Physical and Hydrologic Properties of Water-Bearing Deposits in Subsiding Areas In Central California

GEOLOGICAL SURVEY PROFESSIONAL PAPER 497-A

Physical and Hydrologic Properties of Water-Bearing Deposits in Subsiding Areas In Central California

By A. I. JOHNSON, R. P. MOSTON, *and* D. A. MORRIS

MECHANICS OF AQUIFER SYSTEMS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 497-A

Results of laboratory tests on cores from deposits that in part are compacting, owing to artesian-head decline

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FOREWORD

The problem and the need for study

The land surface is sinking in several areas of intensive ground-water withdrawal in California. (See fig. 1.) Subsidence of the land surface in the central part of the Santa Clara Valley, at the south end of San Francisco Bay, has been known since the early thirties; an area of about 250 square miles has been subsiding, and by 1963 maximum subsidence of 11 feet had occurred in San Jose. In the San Joaquin Valley also, subsidence has been recognized since the middle thirties. About 3,000 square miles, or 30 percent of the valley floor, is subsiding. Subsidence of many feet has been observed in three principal areas in the San Joaquin Valley. Between Los Banos and Kettleman City, on the central west side of the valley, an area of 1,200 square miles has subsided 2 feet or more, and by 1963 maximum subsidence was 23 feet a few miles west of Mendota. In the Tulare-Wasco area, on the southeast side of the valley, subsidence of more than 1 foot had affected at least 800 square miles by 1962, and maximum subsidence was 12 feet. In the Arvin-Maricopa area, at the south end of the valley, subsidence has occurred in about 450 square miles and was as much as 6 feet by 1962.

The areas of subsidence in the San Joaquin Valley are in irrigated lands in part traversed by canals of large capacity and low gradient; additional major trunkline aqueducts are planned or are under construction. Where the rate of subsidence is large—a few tenths of a foot to a foot per year—it poses serious problems in the construction and maintenance of these costly structures and also of local water-distribution systems, sewerage lines, and drainage and flood-control works. In addition, it has caused many well-casing failures as a result of compaction of the sediments and compression of the casings.

Inter-Agency Committee planning

By 1954, preliminary planning for the California Aqueduct and the San Luis project canal of the U.S. Bureau of Reclamation emphasized the critical need for information on the extent, rates, causes, and possible measures for control or alleviation of land subsidence. As a result, concerned Federal and State agencies formed the Inter-Agency Committee on Land Subsidence in the San Joaquin Valley in December 1954, to plan and coordinate subsidence investigations. The actively participating members of the Committee included the following: three Federal agencies—the Bureau of Reclamation and the Geological Survey in the Department of the Interior, and the Coast and Geodetic Survey of the Department of Commerce; two State agencies—the California Department of Water Resources and the Division of Highways, Department of Public Works; and two universities—the University of California at Davis and Stanford University. The first major action of the Committee was the preparation of a proposed program of investigation (Inter-Agency Committee on Land Subsidence in the San Joaquin Valley, 1955).

Cooperative program with the State of California

As one result of the interagency planning, an intensive investigation of land subsidence in the San Joaquin Valley was begun by the Geological Survey in 1956, in financial cooperation with the California Department of Water Resources. The Geological Survey participation in the interagency committee work has been carried on in conjunction with this cooperative program.

The objectives of the cooperative program on land subsidence in the San Joaquin Valley are as follows:

1. To obtain vertical control on the land surface adequate to define the extent, rate, and magnitude of subsidence. The vertical control program is a companion project of the U.S.

Coast and Geodetic Survey, which that agency has carried on since 1960 in financial cooperation with the California Department of Water Resources.

2. To determine causes of the subsidence, the relative magnitude attributable to the different causes, and also the depth range within which compaction causing subsidence is occurring.
3. To furnish criteria for estimating the rates and amounts of subsidence that might occur under assumed hydrologic change; to suggest methods for decreasing or alleviating subsidence; and to determine whether any part of the subsidence is reversible and, if so, to what extent.

A progress report prepared in 1958 (Inter-Agency Committee on Land Subsidence in the San Joaquin Valley, 1958) described the major subsidence areas in the San Joaquin Valley and reported on the methods of investigation and preliminary results. The report, prepared chiefly by the Geological Survey, resulted from the cooperative program of the Geological Survey and the field activities of the Bureau of Reclamation, Coast and Geodetic Survey, California Department of Water Resources and Division of Highways, and the University of California at Davis. The report identified two types of subsidence that occur in the San Joaquin Valley. Most of the subsidence in the three areas is being caused by compaction of artesian aquifer systems, owing to withdrawal of ground water from confined deposits and the resulting decline in artesian head. Locally, on the western and southern flanks of the valley, the second type of subsidence is caused by near-surface compaction of moisture-deficient alluvial-fan deposits above the water table, after initial wetting by percolating irrigation water. This second type of subsidence produces extensive settling and cracking of the land surface along ditches, and irregular undulating topography in irrigated areas underlain by the susceptible deposits. Near-surface subsidence of 10 feet or more has been produced in wetted test plots and in irrigated fields. Near-surface subsidence may produce abrupt changes of several feet in the land-surface altitude in short distances. Hence, it creates serious problems in construction and maintenance of water-transport systems, highways, pipelines, electric transmission towers, and other engineering structures, and in farming.

In the Los Banos-Kettleman City area, a dual-function canal to serve the San Luis project area of the Bureau of Reclamation and to transport water of the California Aqueduct south to Kettleman City is (1964) under construction. It has a design capacity of 13,100 cfs (cubic feet per second) at its head—at San Luis Dam west of Los Banos—which decreases to 7,000 cfs at Kettleman City. This dual-function canal will cross about 70 miles of subsiding ground in the Los Banos-Kettleman City area. All of this 70-mile reach is subsiding because of artesian-head decline, and at least 20 miles is subject to near-surface subsidence as well. In the reach susceptible to near-surface subsidence, the canal alinement is being prewetted for many months to precompact the deposits above the water table before the great canal is built.

The California Aqueduct, which will transport water south from Kettleman City to Kern County and to the Los Angeles area, will be constructed through several tens of miles of subsiding land in the Arvin-Maricopa area. Here, also, the subsidence due to artesian-head decline is the more extensive, but near-surface subsidence also is a serious problem. The total cost of precompaction of the reach susceptible to near-surface subsidence south of Kettleman City—about 55 miles—is estimated by the California Department of Water Resources to be $20 million.[1]

The subsidence in the Los Banos-Kettleman City and Tulare-Wasco areas due to artesian-head decline was described briefly by Poland and Davis (1956). The extent and character of subsidence of near-surface deposits in the Los Banos-Kettleman City area have been summarized by Lofgren (1960); the geology of the alluvial fans and the causes and mechanics of the near-surface subsidence have been described by Bull (1961, 1964). The extent and magnitude of subsidence in the Arvin-Maricopa area as of 1962 have been summarized by Lofgren

[1] Lucas, C. V., and Lombard, F. J., 1964, Land subsidence along the California Aqueduct as related to environment: California Dept. Water Resources; prepared for Am. Soc. Civil Engineers Environmental Eng. Conf., Salt Lake City, Utah, 17 p.

(1963). The cooperative land-subsidence investigations are continuing, and major reports are in preparation on the Los Banos-Kettleman City, Tulare-Wasco, and Arvin-Maricopa areas.

Geological Survey research on mechanics of aquifer systems

The areas of active and substantial land subsidence in the San Joaquin and Santa Clara Valleys offer an unexcelled opportunity to study compaction of sediments in response to change in effective stress. Not only are the aquifer systems compacting at a rate that is susceptible to field measurement, but, equally important, the forces causing this compaction can be determined quantitatively in much of the subsiding area. For this reason, the Geological Survey also began in 1956 a federally financed research project directed toward determining the principles controlling the deformation (compaction or expansion) of aquifer systems resulting from change in grain-to-grain load, caused chiefly by change in internal fluid pressure. One of the principal objectives of this research project is to appraise the changes that occur in the hydraulic characteristics of compactible aquifer systems, particularly the storage characteristics, as the systems compact under increased effective stress, especially under cyclic application of stress.

In the San Joaquin Valley, the needs of the cooperative land-subsidence studies and of the Federal research on mechanics of aquifer deformation with respect to field and laboratory data are in large part common and the findings are mutually beneficial. In the Santa Clara Valley, the study of land subsidence and aquifer deformation is entirely a part of the Federal research program.

The principal elements of the program to supply the needs of both the Federal research and of the cooperative program in the San Joaquin Valley are summarized as follows:

1. Measure magnitude and rate of compaction (or expansion) occurring in the aquifer systems, by means of compaction-recorder installations.
2. Measure changes in hydrostatic head areally and also in or near compaction-recorder wells, for comparison with observed aquifer deformation.
3. Drill core holes into or through the compacting aquifer systems, obtain core and geophysical logs, and preserve selected core samples for laboratory tests and study.
4. Make laboratory tests of core samples to determine their physical and hydrologic properties and consolidation and rebound characteristics.
5. Study the mineralogy and petrography of core samples with special reference to environment of deposition, and determine the mineralogy of the fine-grained clay elements.
6. Utilize the laboratory-test results and the observed change in hydrostatic head to compute compaction of the aquifer system, on the basis of soil-mechanics theory.
7. Compare land subsidence, as observed from changes in elevation of bench marks determined by precise leveling, with the measured compaction of the aquifer system and with computed compaction.
8. Make aquifer tests to obtain coefficients of storage and transmissibility, and, where possible, make simultaneous measurements of aquifer-system compaction and (or) land subsidence.
9. Make laboratory tests simulating the field conditions in compacting aquifer systems, to study pore-pressure decay and compaction of clayey sediments consolidated under controlled conditions.
10. Where control is adequate, evaluate the geologic and hydrologic factors that jointly determine the magnitude and rate of compaction of the aquifer system and, insofar as practicable, relate the areal variation in subsidence per unit of head decline to the controlling geologic parameters.
11. Assemble and review literature on land subsidence due to fluid withdrawal and on methods used in investigating such phenomena, and prepare a report on subsidence due to fluid withdrawal in areas throughout the world.

As one of the primary elements of the field program, eight core holes ranging in depth from 760 to 2,200 feet were drilled. Four of these are in the Los Banos-Kettleman City area, two in the Tulare-Wasco area, and two in the Santa Clara Valley. These multiple-purpose core holes were drilled: (1) to obtain cores for making laboratory tests of physical and hydrologic properties and consolidation and rebound characteristics of selected core samples, (2) to obtain core samples for laboratory study of petrography and clay-mineral assemblages, (3) to obtain electric logs, caliper logs, and lithologic descriptions for study of the geology of the aquifer systems, and (4) to install compaction-measuring equipment.

Core holes in the San Joaquin Valley, which were drilled as part of the Inter-Agency program, were financed chiefly by Geological Survey-State cooperative funds, but the Bureau of Reclamation helped to finance two holes in the Los Banos-Kettleman City area. The Bureau of Reclamation bore all drilling costs for the Oro Loma core hole at the Delta-Mendota Canal. The core holes in the Santa Clara Valley were financed wholly by Geological Survey funds.

All eight core holes were drilled in areas of subsidence caused by artesian-head decline. None is in an area affected by near-surface subsidence.

The present paper by A. I. Johnson, R. P. Moston, and D. A. Morris on the physical and hydrologic properties of water-bearing deposits in subsiding areas in the San Joaquin and Santa Clara Valleys is the first chapter of a series of major reports resulting from the Geological Survey's research program on the mechanics of aquifer systems. It presents the results of the laboratory analyses for physical, hydrologic, and engineering properties of core samples from the compacting sediments, as recovered from the eight core holes. The laboratory analyses, being utilized directly in the interpretive reports of the Geological Survey on land subsidence and the compaction of aquifer systems, are chiefly the particle-size distribution, specific gravity and unit weight, porosity and void ratio, and consolidation and rebound tests. Tests of acid-soluble material and gypsum content were made in connection with study of the environment of deposition and diagenesis of these sediments.

The tests of Atterberg limits and indices are not being utilized quantitatively in the current studies but were made at relatively small additional cost to provide supplementary data. The Atterberg limits and indices, together with the particle-size analyses, illustrate the effect of the percentage of clay-size particles in controlling engineering properties and furnish at least a qualitative index to the compressibility characteristics of the sediments. Furthermore, classification of samples in terms of the Unified Soil Classification System, used by the Bureau of Reclamation, the Corps of Engineers, and many other engineering organizations, requires determination or estimation of Atterberg limits. In the Unified Soil Classification System, the liquid limit is used to distinguish between clay of high compressibility and clay of low compressibility.

The tests for permeability should be useful for other studies. For example, determination of the permeability of the fine-textured sediments is of use in drainage studies being made by the State in the San Joaquin Valley. Furthermore, the tests comparing permeability parallel and normal to the stratification give some data on the relative ease of movement of water in the two directions, and may be of use in studies of leakage between aquifers. Very little information of this type is available on unconsolidated alluvial deposits; most published comparative data have been on consolidated rocks in oil-reservoir studies. It should be noted, however, that the values for vertical permeability obtained in the variable-head permeameter under no load appear to be considerably higher than values computed from consolidation tests for samples of similar texture. Three probable reasons for the discrepancy are discussed on p. A26 and A27.

In addition to the direct application to problems of subsidence and compaction of aquifer systems, the analytical results on the samples from the eight core holes serve a much broader geologic need, because they furnish a substantial body of data on the physical characteristics and hydrologic properties of thick sequences of unconsolidated to semiconsolidated sediments—chiefly of alluvial origin but derived from contrasting source rocks. Basic data of this scope, for continental deposits spanning thicknesses of 1,000–2,000 feet, are rare. They should be useful in many types of studies—geologic, hydrologic, and engineering—in addition to the specific purposes of the investigations of land subsidence and the compaction of aquifer systems.

Several major reports that are products of the Federal research program on mechanics of aquifer systems have been published or approved for publication, as follows:

Meade, R. H., 1964, Removal of water and rearrangement of particles during the compaction of clayey sediments—review: U.S. Geol. Survey Prof. Paper 497–B, 23 p.

——— 1967, Petrology of sediments underlying areas of land subsidence in central California: U.S. Geol. Survey Prof. Paper 497–C, 83 p.

Poland, J. F., and Davis, G. H., Land subsidence due to withdrawal of fluids: Reviews in Engineering Geology, v. 2, Geol. Soc. America (in press).

Other major reports in progress are: Compaction of sediments underlying areas of land subsidence in central California (R. H. Meade); geology of compacting sediments in the Los Banos-Kettleman City subsidence area (R. E. Miller, J. H. Green, and G. H. Davis); and land subsidence and aquifer-system compaction in the Santa Clara Valley, Calif. (J. H. Green). A report on principles controlling the deformation of aquifer systems due to change in grain-to-grain load is planned as the concluding chapter of the series.

J. F. POLAND
Research geologist

CONTENTS

ILLUSTRATIONS

[Plates are in separate volume]

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TABLES

PHYSICAL AND HYDROLOGIC PROPERTIES OF WATER-BEARING DEPOSITS IN SUBSIDING AREAS IN CENTRAL CALIFORNIA

By A. I. Johnson, R. P. Moston, and D. A. Morris

ABSTRACT

Land subsidence in extensive areas of the San Joaquin and Santa Clara Valleys, Calif., is causing serious problems in the construction and maintenance of costly engineering works such as large canals, water-distribution systems, and drainage and flood-control works.

The subsidence in the Los Banos-Kettleman City area, the largest area of subsidence in the San Joaquin Valley, is critical with respect to canal construction, because the dual-function canal serving the San Luis project of the Bureau of Reclamation and transporting water for the California Aqueduct of the State is soon to be constructed through that area; the canal will cross about 70 miles of subsiding ground.

The Tulare-Wasco area, the second largest area of land subsidence in the San Joaquin Valley, is traversed by the Friant-Kern Canal of the Central Valley Project, which supplies water to several irrigation districts in the subsiding area. Although subsidence has not seriously affected the transportation of surface water, continued or accelerated subsidence could create serious problems.

Four core holes, ranging in depth from 1,000 to 2,200 feet, were drilled in 1957 and 1958 along the axis of the subsidence trough in the Los Banos-Kettleman City area in western Fresno County, at sites where subsidence rates ranged from 0.2 to 1 foot per year. These core holes were drilled about to the base of the water-bearing deposits. Two core holes, 760 and 2,200 feet in depth, were drilled in 1958 and 1959 in areas of major subsidence in southern Tulare County, where the rate of subsidence is as much as 0.7 foot per year. Two core holes were drilled in the Santa Clara Valley in 1960 along the axis of the subsidence trough, where subsidence rates were as great as 0.4 foot per year. These core holes were drilled to a depth of about 1,000 feet to span all the deposits tapped by water wells. All eight of these holes were cored through most of their depth to obtain samples for laboratory analysis of physical, hydrologic, and engineering properties.

As part of the study of subsidence and of principles controlling the deformation (compaction or expansion) of aquifer systems due to change in artesian pressure, and hence in grain-to-grain load, selected samples from the core holes were tested in the Geological Survey's Hydrologic Laboratory and the Bureau of Reclamation's Earth Laboratory, both at Denver, Colo. "Undisturbed" samples from the core holes were analyzed for particle-size distribution, permeability, specific gravity, dry unit weight, porosity, Atterberg limits, consolidation, acid solubility, and gypsum content.

The sediments recovered from the core holes in the Los Banos-Kettleman City area and the Santa Clara Valley were predominantly fine textured and primarily of the clayey-silt or silty-clay types by the Shepard classification system. The sediments recovered in the Tulare-Wasco area were predominantly medium-textured and primarily of the silty-sand or sand-silt-clay types by the Shepard system. Recovery of coarse materials (sands and gravels) was very poor, and these materials therefore are not adequately represented or described in this report.

Laboratory data in tabular and graphic form are presented, laboratory analysis methods are described, and interrelationships of some of the physical and hydrologic properties are shown. Reference data required for future interpretive reports on subsidence research are furnished.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

To provide information on the physical, hydrologic, and engineering properties of the sediments that are compacting in the Los Banos-Kettleman City area (fig. 1) four core holes were drilled along the axis of the subsidence trough, and samples were taken for laboratory testing. Selected cores from three of these holes were tested in the Geological Survey's Hydrologic Laboratory and in the Bureau of Reclamation's Earth Laboratory, both at Denver, Colo. Selected samples from the fourth core hole, 12/12–16H1, were tested only by the Bureau of Reclamation. In all, 305 core samples were analyzed by the Geological Survey and 64 core samples were analyzed by the Bureau of Reclamation. Results of these analyses were made available in 1962 (Johnson and Morris, 1962a).

In the Tulare-Wasco area, two core holes were drilled in areas of maximum subsidence, and selected samples were taken for analysis in the Hydrologic Laboratory and in the Earth Laboratory. A total of 157 core samples were analyzed by the Geological Survey and 22 core samples were analyzed by the Bureau of Reclamation.

In the Santa Clara Valley, two core holes were drilled along the axis of the subsidence trough, and selected samples were taken for analysis in the Hydrologic Laboratory and in the Earth Laboratory. In all, 87 core samples were analyzed by the Geological Survey and 21 core samples were analyzed by the Bureau of Reclamation.

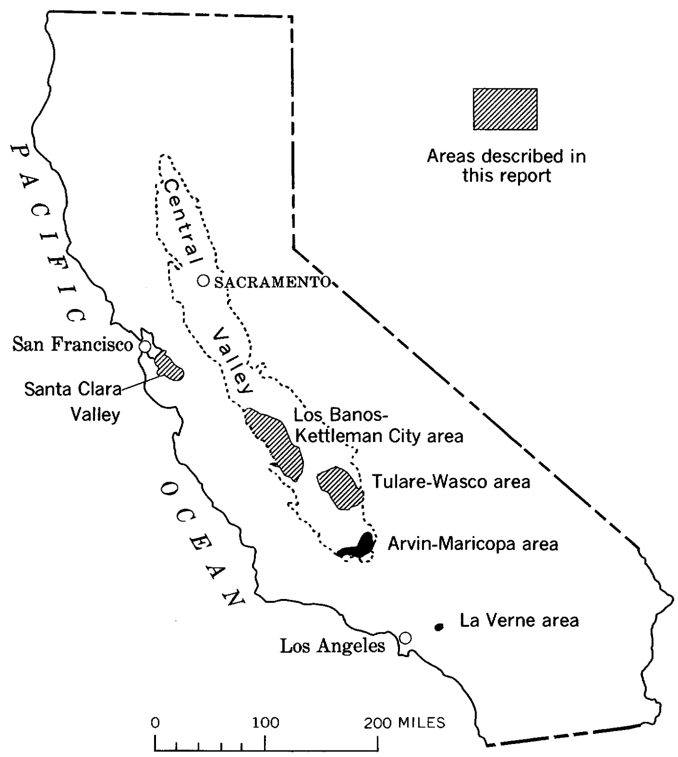


FIGURE 1.—Principal areas of land subsidence in California due to ground-water withdrawal. Compiled by R. E. Miller.

This report describes the methods used in the laboratory and presents the results of the laboratory tests in tabular and graphic form.

Certain of the results—specifically, the particle-size analyses, specific gravity and unit weight, porosity and void ratio, and the consolidation tests—are applicable directly to the studies of land subsidence and the compaction of the aquifer systems. In addition, the test results serve a broad geologic need by furnishing a substantial body of data on the physical characteristics and hydrologic properties of a thick sequence of unconsolidated to semiconsolidated sediments of alluvial and lacustrine origin. Basic data of this scope, for continental deposits spanning thicknesses of 1,000 to 2,000 feet, are rare and should be useful in many types of studies—geologic, hydrologic, and engineering—in addition to the specific purposes of the investigations of land subsidence and the compaction of aquifer systems.

The laboratory analyses by the Geological Survey were made under the direction of A. I. Johnson, chief of the Hydrologic Laboratory, by D. A.Morris, Eugene Shuter, A. C. Doyle, C. R. Jones, I. M. Bloomgren, W. H. Lohman, R. P. Moston, W. E. Teasdale, A. H. Ludwig, N. N. Yabe, E. S. Chun, J. D. Orner, W. N. Lawless, R. E. Taylor, S. F. Versaw, R. A. Speirer, and W. N. Lockwood. Laboratory analyses by the Bureau of Reclamation were made under the direction of W. G. Holtz, chief of the Earth Laboratory Branch, and H. J. Gibbs, head of Special Investigations and Research Section.

LOCATION AND DESCRIPTION OF AREAS

LOS BANOS-KETTLEMAN CITY AREA

The largest of the subsiding areas in the San Joaquin Valley is the Los Banos-Kettleman City area in Merced, Fresno, and Kings Counties (fig. 2). Subsidence of 2 feet or more has occurred throughout approximately 1,200 square miles of this area—the average subsidence has been in excess of 6 feet. Subsidence of 20 feet has occurred during approximately 30 years in small parts of the area west of Mendota. The water-bearing sediments have been described by Davis and Poland (1957, p. 420–430), by the Inter-Agency Committee on Land Subsidence in the San Joaquin Valley (1958, p. 116–138), and in detail by Miller and others (report on geology of compacting sediments, manuscript in preparation). These reports point out that the fresh-water-bearing sediments in the Los Banos-Kettleman City area are primarily unconsolidated to semiconsolidated continental deposits 1,000–3,500 feet thick. The sediments are of Pliocene, Pleistocene, and Recent age, underlain by semiconsolidated to consolidated brackish-water and marine deposits of Pliocene and greater age that contain saline water (fig. 3).

The fresh-water-bearing deposits can be divided into three units: (1) An upper unit, consisting of clay, silt, and sand, which includes the post-Tulare alluvial deposits and the upper part of the Tulare Formation and extends from the land surface to depths ranging from 200 to 800 feet; (2) a middle unit of relatively impervious diatomaceous clay to clayey silt of lacustrine origin, the Corcoran Clay Member of the Tulare Formation, which, in most of the area, has a thickness of 20–120 feet; and (3) a lower unit of clay, silt, and sand, in part of lacustrine origin, which includes the lower part of the Tulare Formation and, locally, parts of the San Joaquin and Etchegoin Formations of Pliocene age. This lower unit is commonly 600–1,500 feet thick but locally is as much as 3,000 feet thick. The Corcoran Clay Member not only serves as a distinctive geologic marker bed but also as the principal confining bed of the artesian aquifers in the San Joaquin Valley.

TULARE-WASCO AREA

The Tulare-Wasco area is in the southeastern part of the San Joaquin Valley. It centers in Tulare County but extends southward into Kern County and westward into Kings County (fig. 4). Delano and Tulare are the largest cities within the Tulare-Wasco subsidence area, which is roughly bisected by U.S. Highway

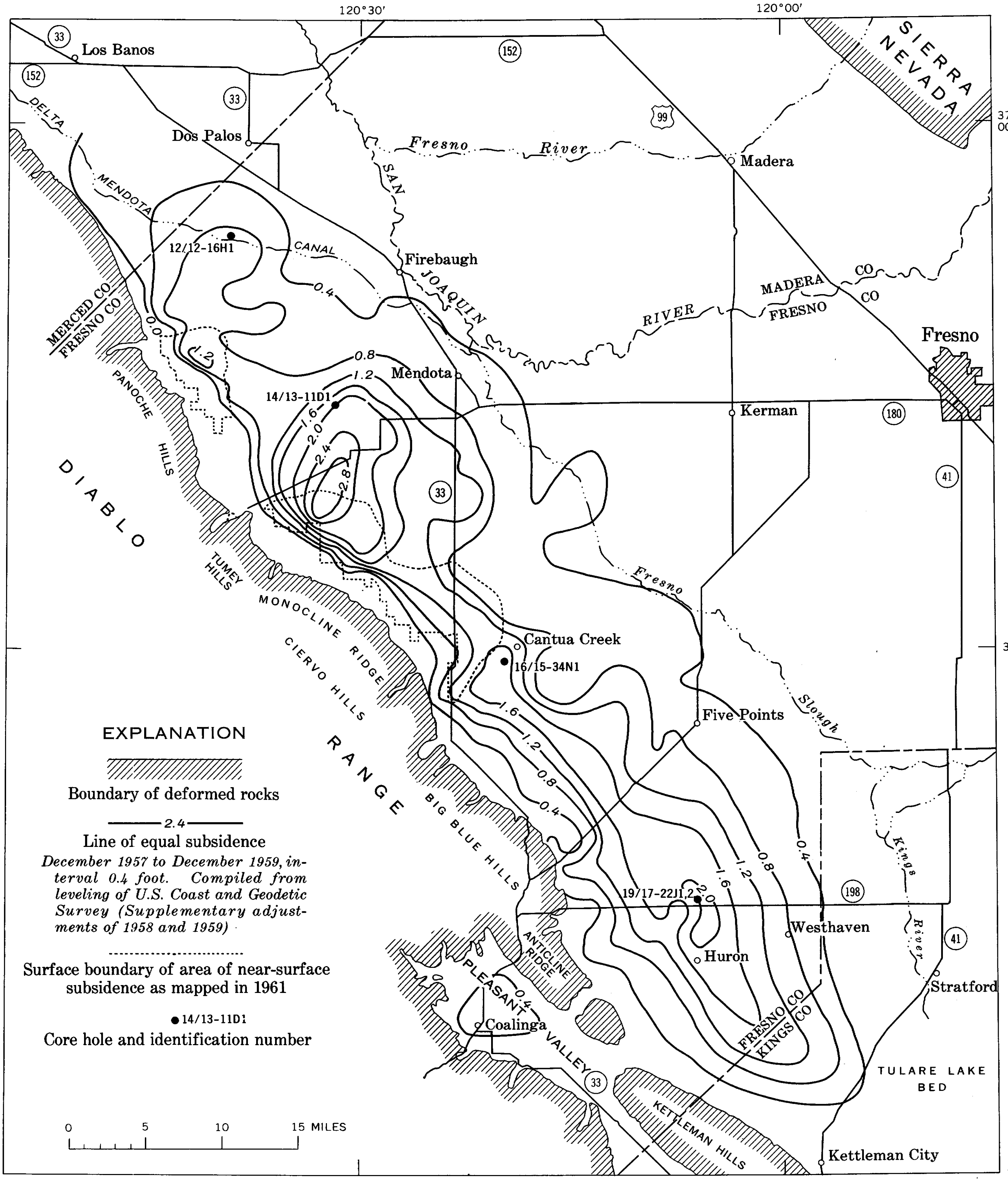


FIGURE 2.—Land subsidence 1957–59 and core-hole locations in the Los Banos-Kettleman City area.

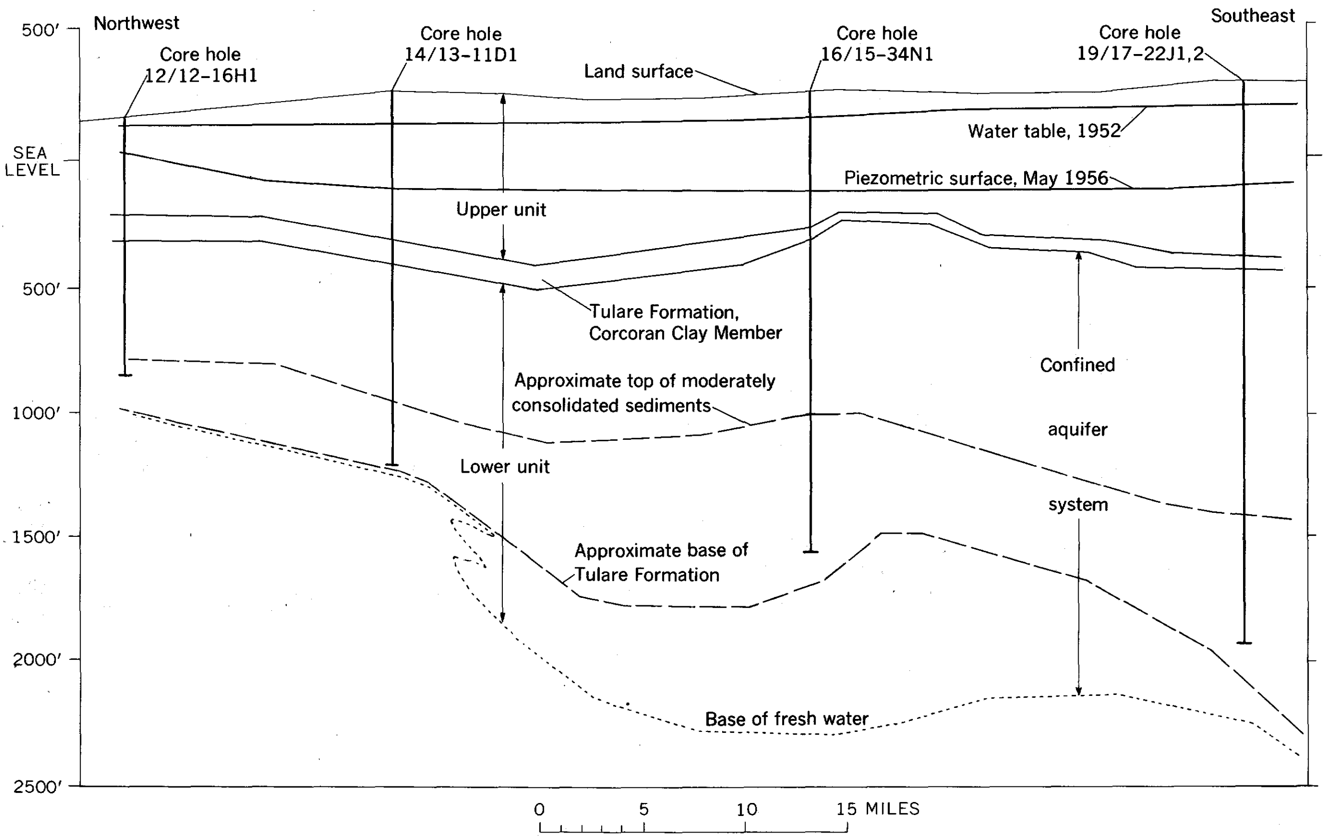


FIGURE 3.—Simplified geologic section through core holes in the Los Banos-Kettleman City area.

99. The land is intensively developed agriculturally and much of it is irrigated by ground water. Approximately 500 square miles, or about one-third of the total, subsided more than 1 foot during the 6-year period from 1948 to 1954, owing to large declines in ground-water levels (Poland and Davis, 1956).

The Tulare-Wasco area is the second largest of land subsidence in the San Joaquin Valley. It is traversed by the Friant-Kern Canal of the Central Valley Project which supplies water to several irrigation districts in the subsiding area. Although subsidence has not seriously affected the transportation of surface water, continued or accelerated subsidence could create serious problems.

Lofgren and Klausing have described the pertinent geologic features of the water-bearing deposits in a separate report (Land subsidence in the Tulare-Wasco area, in preparation), and they have supplied the following brief description for this report.

The unconsolidated deposits comprise the continental deposits from the Sierra Nevada. These deposits consist of poorly permeable to permeable lenticular beds of gravel, sand, silt, and clay that differ widely in extent and thickness and grade both laterally and vertically into one another.

One persistent stratum, the Corcoran Clay Member of the Tulare Formation (Inter-Agency Committee, 1958), can be mapped in the western half of the Tulare-Wasco area west of U.S. Highway 99. Within the area where this stratum occurs, a threefold division of the continental deposits can be made as follows (fig. 5): (1) An upper unit, ranging in thickness from about 300 feet to 700 feet, which includes that part of the continental deposits from the Sierra Nevada overlying the Corcoran Clay Member; (2) the relatively impermeable Corcoran Clay Member, ranging in thickness from a feather edge to 100 feet, which not only serves as a distinctive geologic marker but also as the principal confining bed for the artesian aquifer underlying it; and (3) a lower unit which consists of that part of the continental deposits from the Sierra Nevada lying between the base of the Corcoran Clay Member and the underlying marine strata of upper Pliocene age. Ground water is pumped in considerable quantity for irrigation and other uses both from the semiconfined upper unit and from the confined aquifer system beneath the Corcoran Clay Member.

The unconsolidated deposits penetrated by the core hole at Pixley (23/25–16N1) consist of 280 feet of continental deposits, 16 feet of the confining Corcoran Clay Member, and 464 feet of continental deposits

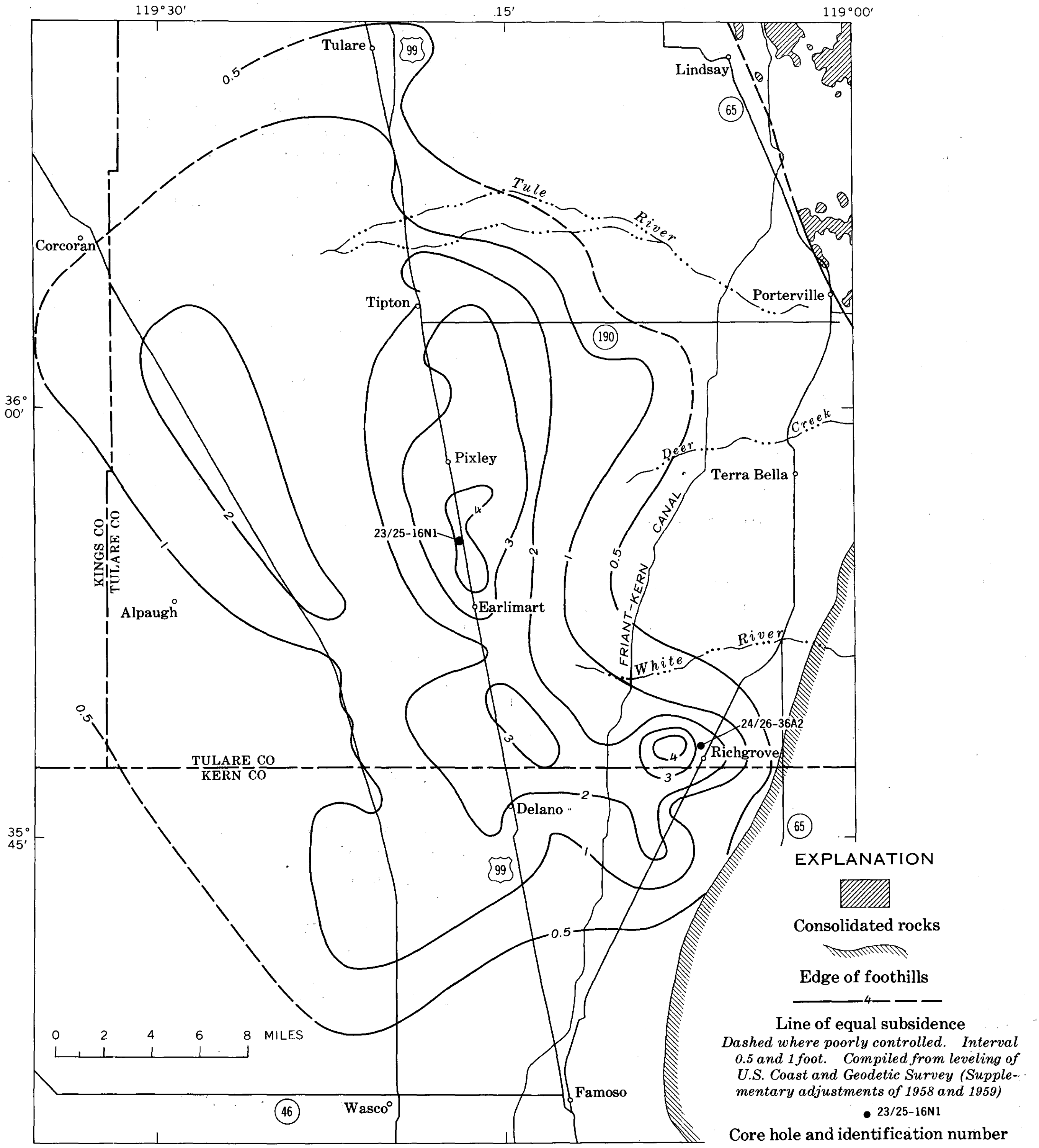


FIGURE 4.—Land subsidence 1948–54 and location of core holes in the Tulare-Wasco area. Prepared in cooperation with the California Department of Water Resources. Compiled by Ben E. Lofgren.

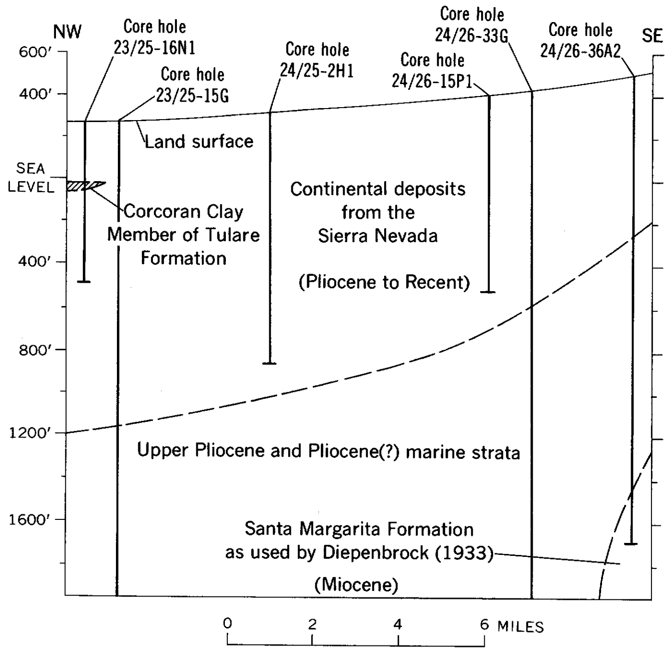


FIGURE 5.—Simplified geologic section through core holes in the Tulare-Wasco area. Correlation by R. L. Klausing.

lying below the Corcoran. These deposits are composed for the most part of yellowish-brown fine- to medium-textured sand, silt, and clay which were deposited chiefly in a subaerial environment. The core hole was drilled through the full depth of deposits tapped by most of the deeper water wells in the vicinity of Pixley.

East of U.S. Highway 99, beyond the extent of the Corcoran Clay Member, the unconsolidated continental deposits range in thickness from about 200 feet to as much as 1,500 feet and are composed largely of lenticular beds of yellowish-brown fine- to coarse-textured sand, silt, clay, and gravel which were laid down as alluvial-fan deposits. These deposits function chiefly as a semiconfined aquifer system and are the principal source of ground water in this area.

Along the east side of the Tulare-Wasco area, consolidated and semiconsolidated marine rocks—upper Pliocene and Pliocene(?) marine strata and the Santa Margarita Formation of Diepenbrock (1933)—of Tertiary age underlie the unconsolidated continental deposits. The depth to the top of these marine rocks ranges from about 600 feet to 1,600 feet below the land surface; the rocks consist of alternating poorly permeable claystone, siltstone, and permeable sand. The sand beds are confined locally, and where they are penetrated by water wells, they function as confined aquifers. Although these rocks were deposited in a marine environment, the saline connate water has subsequently been flushed out of the aquifers and replaced by fresh water. Downdip to the west, however, these aquifers still contain saline water.

Marine rocks were penetrated by the core hole at Richgrove (24/26–36A2) from a depth of 744 feet below the land surface to 2,200 feet. This section of marine rocks is composed of 897 feet of blue-gray claystone and siltstone of upper Pliocene age, underlain successively by 259 feet of sediments of similar texture of Pliocene(?) age, and by 300 feet of well-sorted gray sand of Miocene age (Klausing and Lohman, 1964). The sand has been identified as the Santa Margarita Formation of Diepenbrock (1933, p. 13) and, in the vicinity of Richgrove, it is an important source of water.

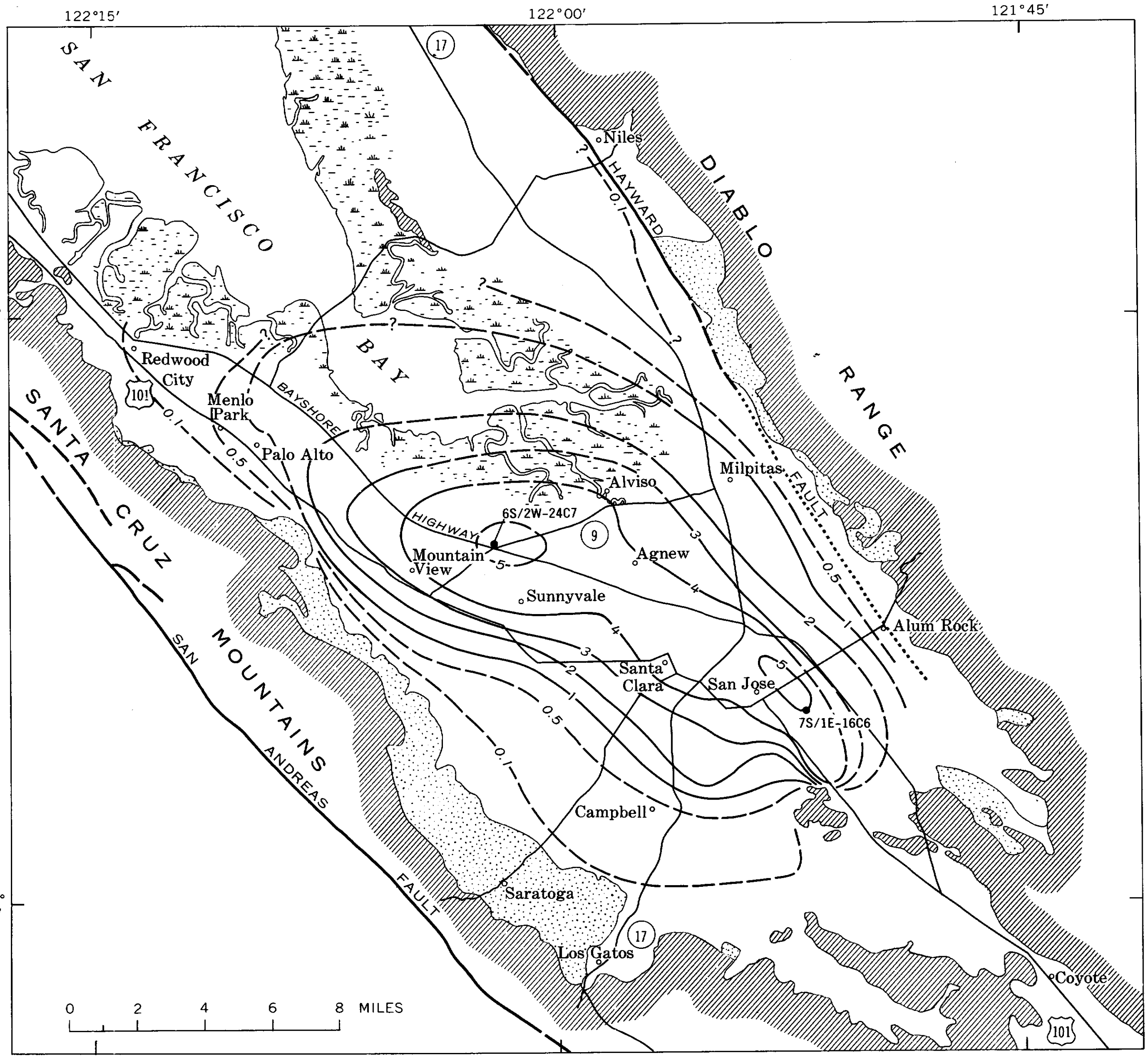
SANTA CLARA VALLEY

The Santa Clara Valley extends about 100 miles southeastward from San Francisco. The valley is a large structural trough bounded on the southwest by the Santa Cruz Mountains and on the northeast by the Diablo Range. Subsidence occurs in the central reach of the valley in an area of intensive ground-water development which extends from Redwood City on the west, and Niles on the east, southeastward about 30 miles to Coyote (fig. 6). It is this central reach that will be referred to hereafter as the Santa Clara Valley. San Jose is the largest city within the subsiding area. Intensive agricultural development is rapidly changing to urban development; both have depended almost wholly on ground water to date (1965).

The area of subsidence lies wholly within the area of valley fill and corresponds in general to the area of confined ground water; the line of 0.1-foot subsidence for the period 1934–54 encloses at least 230 square miles, according to Poland and Green (1962). Subsidence of the land surface from 1934 to 1960 is shown by lines of equal subsidence in figure 6. This map shows that the subsidence in and near San Jose and Sunnyvale during the 26-year period exceeded 5 feet. Core holes were drilled in the two areas of maximum subsidence.

The general geology of the Santa Clara Valley has been described in some detail by Davis and Jennings (1954) and Davis (1955). The water-bearing sediments have been described by Clark (1924), Tolman and Poland (1940), and the California State Water Resources Board (1955). The generalized geology of the central part of the Santa Clara Valley is shown in figure 6. Pertinent geologic features of the water-bearing deposits are described in a separate report (J. H. Green and J. F. Poland, Land subsidence and aquifer-system compaction in the Santa Clara Valley, in preparation).

The water-bearing deposits of the Santa Clara Valley from San Jose north to San Francisco Bay consist primarily of lenses and stringers of clay, silt, and sandy clay, and lesser amounts of sand and gravel. Near San Francisco Bay, fine-textured sediments predominate, but toward the south, west, and east—the sediment source areas—the subsurface sediments are more coarse textured. At the two core holes, and probably beneath



EXPLANATION

Alluvium and bay deposits

Santa Clara Formation
Semiconsolidated deposits

Consolidated rocks
Undifferentiated igneous, metamorphic, and consolidated sedimentary rocks

Fault
Dashed where approximate; Dotted where concealed

0.1

Line of equal subsidence
Interval 1, 0.5, and 0.1 foot; dashed where poorly controlled. Compiled from leveling of U.S. Coast and Geodetic Survey

7S/1E-16C6

Core hole and identification number

FIGURE 6.—Land subsidence, 1934–60, and location of core holes in the Santa Clara Valley. Compiled by J. H. Green.

much of the valley, the water-bearing deposits are more than 1,000 feet thick. The depth to their base is not known.

These water-bearing deposits comprise the unconsolidated alluvial and bay deposits and the underlying Santa Clara Formation of Pliocene and Pleistocene age. The boundary between these two units has not been identified in well logs. However, where it is exposed on the flanks of the valley, the Santa Clara Formation consists of semiconsolidated poorly sorted conglomerate and sandstone, as well as siltstone and claystone, and has a low permeability. The bedrock ranges in age from Jurassic to Pliocene and consists principally of consolidated sedimentary rocks and minor areas of metamorphic and igneous rocks.

FIELD SAMPLING

The samples for which test results are presented in this report were obtained from eight core holes. (See figs. 2–6; table 1.) The core holes in the Los Banos-Kettleman City area were drilled in 1957 and 1958, the holes in the Tulare-Wasco area in 1958 and 1959, and the holes in the Santa Clara Valley in 1960. These core holes were drilled by a rotary-drilling rig operated by Bureau of Reclamation drilling crews experienced in the difficult technique of coring unconsolidated sediments. The rotary core barrels used were modified from commercial core barrels of the double-tube type, which have an outer rotating barrel and an inner stationary barrel. The inside diameter of the core barrel was nominally 3 inches, and the average diameter of core recovered was about 2¾ inches. In most of the work, a core barrel capable of taking a core 10 feet long was used. A 20-foot core barrel was tried but did not give as good core recovery.

Above the Corcoran Clay Member of the Tulare Formation in the Los Banos-Kettleman City area, a 10-foot interval was cored after each 30 feet of drilling. Below the top of the Corcoran Clay Member, coring was generally continuous to the bottom of the hole. Core recovery was excellent for unconsolidated to semiconsolidated alluvial deposits of sand, silt, and clay. For example, at core hole 14/13–11D1, the accumulated cored interval was 998 feet and the aggregate core footage brought to land surface was 696 feet, an average core recovery of 70 percent.

Core hole 19/17–22J1, near Huron, was to be drilled to a depth of 2,200 feet, but the drill pipe became stuck at 1,930 feet. Because efforts to free the pipe were unsuccessful, it was shot off at 1,760 feet. An adjacent hole, 22J2, was drilled to 1,910 feet and cored below. Thus, at core-hole site 19/17–22J1, 2, cores above 1,910 feet are from J1 and below 1,910 feet are from J2. The core hole location is designated 19/17–22J1, 2 in the rest of this paper.

In the Pixley core hole (23/25–16N1) to a depth of 260 feet, a 10-foot interval was cored after each 30 feet of drilling. From 260 feet to 752 feet, coring was continuous. Through the sections cored, core recovery was 73 percent. In the Richgrove core hole (24/26–36A2), no cores were taken to a depth of 50 feet, and then coring was continuous to a depth of 1,965 feet. From 1,965 feet to the well bottom at 2,200 feet, a 10- to 20-foot interval was cored after each 30–40 feet of drilling. Core recovery was about 80 percent in the Richgrove core hole.

At core hole 6S/2W–24C7 in the Santa Clara Valley, the accumulated cored interval was 796 feet and the aggregate core footage brought to land surface was 548 feet, an average core recovery of 69 percent. At core hole 7S/1E–16C6 the average core recovery was only 30 percent because recovery was very low in the coarse, loose water-bearing material. Hence, the core suite obtained does not contain a representative sampling of the coarser, most permeable layers.

