.7	

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