At each of the drilling sites, cores were laid out in sequence in 4-foot wooden core boxes and properly labeled for future reference. From each 10-foot interval cored, the following samples were collected:

1. Physical characteristic sample.—One quart-sized sample (about 6 in. long), taken from the most representative materials of the cored interval, was sealed in wax in a cardboard container to preserve the natural moisture content insofar as practicable and to prevent disturbance of the core. These samples were tested by the Hydrologic Laboratory of the Geological Survey.
2. Petrographic sample.—One or more samples, taken from the same materials and contiguous to the physical characteristic samples, were collected and sealed in wax in a 1-pint cardboard container and retained for petrographic examination. For paleontologic examination, samples also were taken of fossiliferous beds in the Richgrove, San Jose, and Sunnyvale core holes; they were not sealed in wax.
3. General purpose sample.—Two or more half-pint samples were collected for general reference, one representing the fine-textured materials and one representing the coarse-textured layers; they were retained in cardboard cartons but not sealed in wax.

In addition, undisturbed samples of representative fine-grained deposits were collected for consolidation tests in the Earth Laboratory of the Bureau of Reclamation. Quart-sized samples were carefully selected

TABLE 1.—*Identification of core holes*

[Core-hole punch-card code gives location by latitude and longitude. The first 6 digits indicate latitude in degrees, minutes and seconds. The letter N designates north latitude. The next 7 digits indicate longitude in degrees, minutes and seconds. The final digit following the decimal point identifies the well or test hole number at this location]

Area	County	Core hole		Nearest town	Depth (feet)	USGS Hydrologic Laboratory sample numbers	USBR Earth Laboratory sample numbers
		Location	Punch-card code				
Los Banos-Kettleman City	Fresno	12/12-16H1	365326N1203914.1	Oro Loma	1, 005	None	23L91-108.
		14/13-11D1	364358N1203149.1	Mendota	1, 500	57CAL1-103	23L80-90, 194-196.
		16/15-34N1	362913N1201958.1	Cantua Creek	[1] 2, 000	58CAL1-98	23L197-198, 200-202, 204, 206-208, 210, 212, 214, 215, 217, 219, 221-223, 235.
		19/17-22J1,2	361534N1200610.1,2	Huron	2, 203	57CAL104-206	23L181-193.
Tulare-Wasco	Tulare	23/25-16N1	355523N1191706.1	Pixley	760	58CAL99-145	23L226-229, 232, 234.
		24/26-36A2	354807N1190631.1	Richgrove	2, 200	59CAL310-419	23L236-254.
Santa Clara Valley	Santa Clara	6S/2W-24C7	372404N1220204.1	Sunnyvale	1, 004	60CAL10-69	23L255-263, 265, 267, 269.
		7S/1E-16C6	371947N1215206.1	San Jose	1, 002	60CAL70-96	23L271-273, 275, 277, 279, 280, 282-284.

[1] Driller's depth was 2,000 feet and depths for samples given in this report are correlated to the 2,000-foot depth. The electric log was run to a depth of 2,007 feet. Subsequently the new drill pipe used for this hole was measured and was found to be 0.35 foot longer per 100 feet than the figure used during coring.

and then sealed in wax in metal containers to keep them in an undisturbed condition.

Results of the laboratory analyses are given in tables 5–10 at the end of this paper. Tests by the Hydrologic Laboratory of the Geological Survey are reported in tables 5–7, inclusive, and table 10. Tests made in the Earth Laboratory of the Bureau of Reclamation are reported in tables 8 and 9.

COMPOSITE LOGS OF CORE HOLES

An electric log was obtained for each core hole after coring was completed. Graphic logs and generalized lithologic descriptions were prepared from the geologists' logs made at the drill site, supplemented by interpretation of the electric log in zones not cored or of poor recovery. These three elements have been combined to give a composite log for each core hole (pl.1). The depths of the samples tested, both by the Hydrologic Laboratory and by the Earth Laboratory of the Bureau of Reclamation, also are plotted on the composite logs.

The interpretation of electric logs is based on the principle that, in fresh-water-bearing deposits such as those penetrated in this area, high resistivity values are indicative of sand and low resistivity values are indicative of clay and silty clay. Intermediate values are indicative of clayey silt, silt, silty sand, and other sediments classified texturally between sand and clay. Resistivity is indicated by the right-hand curve of the electric log; it increases toward the right. Thus, the Corcoran Clay Member of the Tulare Formation is indicated by a curve segment of uniformly low resistivity (pl. 1*A*). The electric logs of the core holes can be compared with the physical and hydrologic properties of the samples plotted according to depth in pls. 12–14.

ACKNOWLEDGMENTS

The core holes in the San Joaquin Valley were drilled as a part of the interagency program of land-subsidence studies. The following geologists from the three agencies cooperated in the collection and description of the core samples from these core holes: D. C. Blakely, W. B. Bull, W. A. Cochran, J. H. Green, R. L. Klausing, B. E. Lofgren, and R. H. Meade, Geological Survey; W. R. Cooke, R. J. Farina, and N. Prokopovich, Bureau of Reclamation; B. Aarons, R. Bartlett, C. Carlson, W. R. Hail, B. G. Hicks, F. Kreese, and W. D. Pederson, California Department of Water Resources.

The two core holes in the Santa Clara Valley were drilled as a part of the Federal study of mechanics of aquifers. The Survey geologists who collected and described core samples in the Santa Clara Valley were W. B. Bull, R. L. Klausing, R. H. Meade, G. A. Miller, and F. S. Riley. Both core holes were drilled by the Bureau of Reclamation.

Consolidation tests for core holes 12/12–16H1, 16/15–34N1, and 23/25–16N1 were financed by the Bureau of Reclamation, and tests for core holes 14/13–11D1, 19/17–22J1, 2, 24/26–36A2, 6S/2W–24C7, and 7S/1E–16C6 by the Geological Survey. All analyses by the Hydrologic Laboratory were financed by the Geological Survey.

H. J. Gibbs, Head of Special Investigations and Research Section, Bureau of Reclamation, Denver, Colo., provided assistance by his review of parts of this report.

METHODS OF LABORATORY ANALYSIS

In the Hydrologic Laboratory, cores 2 inches in diameter by 2 inches long were obtained by forcing thin-wall brass cylinders into the larger core—one in a direction at right angles to the bedding (vertical) and the other parallel to the bedding (horizontal). These small cores were used for permeability tests and for determining unit weight and porosity. The hydraulic press designed for obtaining the cores is shown in figure 7.

The rest of the large core was prepared and used for determination of specific gravity, particle-size distribution, and Atterberg limits and indices. Sample preparation for these analyses began with the air-drying of chunks of the large core. These chunks of material were then gently but thoroughly separated into individual particles in a mortar with a rubber-covered pestle. Care was taken to prevent crushing of the individual particles.

Core samples were analyzed by the Hydrologic Laboratory using the standard methods described briefly in the following paragraphs. Core samples also were analyzed by the Earth Laboratory following standard procedures described by the U.S. Bureau of Reclamation (1960, p. 407–508). Additional information on the theory and methods of analysis is available in Meinzer (1923, 1949), Wenzel (1942), Taylor (1948), and the American Society for Testing Materials (1958).

PARTICLE-SIZE DISTRIBUTION

A particle-size analysis, also termed a "mechanical analysis," is the determination of the distribution of particle sizes in a sample. Particle sizes smaller than 0.0625 mm were determined by the hydrometer method of sedimentation analysis, and sizes larger than 0.0625 mm were determined by wet-sieve analysis.

The hydrometer method of sedimentation analysis consisted of (1) dispersing a representative part of the prepared sample with a deflocculating agent, sodium

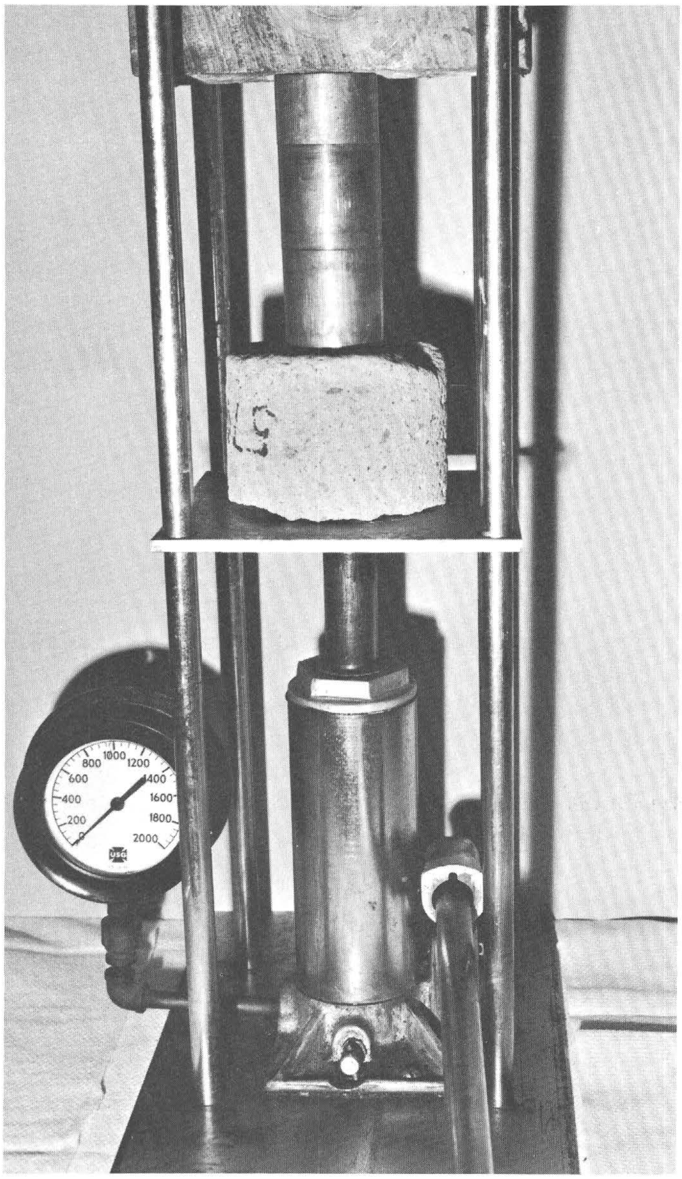


FIGURE 7.—Hydraulic press used for obtaining small cores from large cores of unconsolidated sediments.

hexametaphosphate, in 1 liter of water and (2) measuring the density of the suspension at increasing intervals of time with a soil hydrometer. At given times, the size of the largest particles remaining in suspension at the level of the hydrometer was computed by use of Stokes' law, and the weight of particles finer than that size was computed from the density of the suspension at the same level.

After the hydrometer analysis, the sample was poured into a sieve which had openings of 0.0625 mm. The sample then was gently agitated and washed over the sieve. The material retained was carefully dried and placed in a set of standard 8-inch sieves which were shaken for a period of 15 minutes on a Ro-tap mechanical shaker. The fraction of the sample remaining on each sieve was weighed on a balance.

From the hydrometer analysis and the sieve analysis, the percentage of the particles smaller than a given size was calculated and plotted as a cumulative distribution curve. The particle sizes, in millimeters, were plotted as abscissas on a logarithmic scale and the cumulative percentages of particles smaller than the size shown, by weight, as ordinates on an arithmetic scale. The percentage in each of several size ranges was then determined from this curve.

The analyses were divided into the following groups according to their particle sizes:

	Diameter (mm)
Gravel	>2.0
Very coarse sand	1.0 –2.0
Coarse sand	.5 –1.0
Medium sand	.25 – .5
Fine sand	.125 – .25
Very fine sand	.0625– .125
Silt-size	.004 – .0625
Clay-size	<0.004

This classification system is used by the Water Resources Division, U.S. Geological Survey, and is identical to classifications proposed by Wentworth (1922) and the National Research Council (Lane, 1947), except that those authors proposed further subdivisions of gravel, silt, and clay. Subsequent references to sand, silt, and clay in this report will relate to sand-, silt-, and clay-size particles as specified in the foregoing table.

PERMEABILITY

Permeability is the capacity of rock or incoherent material to transmit water under pressure. It can be determined in the laboratory by observing the rate of percolation of water through a sample of known length and cross-sectional area, under a known difference in head.

The basic law for flow of fluids through porous materials was established by Darcy who demonstrated experimentally that the rate of flow of water was proportional to the hydraulic gradient. Darcy's law may be expressed as

$$Q=kiA,$$

where Q is the quantity of water discharged in a unit of time, A is the total cross-sectional area through which the water flows, i is the hydraulic gradient (the difference in head, h, divided by the length of flow, L), and k is the coefficient of permeability of the material for water, or

$$k=\frac{Q}{iA}=\frac{QL}{hA}.$$

The coefficient of permeability, P, is defined (Wenzel, 1942, p. 7) as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at a temperature of 60°F. Because the water is assumed to be relatively pure, density is ignored.

Coefficients of permeability are determined in the laboratory in constant-head or variable-head permeameters or are computed from consolidation-test results (see p. A18). The constant-head permeameter is generally used for samples of medium to high permeability, and the variable-head permeameter for samples of low permeability. The permeability apparatus used in the Hydrologic Laboratory is shown in figure 8.

The constant-head permeability method requires observations on the rate of discharge of water through a sample in which the difference in head of water at the top and bottom of the sample is maintained at a constant value. From Darcy's law, the basic formula for the constant-head permeameter is

$$k=\frac{QL}{At(h)}\,C_T,$$

where k is the coefficient of permeability, Q is the volume of percolation, L is the length of the sample, A is the area of the sample cylinder, t is the length of the time of flow, h is the difference in head at the top and bottom of the sample and C_T is the ratio of the viscosity of water at the observed temperature to the viscosity at 60° F. In units used by the Geological Survey, the above formula becomes

$$P=\frac{21{,}200QL}{At(h)}\,C_T,$$

when P is in gallons per day per square foot, Q is in cubic centimeters, L and h are in centimeters, A is in square centimeters, and t is in seconds; C_T has no units.

The variable-head permeability method requires the indirect measurement of the quantity of water percolating through the sample by observing the rate of fall of the water level in a manometer connected to the sample. By integrating Darcy's equation, the basic formula for use of the variable-head permeameter is

$$k=2.3\,\frac{aL}{At}\log\frac{h_o}{h}\,C_T,$$

where k is the coefficient of permeability, h_o is the head in the manometer at zero time, h is the head at any given elapsed time, t is the elapsed time, A is the area of the sample cylinder, a is area of manometer, L is length of sample, and C_T is the temperature correction. In units used by the Geological Survey, the above formula becomes

$$P=48{,}815\,\frac{aL}{At}\log\frac{h_o}{h}\,C_T,$$

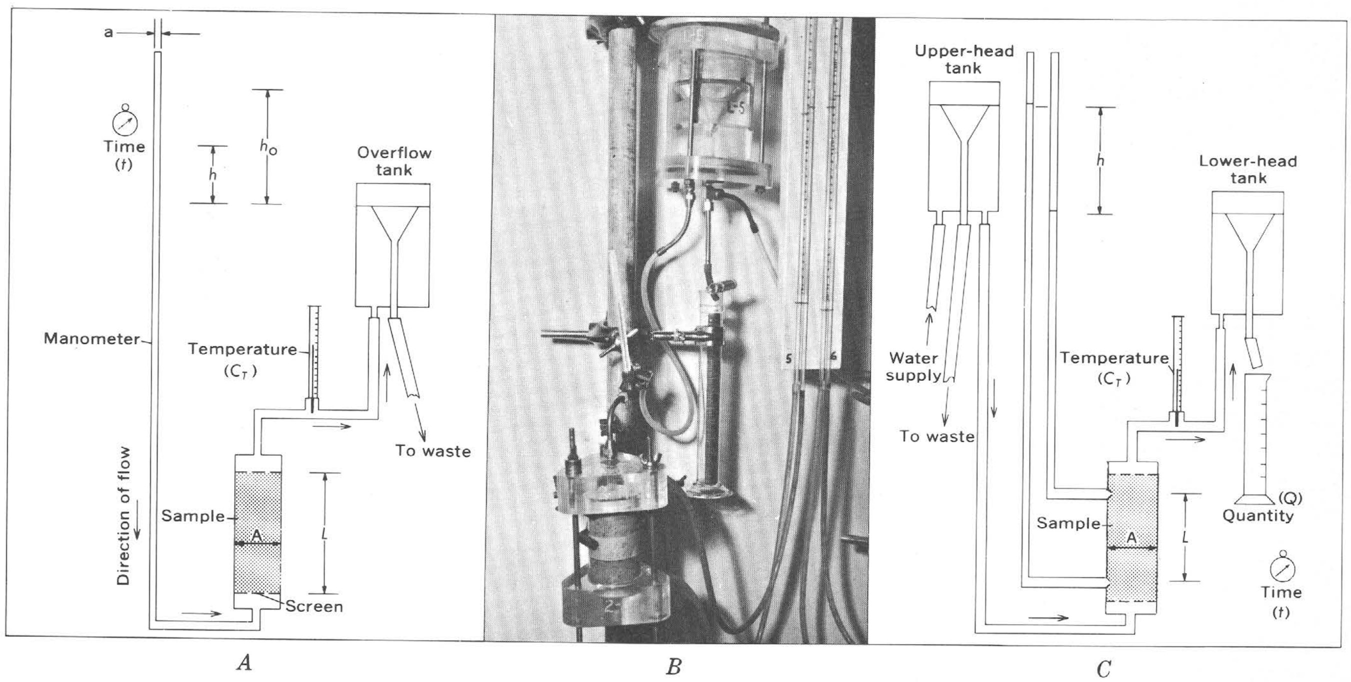


FIGURE 8.—Permeability apparatus. *A*, Diagram of variable-head type, where $k=2.3\,\frac{L}{At}$ 1 $\frac{h_o}{h}\,C_T$. *B*, Photograph of apparatus. *C*, Diagram of constant-head type, where $k=\frac{QL}{At(\Delta h)}\,C_T$.

in which P is in gallons per day per square foot, A and a are in square centimeters, L is in centimeters, t is in seconds, h_o and h are in centimeters, and C_T is dimensionless.

Entrapped air in a sample may cause considerable plugging of pore space and thus reduce the apparent coefficient of permeability. Thus, a specially designed vacuum system is used by the Hydrologic Laboratory to provide de-aired tapwater used as the percolation fluid.

The chemical character of the water used for the permeability tests of fine-grained silty or clayey materials should be compatible with the chemical character of the native pore water. If the test water is not compatible, the clay-water system and the permeability values obtained will be affected. The chemical character of the native pore water in the fine-grained sediments is not yet known. However, as a matter of record, the chemical analysis of the Denver tapwater used in the tests by the Hydrological Laboratory is given in the following table (analyst, B. P. Robinson):

	Parts per million	*Equivalents per million*
Calcium (Ca)	20	0.9
Magnesium (Mg)	4	.33
Sodium (Na) and potassium (K)	3.4	[1] .15
Sulfate (SO_4)	31	.64
Chloride (Cl)	1.5	.042
Bicarbonate (HCO_3)	47	.77
Fluoride (F)	.2	.011
Nitrate (NO_3)	.6	.009
Dissolved solids residue at 180°C	99	----
Hardness ($CaCO_3$)	66	----
Specific conductance micromhos at 25°C	161	----
pH	7.3	----

[1] Calculated as sodium.

The reported coefficient of permeability is the maximum value obtained after several test runs and represents saturation permeability. The 2-inch-diameter "undisturbed" cores cut from the larger original core were retained in their cylinders. These cylinders were installed directly in the permeameter to serve as the percolation cylinder of the apparatus.

DRY UNIT WEIGHT

The dry unit weight is the weight of solids per unit of total volume of oven-dry rock or soil mass. It normally is reported in grams per cubic centimeter or pounds per cubic foot. Void space as well as solid particles are included in the volume represented by the dry unit weight. The dry unit weight divided by the unit weight of distilled water at a stated temperature (usually 4°C) is known as the apparent specific gravity, which is dimensionless.

The volume of the small cores, cut previously from the large cores, was obtained by measurement of the cylinder dimensions. This volume and the ovendry weight of the contained sample were then used to calculate the dry unit weight as follows:

$$\gamma_d=\frac{W_s}{V}$$

where

γ_d=dry unit weight, in grams per cubic centimeter,
W_s=weight of ovendry sample, in grams,
V=total volume of mass sample, in cubic centimeters.

The dry unit weight in grams per cubic centimeter can be multiplied by 62.4 to convert it to pounds per cubic foot.

SPECIFIC GRAVITY OF SOLIDS

Specific gravity of solids, G, is the ratio of (1) the weight in air of a given volume of solids at a stated temperature (unit weight of solid particles or particle density) to (2) the weight in air of an equal volume of distilled water at stated temperature, usually 4°C.

The volumetric-flask method was used for determining the specific gravity of solids. A weighed oven-dry part of the sample was dispersed in water in a calibrated volumetric flask. The volume of the particles was equivalent to the volume of displaced water. The unit weight of the solid particles was obtained by dividing the dry weight of the sample by the volume of the solid particles. Because the density of water at 4°C is unity in the metric system, the specific gravity is numerically equivalent to this unit weight.

POROSITY AND VOID RATIO

Porosity, n, is defined as the ratio of (1) the volume of the void spaces to (2) the total volume of the rock or soil mass. It normally is expressed as a percentage:

Therefore,

$$n=\frac{V_v(100)}{V}=\frac{V-V_s(100)}{V},$$

then as

$$\gamma_d=\frac{W_s}{V}$$

and

$$\gamma_s=\frac{W_s}{V_s},$$

$$n=\frac{W_s/\gamma_d-W_s/\gamma_s}{W_s/\gamma_d}(100),$$

or

$$n=\frac{\gamma_s-\gamma_d}{\gamma_s}(100),$$

where

n=porosity, in percent,
V_v=volume of voids, in cubic centimeters,
V=total mass volume, in cubic centimeters,
W_s=weight of ovendry particles, in grams,
γ_s=unit weight of particles, in grams per cubic centimeter (equal numerically to specific gravity of solids in metric system),
γ_d=dry unit weight of sample, in grams per cubic centimeter,

and

V_s=volume of solid particles, in cubic centimeters.

After the dry unit weight and the specific gravity of solids had been determined for the sample, the porosity was calculated from the above equation. The relation among these three properties is illustrated in figure 9.

The void ratio is defined as the ratio of (1) the volume of voids to (2) the volume of solid particles in a soil mass. Its relation to porosity is expressed by

$$e=\frac{n}{1-n}$$

where

e=void ratio,

and

n=porosity, in percent.

The relation between void ratio and porosity is illustrated in figure 10.

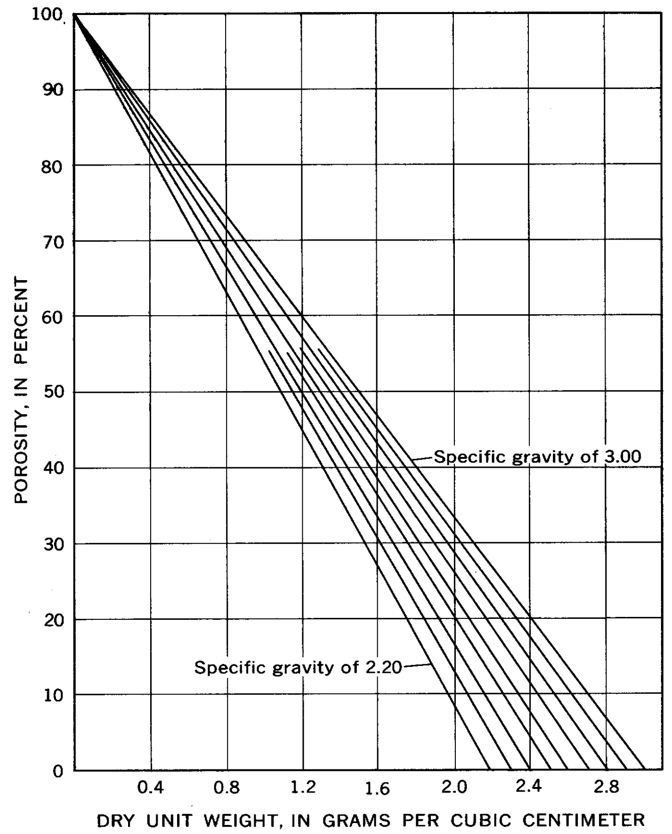


FIGURE 9.—Relation of porosity to dry unit weight for various specific gravities of solids.

MOISTURE CONTENT

The moisture content of rock or soil material is the ratio of the weight of water contained in a sample to the oven-dry weight of solid particles, expressed as a percentage. Usually, samples, in moisture-proof containers, are weighed to obtain their wet weight. They are ovendried to constant weight at 110°C and reweighed. The loss of weight (the amount of contained water) divided by the dry weight of the sample equals the moisture content.

ATTERBERG LIMITS

Atterberg (1911), a Swedish soil scientist, suggested a series of arbitrary limits for indicating the effects of variations of moisture content on the plasticity of soil materials. The most commonly used Atterberg limits, sometimes referred to as limits of consistency, are the liquid, plastic, and shrinkage limits. Among a number of indices, the plasticity index is most commonly determined.

The moisture contents at which fine-textured sediments pass from one state of consistency to another are governed by the texture and composition of the sediments. Atterberg (1911), Terzaghi (1926), and Goldschmidt (1926) found that plasticity is a function of the amount of fine platelike particles in a sediment mass. Thus, the Atterberg consistency limits and indices are influenced by the clay content of the sediments tested.

Although the Atterberg limits are somewhat empirical, most soil investigators believe that they are valuable in characterizing the plastic properties of fine-textured sediments (Casagrande, 1932).

Only the smaller size particles of a given sample, those passing a U.S. Standard No. 40 sieve (finer than 0.42 mm in diameter) are used for Atterberg tests. Although limits and indices are calculated as moisture content in percent of dry weight, all values are usually reported as numbers only.

LIQUID LIMIT

The liquid limit, w_L, is the moisture content, expressed as a percentage of the oven-dry weight, at which

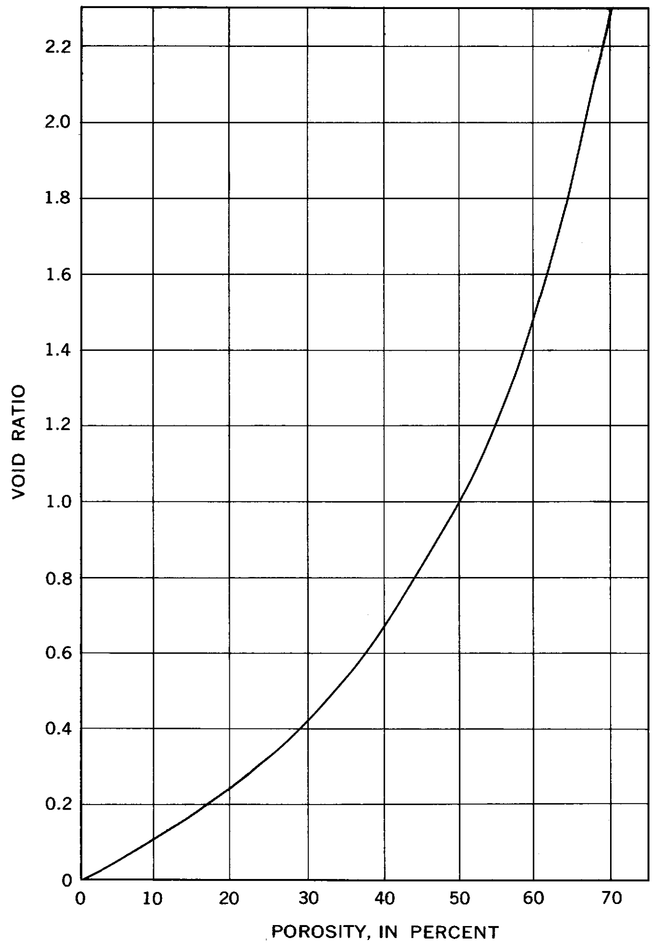


FIGURE 10.—Relation of void ratio to porosity.

any particular soil material passes from the plastic to the liquid state. It is that moisture content at which a pat of soil, cut by a groove of standard dimensions, will close for a distance of half an inch under the impact of 25 shocks in a standard liquid-limit apparatus. The moist sample was placed in the round-bottomed brass cup of the mechanical liquid-limit device and was divided into two halves by a V-shaped grooving tool. A cam on the device raised the cup and let it drop against the base of the machine until the two edges of the groove flowed together for the specified half an inch. The number of taps, or shocks, were recorded, and the moisture content of a part of the sample was determined. This process was repeated three times at different moisture contents. These data are plotted as a "flow curve" on a semilogarithmic graph, the number of shocks plotted as abscissa on the logarithmic scale and the moisture content as ordinates on the arithmetic scale. The moisture content corresponding to the intersection of the flow curve with the 25-shock line was taken as the liquid limit of that soil material.

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PLASTIC LIMIT

The plastic limit, w_p, is the minimum moisture content, expressed as a percentage of the oven-dry weight, at which soil material can be rolled into ⅛-inch-diameter threads without the threads breaking into pieces. This moisture content represents the transition point between the plastic and semisolid states of consistency. The moist sample was rolled between the hand and a glass plate until a thread one-eighth inch in diameter was formed. The sample was then kneaded together and again rolled out. This process was continued at slowly decreasing water contents until crumbling prevented the formation of the thread. The pieces of the crumbled sample were then collected together and the moisture content was determined. This moisture content was considered to be the plastic limit.

SHRINKAGE LIMIT

The shrinkage limit, w_s, is the maximum moisture content at which a reduction in moisture content produces no further decrease in volume of the sample mass. This moisture content represents the transition point between the semisolid and solid states of consistency. Moist soil material in the plastic range was packed densely into a small dish and leveled off so that it exactly filled the complete volume of the dish, and the dish and sample were weighed immediately. The dish of sample was air dried and then oven dried to constant weight at 110°C, the moisture content was calculated, and the volume of the dry sample pat was obtained by mercury immersion. The shrinkage limit was then calculated from the formula

$$w_s = w - \left[\frac{V_{sw} - V_s}{W_s}\right] 100,$$

where

w_s=shrinkage limit, moisture content in percent of ovendry weight,

w=moisture content of wet sample, in percent of ovendry weight,

V_{sw}=volume of wet sample pat, in cubic centimeters,

V_s=volume of ovendry sample pat, in cubic centimeters,

and

W_s=weight of ovendry sample pat, in grams.

SHRINKAGE FACTORS

SHRINKAGE RATIO

The shrinkage ratio is the ratio of (1) a given volume change, expressed as a percentage of the dry volume, to (2) the corresponding change in moisture content above the shrinkage limit, expressed as a percentage of the weight of the ovendried soil.

VOLUMETRIC AND LINEAR SHRINKAGE

Volumetric shrinkage is the decrease in volume, expressed as a percentage of the soil mass when dried, of the soil mass when the moisture content is reduced from a given percentage to the shrinkage limit. The liquid limit was used for calculating volumetric shrinkage.

Linear shrinkage is the decrease in one dimension of the soil mass, expressed as a percentage of the original dimension, when the moisture content is reduced from a given value to the shrinkage limit. The linear shrinkage also was calculated from the liquid limit.

The volumetric and linear shrinkage were determined by the following equations:

$$V_s=(w_L-w_s)R$$

and

$$L_s=(100)\left[1-\sqrt[3]{\frac{100}{V_s+100}}\right],$$

where

V_s=volumetric shrinkage, in percent by volume,
w_L=liquid limit, in percent,
w_s=shrinkage limit, in percent,
R=shrinkage ratio, in grams per cubic centimeter,

and

L_s=linear shrinkage, in percent of wet length.

ATTERBERG INDICES

PLASTICITY INDEX

The plasticity index, I_p, is the difference between the liquid limit and the plastic limit:

$$I_p=w_L-w_p,$$

where

I_p=plasticity index, in percent,
w_L=liquid limit, in percent,

and

w_p=plastic limit, in percent.

FLOW INDEX

The flow index, I_f, is the slope of the liquid-limit flow curve. It is the change in moisture content over one log cycle of the curve.

TOUGHNESS INDEX

The toughness index, I_t, is the ratio of the plasticity index to the flow index:

$$I_t=I_p/I_f,$$

where

I_t=toughness index,
I_p=plasticity index, in percent,

and

I_f=flow index, in percent.

SHRINKAGE INDEX

The shrinkage index, I_s, is defined as the difference between the plastic and shrinkage limits:

$$I_s=w_p-w_s$$

where

I_s=shrinkage index, in percent,
w_p=plastic limit, in percent,

and

w_s=shrinkage limit, in percent.

ACID SOLUBILITY

A weighed part of an ovendried sample was placed in dilute hydrochloric acid (25-percent solution, c.p.) at room temperature until effervescence had ceased. The sample then was washed and filtered, ovendried, and reweighed. The acid-soluble material was then determined by calculating the percentage of the original dry weight of the sample dissolved by the acid.

According to Twenhofel and Tyler (1941, p. 121), cold dilute hydrochloric acid dissolves such carbonates as calcite and aragonite, and a few less common carbonates. To dissolve dolomite, magnesite, and siderite, the minerals must be powdered or the acid must be heated. Furthermore, R. H. Meade (written commun., 1965) has pointed out that some noncarbonate minerals common in these sediments, such as chlorite and montmorillonite, are slightly soluble in cold dilute hydrochloric acid. However, in alluvial deposits derived from noncarbonate rocks, as were the alluvial deposits of these studies, the predominant carbonate normally is calcium carbonate, and therefore, the percentage of acid-soluble material in these samples is considered to be an approximate measure of the calcium-carbonate content.

GYPSUM CONTENT

The gypsum ($CaSO_4 \cdot 2H_2O$) content of the samples was determined by the acetone precipitation method. A sample of filtered soil extract was mixed with an equal quantity of acetone and allowed to precipitate. After it was centrifuged at 1,000 times gravity, the precipitate was washed with acetone, centrifuged again, drained, and then mixed with a known volume of distilled water. The electrical conductivity of this solution was measured, and the concentration of gypsum was determined from a graph showing the relation between concentration and electrical conductivity.

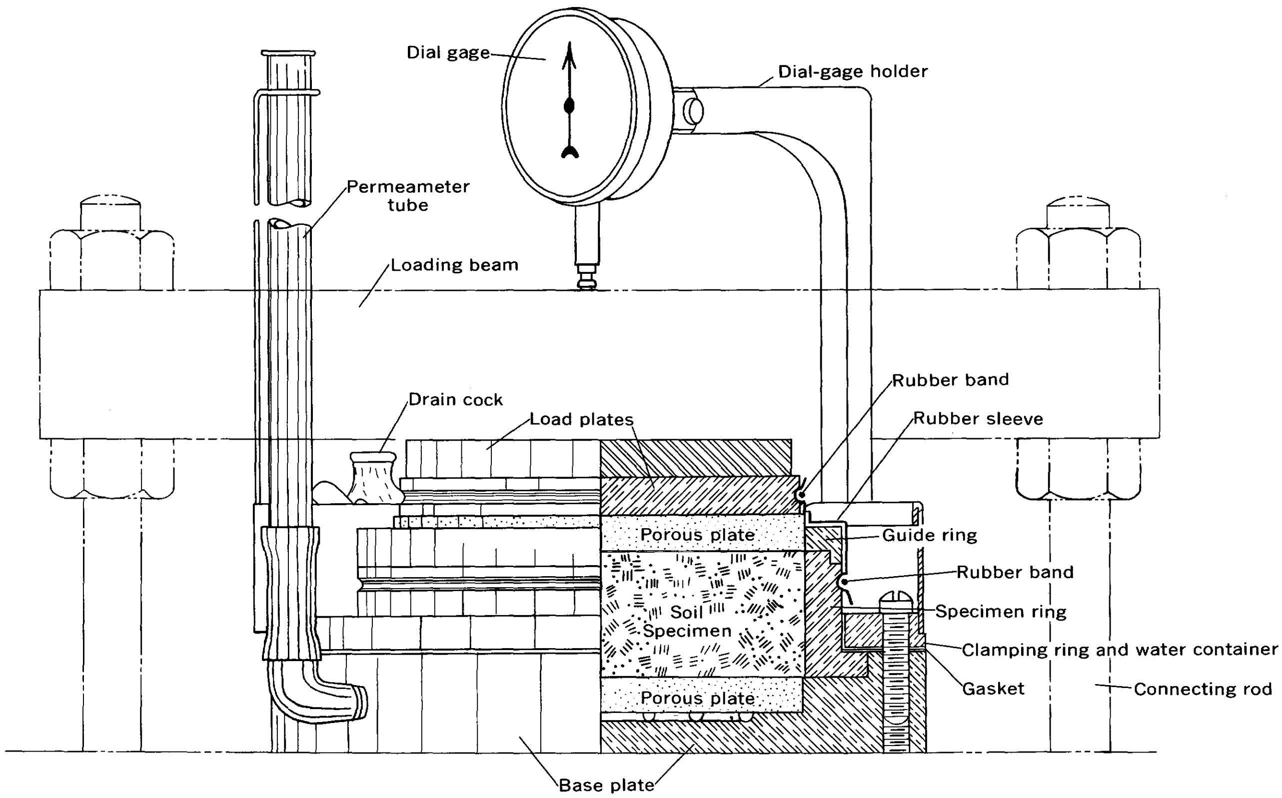


FIGURE 11.—One-dimensional consolidometer specimen container. From Bureau of Reclamation (1960, p. 495).

Gypsum content is usually reported in milliequivalents of gypsum per 100 grams of soil or in tons of gypsum per acre-foot of soil. The percentage of gypsum may be calculated by assuming that 1 acre-foot of soil weighs approximately 4 million pounds; 20 tons of gypsum per acre-foot of soil is equivalent to 1 percent of gypsum.

CONSOLIDATION

When a saturated soil sample is subjected to a load, that load initially is carried by the water in the voids of the sample because the water is incompressible in comparison with the sample's structure. If water can escape from the sample voids as a load is continually applied to the sample, an adjustment takes place wherein the load is gradually shifted to the soil structure. This process of load transference is generally slow for clay and is accompanied by a change in volume of the soil mass. Taylor (1948, p. 212) defines consolidation as that gradual process which involves, simultaneously, a slow escape of water, a gradual compression, and a gradual pressure adjustment. This use of the term should not be confused with the geologists' definition which refers to the processes by which a material becomes firm or coherent (Am. Geol. Inst., 1957, p. 62). The theory of consolidation is discussed in detail by Terzaghi (1943, p. 265–297).

To determine the rate and magnitude of consolidation of sediments, a small-scale laboratory test known as a one-dimensional consolidation test is used. The test and apparatus are described in detail by the U.S. Bureau of Reclamation (1960) but are discussed briefly for the benefit of the reader in the following paragraphs. The application of one-dimensional consolidation test data to a foundation-settlement analysis has been described by Gibbs (1953). The apparatus (consolidometer) used by the Bureau of Reclamation is shown in figure 11. In addition to the unit shown, a means of loading is required—usually a platform scale with a weighing beam attached to the connecting rods of the consolidometer.

Normally, the sample is trimmed to the size of the specimen rings, which are 4¼ inches in inside diameter and 1¼ inches high. Samples must be in as near an undisturbed condition as possible. Because of the small size of the cores collected for the subsidence studies, however, consolidation specimens of standard size could not be used, and the core diameter had to be trimmed to fit 2-inch rings.

Loads are applied to the specimen in increments, but the minimum number of increments is usually four—12½, 25, 50, and 100 percent of the maximum desired load. Increments are usually selected so that each succeeding load is double that of the previous load. Each load is applied to the consolidometer while dial readings of consolidation are taken and recorded for 4, 10, 20 seconds, and other time intervals up to 24 hours. Additional readings are taken at 24-hour intervals until the consolidation is virtually complete for that load.

The percentage of consolidation of the specimen is computed, and a curve of consolidation versus time is obtained for each load increment. The final stress-strain relations are presented as a curve showing the void ratio versus log of pressure (load), the final condition for each increment of load being a point on the curve (fig. 12).

Two important soil properties furnished by a consolidation test are the coefficient of consolidation and the compression index. The coefficient of consolidation, C_v, represents the rate of consolidation under a load increment. It is determined by use of the 50-percent point on the time consolidation curve and the equation

$$C_v=\frac{T_{50}H_{50}^2}{t_{50}},$$

where

T_{50}=time factor at 50-percent consolidation= 0.20,

H_{50}=one-half the specimen thickness at 50-percent consolidation,

and

t_{50}=time required for specimen to reach 50-percent consolidation.

The coefficient of consolidation is usually reported in square inches per second or in square feet per year.

The compression index, C_c, represents the compressibility of the soil sample. It is the slope of the void ratio-log of pressure (load) curve:

$$C_c=\frac{e_o-e}{\log\frac{p_o+\Delta p}{p_o}}=\text{difference in void ratio for}$$

one logarithmic increment of load,

The symbols used are as identified in figure 12A; the compression index is dimensionless.

When the consolidation is complete under maximum loading, the consolidometer can be used as a variable-head permeameter, and the permeability of the soil sample can be determined directly. The mechanical procedure is similar to that described previously (p. A12). The permeability also can be computed from the consolidation data. The equation for computing the permeability, k, from time-consolidation characteristics is

$$k=\frac{C_v(\gamma_w)(e_o-e)}{\Delta p(1+e_o)},$$

where

C_v=coefficient of consolidation,

γ_w=unit weight of water,

e_o=void ratio at start of load increment,

e=final void ratio,

and

Δp=increment of load.

The Bureau of Reclamation usually reports the coefficient of permeability, k, as feet per year, where

$$k=\frac{\text{ft}^3}{\text{yr ft}^2\ (1\text{ ft } H_2O\text{ per ft})}.$$

To convert from feet per year to gallons per day per square foot at the same temperature, multiply by 0.0205.

RESULTS OF LABORATORY ANALYSES

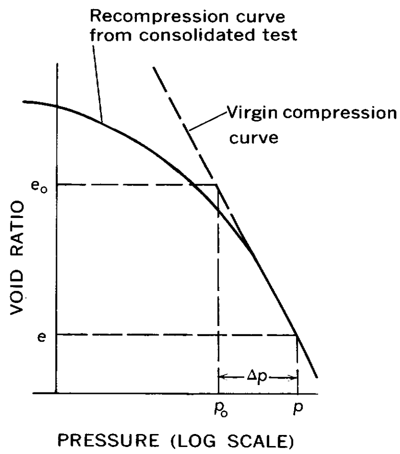
PARTICLE-SIZE DISTRIBUTION

The particle-size distribution data are summarized in table 5; the percentage of gravel-, sand, silt-, and clay-size particles are shown for each of the 549 samples from seven core holes analyzed by the Hydrologic Laboratory. Particle-size distribution curves for these samples are plotted in plates 2–9. The estimated size-distribution (gradation) for samples tested for consolidation by the Bureau of Reclamation is given in table 8 for all eight core holes. The Hydrologic Laboratory also made particle-size distribution analyses of the Bureau's consolidation samples from all core holes except 14/13–11D1; the curves for those analyses are included in plates 2-9, but the size-distribution data are not tabulated in this report.

Because clay content has an important influence on many of the properties of sediments, the clay content for all the Survey samples is plotted on plates 12–14 to facilitate comparison with the other properties. In table 5, the percentage of particles smaller than 2-micron (0.002-mm) clay, as well as smaller than 4-micron (0.004-mm) clay, has been reported. As shown in table 5, 78.5 percent of the samples showed less than 10 percent greater clay content when the 4-micron rather than the 2-micron size was used as the criterion. In addition, 20.9 percent of the samples showed 10–20 percent greater clay content and 0.6 percent of the samples showed more than 20 percent greater clay content for the 4-micron than for 2-micron size criterion.

SEDIMENT CLASSIFICATION TRIANGLES

Most clastic sediments are a mixture of sand-, silt-, and clay-size particles in varying proportions. A



The virgin compression curve or the field consolidation curve, for clayey soils, appears on a semilogarithmic diagram as a straight line as shown at left. This line can be represented by the equation

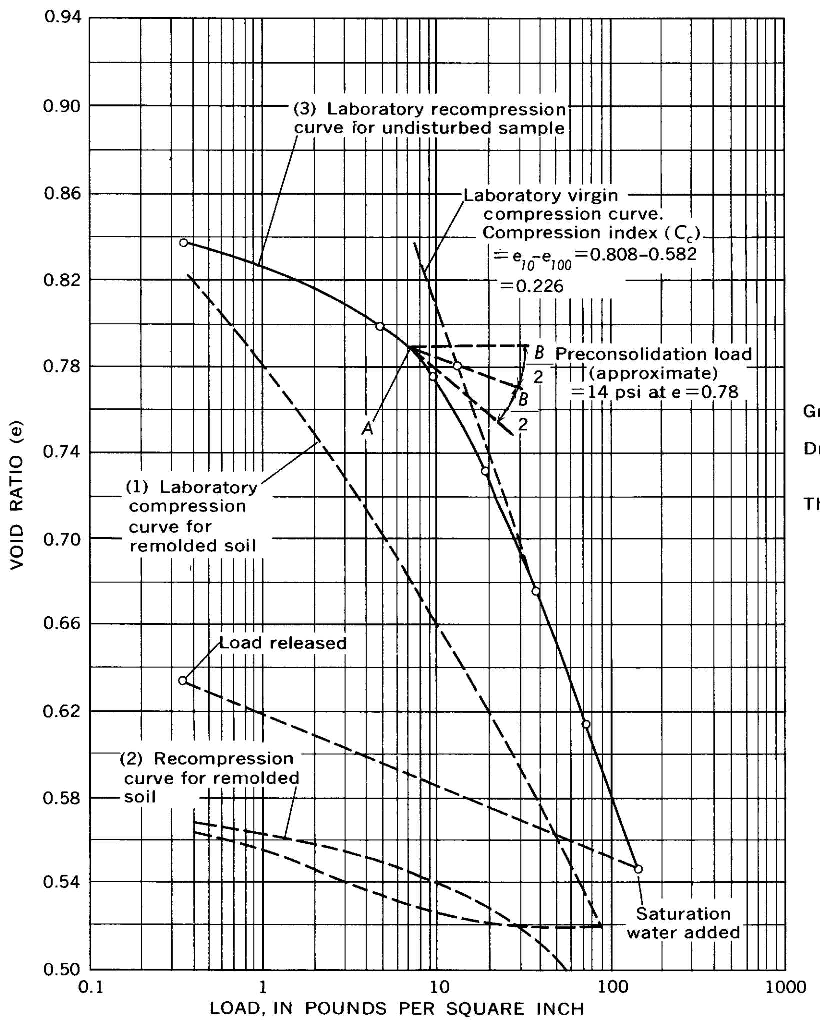
$$e = e_o - C_c \log_{10} \frac{P_o + \Delta P}{P_o}$$

in which C_c (dimensionless) is the compression index

The virgin compression curve is established by extending the straight-line part of the recompression curve. By selecting two points (e_o, p_o) and (e, p) and substituting in the above equation, C_c can be determined

$$C_c = \frac{e_o - e}{\log_{10} \frac{P_o + \Delta P}{P_o}}$$

A. METHOD OF DETERMINING THE COMPRESSION INDEX (C_c)



Graphical determination of preconsolidation load:

Draw tangent and horizontal line to point of maximum curvature (*A*)

The point of intersection between virgin compression curve and line bisecting angle *B*, is preconsolidation load and void ratio

B. VOID RATIO-LOAD CURVES AND PRECONSOLIDATION LOAD

FIGURE 12.—Void ratio-load curve, compression index, and preconsolidation load. Modified from Bureau of Reclamation (1960, p. 58).

suitable nomenclature for sediments is therefore important to describe the approximate relations among these three main constituents. Because sediment classification is often based on the relative percentages of sand-, silt-, and clay-size particles, it is convenient to plot these three constituents on a triangular chart.

A large number of triangular classification systems have been devised over the years. Some were developed primarily for the use of geologists in relating classification to sedimentation characteristics, and others were developed for the use of soils engineers in relating classification to the engineering properties of the sediments. Shepard (1954) developed a sediment classification triangle based on the needs of sedimentologists for studying mode of transport and environment of deposition of sediments. Shepard's classification gives equal importance to sand-, silt-, and clay-size particles (figs. 13, 14).

Because the mode of transport and environment of deposition of the sediments are being studied, as well as the engineering properties, Shepard's classification has been used in this report to determine the sediment class name listed for each sample in table 5. For classification of sediments in the lower Mississippi Valley, the U.S. Army Corps of Engineers (Casagrande, 1948) developed a triangle which emphasizes the importance of clay-size particle content. To assist soils engineers in relating the classification of samples to their engineering properties, a transparent overlay of the Mississippi Valley classification triangle is included in the pocket at the end of this report (pl. 10).

The textural classification used in table 5, summarized in table 2 and based on the Shepard system, is a laboratory classification derived from particle-size distribution graphs. It departs substantially from the field description made from examination of cores and drill cuttings by geologists, especially for the fine-textured materials. In the field examination, material containing more than 30–40 percent of clay-size particles has sufficient clay content to give it the physical properties of clay, such as plasticity. Therefore, the textural description of cores or samples in the field by geologists is not directly comparable to the laboratory textural classification by the Shepard system. Field examination by the geologists results in a textural description much closer to that of the Mississippi Valley classification than to that of the Shepard classification.

LOS BANOS-KETTLEMAN CITY AREA

As shown by table 2, the sediments from the core holes in the Los Banos-Kettleman City area described in table 5 fall into nine categories, ranging from sand to silty clay, but they are mostly fine textured: 43 percent is clayey silt or silty clay, whereas only 13 percent is sand or coarser material. These samples are repre-

TABLE 2.—*Classification of sediment samples from core holes*

[Based on sediment classification system of Shepard (1954)]

Core hole	Sand (including gravel)	Silty sand	Clayey sand	Sandy silt	Sand-silt-clay	Sandy clay	Silt	Clayey silt	Silty clay	Clay	Total samples
Los Banos-Kettleman City area											
14/13–11D1	21	17	4	5	18	--------	2	25	12	--------	104
16/15–34N1	11	11	2	6	23	1	1	21	22	--------	98
19/17–22J1, 2	7	10	--------	7	26	1	--------	33	19	--------	103
Sum	39	38	6	18	67	2	3	79	53	--------	305
Percent	13	12	2	6	21	1	2	26	17	--------	100
Tulare-Wasco area											
23/25–16N1	2	9	--------	8	14	--------	--------	12	2	--------	47
24/26–36A2	12	45	7	10	29	2	1	2	2	--------	110
Sum	14	54	7	18	43	2	1	14	4	--------	157
Percent	9	34	4	12	27	1	1	9	3	--------	100
Santa Clara Valley											
6S/2W–24C7	1	1	--------	4	16	--------	--------	20	17	1	60
7S/1E–16C6	3	3	--------	1	12	--------	--------	7	1	--------	27
Sum	4	4	--------	5	28	--------	--------	27	18	1	87
Percent	5	5	--------	6	32	--------	--------	31	20	1	100

sentative of all but the coarsest sediments (sand and minor gravel), which, in large part, were not recovered because they were too incoherent to be retained in the core barrel during removal from the hole.

In the Shepard system, none of these 305 samples falls into the clay category. If the Mississippi Valley classification system had been used, 10 samples from core hole 14/13–11D1 would have been classed as clay, 16 samples from core hole 16/15–34N1, and 13 samples from core hole 19/17–22J1, 2.

TULARE-WASCO AREA

Under the Shepard classification system, the continental deposits from the Sierra Nevada are predominantly sand-silt-clay, and silty sand. The Corcoran Clay Member in core hole 23/25–16N1 is predominantly clayey silt, and the upper Pliocene marine strata in core hole 24/26–36A2 are predominantly clayey sand and silty sand.

As shown by table 2, the samples described in table 5 fall into nine categories ranging from gravelly sand to silty clay, but they are mostly medium textured: 46 percent is silty sand or sandy silt, whereas only 13 percent is silt or finer material. As are the samples from the Los Banos-Kettleman City area, these samples are representative of all but the coarsest sediments (sand and minor gravel), which, in large part, were not recovered. However, four samples from core hole 24/26–36A2 had more than 20 percent gravel; gravel was added to sand in plotting these samples on figure 11.

In the Shepard system, none of the 157 samples falls into the clay category. If the Mississippi Valley classification system (Casagrande, 1948) had been used, 1 sample from core hole 23/25–16N1 and 2 samples from core hole 24/26–36A2 would have been classed as clay.

SANTA CLARA VALLEY

As shown by table 2, the sediments from the Santa Clara Valley described in table 5 fall into seven categories, ranging from gravelly sand to clay, but they are mostly fine-textured; 51 percent is clayey silt or silty clay, and 32 percent is sand-silt-clay, whereas only 5 percent is sand or coarser material. Again, these samples are representative of all but the coarsest sediments (sand and gravel).

In the Shepard system, only one of the samples, from core hole 6S/2W–24C7, falls into the clay category. If the Mississippi Valley classification system (Casagrande, 1948) had been used, 16 samples from core hole 6S/2W–24C7 and 1 sample from core hole 7S/1E–16C6 would have been classed as clay.

STATISTICAL MEASURES

For comparison and statistical analysis, it is convenient to have characteristics of particle-size distribution (mechanical-analysis) curves expressed as numbers.

The measure of central tendency is the value (size of particle) about which all other values (sizes) cluster. One such measure is the median diameter, D_{50}, which is defined as that particle diameter which is larger than 50 percent of the diameters and smaller than the other 50 percent. It is determined by reading, from the particle-size distribution curve, the particle diameter at the point where the particle-size distribution curve intersects the 50-percent line.

The quartile deviation is a measure of spread of particle sizes. Quartiles are the particle-diameter values read at the intersection of the curve with the 25- (Q_1), 50- (Q_2), and 75- (Q_3) percent lines. By convention, the third quartile (Q_3) is always taken as the larger value, regardless of the manner of plotting. The geometrical quartile deviation, or the "sorting coefficient," *So*, of Trask (1932, p. 70–72), is represented by the equation

$$So=\sqrt{Q_3/Q_1}.$$

The log quartile deviation is the log of the geometrical quartile deviation, or sorting coefficient, *So*, and is represented by the equation

$$\text{Log}_{10}\, So=(\log Q_3-\log Q_1)/2.$$

The log *So* can be expressed to the base 10 (Krumbein and Pettijohn, 1938, p. 232) and is so tabulated in this report.

As noted by Krumbein and Pettijohn (1938, p. 232), the geometric quartile measures are ratios between quartiles and thus have an advantage over the arithmetic quartile measures in that they eliminate both the size factor and the unit of measurement. They do not, however, give a directly comparable value for the spread of the curve. The logarithmic measures do give a direct comparison because the $\log_{10} So$ (the log quartile deviation) increases arithmetically. Thus, a sediment having $\log_{10} So=0.402$ is twice as widely spread between Q_1 and Q_3 as one having $\log_{10} So=0.201$.

Many sedimentologists now use a ϕ scale in which

$$\phi=-\log_2 d,$$

in which d is the diameter in millimeters. This scale has certain advantages over the $\log_{10}$ scale for expressing quartile deviation and other statistical parameters (Krumbein and Pettijohn, 1938, p. 233–235). Therefore, statistical parameters have been listed in terms of the ϕ scale by Meade (1967).

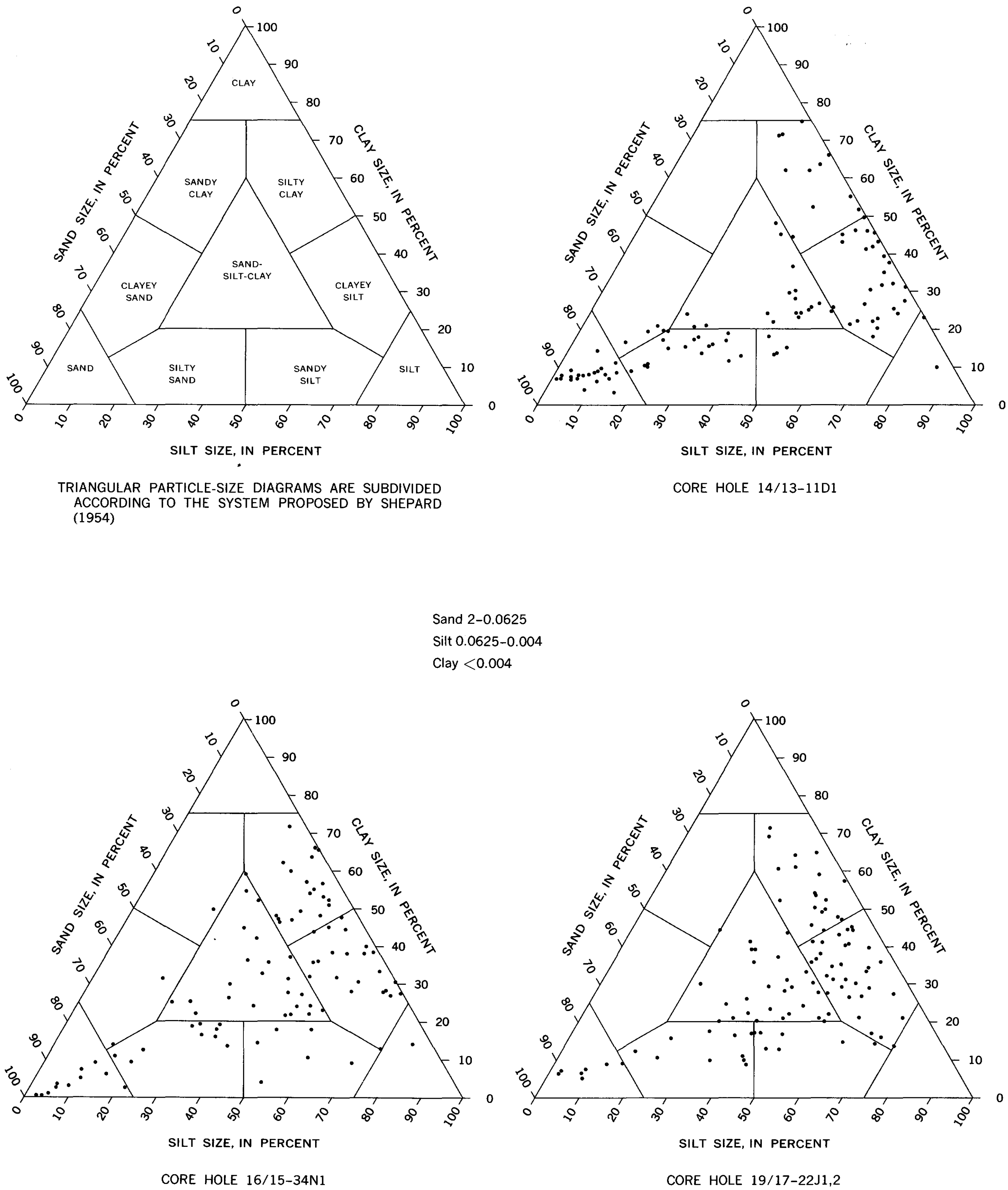


FIGURE 13.—Sediment classification for samples from core holes in the Los Banos-Kettleman City area.

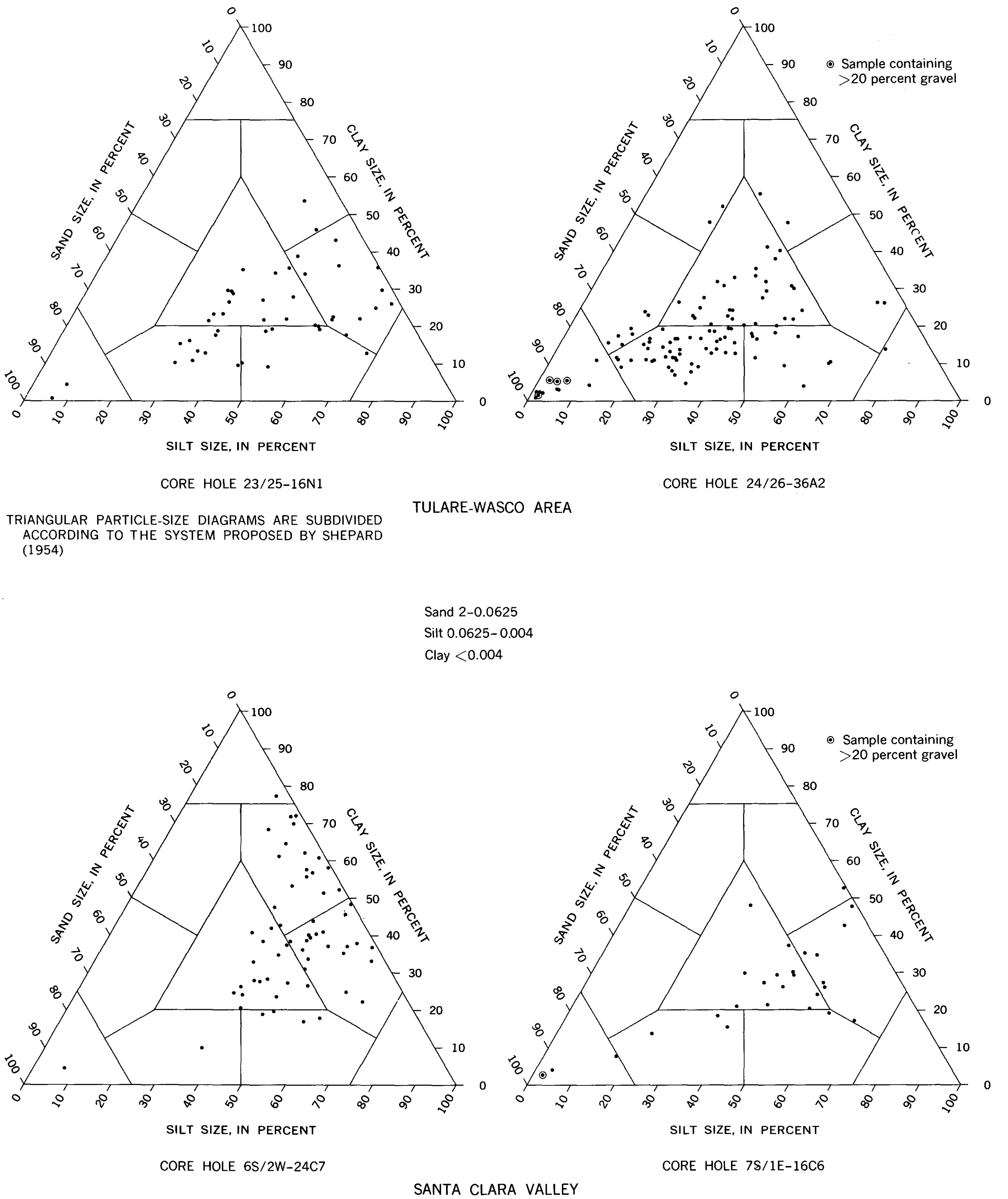


FIGURE 14.—Sediment classification for samples from core holes in the Tulare-Wasco area and Santa Clara Valley.

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The statistical measures for samples from core holes in the Los Banos-Kettleman City area (table 5) are summarized as follows:

1. Median diameter ranges from 0.001 to 0.520 mm, those for samples of the Corcoran Clay Member being near the lower limit.
2. The sorting coefficient, *So*, ranges from 1.1 to 17.2. According to Krumbein and Pettijohn (1938, p. 232), an *So* value of less than 2.5 indicates a well-sorted sediment, of 3 a normally sorted sediment, and of 4.5 a poorly sorted sediment.
3. The log quartile deviation, $\log_{10}$ *So*, ranges from 0.061 to 1.236, the maximum spread being about 20 times as great as the minimum.

The statistical measures for samples from core holes in the Tulare-Wasco area (table 5) are summarized as follows:

1. Median diameter ranges from about 0.01 to 0.3 mm for core hole 23/25–16N1 and from about 0.003 to 1.4 mm for core hole 24/26–36A2, those for samples of the Corcoran Clay Member being near the lower limit.
2. The sorting coefficient, *So*, ranges from 1.4 to 7.2 for core hole 23/25–16N1, and from 1.2 to 14.1 for core hole 24/26–36A2.
3. The log quartile deviation ($\log_{10}$ *So*) for core hole 23/25-16N1 ranges from 0.132 to 0.948, the maximum spread being about 10 times as great as the minimum. For core hole 24/26–36A2, the range is 0.095 to 1.150, the maximum spread being about 12 times as great as the minimum.

The statistical measures for samples from core holes in the Santa Clara Valley (table 5) are summarized as follows:

1. Median diameter ranges from about 0.001 to 0.2 mm, for core hole 6S/2W–24C7 and from about 0.004 to 1.5 mm for core hole 7S/1E–16C6.
2. The sorting coefficient, *So*, ranges from 1.3 to 7.5 for core hole 6S/2W–24C7 and ranges from 1.3 to 7.8 for core hole 7S/1E–16C6.
3. The log quartile deviation, $\log_{10}$ *So*, for core hole 6S/2W–24C7 ranges from 0.127 to 0.876, the maximum spread being about seven times as great as the minimum. For core hole 7S/1E–16C6, the range is 0.246 to 0.885, the maximum spread being about four times as great as the minimum.

The above averages, however, represent only the fine-textured sediments and do not include the coarser sediments that were not recovered.

PERMEABILITY

The value of the coefficient of permeability depends in general on the degree of sorting and upon the arrangement and size of particles. It is usually low for clay and other fine-grained or tightly cemented materials and high for coarse clean gravel. In general, the permeability in a direction parallel to the bedding plane of the sediments (referred to as horizontal permeability in this report) is greater than the permeability perpendicular to the bedding plane (referred to as vertical permeability in this report). Most water-bearing materials of significance as sources of water have coefficients of permeability above 100 gpd per sq ft (gallons per day per square foot).

The coefficients of vertical permeability for 205 samples from core holes in the Los Banos-Kettleman City area (table 5) ranged from 0.00007 to 370 gpd per sq ft. Samples from the Corcoran Clay Member were of consistently low permeability. Figure 15 shows that the greatest percentage of the samples tested had vertical permeabilities in the range of 0.0001 to 0.001 gpd per sq ft and the next greatest in the range of 0.001 to 0.01. The greatest percentage had horizontal permeabilities in the range of 0.001 to 0.01. Vertical and horizontal permeabilities were obtained on 62 paired samples, chiefly from core hole 16/15–34N1. The vertical permeabilities for these 62 paired samples ranged from 0.0002 to 260 gpd per ft, and the horizontal permeabilities ranged from 0.0002 to 330. For 54 of these samples, horizontal permeability did not exceed 10 times the vertical permeability, but for 8 samples horizontal permeability was in the range of 11 to 200 times as great as vertical permeability. Excluding the 8 samples having the high ratios, the average vertical permeability for the 54 paired samples was 9.3 gpd per sq ft, and their ratios of horizontal to vertical permeability averaged 2.7.

The coefficients of vertical permeability for 138 samples from core holes in the Tulare-Wasco area (table 5) ranged from 0.0002 to 650 gpd per sq ft. Samples from the Corcoran Clay Member (hole 23/25–16N1, samples 58CAL106 and 107) were of consistently low permeability. The range for horizontal permeability for 79 samples was 0.0003 to 61 gpd per sq ft. The greatest percentage of samples tested had vertical permeabilities in the range of 0.01 to 0.1 gpd per sq ft (fig. 15) and the next greatest in the range of 0.001 to 0.01. Vertical and horizontal permeabilities were obtained on 76 paired samples from the Tulare-Wasco area. Horizontal permeability was greater (as much as 100 times greater) than vertical permeabilities in 47 samples, 17 of them from 23/25–16N1 and 30 from 24/26–36A2. Vertical permeability was greater (usually not more than two or three times greater) than horizontal permeability in 16 samples, 10 of them from 23/25–16N1 and 6 from 24/26–36A2. In 13 samples—6 from 23/25–16N1 and 7 from 24/26–36A2—vertical permeability equaled horizontal permeability. The average

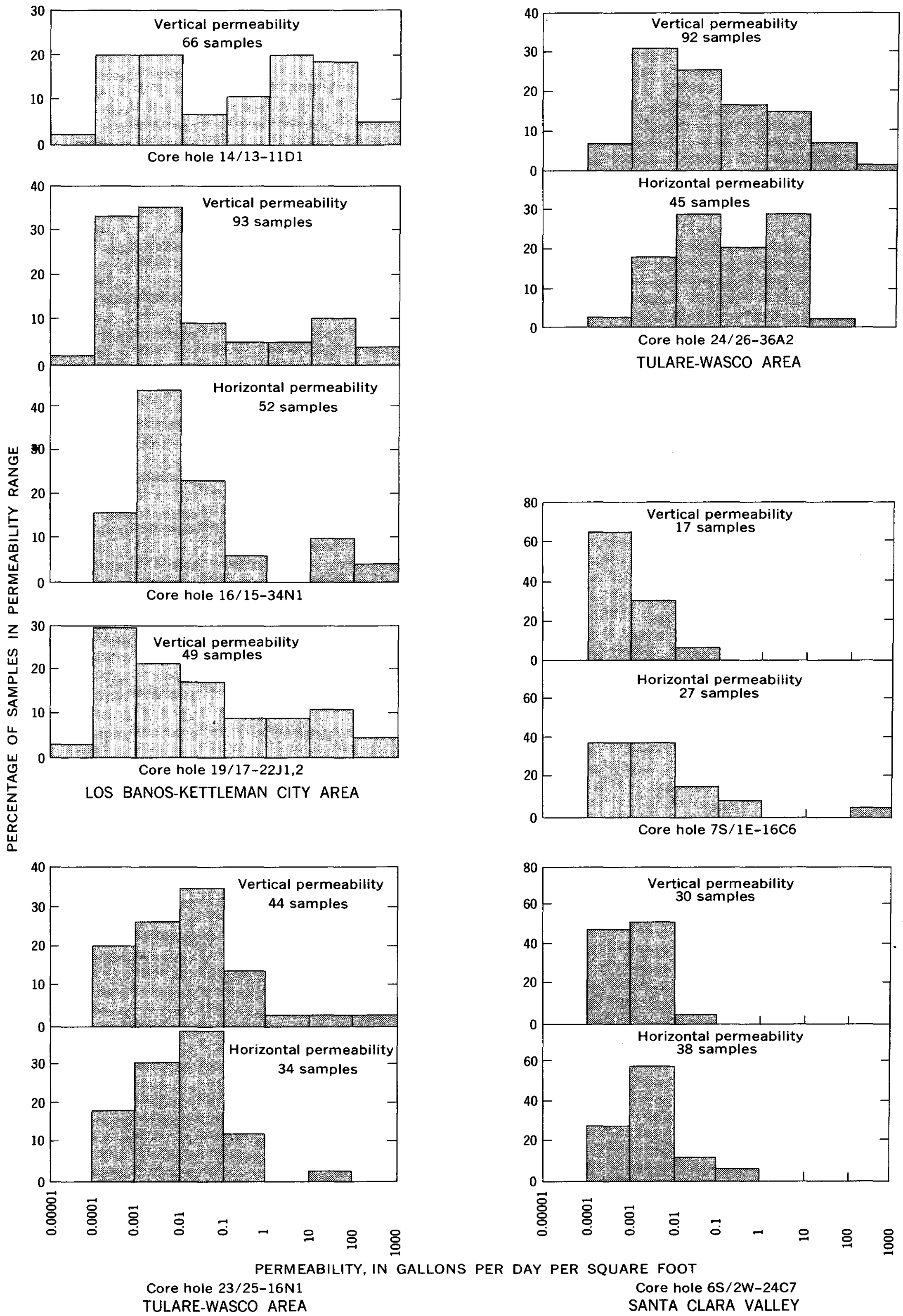

FIGURE 15.—Range in permeability of samples from core holes.

vertical permeability of the 76 paired samples was 0.5 gpd per sq ft, and the average horizontal permeability was 0.7 gpd per sq ft.

The coefficients of vertical permeability for 47 samples from core holes in the Santa Clara Valley (table 5) ranged from 0.0001 to 0.03 gpd per sq ft. The range for horizontal permeability for 65 samples was 0.0002 to 190 gpd per sq ft. The greatest percentage of samples tested had horizontal permeabilities in the range of 0.001 to 0.01 gpd per sq ft and the next greatest in the range of 0.0001 to 0.001; the greatest percentage for vertical permeabilities was in the range 0.0001 to 0.001, and the next greatest was in the range of 0.001 to 0.01. Vertical and horizontal permeabilities were obtained on 47 paired Santa Clara Valley samples. Horizontal permeability was greater (as much as 200 times greater) than vertical permeability in 31 samples, 22 of them from 6S/2W–24C7 and 9 from 7S/1E–16C6. Vertical permeability was greater (usually not more than two or three times greater) than horizontal permeability in seven samples, three of them from 6S/2W–24C7 and four from 7S/1E–16C6. In nine samples—five from 6S/2W–24C7 and four from 7S/1E–16C6—vertical permeability equaled horizontal permeability. The average vertical permeability of the 47 paired samples was 0.003 gpd per sq ft and the average horizontal permeability was 0.02 gpd per sq ft.

As noted before, the coarser, most permeable deposits were not recovered in the core barrel. Thus, the average permeability for all samples tested in each core hole does not represent the true average permeability of the sediments penetrated. It is estimated that coarse-textured deposits having permeabilities at least as great as 2,000–3,000 gpd per sq ft were present in each of the core holes, but the samples were not cored or were lost during the coring.

Figures 16 and 17 are diagrams showing the relation between vertical permeability and texture for samples from core holes in the San Joaquin and Santa Clara Valleys. Permeabilities have been grouped into eight ranges; a symbol representing the proper permeability range for each sample is plotted in the appropriate textural location on the triangle, which is subdivided according to the system proposed by Shepard (1954). Although the highest permeabilities occur in the coarse-textured and well-sorted samples, permeabilities within each textural classification vary considerably.

Vertical permeability values are plotted according to depth for samples from all three areas in plates 12–14. In these figures vertical permeability values can be compared to other physical properties.

The coefficients of vertical permeability for the clayey sediments of low permeability ($P<0.01$–0.001 gpd per sq ft) tested by the Hydrologic Laboratory in the variable-head permeameter under no load (table 5) in general appear to be in a considerably higher range than those in table 9 (ft per yr$\times$0.0205=gpd per sq ft) which were computed from the consolidation tests made by the Bureau of Reclamation for samples of similar texture. There are at least three reasons for this difference:

1. The permeability of a clayey sediment decreases markedly with decrease in void ratio (or porosity). The coefficients of permeability given in table 9 (in feet per year) are computed from time-consolidation data derived from test loads ranging from 100 to 1,600 psi (pounds per square inch) and thus represent conditions of substantially reduced void ratios from those of the samples tested in an unloaded condition in the variable-head permeameter. For sample 23L–207 (table 9), the computed coefficient of vertical permeability for the load range 100 to 200 psi is about 50 times as high as that for the load range 800 to 1,600 psi. For sample 23L–253 (table 9), the computed coefficient of permeability for the load range 400 to 800 psi is about four times as high as that for the load range 800 to 1,600 psi. For sample 23L–277, taken at a depth of 509 feet in core hole 7S/1E–16C6 (table 9), the computed coefficient of permeability for the load range 100 to 200 psi is about six times as high as for the load range 800 to 1,600 psi. The coefficients at unloaded conditions would be even higher.
2. For a clayey sediment, the water used for testing permeability in the variable-head permeameter, if not chemically compatible with the pore water, may affect the results substantially. In the water used in the Hydrologic Laboratory for the variable-head tests, calcium was the predominant cation (see analysis, p. A13); however, sodium is the predominant cation in the pore water of the sediments beneath the Corcoran Clay Member in the Los Banos-Kettleman City area. The use of water in which the calcium ion is predominant in testing cores of such sediments would tend to increase the value of the coefficient of permeability obtained in the variable-head tests. The consolidation tests, however, did not involve the passage of water through the sample, only the squeezing out of native pore water.
3. For a sample of very low permeability tested under no load in a variable-head permeameter, the disturbed condition of the sample at and near the container wall creates a boundary region which may produce a zone of appreciably higher permeability than that of the undisturbed sample

matrix. Tests in a consolidometer, however, create lateral pressure against the container walls and thus tend to reduce the permeability of the disturbed boundary region to approximately that of the sample matrix.

For these three reasons, the coefficients of permeability of the clayey sediments as derived from the unloaded variable-head permeameter tests (table 5) are not directly comparable to those computed from the time-consolidation data (table 9). Coefficients from the consolidation tests are considered more reliable for samples taken as deep as these, but, to be meaningful for field applications, the coefficients would have to be computed at the void ratio, or porosity, existing under the overburden (effective) stress conditions in the field.

SPECIFIC GRAVITY, UNIT WEIGHT, AND POROSITY

The specific gravity of a sediment is the average of the specific gravities of all the constituent mineral particles. The specific gravity of most clean sands is usually near 2.65, whereas that of clays ranges from 2.5 to 2.9. Organic matter in the sediment will lower its specific gravity.

The dry unit weight of a sediment is dependent upon the shape, arrangement, and mineral composition of the constituent particles, the degree of sorting, the amount of compaction, and the amount of cementation. Dry unit weights of unconsolidated sediments commonly range from 1.2 to 1.8 g per cc (grams per cubic centimeter), or 75 to 112 lb per cu ft (pounds per cubic foot).

Because porosity is calculated from the dry unit weight and specific gravity of the sediment, it is dependent upon the same factors. Most natural sands have porosities ranging from 25 to 50 percent, and soft clays from 30 to 60 percent. Compaction and cementation tend to reduce these values.

The results of the tests for these three properties of the sediments described in this report are given in table 4. The specific gravity of samples from the Los Banos-Kettleman City area ranged from 2.62 to 2.79, core hole 14/13–11D1; from 2.43 to 2.76, core hole 16/15–34N1; and from 2.48 to 2.76, core hole 19/17–22J1, 2 (plate 12). The lowest specific gravities in this area were for a few samples taken between depths of approximately 1,700 and 1,950 feet in the central (16/15–34N1) and southern (19/17–22J1, 2) core holes and appear to be due to a high organic content. The specific gravity of solids of samples from the Tulare-Wasco area ranged from 2.65 to 2.75, core hole 23/25–16N1, and from 2.41 to 2.79, core hole 24/26–36A2 (pl. 13). The lowest specific gravity was for a sample from core hole 24/26–36A2 taken at a depth of 1,058 feet, which is a rhyolitic ash zone. The specific gravity of solids from the Santa Clara Valley ranged from 2.67 to 2.79, core hole 6S/2W–24C7, and from 2.68 to 2.80, core hole 7S/1E–16C6 (pl. 14). In general, specific gravity increases with depth below 300 feet in samples from core hole 7S/1E–16C6.

The dry unit weight for samples from the Los Banos-Kettleman City area ranged from 1.17 to 1.95 g per cc (73.0 to 121.7 lb per cu ft) for sediments from core hole 14/13–11D1; from 1.10 to 1.81 g per cc (68.6 to 112.9 lb per cu ft), core hole 16/15–34N1; and from 1.33 to 1.84 g per cc (83.0 to 114.8 lb per cu ft), core hole 19/17–22J1, 2 (pl. 12). The dry unit weight for samples from the Tulare-Wasco area ranged from 1.05 to 1.82 g per cc (65.5 to 113.6 lb per cu ft) for sediments from core hole 23/25–16N1, and from 1.00 to 1.94 g per cc (62.4 to 121.1 lb per cu ft), core hole 24/26–36A2 (pl. 13). The dry unit weight for samples from the Santa Clara Valley ranged from 1.34 to 1.88 g per cc (83.7 to 117.4 lb per cu ft) for sediments from core hole 6S/2W–24C7 and from 1.55 to 1.91 g per cc (96.8 to 119.2 lb per cu ft), core hole 7S/1E–16C6 (pl. 14).

The porosity for samples from the Los Banos-Kettleman City area ranged from 28.0 to 56.2 percent (void ratio 0.39 to 1.28) for the sediments from core hole 14/13–11D1; from 32.7 to 54.7 percent (void ratio 0.49 to 1.20), core hole 16/15–34N1; and from 32.8 to 50.0 (void ratio 0.49 to 1.00), core hole 19/17–22J1, 2 (pl. 12). For samples from the Tulare-Wasco area, the porosity ranged from 32.1 to 61.0 percent (void ratio 0.47 to 1.56) for the sediments from core hole 23/25–16N1, and from 28.4 to 61.2 (void ratio 0.40 to 1.58), core hole 24/26–36A2 (pl. 13). In general, samples from the Corcoran Clay Member have high porosities and low dry unit weights. This characteristic undoubtedly is due in part to the diatom frustules so common in the Corcoran Clay Member. Samples from the upper Pliocene marine strata also had high porosities and low dry unit weights. For samples from Santa Clara Valley, the porosity ranged from 31.4 to 50.4 percent (void ratio 0.46 to 1.01) for the sediments from core hole 6S/2W–24C7, and from 30.5 to 43.0 (void ratio 0.44 to 0.75), core hole 7S/1E–16C6 (pl. 14).

In general, the porosities decrease with depth below land surface, and dry unit weights increase with depth. Athy (1930) described just such a progressive compaction of sediments as the load of overlying material increased with deposition. However, the graphs in plate 13 show that the porosity increases with depth in core hole 24/26–36A2, especially in the depth range from 600 to 1,600 feet. Thus, the usual relation of porosity and dry unit weight to depth is markedly anomalous in this core hole. Plate 13 also shows that the porosity and dry unit weight do not change appreciably with depth in core hole 23/25–16N1, but

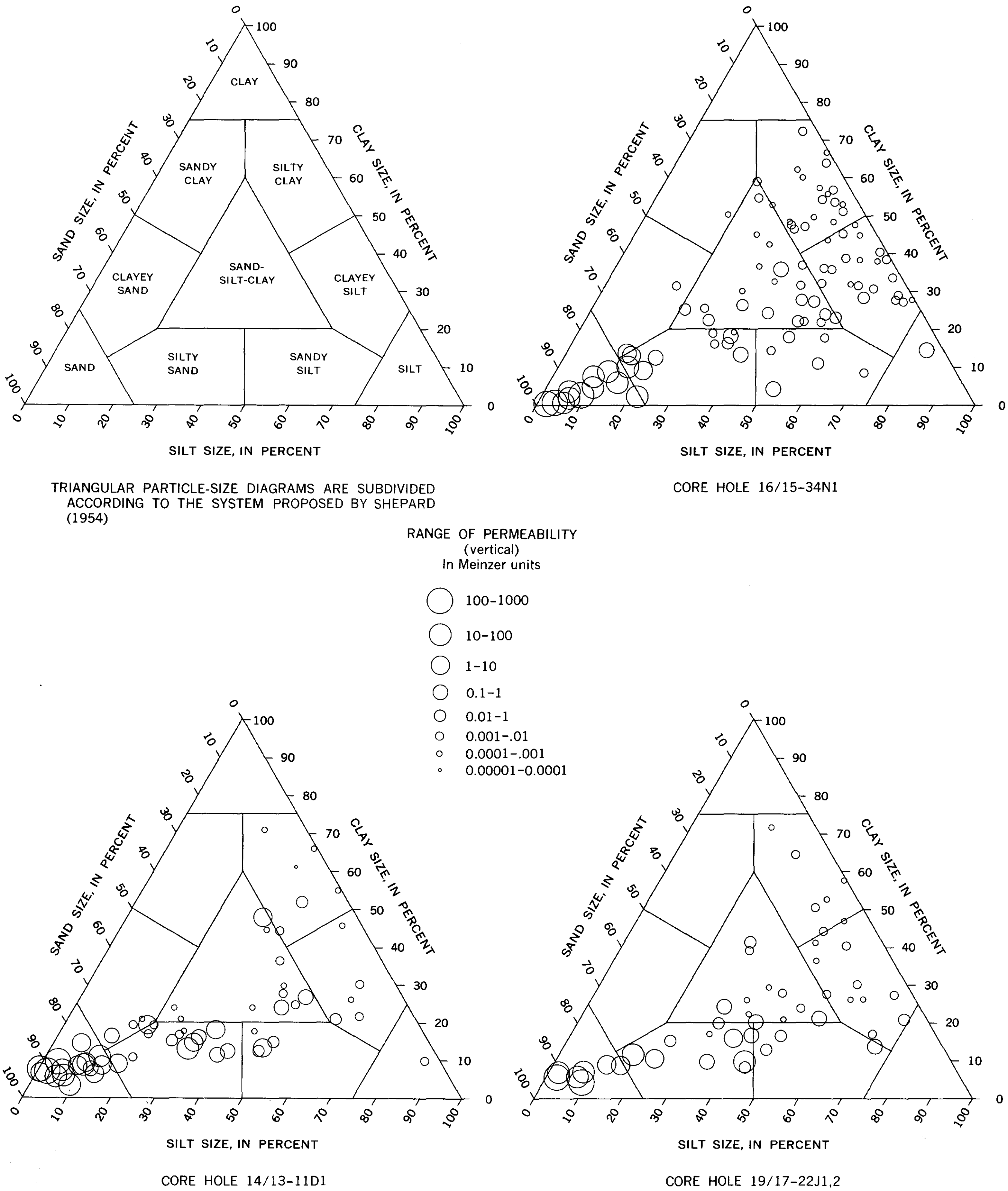

FIGURE 16.—Relation between permeability and texture for samples from core holes in the Los Banos-Kettleman City area.

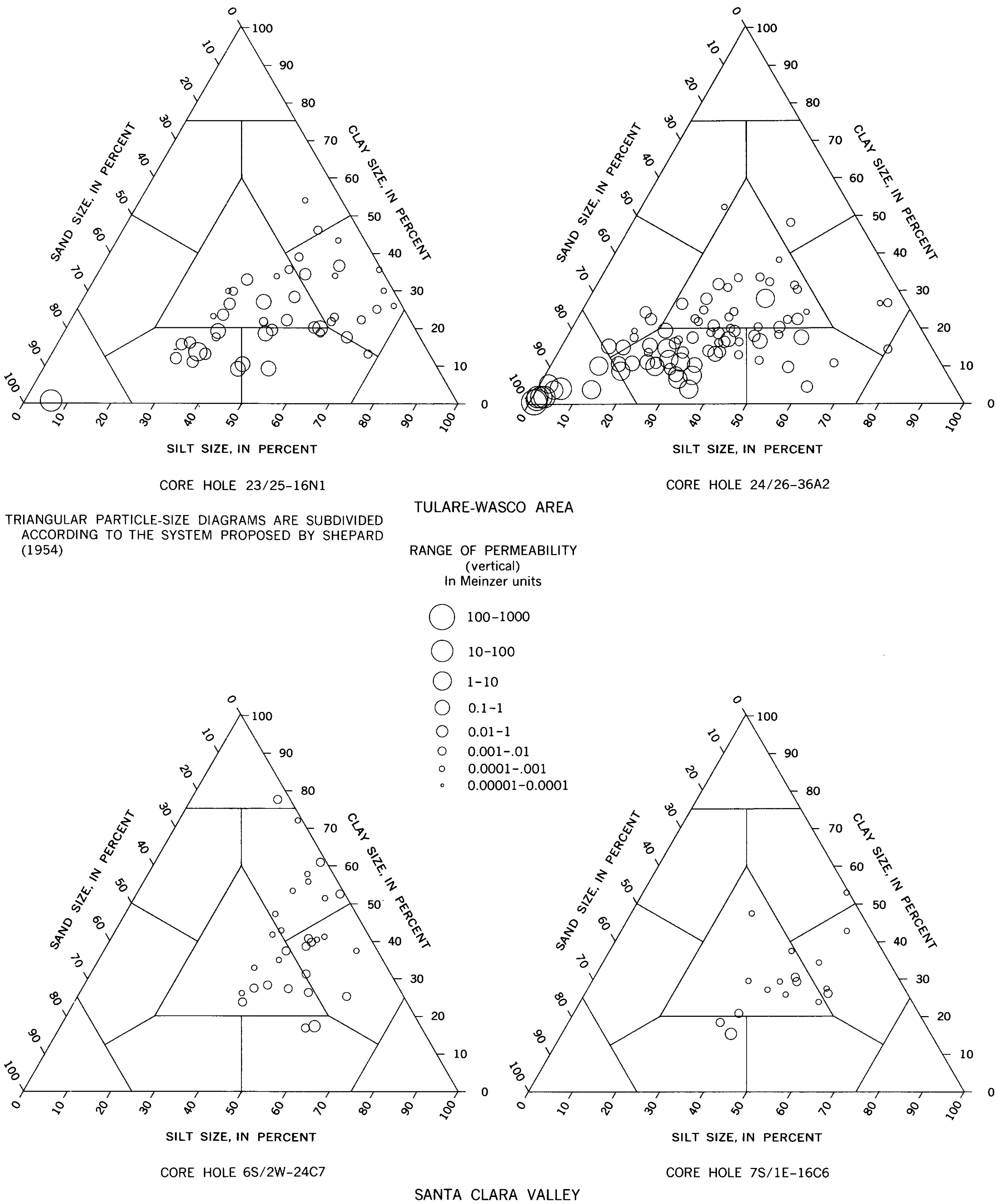

FIGURE 17.—Relation between permeability and texture for samples from core holes in the Tulare-Wasco area and the Santa Clara Valley.

these properties also are relatively constant in the same depth interval of core hole 24/26–36A2. The anomalous porosity-depth relation for core hole 24/26–36A2 is being appraised statistically and analyzed in detail by R. H. Meade (Compaction of sediments underlying areas of land subsidence in central California, manuscript in preparation).

The general trends discussed in the previous paragraphs are complicated by other factors which affect the unit weight and porosity of individual samples. These factors are (1) differences in particle sizes or in particle-size distribution, (2) differences in type of clay mineral, (3) exposure to atmosphere and preconsolidation, such as by desiccation, during their depositional history, (4) differences in intergranular structure as originally deposited, and (5) change in volume and structure of the core during and subsequent to the sampling operations.

The first four factors are natural phenomena, whereas the last one, the change in volume and structure of the core during and subsequent to the sampling operation, is introduced by man in his disturbance of the natural state in order to procure the sample. The sediments cored in these holes ranged in depth from 70 to 2,100 feet below the land surface. The effective stress, or grain-to-grain load, of the overburden on these materials in place increased from about 50 to 1,000 psi in this depth range. While the core was being cut, additional load was placed on the material by the core barrel and drill pipe, especially near the outer edge of the core. As soon as the materials were encased in the core barrel, however, the effective stress of the overburden was removed and they expanded elastically. Thus, the change in volume (porosity and unit weight) from the natural to the laboratory condition is a function of several variables:

1. Compacting effect produced by displacement of the material by the cutting edge, by the inside-wall friction, or by overdriving of the core barrel.
2. Expanding effect of removal of the effective stress of the overburden load at the time the core enters the barrel; the magnitude depends on the elasticity of the material and on the amount of the effective stress removed (increasing with depth).
3. Disturbing effects of mechanical rotation of core-barrel teeth and core catcher while cutting the core, removal of core from barrel, packing, shipping, unpacking, and processing.

The net effect of this sampling process is believed to be an expansion of the sediments as tested in the laboratory; thus the values given in table 5 are slightly higher for porosity and lower for unit weight than exist in the natural state. On the basis of a study of the consolidation and rebound data, the laboratory-determined porosity of the fine-textured materials is estimated to be as much as 2–3 percent higher than the in-place field porosity (J. F. Poland, written commun., 1963).

The effect of differences in particle size or particle-size distribution on porosity and unit weight is discussed on page A27.

MOISTURE CONTENT

The moisture contents of samples from core hole 6S/2W–24C7 in the Santa Clara Valley are listed in table 3. The wet weights of the samples were determined in the field immediately upon removal from the core barrel. The samples were dried at 110°C for 48 hours and reweighed, and the moisture contents then were calculated. Replicate tests provided some indication of the validity of the moisture-content data—the larger the difference between the two tests, the less reliable the values. Samples that had abnormally high differences between the replicate values are indicated so in table 3. Most of the variation in moisture content with depth seems to be related mainly to the changes in particle-size distribution.

Core hole 6S/2W–24C7 was the only one for which moisture content was determined in the field. Moisture content was determined at the Hydrologic Laboratory in Denver for some of the core samples from the Los Banos-Kettleman City area, but the results are not reported here because analysis data indicated that appreciable moisture had been lost from some of the samples tested.

TABLE 3—*Natural moisture content of sediments from core hole 6S/2W–24C7, Santa Clara County*

[Moisture determinations by R. H. Meade]

Sample depth (feet below surface, as logged)	Average moisture content (percent of dry weight)	Difference between replicate determinations	
		Percent of dry weight	Percent average moisture content
42.0	22.8	0.3	1.3
50±	23.1	1.0	4.3
72	23.7	.5	2.1
91±	27.9	.3	1.1
100±	25.2	.4	1.6
113.3	30.8	.7	2.3
121.1±	30.1	1.4	4.7
127±	27.2	1.1	4.1
142.2±	[1] 27.5	2.4	8.7
152	27.0	.2	.7
160.9±	26.2	.3	1.1
178.9±	23.5	.6	2.6
180.9±	27.0	1.1	4.1
192±	21.1	.4	1.9
210.6	24.9	.3	1.2
212.4	24.6	1.3	5.3
222.8	30.5	1.3	4.3
228.9	21.2	.2	.9
236.5	[2] 23.0	2.3	10.0
259	26.6	.1	.4
307.4	22.3	.2	.9
312.7	20.1	.1	.5
330.5	20.6	.0	.0
340.2	23.2	.6	2.6

See footnotes at end of table.

TABLE 3.—*Natural moisture content of sediments from core hole 6S/2W–24C7, Santa Clara County*—Continued

Sample depth (feet below surface, as logged)	Average moisture content (percent of dry weight)	Difference between replicate determinations	
		Percent of dry weight	Percent average moisture content
348.4	24.9	1.1	4.4
408.3	22.2	.1	.5
419.5	16.9	.1	.6
443.9±	25.4	.2	.8
447.1±	23.3	.3	1.3
459.4±	22.2	.6	2.7
462.9±	[1] 20.8	5.8	27.9
523.3±	29.8	1.1	3.7
526±	29.0	.1	.3
544.9	21.0	.1	.4
555.2	17.3	1.1	6.4
563.7	21.7	.7	3.2
574.8	22.7	1.0	4.4
606.4	20.9	1.2	5.7
619.1	26.5	.1	.4
633.1	[1] 34.8	5.5	15.8
646.2	[1] 42.0	2.8	6.7
656	[1] 37.6	2.9	7.7
664	[1] 39.6	2.0	5.1
716	[1] 25.1	1.5	6.0
721.8	17.8	.4	2.2
731.1	23.7	.3	1.3
742	23.7	.1	.4
756	[1] 22.6	1.5	6.6
772.9	24.4	.5	2.0
789.4	[1] 44.8	2.9	6.5
813±	[1] 40.2	3.2	8.0
825.4	37.9	1.7	4.5
835.8	[3] 26.3	.6	2.3
842.7	25.9	.4	1.5
854.6	22.0	.3	1.4
866.4	23.5	.0	.0
873.8	16.9	.2	1.2
882.1	19.3	1.0	5.2
901.3	21.4	.1	.5
911.3	27.2	1.3	4.8
924.6	30.7	.6	2.0
930.3	19.7	.4	2.0
937.6	[1] 31.2	2.6	8.3
959.4	23.4	.1	.4
966.9	20.3	.3	1.5
977.5	23.6	.8	3.4
994	[1] 24.6	6.8	27.6

[1] Must be used with caution because difference between values obtained for the 2 tests is unduly large.
[2] Of the 2 samples from this depth, 1 contained many hard calcite concretions and the other contained only a few. Moisture content of latter, 24.2 percent, is probably more significant than the average value of 23.0 percent.
[3] Although sample was a loose medium-grained sand, value is probably accurate because moisture content was measured as soon as the core was extracted from the barrel.

ATTERBERG LIMITS AND INDICES

The Atterberg limits and indices determined by the Hydrologic Laboratory for selected fine-textured samples from seven core holes are presented in tables 4 and 6 (p. A55). Table 4 summarizes the range in values of consistency for each of the limits and indices for each core hole. Table 6 presents the values of the limits and indices for each sample tested. The Earth Laboratory of the U.S. Bureau of Reclamation determined the liquid limit, plastic limit, and plasticity index for 73 samples from six core holes, These data are presented in table 8 (p. A60). The rest of the discussion of Atterberg limits and indices concerns only the samples tested by the Hydrologic Laboratory.

Predominantly fine textured samples to be tested by the Hydrologic Laboratory were selected by visual inspection. Becuase the Atterberg limits describe properties of the fine part of a sample, presenting Atterberg limit data for samples which are predominantly coarse textured could be misleading. When the influence which the limits of consistency have on the behavior of a sample is being judged, the percentage of the sample tested must be considered. Table 6 includes a column which shows the percent (by weight) of the total sample which passed a No. 40 sieve (0.42-mm openings) and was therefore the part of the sample tested for Atterberg limits.

Most of these Atterberg limits and indices are not directly applicable to the study of subsidence and compaction of sediments under increased effective overburden load, but they do furnish a rough comparative measure of the way in which fine-grained sediments respond to a decrease in moisture content as they pass from the liquid to the solid state. Because the values of these indices are related to texture, composition, clay content, and type of clay minerals present, they may be of qualitative use in comparing the fine-textured clayey deposits in these three areas to each other and to fine-textured sediments in other areas for which Atterberg indices have been obtained but for which the clay content and the type of clay minerals present are not known.

TABLE 4.—*Range in values of consistency*

Test	Core hole						
	14/13-11D1	16/15-34N1	19/17-22J,2	23/25-16N1	24/26-36A2	6S/2W-24C7	7S/1E-16C6
Liquid limit	25–82	30–76	26–65	22–63	22–107	26–68	24–50
Plastic limit	18–46	23–59	21–44	21–48	18–62	18–32	18–25
Shrinkage limit	4–31	7–31	9–32	9–24	5–44	8–20	14–19
Plasticity index	1–48	4–22	1–27	3–18	4–59	5–38	3–25
Flow index	4–42	7–32	5–26	5–14	4–32	4–17	2–7
Toughness index	0.2–3.6	0.2–2.2	0.1–2.2	0.2–2.2	0.5–3.4	0.9–3.3	1.5–5.7
Shrinkage index	0–36	2–49	1–32	5–29	0–46	1–18	3–8
Shrinkage ratio	1.4–2.3	1.4–2.0	1.4–2.0	1.6–2.0	1.2–2.1	1.7–2.2	1.8–2.0
Volumetric shrinkage	4–168	12–122	13–101	5–75	7–166	14–103	11–56
Linear shrinkage	1–28	4–23	4–21	2–17	2–28	4–21	3–14

LIQUID LIMIT

Data correlating liquid limits determined by a single-point method with liquid limits determined by the standard multiple-point method were presented by Morris and Johnson (1959) and showed that a good correlation existed. However, only the multiple-point data are reported in table 6.

The liquid limits for core-hole samples from the Los Banos-Kettleman City area range from 25 to 82 and, except for a few cores taken from the thick section of the Corcoran Clay Member in core hole 14/13–11D1, show general similarity between core holes (pl. 12). The Corcoran Clay Member in this core hole had liquid limits ranging from 67 to 82. The liquid limits for the core-hole samples from the Tulare-Wasco area range from 22 to 107 (pl. 13). The Corcoran Clay Member in core hole 23/25–16N1 had liquid limits of 56 and 63. Most samples from the upper Pliocene marine strata had even higher liquid limits.

The liquid limits for the core-hole samples from the Santa Clara Valley range from 24 to 68 (pl. 14). Samples from core hole 6S/2W–24C7 had generally higher values.

PLASTIC LIMIT

In materials in contact with the atmosphere, the voids remain saturated down to the plastic limit, at which time air begins to enter the soil mass. The plastic limits ranged from 18 to 59 for all the fine-textured core-hole samples from the Los Banos-Kettleman City area, the highest plastic limits being for samples of the Corcoran Clay Member. The plastic limits ranged from 18 to 62 for all core-hole samples tested from the Tulare-Wasco area. The plastic limits ranged from 18 to 32 for the clayey core-hole samples tested from the Santa Clara Valley.

The liquid and plastic limits (moisture content, in percent) for samples from all core holes are plotted against clay-size particles, in percent, in figure 18. As shown by the trend lines drawn in figure 18, both limits tend to increase with an increase in clay content, the liquid limit increasing at a greater rate than the plastic limit.

The trend lines shown in figure 18 were plotted from equations derived by computer in the U.S. Geological Survey Computation Branch. The equations are of the form $y=a+bx$, in which y represents the moisture content (w), x represents the clay content (C), both in percent, and a and b are constants. In figure 18*A* the equation of the liquid-limit trend line is $w_L=28.1+0.53C$ and that of the plastic-limit trend line is $w_p=26.8+0.17C$. In figure 18*B* the equation of the liquid-limit trend line is $w_L=13.5+1.3C$ and that of the plastic-limit trend line is $w_p=17.3+0.54C$. In figure 18*C* the equation of the liquid-limit trend line is $w_L=14.0+0.72C$ and that of the plastic-limit trend line is $w_p=14.7+0.22C$. The equations of all these trend lines are for samples having clay content based on the percentage of particles less than 0.004 mm in size.

Figure 18*D* shows trends which are composites of all the samples shown in figures 18*A–C*. The equation of line 1, the liquid-limit trend line for clay sizes less than 0.002 mm, is $w_L=27.8+0.71C$. The equation of line 2, the liquid-limit trend line for clay sizes less than 0.004 mm, is $w_L=25.8+0.60C$. The equation of line 3, the plastic-limit trend line for clay sizes less than 0.002 mm is $w_p=25.6+0.21C$. The equation of line 4, the plastic-limit trend line for clay sizes less than 0.004 mm is $w_p=24.5+0.19C$. Lines 1 and 3 are included to show the relation between liquid and plastic limits and percent of clay-size particles if 0.002 mm is chosen as the upper limit of the clay-size range.

The value of the standard error for each trend line was obtained from the computer. The pairs of dashed lines which parallel each trend line designate two standard errors on either side of the trend line. The probability is 19 to 1 that, for a given value of clay content (in percent), the observed liquid limit or plastic limit will lie within the interval between the dashed lines.

PLASTICITY INDEX

The difference between the liquid and plastic limits, or the plasticity index, represents the range of moisture content within which a sediment mass will remain in the plastic state. Plastic clay normally has a plasticity index of 15 or greater, and clean sand an index close to 0. The fine-textured samples from the Los Banos-Kettleman City area had plasticity indices ranging from 1 to 48, and most sediments from core hole 14/13–11D1 had a higher plastic range than those from the other two holes. The samples of the Corcoran Clay Member from core hole 14/13–11D1 had a particularly high range of plasticity indices, from 31 to 40. The plasticity indices of core-hole samples from the Tulare-Wasco area ranged from 2 to 58. The two samples of the Corcoran Clay Member from core hole 23/25–16N1 had a plasticity index of 38 and 48, respectively. The fine-textured samples from the Santa Clara Valley had plasticity indices ranging from 3 to 38. The moisture content difference between the liquid-limit trend line and the plastic-limit trend line in each part of figure 18 represents the average plasticity index for different clay contents.

Casagrande (1948, p. 919) devised a chart on which the liquid limit is plotted against the plasticity index and used it for rough classification of soils. Points representing different samples from the same stratum or fine-grained deposit plot as a straight line that is roughly parallel to an "A" line, an empirical boundary

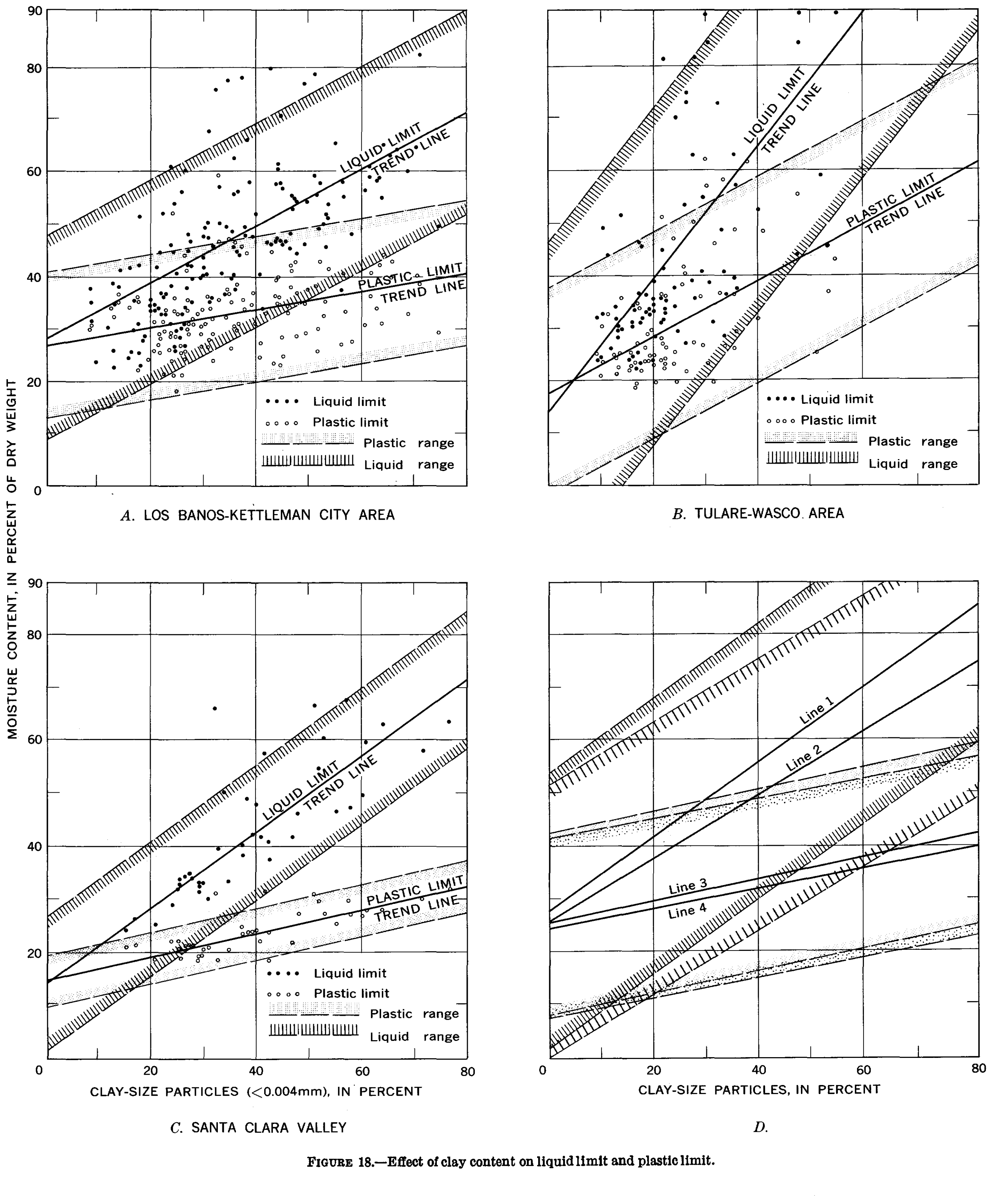

FIGURE 18.—Effect of clay content on liquid limit and plastic limit.

between typically inorganic clays above and plastic organic soils below the line. The higher a sample plots on this chart at a given liquid limit, the greater its toughness and dry strength and the lower its permeability and rate of volume change. Figure 19 shows plasticity charts of the Casagrande type on which the data for all samples tested by the Hydrologic Laboratory have been plotted. The sediment-classification names used in figure 22 are different from the Shepard classification names used earlier in this report.

As shown by figure 19*A*, most of the Atterberg limits of the sediments from all core holes in the Los Banos-Kettleman City area fall in a rather narrow band beneath the "A" line, in the region typical for either organic or inorganic silt and silt-clay or micaceous and diatomaceous fine sandy and silty soils, elastic silt, and organic clay. A few samples are above the "A" line and are classified as inorganic clay of medium and high plasticity. Atterberg limits of nearly all the fine-textured samples from core hole 14/13–11D1 fall near the "A" line of the chart, the samples of the Corcoran Clay Member being the highest in plasticity (upper right of the chart).

Atterberg limits of most of the fine-textured sediments from both core holes in the Tulare-Wasco area fall in a rather narrow band near the "A" line (fig. 19*B*) in the region typical for organic or inorganic silt and silt-clay of low plasticity, inorganic clay of low to medium plasticity, and organic clay of medium to high plasticity. All samples having liquid limits greater than 50 are from core hole 24/26–36A2, except two samples of the Corcoran Clay Member from core hole 23/25–16N1. Samples of the Corcoran Clay Member have a MH classification (fig. 19*A*) in the Unified Soil Classification system, and samples from the upper Pliocene marine strata are classified predominantly as OH and OL. The continental deposits from the Sierra Nevada are predominantly of CL and ML classification.

Atterberg limits of most of the fine-textured sediments tested from both core holes in the Santa Clara Valley fall in a rather narrow band above the "A" line (fig. 19*C*), in the region typical for inorganic clay having low to medium plasticity, gravelly clay, sandy clay, silty clay, lean clay, and inorganic clay having high plasticity. All samples that fall on the right side of the line through a liquid limit of 50 are from core hole 6S/2W–24C7.

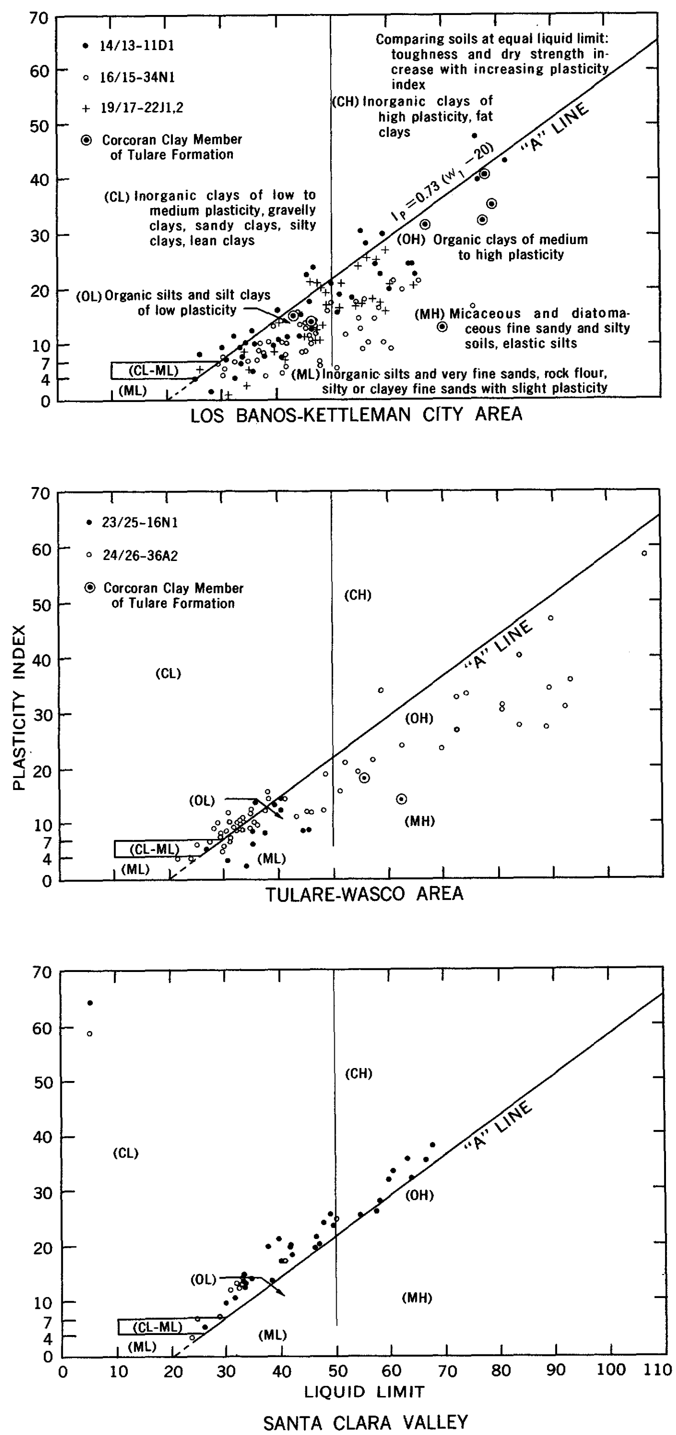

FIGURE 19.—Unified soil classification plasticity for core-hole samples. (ASTM, 1958, p. 188–189.)

SHRINKAGE LIMIT

The shrinkage limit represents the minimum moisture content needed to fill the pores when the soil is at the minimum volume that it will attain by drying. The shrinkage index represents the range of moisture content in which a sediment mass remains in a semisolid state of consistency. Shrinkage limits for the fine-textured samples from the Los Banos-Kettleman City area ranged from 4 to 32 percent and shrinkage indices ranged from 0 to 49 (table 6).

Shrinkage limits for the fine-textured samples from the two core holes in the Tulare-Wasco area ranged from

5 to 44 percent, and shrinkage indices ranged from 0 to 46 (table 6). The samples from core hole 23/25–16N1 have, in general, higher shrinkage indices than samples from corresponding depths in core hole 24/26–36A2.

Shrinkage limits for the fine-textured samples from the Santa Clara Valley ranged from 8 to 20 percent, and shrinkage indices ranged from 1 to 18 (table 6). Samples from two zones in core hole 6S/2W–24C7 had high shrinkage indices. These zones are at 140–223 feet, where the shrinkage indices range from 10 to 15, and at 715–959 feet, where the shrinkage indices range from 9 to 18.

VOLUMETRIC SHRINKAGE

The volumetric shrinkage, or the total volumetric change possible as the moisture content decreases from the liquid limit to the shrinkage limit, compared to depth below land surface, is illustrated for the Los Banos-Kettleman City area in plate 12, and values of volumetric and linear shrinkage are provided in table 6. Plate 12 shows that the volumetric-shrinkage values for the sediments from core holes 16/15–34N1 and 19/17–22J1, 2 were similar but values for core hole 14/13–11D1 were generally higher. However, a general decrease in volumetric shrinkage values may be noted southward from core hole 14/13–11D1 to 19/17–22J1, 2. The volumetric shrinkage ranged from 4 to 168 percent.

The volumetric-shrinkage values are generally high for samples from the Corcoran Clay Member in the Tulare-Wasco area, and are especially high for some samples from the upper Pliocene marine strata. The volumetric shrinkage is compared to depth below land surface in plate 13, and values of volumetric, as well as linear, shrinkage are provided in table 6. Plate 13 shows that the volumetric shrinkage for sediments from core hole 23/25–16N1 is generally higher and exhibits greater variation than the volumetric shrinkage for comparable depths from core hole 24/26–36A2. Volumetric shrinkage for fine-textured samples from core hole 23/25–16N1 ranges from 5 to 75 and averages 34. Volumetric shrinkage for samples above 750 feet in core hole 24/26–36A2 ranges from 7 to 87 and averages 28; below 750 feet, however, it ranges from 22 to 166 and averages 86. Thus, the average volumetric shrinkage for samples from the upper Pliocene marine strata is about three times as great as for the overlying continental sediments.

The volumetric shrinkage is compared to depth below land surface for the fine-textured samples from the Santa Clara Valley in plate 14, and values of volumetric and linear shrinkage are provided in table 6. Plate 14 shows that the volumetric shrinkage of sediments from core hole 6S/2W–24C7 is generally higher and exhibits greater variation than the volumetric shrinkage of sediments from core hole 7S/1E–16C6. Volumetric shrinkage of fine-grained samples from above 700 feet in core hole 6S/2W–24C7 ranges from 14 to 76 and averages 43; below 700 feet it ranges from 50 to 103 and averages 88. Volumetric shrinkage of samples from core hole 7S/1E–16C6 ranges from 11 to 56 and averages 32.

Johnson and Morris (1962b) showed that the volumetric shrinkage in a sediment mass is proportional to the percentage of clay-size particles in that sediment, a 10-percent increase in clay content causing an approximate increase of 20–30 percent in volumetric shrinkage.

Figure 20 shows the relation between volumetric shrinkage and the percentage of clay-size particles. Equations of the form $y=a+bx$ were calculated in the Geological Survey Computation Branch for the relationships between values for volumetric shrinkage and for clay content (both <0.004 and <0.002 mm). In these equations, y represents volumetric shrinkage (V_s), x represents clay content (C), both in percent, and a and b constants. The computer also calculated the standard error for each relation.

Figure 20*A* shows the relation between volumetric shrinkage and the percentage of clay-size particles (both <0.004 and <0.002 mm) for the tested core-hole samples from the Los Banos-Kettleman City area. The two trend lines are plotted from the equations furnished by the computer. The pairs of dashed lines parallel to the trend lines designate two standard errors (as calculated by the computer) on either side of the trend lines. The probability is 19 to 1 that, for a given clay content in percent, the observed volumetric shrinkage will lie within the interval designated by the dashed parallel lines. Figure 20*B* shows these relations for the tested core-hole samples from the Tulare-Wasco area, and figure 20*C* shows these relations for the tested core-hole samples from the Santa Clara Valley. Figure 20*D* is a composite showing the relations calculated by the computer for all the samples included in figures 20*A*–*C*.

For samples from the Los Banos-Kettleman City area (fig. 20*A*) the equation for the trend line using clay sizes less than 0.002 mm is $V_s=4.4+1.9C$, and the equation using clay sizes less than 0.004 mm is $V_s=0.15+1.5C$. For samples from the Tulare-Wasco area (fig. 20*B*) the equation for the trend line using clay sizes less than 0.002 mm is $V_s=-3.5+2.5C$, and the equation using clay sizes less than 0.004 mm is $V_s=-15.2+2.4C$. For samples from the Santa Clara Valley (fig. 20*C*) the equation for the trend line using clay sizes less than 0.002 mm is $V_s=-15.2+2.1C$, and the equations using clay sizes less than 0.004 mm is $V_s=-9.8+1.5C$. For all samples tested (fig. 20*D*), the equation for the trend line using clay sizes less than 0.002 mm is $V_s=3.5+1.9C$, and the equation using clay sizes less than 0.004 mm is $V_s=0.12+1.5C$.

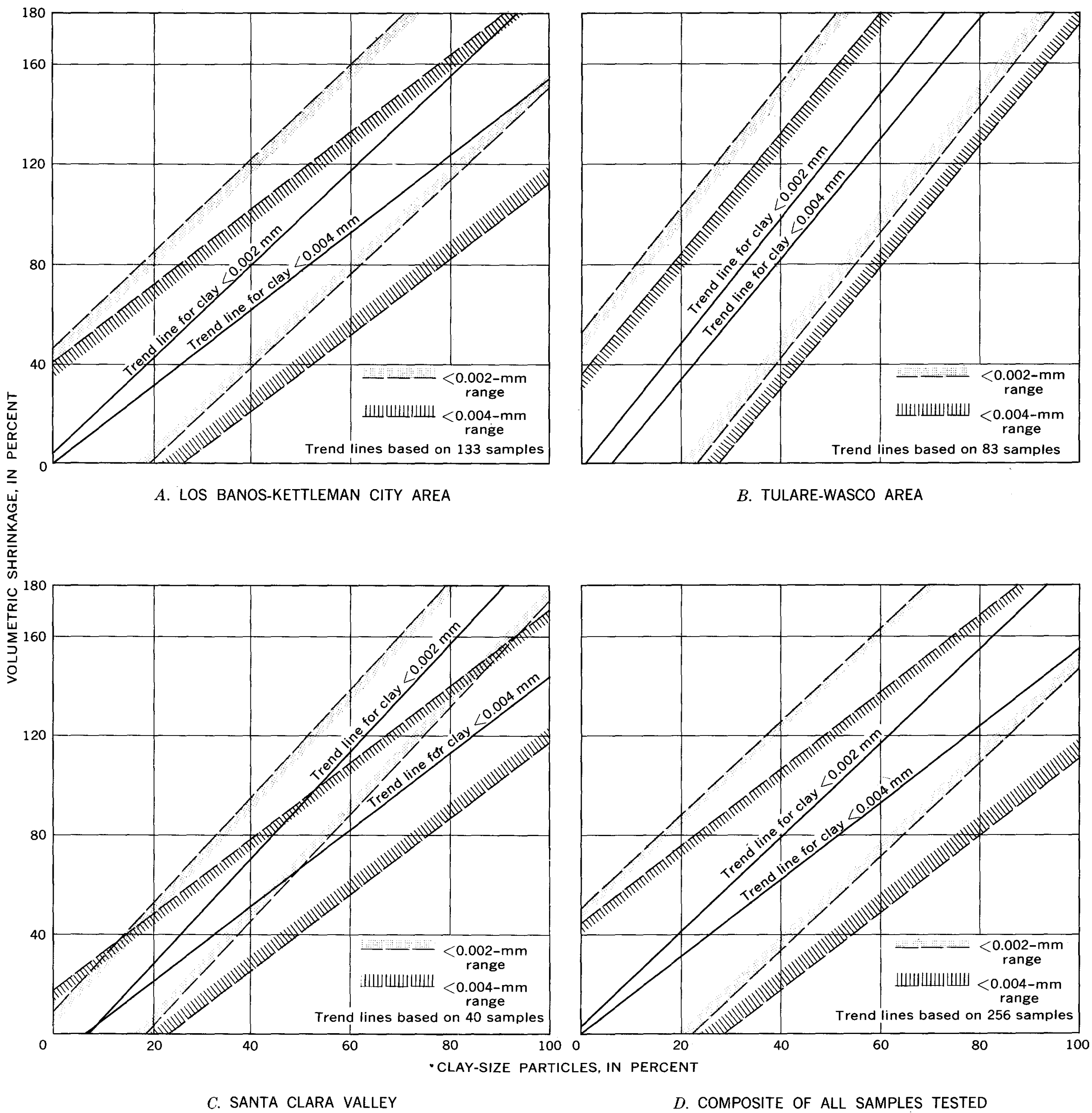

FIGURE 20.—Relation of volumetric shrinkage to clay content for samples from core holes.

TOUGHNESS INDEX

The toughness index is considered an expression of the relative toughness or shearing strength at the plastic limit. It generally falls between 1 and 3 for most clays. A sediment is friable at the plastic limit if this index is less than 1. Plate 12 and table 6 show that samples from core holes 16/15–34N1 and 19/17–22J1, 2 in the Los Banos-Kettleman City area had a toughness index ranging from 0.1 to 2.2, the samples from 16/15–34N1 generally having a toughness index less than 1 and samples from 19/17–22J1, 2 generally having a toughness index greater than 1. The toughness index of samples from core hole 14/13–11D1 was somewhat higher—ranging from 0.2 to 3.6 and generally greater than 1. The Corcoran Clay Member from core hole 14/13–11D1 had a toughness index close to 3.

Plate 13 and table 6 show that samples from core hole 23/25–16N1 in the Tulare-Wasco area had a toughness index ranging from 0.2 to 2.2 and the samples from core hole 24/26–36A2 had a toughness index ranging from 0.5 to 3.4. The toughness index of samples from core hole 24/26–36A2 was generally higher in samples taken below 750 feet. The Corcoran Clay Member from core hole 23/26–16N1 had a toughness index averaging 1.6.

Plate 14 and table 6 show that the samples from core hole 6S/2W–24C7 in Santa Clara Valley had a toughness index ranging from 0.9 to 3.3 and the samples from core hole 7S/1E–16C6 had a toughness index ranging from 1.5 to 5.7. The toughness index for samples from core hole 7S/1E–16C6 was generally higher than the toughness index for samples from core hole 6S/2W–24C7.

ACID SOLUBILITY

Calcite and, to a lesser extent, dolomite, and possibly magnesite, are the carbonates usually occurring in significant quantities in the soils of arid regions. A high carbonate content at some depth in the subsurface sediments may be indicative of an old buried soil horizon.

The percentage of material dissolved out of a sample by cold dilute hydrochloric acid is reported as acid solubility in table 7. For reasons discussed on p. A16, the percentage of acid-soluble material is only an approximate measure of the calcium carbonate content of the samples tested.

Test results for selected samples from the three core holes in the Los Banos-Kettleman City area (table 7; pl. 12) indicate that acid solubility ranged from about 1 to 16 percent, averaging 5 percent for 60 samples from core hole 14/13–11D1, 7 percent for 59 samples from core hole 16/15–34N1, and 8 percent for 21 samples from core hole 19/17–22J1, 2. No consistent trend for acid solubility and depth was apparent; core hole 16/15–34N1 showed a general decrease with depth, and core hole 14/13–11D1 showed markedly lower values from 700 to 1,350 feet. In core hole 14/13–11D1, the highest acid solubility (nearly 15 percent) was found at a depth of 1,397 feet, in a hard, brittle clay logged from 1,348 to 1,455 feet in depth.

Test results for selected samples from the two core holes in the Tulare-Wasco area (table 7; pl. 13) indicate that acid solubility ranged from 0.4 to 20.8 percent, averaging 6 percent for 16 samples from core hole 23/25–16N1 and 5 percent for 95 samples from core hole 24/26–36A2. No consistent trend for acid solubility and depth was apparent, but three zones of high acid solubility were found in core hole 24/26–36A2, at depths of approximately 400, 750, and 1,750 feet.

Test results for selected samples from the two core holes in the Santa Clara Valley (table 7; pl. 14) indicate that acid solubility ranged from 6.5 to 19.1 percent, averaging 10 percent, for 30 samples from core hole 6S/2W–24C7 and ranged from 11.0 to 18.4 percent, averaging 14 percent, for 10 samples from core hole 7S/1E–16C6. No consistent trend of acid solubility with depth was apparent, but generally higher acid solubilities were found in 7S/1E–16C6 than in 6S/2W–24C7.

GYPSUM CONTENT

Gypsum ($CaSO_4 \cdot 2H_2O$) is often found in the soil materials of arid regions. It occurs either in the soil zone, owing to precipitation of calcium and sulfate during salinization, or at any depth, owing to the composition of the sedimentary deposits. Reitemeier (1946) showed that precise determination of gypsum content is difficult because several factors other than the solution of gypsum in water may influence the amounts of calcium and sulfate extracted from gypsiferous soil materials. Those factors are (1) the solution of calcium and sulfate from sources other than gypsum and (2) exchange reactions in which soluble calcium replaces other cations, such as sodium and magnesium.

In earlier studies related to near-surface subsidence in the Los Banos-Kettleman City area, gypsum was found in samples from shallow core holes (Bull, 1964, p. 61). In areas of active or potential near-surface subsidence, gypsum content in two core holes 300 feet deep ranged from 0.1 to 4.8 percent in 85 samples (Inter-Agency Committee, 1958, pls. 18, 23). Data in table 7 indicate that no gypsum was found in selected samples tested from core holes 14/13–11D1 and 16/15–34N1. Only three of the samples tested from core hole 19/17–22J1, 2 had a small amount (<1 percent) of gypsum. These samples, taken at depths of approximately 1,805, 1,874, and 1,957 feet, had gypsum contents of 12.7, 4.0, and 7.6 tons per acre-foot of soil, respectively.

No gypsum was found in samples tested from core hole 23/25–16N1 in the Tulare-Wasco area (table 7). Only 11 of the samples tested from core hole 24/26–36A2 contained any gypsum, and all except 3 of these had less than 1 percent gypsum (20 tons per acre-foot is considered equal to 1 percent gypsum). These samples were from depths of 698 to 1,892 feet and had gypsum contents ranging from 0.3 to 24.4 tons per acre-foot of soil.

No gypsum was found in samples tested from either core hole 6S/2W–24C7 or 7S/1E–16C6 in the Santa Clara Valley (table 7).

CONSOLIDATION

As one phase of the research on subsidence and compaction of aquifer systems, laboratory consolidation tests were made on representative cores from eight core holes. These consolidation tests were made in the Earth Laboratory of the U.S. Bureau of Reclamation at Denver, Colo. The visual classification, including the group symbol of the Unified Soil Classification (fig. 19; see also ASTM, 1958, p. 188–189), and Atterberg limits (also determined by the Bureau of Reclamation) for the samples tested for consolidation are listed in table 8. The consolidation-tests results are summarized in table 9.

The results of these consolidation tests are being utilized in interpretive reports of the Geological Survey to compute compaction in the confined aquifer system in response to the known decline in artesian head. The method has been described by Miller (1961); it is a refinement of a technique outlined by Gibbs (1959, p. 4–5) based upon Terzaghi's theory (1943) of consolidation and the use of one-dimensional consolidation tests.

Consolidation-test curves for samples tested by the Bureau of Reclamation, composited for each of the eight core holes, are shown in plate 11.

Plate 11*A–D* shows, in general, that in the Los Banos-Kettleman City area the Corcoran Clay Member has a greater unit consolidation potential than any of the other sediments. The compaction of the Corcoran Clay Member, however, has contributed very little to the total subsidence to date (Miller, 1961, p. B57) because, where the Corcoran is thick, water moves out very slowly owing to the Corcoran's low vertical permeability. Where the Corcoran is thin and more permeable, it forms only a small percentage of the water-bearing section. Consolidation curves for the Corcoran Clay Member are generally steep in the load range 200–1,000 psi and indicate that the clay is normally loaded and has not been precompressed. Therefore the clay has only partly completed its potential consolidation at the present time and at the present artesian pressure.

Initial void ratios of samples tested from core hole 12/12–16H1 ranged from 0.55 to 1.51, and void ratios of the seven samples tested at 1,000 psi ranged from approximately 0.33 to 0.66 (pl. 11*A*). Initial void ratios of samples tested from core hole 14/13–11D1 ranged from 0.58 to 1.19, and void ratios at 1,000 psi ranged from 0.38 to 0.67. Initial void ratios of samples tested from core hole 16/15–34N1 ranged from 0.52 to 1.09, and void ratios at 1,000 psi ranged from 0.37 to 0.67. Initial void ratios of samples tested from core hole 19/17–22J1, 2 ranged from 0.53 to 0.96, and void ratios at 1,000 psi ranged from 0.37 to 0.58.

Several zones of high compressibility were indicated by the consolidation tests. Core holes 16/15–34N1 and 19/17–22J1, 2 in the southern part of the Los Banos-Kettleman City area have considerable thicknesses of highly compressible silty clay beds. The Corcoran Clay Member is thinner and less representative in these holes than in core holes 12/12–16H1 and 14/13–11D1 in the northern part of the area, where it is highly compressible.

The consolidation tests (pls. 11*E*, *F*) indicate that in the Tulare-Wasco area, the Corcoran Clay Member, which is the principal confining layer throughout much of the valley, is the only highly compressible clay in the continental deposits penetrated by the two core holes. The Corcoran is only 16 feet thick in core hole 23/25–16N1 and is nonexistent in core hole 24/26–36A2. A large thickness of firm upper Pliocene marine claystone was penetrated in core hole 24/26–36A2 between depths of 744 and 1,641 feet; in general, these sediments have a greater unit consolidation potential than any of the other sediments tested from the two core holes in the Tulare-Wasco area. The consolidation tests of the claystone indicate preconsolidation to approximately 700–800 psi and, for the respective depths of about 900–1,500 feet, suggest normal loading of the sediments (pl. 11*F*).

Initial void ratios of the samples from core hole 23/25–16N1 ranged from 0.52 to 1.10 and void ratios at 1,000 psi ranged from approximately 0.30 to 0.60. Samples tested from core hole 24/26–36A2 had initial void ratios ranging from 0.46 to 1.47, and void ratios at 1,000 psi ranged from approximately 0.30 to 1.25.

The consolidation tests of cores from the Santa Clara Valley indicate only moderately compressible silty clay in contrast to the highly compressible Corcoran Clay Member found in the Los Banos-Kettleman City area. Core-hole samples exhibit more uniform compression indices and initial void ratios than the samples from the other two areas (table 8; pl. 11*G*, *H*). None of the Santa Clara Valley samples produced such steep void-ratio versus log-load curves as did samples of the Corcoran Clay Member from the San Joaquin Valley. Initial void ratios of the samples from core hole 6S/2W–24C7 ranged from 0.55 to 0.82 and void ratios at 1,000 psi ranged from 0.33 to 0.50. The samples tested from core hole 7S/1E–16C6 had initial void ratios ranging from 0.52 to 0.69 and void ratios at 1,000 psi ranging from 0.28 to 0.48.

Terzaghi and Peck (1948, p. 66) stated that values for the compression index, C_c, of ordinary clays of medium or low sensitivity can be estimated roughly from the liquid limit, w_L, by use of the following equation:

$$C_c = 0.009(w_L - 10).$$

Thus, for such clays, values of C_c can be estimated by making no tests other than liquid-limit tests. Terzaghi and Peck also, however, concluded that the equation furnishes merely a lower limiting value for the compression of an extra-sensitive clay—the actual compression may be several times greater.

For comparison, the values of the compression index, C_c, obtained by the Bureau of Reclamation from the above equation and from consolidation tests are given in table 9. Many of the estimates computed from the liquid limit are close to the values obtained from consolidation tests but a few differ greatly.

Figure 21 shows the relation of liquid limit to the compression index, C_c, for samples from six core holes. Both the liquid limit and the compression index were determined experimentally by the Bureau of Reclamation. A solid line in each of the four parts of the figure provides a graphical representation of the Terzaghi and Peck equation. Thus, the values of liquid limit and compression index, determined experimentally for the core hole samples, can be compared with values derived from the equation.

In part *D* of figure 21, the regression lines determined by computer for the actual data for samples from the San Joaquin and Santa Clara Valleys are compared with the regression line for the data from Terzaghi and Peck (1948, p. 66). The equation for the regression line for samples from San Joaquin Valley is $C_c=0.015(w_L-20)$, and for samples from the Santa Clara Valley is $C_c=0.0033(w_L+30)$, both of which compare with the equation of $C_c=0.009(w_L-10)$ for data from Terzaghi and Peck.

The pairs of dashed or dotted lines parallel to the trend lines in figure 21*D* designate the zone in which the probability is 19 to 1 that, for a given value of liquid limit, the observed compression index will lie. The closer plot to their trend line of data for samples from

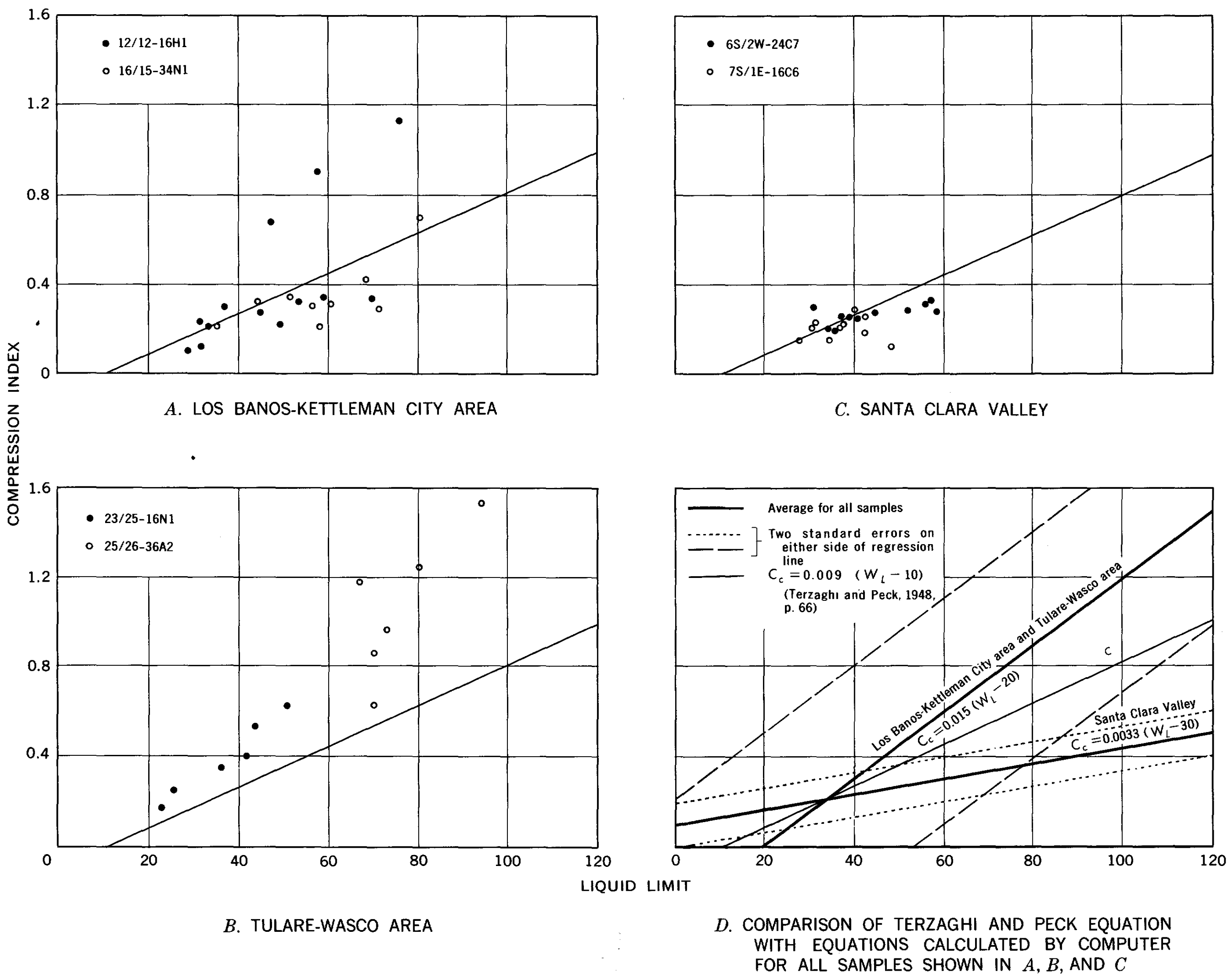

FIGURE 21.—Relation between liquid limit and compression index for samples from core holes.

core holes in the Santa Clara Valley indicate better correlation than do the plot of data for samples from the San Joaquin Valley. The dashed lines for the San Joaquin Valley are so far apart, owing to the wide scatter of the plotted points, that the computed equation for the data for samples from that area is not particularly significant and should be used for approximate comparative purposes only.

The permeability for each sample tested for consolidation by the Bureau of Reclamation is presented in table 9. The permeability was calculated from consolidation data or was determined while the sample was under load in the consolidation apparatus and after consolidation was complete. Permeability values are presented for various load ranges, the value given representing permeability at maximum load. The units of permeability are expressed in feet per year (ft per yr×0.0205=gpd per sq ft).

The Unified Soil Classification group symbol is also listed in table 9 for each sample tested for consolidation by the Bureau of Reclamation (ASTM, 1958, p. 188–189).

SUMMARY OF LABORATORY ANALYSES RESULTS BY AREA

Results of the tests on physical and hydrologic properties of the various core-hole samples have thus far been discussed by type of test so that the physical characteristics of the deposits in the three areas could be compared. In this section the results of the laboratory analyses are summarized briefly by individual subsidence area.

It must be emphasized again that the laboratory samples described in this report represent, primarily, the fine-textured materials from the core holes; the coarse sediments (loose sand and gravel) were not recovered in the coring operation. Therefore any ranges and averages cited are not representative of the sediments as a whole. However, because compaction due to artesian-head decline occurs chiefly in the fine-textured deposits, their physical and hydrologic properties are the most pertinent to the study of land subsidence and compaction of aquifer systems.

The data being utilized directly in the interpretive reports of the Geological Survey are the results of the particle-size analyses and of the tests for the specific gravity, unit weight, porosity and void ratio, and consolidation. The tests for acid solubility and gypsum content were made to facilitate study of the environment of deposition and diagenesis of the sediments. Atterberg limits and indices, in conjunction with the particle-size analyses, illustrate the effect of the percentage of clay-size particles on engineering properties and furnish a qualitative index to the compressibility characteristics of the sediments. The tests for permeability should prove useful to other related studies. The analytical results on these samples furnish a substantial body of data on the physical and hydrologic properties of thick sequences of unconsolidated to semiconsolidated sediments.

LOS BANOS-KETTLEMAN CITY AREA

The results of the tests for the most pertinent properties of samples analyzed from three core holes—14/13–11D1, 16/15–34N1, and 19/17–22J1, 2—have been plotted on plate 12 in conjunction with the electric (self-potential and resistivity) logs for each core hole. Permeability, clay content, dry unit weight, specific gravity, porosity and void ratio, Atterberg limits, volumetric shrinkage, toughness index, acid solubility, and gypsum content are shown. Plate 12 thus serves as a graphic summary of most of the analyses made at the U.S. Geological Survey Hydrologic Laboratory on samples from these three core holes. The number of analyses made by the Bureau of Reclamation Earth Laboratory for core hole 12/12–16H1 was so small that the data were not plotted. However, the sample depths, the electric log, graphic log, and lithologic description for this core hole are presented in plate 1*A* for comparison with the other three core holes and for use with tables 8 and 9.

The data for the three core holes for which samples were tested by the Hydrologic Laboratory are so arranged in plate 12 that the northernmost hole is located at the top of the figure and the southernmost hole is at the bottom. The total subsidence from 1932 to 1956 was 8 feet at core hole 12/12–16H1, 13 feet at 14/13–11D1, 7 feet at 16/15–34N1, and 12 feet at 19/17–22J1, 2.

Certain broad trends are evident from a study of plate 12 or the tables. The sediments cored were predominantly fine textured and primarily of clayey-silt or silty-clay types in the Shepard classification. According to the Unified Soil Classification plasticity chart, the sediments from all three core holes are classified as inorganic silt and silt-clay or micaceous and diatomaceous silt and clay. The samples had median diameters ranging from 0.001 to 0.520 mm, samples from the Corcoran Clay Member of the Tulare Formation being near the lower limit. The sorting coefficient ranged from 1.1 to 17.2 and averaged about 3, and the log quartile deviation ranged from about 0.061 to 1.236.

The permeability of samples from these core holes ranged from 0.00007 to 370 gpd per sq ft. The greatest percentage of samples had permeabilities ranging from 0.0001 to 0.001 gpd per sq ft. The ratio of horizontal to vertical permeability averaged 2.7. The Corcoran Clay Member had consistently low permeability.

The specific gravity ranged from 2.43 to 2.79 and averaged 2.69. Samples that were taken between depths of approximately 1,750 and 1,950 feet in core holes 16/15–34N1 and 19/17–22J1,2 had the lowest values.

The dry unit weight ranged from 1.10 to 1.95 g per cc (68.6 to 121.7 lb per cu ft), and the porosity from approximately 28 to 56 percent. The void ratio ranged from 0.38 to 1.25. Samples of the Corcoran Clay Member had the highest porosities and the lowest dry unit weights.

The liquid limits ranged from 25 to 82 and showed similarity between holes, except for a few cores taken from the thick section of the Corcoran Clay Member in core hole 14/13–11D1 for which the liquid limit ranged from 67 to 82. The plastic limit ranged from 18 to 59, and the shrinkage limit from 4 to 32. The plasticity indices ranged from 1 to 48, sediments from core hole 14/13–11D1 having a higher plastic range. Shrinkage indices ranged from 0 to 49. Volumetric shrinkage was similar for samples from all core holes although a general decrease was noted from north to south. Samples from core holes 14/13–11D1 and 19/17–22J1, 2 had a toughness index ranging from 0.1 to 3.6 and usually greater than 1. For samples from hole 16/15–34N1 the index was lower, ranging from 0.2 to 2.1, and usually less than 1. The Corcoran Clay Member had a toughness index close to 3.

The acid solubility ranged from 1 to 16 percent and averaged 5, 7, and 8 percent for samples from core holes 14/13–11D1, 16/15–34N1, and 19/17–22J1, 2, respectively. The gypsum content was 0 in selected samples tested from core holes 14/13–11D1 and 16/15–34N1 and less than 1 percent in samples taken at three depths between 1,800 and 1,960 feet in core hole 19/17–22J1, 2.

Consolidation-test curves show, in general, that the Corcoran Clay Member has a greater unit consolidation potential than any of the other sediments. Because of its low vertical permeability, however, the compaction of the Corcoran Clay Member has contributed very little to the total subsidence to date (Miller, 1961, p. B57).

The particle size and particle-size distribution have a dominant influence on several of the physical and hydrologic properties of unconsolidated sediments. Although more refined statistical measures could be utilized, a rough comparison of the effect of particle size and particle-size distribution can be achieved by grouping the samples by sediment class and deriving average values for the properties of particular interest. Accordingly, in table 10, the samples from the three core holes analyzed by the Hydrologic Laboratory have been grouped by sediment class (Shepard classification) and the range in, and average values for, the most pertinent properties have been listed. The sediment classes have been arranged, in general, from coarse to fine texture. For some of the sediment classes included, such as clayey sand, sandy silt, and silt, and for some of the properties listed for other classes, the number of tests is too small to compute a meaningful average. The data show that, in general, as the sediment class becomes finer, the permeability decreases and the liquid limit increases, but there does not seem to be any other consistent relation between other properties and the sediment class.

Another factor important in interpreting or applying the results of these tests is the effect, if any, of depth on the averages. For example, porosity and dry unit weight are affected by thickness of overburden. Therefore, for the three most prevalent sediment classes, sand-silt-clay, clayey silt, and silty clay, porosity and dry unit weight have been plotted against depth by sediment class (fig. 22). The decrease in porosity (increase in dry unit weight) is most noticeable for core hole 14/13–11D1 and least for core hole 19/17–22J1, 2. The relation of porosity to effective overburden load for sediments in all three areas is being appraised statistically by R. H. Meade (report on compaction of sediments, manuscript in review).

TULARE-WASCO AREA

The results of the tests for the most pertinent properties of samples analyzed for core holes 23/25–16N1 and 24/26–36A2 have been plotted on plate 13 in conjunction with the electric (self-potential and resistivity) logs for each core hole. Permeability, clay content, specific gravity, dry unit weight, porosity and void ratio, Atterberg limits, volumetric shrinkage, toughness index, acid solubility, and gypsum content are shown. Plate 13 thus serves as a graphic summary of most of the analyses made at the Hydrologic Laboratory on samples from the Tulare-Wasco area.

The electric logs shown in plate 13 were made immediately after the core holes were drilled. The Corcoran Clay Member of the Tulare Formation and the upper Pliocene claystone are indicated by uniformly low resistivity.

The sediments recovered were predominantly medium textured and primarily of silty-sand or sand-silt-clay types according to the Shepard classification system. According to the Unified Soil Classification plasticity chart, the sediments from both core holes are classified as organic or inorganic silt and silt-clay of low plasticity, inorganic clay of low to medium plasticity, and organic clay of medium to high plasticity. The samples had median diameters ranging from about 0.01 to 0.3 mm for core hole 23/25–16N1 and from about 0.003 to 1.4 for core hole 24/26–36A2,

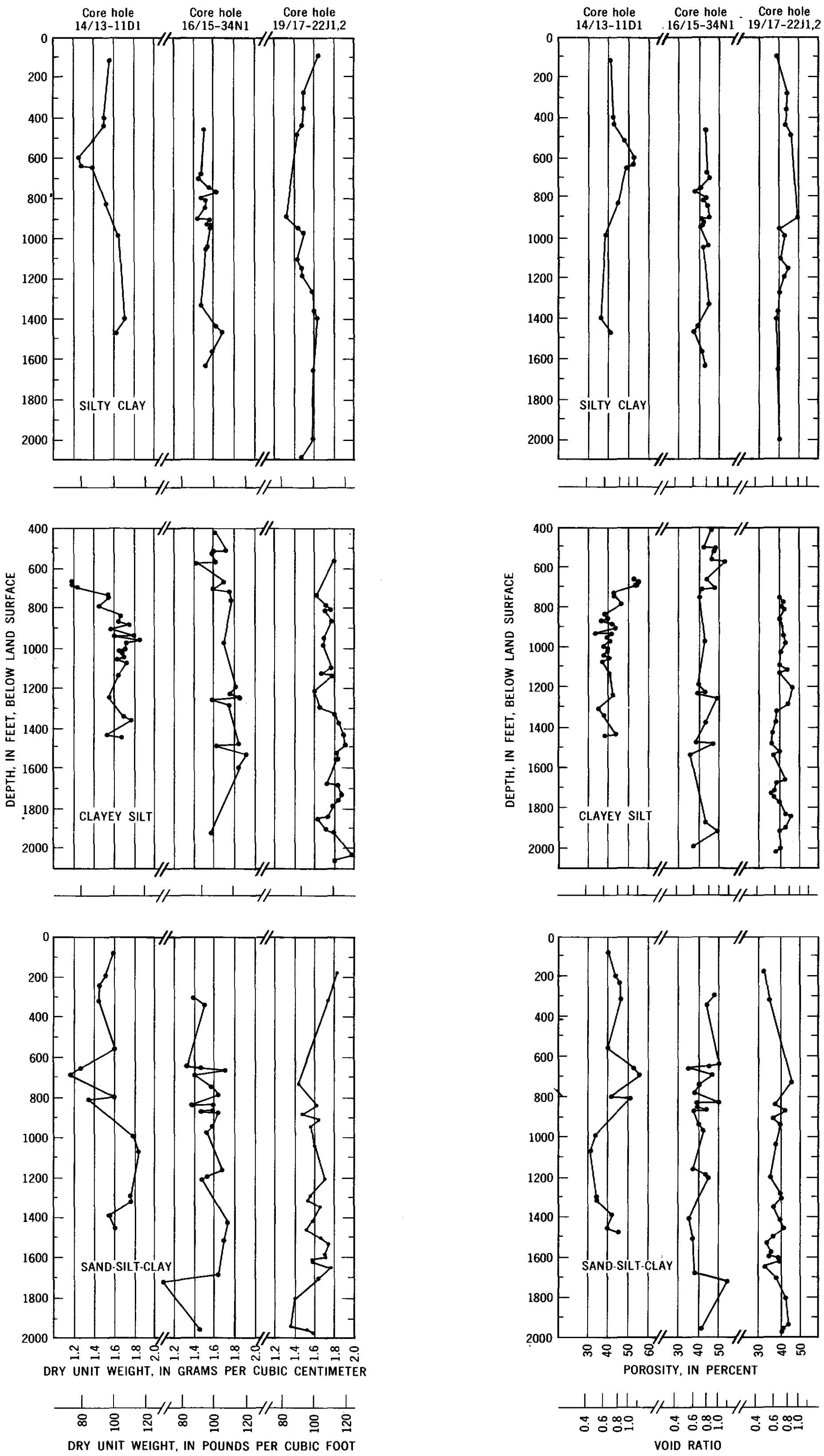

FIGURE 22.—Relation of dry unit weight, porosity, and void ratio to depth for principal sediment classes from core holes in Los Banos-Kettleman City area.

samples from the Corcoran Clay Member of the Tulare Formation being near the lower limit. The sorting coefficient ranged from 1.36 to 9.59 for core hole 23/25-16N1 and from 1.24 to 14.14 for core hole 24/26-36A2. The log quartile deviation ranged from about 0.095 to 1.150.

Vertical permeability for the 138 samples tested from these core holes ranged from 0.0002 to 650 gpd per sq ft; horizontal permeability for the 79 samples tested ranged from 0.0003 to 61. About 30 percent of the samples had permeabilities between 0.01 and 0.1 gpd per sq ft. For the 76 samples tested for both, the ratio of horizontal to vertical permeability averaged 1.4. The Corcoran Clay Member had consistently low permeability.

The specific gravity of solids ranged from 2.41 to 2.79, and averaged 2.70. The lowest values were for samples taken between depths of approximately 1,050 and 1,800 feet in core hole 24/26-36A2.

The dry unit weight ranged from 1.00 to 1.94 g per cc (62.4 to 121.1 lb per cu ft) and the porosity from approximately 28 to 61 percent. The void ratio ranged from 0.40 to 1.58. Samples of the Corcoran Clay Member and the upper Pliocene marine strata had the highest porosities and the lowest dry unit weights. The average porosity for core hole 24/26-36A2 increased gradually with depth down to 1,900 feet—from about 35 to 50 percent.

The liquid limits ranged from 22 to 107; for cores taken from the thin section of the Corcoran Clay Member in core hole 23/25-16N1 the liquid limit ranged from 56 to 63 and for the thick section of upper Pliocene claystone in core hole 24/26-36A2 it ranged from 62 to 106. The plastic limit ranged from 18 to 62, and the shrinkage limit from 5 to 44. The plasticity indices ranged from 3 to 59, sediments in core hole 24/26-36A2 having a higher plastic range. Shrinkage indices ranged from 0 to 46, the higher indices being for the claystone of core hole 24/26-36A2. Volumetric shrinkage was highest for samples from the upper Pliocene marine strata, intermediate for the continental deposits in core hole 23/25-16N1, and lowest for the continental deposits in core hole 24/26-36A2. Samples from the core holes had a toughness index ranging from 0.2 to 3.4, and usually 1 or greater. The Corcoran Clay Member and the upper Pliocene claystone had a toughness index generally greater than 2.

The acid-soluble material ranged from about 1 to 21 percent and averaged 6 percent for core hole 23/25-16N1 and 5.2 percent for core hole 24/26-36A2. The gypsum content was 0 in selected samples from core hole 23/25-16N1 and only 1 percent or slightly greater in selected samples taken between 1,700 and 1,900 feet in core hole 24/26-36A2.

The consolidation-test curves and the compression-index values show, in general, that the claystone of the upper Pliocene marine strata has a greater unit consolidation potential than any of the continental sediments. The unit consolidation potential for the Corcoran Clay Member is only about half as great as for the upper Pliocene marine strata, but it is much higher than that for the other continental deposits.

In table 10, the samples from the two core holes in the Tulare-Wasco area analyzed by the Hydrologic Laboratory have been grouped by sediment class (Shepard classification) and the range in, and average values for, the most pertinent properties have been listed. The sediment classes have been arranged, in general, from coarse to fine texture. For some of the sediment classes included—such as sandy clay, silty clay, and silt—and for some of the properties listed for other classes, the number of tests is too small to compute a meaningful average. The data show that, in general, the permeability decreases as the sediment class becomes finer. The liquid limit increases as the sediment class becomes finer, but there does not seem to be any other consistent relation between other properties and the sediment class.

For the three most prevalent sediment classes, sand-silt-clay, sandy silt, and silty sand, porosity and dry unit weight have been plotted against depth by sediment class (fig. 23). Normally, porosity is considered to decrease with depth and dry unit weight to increase. These plots show that the porosity increases with depth in core hole 24/26-36A2 in the depth range from 750 to 1,600 feet—even more clearly defined in the porosity plot for all samples in plate 13. Thus, the relation of porosity (and dry unit weight) to depth is markedly anomalous in 24/26-36A2.

In core hole 23/25-16N1 the porosity and dry unit weight do not change appreciably with depth, as shown in the porosity-depth plot for all samples in plate 13.

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The results of the tests for the most pertinent properties of samples analyzed for the two Santa Clara Valley core holes—6S/2W-24C7 and 7S/1E-16C6—have been plotted on plate 14 in conjunction with the electric (self-potential and resistivity) logs for each core hole. Permeability, clay content, dry unit weight, specific gravity, porosity and void ratio, Atterberg limits, volumetric shrinkage, toughness index, acid solubility, and gypsum content also are shown. Plate 14 thus serves as a graphic summary of most of the analyses made at the Hydrologic Laboratory on samples from the Santa Clara Valley.

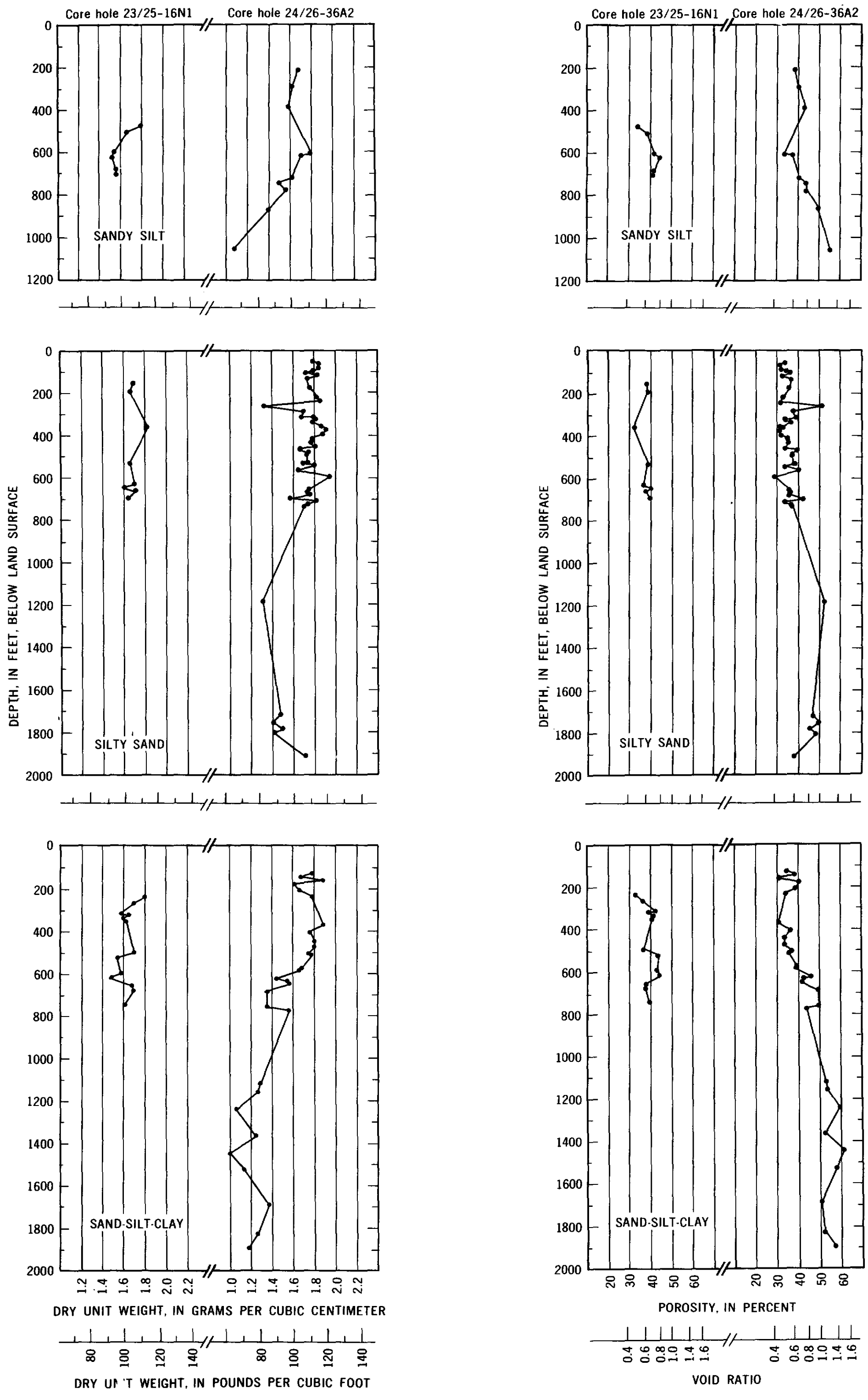

FIGURE 23.—Relation of dry unit weight, porosity, and void ratio to depth for principal sediment classes from core holes in Tulare-Wasco area.

The data for the two core holes are so arranged in plate 14 that the northern hole is located at the top of the figure and the southern hole is at the bottom. The total subsidence from 1934 to 1960 at each core-hole site was about 5 feet (fig. 6).

The graphic logs and generalized lithologic descriptions (pls. 1*G*, *H*) were prepared by J. H. Green from the geologist's logs made at the wells, supplemented by interpretation of the electric logs, especially in zones of poor core recovery. The electric logs were made immediately after the core holes were drilled.

Certain broad trends are evident from a study of plate 14 or the tables. The sediments recovered were predominantly fine textured and primarily of sand-silt-clay, clayey-silt, or silty-clay types, according to the Shepard classification system. According to the Unified Soil Classification plasticity chart (fig. 19), the sediments from both core holes are classified as predominately inorganic clay of low to medium plasticity, sandy clay, silty clay, lean clay, inorganic clay of high plasticity, and fat clay; one sample is organic clay of medium to high plasticity. The samples had median diameters ranging from about 0.001 to 0.2 mm for core hole 6S/2W–24C7 and from about 0.004 to 1.5 mm for core hole 7S/1E–16C6. The sorting coefficient ranged from 1.3 to 7.5 for samples from core hole 6S/2W–24C7 and from 1.3 to 7.7 for samples from core hole 7S/1E–16C6. The log quartile deviation ranged from about 0.127 to 0.876 for samples from core hole 6S/2W–24C7 and from 0.107 to 0.885 for samples from core hole 7S/1E–16C6.

Vertical permeability for 47 samples from these core holes ranged from 0.0001 to 0.03 gpd per sq ft, horizontal permeability for 65 samples ranged from 0.0002 to 190. The range of permeability for the greatest percentage of samples was from 0.01 to 0.0001 gpd per sq ft. For the 47 samples tested for both, the average horizontal permeability was seven times greater than the average vertical permeability.

The specific gravity of solids ranged from 2.67 to 2.80 and averaged 2.73.

The dry unit weight ranged from 1.34 to 1.91 g per cc (83.7 to 119.2 lb per cu ft) and the porosity from approximately 30 to 50 percent. The void ratio ranged from 0.43 to 1.01.

The liquid limits ranged from 24 to 68. The plastic limit ranged from 18 to 32, and the shrinkage limit from 8 to 20. The plasticity indices ranged from 3 to 38, sediments taken below 700 feet in core hole 6S/2W–24C7 having a higher plastic range. Shrinkage indices ranged from 1 to 18, the higher indices being for samples taken in the zones from 140 to 223 feet and 715 to 959 feet in core hole 6S/2W–24C7. Volumetric shrinkage ranged from 11 to 103 percent, the highest values being for samples taken below 700 feet in core hole 6S/2W–24C7. Samples from the core holes had a toughness index ranging from 0.9 to 5.7 and was usually 1 or greater.

The acid solubility ranged from about 7 to 19 percent and averaged 10.4 percent for samples from core hole 6S/2W–24C7 and 14.2 percent for samples from core hole 7S/1E–16C6. The gypsum content was 0 in both core holes for all samples analyzed for this property.

Consolidation-test curves show, in general, that the fine-textured sediments in the Santa Clara Valley have considerable consolidation potential.

In table 9, the samples from the two Santa Clara Valley core holes analyzed by the Hydrologic Laboratory have been grouped by sediment class (Shepard classification), and the range in, and average values for, the most pertinent properties have been listed. The sediment classes have been arranged, in general, from coarse to fine texture. For some of the sediment classes included, such as sand, silty sand, and sandy silt, and for some of the properties listed for other classes, the number of tests is too small to compute a meaningful average. If only one sample falls within a certain sediment class, that class is omitted from table 10. The data show that, in general, the permeability decreases as the sediment class becomes finer. The liquid limit tends to increase as the sediment class becomes finer. There does not seem to be any other consistent relation between the other properties and sediment class.

For the three most prevalent sediment classes, sand-silt-clay, clayey silt, and silty clay, porosity and dry unit weight have been plotted against depth by sediment class (fig. 24). No significant trend can be noticed in these plots.

TABULATED STATISTICAL DATA

Statistical data from the U.S. Geological Survey Hydrologic Laboratory and U.S. Bureau of Reclamation Earth Laboratory are tabulated in tables 5–10 following. Unless indicated otherwise analyses were made in the Hydrologic Laboratory.

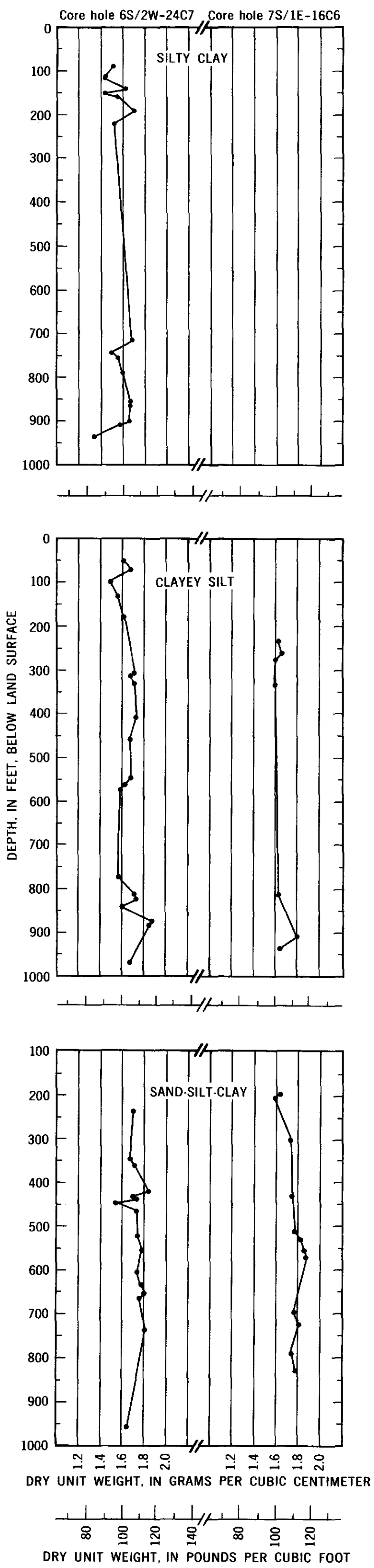

FIGURE 24.—Relation of dry unit weight, porosity, and void ratio to depth for principal sediment classes from core holes in Santa Clara valley.

TABLE 5.—*Physical and hydrologic properties of samples from core holes*

Hydrologic laboratory sample	Sample depth (feet)	Particle analysis, percentage of—					Median diameter, D_{50} (mm)	Geometrical quartile deviation (sorting coefficient), *So*	Log quartile deviation (log sorting coefficient), $\log_{10}$ *So*	Sediment class (Shepard system)	Specific gravity of solids	Dry unit weight		Total porosity (percent)	Void ratio	Coefficient of permeability (gp per sq ft at 60°F)	
		Gravel	Sand	Silt	Clay <0.004 mm	Clay <0.002 mm						G per cc	Lb per cu ft			Vertical	Horizontal
Core hole 14/13–11D1																	
57CAL1	77.0– 77.5		24.8	49.5	25.7	18	0.024	4.04	0.606	Sand-silt-clay	2.66	1.60	99.8	39.9	0.66		
2	110.5– 111.0		10.7	37.3	52.0	44	.0034	[1]	[1]	Silty clay	2.66	1.56	97.3	41.4	.71	0.01	0.03
3	153.0– 153.5		87.1	3.7	9.2	9	.19	1.46	.164	Sand	2.67	1.37	85.5	48.7	.95	360	
4	191.5– 192.0		29.0	46.8	24.2	20	.028	3.92	.593	Sand-silt-clay	2.70	1.52	94.8	43.7	.78	.2	.2
5a	232.5– 233.0		21.6	30.4	48.0	39	.0045	[1]	[1]	do	2.68	1.47	91.7	45.1	.82	2	
5b	232.5– 233.0		61.6	18.9	19.5	16	.092	3.16	.500	Clayey sand	2.64	1.64	102.3	37.9	.61	4	
6	277.1– 277.6	1.3	89.0	1.9	7.8	7	.25	1.59	.201	Sand	2.68	1.52	94.8	43.3	.76	270	
7	314.0– 314.5		22.3	51.0	26.7	22	.019	4.12	.615	Sand-silt-clay	2.70	1.46	91.1	45.9	.85	.6	
8	353.0– 353.5		47.0	34.3	18.7	16	.060	3.37	.528	Silty sand	2.66	1.54	96.1	42.1	.73	2	10
9	398.0– 398.5		.6	33.4	66.0	56	.0010	[1]	[1]	Silty clay	2.62	1.51	94.2	42.4	.74	.0007	.002
10	432.0– 432.5		7.0	31.2	61.8	50	.0020	[1]	[1]	do	2.64	1.51	94.2	42.8	.75	.00007	
11	471.5– 472.0		47.3	40.0	12.7	11	.059	2.00	.301	Silty sand	2.69	1.63	101.7	39.4	.65	.7	
12	510.3– 510.8	.6	8.9	19.5	71.0	61	[1]	[1]	[1]	Silty clay	2.64	1.39	86.7	47.3	.90	.0002	
13	552.5– 553.0		22.0	33.0	45.0	36	.0062	[1]	[1]	Sand-silt-clay	2.68	1.63	101.7	39.2	.65	.0001	
14	594.0– 594.5		8.8	19.7	71.5	59	.0012	[1]	[1]	Silty clay	2.65	1.25	78.0	52.8	1.12		
15	631.0– 631.5		19.2	36.3	44.5	34	.0057	5.68	.754	do	2.67	1.28	79.9	52.1	1.09	.005	
16	646.6– 647.1		1.0	47.5	51.5	40	.0036	[1]	[1]	do	2.72	1.39	86.7	48.9	.96		
17	652.3– 652.8		23.3	40.1	36.6	26	.0096	5.20	.716	Sand-silt-clay	2.70	1.28	79.9	52.6	1.11	.004	
18	662.1– 662.6		.8	56.2	43.0	30	.0058	3.26	.513	Clayey silt	2.68	1.18	73.6	56.2	1.28		
19	674.0– 674.5		1.0	61.5	37.5	25	.0068	2.61	.417	do	2.63	1.18	73.6	55.1	1.23		
20	682.5– 683.0		26.8	45.2	28.0	20	.013	5.06	.704	Sand-silt-clay	2.65	1.17	73.0	55.8	1.26	.008	
21	697.0– 697.5		.6	68.4	31.0	20	.0082	2.51	.400	Clayey silt	2.67	1.23	76.8	54.1	1.18		
22	707.0– 707.5		80.2	16.1	3.7	3	.26	1.68	.225	Sand	2.67	1.38	86.1	48.3	.94		
23	713.0– 713.5		.2	76.8	23.0	14	.010	2.00	.301	Silt	2.68	1.33	83.0	50.4	1.02		
24	721.5– 722.0		4.0	86.0	10.0	7	.012	1.48	.170	do	2.74	1.31	81.7	52.2	1.09	.002	
25	731.0– 731.5		1.6	59.4	39.0	26	.0067	2.99	.476	Clayey silt	2.72	1.55	96.7	42.8	.75		
26	743.0– 743.5		6.0	70.0	24.0	17	.013	2.57	.410	do	2.72	1.55	96.7	42.9	.75		
27	757.0– 757.5		50.2	38.1	11.7	8	.062	3.06	.486	Silty sand	2.73	1.57	98.0	42.7	.75	.2	
28	764.9– 765.4		77.4	13.9	8.7	7	.34	2.42	.384	Sand	2.71	1.75	109.2	35.4	.55	4	
29	773.0– 773.5		38.2	48.0	13.8	11	.050	2.22	.346	Sandy silt	2.75	1.57	98.0	42.9	.75	2	2
30	784.5– 785.0		16.2	61.8	22.0	14	.020	2.94	.468	Clayey silt	2.72	1.45	90.5	46.7	.88		
31	791.0– 791.5		26.0	44.2	29.8	26	.026	5.89	.770	Sand-silt-clay	2.76	1.62	101.1	41.3	.70	.0006	
32	802.0– 802.5		35.4	43.0	21.6	16	.040	3.56	.551	do	2.75	1.35	84.2	50.9	.04		
33	812.0– 812.5		80.2	11.8	8.0	8	.25	2.36	.373	Sand	2.67	1.57	98.0	41.2	.70	.2	
34	813 – 821	.3	91.7	1.0	7.0	7	.21	1.27	.104	do	2.69	1.47	91.7	45.4	.83	2	
35	826.0– 826.5		1.0	44.0	55.0	38	.0033	2.72	.435	Silty clay	2.74	1.53	95.5	44.2	.80	.0001	
36	831.5– 832.0		12.2	61.3	26.5	20	.020	3.46	.539	Clayey silt	2.74	1.68	104.8	38.7	.63	.0006	
37	843.5– 844.0		69.0	20.0	11.0	9	.12	1.91	.281	Silty sand	2.73	1.48	92.4	45.8	.85	.007	
38	853.0– 853.5		83.2	10.6	6.2	5	.12	1.31	.117	Sand	2.74	1.49	93.0	45.6	.84	33	
39	860.0– 860.5		2.4	70.4	27.2	21	.145	3.01	.479	Clayey silt	2.74	1.62	103.0	39.8	.66		
40	867.0– 867.5		54.2	27.8	18.0	16	.010	[1]	[1]	Silty sand	2.72	1.64	102.3	39.7	.66	.0005	
41	871.0– 871.5		70.0	19.8	10.2	9	.099	1.73	.238	do	2.71	1.44	89.9	46.9	.88	22	
42	877.0– 877.5		4.5	49.5	46.0	34	.0050	4.24	.627	Clayey silt	2.77	1.76	109.8	36.5	.57	.0007	
43	887.5– 888.0		.8	49.7	49.5	37	.0041	3.16	.500	Silty clay	2.72	1.59	99.2	41.5	.71		
44	901.0– 901.5		8.6	61.2	30.2	19	.011	2.97	.473	Clayey silt	2.76	1.57	98.0	43.1	.76	.001	
45	911.5– 912.0		48.4	34.6	17.0	16	.056	3.52	.547	Silty sand	2.71						
46	917.2– 917.7		80.0	13.0	7.0	7	.22	1.58	.199	Sand	2.68					3	
47	932.0– 932.5		8.0	47.3	44.7	37	.0064	[1]	[1]	Clayey silt	2.70	1.80	112.3	33.2	.50		
48	936.5– 937.0		12.6	65.4	22.0	14	.016	2.60	.415	do	2.74	1.61	100.5	41.2	.70	.001	
49	951.0– 951.5		4.6	54.4	41.0	33	.0082	5.10	.708	do	2.74	1.87	116.7	31.8	.47		
50	957.5– 958.0		39.4	47.4	13.2	11	.044	2.34	.369	Sandy silt	2.72	1.62	101.1	40.4	.68	.01	
51	968.5– 969.0		6.0	68.8	25.2	20	.016	2.86	.456	Clayey silt	2.75	1.63	101.7	40.7	.69		
52	984.0– 984.5		2.2	23.1	74.7	58	.0015	[1]	[1]	Silty clay	2.67	1.65	103.0	38.2	.62		
53	987.6– 988.0		27.2	43.0	29.8	26	.026	6.57	.818	Sand-silt-clay	2.72	1.80	112.3	33.8	.51		
54	1,000.5–1,001.0		4.2	54.8	41.0	32	.0068	4.42	.645	Clayey silt	2.75	1.72	107.3	37.5	.60		
55	1,005.1–1,005.6		2.8	65.2	32.0	22	.0090	2.79	.446	do	2.73	1.65	103.0	39.8	.66		
56	1,010.8–1,021.3		11.4	65.8	22.8	16	.024	2.83	.452	do	2.79	1.69	105.5	39.4	.65		
57	1,033.8–1,034.2		52.0	32.0	16.0	13	.070	4.39	.642	Silty sand	2.72	1.58	98.6	41.9	.72	.1	
58	1,039.5–1,040.0		1.8	52.2	46.0	36	.0048	[1]	[1]	Clayey silt	2.76	1.71	106.7	38.0	.61		
59	1,051.5–1,052.0		12.4	67.6	20.0	15	.025	2.51	.400	do	2.78	1.64	102.3	41.0	.70		
60	1,063.5–1,064.0		35.6	40.4	24.0	20	.026	6.14	.788	Sand-silt-clay	2.69	1.86	116.1	30.9	.45	.0001	
61	1,070.8–1,071.3		19.5	54.5	26.0	21	.020	3.67	.565	Clayey silt	2.75	1.73	108.0	37.1	.59		
62	1,075.0–1,075.5		55.6	27.2	17.2	14	.079	3.02	.480	Silty sand	2.75	1.77	110.4	35.6	.55	.004	
63	1,088.5–1,089.0		81.6	9.4	9.0	8	.18	1.67	.223	Sand	2.73	1.62	101.1	40.7	.69	42	
64	1,092.0–1,092.5		35.4	49.6	15.0	12	.042	3.16	.500	Sandy silt	2.75	1.78	111.1	35.3	.55	.04	
65	1,104.6–1,105.1		38.0	44.0	18.0	15	.037	1.15	.061	do	2.68	1.69	105.5	36.9	.59	.0006	
66	1,113.5–1,114.0		91.2	1.6	7.2	7	.23	1.23	.090	Sand	2.70	1.58	98.6	41.5	.71	174	
67	1,123.5–1,124.0		84.2	7.8	8.0	7	.16	1.38	.140	do	2.74	1.57	98.0	42.7	.75	50	

See footnotes at end of table.

TABLE 5.—*Physical and hydrologic properties of samples from core holes*—Continued

Hydrologic laboratory sample	Sample depth (feet)	Particle analysis, percentage of—					Median diameter, D_{50} (mm)	Geometrical quartile deviation (sorting coefficient), *So*	Log quartile deviation (log sorting coefficient), $\log_{10} So$	Sediment class (Shepard system)	Specific gravity of solids	Dry unit weight		Total porosity (percent)	Void ratio	Coefficient of permeability (gpd per sq ft at 60°F)	
		Gravel	Sand	Silt	Clay <0.004 mm	Clay <0.002 mm						G per cc	Lb per cu ft			Vertical	Horizontal
Core hole 1413-11D1—Continued																	
57CAL68	1,133.0–1,133.5		5.4	62.8	31.8	24	0.010	3.16	0.500	Clayey silt	2.77	1.65	103.0	40.3	0.68		
69	1,160 –1,166	2.1	83.4	6.5	8.0	7	.25	1.50	.176	Sand	2.77	1.61	100.5	41.9	.72	38	
70	1,174.0–1,174.5	4.8	83.6	4.1	7.5	7	.52	1.68	.225	do	2.71	1.60	99.8	41.0	.70	40	
71	1,207.5–1,208.0	28.9	58.0	6.1	7.0	6	.52	3.26	.513	do	2.73	1.56	97.3	42.9	.75	39	
72	1,219.0–1,219.5	4.4	76.1	9.7	9.8	9	.25	1.81	.258	do	2.75	1.57	98.0	42.9	.75	1	
73	1,221.2–1,221.7	6.7	72.4	6.7	14.2	12	.35	2.43	.386	do	2.70	1.50	93.6	44.4	.80	2	
74	1,232.0–1,232.5	11.6	75.3	8.9	4.2	3	.37	2.03	.308	do	2.69	1.50	93.6	44.2	.79	45	
75	1,242.0–1,242.5		14.6	67.4	18.0	13	.021	2.37	.375	Clayey silt	2.69	1.56	97.3	42.0	.72		
76	1,252+–1,252.5		73.8	17.2	9.0	7	.12	1.77	.248	Silty sand	2.72	1.60	99.8	41.2	.70	2	
77	1,257.0–1,257.5	.1	76.3	12.6	11.0	11	.16	1.85	.267	Sand	2.71	1.40	87.4	48.3	.93	10	
78	1,269.5–1,270.0		53.6	22.2	24.2	24	.082	6.38	.805	Sand-silt-clay	2.70	1.84	114.8	31.9	.47	.0002	
79	1,271.0–1,271.5		71.4	12.1	16.5	14	.185	2.83	.452	Clayey sand	2.69	1.70	106.1	36.8	.58	.9	
80	1,284.0–1,284.5		86.4	5.6	8.0	7	.017	1.41	.149	Sand	2.72	1.63	101.7	40.1	.67	27	
81	1,293.0–1,293.5		53.6	25.6	20.8	18	.082	4.68	.670	Sand-silt-clay	2.71	1.78	111.1	34.3	.52	.0004	
82	1,300.0–1,300.5		62.2	16.8	21.0	18	.12	4.37	.640	Clayey sand	2.72	1.93	120.4	29.0	.41	.0001	
83	1,312.0–1,312.5		25.4	49.6	25.0	20	.022	4.25	.628	Sand-silt-clay	2.74	1.79	111.7	34.7	.53	.008	
84	1,319.4–1,319.9		62.8	20.2	17.0	16	.18	4.26	.629	Silty sand	2.72	1.94	121.1	28.7	.40	.004	
85	1,330.8–1,331.3		65.0	15.8	19.2	17	.12	3.82	.582	Clayey sand	2.71	1.95	121.7	28.0	.39	.004	
86	1,339.5–1,340.0		18.2	60.6	21.2	16	.022	2.97	.473	Clayey silt	2.71	1.70	106.1	37.3	.60	.01	
87	1,348.0–1,348.5	9.0	79.7	4.3	7.0	7	.47	1.88	.274	Sand	2.74	1.39	86.7	49.3	.97	13	
88	1,357.0–1,357.5		9.0	48.0	43.0	32	.0058	4.03	.605	Clayey silt	2.73	1.78	111.1	35.0	.54		
89	1,362.5–1,363.0		29.0	48.0	23.0	19	.030	3.67	.565	Sand-silt-clay	2.73						
90	1,373.4–1,373.9		51.0	28.0	21.0	17	.065	4.70	.672	do	2.70	1.46	91.1	45.9	.85		
91	1,385.0–1,385.5		21.4	53.9	24.7	16	.016	3.28	.516	do	2.69	1.56	97.3	42.0	.72		
92	1,397.0–1,397.5		12.8	25.2	62.0	47	.0023	(1)	(1)	Silty clay	2.69	1.72	107.3	36.1	.56		
93	1,406.0–1,406.5		60.2	20.3	19.5	16	.11	4.83	.684	Silty sand	2.72	1.81	112.9	33.5	.50	.006	
94	1,415.0–1,415.5		58.4	26.1	15.5	14	.090	3.13	.496	do	2.70	1.48	92.4	45.2	.83	.07	
95	1,423.7–1,424.2		62.4	22.6	15.0	13	.086	2.55	.407	do	2.74	1.63	101.7	40.5	.68		
96	1,432.5–1,433.0		3.8	61.4	34.8	27	.0090	3.61	.558	Clayey silt	2.69	1.53	95.5	43.3	.76		
97	1,446.0–1,446.5		.4	54.4	45.2	35	.0048	(1)	(1)	do	2.72	1.69	105.5	38.1	.62		
98	1,454.5–1,455.0		27.4	48.1	24.5	19	.020	4.15	.618	Sand-silt-clay	2.70	1.63	101.7	39.6	.66		
99	1,465.0–1,465.5		3.8	33.0	63.2	47	.0023	(1)	(1)	Silty clay	2.76	1.63	101.7	40.9	.69		
100	1,474.0–1,474.5		69.4	20.4	10.2	9	.12	1.85	.267	Silty sand	2.73	1.54	96.1	43.6	.77	4	
101	1,481.0–1,481.5	1.7	51.5	31.6	15.2	10	.074	4.56	.659	do	2.73	1.63	101.7	40.3	.67	1	
102	1,487.0–1,487.5		82.8	8.7	8.5	7	.22	1.49	.173	Sand	2.74	1.51	94.2	44.9	.82	8	
103	1,494.5–1,495.0		55.4	30.9	13.7	11	.089	3.52	.547	Silty sand	2.72	1.42	88.6	47.8	.92	18	
Core hole 16/15-34N1																	
58CAL1	250.0– 250.5	2.3	64.5	20.7	12.5	11	0.12	2.47	0.393	Silty sand	2.69	1.59	99.2	40.9	.69	0.8	
2	298.2– 298.7	.3	22.8	49.6	27.3	22	.017	4.36	.639	Sand-silt-clay	2.68	1.40	87.4	47.8	.92	.04	
3	332.4– 332.9		26.6	37.7	35.7	28	.010	7.26	.861	do	2.68	1.52	94.8	43.3	.76	.1	
4	371.7– 372.1		72.4	13.7	13.9	12	.14	2.44	.387	Clayey sand	2.66	1.51	94.2	43.2	.76	1	
5	418.5– 419.1		15.2	48.9	35.9	22	.0085	4.01	.603	Clayey silt	2.66	1.42	88.6	46.6	.87	.003	
6	454.3– 454.8		18.6	33.4	48.0	42	.0050	(1)	(1)	Silty clay	2.66	1.50	93.6	43.6	.77	.0003	
7	496.4– 496.9		71.8	14.9	13.3	12	.15	2.16	.334	Silty sand	2.70	1.48	92.4	45.2	.83	3	
8	507.4– 507.9	1.1	9.5	51.1	38.3	29	.0075	3.96	.598	Clayey silt	2.68	1.53	95.5	42.9	.75	.002	
9	509.5– 510.0		4.6	67.7	27.7	20	.0096	2.58	.412	do	2.71	1.40	87.4	48.4	.94	.006	.004
10	525.9– 526.3		2.0	58.0	40.0	27	.0057	2.58	.412	do	2.65	1.38	86.1	47.9	.92	.002	.004
11	532.4– 532.9		38.2	31.8	30.0	24	.028	7.66	.884	Sand-silt-clay	2.68					.0003	.03
12	552.8– 553.2		19.4	48.7	31.9	23	.016	4.42	.645	Clayey silt	2.65					.004	.004
13	563.7– 564.2		16.2	47.8	36.0	25	.0092	4.36	.639	do	2.63	1.42	88.6	46.2	.86	.002	.003
14	570.7– 571.2		8.0	47.0	45.0	35	.0054	4.85	.686	do	2.68	1.23	76.8	54.1	1.18	.002	.0004
15	580.5– 581.0		91.0	6.3	2.7	2	.20	1.35	.130	Sand	2.70	1.49	93.0	45.0	.82	13	52
16	591.7– 592.2		96.8	2.8	.4		.26	1.24	.093	do	2.70	1.47	91.7	45.8	.85	260	270
17	601.7– 602.2		93.8	5.2	1.0	1	.30	1.46	.164	do	2.69	1.58	98.6	41.5	.71	53	55
18	622.3– 622.8		84.6	10.5	4.9	4	.18	1.61	.207	do	2.70	1.47	91.7	45.6	.84	12	45
19	636.4– 636.9		25.8	50.2	24.0	16	.021	3.86	.587	Sand-silt-clay	2.68	1.34	83.6	50.6	1.03		
20	643.2– 643.7		29.6	48.5	21.9	18	.028	3.35	.525	do	2.69	1.48	92.4	45.0	.82	.01	.05
21	652.6– 653.1		40.0	33.8	26.2	21	.037	6.42	.808	do	2.68	1.72	107.3	36.0	.56	.01	
22	666.0– 666.5		4.0	48.5	47.5	36	.0044	3.13	.496	Clayey silt	2.68	1.51	94.2	43.9	.78	.0005	.002
23	673.6– 674.1		3.8	24.4	71.8	57	.0015	(1)	(1)	Silty clay	2.64	1.48	92.4	44.2	1.79	.002	.0002
24	683.7– 684.2		20.4	56.6	23.0	19	.030	3.11	.493	Sand-silt-clay	2.67	1.41	88.0	47.4	.90	.06	.1
25	696.6– 697.1		2.4	34.0	63.6	50	.0020	(1)	(1)	Silty clay	2.66	1.45	90.5	45.5	.83	.001	.004
26	701.8– 702.4		11.6	60.4	28.0	22	.015	3.37	.528	Clayey silt	2.69	1.40	87.4	48.0	.92	.02	.02
27	713.4– 713.9		4.4	51.1	44.5	26	.0050	2.65	.423	do	2.65	1.56	97.3	41.2	.70	.0002	.0007
28	721.3– 721.8		46.8	35.2	18.0	17	.056	3.30	.519	Silty sand	2.67	1.55	96.7	42.2	.73	.6	

29	732.0- 732.6		22.4	53.6	24.0	23	.021	3.22	.508	Sand-silt-clay	2.67	1.59	99.2	40.6	.68	.01	.03
30	745.3- 745.9		10.0	28.2	61.8	54		[1]	[1]	Silty clay	2.63	1.56	97.3	40.7	.69	.0003	
31	753.8- 754.3		8.4	61.1	30.5	23	.12	3.23	.509	Clayey silt	2.68	1.59	99.2	40.9	.69	.003	.004
32	762.4- 762.9		18.6	34.9	46.5	36	.0050	5.83	.766	Silty clay	2.64					.005	
33	773.3- 773.8		35.4	40.4	24.2	19	.033	4.62	.665	Sand-silt-clay	2.66	1.66	103.6	37.8	.61	.03	.05
34	785.0- 785.5	.5	82.6	9.5	7.4	7	.18	1.53	.185	Sand	2.69	1.52	94.8	43.5	.77	69	62
35	795.0- 795.5		9.6	30.6	59.8	50	.0021	[1]	[1]	Silty clay	2.62	1.47	91.7	43.9	.78	.0002	.0002
36	806.1- 806.6		7.2	35.8	57.0	44	.0029	[1]	[1]	do	2.64	1.52	94.8	42.6	.74	.0001	.02
37	810.5- 811.0		33.4	48.6	18.0	16	.042	2.73	.436	Sandy silt	2.68	1.57	98.0	41.6	.71	.01	.03
38	822.1- 822.6		20.4	27.4	52.2	44	.0032	[1]	[1]	Sand-silt-clay	2.73	1.38	86.1	49.7	.99	.0007	.001
39	827.8- 828.2		26.2	31.8	42.0	34	.0082	[1]	[1]	do	2.65					.0007	.06
40	837.7- 838.2		4.6	43.2	52.2	39	.0036	3.54	.549	Silty clay	2.72	1.52	94.8	44.1	.79	.0002	.0002
41	852.2- 852.7		49.8	28.0	22.2	18	.062	4.85	.686	Sand-silt-clay	2.65	1.60	99.8	39.8	.661	.01	.01
42	860.1- 860.6		26.0	46.5	27.5	22	.016	4.62	.665	do	2.70	1.49	93.0	44.8	.81	.05	
43	866.7- 867.3		53.4	21.6	25.0	24	.070	5.45	.736	do	2.66	1.66	103.6	37.8	.61	.01	.05
44	876.6- 877.1		79.0	12.0	9.0	8	.190	1.75	.243	Sand	2.68	1.56	97.3	41.8	.72	11	48
45	891.6- 892.1		18.6	34.4	47.0	38	.0054	[1]	[1]	Silty clay	2.62	1.44	89.9	45.1	.82	.006	
46	901.2- 901.7		6.4	38.6	55.0	42	.0031	[1]	[1]	do	2.63	1.56	97.3	40.7	.69	.0007	
47	910.6- 911.1	.4	73.5	15.1	11.0	11	.14	1.87	.272	Silty sand	2.68	1.55	96.7	42.4	.74	5	19
48	922.6- 923.1		12.4	38.2	49.4	38	.0042	[1]	[1]	do	2.65	1.54	96.1	41.9	.72	.0002	
49	931.2- 931.7		24.2	44.3	31.5	25	.010	5.48	.739	Sand-silt-clay	2.67	1.60	99.8	40.1	.67	.009	.04
50	940.6- 941.1		12.0	44.0	44.0	36	.0064	[1]	[1]	Silty clay	2.65	1.57	98.0	40.8	.69	.0004	.004
51	946.3- 946.8		.8	33.3	65.9	49	.0021	[1]	[1]	do	2.63	1.57	98.0	40.5	.68	.002	.005
52	963.7- 964.2		28.2	49.7	22.1	17	.028	3.50	.544	Sand-silt-clay	2.68	1.54	96.1	42.6	.74	.003	.005
53	971.5- 972.0		2.5	64.2	33.3	24	.0086	2.94	.468	Clayey silt	2.65	1.50	93.6	43.4	.77	.003	
54	980.6- 981.1		21.0	70.2	8.8	6	.038	1.73	.238	Sandy silt	2.75	1.59	99.2	42.2	.73	.007	
55	998.4- 998.9	.1	95.5	3.9	.5		.48	1.49	.173	Sand	2.70	1.52	94.8	43.7	.78	370	
56	1,012.2-1,012.7	.1	87.9	9.0	3.0	3	.21	1.62	.210	do	2.70	1.54	96.1	43.0	.75	163	
57	1,037.2-1,037.7		5.0	44.1	50.9	36	.0038	[1]	[1]	Silty clay	2.76	1.54	96.1	44.2	.79	.003	.005
58	1,042.8-1,043.3		8.0	38.0	54.0	42	.0032	[1]	[1]	do	2.67	1.53	95.5	42.7	.75	.005	
59	1,154.0-1,154.5		24.2	53.8	22.0	14	.020	3.49	.543	Sand-silt-clay	2.72	1.70	106.1	37.5	.60	.003	
60	1,181.2-1,181.7		20.2	20.8	59.0	52	.0016	[1]	[1]	Silty clay	2.74	1.55	96.7	43.4	.77	.006	.009
61	1,189.5-1,190.0		11.4	57.3	31.3	26	.018	4.85	.686	Clayey silt	2.71	1.63	101.7	39.9	.66	.001	.001
62	1,202.5-1,203.0		22.0	23.3	54.7	45	.0028	[1]	[1]	Sand-silt-clay	2.71	1.49	93.0	45.0	.82	.002	
63	1,225.0-1,225.5		12.6	74.4	13.0	10	.023	2.11	.324	Clayey silt	2.73	1.55	96.7	43.4	.77		.004
64	1,238.1-1,238.6		3.8	58.4	37.8	25	.0068	2.78	.444	do	2.75	1.66	103.6	39.6	.66	.0006	
65	1,240.5-1,241.0		30.2	58.8	11.0	8	.044	1.97	.294	Sandy silt	2.74	1.59	99.2	42.0	.72	.07	
66	1,254.9-1,255.4		4.4	81.4	14.2	11	.015	1.79	.253	Silt	2.73	1.38	86.1	49.5	.98	.1	
67	1,280.2-1,280.7		3.0	69.7	27.3	18	.014	2.95	.470	Clayey silt	2.75	1.55	96.7	43.6	.77	.001	
68	1,325.5-1,326.0		8.6	43.4	48.0	34	.0044	3.33	.522	Silty clay	2.70	1.48	92.4	45.2	.82	.0002	
69	1,331.9-1,332.4	.1	78.1	15.7	6.1	6	.10	1.36	.134	Sand	2.71	1.58	98.6	41.9	.72	10	26
70	1,351.4-1,351.9		25.4	56.9	17.7	16	.030	2.43	.386	Sandy silt	2.73	1.44	89.9	47.3	.90	.001	
71	1,363.6-1,364.1		75.4	21.9	2.7	2	.10	1.60	.204	Sand	2.70	1.50	93.6	44.6	.81	81	
72	1,371.5-1,372.0		43.8	51.9	4.3	3	.056	1.73	.238	Sandy silt	2.70	1.65	103.0	39.9	.66	.5	.3
73	1,391.7-1,392.2		39.4	46.1	14.5	8	.038	3.54	.549	do	2.70	1.51	94.2	40.6	.68	.003	.3
74	1,401.8-1,402.3		71.0	19.6	9.4	8	.14	2.17	.336	Silty sand	2.68	1.71	106.7	36.2	.57	3	
75	1,413.8-1,414.3	.6	48.3	25.7	25.4	24	.062	7.37	.867	Sand-silt-clay	2.71	1.75	109.2	35.5	.55	.002	.002
76	1,421.5-1,422.0		51.2	32.2	16.6	13	.066	3.16	.500	Silty sand	2.72	1.73	108.0	36.3	.57	.008	
77	1,432.0-1,432.5		15.4	37.8	46.8	36	.0049	5.05	.703	Silty clay	2.70	1.63	101.7	39.7	.66	.001	.002
78	1,458.9-1,459.4			34.5	65.5	42	.0026	2.04	.310	do	2.70	1.69	105.5	37.4	.60		
79	1,476.0-1,476.5		7.6	54.4	38.0	29	.0088	4.40	.643	Clayey silt	2.69	1.65	103.0	38.7	.63	.0002	
80	1,482.7-1,483.2		3.6	67.9	28.5	21	.012	3.11	.493	do	2.74	1.44	89.9	47.5	.91	.003	
81	1,495.9-1,496.4		45.4	35.1	19.5	17	.052	3.67	.565	Silty sand	2.69	1.81	112.9	32.7	.49	.0008	.006
82	1,506.7-1,507.2		48.2	35.7	16.1	13	.059	2.96	.471	do	2.72	1.66	103.6	39.2	.65	.01	.08
83	1,507.2-1,507.7		30.8	32.7	36.5	30	.014	9.74	.989	Sand-silt-clay	2.71	1.71	106.7	37.1	.59	.0004	
84	1,526.0-1,526.5		12.8	55.5	31.7	24	.010	3.54	.549	Silty clay	2.69	1.73	108.0	35.9	.56	.0002	.0002
85	1,550.5-1,551.0		90.4	6.0	3.6	3	.24	1.48	.170	Sand	2.71	1.52	94.8	44.0	.79	14	160
86	1,558.1-1,558.6		4.2	39.3	56.5	38	.0031	2.72	.435	Silty clay	2.70	1.59	99.2	41.1	.70	.002	
87	1,566.0-1,566.5		51.8	29.2	19.0	18	.066	3.46	.539	Silty sand	2.67	1.71	106.7	35.8	.56		
88	1,589.3-1,589.8		.2	69.5	30.3	23	.0050	1.75	.243	Clayey silt	2.66	1.66	103.6	37.6	.60		
89	1,631.2-1,631.7		5.4	41.6	53.0	32	.0037	2.85	.455	Silty clay	2.69	1.52	94.8	43.5	.77	.004	
90	1,676.6-1,677.1		21.0	42.0	37.0	30	.016	6.88	.838	Sand-silt-clay	2.70	1.66	103.6	38.7	.63	.002	.007
91	1,714.1-1,714.5		29.6	37.7	32.7	27	.020	7.46	.873	do	2.43	1.10	68.6	54.7	1.21	.0003	
92	1,752.0-1,752.5		31.8	18.3	49.9	43	.0042	[1]	[1]	Sandy clay	2.69	1.79	111.7	33.5	.50	.0004	
93	1,792.7-1,793.2		50.0	30.7	19.3	15	.062	3.63	.560	Silty sand	2.70	1.71	106.7	36.9	.59	.001	.007
94	1,837.6-1,838.1		46.8	39.8	13.4	10	.059	2.21	.344	do	2.72	1.60	99.8	41.2	.70	.3	.8
95	1,871.3-1,871.8		.6	71.8	27.6	18	.0096	2.30	.362	Clayey silt	2.71	1.53	95.5	43.5	.77	.0005	.004
96	1,916.9-1,917.4		1.4	60.3	38.3	28	.0070	2.87	.458	do	2.71	1.38	86.1	49.1	.97	.001	
97	1,953.0-1,953.5		27.2	27.8	45.0	38	.0069	[1]	[1]	Sand-silt-clay	2.50	1.46	91.1	41.6	.71	.0005	
98	1,990.0-1,990.5		52.6	16.0	31.4	27	.088	17.2	1.236	Clayey sand	2.68	1.67	104.2	37.7	.61	.001	

Core hole 19/17-22J1, 2

57CAL104	89.6- 90.0		5.7	35.6	58.7	45	0.0026	[1]	[1]	Silty clay	2.67	1.64	102.3	38.6	0.63		
105	160 - 172		32.0	38.8	29.2	24	.020	6.61	0.820	Sand-silt-clay	2.74	1.84	114.8	32.8	.49	0.0009	
106	233.8- 234.4		41.8	41.2	17.0	14	.047	3.00	.477	Silty sand	2.69	1.71	106.7	36.4	.57	.4	
107	270 - 279		8.4	27.6	64.0	50	.0020	[1]	[1]	Silty clay	2.67	1.50	93.6	44.4	.80	.001	0.002
108	310.0- 310.5		44.2	31.3	24.5	21	.050	5.68	.754	Sand-silt-clay	2.71	1.76	109.8	35.1	.54	.2	
109	350.3- 350.8		7.6	40.4	52.0	40	.0036	[1]	[1]	Silty clay	2.66	1.50	93.6	43.8	.78	.0005	.001
110	399.4- 399.9	0.2	84.6	8.0	7.2	6	.24	1.39	.143	Sand	2.68	1.63	101.7	39.2	.64	72	
111	430.9- 431.4		14.0	40.7	45.3	40	.0059	[1]	[1]	Silty clay	2.63	1.48	92.4	43.7	.78		
112	476.0- 476.4		1.0	42.0	57.0	38	.0032	2.57	.410	do	2.67	1.43	89.2	46.4	.87	.0003	

See footnotes at end of table.

TABLE 5.—*Physical and hydrologic properties of samples from core holes*—Continued

Hydrologic laboratory sample	Sample depth (feet)	Particle analysis, percentage of— Gravel	Sand	Silt	Clay <0.004 mm	Clay <0.002 mm	Median diameter, D_{50} (mm)	Geometrical quartile deviation (sorting coefficient), So	Log quartile deviation (log sorting coefficient), $\log_{10}$ So	Sediment class (Shepard system)	Specific gravity of solids	Dry unit weight G per cc	Dry unit weight Lb per cu ft	Total porosity (percent)	Void ratio	Coefficient of permeability (gpd per sq ft at 60°F) Vertical	Horizontal
Core hole 19/17-22J1,2—Continued																	
57CAL113	510.0– 510.6		71.2	16.8	12.0	12	0.13	1.88	0.274	Silty sand	2.72	1.53	95.5	43.8	0.78	13	
114	553.9– 554.4		13.6	55.4	31.0	23	.010	3.59	.555	Clayey silt	2.69	1.59	99.2	40.9	.69		
115	593.3– 593.8		47.0	43.0	10.0	8	.058	1.86	.270	Silty sand	2.70	1.52	94.8	43.7	.78	16	
116	631.2– 631.7		55.4	34.6	10.0	8	.072	2.54	.405	do	2.70	1.56	97.3	42.2	.73	.5	
117	676.0– 676.4		91.6	2.4	6.0	5	.020	1.41	.149	Sand	2.67	1.46	91.1	45.3	.83	120	
118	712.8– 713.2		86.2	7.3	6.5	6	.15	1.24	.093	do	2.67	1.45	90.5	46.3	.86	60	100
119	726.8– 727.1		75.4	15.6	9.0	8	.10	1.48	.170	do	2.72	1.46	91.1	46.3	.86	7	
120	732.0– 732.5		11.4	58.6	30.0	22	.013	3.19	.504	Clayey silt	2.69	1.42	88.6	47.2	.89	.002	
121	745.7– 746.2		26.8	44.2	29.0	25	.023	5.61	.749	Sand-silt-clay	2.68	1.57	98.0	41.4	.71		
122	767.1– 767.6		90.4	2.6	7.0	6	.32	1.35	.130	Sand	2.66	1.52	94.8	42.9	.75	11	330
123	778.8– 779.3		12.0	61.2	26.8	20	.016	3.21	.507	Clayey silt	2.66	1.52	94.8	42.9	.75	.0004	
124	789.1– 789.6		11.6	74.9	13.5	9	.030	1.78	.250	do	2.66						
125	799.6– 800.0		3.6	60.9	35.5	20	.0064	2.40	.380	do	2.68	1.56	97.3	41.8	.72		
126	810.0– 810.5		19.6	52.9	27.5	20	.018	4.02	.604	do	2.67	1.51	94.2	43.4	.77	.005	
127	831.1– 831.6		21.6	45.4	33.0	26	.012	5.27	.722	Sand-silt-clay	2.66	1.64	102.3	38.3	.62		
128	860.7– 861.2		14.8	68.2	17.0	12	.021	2.29	.360	Clayey silt	2.67	1.58	98.6	40.8	.69	.001	
129	869.7– 870.2		40.8	46.2	13.0	10	.045	2.50	.398	Sandy silt	2.70	1.65	103.0	38.9	.64	.05	
130	870.0– 870.5		27.2	48.8	24.0	18	.022	4.14	.617	Sand-silt-clay	2.66	1.50	93.6	43.6	.77	.001	
131	888.6– 889.1		3.6	31.9	64.5	50	.0020	(1)	(1)	Silty clay	2.64	1.33	83.0	49.6	.98		
132	905.3– 905.7		30.2	28.8	41.0	30	.0086	7.74	.889	Sand-silt-clay	2.67	1.67	104.2	37.5	.60	.05	
133	936.8– 937.3		24.8	54.2	21.0	15	.024	3.33	.522	do	2.64	1.58	98.6	40.2	.67	.1	
134	945.4– 945.9		4.0	56.5	39.5	20	.0056	2.10	.322	Clayey silt	2.61	1.50	93.6	42.5	.74		
135	948.0– 948.5		8.8	37.7	53.5	38	.0034	3.57	.553	Silty clay	2.65	1.45	90.5	45.3	.83		
136	958.0– 958.5	.6	60.4	23.5	15.5	12	.12	3.87	.588	Silty sand	2.69	1.43	89.2	46.8	.88	.01	
137	971.5– 971.9		11.0	39.0	50.0	33	.0039	2.93	.467	Silty clay	2.66	1.50	93.6	43.5	.77	.002	
138	982.8– 983.2		8.2	58.8	33.0	23	.0082	2.96	.471	Clayey silt	2.65	1.49	93.0	43.8	.78		
139	993.4– 993.9		47.4	43.6	9.0	6	.060	2.24	.350	Silty sand	2.68	1.50	93.6	44.0	.79	.02	
140	1,003.1–1,003.6		51.6	31.1	17.3	14	.072	5.39	.732	do	2.70	1.68	104.8	37.8	.61	.0003	
141	1,028.0–1,028.5		6.4	46.9	46.7	32	.0045	3.28	.516	Silty clay	2.66	1.56	97.3	41.4	.71	.0007	
142	1,032.0–1,032.5		47.8	32.2	20.0	14	.058	1.31	.117	Sand-silt-clay	2.65	1.62	101.1	38.9	.64	.07	
143	1,042.0–1,042.5		86.4	8.6	5.0	4	.18	1.48	.170	Sand	2.70	1.35	84.2	50.0	1.00	230	
144	1,093.8–1,094.3		12.4	52.6	35.0	24	.0082	3.63	.560	Clayey silt	2.65	1.57	98.0	40.8	.69		
145	1,104.3–1,104.7		12.0	44.0	44.0	30	.0052	3.42	.534	Silty clay	2.66	1.44	89.9	45.9	.85	.002	
146	1,119.6–1,120.1		6.4	49.2	44.4	30	.0048	2.94	.468	Clayey silt	2.67	1.47	91.7	44.9	.82		
147	1,131.7–1,132.2		19.4	45.1	35.5	29	.0099	5.62	.750	do	2.66	1.58	98.6	40.6	.68		
148	1,143.3–1,143.8		9.0	37.2	53.8	35	.0035	2.62	.418	Silty clay	2.66	1.48	92.4	44.4	.80		
149	1,145.2–1,145.7		22.5	62.9	14.6	14	.028	2.35	.371	Sandy silt	2.66	1.55	96.7	41.7	.72		
150	1,159.8–1,160.3		15.6	70.4	14.0	10	.026	2.19	.340	do	2.67	1.67	104.2	37.5	.60	.1	
151	1,179.7–1,180.2		10.8	18.2	71.0	57	.0016	(1)	(1)	Silty clay	2.60	1.49	93.0	42.7	.75	.0001	
152	1,198.5–1,199.2		40.0	37.8	22.2	16	.037	5.09	.707	Sand-silt-clay	2.68	1.72	107.3	35.8	.56	.0006	
153	1,209.1–1,209.6		13.2	70.8	16.0	9	.016	2.27	.356	Clayey silt	2.66	1.41	88.0	47.0	.89		
154	1,216.0–1,216.5		40.2	42.8	17.0	11	.035	4.03	.605	Sandy silt	2.68	1.65	103.0	37.3	.50		
155	1,232.0–1,232.5		46.2	37.6	16.2	13	.054	2.67	.427	Silty sand	2.69	1.63	101.7	39.6	.66	2	.3
156	1,247.4–1,247.9	2.5	76.2	12.3	9.0	9	.29	2.24	.350	Sand	2.69					7	
157	1,262.5–1,262.9		7.4	45.1	47.5	36	.0043	(1)	(1)	Silty clay	2.65	1.59	99.2	40.0	.67		
158	1,283.3–1,283.8		20.6	35.9	43.5	31	.0054	5.34	.728	Sand-silt-clay	2.67	1.57	98.0	41.2	.70		
159	1,291.0–1,291.5		5.4	50.6	44.0	30	.0050	3.16	.500	Clayey silt	2.65	1.46	91.1	44.9	.82		
160	1,305.9–1,306.4		32.2	31.8	36.0	28	.014	8.29	.919	Sand-silt-clay	2.66	1.55	96.7	41.7	.72		
161	1,321.0–1,321.5		15.0	50.5	34.5	26	.0090	4.12	.615	Clayey silt	2.66	1.61	100.5	39.5	.65		
162	1,346.5–1,347.0		38.6	35.4	26.0	16	.028	5.70	.756	Sand-silt-clay	2.68	1.67	104.2	37.7	.61	.0008	
163	1,356.5–1,357.1		8.8	41.7	49.5	36	.0041	3.81	.581	Silty clay	2.67	1.62	101.1	39.3	.65		
164	1,376.2–1,376.8		9.2	61.8	29.0	22	.010	3.05	.484	Clayey silt	2.68	1.65	103.0	38.4	.62		
165	1,392.0–1,392.5		10.0	41.0	49.0	34	.0042	3.54	.549	Silty clay	2.68	1.64	102.3	38.8	.63		
166	1,416.8–1,417.4		21.6	50.9	27.5	19	.014	3.85	.585	Sand-silt-clay	2.66	1.59	99.2	40.2	.67		
167	1,427.9–1,428.4		17.6	45.9	36.5	27	.0092	4.73	.675	Clayey silt	2.69	1.70	106.1	36.8	.58	.0002	
168	1,432.7–1,433.2		31.2	46.8	22.0	17	.024	4.18	.621	Sand-silt-clay	2.69	1.61	100.5	40.1	.67		
169	1,453.4–1,453.9		21.6	48.4	30.0	21	.010	3.88	.589	do	2.67	1.53	95.5	42.7	.75		
170	1,480.0–1,480.5		17.6	50.4	32.0	22	.0094	3.80	.580	Clayey silt	2.70	1.71	106.7	36.7	.58		
171	1,484.1–1,484.6		5.6	73.4	21.0	13	.012	2.14	.330	do	2.66					.01	
172	1,498.2–1,498.7		27.2	41.8	31.0	22	.014	5.37	.730	Sand-silt-clay	2.67	1.68	104.8	37.1	.59		
173	1,517.8–1,518.3		15.0	58.8	26.2	19	.014	3.42	.534	Clayey silt	2.69	1.61	100.5	40.1	.67	.0006	
174	1,526.5–1,526.9		39.2	40.5	20.3	16	.039	4.08	.611	Sand-silt-clay	2.67	1.76	109.8	34.1	.52	.1	
175	1,539.0–1,539.4		14.0	45.0	41.0	30	.0064	4.31	.634	Clayey silt	2.63	1.63	101.7	38.0	.61		
176	1,543.7–1,544.2		41.6	41.4	17.0	14	.048	2.67	.427	Sandy silt	2.70	1.66	103.6	38.5	.63		
177	1,550.6–1,551.0		67.2	22.3	10.5	9	.11	1.88	.274	Silty sand	2.70	1.78	111.1	34.1	.52	2	
178	1,475.9–1,575.4		32.8	46.2	21.0	19	.026	3.74	.573	Sand-silt-clay	2.70	1.72	107.3	36.3	.57	.0009	.09
179	1,590.2–1,590.7		22.0	56.0	22.0	16	.020	3.32	.521	do	2.67	1.73	108.0	35.2	.52		
180	1,605.0–1,605.5		24.0	56.0	20.0	14	.030	2.93	.467	do	2.67	1.59	99.2	40.4	.68		
181	1,615.0–1,615.5		29.2	42.8	28.0	20	.016	4.87	.688	do	2.67	1.60	99.8	40.1	.67	.005	
182	1,642.0–1,642.5		34.8	41.9	23.3	18	.030	4.57	.660	do	2.66	1.77	110.4	33.5	.50		

183	1,650.2-1,650.7	--------	18.0	30.0	52.0	39	.0036	(1)	(1)	Silty clay	2.65	1.60	99.8	39.6	.66	--------	--------
184	1,668.5-1,668.9	--------	15.6	55.4	29.0	20	.013	3.37	.528	Clayey silt	2.65	1.53	95.5	42.3	.73	--------	--------
185	1,677.8-1,678.3	--------	8.0	51.5	40.5	30	.0068	4.14	.617	do	2.66	1.64	102.3	38.3	.62	--------	--------
186	1,698.5-1,699.0	--------	44.0	35.0	21.0	17	.046	4.33	.636	Sand-silt-clay	2.70	1.65	103.0	38.9	.64	--------	--------
187	1,718.8-1,719.2	--------	9.0	51.0	40.0	29	.0064	3.83	.583	Clayey silt	2.67	1.67	104.2	37.5	.60	.001	--------
188	1,727.5-1,728.0	--------	16.6	52.4	31.0	23	.013	3.95	.597	do	2.64	1.68	104.8	36.4	.57	--------	--------
189	1,748.0+	--------	9.2	47.8	43.0	27	.0052	2.84	.453	do	2.63	1.64	102.3	37.6	.60	--------	--------
190	1,779.3-1,779.8	--------	7.0	59.0	34.0	25	.0096	3.74	.573	do	2.67	1.59	99.2	40.4	.68	--------	--------
191	1,800.1-1,800.6	--------	30.2	30.8	39.0	36	.013	(1)	(1)	Sand-silt-clay	2.52	1.41	88.0	44.0	.79	--------	--------
192	1,804.5-1,805.0	--------	38.0	49.2	12.8	4	.037	3.42	.534	Sandy silt	2.69	--------	--------	--------	--------	--------	--------
193	1,831.1-1,831.6	--------	4.6	68.2	27.2	13	.0076	1.94	.288	Clayey silt	2.73	1.54	96.1	43.6	.77	.006	--------
194	1,841.4-1,842.0	--------	15.8	46.2	38.0	28	.0090	4.68	.670	do	2.66	1.43	89.2	46.2	.86	--------	--------
195	1,867.5-1,868.0	--------	46.8	42.2	11.0	4	.050	4.36	.639	Silty sand	2.48	--------	--------	--------	--------	--------	--------
196	1,873.1-1,873.6	--------	35.2	48.1	16.7	14	.050	2.41	3.82	Sandy silt	2.69	1.64	102.3	39.0	.64	.03	--------
197	1,899.3-1,899.8	--------	5.2	49.8	45.0	32	.0050	3.57	.553	Clayey silt	2.71	1.52	94.8	43.9	.78	--------	--------
198	1,912.5+	--------	15.8	43.2	41.0	31	.0072	4.96	.695	do	2.67	1.60	99.8	40.1	.67	.0004	--------
199	1,937.0+	--------	31.2	29.8	39.0	30	.0090	10.0	1.000	Sand-silt-clay	2.50	1.37	85.5	45.2	.83	.002	--------
200	1,956.3-1,956.7	--------	47.0	23.0	30.0	27	.049	11.2	1.049	do	2.69	1.54	96.1	42.8	.75	--------	--------
201	1,976.0+	--------	35.4	20.1	44.5	37	.0072	(1)	(1)	Sandy clay	2.76	1.59	99.2	42.0	.72	--------	--------
202	1,993.0-1,993.5	--------	12.2	18.8	69.0	51	.0019	(1)	(1)	Silty clay	2.71	1.60	99.8	41.2	.70	--------	--------
203	2,019.5-2,020.0	--------	16.2	46.6	37.2	25	.0066	3.31	.520	Clayey silt	2.72	1.68	104.8	38.2	.62	--------	--------
204	2,049.3-2,049.7	--------	15.6	63.7	20.7	8	.013	2.81	.449	do	2.73	1.60	99.8	41.0	.70	--------	--------
205	2,064.0-2,064.5	--------	10.2	28.8	61.0	50	.0020	(1)	(1)	Silty clay	2.71	--------	--------	--------	--------	--------	--------
206	2,091.2-2,092.6	--------	14.2	25.3	60.5	37	.0029	2.30	.362	do	2.68	1.49	93.0	44.4	.80	.002	--------

Core hole 23/25-16N1

58CAL99	31.3 31.9	--------	46.6	32.0	21.4	20	0.049	6.27	0.797	Sand-silt-clay	2.67	--------	--------	--------	--------	--------	--------
100	70.3- 70.4	--------	22.2	58.7	20.0	14	.025	3.01	.478	do	2.71	--------	--------	--------	--------	0.4	--------
101	118.3- 118.8	--------	45.8	35.2	19.0	11	.049	5.86	.768	Silty sand	2.67	--------	--------	--------	--------	.8	--------
102	155.1- 155.6	--------	51.6	35.3	13.1	12	.065	2.19	.341	do	2.72	1.68	104.8	38.2	0.62	.06	0.02
103	193.5- 194.0	--------	53.6	30.2	16.2	14	.075	4.60	.662	do	2.69	1.66	103.6	383	.62	.02	.2
104	235.3- 235.8	--------	44.7	32.0	23.3	18	.053	4.66	.668	Sand-silt-clay	2.66	1.79	111.7	32.7	.48	.0005	.0008
105	268.3- 268.8	--------	39.4	34.1	26.5	16	.0295	7.07	.849	do	2.67	1.69	105.5	36.7	.58	.05	.03
106	287.2- 287.7	--------	2.2	71.9	25.9	20	.014	2.57	.410	Clayey silt	2.68	1.32	82.4	50.7	1.02	.0004	.0005
107	294.6- 295.2	--------	.2	64.1	35.7	27	.0088	3.35	.525	do	2.69	1.05	65.5	61.0	1.56	.0004	.0004
108	304.7- 305.1	--------	92.4	6.6	1.0	1	.227	1.36	.132	Sand	2.68	1.66	103.6	38.1	1.61	38	--------
109	316.4- 316.9	--------	22.8	57.1	20.1	17	.030	2.71	.434	Sand-silt-clay	2.72	1.57	98.0	42.3	.74	.91	.02
110	320.3- 320.8	--------	42.6	34.2	23.2	19	.041	5.45	.737	do	2.68	1.64	102.3	38.8	.63	.09	--------
111	335.8- 336.4	--------	32.2	35.0	32.8	26	.0163	9.59	.982	do	2.71	1.59	99.2	41.3	.71	.01	.01
112	343.0- 343.5	--------	9.2	54.6	36.2	26	.0071	3.42	.534	Clayey silt	2.71	1.64	102.3	39.5	.65	.01	.004
113	352.8- 353.3	--------	24.0	48.0	28.0	24	.0227	4.89	.690	Sand-silt-clay	2.72	1.62	101.1	40.4	.68	.01	.02
114	362.5- 363.0	--------	46.8	35.4	17.8	114	.055	3.92	.593	Silty sand	2.68	1.82	113.6	32.1	.46	.002	.02
115	370.3- 370.8	--------	18.2	59.9	21.9	8	.0216	2.85	.455	Clayey silt	2.74	1.59	99.2	42.0	.73	.004	.1
116	418.0- 418.5	--------	18.2	47.8	34.0	26	.0125	4.95	.695	do	2.70	1.55	96.7	42.6	.75	.06	--------
117	427.1- 427.7	--------	11.8	54.5	33.7	29	.0107	(1)	(1)	do	2.69	1.58	98.6	41.3	.70	.0002	.0006
118	442.4- 442.9	--------	9.8	44.4	45.8	34	.0050	(1)	(1)	Silty clay	2.71	1.41	88.0	48.0	.93	.001	.0006
119	450.5- 451.0	--------	2.8	67.4	29.8	22	.0098	2.70	.431	Clayey silt	2.73	1.50	93.6	45.1	.83	.0005	.0006
120	465.0- 465.5	--------	11.6	66.4	22.0	17	.0214	2.50	.398	do	2.75	1.34	83.6	51.3	1.04	.002	.007
121	475.3- 475.8	--------	35.0	46.3	18.7	13	.0355	4.39	.643	Sandy silt	2.72	1.79	111.7	34.2	.51	.6	.09
122	482.0- 482.5	--------	8.6	37.8	53.6	38	.0035	(1)	(1)	Silty clay	2.69	1.52	94.8	43.5	.78	.005	--------
123	496.0- 496.5	--------	31.4	31.6	27.0	22	.0275	5.27	.722	Sand-silt-clay	2.68	1.69	105.5	36.9	.58	.2	--------
124	508.8- 509.3	--------	33.2	47.6	19.2	16	.0335	3.39	.531	Sandy silt	2.70	1.66	103.6	38.5	.63	.01	.02
125	511.0- 511.5	--------	17.4	43.9	38.7	31	.0094	5.82	.764	Clayey silt	2.70	1.64	102.3	39.3	.65	.001	.004
126	523.0- 523.5	--------	37.4	33.2	29.4	24	.030	7.22	.858	Sand-silt-clay	2.72	1.53	95.5	43.8	.79	.002	.004
127	534.0- 534.5	--------	45.8	44.5	9.7	6	.057	1.98	.296	Silty sand	2.68	1.65	103.0	38.4	.63	.4	.2
128	545.5- 546.0	--------	6.4	50.6	43.0	30	.0055	3.21	.507	Clayey silt	2.69	1.53	95.5	43.1	.76	.0003	.002
129	560.6- 561.1	--------	17.0	65.3	17.7	12	.0272	2.46	.392	do	2.66	1.52	94.8	42.9	.76	.02	.02
130	581.5- 582.1	--------	87.4	8.1	4.5	4	.300	1.98	.297	Sand	2.72	1.55	96.7	43.0	.76	--------	61
131	594.5- 595.0	--------	21.2	43.3	35.5	25	.0096	4.81	.682	Sand-silt-clay	2.74	1.57	98.0	42.7	.75	.001	.001
132	600.5- 601.0	--------	22.4	58.6	19.0	14	.0228	2.88	.459	Sandy silt	2.66	1.54	96.1	42.1	.73	.008	.03
133	616.0- 616.4	--------	25.0	41.0	34.0	26	.012	5.97	.776	Sand-silt-clay	2.65	1.48	92.4	44.2	.80	.0009	--------
134	621.7- 622.2	--------	44.8	45.0	10.2	8	.054	2.25	.352	Sandy silt	2.75	1.52	94.8	44.7	.81	.04	--------
135	630.7- 631.2	--------	58.8	29.2	12.0	10	.079	2.16	.334	Silty sand	2.68	1.70	106.1	36.6	.57	.05	.02
136	644.0- 644.5	--------	53.0	33.4	13.6	11	.068	2.72	.434	do	2.66	1.60	99.8	39.8	.66	2	.005
137	654.1- 654.6	--------	28.6	49.4	22.0	13	.0253	3.77	.576	Sand-silt-clay	2.68	1.67	104.2	37.7	.60	.05	.02
138	660.0- 660.5	--------	55.2	33.8	11.0	10	.072	2.08	.318	Silty sand	2.73	1.71	106.7	37.4	.59	.03	--------
139	673.1- 673.6	--------	34.0	44.2	21.8	18	.029	4.10	.612	Sand-silt-clay	2.70	1.69	105.5	37.4	.59	.007	--------
140	682.7- 683.2	--------	14.6	72.3	13.1	8	.027	2.09	.321	Sandy silt	2.69	1.56	97.3	42.0	.73	.005	.005
141	694.0- 694.5	--------	55.8	28.5	15.7	14	.081	3.25	.512	Silty sand	2.69	1.63	101.7	39.4	.65	.09	.05
142	705.1- 705.6	--------	39.2	51.7	9.1	6	.0445	2.12	.327	Sandy silt	2.67	1.56	97.3	41.6	.72	.1	.1
143	723.8- 724.3	--------	17.6	59.8	22.6	16	.0163	2.87	.458	Clayey silt	2.67	1.48	92.4	44.6	.81	.002	.003
144	730.5- 731.0	--------	6.8	68.5	24.7	16	.0107	2.30	.362	do	2.71	1.50	93.6	44.6	.81	.001	.008
145	748.0- 748.5	--------	38.0	32.3	29.7	26	.030	8.88	.948	Sand-silt-clay	2.66	1.61	100.5	39.5	.65	.0002	--------

See footnotes at end of table.

TABLE 5.—*Physical and hydrologic properties of samples from core holes*—Continued

Hydrologic laboratory sample	Sample depth (feet)	Particle analysis, percentage of—					Median diameter, D_{50} (mm)	Geometrical quartile deviation (sorting coefficient), *So*	Log quartile deviation (log sorting coefficient), $\log_{10} So$	Sediment class (Shepard system)	Specific gravity of solids	Dry unit weight		Total porosity (percent)	Void ratio	Coefficient of permeability (gpd per sq ft at 60°F)	
		Gravel	Sand	Silt	Clay <0.004 mm	Clay <0.002 mm						G per cc	Lb per cu ft			Vertical	Horizontal
								Core hole 24/26–36A2									
59CAL310	54.3– 54.8	6.2	59.3	19.5	15.0	13	0.255	2.63	0.420	Silty sand	2.68	1.79	111.7	33.2	0.49	--------	--------
311	63.4– 63.9	16.5	56.9	14.9	11.7	11	.355	4.96	.695	do	2.68	1.84	114.8	31.3	.44	--------	--------
312	84.6– 85.1	5.9	54.2	26.4	13.5	11	.107	4.45	.648	do	2.70	1.84	114.8	31.9	.46	--------	--------
313	93.0– 93.5	1.8	49.5	31.6	17.1	13	.070	5.69	.755	do	2.70	1.78	111.1	34.1	.51	--------	--------
314	102.6– 103.1	8.6	55.6	20.1	15.7	15	.170	5.84	.767	do	2.69	1.71	106.7	36.4	.57	.2	2
315	117.6– 118.1	7.3	51.4	21.8	19.5	16	.133	7.76	.890	do	2.70	1.83	114.2	32.2	.46	.5	--------
316	124.2– 124.6	2.5	44.5	32.2	20.8	18	.053	4.66	.668	Sand-silt-clay	2.71	1.78	111.1	34.3	.51	.02	.08
317	133.0– 133.5	1.8	43.8	37.0	17.4	13	.052	3.42	.535	Silty sand	2.73	1.73	108.0	36.6	.58	.2	--------
318	142.6– 143.1	3.8	43.5	27.7	25.0	22	.0495	9.49	.977	Sand-silt-clay	2.71	1.67	104.2	38.4	.61	.005	.1
319	148.0– 148.5	1.1	27.7	19.3	51.9	49	.0024	[1]	[1]	Sandy clay	2.71	1.67	104.2	38.4	.61	.0002	.0003
320	156.3– 156.8	.2	39.9	28.0	31.9	26	.036	8.85	.947	Sand-silt-clay	2.72	1.88	117.3	30.9	.43	.04	--------
321	173.0– 173.5	1.6	26.0	50.4	22.0	16	.0245	3.59	.554	do	2.70	1.61	100.5	40.4	.67	.04	--------
322	176.3– 176.8	3.6	57.3	24.3	14.8	10	.12	4.48	.652	Silty sand	2.72	1.76	109.8	35.3	.54	2	2
323	187.0– 187.5	28.5	61.9	4.3	5.3	5	1.09	2.28	.358	Gravelly sand	2.70	1.74	108.6	35.6	.55	[2] 20	--------
324	203.5– 204.0	5.0	46.5	22.0	26.5	23	.076	14.14	1.150	Sand-silt-clay	2.71	1.66	103.6	38.7	.63	.06	3
325	210.0– 210.5	.9	37.9	44.7	16.5	12	.035	3.76	.576	Sandy silt	2.71	1.67	104.2	38.4	.61	.5	--------
326	220.5– 221.0	5.8	41.3	33.9	19.0	15	.0522	6.90	.839	Silty sand	2.70	1.82	113.6	32.6	.48	.02	.2
327	231.6– 232.0	3.5	38.8	34.9	22.8	16	.040	5.79	.763	Sand-silt-clay	2.70	1.78	111.1	34.1	.51	.001	--------
328	240.2– 240.7	8.0	48.8	26.1	17.1	13	.103	6.13	.788	Silty sand	2.71	1.85	115.4	31.7	.45	--------	--------
329	251.5– 251.9	33.9	57.9	2.6	5.6	5	1.30	2.13	.328	Gravelly sand	2.68	1.61	100.5	39.9	.66	5	--------
330	260.2– 260.7	2.1	53.3	34.9	9.7	8	.078	2.41	.382	Silty sand	2.70	1.32	82.4	51.1	1.01	[2] 1	--------
331	273.5– 274.0	8.9	61.4	14.7	15.0	13	.295	5.15	.712	Clayey sand	2.72	1.77	110.4	34.9	.53	.1	.1
332	284.5– 284.9	.2	59.7	28.1	12.0	10	.091	2.68	.428	Silty sand	2.70	1.70	106.1	37.0	.59	.07	--------
333	289.8– 290.3	--------	28.8	53.7	17.5	12	.028	3.08	.488	Sandy silt	2.73	1.63	101.7	40.3	.68	.2	--------
334	300.5– 301.0	1.6	68.7	12.2	17.5	15	.170	3.79	.579	Clayey sand	2.71	1.82	113.6	32.8	.49	--------	--------
335	315.3– 315.8	1.3	56.3	28.6	13.8	12	.088	3.23	.509	Silty sand	2.71	1.67	104.2	38.4	.61	.01	.02
336	318.0– 318.5	1.0	61.0	29.4	8.6	7	.103	2.73	.437	do	2.71	1.79	111.7	33.9	.50	.1	--------
337	328.5– 329.0	2.3	55.9	29.0	12.8	12	.099	4.13	.616	do	2.74	1.81	112.9	33.9	.50	.06	--------
338	338.0– 338.5	.4	47.8	35.5	16.3	13	.056	3.74	.573	do	2.76	1.77	110.4	35.9	.55	.003	.006
339	356.8– 357.3	1.8	45.6	39.0	13.6	12	.056	3.10	.492	do	2.72	1.86	116.1	31.6	.45	--------	--------
340	358.7– 359.2	3.3	63.6	21.9	11.2	8	.170	3.79	.578	do	2.74	1.86	116.1	32.1	.51	.2	--------
341	370.0– 370.5	2.9	47.2	27.1	22.8	16	.0625	7.92	.899	Sand-silt-clay	2.71	1.88	117.3	30.6	.43	.007	--------
342	374.3– 374.8	2.7	56.0	25.3	16.0	13	.109	4.36	.640	Silty sand	2.75	1.90	118.6	30.9	.43	.01	.5
343	389.1– 389.6	.1	35.8	54.4	9.7	8	.037	2.33	.368	Sandy silt	2.78	1.58	98.6	43.2	.75	.09	--------
344	399.0– 399.5	3.4	45.2	32.4	19.0	14	.057	6.10	.785	Silty sand	2.76	1.88	117.3	31.9	.45	.003	.002
345	403.0– 403.5	.4	49.8	27.3	22.5	17	.0625	6.48	.812	Sand-silt-clay	2.76	1.75	109.2	36.6	.57	.002	--------
346	414.9– 415.4	2.4	70.9	15.5	11.2	9	.23	3.40	.532	Silty sand	2.73	1.77	110.4	35.2	.54	.8	2
347	423.0– 423.5	4.5	65.9	18.6	11.0	8	.21	3.71	.569	do	2.73	1.77	110.4	35.2	.54	.1	--------
348	433.3– 433.7	1.3	49.2	36.0	13.5	8	.064	3.17	.501	do	2.74	1.76	109.8	35.8	.55	.1	.1
349	443.0– 443.5	.7	39.3	39.9	20.1	14	.0305	5.65	.752	Sand-silt-clay	2.72	1.80	112.3	33.8	.50	--------	--------
350	458.5– 459.0	3.7	55.9	28.9	11.5	8	.103	4.26	.630	Silty sand	2.74	1.81	112.9	33.9	.50	.5	--------
351	467.3– 467.8	2.0	49.6	34.1	14.3	10	.071	5.02	.701	do	2.74	1.66	103.6	39.4	.65	.02	.01
352	474.7– 475.3	2.2	38.9	34.5	24.4	18	.038	6.26	.797	Sand-silt-clay	2.68	1.79	111.7	33.2	.48	.008	.04
353	488.0– 488.5	.5	44.8	41.7	13.0	7	.051	2.78	.443	Silty sand	2.76	1.74	108.6	37.0	.59	.002	--------
354	494.0– 494.5	.5	42.6	37.3	19.6	14	.0415	4.93	.693	do	2.74	1.73	108.0	36.9	.59	.05	.03
355	507.0– 507.5	.7	36.3	42.5	20.5	17	.0405	3.79	.579	Sand-silt-clay	2.75	1.74	108.6	36.7	.58	.004	--------
356	516.3– 516.8	1.0	38.0	30.2	30.8	22	.0177	9.81	.992	do	2.75	1.77	110.4	35.6	.55	.001	--------
357	531.0– 531.5	.4	46.6	46.1	16.9	12	.057	3.31	.520	Silty sand	2.77	1.73	108.0	37.5	.61	.01	.04
358	533.1– 533.6	7.9	65.9	16.9	9.3	6	.240	3.58	.554	do	2.74	1.69	105.5	38.3	.63	3	--------
359	544.0– 544.5	5.3	57.8	20.0	16.9	14	.139	4.95	.694	do	2.72	1.80	112.3	33.8	.50	--------	--------
360	552.6– 553.1	5.0	73.3	10.9	10.8	10	.23	3.00	.477	Sand	2.75	1.73	108.0	36.9	.59	3	3
361	565.1– 565.6	2.8	46.3	36.7	14.2	9	.060	2.89	.461	Silty sand	2.74	1.64	102.3	40.4	.67	.06	--------
362	574.6– 575.1	2.0	30.4	47.3	20.3	15	.0225	4.56	.659	Sand-silt-clay	2.76	1.68	104.8	39.1	.64	.01	--------
363	582.6– 583.1	5.7	23.8	48.3	22.2	15	.0193	4.10	.612	do	2.69	1.65	103.0	38.7	.63	.001	.03
364	595.1– 595.6	1.2	42.7	40.0	16.1	12	.046	4.28	.631	Silty sand	2.71	1.94	121.1	28.4	.39	.001	--------
365	607.5– 608.0	.1	24.6	64.5	10.8	7	.038	2.25	.353	Sandy silt	2.71	1.79	111.7	33.9	.50	.001	.03
366	613.8– 614.3	.4	33.1	48.2	18.3	13	.0405	2.81	.449	do	2.71	1.70	106.1	37.3	.59	.006	--------
367	623.0– 623.5	1.3	28.8	40.4	29.5	23	.019	5.68	.754	Sand-silt-clay	2.66	1.44	89.9	45.9	.85	--------	--------
368	631.2– 631.7	.5	34.8	31.6	33.1	25	.0162	9.28	.968	do	2.66	1.54	96.1	42.1	.73	.001	.002
369	648.2– 648.7	.3	21.3	38.2	40.2	32	.007	5.66	.753	do	2.67	1.56	97.3	41.6	.71	--------	--------
370	658.8– 659.3	.7	43.1	36.3	19.9	16	.046	4.32	.636	Silty sand	2.69	1.74	108.6	35.3	.54	.004	--------
371	668.3– 668.8	1.2	56.1	25.7	17.0	14	.093	4.93	.693	do	2.70	1.72	107.3	36.3	.55	.005	.009
372	678.5– 679.0	4.1	55.6	29.3	11.0	8	.100	3.63	.560	do	2.73	1.75	109.2	35.9	.55	.1	.1
373	686.5– 686.9	.3	29.1	34.9	35.7	28	.0141	7.55	.878	Sand-silt-clay	2.66	1.35	84.2	49.2	.96	--------	--------
374	697.5– 698.0	--------	58.2	33.8	8.0	6	.075	2.03	.307	Silty sand	2.72	1.56	97.3	42.6	.75	2	2
375	709.0– 709.5	.8	61.7	28.0	9.5	7	.098	3.23	.509	do	2.74	1.81	112.9	33.9	.50	.08	--------
376	719.4– 720.0	.2	41.1	47.0	11.7	8	.0395	3.10	.491	Sandy silt	2.73	1.61	100.5	41.0	.69	.002	--------
377	726.1– 726.6	.7	56.2	32.8	10.3	8	.084	3.24	.511	Silty sand	2.74	1.73	108.0	36.9	.57	.3	.2
377	735.4– 735.9	1.5	63.6	23.8	11.1	8	.178	4.35	.638	do	2.71	1.70	106.1	37.3	.59	.05	5
379	744.0– 744.5	--------	39.0	43.5	17.5	14	.033	4.14	.617	Sandy silt	2.66	1.49	93.0	44.0	.79	--------	--------

380	756.9– 757.4		23.8	34.8	41.4	32	.0073	6.48	.812	Sand-silt-clay	2.66	1.35	84.2	49.2	.96	[2].003	
381	763.0– 763.5		33.8	18.4	47.8	40	.0052	(1)	(1)	Sandy clay	2.66	1.34	83.6	49.6	.98		
382	775.6– 776.1	.3	39.9	35.5	24.3	18	.030	5.51	.742	Sand-silt-clay	2.77	1.56	97.3	43.7	.78		.01
383	777.7– 778.2	5.4	33.7	42.9	18.0	12	.039	3.55	.550	Sandy silt	2.79	1.56	97.3	44.1	.79	.07	
384	791.7– 792.2		18.4	26.5	55.1	46	.0027	(1)	(1)	Silty clay	2.76	1.29	80.5	53.3	1.12		
385	843.3– 843.8		4.4	69.3	26.3	17	.0109	2.27	.356	Clayey silt	2.76	1.41	88.0	48.9	.92	.003	
386	852.0– 852.5		10.2	75.6	14.2	10	.023	2.11	.324	Silt	2.74	1.48	92.4	46.0	.86	.006	
387	861.0– 861.5	.4	65.5	14.4	19.7	18	.127	3.96	.598	Clayey sand	2.75	1.74	108.6	36.7	.58	.0007	
388	866.3– 866.8		25.2	64.3	10.5	4	.0285	2.28	.358	Sandy silt	2.75	1.39	86.7	49.5	.98		.05
389	916.4– 916.9		6.0	67.6	26.4	18	.0101	2.45	.390	Clayey silt	2.75	1.46	91.1	46.9	.88	.0006	.02
390	1,036.3–1,036.8		15.8	36.6	47.6	38	.0045	(1)	(1)	Silty clay	2.77	1.38	86.1	50.2	1.00	.004	
391	1,058.0–1,058.5		34.0	61.4	4.6	3	.0385	2.23	.348	Sandy silt	2.41	1.07	66.8	55.6	1.24	.04	10
392	1,099.1–1,099.6	26.0	61.9	6.6	5.5	4	.62	2.70	.431	Gravelly sand	2.70	1.59	99.2	41.1	.70		
393	1,116.8–1,117.8	.3	44.9	27.0	27.8	22	.040	7.72	.888	Sand-silt-clay	2.72	1.29	80.5	52.6	1.10	.04	.7
394	1,155.4–1,155.9	.7	28.0	39.3	32.0	24	.0148	6.53	.815	do	2.72	1.26	78.6	53.7	1.14	.001	.04
395	1,184.3–1,184.7	1.6	52.0	29.0	17.4	15	.076	4.06	.608	Silty sand	2.74	1.31	81.7	52.2	1.08	.09	2
396	1,240.5–1,241.0		23.8	38.2	38.0	29	.0106	6.21	.793	Sand-silt-clay	2.60	1.06	66.1	59.2	1.46	.0005	.001
397	1,363.0–1,363.5		24.4	51.3	24.3	22	.0182	3.59	.555	do	2.64	1.25	78.0	52.7	1.06	.0005	.001
398	1,369.5–1,370.0	.3	66.4	15.3	18.0	16	.140	3.58	.554	Clayey sand	2.70	1.43	89.2	47.0	.89	.003	.01
399	1,421.2–1,421.7	.2	60.7	15.1	24.0	20	.226	10.20	1.009	do	2.65	1.25	78.0	52.8	1.10	.01	
400	1,431.0–1,431.5		60.6	16.6	22.8	19	.155	9.91	.996	do	2.65	1.29	80.5	51.3	1.04	.01	2
401	1,446.9–1,447.4		23.4	46.6	30.0	25	.0153	5.13	.710	Sand-silt-clay	2.58	1.00	62.4	61.2	1.50	.004	.006
402	1,492.0–1,492.5	.3	73.2	10.9	15.6	14	.157	2.23	.348	Clayey sand	2.70	1.58	98.6	41.5	.71	.4	
403	1,526.6–1,527.1		23.6	45.9	30.5	25	.0138	5.16	.712	Sand-silt-clay	2.66	1.13	70.5	57.5	1.35	.001	.004
404	1,688.0–1,688.5		30.4	36.1	33.5	29	.0098	9.20	.964	do	2.75	1.37	85.5	50.2	1.00	.002	.6
405	1,720.4–1,720.9		61.8	30.8	7.4	4	.110	2.51	.400	Silty sand	2.75	1.47	91.7	46.5	0.85	1	6
406	1,751.7–1,752.2	8.0	53.7	26.0	12.3	7	.0920	2.60	.414	do	2.76	1.40	87.4	49.3	.97	6	6
407	1,785.0–1,785.5	.2	60.5	34.6	4.7	3	.117	2.69	.431	do	2.73	1.50	93.6	45.1	.83	4	3
408	1,802.5–1,803.0	.5	65.1	23.6	10.8	10	.097	2.48	.395	do	2.71	1.41	88.0	48.0	.91	5	
409	1,814.0–1,814.5	6.6	76.6	12.2	4.6	3	.178	2.84	.454	Sand	2.69	1.65	103.0	38.7	.63	4	
410	1,826.5–1,827.0		31.6	40.5	27.9	8	.0142	5.02	.701	Sand-silt-clay	2.62	1.26	78.6	51.9	1.06	5	
411	1,892.2–1,892.7		41.4	36.6	22.0	17	.038	4.96	.696	do	2.72	1.17	73.0	57.0	1.31	[2].0009	
412	1,911.5–1,912.0		65.2	20.8	14.0	12	.083	1.782	.251	Silty sand	2.74	1.71	106.7	37.6	.60	.002	
413	1,943.2–1,943.7		91.6	8.4		(3)	.14	1.245	.095	Sand	2.69	1.54	96.1	42.8	.74	2	
414	1,955.5–1,956.0	1.6	95.9	2.5		(3)	.55	1.605	.206	do	2.67	1.60	99.8	40.1	.67	650	
415	1,964.1–1,964.6	5.5	89.8	4.7		(3)	.74	1.691	.228	do	2.66	1.63	101.7	38.7	.63	15	
416	2,010.0–2,010.5	2.4	93.9	3.7		(3)	.81	1.455	.163	do	2.65	1.62	101.1	38.9	.64	18	3
417	2,051.0–2,051.5	7.2	88.3	4.5		(3)	.30	2.35	.371	do	2.66	1.67	104.2	37.2	.58	60	
418	2,102.0–2,102.5	37.5	58.4	4.1		(3)	1.35	2.96	.471	Gravelly sand	2.67	1.70	106.1	36.3	.55	60	
419	2,174.0–2,174.5	.2	90.4	9.4		(3)	.255	1.608	.206	Sand	2.68	1.64	102.3	38.8	.63	90	

Core hole 6S/2W-24C7

60CAL10	36.5– 37.0	1.0	34.5	45.5	19.0	16	0.036	3.46	0.539	Sandy silt	2.70	1.61	100.5	40.4	.68		
11	50±	1.8	15.7	46.4	36.1	29	.011			Clayey silt	2.72	1.61	100.5	40.8	.69		
12	71.4– 71.9		19.6	49.3	31.1	26	.0123	4.94	.694	do	2.75	1.67	104.3	39.3	.65	0.001	0.001
13	90.4– 90.8		6.8	37.7	55.5	44	.0029			Silty clay	2.73	1.51	94.3	44.7	.81	.0005	.0008
14	100.4– 100.9		3.0	51.2	45.8	32	.005	3.23	.509	Clayey silt	2.75	1.48	92.4	46.2	.86		
15	112.4– 112.9		2.2	26.0	71.8	52	.0018			Silty clay	2.71	1.44	89.9	46.9	.88		
16	120.3– 120.8		.4	41.5	58.1	38	.0031			do	2.72	1.44	89.9	47.1	.89		
17	131.0– 131.5		10.6	67.1	22.3	17	.014	2.53	.403	Clayey silt	2.67	1.55	96.8	41.9	.72		
18	140.8– 141.4	2.8	15.4	34.6	47.2	39	.005			Silty clay	2.74	1.63	101.8	40.5	.68	.0004	.0007
19	151.0– 151.5		5.0	38.4	56.6	42	.003			do	2.74	1.43	89.3	47.8	.92		
20	160.0– 160.5		1.4	38.1	60.5	44	.0027			do	2.74	1.55	96.8	43.4	.77	.002	.002
21	178.0– 178.5		14.2	45.5	40.3	32	.0073			Clayey silt	2.73	1.61	100.5	41.0	.69	.004	.002
22	191.3– 191.8	1.3	18.4	37.8	42.5	34	.0070			Silty clay	2.69	1.70	106.1	36.8	.58	.0006	.0007
23	210.1– 210.6		24.4	57.9	17.7	14	.029	2.75	.439	Sandy silt	2.72	1.61	100.5	40.8	.69	.01	.1
24	222.3– 222.8		1.2	46.8	52.0	36	.0037			Silty clay	2.68	1.52	94.9	43.3	.76	.004	.001
25	228.4– 228.9	1.1	31.5	47.4	20.0	14	.027	3.70	.568	Sandy silt	2.72	1.67	104.3	38.6	.63		
26	236.0– 236.5	2.7	27.2	46.7	23.4	17	.022	4.07	.609	Sand-silt-clay	2.75	1.70	106.1	38.2	.62		.004
27	253.4– 253.8	1.0	25.9	56.0	17.1	14	.028	2.93	.467	Sandy silt	2.71	1.74	108.6	35.8	.56	.005	.009
28	307.0– 307.4		4.6	57.7	37.7	30	.0075			Clayey silt	2.72	1.71	106.8	37.1	.59	.0002	.0004
29	312.8– 313.3		11.4	51.7	36.9	29	.0075	4.30	.634	do	2.69	1.67	104.3	37.9	.61		
30	330.0– 330.5		14.0	46.5	39.5	29	.007	4.24	.627	do	2.74	1.71	106.8	37.6	.60	.008	.009
31	344.4– 344.8		21.2	52.3	26.5	21	.017	3.78	.577	Sand-silt-clay	2.72	1.67	104.3	38.6	.63	.009	.02
32	361.3– 361.8	3.0	17.8	41.7	37.5	27	.0084	4.53	.056	do	2.72	1.71	106.8	37.1	.59	.006	.3
33	408.4– 408.9	.1	10.4	48.4	41.1	33	.007			Clayey silt	2.72	1.73	108.0	36.4	.57	.0001	.003
34	419.6– 420.1		39.6	39.4	21.0	18	.035	4.28	.631	Sand-silt-clay	2.73	1.84	114.9	32.6	.48		.002
35	431.5– 342.0	.6	29.2	42.0	28.2	24	.0205	5.66	.753	do	2.74	1.70	106.1	38.0	.61	.002	.008
36	436.7– 437.2	1.7	31.3	39.2	27.8	23	.022	6.19	.792	do	2.71	1.74	108.6	35.8	.56	.005	.03
37	446.0– 446.5		25.2	36.2	38.6	27	.0071	6.06	.782	do	2.75	1.54	96.1	44.0	.79		
38	458.3– 458.8		13.0	61.7	25.3	22	.0152	3.08	.439	Clayey silt	2.75	1.67	104.3	39.3	.65	.001	.005
39	463.0– 463.5		39.2	36.1	24.7	21	.038	4.88	.688	Sand-silt-clay	2.72	1.73	108.0	36.4	.57		.003
40	522.5– 522.9	.1	23.8	41.1	35.0	27	.011	5.86	.768	do	2.73	1.74	108.6	36.3	.57	.0007	.007
41	545.0– 545.5		8.8	56.2	35.0	27	.0089	3.73	.572	Clayey silt	2.73	1.68	104.9	38.5	.63		.0003
42	554.7– 555.2	.7	36.7	38.4	24.2	21	.038	4.66	.668	Sand-silt-clay	2.74	1.79	111.7	34.7	.53	.001	.001
43	563.2– 563.7		15.6	45.8	38.6	31	.008	5.16	.713	Clayey silt	2.71	1.63	101.8	39.9	.66	.002	.002
44	574.3– 574.8		7.0	56.0	37.0	28	.0081	4.06	.609	do	2.71	1.58	98.6	41.7	.71		
45	605.3– 605.8	1.3	29.0	36.7	33.0	28	.020	7.51	.876	Sand-silt-clay	2.71	1.74	108.6	35.8	.56	.0004	.08
46	633.8– 634.3		36.6	37.1	26.3	22	.028	5.80	.763	do	2.75	1.77	110.5	35.6	.55	.0004	.03
47	656.5– 656.9	.1	26.6	32.6	40.7	33	.0082			do	2.72	1.82	113.6	33.1	.49		.0003
48	665.5– 665.9	1.5	24.0	47.0	27.5	22	.023	4.56	.659	do	2.72	1.76	109.9	35.3	.54	.001	.001

See footnotes at end of table.

TABLE 5.—*Physical and hydrologic properties of samples from core holes*—Continued

Hydrologic laboratory sample	Sample depth (feet)	Particle analysis, percentage of—					Median diameter, D_{50} (mm)	Geometrical quartile deviation (sorting coefficient), *So*	Log quartile deviation (log sorting coefficient), $\log_{10}$ *So*	Sediment class (Shepard system)	Specific gravity of solids	Dry unit weight		Total porosity (percent)	Void ratio	Coefficient of permeability (gpd per sq ft at 60°F)	
		Gravel	Sand	Silt	Clay <0.004 mm	Clay <0.002 mm						G per cc	Lb per cu ft			Vertical	Horizontal
Core hole 6S/2W-24C7—Continued																	
60CAL49	715.5– 716.1		11.4	35.5	53.1	41	.0033			Silty clay	2.70	1.68	104.9	37.8	.61	.0007	.0005
50	735.3– 735.8		31.4	40.8	27.8	25	.028	6.07	.783	Sand-silt-clay	2.71	1.82	113.6	32.8	.49		
51	744.9– 745.4		6.0	36.5	57.5	43	.0027			Silty clay	2.72	1.50	93.6	44.9	.81	.0005	.001
52	756.4– 756.9		7.2	28.7	64.1	52	.0018			do	2.70	1.56	97.4	42.2	.73		
53	773.0– 773.5		5.0	62.5	32.5	20	.0078	2.51	.400	Clayey silt	2.70	1.57	98.0	41.9	.72		
54	789.5– 790.0		5.2	43.6	51.6	38	.0037	3.44	.537	Silty clay	2.74	1.60	99.9	41.6	.71	.0002	.006
55	796.5– 797.0		53.6	36.3	10.1	8	.068	1.91	.281	Silty sand	2.75	1.62	101.1	41.1	.70		
56	812.0– 812.5		12.2	47.6	40.2	31	.0078	4.85	.686	Clayey silt	2.73	1.71	106.8	37.4	.60	.0004	.001
57	824.2– 824.7		1.2	62.0	36.8	26	.0082	3.42	.534	do	2.74	1.74	108.6	36.5	.57		
58	835.3– 835.8		88.0	7.7	4.3	4	.165	1.34	.127	Sand	2.74	1.51	94.3	44.9	.81		
59	842.2– 842.7		.2	51.5	48.3	33	.0043	3.02	.480	Clayey silt	2.77	1.60	99.9	42.2	.73		.0008
60	854.1– 854.6		2.6	27.9	69.5	52	.0019			Silty clay	2.73	1.67	104.3	38.8	.63		
61	865.9– 866.4		1.0	27.2	71.8	53	.0018			do	2.79	1.67	104.3	40.1	.67	.0002	.0008
62	873.9– 874.4		19.2	42.4	38.4	33	.012			Clayey silt	2.74	1.88	117.4	31.4	.46		.0002
63	882.8– 883.3		17.8	48.8	33.4	28	.016	5.92	.772	do	2.72	1.85	115.5	32.0	.47		
64	900.2– 900.7		10.2	29.0	60.8	48	.0022			Silty clay	2.74	1.66	103.6	39.4	.65		.004
65	910.0– 910.5		4.0	34.2	61.8	45	.0025			do	2.73	1.57	98.0	42.5	.74		
66	923.6– 924.1		3.0	20.0	77.0	62	.0013			Clay	2.70	1.52	94.9	43.7	.78	.004	.007
67	936.6– 937.1		9.2	22.7	68.1	61				Silty clay	2.70	1.34	83.7	50.4	1.02		
68	958.3– 958.8		21.8	36.4	41.8	33	.008	7.14	.854	Sand-silt-clay	2.71	1.65	103.0	39.1	.64	.0008	.006
69	967.0– 967.5		11.2	45.1	43.7	37	.007			Clayey silt	2.69	1.68	104.9	37.5	.60		
Core hole 7S/1E-16C6																	
60CAL70	196.3– 196.8	0.1	24.6	27.8	47.5	42	0.0052			Sand-silt-clay	2.72	1.64	102.4	39.7	0.66	0.00007	0.0007
71	206.4– 206.9		24.6	54.9	20.5	16	.024	3.22	0.508	do	2.70	1.59	99.3	41.1	.70		.01
72	232.5– 233.0		5.4	52.0	42.6	31	.0056	3.61	.558	Clayey silt	2.80	1.62	101.1	42.1	.73	.0006	.0006
73	258.0– 258.5	3.3	14.8	46.6	35.3	30	.013			do	2.79	1.65	103.0	40.9	.69		.0002
74	275.4– 275.8	.1	18.0	55.9	26.0	21	.016	3.55	.550	do	2.75	1.60	99.9	41.8	.72	.007	.004
75	301.0– 301.5	1.5	22.1	47.0	29.4	25	.020	5.29	.723	Sand-silt-clay	2.72	1.74	108.6	36.0	.56	.002	.002
76	323.8– 324.3	1.4	90.5	8.1		(3)	.257	1.28	.107	Sand	2.72	1.69	105.5	37.9	.61		.6
77	334.1– 334.4		1.2	51.6	47.2	34	.0045			Clayey silt	2.68	1.59	99.3	40.7	.69		.0002
78	354.5– 355.0	.1	45.6	38.9	15.4	12	.054	2.47	.393	Silty sand	2.71	1.73	108.0	36.2	.57	.03	.07
79	401.3– 401.8		.2	47.1	52.7	40	.0035			Silty clay	2.72	1.55	96.8	43.0	.75	.0003	.001
80	430.1– 430.6	.2	27.3	43.1	29.4	24	.018	5.51	.741	Sand-silt-clay	2.72	1.75	109.3	35.7	.56	.0001	.0008
81	440.6– 441.1	.3	75.2	16.8	7.7	6	.134	1.76	.246	Sand	2.77	1.65	103.0	40.4	.68		.4
82	509.5– 510.0	5.8	28.6	35.9	29.7	25	.024	7.68	.885	Sand-silt-clay	2.72	1.77	110.5	34.9	.54	.0005	.0002
83	530.7– 531.2	1.2	30.4	41.2	27.2	24	.025	5.98	.777	do	2.76	1.83	114.2	33.7	.51	.0001	.0003
84	554.3– 554.8	.6	40.4	38.0	21.0	16	.037	4.52	.655	do	2.74	1.86	116.1	32.1	.47	.004	.003
85	569.7– 570.2	.2	33.5	44.9	21.4	18	.031	2.52	.547	do	2.75	1.88	117.4	31.6	.46		.002
86	598.8– 599.3	4.4	42.1	35.0	18.5	16	.050	3.91	.592	Silty sand	2.76	1.86	116.1	32.6	.48	.004	.001
87	696.3– 696.8	2.4	21.1	46.4	30.1	25	.014	4.74	.676	Sand-silt-clay	2.75	1.77	110.5	35.6	.55	.005	.005
88	704.8– 705.2	6.2	58.5	21.8	13.5	11	.162	3.85	.585	Silty sand	2.75	1.91	119.2	30.5	.44		.02
89	724.4– 724.9	.5	20.5	41.9	37.1	33	.013			Sand-silt-clay	2.72	1.81	113.0	33.5	.50	.0002	.002
90	750.1– 750.5	45.6	49.0	5.4		(3)	1.500	3.53	.548	Gravelly sand	2.79	1.67	104.3	40.1	.67		19
91	790.6– 791.1	.7	27.2	46.0	26.1	19	.023	4.47	.650	Sand-silt-clay	2.76	1.74	108.6	37.0	.59	.0003	.0007
92	811.6– 812.2		15.8	66.9	17.3	13	.024	2.41	.382	Clayey silt	2.76	1.63	101.8	40.9	.69		.01
93	832.4– 832.9		21.0	54.8	24.2	19	.019	3.50	.544	Sand-silt-clay	2.79	1.78	111.1	36.2	.57	.0005	.0006
94	845.2– 845.8		20.8	60.2	19.0	16	.025	2.88	.459	Sandy silt	2.76	1.77	110.5	35.9	.56		.005
95	908.2– 908.7		18.0	54.7	27.3	22	.016	3.87	.588	Clayey silt	2.76	1.80	112.4	34.8	.53	.0002	.0003
96	937.4– 937.9	.1	15.8	49.8	34.3	28	.012	4.83	.684	do	2.77	1.64	102.4	40.8	.69	.0001	.002

[1] Nondeterminable. [2] Repacked sample. [3] Not measured.

TABLE 6.—*Atterberg limits and indices of samples from core holes*

Hydrologic Laboratory sample	Depth (feet)	Percent passing No. 40 sieve	Liquid limit	Plastic limit	Shrinkage limit	Plasticity index	Flow index	Toughness index	Shrinkage index	Shrinkage ratio	Volumetric shrinkage	Linear shrinkage
					Core hole 14/13-11D1							
57CAL1	77.0- 77.5	100	28	27	19	1	6	0.2	8	1.7	15	4
2	110.5- 111.0	99	56	26	(1)	30	16	1.9	(2)	(2)	(2)	(2)
4	191.5- 192.0	100	33	24	15	9	8	1.1	9	1.8	32	8
5a	232.5- 233.0	100	44	29	12	15	6	2.5	17	2.0	64	15
7	314.0- 314.5	100	34	24	18	10	8	1.3	6	1.7	27	8
9	398.0- 398.5	100	64	40	13	24	19	1.3	27	1.9	97	20
10	432.0- 432.5	100	59	36	12	23	28	.8	24	1.9	89	19
12	510.3- 510.8	97	65	40	8	25	11	2.3	32	2.0	114	22
14	594.0- 594.5	100	82	39	9	43	22	2.0	30	1.9	139	25
16	646.6- 647.1	100	78	38	17	40	17	2.4	21	1.8	110	22
18	662.1- 662.6	100	80	44	24	36	11	3.3	20	1.6	90	19
19	674.0- 674.5	100	78	46	28	32	9	3.6	18	1.4	70	16
21	697.0- 697.5	100	67	36	28	31	11	2.8	8	1.5	58	14
23	713.0- 713.5	100	52	33	31	19	9	2.1	2	1.4	29	8
25	731.0- 731.5	100	58	34	15	24	26	.9	19	1.8	77	17
26	743.0- 743.5	100	46	28	21	18	19	.9	7	1.6	40	11
27	757.0- 757.5	98	30	(3)	27	(3)	11	(3)	(3)	1.5	4	1
28	764.9- 765.4	65	38	30	26	8	6	1.3	4	1.6	19	5
31	791.0- 791.5	100	40	30	20	10	10	1.0	10	1.7	34	9
32	802.0- 802.5	100	34	26	24	8	13	.6	2	1.7	17	5
35	826.0- 826.5	100	65	43	20	22	14	1.6	23	1.7	77	17
36	831.5- 832.0	100	31	26	19	5	25	.2	7	1.7	20	6
39	860.0- 860.5	100	42	31	23	11	10	1.1	8	1.6	30	8
43	887.5- 888.0	100	76	29	13	47	42	1.1	16	1.9	120	23
44	901.0- 901.5	100	40	30	23	10	15	.7	7	1.6	27	8
47	932.0- 932.5	99	47	23	10	24	9	2.7	13	2.0	74	17
48	936.5- 937.0	100	33	29	20	4	16	.2	9	1.7	22	6
49	951.0- 951.5	100	34	27	13	7	6	1.2	14	1.9	40	11
51	968.5- 969.0	100	41	33	17	8	12	.7	16	1.8	43	11
52	984.0- 984.5	100	59	29	10	30	15	2.0	19	2.0	98	20
54	1,000.5-1,001.0	100	40	24	12	16	8	2.0	12	1.9	53	14
55	1,005.1-1,005.6	100	50	29	11	21	14	1.5	18	2.0	78	17
56	1,020.8-1,021.3	100	36	31	17	5	7	.7	14	1.8	34	9
38	1,039.5-1,040.0	100	47	34	12	13	10	1.3	22	1.9	67	16
59	1,051.5-1,052.0	100	33	24	17	9	10	.9	7	1.8	29	8
61	1,070.8-1,071.3	100	30	21	16	9	11	.8	5	1.8	25	7
65	1,104.6-1,105.1	88	25	22	15	3	15	.2	7	1.8	18	5
68	1,133.0-1,133.5	100	36	24	16	12	10	1.2	8	1.8	36	10
75	1,242.0-1,242.5	100	51	36	25	15	26	.6	11	1.5	39	11
83	1,312.0-1,312.5	98	26	18	18	8	4	2.0	0	1.8	14	4
86	1,339.5-1,340.0	100	36	26	23	10	6	1.7	3	1.6	21	6
88	1,357.0-1,357.5	100	46	23	10	23	14	1.6	13	2.0	72	17
89	1,362.5-1,363.0	100	32	21	18	11	16	.7	3	1.7	24	7
91	1,385.0-1,385.5	100	54	36	13	18	12	1.5	23	1.8	74	17
92	1,397.0-1,397.5	98	61	41	5	20	17	1.2	36	2.1	118	23
96	1,432.5-1,433.0	100	77	38	4	39	14	2.8	34	2.3	168	28
97	1,446.0-1,446.5	100	56	28	5	28	15	1.9	23	2.2	112	22
98	1,454.5-1,455.0	100	44	33	16	11	9	1.2	17	1.7	48	13
99	1,465.0-1,465.5	100	58	34	8	24	11	2.2	26	2.1	105	21
					Core hole 16/15-34N1							
58CAL2	298.2- 298.7	98	38	30	13	8	11	0.7	17	1.9	48	13
3	332.4- 332.9	98	40	26	12	14	14	1.0	14	1.9	53	14
5	418.5- 419.0	100	44	30	13	14	11	1.3	17	1.9	59	15
6	454.3- 454.8	99	54	37	8	17	23	.7	29	2.0	92	20
9	509.5- 510.0	100	46	35	15	11	18	.6	20	1.8	56	14
11	532.4- 532.9	97	42	34	12	8	9	.9	22	1.9	57	14
12	552.8- 553.2	100	45	32	11	13	8	1.6	21	1.9	65	16
13	563.7- 564.2	100	56	46	12	10	13	.8	34	1.9	84	18
14	570.7- 571.2	100	70	58	9	12	18	.7	49	2.0	122	23
19	636.4- 636.9	99	61	52	20	9	14	.6	32	1.6	66	16
20	643.2- 643.7	99	31	25	22	6	19	.3	3	1.6	14	4
21	652.6- 653.1	96	32	26	12	6	12	.5	14	1.8	36	10
22	666.0- 666.5	100	55	43	15	12	15	.8	28	1.8	72	17
24	683.7- 684.2	100	36	30	19	6	16	.4	11	1.7	29	8
25	696.6- 697.1	100	59	42	12	17	8	2.1	30	1.8	85	18
26	701.8- 702.4	100	42	32	17	10	18	.6	15	1.7	43	11
27	713.4- 713.9	99	61	40	7	21	16	1.3	33	2.0	108	22
29	732.0- 732.6	100	39	28	18	11	12	.9	10	1.7	36	10
31	753.8- 754.3	100	41	30	14	11	17	.6	16	1.8	49	13
32	762.4- 762.9	100	46	33	7	13	14	.9	26	2.0	78	17
33	773.3- 773.8	100	30	26	19	4	10	.4	7	1.7	19	5
36	806.1- 806.6	100	55	40	12	15	15	1.0	28	1.8	77	17
38	822.1- 822.6	98	60	49	10	11	12	.9	39	1.9	95	20
39	827.8- 828.2	100	47	33	13	14	20	.7	20	1.8	61	15
40	837.7- 838.2	100	58	43	14	15	17	.9	29	1.8	79	18
42	860.1- 860.6	100	31	24	22	7	13	.5	2	1.6	14	4
43	866.7- 867.3	100	30	23	18	7	7	1.0	5	1.7	20	6
45	891.6- 892.1	100	53	41	11	12	15	.8	30	1.9	80	18
48	922.6- 923.1	100	46	35	13	11	14	.8	22	1.8	59	15
49	931.2- 931.7	100	35	28	15	7	12	.6	13	1.8	36	10
50	940.6- 941.1	100	46	36	9	10	8	1.2	27	2.0	74	17
51	946.3- 946.8	100	63	43	7	20	22	.9	36	2.0	112	22
52	963.7- 964.2	100	37	28	16	9	14	.6	12	1.8	38	10
53	971.5- 972.0	100	57	46	16	11	20	.6	30	1.7	70	16
54	980.6- 981.1	100	35	(3)	27	(3)	14	(3)	(3)	1.5	12	3
58	1,042.8-1,043.3	100	51	45	14	6	13	.5	31	1.8	67	16
61	1,189.5-1,190.0	100	47	34	16	13	24	.5	18	1.8	56	14
63	1,225.0-1,225.5	100	38	34	25	4	14	.3	9	1.6	21	6
64	1,238.1-1,238.6	100	47	36	17	11	16	.7	19	1.7	51	13
66	1,254.9-1,255.4	100	41	36	30	5	7	.7	6	1.4	15	4

See footnotes at end of table.

TABLE 6.—*Atterberg limits and indices of samples from core holes*—Continued

Hydrologic Laboratory sample	Depth (feet)	Percent passing No. 40 sieve	Liquid limit	Plastic limit	Shrinkage limit	Plasticity index	Flow index	Toughness index	Shrinkage index	Shrinkage ratio	Volumetric shrinkage	Linear shrinkage
Core hole 16/15-34N1—Continued												
58CAL67	1,280.2-1,280.7	100	48	41	24	7	21	0.3	17	1.6	38	10
70	1,351.4-1,351.9	100	42	36	31	6	32	.2	5	1.4	15	4
77	1,432.0-1,432.5	97	48	42	20	6	12	.5	22	1.7	48	13
79	1,476.0-1,476.5	100	50	34	13	16	14	1.1	21	1.9	70	16
83	1,507.2-1,507.7	98	56	38	10	18	19	.9	28	2.0	92	19
86	1,558.1-1,558.6	100	37	27	14	10	10	1.0	13	17.	39	11
89	1,631.2-1,631.7	100	50	32	23	18	14	1.3	9	1.6	43	11
90	1,676.6-1,677.1	100	44	31	18	13	8	1.6	13	1.7	44	12
91	1,714.1-1,714.5	99	76	59	29	17	12	1.4	30	1.4	66	16
96	1,916.9-1,917.4	100	66	44	17	22	32	.7	27	1.7	83	18
Core hole 19/17-22J1, 2												
57CAL104	89.6- 90.0	100	48	28	12	20	15	1.3	16	2.0	72	17
107	271.2- 271.7	99	55	31	16	24	11	2.2	15	1.9	74	17
108	310.0- 310.5	98	26	21	17	5	8	.6	4	1.8	16	5
109	350.3- 350.8	100	49	30	16	19	10	1.9	14	1.8	59	15
111	430.9- 431.4	99	46	25	9	21	20	1.0	16	2.0	74	17
112	476.0- 476.4	100	58	33	14	25	16	1.6	19	1.9	84	18
114	553.9- 554.4	100	40	26	18	14	14	1.0	8	1.8	40	11
120	732.0- 732.5	100	43	29	20	14	13	1.1	9	1.7	39	11
121	745.7- 746.2	99	46	33	17	13	14	.9	16	1.7	49	13
123	778.8- 779.3	100	60	44	27	16	14	1.1	17	1.6	53	14
124	789.1- 789.6	100	35	32	26	3	13	.2	6	1.6	14	4
125	799.6- 800.0	100	48	35	17	13	8	1.6	18	1.8	56	14
128	860.7- 861.2	100	35	30	22	5	9	.6	8	1.7	22	6
131	886.6- 889.1	100	65	44	12	21	26	.8	32	1.9	101	21
134	945.4- 945.9	100	48	37	13	11	8	1.4	24	1.8	63	15
135	948.0- 948.5	100	52	35	12	17	15	1.1	23	1.9	76	17
137	971.5- 971.9	100	54	37	18	17	15	1.1	19	1.8	65	16
138	982.8- 983.2	100	50	35	21	15	13	1.2	14	1.7	49	13
139	993.4- 993.9	100	31	30	23	1	7	.1	7	1.6	13	4
141	1,028.0-1,028.5	100	55	38	17	17	10	1.7	21	1.8	68	16
144	1,093.8-1,094.3	100	47	36	22	11	9	1.2	14	1.7	43	11
145	1,104.3-1,104.7	100	57	39	20	18	11	1.6	19	1.7	63	15
146	1,119.6-1,120.1	100	47	35	17	12	12	1.0	18	1.8	54	14
148	1,143.3-1,143.8	100	59	42	14	17	13	1.3	28	1.9	86	19
153	1,209.1-1,209.6	100	41	34	26	7	12	.6	8	1.6	24	7
161	1,321.0-1,321.5	100	50	32	14	18	10	1.8	18	1.8	65	16
167	1,427.9-1,428.4	100	45	30	12	15	10	1.5	18	1.9	63	15
171	1,484.1-1,484.6	100	42	31	19	11	9	1.2	12	1.6	37	10
178	1,574.9-1,575.4	100	34	26	21	8	5	1.6	5	1.7	22	6
181	1,615.0-1,615.5	100	39	31	20	8	7	1.1	11	1.7	32	9
187	1,718.8-1,719.2	99	52	31	9	21	14	1.5	22	1.9	82	18
200	1,956.3-1,956.7	99	48	27	21	21	10	2.1	6	1.7	46	12
201	1,976.0	100	61	36	21	25	14	1.8	15	1.7	68	16
202	1,993.0-1,993.5	99	60	33	32	27	12	2.2	1	1.4	39	11
205	2,064.0-2,064.5	100	56	31	11	25	4	6.2	20	2.0	90	19
Core hole 23/25-16N1												
58CAL100	70.3- 70.4	100	35	29	21	6	9	0.7	8	1.6	22	6
102	155.1- 155.6	98	22	(3)	16	(3)	5	(2)	(2)	1.9	11	3
103	193.5- 194.0	91	25	(3)	18	(3)	5	(2)	(2)	1.8	13	4
105	268.3- 268.8	91	27	21	16	6	8	.8	5	1.9	21	6
106	287.2- 287.7	100	56	38	24	18	9	2.0	14	1.6	51	13
107	294.6- 295.2	100	63	48	19	15	12	1.2	29	1.7	75	17
109	316.4- 316.9	98	34	25	15	9	14	.6	10	1.8	34	9
112	343.0- 343.5	99	38	29	12	9	5	1.8	17	1.9	49	13
113	352.8- 353.3	100	35	27	13	8	6	1.3	14	1.9	42	11
114	362.5- 363.0	92	23	(3)	15	(3)	8	(2)	(2)	1.9	15	4
115	370.3- 370.8	96	31	28	19	3	14	.2	9	1.8	22	6
117	427.1- 427.7	100	40	28	9	12	10	1.2	19	2.0	62	15
120	465.0- 465.5	100	45	36	18	9	9	1.0	18	1.7	46	12
122	482.0- 482.5	100	45	37	12	8	11	.7	25	1.9	63	15
124	508.8- 509.3	96	29	(3)	17	(3)	8	(2)	(2)	1.8	22	6
127	534.0- 534.5	100	23	(3)	24	(3)	10	(2)	(2)	1.6	(4)	---
129	560.6- 561.1	100	31	(3)	18	(3)	14	(2)	(2)	1.7	22	6
131	594.5- 595.0	100	39	26	15	13	6	2.2	11	1.8	43	11
133	616.0- 616.4	92	36	26	14	10	10	1.0	12	1.9	42	11
135	630.7- 631.2	98	26	(3)	23	(3)	13	(2)	(2)	1.6	5	1
137	654.1- 654.6	97	31	(3)	17	(3)	9	(2)	(2)	1.8	25	7
138	660.0- 660.5	99	---	---	22	(3)	---	(2)	---	1.6	---	---
140	682.7- 683.2	100	34	(3)	19	(3)	11	(2)	(2)	1.7	26	7
141	694.0- 694.5	98	24	(3)	20	(3)	14	(2)	(2)	1.7	7	2
143	723.8- 724.3	100	36	22	11	14	10	1.4	11	2.0	50	13
145	748.0- 748.5	96	40	26	12	14	14	1.0	14	2.0	56	14
Core hole 24/26-36A2												
59CAI 313	93.0- 93.5	80	22	18	16	4	6	0.7	2	1.9	11	3
316	124.2- 124.6	88	28	19	14	9	8	1.1	5	1.9	27	8
317	133.0- 133.5	88	25	19	17	6	8	.8	2	1.8	14	4
318	143.8- 144.6	79	29	19	13	10	9	1.1	6	2.0	32	9
319	148.0- 148.5	88	59	25	13	34	14	2.4	12	1.9	87	19
320	156.3- 156.8	92	31	19	14	12	10	1.2	5	2.0	34	9
321	173.0- 173.5	90	35	23	20	12	11	1.1	3	1.8	27	8
325	210.0- 210.5	92	34	25	18	9	9	1.0	7	1.8	29	8
326	220.5- 221.0	76	32	23	19	9	10	.9	4	1.8	23	7
327	231.6- 232.0	85	33	23	17	10	9	1.1	6	1.8	29	8
333	289.8- 290.3	98	36	27	22	9	10	.9	5	1.7	24	7
335	315.3- 315.8	90	29	22	21	7	8	.9	1	1.7	14	4

See footnotes at end of table.

TABLE 6.—*Atterberg limits and indices of samples from core holes*—Continued

Hydrologic Laboratory sample	Depth (feet)	Percent passing No. 40 sieve	Liquid limit	Plastic limit	Shrinkage limit	Plasticity index	Flow index	Toughness index	Shrinkage index	Shrinkage ratio	Volumetric shrinkage	Linear shrinkage
Core hole 24/26-36A2—Continued												
59CAI 338	338.0- 338.5	95	31	22	19	9	7	1.3	3	1.8	22	6
339	356.8- 357.3	89	30	24	21	6	8	.8	3	1.7	15	4
341	370.0- 370.5	80	35	26	17	9	8	1.1	9	1.8	32	9
343	389.1- 389.6	98	31	24	23	7	4	1.8	1	1.6	13	4
344	399.0- 399.5	82	36	26	22	10	12	.8	4	1.7	24	7
345	403.0- 403.5	90	33	24	21	9	9	1.0	3	1.7	20	6
348	433.3- 433.7	90	28	21	20	7	7	1.0	1	1.7	14	4
349	443.0- 443.5	90	33	23	21	10	9	1.1	2	1.7	20	6
352	474.7- 475.3	88	34	23	17	11	10	1.1	6	1.8	31	9
353	488.0- 488.5	93	31	24	20	7	14	.5	4	1.7	19	5
354	494.0- 494.5	88	32	24	19	8	10	.8	5	1.8	23	7
355	507.0- 507.5	94	38	24	18	14	12	1.2	6	1.8	36	10
356	516.3- 516.8	86	38	23	18	15	7	2.1	5	1.8	36	10
357	531.0- 531.5	89	33	22	22	11	13	.8	0	1.7	19	5
361	565.1- 565.6	92	30	25	22	5	9	.6	3	1.7	14	4
362	574.6- 575.1	84	35	23	20	12	11	1.1	3	1.8	27	8
363	582.6- 583.1	91	41	27	20	14	11	1.3	7	1.8	38	10
364	595.1- 595.6	90	30	22	20	8	6	1.3	2	1.8	18	5
365	607.5- 608.0	99	32	23	22	9	9	1.0	1	1.7	17	5
366	613.8- 614.3	96	31	21	21	10	8	1.2	0	1.7	17	5
367	623.0- 623.5	97	55	36	17	19	9	2.1	19	1.8	68	16
368	631.2- 631.7	86	48	36	25	12	11	1.1	11	1.6	37	10
369	648.2- 648.7	94	52	31	16	21	11	1.9	15	1.9	68	16
370	658.8- 659.3	88	33	24	23	9	9	1.0	1	1.7	17	5
373	683.1- 683.5	92	57	36	21	21	18	1.2	15	1.7	61	15
376	719.4- 720.0	96	44	32	30	12	11	1.1	2	1.5	21	6
377	726.1- 726.6	90	24	20	20	4	8	.5	0	1.7	7	2
379	744.0- 744.5	99	46	34	27	12	7	1.7	7	1.6	30	8
380	756.9- 757.4	100	107	48	15	59	24	2.5	33	1.8	166	28
381	763.0- 763.5	92	89	55	19	34	28	1.2	36	1.7	119	23
382	775.6- 776.1	94	37	25	23	12	7	1.7	2	1.7	24	7
383	777.7- 778.2	88	45	33	30	12	7	1.7	3	1.5	22	6
384	791.7- 792.2	96	90	43	16	47	32	1.5	27	1.8	133	25
385	843.3- 843.8	100	72	40	24	32	24	1.3	16	1.6	77	17
386	852.0- 852.5	100	51	35	28	16	26	.6	7	1.5	34	9
388	866.3- 866.8	100	49	30	21	19	10	1.9	9	1.7	48	13
389	916.4- 916.9	100	74	41	24	33	18	1.8	17	1.6	80	18
390	1,036.3-1,036.8	100	84	44	18	40	20	2.0	26	1.7	112	22
393	1,116.8-1,117.3	93	62	39	18	23	9	2.6	21	1.7	75	17
394	1,155.4-1,155.9	93	73	46	31	27	13	2.1	15	1.5	63	15
396	1,240.5-1,241.0	100	92	61	44	31	12	2.6	17	1.2	58	15
397	1,363.0-1,363.5	100	70	47	37	23	10	2.3	10	1.3	43	11
401	1,446.9-1,447.4	100	89	62	39	27	9	3.0	23	1.3	65	16
403	1,526.6-1,527.1	100	84	57	28	27	8	3.4	29	1.5	84	18
404	1,688.0-1,688.5	100	93	58	20	35	28	1.3	38	1.7	124	24
410	1,826.5-1,827.0	100	81	50	9	31	15	2.1	41	2.0	144	26
411	1,892-2-1,892.7	100	81	51	5	30	14	2.1	46	2.1	160	27
Core hole 6S/2W-24C7												
60CAL12	71.4- 71.9	100	30	20	15	10	11	0.9	5	1.9	28	8
13	90.4- 90.8	100	47	25	18	22	11	2.0	7	1.8	52	13
16	120.3- 120.8	100	47	27	19	20	11	1.8	8	1.8	50	13
18	140.8- 141.4	96	42	22	12	20	8	2.5	10	2.0	60	15
20	160.0- 160.5	100	50	26	14	24	16	1.5	12	1.9	68	16
22	191.3- 191.8	97	38	18	8	20	12	1.7	10	2.2	66	16
24	222.3- 222.8	100	55	29	15	26	15	1.7	14	1.9	76	17
27	253.4- 253.8	98	26	21	18	5	5	1.0	3	1.8	14	4
28	307.0- 307.4	100	40	23	14	17	11	1.5	9	1.9	49	13
30	330.0- 330.5	100	42	24	16	18	14	1.3	8	1.8	47	12
31	344.3- 344.8	100	34	21	18	13	4	3.3	3	1.8	29	8
32	361.3- 361.8	95	38	25	19	13	9	1.4	6	1.8	34	9
33	408.4- 408.9	99	42	22	16	20	11	1.8	6	1.9	49	13
36	436.7- 437.2	96	34	21	18	13	14	.9	3	1.8	29	8
38	458.3- 458.8	100	32	21	18	11	11	1.0	3	1.8	25	7
40	522.5- 522.9	95	33	20	16	13	8	1.6	4	1.8	31	9
43	563.2- 563.7	98	49	24	18	25	8	3.1	6	1.8	56	14
45	605.3- 605.8	96	40	18	16	22	14	1.6	2	1.9	46	12
46	633.8- 634.3	100	33	19	18	14	13	1.1	1	1.8	27	8
48	665.5- 665.9	98	35	21	20	14	15	.9	1	1.7	26	7
49	715.5- 716.1	99	61	27	14	34	16	2.1	13	1.9	89	19
51	744.9- 745.4	100	68	30	14	38	15	2.5	16	1.9	103	21
52	756.4- 756.9	100	63	28	12	35	17	2.1	16	2.0	102	21
54	789.5- 790.0	99	67	31	14	36	12	3.0	17	1.9	101	21
56	812.0- 812.5	100	48	24	13	24	16	1.5	11	2.0	70	16
59	842.2- 842.7	100	46	27	18	19	12	1.6	9	1.8	50	13
61	865.9- 866.4	100	58	30	14	28	16	1.8	16	2.0	88	19
64	900.2- 900.7	100	60	28	14	32	14	2.3	14	2.0	92	19
66	923.6- 924.1	100	64	32	14	32	15	2.1	18	2.0	100	21
68	958.3- 958.8	100	58	32	14	26	12	2.2	18	1.9	84	19
Core hole 7S/1E-16C6												
72	232.5- 233.0	100	41	24	16	17	3	5.7	8	1.9	48	13
75	301.0- 301.5	98	31	19	14	12	4	3.0	5	1.9	32	9
78	354.5- 355.0	99	24	21	18	3	2	1.5	3	1.8	11	3
80	430.1- 430.6	98	32	19	14	13	3	4.3	5	1.9	34	9
82	509.5- 510.0	91	33	19	14	14	6	2.3	5	2.0	38	10
84	554.3- 554.8	95	25	18	14	7	2	3.5	4	1.9	21	6
87	696.3- 696.8	95	33	20	16	13	3	4.3	4	1.9	32	9
91	790.6- 791.1	98	32	20	16	12	3	4.0	4	1.8	29	8
93	832.4- 832.9	99	29	22	18	7	2	3.5	4	1.8	20	6
96	937.4- 937.9	99	50	25	19	25	7	3.6	6	1.8	56	14

[1] Insufficient sample. [2] Nondeterminable. [3] Nonplastic. [4] Negative value.

TABLE 7.—*Acid solubility and gypsum content of samples from core holes*

Hydrologic Laboratory sample	Sample depth (feet)	Acid solubility (percent)	Gypsum content	
			(meg per 100 g soil)	(Tons per acre-foot)
Core hole 14/13-11D1				
57CAL1	77.0- 77.5	5.6	----------	----------
2	110.5- 111.0	8.4	0	0
4	191.5- 192.0	6.4	0	0
6	277.1- 277.6	4.8	0	0
8	353.0- 353.5	5.6	0	0
9	398.0- 389.5	10.0	----------	----------
10	432.0- 432.5	10.8	0	0
11	471.5- 472.0	6.4	----------	----------
12	510.3- 510.8	10.4	0	0
14	594.0- 594.5	8.0	----------	----------
16	646.6- 647.1	6.8	0	0
18	662.1- 662.6	7.2	0	0
20	682.5- 683.0	3.6	0	0
21	697.0- 697.5	8.8	----------	----------
22	707.0- 707.5	.8	0	0
24	721.5- 722.0	4.0	0	0
26	743.0- 743.5	5.2	0	0
28	764.9- 765.4	1.2	0	0
30	784.5- 785.0	3.2	0	0
31	791.0- 791.5	2.8	----------	----------
32	802.0- 802.5	4.8	0	0
34	813.0- 821.0	2.0	0	0
36	831.5- 832.0	4.0	0	0
38	853.0- 853.5	2.0	0	0
40	867.0- 867.5	4.0	0	0
42	877.0- 877.5	4.0	0	0
43	887.5- 888.0	6.0	----------	----------
44	901.0- 901.5	4.4	0	0
46	917.2- 917.7	.8	0	0
48	936.5- 937.0	4.0	0	0
50	957.5- 958.0	1.6	0	0
52	984.0- 984.5	3.6	0	0
53	987.6- 988.0	3.6	----------	----------
54	1,000.5-1,001.0	2.0	0	0
56	1,020.8-1,021.3	4.0	0	0
58	1,039.5-1,040.0	7.2	9	0
60	1,063.5-1,064.0	5.2	0	0
62	1,075.0-1,075.5	4.4	0	0
64	1,092.0-1,092.5	3.6	0	0
66	1,113.5-1,114.0	2.4	0	0
68	1,133.0-1,133.5	5.2	0	0
70	1,174.0-1,174.5	1.2	0	0
72	1,219.0-1,219.5	4.0	0	0
74	1,232.0-1,232.5	3.2	0	0
76	1,252+-1,252.5	4.4	0	0
78	1,269.5-1,270.0	6.4	0	0
80	1,284.0-1,284.5	2.8	0	0
81	1,293.0-1,293.5	4.0	----------	----------
82	1,300—-1,300.5	3.2	0	0
84	1,319.4-1,319.9	3.2	0	0
86	1,339.5-1,340.0	5.2	----------	----------
88	1,357.0-1,357.5	4.4	0	0
90	1,373.4-1,373.9	7.6	0	0
92	1,397.0-1,397.5	14.8	0	0
94	1,415.0-1,415.5	6.0	0	0
96	1,432.5-1,433.0	8.8	0	0
98	1,454.5-1,455.0	6.8	0	0
100	1,474.0-1,474.5	5.2	0	0
102	1,487.0-1,487.5	6.0	0	0
103	1,494.5-1,495.0	5.2	----------	----------
Core hole 16/15-34N1				
58CAL2	298.2- 298.7	8.2	0	0
4	371.7- 372.1	5.2	0	0
5	418.5- 419.0	12.2	----------	----------
6	454.3- 554.8	8.8	0	0
8	507.4- 507.9	9.2	0	0
10	525.9- 526.3	13.6	0	0
12	552.8- 553.2	8.0	0	0
14	570.7- 571.2	8.8	----------	----------
16	591.7- 592.2	2.0	0	0
17	601.7- 602.2	4.0	----------	----------
18	622.3- 622.8	4.0	0	0
20	643.2- 643.7	7.6	0	0
22	666.0- 666.5	9.2	0	0
24	683.7- 684 2	8.8	0	0
25	696.6- 697 1	11.6	----------	----------
26	701.8- 70[illegible] 4	9.6	0	0
28	721.3- 721 8	6.8	0	0
30	745.3- 745.9	9.2	0	0
32	762.4- 762.9	8.4	0	0
34	785.0- 785.5	3.2	0	0
35	795.0- 795.5	11.0	----------	----------
36	806.1- 806.6	9.2	0	0
38	822.1- 822.6	9.2	0	0
40	837.7- 838.2	8.8	0	0
42	860.1- 860.6	5.6	0	0
44	876.6- 877.1	3.6	0	0
45	891.6- 892.1	11.6	----------	----------
46	901.2- 901.7	9.6	0	0
Core hole 16/15-34N1—Continued				
58CAL48	922.6- 923.1	8.4	0	0
50	940.6- 941.1	9.6	0	0
52	963.7- 964.2	4.8	0	0
54	980.6- 981.1	6.4	0	0
56	1,012.2-1,012.7	1.8	0	0
58	1,042.8-1,043.3	6.0	0	0
59	1,154.0-1,154.5	1.2	----------	----------
60	1,181.2-1,181.7	9.6	0	0
62	1,202.5-1,203.0	7.0	0	0
64	1,238.1-1,238.6	6.0	0	0
66	1,254.9-1,255.4	6.0	0	0
67	1,280.2-1,280.7	3.4	----------	----------
68	1,325.5-1,326.0	6.8	0	0
70	1,351.4-1,351.9	4.8	0	0
72	1,371.5-1,372.0	5.2	0	0
73	1,391.7-1,392.2	3.0	----------	----------
74	1,401.8-1,402.3	2.8	0	0
76	1,421.5-1,422.0	4.8	0	0
78	1,458.9-1,459.4	1.6	0	0
80	1,482.7-1,483.2	6.8	0	0
82	1,506.7-1,507.2	1.4	0	0
84	1,526.0-1,526.5	4.0	0	0
86	1,558.1-1,558.6	3.2	0	0
88	1,589.3-1,589.8	5.4	0	0
90	1,676.6-1,677.1	6.0	0	0
91	1,714.1-1,714.5	4.4	----------	----------
92	1,752.0-1,752.5	8.0	0	0
94	1,837.6-1,838.1	5.4	0	0
96	1,916.9-1,917.4	6.8	0	0
97	1,953.0-1,953.5	6.0	----------	----------
98	1,990.0-1,990.5	4.0	0	0
Core hole 19/17-22J1, 2				
57CAL104	89.6- 90.0	5.6	0	0
105	160 - 172	16.0	----------	----------
106	233.8- 234.4	----------	0	0
107	271.2- 271.7	10.8	----------	----------
108	310.0- 310.5	----------	0	0
110	399.4- 399.9	4.0	0	0
112	476.0- 476.4	8.4	0	0
114	553.9- 554.4	----------	0	0
115	593.3- 593.8	5.6	----------	----------
116	631.2- 631.7	----------	0	0
117	676.0- 676.4	5.6	----------	----------
118	712.8- 713.2	----------	0	0
120	732.0- 732.5	----------	0	0
122	767.1- 767.6	----------	0	0
124	789.1- 789.6	----------	0	0
125	799.6- 800.0	8.8	----------	----------
126	810.0- 810.5	----------	0	0
128	860.7- 861.2	----------	0	0
130	870.0- 870.5	----------	0	0
131	888.6- 889.1	10.4	----------	----------
132	905.3- 905.7	----------	0	0
134	945.4- 945.9	----------	0	0
136	958.0- 958.5	----------	0	0
138	982.8- 983.2	----------	0	0
139	993.4- 993.9	6.8	----------	----------
140	1,003.1-1,003.6	----------	0	0
142	1,032.0-1,032.5	----------	0	0
144	1,093.8-1,094.3	8.0	0	0
146	1,119.6-1,120.1	----------	0	0
148	1,143.3-1,143.8	----------	0	0
150	1,159.8-1,160.3	----------	0	0
152	1,198.5-1,199.2	6.4	0	0
154	1,216.0-1,216.5	----------	0	0
156	1,247.4-1,247.9	----------	0	0
158	1,283.3-1,283.8	----------	0	0
159	1,291.0-1,291.5	8.0	----------	----------
160	1,305.9-1,306.4	----------	0	0
162	1,346.5-1,347.0	----------	0	0
164	1,376.2-1,376.8	----------	0	0
165	1,392.0-1,392.5	9.2	----------	----------
166	1,416.8-1,417.4	----------	0	0
168	1,432.7-1,433.2	----------	0	0
170	1,480.0-1,480.5	----------	0	0
172	1,498.2-1,498.7	11.2	0	0
174	1,526.5-1,526.9	----------	0	0
176	1,543.7-1,544.2	----------	0	0
178	1,574.9-1,575.4	----------	0	0
179	1,590.2-1,590.7	7.2	----------	----------
180	1,605.0-1,605.5	----------	0	0
182	1,642.0-1,642.5	----------	0	0
184	1,668.5-1,668.9	----------	0	0
186	1,698.5-1,699.0	4.8	0	0
188	1,727.5-1.728.0	----------	0	0
190	1,779.3-1,779.8	12.0	0	0
192	1,804.5-1,805.0	----------	7.4	12.7
194	1,841.4-1,842.0	----------	0	0
196	1,873.1-1,873.6	----------	2.3	4.0

TABLE 7.—*Acid solubility and gypsum content of samples from core holes*—Continued

Hydrologic Laboratory sample	Sample depth (feet)	Acid solubility (percent)	Gypsum content (meg per 100 g soil)	Gypsum content (Tons per acre-foot)
Core hole 19/17-22J1.2—Continued				
57CAL197	1,899.3-1,899.8	8.4	----	----
198	1,912.5+	----	0	0
200	1,956.3-1,956.7	----	4.4	7.6
202	1,993.0-1,993.5	8.8	0	0
204	2,049.3-2,049.7	----	0	0
206	2,092.2-2,092.6	9.6	0	0
Core hole 23/25-16N1				
58CAL102	155.1- 155.6	1.7	0	0
106	287.2- 287.7	7.1	0	0
109	316.4- 316.9	8.8	0	0
110	320.3- 320.8	----	0	0
113	352.8- 353.3	7.6	0	0
116	418.0- 418.5	7.0	0	0
120	465.0- 465.5	4.7	0	0
123	496.0- 496.5	3.7	0	0
125	511.0- 511.5	7.6	0	0
128	545.5- 546.0	3.5	0	0
131	594.5- 595.0	2.9	0	0
133	616.0- 616.4	5.0	0	0
135	630.7- 631.2	6.2	0	0
137	654.1- 654.6	6.1	0	0
139	673.1- 673.6	7.0	0	0
141	694.0- 694.5	6.2	0	0
144	730.5- 731.0	11.1	0	0
Core hole 24/26-36A2				
59CAL310	54.3- 54.8	1.7	0	0
311	63.4- 63.9	2.0	----	----
312	84.6- 85.1	2.9	----	----
313	93.0- 93.5	2.8	----	----
314	102.6- 103.1	1.5	0	0
315	117.6- 118.1	2.4	----	----
316	124.2- 124.6	2.9	----	----
317	133.0- 133.5	3.2	----	----
318	143.8- 144.6	3.7	0	0
319	148.0- 148.5	6.0	----	----
320	156.3- 156.8	1.7	----	----
321	173.0- 173.5	4.4	----	----
322	176.3- 176.8	3.8	0	0
323	187.0- 187.5	2.4	----	----
324	203.5- 204.0	4.1	----	----
325	210.0- 210.5	5.2	----	----
326	220.5- 221.0	4.5	0	0
327	231.6- 232.0	4.4	----	----
328	240.2- 240.7	1.8	----	----
329	251.5- 251.9	1.5	----	----
330	260.2- 260.7	7.3	0	0
331	263.5- 274.0	2.8	----	----
332	284.5- 284.9	7.1	----	----
333	289.8- 290.3	4.8	----	----
334	300.5- 301.0	7.8	0	0
335	313.3- 315.8	4.4	----	----
336	318.0- 318.5	8.8	----	----
337	328.5- 329.0	6.4	----	----
338	338.0- 338.5	7.6	0	0
339	356.8- 357.3	10.0	----	----
340	358.7- 359.2	10.2	----	----
341	370.0- 370.5	7.2	----	----
342	374.3- 374.8	4.9	0	0
343	389.1- 389.6	4.8	----	----
344	399.1- 399.5	12.8	----	----
345	403.0- 403.5	5.2	----	----
346	414.9- 415.4	7.0	0	0
347	423.0- 423.5	2.8	----	----
348	433.3- 433.7	9.0	----	----
349	443.0- 443.5	4.0	----	----
350	458.5- 459.0	3.4	0	0
351	467.3- 467.8	.8	----	----
352	474.7- 475.3	4.7	----	----
353	488.0- 488.5	4.4	----	----
354	494.0- 494.5	3.7	0	0
355	507.0- 507.5	6.0	----	----
356	516.3- 516.8	7.6	----	----
357	531.0- 531.5	3.6	----	----
358	533.1- 533.6	2.9	0	0
359	544.0- 544.5	3.2	----	----
360	552.6- 553.1	3.5	----	----
361	565.1- 565.5	4.0	----	----
362	574.6- 575.1	5.1	0	0
363	582.6- 583.1	6.4	----	----
364	595.1- 595.6	2.9	----	----
365	607.5- 608.0	8.8	----	----
366	613.8- 614.3	5.0	0	0
367	623.0- 623.5	9.2	----	----
Core hole 24/26-36A2—Continued				
59CAL368	631.2- 631.7	6.2	----	----
369	648.2- 648.7	6.8	----	----
370	658.8- 659.3	6.1	0	0
371	668.3- 668.8	4.0	----	----
372	678.5- 679.0	7.0	0	0
373	683.1- 683.5	8.0	----	----
374	697.5- 698.0	6.2	2.8	4.8
375	709.0- 709.5	4.8	----	----
376	719.4- 720.0	12.1	0	0
377	726.1- 726.6	3.2	----	----
378	735.4- 735.9	11.1	0	0
379	744.0- 744.5	8.8	----	----
380	756.9- 757.4	6.4	----	----
382	775.6- 776.1	20.8	0	0
384	791.7- 792.2	7.9	----	----
386	852.0- 852.5	7.3	0	0
388	866.3- 866.8	11.4	----	----
389	916.4- 916.9	3.2	0	0
390	1,036.3-1,036.8	7.8	0	0
392	1,099.1-1,099.6	1.8	4.2	7.2
394	1,155.4-1,155.9	1.5	.2	.3
396	1,240.5-1,241.0	3.4	0	0
398	1,369.5-1,370.0	4.3	----	----
399	1,421.2-1,421.7	1.0	4.7	8.1
400	1,431.0-1,431.5	1.2	----	----
402	1,492.0-1,492.5	4.0	5.1	8.8
403	1,526.6-1,527.1	----	0	0
404	1,688.0-1,688.5	2.0	0	0
405	1,720.4-1,720.9	8.1	14.2	24.4
406	1,751.7-1,752.2	12.5	8.6	14.8
407	1,785.0-1,785.5	6.1	14.1	24.3
408	1,802.5-1,803.0	7.5	9.3	16.0
410	1,826.5-1,827.0	5.6	10.3	17.7
411	1,892.2-1,892.7	----	12.0	20.6
412	1,911.5-1,912.0	2.2	0	0
414	1,955.5-1,956.0	.8	0	0
416	2,010.0-2,010.5	.4	----	----
418	2,102.0-2,102.5	.4	0	0
419	2,174.0-2,174.5	1.0	----	----
Core hole 6S/2W-24C7				
60CAL10	36.5- 37.0	10.1	0	0
12	71.4- 71.9	10.4	----	----
13	90.4- 90.8	7.2	0	0
16	120.3- 120.8	7.8	0	0
18	140.8- 141.4	9.7	0	0
21	178.0- 178.5	12.5	----	----
22	191.3- 191.8	10.0	0	0
24	222.3- 222.8	7.5	----	----
27	253.4- 253.8	10.5	0	0
28	307.0- 307.4	7.9	0	0
31	344.3- 344.8	13.0	0	0
32	361.3- 361.8	11.8	----	----
33	408.4- 408.9	12.4	0	0
36	436.7- 437.2	11.4	----	----
38	458.3- 458.8	11.6	0	0
40	522.5- 522.9	12.1	0	0
41	545.0- 545.5	10.9	----	----
43	563.2- 563.7	9.0	----	----
45	605.3- 605.8	9.3	0	0
46	633.8- 634.3	19.1	----	----
48	665.5- 665.9	7.5	0	0
49	715.5- 716.1	11.2	0	0
51	744.9- 745.4	11.0	----	----
54	789.5- 790.0	8.7	----	----
56	812.0- 812.5	8.9	0	0
59	842.2- 842.7	10.8	----	----
61	865.9- 866.4	11.9	0	0
64	900.2- 900.7	10.2	----	----
66	923.6- 924.1	6.5	0	0
68	958.3- 958.8	12.0	0	0
Core hole 7S/1E-16C6				
70	196.3- 196.8	15.6	0	0
74	275.4- 275.8	11.4	0	0
78	354.5- 355.0	11.0	0	0
80	430.1- 430.6	12.7	0	0
84	554.3- 554.8	12.9	0	0
86	598.8- 599.3	13.5	0	0
87	696.3- 696.8	17.7	0	0
90	750.1- 750.5	12.2	0	0
93	832.4- 832.9	18.4	0	0
96	937.4- 937.9	16.1	0	0

TABLE 8.—*Visual classification, Atterberg limits, and specific gravities of samples tested for consolidation*

[Data from Earth Laboratory, U.S. Bureau of Reclamation, Denver, Colo.]

Earth Laboratory sample	Depth (feet)	Gradation (estimated)				Color (wet)	Soil classification and description	Unified Soil Classification symbol	Atterberg limits			Specific gravity of solids
		Maximum size (U.S. Standard sieve No.)	Gravel >4.76 mm (percent)	Sand, 4.76–0.074 mm (percent)	Silt and clay <0.074 mm (percent)				Liquid limit (percent)	Plastic limit (percent)	Plasticity index	
Core hole 12/12–16H1												
23L91	84.3– 84.6	30	0	10	90	Brown	Clay, containing some fine sand; medium plasticity; slight dilatancy; medium dry strength; no reaction to HCl; trace of gypsum.	CL	31	14	17	2.80
92	159.4– 159.8	100	0	10	90	do	Clay, containing some fine sand; medium to high plasticity; slow dilatancy; medium reaction to HCl.	CL–CH	50	19	31	2.74
93	230.8– 231.2	50	0	10	90	Tan to brown	Clay, lean; low plasticity; slight dilatancy; low dry strength; slight reaction to HCl.	CL	33	11	22	2.73
94	324.5– 324.9	100	0	20	80	Gray	Clay, containing fine sand; low plasticity; medium dilatancy; ome micaceous material present; no reaction to HCl.	CL	29	19	10	2.68
95	374.0– 374.5	200	0	0	100	do	Clay, fat; high plasticity; no dilatancy; no reaction to HCl	CH	54	23	31	2.73
96	425.0– 425.3	100	0	10	90	do	Clay, fat, containing fine sand lenses; high plasticity; no dilatancy; no reaction to HCl; moist, and firm.	CH	76	27	49	2.67
97	471.2– 471.5	100	0	5	95	do	Clay, fat; high plasticity; no dilatancy; lensed with fine sand	CH	58	20	38	2.68
98	516.5– 516.9	50	0	75	25	Gray to black	Sand, fine, no plasticity; fast dilatancy; strong organic odor present; soft and loosely cemented.	SM			(1)	2.70
99	579.0– 579.3	100	0	35	65	Tan	Clay, silty containing fine sand; medium plasticity; slight dilatancy.	CL	32	14	18	2.69
100	625.0– 625.4	200	0	0	100	Gray	Clay, fat; high plasticity; no dilatancy; firm; numerous planes containing some silt.	CH	59	19	40	2.79
101	675.9– 676.2	50	0	45	55	do	Clay, silty containing fine sand, medium plasticity, slow dilatancy; clay on outer surface; sand in center, angular.	CL	45	14	31	2.72
102	722.0– 722.3	100	0	5	95	do	Clay, fat; high plasticity; no dilatancy, blocky structure; fractures contain silt.	CH	70	20	50	2.69
103	773.0– 773.4	50	0	60	40	Brown to gray	Sand, fine containing silt; no plasticity; fast dilatancy; lensed with clay and silt; medium cementation; no reaction to HCl.	SM			(1)	2.77
104	821.4– 821.8	50	0	55	45	Gray	Sand, fine containing silt; no plasticity; fast dilatancy; organic odor present; no reaction to HCl.	SM			(1)	2.74
105	877.4– 877.8	30	0	65	35	Brown	Sand, fine, uniform; no plasticity; fast dilatancy; free water present; no reaction to HCl.	SM			(1)	2.71
106	926.8– 927.2	50	0	20	80	Gray	Clay, silty; medium plasticity; slow dilatancy; no reaction to HCl; top of sample contained sand of No. 30 size; rest of sample was silt and clay lensed.	CL	47	32	15	2.72
107	972.0– 972.4	30	0	75	25	do	Sand, fine: no plasticity; fast dilatancy; slight binder	SM			(1)	2.70
108	998.6– 999.0	50	0	40	60	Brown	Clay containing fine sand; medium plasticity, slow dilatancy; sample lensed with clay and fine sand.	CL	37	20	17	2.68
Core hole 14/13–11D1												
23L80	315.0– 315.3	50	0	80	20	Brown	Sand, fine, angular, poorly graded, loosely cemented, wet	SP				
194	397.0– 397.3	100	0	10	90	do	Clay, silty; medium plasticity; slight dilatancy; medium reaction to HCl.	CL				
81	554.0– 554.4	50	0	10	90	Tan-gray	Clay containing some fine sand; medium to high plasticity; slow to no dilatancy; structure slightly blocky.	CL				
195	642.0– 642.3	100	0	0	100	Gray	Clay; high plasticity; no dilatancy; no reaction to HCl (sample not tested because of fractured condition).	CH				
82	644.8– 645.2	50	0	10	90	do	Clay containing some fine sand; medium plasticity; slow dilatancy; some slickensides; sample was not suitable for testing because of many fractures and poor condition.	CL				
83	699.0– 699.4	100	0	10	90	do	Clay, lean; medium plasticity; no to slow dilatancy, low dry strength.	CL				
84	746.0– 746.4	50	0	45	55	do	Clay containing very fine sand and silt; medium to high plasticity; no to slow dilatancy.	CL				
196$_1$[2]	832.3–832.7		0	60	40	Light gray	Sand, fine, angular, containing clay; slight plasticity; slight dilatancy; micaceous material present; breaks down on wetting and working; not tested because of wax and poor condition of top half.	SC				
196$_2$[3]	832.3– 832.7	50	0	20	80	Gray	Clay containing some fine sand; medium plasticity; medium dilatancy; slight micaceous material; no reaction to HCl.	CL				
85	983.6– 984.0	100	0	5	95	Brown	Clay containing some fine sand; medium to high plasticity; no to slow dilatancy.	CL				
86	1,076.0–1,076.4	50	0	60	40	do	Sand, silty; slight plasticity; fast dilatancy; micaceous; slight cementation.	SM				
87	1,249.0–1,249.4	16	0	8	15	do	Sand, coarse to fine; skip graded; wet; micaceous; not suitable for testing because of drilling mud penetration.	SP				

88	1,350.5–1,350.8	16	0	85	15	do	Sand, coarse to fine; uniform graded; angular to rounded; free H_2O.	SP				
89	1,395.0–1,395.3	100	0	0	100	do	Clay, lean; medium plasticity; slow dilatancy; blocky structure; granular feeling and appearance which breaks down on wetting; very hard and brittle.	CL				
90	1,450.0–1,450.3	50	0	45	55	do	Clay containing fine sand, medium plasticity slight dilatancy, sample blocky and fractured.	CL				
							Core hole 16/15–34N1					
23L197	299.1– 299.5	100	0	0	100	Tan	Clay, silty; medium to high plasticity; no dilatancy; moist	CH	52	21	31	2.7
198	418.1– 418.5	100	0	0	100	do	Clay, lean; medium plasticity; no dilatancy	CL	44	18	26	2.71
200	538.9– 539.2	100	0	0	100	Brown	Clay, fat; medium plasticity; no dilatancy	CH	56	21	35	2.73
235	563.3– 563.7							CH				2.77
201	571.2– 571.6	200	0	0	100	Gray	Clay, fat; high plasticity; no dilatancy	CH	83	29	54	2.74
202	636.9– 637.3	200	0	0	100	do	do	CH	80	25	55	2.75
204	713.1– 713.4	100	0	0	100	Tan	Clay, silty; high plasticity; no dilatancy	CH	61	24	37	2.74
206	859.7– 860.1	30	0	60	40	Gray	Sand containing silt and clay; low plasticity; medium dilatancy	SC	31	18	13	2.68
207	901.7– 902.1	100	0	0	100	Brown	Clay containing silt; high plasticity; no dilatancy; sample fractured.	CH	72	24	48	2.75
208	972.0– 972.4	50	0	5	100	do	Clay containing silt; high plasticity; no dilatancy	CH	69	22	47	2.74
210	1,153.6–1,154.0	50	0	20	80	Gray	Clay, silty, containing fine sand; medium plasticity; no dilatancy.	CL	36	19	17	2.71
212	1,237.7–1,238.1	200	0	0	100	do	Clay, fat; high plasticity; no dilatancy; sample fractured	CH	67	27	40	2.76
214	1,332.4–1,332.8	30	0	75	25	do	Sand, fine, containing silt; nonplastic; fast dilatancy	SM		(1)	(1)	2.71
215	1,391.3–1,391.7	30	0	50	50	do	Sand, fine, containing clay and silt; low plasticity; fast dilatancy.	SM	32	22	10	2.70
217	1,511.3–1,511.7	50	0	20	80	do	Clay, sandy, fine; high plasticity; no dilatancy	CH	95	24	71	2.69
219	1,631.7–1,632.1	100	0	0	100	do	Clay, fat; high plasticity; no dilatancy	CH	58	23	35	2.71
221	1,792.3–1,792.7	30	0	15	85	Brown	Clay, sandy, fine; medium plasticity; no dilatancy	CH	55	22	33	2.71
222	1,871.8–1,872.2	100	0	0	100	Gray	Clay, fat; high plasticity; no dilatancy	CH	77	26	51	2.72
223	1,952.6–1,953.0	200	0	0	100	do	do	CH	107	48	59	2.55
							Core hole 19/17–22J1, 2					
23L181	311.5– 311.9	100	0	5	95	Brown	Clay, silty; low to medium plasticity; slight to slow dilatancy; no reaction to HCl; soft, wet natural condition.	CL				
182	554.4– 554.8	50	0	10	90	do	Clay, silty; somewhat more silt than 23L181; low to medium plasticity; medium to fast dilatancy; high reaction to HCl; low cementation in sample; higher moisture at outside edge of sample possibly due to drilling fluid.	CL				
183	734.6– 734.9	100	0	5	95	Dark gray	Clay, silty; low to medium plasticity; slight dilatancy; no reaction to HCl; firm blocky structure; slight amount of mica and organic material present.	CL				
184	904.9– 905.3	100	0	10	90	Tan	Clay containing some silt; medium plasticity; medium dilatancy moist; slight reaction to HCl; sample has slickensides present.	CL				
185	1,093.4–1,093.8	50	0	20	80	Brown	Silt containing trace of fine sand; low plasticity; medium to fast dilatancy; slight reaction to HCl.	ML				
186	1,251.0–1,251.4	50	0	15	85	Tan	Silt, somewhat clayey; medium plasticity; medium dilatancy; slight reaction to HCl.	ML				
187	1,345.2–1,345.6	8	0	40	60	do	Silt containing fine sand; low plasticity; medium to fast dilatancy; slightly micaceous; breaks down on wetting and working; high reaction to HCl.	ML				
188	1,524.3–1,524.7	30	0	60	40	Brown	Sand, silty, fine to medium; low plasticity; medium to fast dilatancy; not suitable for testing because drilling mud and wax penetrated sample.	SM				
189	1,601.2–1,601.5	50	0	60	40	do	Sand, silty, fine, nonplastic; fast dilatancy; micaceous and firm; slight reaction to HCl.	SM				
190	1,749.6–1,750.0	100	0	0	100	do	Clay, silty; medium plasticity; medium dilatancy; slight reaction to HCl.	CL				
191	1,955.9–1,956.3	100	0	10	90	Gray	Clay, lean, dense; medium plasticity; slow dilatancy; no reaction to HCl.	CL				
192	2,021.0	100	0	10	90	do	Clay, lean, dense; medium plasticity; slow to no dilatancy; lensed with fine sand; no reaction to HCl.	CL				
193	2,092.9 +	100	0	10	90	do	Clay, lean, very dense; medium plasticity; medium to fast dilatancy; mottled carbonate concressions; micaceous; breaks down on working; brittle and hard.	CL				

See footnotes at end of table.

TABLE 8.—*Visual classification, Atterberg limits, and specific gravities of samples tested for consolidation*—Continued

Earth Laboratory sample	Depth (feet)	Gradation (estimated): Maximum size (U.S. Standard sieve No.)	Gradation (estimated): Gravel >4.76 mm (percent)	Gradation (estimated): Sand, 4.76–0.074 mm (percent)	Gradation (estimated): Silt and clay <0.074 mm (percent)	Color (wet)	Soil classification and description	Unified Soil Classification symbol	Atterberg limits: Liquid limit (percent)	Atterberg limits: Plastic limit (percent)	Atterberg limits: Plasticity index	Specific gravity of solids
Core hole 23/25–16N1												
23L226	261.7 - 261.9	16	0	55	45	Brown	Sand containing clay, medium to fine; medium plasticity; no dilatancy; sample not homogeneous, well cemented.	SC	23	17	6	2.73
227	283.5 - 283.9	50	0	10	90	Gray	Clay containing some fine sand; medium to high plasticity; no dilatancy.	CL-CH	51	27	24	2.79
228	292.0 - 292.4	50	0	20	80	Gray-brown	Clay containing fine sand; medium plasticity; no dilatancy	CL	44	28	16	2.75
229	450.1 - 450.5	100	0	5	95	Brown	Clay, silty; medium plasticity; no dilatancy	CL	42	22	20	2.80
232	630.3 - 630.7	4	0	55	45	do	Sand, silty (some clay); low plasticity; medium to fast dilatancy.	SM	26	(1)	(1)	2.73
234	723.5 - 723.8	50	0	40	60	do	Silt sandy (some clay); low plasticity; medium to fast dilatancy.	ML	36	30	6	2.74
Core hole 24/26–36A2												
23L236	123.1 - 123.4	8	0	15	85	Brown	Clay, silty, containing medium to fine sand; low dilatancy; medium plasticity.	CL	29	17	12	2.71
237	157.1 - 157.4	8	0	80	20	do	Sand, medium to fine; no plasticity; some clay binder	SC	30	16	14	2.71
238	315.0 - 315.3	8	0	60	40	do	Sand, medium to fine, containing some clay, very firm, brittle, well cemented; not tested because of fractures and drilling mud.	SC				
239	443.0- 443.2	8	0	70	30	Tan	Sand containing clay, medium to fine; low plasticity; no dilatancy; micaceous.	SC	30	18	12	2.76
240	516.0- 516.3	50	0	20	80	Brown	Clay, silty, containing fine sand; no dilatancy; medium plasticity; moist, firm, micaceous.	CL	43	23	20	2.75
241	607.2- 607.5	4	0	20	80	Tan	Silt containing fine sand; slow dilatancy; slight plasticity; some sand in concretions.	ML	33	23	10	2.73
242	725.6- 725.9	50	0	15	85	Gray	Clay, silty; some fine sand; medium plasticity; no dilatancy; micaceous.	CL	49	27	22	2.73
243	843.0- 843.3	200	0	0	100	do	Clay, fat; high plasticity; no dilatancy	CH	99	36	63	2.71
244	916.1- 916.4	100	0	5	95	do	Clay, fat; high plasticity; no dilatancy; micaceous	CH	70	21	49	2.69
245	1,036.0-1,036.3						Similar to sample 244; not tested because of numerous cracks	CH				
246	1,115.7-1,116.1	50	0	20	80	Gray	Clay, fat; fine-to medium-sand pockets; high plasticity; no dilatancy; firm; micaceous.	CH	67	25	42	2.70
247	1,155.1-1,155.4	100	0	5	95	do	Clay, fat; high plasticity; no dilatancy; small amount of sand in pockets; micaceous.	CH	70	33	37	2.68
248	1,241.0-1,241.3	100	0	5	95	do	Clay, fat; lensed with silt; high plasticity; no dilatancy; firm	CH-MH	94	41	53	2.66
249	1,362.7-1,363.0	100	0	5	95	do	Clay, fat; high plasticity; no dilatancy; contains some silt lenses.	CH-MH	73	35	38	2.66
250	1,447.4-1,447.8	50	0	10	90	do	Clay, fat; high plasticity; no dilatancy; lensed with silt and fine sand.	CH-MH	80	39	41	2.62
251	1,526.2-1,526.6	100	0	10	90	do	Clay, fat; high plasticity; no dilatancy; firm; silt pockets in sample lensed with some fine sand and silt; micaceous.	CH	78	34	44	2.63
252	1,687.0-1,687.3	200	0	0	100	do	Clay, fat; high plasticity; no dilatancy; firm; moist (claystone)	CH	75	34	41	2.71
253	1,826.2-1,826.5	200	0	0	100	do	Clay; fat; high plasticity; no dilatancy	CH	85	36	49	2.77
254	1,892.7-1,893.1	200	0	0	100	do	Clay; high plasticity; no dilatancy; not tested because of slickensides throughout sample.	CH				
Core hole 6S/2W–24C7												
23L255	140.5- 140.8	100	0	0	100	Gray	Clay, fat; no dilatancy; high plasticity; firm; moist; medium dry strength; slight reaction to HCl.	CH	52	18	34	2.73
256	191.0- 191.3	16	0	5	95	do	Clay, lean; no dilatancy; medium plasticity; some sand; high reaction to HCl.	CL	35	15	20	2.71
257	307.5- 307.8	200	0	0	100	Brown	Clay, lean; no dilatancy; medium plasticity; medium dry strength; high reaction to HCl.	CL	40	19	21	2.72
258	253.1- 253.4	100	0	20	80	Gray	Clay, silty, containing fine sand; medium dry strength; no dilatancy; medium plasticity; sheet micaceous material present; high reaction to HCl.	CL	31	18	13	2.64
259	344.0- 344.3	50	0	20	80	do	Clay, silty, containing fine sand; medium dry strength; no dilatancy; medium plasticity; medium reaction to HCl.	CL	37	17	20	2.72
260	458.0- 458.3						Not tested because of fractured condition of sample					
261	436.4- 436.7	100	0	10	90	Gray	Clay, silty, some fine sand; no dilatancy; medium plasticity; high reaction ti HCl; alternate for 23L260.	CL	40	20	20	2.72

262	522.0– 522.4	200	0	0	100	Brown	Clay, silty; medium dry strength; slow dilatancy; medium plasticity; white concretions and streaks; high reaction to HCl.	CL	36	16	20	2.71
263	605.0– 605.3	100	0	5	95	Gray	Clay containing silt; medium plasticity; no dilatancy; firm; moist; white streaks; high reaction to HCl.	CL	45	18	27	2.73
265	715.1– 715.5	100	0	0	100	do	Clay, fat; no dilatancy; high plasticity; high dry strength; firm; moist, white concretions; moderate reactions to HCl.	CH	56	18	38	2.74
267	865.0– 865.3	200	0	0	100	Dark gray	Clay, fat; no dilatancy; high plasticity; high dry strength; firm; moist; streaked with white layers; high reaction to HCl.	CH	57	21	36	2.76
269	958.0– 958.3	100	0	Tr	100	Gray	Clay, fat; no dilatancy; high plasticity; high dry strength; streaked with carbonaceous modules; high reaction to HCl.	CH	59	22	37	2.76
							Core hole 7S/1E–16C6					
23L271	233.0– 233.6	100	0	0	100	Brown	Clay containing silt; no dilatancy; medium plasticity; medium dry strength; no reaction to HCl.	CL	42	20	22	2.75
272	300.6– 301.0	100	0	0	100	do	Silt with clay binder; slight dilatancy; medium plasticity; medium dry strength; no reaction to HCl.	ML–CL	37	15	22	2.68
273	353.4– 353.9	3/8	0	40	60	Gray	Sand, medium to coarse, containing clay; not homogeneous; well cemented.	SC	35	16	19	2.68
275	429.8– 430.1	16	0	10	90	Brown	Clay, lean, containing some fine sand; medium dry strength; medium plasticity; no dilatancy; no reaction to HCl.	CL	40	17	23	2.78
277	509.2– 509.5	200	0	0	100	do	Clay, silty; no dilatancy; medium plasticity; medium dry strength; carbonaceous concretions which react highly to HCl.	CL	42	17	25	2.76
279	554.0– 554.3	200	0	0	100	do	Clay, lean; no dilatancy; medium plasticity; medium dry strength; carbonaceous concretions which react highly to HCl.	CL	31	20	11	2.72
280	696.0– 696.3	200	0	0	100	do	Clay, silty; slight dilatancy; medium plasticity; firm; moist; moderate reaction to HCl.	CL	37	18	19	2.75
282	790.2– 790.6	8	0	30	70	do	Clay, silty, mixed with fine sand and some coarse sand; slight dilatancy; medium plasticity; moderate reaction to HCl.	CL–SM	28	17	11	2.74
283	832.0– 832.4	200	0	0	100	do	Clay, silty; no dilatancy; medium plasticity; moderate reaction to HCl.	CL	32	19	13	2.75
284	936.5– 936.9	50	0	10	90	do	Clay, silty, containing some fine sand; medium plasticity; no dilatancy; slight reaction to HCl.	CL	48	17	31	2.72

[1] Nonplastic. [2] Top half of sample. [3] Bottom half of sample.

TABLE 9.—*Consolidation test summaries*

[Data from Earth Laboratory, U.S. Bureau of Reclamation, Denver, Colo.]

Earth laboratory sample	Depth (feet)	Compression index, C_c: From consolidation curve	Compression index, C_c: From Atterberg test	Time-consolidation data: Load range (psi)	Coefficient of consolidation, C_v: Sq in. per sec	Coefficient of consolidation, C_v: Sq ft per yr	Coefficient of permeability: Calculated (ft per yr)	Coefficient of permeability: From test (ft per yr)	Unified soil classification symbol
Core hole 12/12-16H1									
23L91	84.3- 84.6	0.12	0.19	100- 200	3.3×10^{-4}	72.5	8.5×10^{-3}		CL
				200- 400	1.5×10^{-4}	31.8	2.0×10^{-3}		
92	159.4- 159.8	[1] .22	.36	100- 200	9.2×10^{-5}	20.1	2.8×10^{-3}		CL-CH
				200- 400	5.1×10^{-5}	11.2	1.3×10^{-3}		
93	230.8- 231.2	.21	.21	200- 400	1.7×10^{-4}	37.2	4.0×10^{-3}		CL
94	324.5- 324.9	.11	.17						CL
95	374.0- 374.5	.32	.39	200- 400	1.5×10^{-5}	3.3	2.9×10^{-4}		CH
				400- 800	1.0×10^{-5}	2.2	1.5×10^{-4}		
96	425.0- 425.3	1.13	.59	200- 400	4.2×10^{-6}	0.92	3.2×10^{-4}		CH
				400- 800	3.2×10^{-6}	.70	1.2×10^{-4}		
97	471.2- 471.5	.90	.43	200- 400	1.3×10^{-4}	28.5	8.0×10^{-3}		CH
				400- 800	1.3×10^{-4}	28.5	3.6×10^{-3}		
98	516.5- 516.9	.41						5.7	SM
99	579.0- 579.3	.23	.20	200- 400	5.6×10^{-4}	122.0	7.2×10^{-3}		CL
				400- 800	3.8×10^{-4}	83.2	4.4×10^{-3}		
				800-1,600	2.5×10^{-4}	54.8	1.5×10^{-3}		
100	625.0- 625.4	.34	.44	400- 800	1.7×10^{-5}	3.7	2.6×10^{-4}		CH
				800-1,600	8.0×10^{-6}	1.8	6.0×10^{-5}		
101	675.9- 676.2	.27	.32	400- 800	1.1×10^{-3}	232.1	1.2×10^{-2}		CL
				800-1,600	6.9×10^{-4}	151.1	4.8×10^{-3}		
102	722.0- 722.3	.34	.54	400- 800	2.7×10^{-5}	5.9	3.3×10^{-4}		CH
				800-1,600	6.0×10^{-6}	1.3	5.0×10^{-5}		
103	773.0- 773.4	[1] .33	([2])	800-1,600	4.3×10^{-5}	9.4	3.5×10^{-4}		SM
104	821.4- 821.8	[1] .20						14.2	SM
105	877.4- 877.8	[1] .18						33.9	SM
106	926.8- 927.2	.68	.34	400- 800	1.6×10^{-4}	35.0	3.7×10^{-3}		CL
				800-1,600	8.5×10^{-5}	18.6	1.2×10^{-3}		
107	972.0- 972.4	.33						38.4	SM
108	998.6- 999.0	[1] .30	.24					1.4	CL
Core hole 14/13-11D1									
23L80	315.0- 315.3	([3])						25.3	SP
194	397.0- 397.3	0.36		200- 400	1.8×10^{-4}	39.4	4.0×10^{-3}		CL
				400- 800	5.1×10^{-5}	11.2	8.1×10^{-4}		
				800-1,600	1.2×10^{-5}	2.6	9.0×10^{-5}		
81	554.0- 554.4	.22		200- 400	6.8×10^{-5}	15.0	9.5×10^{-4}		CL
				400- 800	2.2×10^{-5}	4.9	2.2×10^{-4}		
				800-1,600	4.1×10^{-5}	9.0	1.8×10^{-4}		
83	699.0- 699.4	.97		400- 800	5.8×10^{-5}	12.8	2.1×10^{-3}		CL
				800-1,600	3.2×10^{-5}	7.1	5.0×10^{-4}		
84	746.0- 746.4	.30		200- 400	1.7×10^{-4}	37.4	2.6×10^{-3}		
				400- 800	1.2×10^{-4}	26.9	1.5×10^{-3}		
				800-1,600	6.6×10^{-5}	14.5	5.5×10^{-4}		
196	832.2- 832.7	.36		200- 400	2.0×10^{-4}	43.8	3.6×10^{-3}		CL
				400- 800	6.7×10^{-5}	14.7	9.4×10^{-4}		
				800-1,600	4.5×10^{-5}	9.9	3.7×10^{-4}		
85	983.6- 984.0	[1] 0.35		200- 400	1.2×10^{-5}	2.6	2.1×10^{-4}		CL
				400- 800	1.0×10^{-5}	2.2	1.1×10^{-4}		
				800-1,600	1.2×10^{-5}	2.6	1.2×10^{-4}		
86	1,076.0-1,076.4	([3])						1.7	SM
88	1,350.5-1,350.8	([3])						19.3	SP
89	1,395.0-1,395.3	([3])		200- 400	1.0×10^{-4}	21.8	1.2×10^{-3}		CL
				400- 800	1.7×10^{-5}	3.6	1.5×10^{-4}		
				800-1,600	1.1×10^{-5}	2.4	8.0×10^{-5}		
90	1,450.0-1,450.3	[1] .29		800-1,600	3.9×10^{-5}	8.4	2.4×10^{-4}		CL
Core hole 16/15-34N1									
23L197	299.1- 299.5	0.34	0.38	200- 400	3.4×10^{-4}	74.9	1.1×10^{-2}		CH
198	418.1- 418.5	.32	.31	100- 200	1.7×10^{-3}	361.4	6.3×10^{-2}		CL
				200- 400	5.0×10^{-4}	109.5	1.3×10^{-2}		
				400- 800	1.4×10^{-4}	30.7	2.1×10^{-3}		
200	538.9- 539.2	[1] .30	.42	200- 400	3.4×10^{-4}	74.5	6.3×10^{-3}		CH
				400- 800	1.3×10^{-4}	28.5	2.1×10^{-3}		
201	571.2- 571.6	([3] [4])	.65						CH
202	636.9- 637.3	.70	.63	400- 800	1.8×10^{-5}	3.9	4.0×10^{-4}		CH
				800-1,600	8.1×10^{-6}	1.8	1.3×10^{-4}		
204	713.1- 713.4	.31	.46	200- 400	3.3×10^{-4}	72.3	3.6×10^{-3}		CH
				400- 800	7.0×10^{-5}	15.3	8.9×10^{-4}		
				800-1,600	5.0×10^{-5}	11.0	4.1×10^{-4}		
206	859.7- 860.1	([3])	.19	800-1,600	5.6×10^{-4}	122.6	4.6×10^{-3}		SC
207	901.7- 902.1	.29	.55	100- 200	1.4×10^{-4}	30.7	3.0×10^{-3}		CH
				200- 400	3.1×10^{-5}	6.6	4.9×10^{-4}		
				400- 800	1.6×10^{-5}	3.5	2.0×10^{-4}		
				800-1,600	7.5×10^{-6}	1.6	6.1×10^{-5}		
208	972.0- 972.4	.42	.53	200- 400	2.3×10^{-4}	50.4	3.1×10^{-3}		CH
				400- 800	2.2×10^{-5}	4.8	3.6×10^{-4}		
				800-1,600	6.5×10^{-6}	1.4	7.0×10^{-5}		
210	1,153.6-1,154.0	[1] .21	.23	400- 800	6.2×10^{-4}	135.8	5.1×10^{-3}		CL
				800-1,600	3.2×10^{-4}	70.0	2.2×10^{-3}		
212	1,237.7-1,238.1	([3])		400- 800	3.7×10^{-5}	8.1	2.7×10^{-4}		CH

See footnotes at end of table.

TABLE 9.—*Consolidation test summaries*—Continued

Earth laboratory sample	Depth (feet)	Compression index, C_c		Time-consolidation data					Unified soil classification symbol
		From consolidation curve	From Atterberg test	Load range (psi)	Coefficient of consolidation, C_v		Coefficient of permeability		
					Sq in. per sec	Sq ft per yr	Calculated (ft per yr)	From test (ft per yr)	
Core hole 16/15-34N1—Continued									
				800–1,600	1.0×10^{-5}	2.2	8.3×10^{-5}		
23L214	1,332.4–1,332.8	(3)						350	SM
215	1,391.3–1,391,7	(3)	0.20					.099	SM
217	1,511.3–1,511.7	(3)	.77	800–1,600	4.7×10^{-5}	10.3	3.3×10^{-4}		CH
219	1,631.7–1,632.1	[1] .21	.44	800–1,600	3.0×10^{-4}	65.7	2.0×10^{-3}		CH
221	1,792.3–1,792.7	(3)	.41	800–1,600	1.3×10^{-4}	28.5	7.4×10^{-4}		CH
222	1,871.8–1,872.2	(3)	.60	800–1,600	7.6×10^{-5}	16.6	5.5×10^{-4}		CH
223	1,952.6–1,953.0	[5] .12	.87	800–1,600	3.3×10^{-4}	72.3	1.0×10^{-3}		CH
235	563.3–563.7	.47		200–400	1.0×10^{-4}	21.9	2.0×10^{-3}		CH
				400–800	2.6×10^{-5}	5.7	4.3×10^{-4}		
				800–1,600	6.0×10^{-6}	1.3	6.1×10^{-5}		
Core hole 19/17-22J1, 2									
23L181	311.5–311.9	0.35		50–100	1.4×10^{-4}	30.9	7.2×10^{-3}		CL
				100–200	7.1×10^{-5}	15.6	2.6×10^{-3}		
				200–400	5.3×10^{-5}	11.5	1.3×10^{-3}		
				400–800	1.7×10^{-5}	3.6	2.8×10^{-4}		
182	554.4–554.8	.36		800–1,600	5.1×10^{-4}	111.7	4.7×10^{-3}		CL
183	734.6–734.9	.49		400–800	2.4×10^{-4}	52.6	4.4×10^{-3}		CL
				800–1,600	1.0×10^{-4}	21.9	1.1×10^{-3}		
184	904.9–905.3	.47		200–400	1.2×10^{-4}	26.3	2.0×10^{-3}		CL
				400–800	3.4×10^{-5}	7.4	4.8×10^{-4}		
				800–1,600	1.2×10^{-5}	2.6	1.3×10^{-4}		
185	1,093.4–1,093.8	.36		800–1,600	2.8×10^{-4}	61.3	2.6×10^{-3}		ML
186	1,251.0–1,251.4	.28		400–800	5.3×10^{-5}	11.6	5.9×10^{-4}		ML
				800–1,600	2.0×10^{-5}	4.4	1.5×10^{-4}		
187	1,345.2–1,345.6	.28		800–1,600	1.2×10^{-4}	26.3	8.9×10^{-4}		ML
189	1,601.2–1,601.5	(3)	(3)						SM
190	1,749.6–1,750.0	(3)	(3)	800–1,600	1.3×10^{-4}	28.5	6.9×10^{-4}		CL
191	1,955.9–1,956.3	(3)	(3)	800–1,600	1.6×10^{-4}	35.0	8.3×10^{-4}		CL
192	2,021.0(−)	[1] .24		800–1,600	4.7×10^{-5}	10.4	2.9×10^{-4}		CL
193	2,092.9(+)	[1] .09							CL
Core hole 23/25-16N1									
23L226	261.7–261.9	0.17	0.12	200–400	1.4×10^{-3}	311.0	2.4×10^{-2}		SM
				400–800	7.4×10^{-4}	162.1	6.5×10^{-3}		
227	283.5–283.9	.62	.37	200–400	4.5×10^{-5}	9.9	9.0×10^{-4}		CL–CH
				400–800	1.9×10^{-5}	4.2	4.8×10^{-4}		
228	292.0–292.4	.53	.30	200–400	8.8×10^{-4}	192.7	3.2×10^{-2}		CL
				400–800	4.7×10^{-4}	102.9	1.1×10^{-2}		
229	450.1–450.5	.40	.29	300–600	2.2×10^{-5}	4.8	5.8×10^{-4}		CL
				600–1,200	1.3×10^{-5}	2.9	1.6×10^{-4}		
232	630.3–630.7	.25	(2)					0.25	SM
234	723.5–723.8	.35	.24					.05	ML
Core hole 24/26-36A2									
23L236	123.1–123.4		.17					0.15	CL
237	157.1–157.4		.18	400–800	2.6×10^{-4}	55.9	3.5×10^{-3}		SC
239	443.0–443.2		.18	400–800	5.5×10^{-4}	120.7	7.7×10^{-3}		SC
240	516.0–516.3		.29	400–800	1.1×10^{-4}	24.5	1.6×10^{-3}		CL
241	607.2–607.5		.21	800–1,600	5.5×10^{-4}	120.7	4.2×10^{-3}		ML
242	725.6–725.9		.35	800–1,600	3.3×10^{-4}	71.2	3.5×10^{-3}		CL
243	843.0–843.3	0.76	.80	800–1,600	3.0×10^{-5}	6.6	4.8×10^{-4}		CH
244	916.1–916.4	.63	.54	800–1,600	2.2×10^{-5}	4.8	2.9×10^{-4}		CH
246	1,115.7–1,116.1	1.18	.51	800–1,600	2.9×10^{-5}	6.4	6.1×10^{-4}		CH
247	1,155.1–1,155.4	0.86	0.54	800–1,600	5.7×10^{-5}	12.5	9.6×10^{-4}		CH
248	1,241.0–1,241.3	1.53	.76	800–1,600	3.3×19^{-5}	7.2	7.9×10^{-4}		CH–MH
249	1,362.3–1,362.7	.97	.57	800–1,600	2.6×10^{-5}	5.6	4.1×10^{-4}		CH–MH
250	1,447.4–1,447.8	1.24	.63	800–1,600	2.1×10^{-5}	4.5	4.1×10^{-4}		CH–MH
251	1,526.2–1,526.6		.61	800–1,600	6.7×19^{-6}	1.5	8.4×10^{-5}		CH
252	1,687.0–1,687.3		.59	800–1,600	8.3×19^{-5}	18.1	6.1×10^{-5}		CH
253	1,826.2–1,826.5		.68	400–800	7.0×10^{-5}	15.4	4.3×10^{-4}		CH
				800–1,600	1.1×10^{-5}	2.5	1.0×10^{-4}		CH

See footnotes at end of table.

TABLE 9.—*Consolidation test summaries*—Continued

Laboratory sample number	Depth (feet)	Compression index, C_c: From consolidation curve	Compression index, C_c: From Atterberg test	Time-consolidation data: Load range (psi)	Coefficient of consolidation, C_v: Sq in. per sec	Coefficient of consolidation, C_v: Sq ft per yr	Coefficient of permeability: Calculated (ft per yr)	Coefficient of permeability: From test (ft per yr)	Unified Soil Classification symbol
Core hole 6S/2W-24C7									
23L255	140.5–140.8	0.29	0.38	25–50	6.0×10^{-5}	13.14	6.4×10^{-3}	....	CH
				50–100	4.0×10^{-5}	8.76	3.5×10^{-3}	....	
				100–200	2.5×10^{-5}	5.48	1.2×10^{-3}	....	
				200–400	2.0×10^{-5}	4.38	5.4×10^{-4}	....	
				400–800	1.3×10^{-5}	2.85	1.9×10^{-4}	....	
256	191.0–191.3	.21	.22	100–200	5.8×10^{-4}	129.21	1.8×10^{-2}	....	CL
				200–400	3.5×10^{-4}	76.65	6.7×10^{-3}	....	
				400–800	2.9×10^{-4}	63.51	3.4×10^{-3}	....	
257	307.5–307.8	.24	.27	50–100	1.6×10^{-4}	35.04	7.5×10^{-3}	....	CL
				100–200	1.0×10^{-4}	21.90	3.0×10^{-3}	....	
				200–400	6.6×10^{-5}	14.45	1.4×10^{-3}	....	
				400–800	5.7×10^{-5}	12.48	6.5×10^{-4}	....	
258	253.1–253.4	.30	.19	200–400	3.0×10^{-3}	662.48	8.0×10^{-2}	....	CL
				400–800	2.1×10^{-3}	455.52	2.9×10^{-2}	....	
259	344.0–344.3	.24	.25	200–400	3.5×10^{-4}	76.65	7.6×10^{-3}	....	CL
				400–800	2.4×10^{-4}	52.56	3.1×10^{-3}	....	
261	436.4–436.7	.26	.27	100–200	2.4×10^{-3}	525.60	7.2×10^{-2}	....	CL
				200–400	1.2×10^{-3}	262.80	2.2×10^{-2}	....	
				400–800	9.0×10^{-4}	197.10	1.3×10^{-2}	....	
262	522.0–522.4	.20	.24	200–400	2.8×10^{-4}	61.32	4.6×10^{-3}	....	CL
				400–800	1.3×10^{-4}	28.47	1.3×10^{-3}	....	
				800–1,600	8.1×10^{-5}	17.74	4.3×10^{-4}	....	
263	605.0–605.3	.28	.31	100–200	1.2×10^{-4}	26.28	2.8×10^{-3}	....	CL
				200–400	5.4×10^{-5}	11.83	9.7×10^{-4}	....	
				400–800	3.2×10^{-5}	7.01	4.0×10^{-4}	....	
				800–1,600	1.6×10^{-5}	3.50	1.2×10^{-4}	....	
265	715.1–715.5	.32	.42	200–400	8.6×10^{-5}	18.8	1.5×10^{-3}	....	CH
				400–800	2.9×19^{-5}	6.4	4.4×10^{-4}	....	
				800–1,600	1.3×10^{-5}	2.8	1.0×10^{-4}	....	
267	865.0–865.3	.33	.43	400–800	3.5×10^{-5}	7.58	4.7×10^{-4}	....	CH
				800–1,600	2.5×10^{-5}	5.54	2.2×10^{-4}	....	
269	958.0–958.3	[1] .28	.44	400–800	1.1×10^{-4}	24.09	1.1×10^{-3}	....	CH
				800–1,600	2.6×10^{-5}	5.69	2.0×10^{-4}	....	
Core hole 7S/1E-16C6									
23L271	233.0–233.6	0.26	0.29	200–400	2.8×10^{-4}	61.32	6.8×10^{-3}	....	CL
				400–800	1.4×10^{-4}	30.66	1.8×10^{-3}	....	
272	300.6–301.0	.21	.24	25–50	9.0×10^{-5}	19.71	8.7×10^{-3}	....	ML-CL
				50–100	7.5×10^{-5}	16.43	3.7×10^{-3}	....	
				100–200	7.1×10^{-5}	15.55	2.3×10^{-3}	....	
				200–400	4.6×10^{-5}	10.07	9.1×10^{-4}	....	
				400–800	4.0×10^{-5}	8.76	4.8×10^{-4}	....	
273	353.4–353.9	.16	.22	200–400	3.4×10^{-3}	744.6	5.7×10^{-2}	....	SC
				400–800	2.1×10^{-3}	459.9	1.8×10^{-2}	....	
275	429.8–430.1	.30	.27	25–50	2.4×10^{-5}	5.26	2.3×10^{-3}	....	CL
				50–100	3.1×10^{-5}	6.79	1.9×10^{-3}	....	
				100–200	2.9×10^{-5}	6.35	1.1×10^{-3}	....	
				200–400	2.3×10^{-5}	5.04	4.5×10^{-4}	....	
				400–800	2.6×10^{-5}	5.69	2.2×10^{-4}	....	
277	509.2–509.5	.19	.29	50–100	1.1×10^{-4}	24.09	5.4×10^{-3}	....	CL
				100–200	5.9×10^{-5}	12.92	1.5×10^{-3}	....	
				200–400	7.8×10^{-5}	17.08	1.3×10^{-3}	....	
				400–800	3.7×10^{-5}	8.10	3.1×10^{-4}	....	
				800–1,600	4.8×10^{-5}	10.51	2.5×10^{-4}	....	
279	554.0–554.3	.20	.19	800–1,600	7.8×10^{-4}	170.82	5.1×10^{-3}	....	CL
280	696.0–696.3	.22	.24	200–400	6.4×10^{-4}	140.16	8.1×10^{-3}	....	CL
				400–800	2.7×10^{-4}	59.13	2.6×10^{-3}	....	
				800–1,600	1.5×10^{-4}	32.85	1.0×10^{-3}	....	
282	790.2–790.6	.15	.16	200–400	2.9×10^{-4}	63.51	4.0×10^{-3}	....	CL-SM
				400–800	3.2×10^{-4}	70.08	2.8×10^{-3}	....	
				800–1,600	2.1×10^{-4}	45.99	9.6×10^{-4}	....	
283	832.0–832.4	.23	.19	400–800	5.2×10^{-4}	115.88	7.3×10^{-4}	....	CL
				800–1,600	2.8×10^{-4}	61.32	1.7×10^{-4}	....	
284	936.5–936.9	.13	.35	800–1,600	3.7×10^{-5}	8.10	1.2×10^{-4}	....	CL

[1] C_c was roughly evaluated for comparison purpose although it was realized that the curve does not give a straight line.
[2] Nonplastic.
[3] C_c was not measurable because of pronounced curvature and insufficient straight-line portion.
[4] Sample 23L235 tested for sample 23L20.
[5] C_c value is doubtful because of the firmness of the specimen, and pressures are not high enough to exceed overburden pressures for a sufficient portion of the curve.

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*

Property	Samples	Range: Low	Range: High	Average
CORE HOLE 14/13-11D1				
Sand				
Permeability:				
Vertical, gpd per sq ft	20	0.2	360	58
Horizontal, gpd per sq ft				
Dry unit weight, g per cc	20	1.37	1.75	1.53
Specific gravity	20	2.67	2.77	2.71
Porosity, percent	20	35.4	49.3	43.6
Acid solubility, do	12	.8	6.0	2.6
Liquid limit	1			38
Clayey sand				
Permeability:				
Vertical, gpd per sq ft	4	0.0001	4	1
Horizontal, gpd per sq ft				
Dry unit weight, g per cc	4	1.64	1.95	1.81
Specific gravity	4	2.64	2.72	2.69
Porosity, percent	4	28.0	37.9	32.7
Acid solubility, do	1	3.2	3.2	3.2
Liquid limit				
Sand-silt-clay				
Permeability:				
Vertical, gpd per sq ft	11	0.0001	2	0.3
Horizontal, gpd per sq ft	1	.2	0.2	.2
Dry unit weight, g per cc	15	1.17	1.86	1.56
Specific gravity	16	2.65	2.76	2.70
Porosity, percent	15	30.9	55.8	42.2
Acid solubility, do	11	2.8	7.6	5.2
Liquid limit	10	26	54	37
Clayey silt				
Permeability:				
Vertical, gpd per sq ft	5	0.0006	0.01	0.003
Horizontal, gpd per sq ft				
Dry unit weight, g per cc	26	1.18	1.87	1.61
Specific gravity	26	2.63	2.79	2.73
Porosity, percent	26	31.8	55.1	41.1
Acid solubility, do	15	2.0	8.8	5.2
Liquid limit	24	30	80	48
Silty sand				
Permeability:				
Vertical, gpd per sq. ft	16	0.0005	22	3
Horizontal, gpd per sq. ft	1	10	10	10
Dry unit weight, g per cc	17	1.42	1.94	1.62
Specific gravity	17	2.66	2.75	2.72
Porosity, percent	17	28.7	47.8	40.6
Acid solubility, do	9	3.2	6.4	4.9
Liquid limit	1			30
Sandy silt				
Permeability:				
Vertical, gpd per sq. ft	4	0.0006	0.2	0.7
Horizontal, gpd per sq. ft	1	2	2	2
Dry unit weight, g per cc	4	1.57	1.69	1.63
Specific gravity	4	2.68	2.75	2.72
Porosity, percent	4	36.9	42.9	40.1
Acid solubility, do	2	1.6	3.6	2.6
Liquid limit	1			25
Silt				
Permeability:				
Vertical, gpd per sq. ft	1	0.002	0.002	0.002
Horizontal, gpd per sq. ft				
Dry unit weight, g per cc	2	1.31	1.33	1.32
Specific gravity	2	2.68	2.74	2.71
Porosity, percent	2	50.4	52.2	51.3
Acid solubility, do	1	4.0	4.0	4.0
Liquid limit				
Silty clay				
Permeability:				
Vertical, gpd per sq. ft	6	0.0001	0.01	0.003
Horizontal, gpd per sq. ft	2	.002	.03	.02
Dry unit weight, g per cc	12	1.25	1.72	1.49
Specific gravity	12	2.62	2.76	2.68
Porosity, percent	12	36.1	52.8	44.3
Acid solubility, do	9	3.6	14.8	8.8
Liquid limit	11	56	82	65

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*—Continued

Property	Samples	Range: Low	Range: High	Average
CORE HOLE 16/15-34N1				
Sand				
Permeability:				
Vertical, gpd per sq ft	11	10	374	96
Horizontal, gpd per sq ft	8	26	315	110
Dry unit weight, g per cc	11	1.47	1.58	1.52
Specific gravity	11	2.62	2.71	2.69
Porosity, percent	11	41.5	45.8	44.6
Acid solubility, do	6	1.8	4.0	3.1
Liquid limit				
Clayey sand				
Permeability:				
Vertical, gpd per sq ft	2	0.001	1	0.5
Horizontal, gpd per sq ft				
Dry unit weight, g per cc	2	1.51	1.67	1.59
Specific gravity	2	2.66	2.68	2.67
Porosity, percent	2	37.7	42.4	40.1
Acid solubility, do	2	4.0	5.2	4.6
Liquid limit				
Sand-silt-clay				
Permeability:				
Vertical, gpd per sq ft	22	0.0003	0.1	0.01
Horizontal, gpd per sq ft	12	.0003	.1	.03
Dry unit weight, g per cc	21	1.10	1.75	1.54
Specific gravity	23	2.43	2.74	2.67
Porosity, percent	21	34.8	54.7	42.3
Acid solubility, do	5	1.2	9.2	6.3
Liquid limit	18	28	76	42
Silty clay				
Permeability:				
Vertical, gpd per sq ft	20	0.0001	0.006	0.0002
Horizontal, gpd per sq ft	12	.0001	.02	.004
Dry unit weight, g per cc	21	1.44	1.73	1.55
Specific gravity	21	2.62	2.76	2.67
Porosity, percent	21	35.6	45.5	41.8
Acid solubility, do	17	1.6	11.6	8.1
Liquid limit	13	37	63	51
CORE HOLE 16/15-34N1				
Silty sand				
Permeability:				
Vertical, gpd per sq ft	10	0.0008	5	2
Horizontal, gpd per sq ft	5	.004	19	2
Dry unit weight, g per cc	11	1.48	1.81	1.65
Specific gravity	11	2.67	2.72	2.70
Porosity, percent	11	32.7	45.2	39.0
Acid solubility, do	5	1.4	6.8	4.2
Liquid limit				
Sandy silt				
Permeability:				
Vertical, gpd per sq. ft	6	0.001	0.07	0.01
Horizontal, gpd per sq. ft	3	.03	.3	.2
Dry unit weight, g per cc	6	1.44	1.78	1.60
Specific gravity	6	2.68	1.75	2.72
Porosity, percent	6	39.9	47.3	42.3
Acid solubility, do	4	3.0	6.4	4.9
Liquid limit	2	35	42	38
Clayey silt				
Permeability:				
Vertical, gpd per sq. ft	19	0.0002	0.2	0.02
Horizontal, gpd per sq. ft	12	.0002	.2	.004
Dry unit weight, g per cc	21	1.23	1.73	1.50
Specific gravity	21	2.63	2.75	2.69
Porosity, percent	21	35.9	54.1	44.13
Acid solubility, do	12	3.4	13.6	8.3
Liquid limit	16	38	70	50

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*—Continued

Property	Samples	Range Low	Range High	Average
CORE HOLE 19/17-22J1, 2				
Sand				
Permeability:				
Vertical.............gpd per sq ft..	7	11	230	99
Horizontal..........gpd per sq ft..	2	100	330	215
Dry unit weight..............g per cc..	6	1.35	1.63	1.50
Specific gravity	7	2.66	2.70	2.67
Porosity....................percent..	6	39.2	50.0	44.2
Acid solubility..................do....	2	4.0	5.6	4.8
Liquid limit				
Silty sand				
Permeability:				
Vertical.............gpd per sq ft..	8	0.0003	16	4
Horizontal..........gpd per sq ft	1			
Dry unit weight..............g per cc..	8	1.43	1.78	1.60
Specific gravity	9	2.48	2.72	2.68
Porosity....................percent..	8	34.1	46.8	40.7
Acid solubility..................do....	2	5.6	6.8	5.2
Liquid limit	1			31
Clayey silt				
Permeability:				
Vertical.............gpd per sq ft..	10	0.0002	0.01	0.003
Horizontal..........gpd per sq ft..				
Dry unit weight..............g per cc..	31	1.41	1.71	1.57
Specific gravity	33	2.61	2.73	2.67
Porosity....................percent..	31	36.4	47.2	41.2
Acid solubility..................do....	5	8.0	12.0	9.0
Liquid limit	15	35	60	46
CORE HOLE 23/25-16N1				
Sand				
Permeability:				
Vertical.............gpd per sq ft..	2	38	130	84
Horizontal..........gpd per sq ft..	1			61
Dry unit weight..............g per cc..	2	1.55	1.66	1.61
Specific gravity	2	2.68	2.72	2.70
Porosity....................percent..	2	38.1	43.0	40.6
Acid solubility..................do....				
Liquid limit				
Sandy silt				
Permeability:				
Vertical.............gpd per sq ft..	4	0.03	0.01	0.06
Horizontal..........gpd per sq ft..				
Dry unit weight..............g per cc..	6	1.55	1.67	1.63
Specific gravity	7	2.63	2.70	2.68
Porosity....................percent..	6	37.3	41.7	39.1
Acid solubility..................do....				
Liquid limit				
Sand-silt-clay				
Permeability:				
Vertical.............gpd per sq ft..	12	0.0006	7	0.6
Horizontal..........gpd per sq ft..	1	.09	0.09	.09
Dry unit weight..............g per cc..	26	1.37	1.84	1.62
Specific gravity	26	2.50	2.76	2.67
Porosity....................percent..	26	32.8	46.3	39.3
Acid solubility..................do....	5	4.8	16.0	9.1
Liquid limit	5	26	61	42
Silty clay				
Permeability:				
Vertical.............gpd per sq ft..	7	0.0001	0.002	0.001
Horizontal..........gpd per sq ft..	2	.0005	.001	.008
Dry unit weight..............g per cc..	18	1.33	1.64	1.52
Specific gravity	19	2.60	2.71	2.66
Porosity....................percent..	18	38.6	49.6	43.0
Acid solubility..................do....	7	5.6	10.8	9.3
Liquid limit	12	28	65	53

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*—Continued

Property	Samples	Range Low	Range High	Average
CORE HOLE 23/25-16N1—Continued				
Silty sand				
Permeability:				
Vertical.............gpd per sq ft..	9	0.002	2	0.4
Horizontal..........gpd per sq ft..	7	.005	.2	.07
Dry unit weight..............g per cc..	8	1.60	1.82	1.68
Specific gravity	9	2.66	2.73	2.69
Porosity....................percent..	8	32.1	39.8	37.5
Acid solubility..................do....	3	1.7	6.2	4.7
Liquid limit	6	22	26	24
Sandy silt				
Permeability:				
Vertical.............gpd per sq ft..	6	0.005	0.6	0.1
Horizontal..........gpd per sq ft..	5	.005	.1	.05
Dry unit weight..............g per cc..	6	1.52	1.79	1.61
Specific gravity	6	2.66	2.75	2.70
Porosity....................percent..	6	34.2	44.7	40.5
Acid solubility..................do....				
Liquid limit	2	29	34	32
Clayey silt				
Permeability:				
Vertical.............gpd per sq ft..	13	0.0002	0.06	0.008
Horizontal..........gpd per sq ft..	12	.0004	.1	.01
Dry unit weight..............g per cc..	13	1.05	1.64	1.48
Specific gravity	13	2.66	2.75	2.70
Porosity....................percent..	13	39.3	61.0	45.2
Acid solubility..................do....	6	3.5	11.1	6.8
Liquid limit	8	31	63	42
CORE HOLE 24/26-36A2				
Sand (including gravel)				
Permeability:				
Vertical.............gpd per sq ft..	10	2	650	95
Horizontal..........gpd per sq ft..	2	3	3	3
Dry unit weight..............g per cc..	12	1.54	1.74	1.65
Specific gravity	12	2.65	2.74	2.68
Porosity....................percent..	12	35.6	42.8	38.7
Acid solubility..................do....	8	0.4	3.5	1.5
Liquid limit				
Clayey sand				
Permeability:				
Vertical.............gpd per sq ft..	6	0.0007	0.4	0.09
Horizontal..........gpd per sq ft..	3	.01	2	.7
Dry unit weight..............g per cc..	7	1.25	1.82	1.55
Specific gravity	7	2.65	2.75	2.70
Porosity....................percent..	7	32.8	52.8	52.4
Acid solubility..................do....	6	1.0	7.8	3.5
Liquid limit				
Sand-silt-clay				
Permeability:				
Vertical.............gpd per sq ft..	14	0.0002	0.4	0.06
Horizontal........................do....	8	.0008	.03	.01
Dry unit weight..............g per cc..	13	1.48	1.79	1.63
Specific gravity	15	2.65	2.74	2.69
Porosity....................percent..	13	32.7	44.2	39.6
Acid solubility..................do....	7	2.9	8.8	5.9
Liquid limit	8	27	40	35
Silty clay				
Permeability:				
Vertical.............gpd per sq ft..	2	0.0005	0.001	0.0008
Horizontal........................do....	1			.0006
Dry unit weight..............g per cc..	2	1.41	1.52	1.47
Specific gravity	2	2.69	2.71	2.70
Porosity....................percent..	2	43.5	48.0	45.8
Acid solubility..................do....				
Liquid limit	1			45.4

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*—Continued

Property	Samples	Range		Average
		Low	High	
CORE HOLE 24/26-36A2—Continued				
Silty sand				
Permeability:				
Vertical.......gpd per sq ft..	38	0.001	6	0.7
Horizontal.......do....	21	.002	6	1
Dry unit weight.......g per cc..	45	1.31	1.94	1.72
Specific gravity..............	45	2.68	2.77	2.73
Porosity.......percent..	45	28.4	52.2	36.9
Acid solubility.......do....	44	.8	12.8	5.3
Liquid limit..............	15	22	36	30
Sandy silt				
Permeability:				
Vertical.......gpd per sq ft..	8	0.001	0.5	0.1
Horizontal.......do....	3	.03	10	3
Dry unit weight.......g per cc..	10	1.07	1.79	1.55
Specific gravity..............	10	2.41	2.79	2.70
Porosity.......percent..	10	33.9	55.6	42.7
Acid solubility.......do....	8	4.8	12.1	7.6
Liquid limit..............	9	31	49	39
Sand-silt-clay				
Permeability:				
Vertical.......gpd per sq ft..	24	0.0005	5	0.2
Horizontal.......gpd per sq ft..	14	.001	3	.3
Dry unit weight.......g per cc..	29	1.00	1.88	1.52
Specific gravity..............	29	2.58	2.77	2.70
Porosity.......percent..	29	30.6	61.2	43.8
Acid solubility.......do....	24	1.5	20.8	5.7
Liquid limit..............	28	28	107	54
Clayey silt				
Permeability:				
Vertical.......gpd per sq ft..	2	0.0006	0.003	0.002
Horizontal.......gpd per sq ft..	1	----------	----------	.02
Dry unit weight.......g per cc..	2	1.41	1.46	1.44
Specific gravity..............	2	2.75	2.76	2.76
Porosity.......percent..	2	46.9	48.9	47.9
Acid solubility.......do....	1			3.2
Liquid limit..............	2	72	74	73
CORE HOLE 6S/2W-24C7				
Sandy silt				
Permeability:				
Vertical.......gpd per sq ft..	2	0.005	0.01	0.008
Horizontal.......gpd per sq ft..	2	.009	.1	.05
Dry unit weight.......g per cc..	4	1.61	1.74	1.66
Specific gravity..............	4	2.70	2.72	2.71
Porosity.......percent..	4	35.8	40.8	38.9
Acid solubility.......do....	2	10.1	10.5	10.3
Liquid limit..............	1	----------	----------	26
Clayey silt				
Permeability:				
Vertical.......gpd per sq ft..	8	0.0001	0.008	0.002
Horizontal.......gpd per sq ft..	11	.0002	.009	.002
Dry unit weight.......g per cc..	20	1.55	1.88	1.67
Specific gravity..............	20	2.67	2.77	2.72
Porosity.......percent..	20	31.4	46.2	38.8
Acid solubility.......do....	9	7.9	12.5	10.5
Liquid limit..............	8	30	49	41
Sandy clay				
Permeability:				
Vertical.......gpd per sq ft..	1	----------	----------	0.0002
Horizontal.......gpd per sq ft..	1			.0003
Dry unit weight.......g per cc..	2	1.34	1.67	1.51
Specific gravity..............	2	2.66	2.71	2.69
Porosity.......percent..	2	38.4	49.6	44.0
Acid solubility.......do....	1	----------	----------	6.0
Liquid limit..............	2	59	89	74

TABLE 10.—*Summary of selected physical and hydrologic properties for samples grouped by sediment class (Shepard system)*—Continued

Property	Samples	Range		Average
		Low	High	
CORE HOLE 6S/2W-24C7—Continued				
Silty clay				
Permeability:				
Vertical.......gpd per sq ft..	1	----------	----------	0.004
Horizontal.......gpd per sq ft..	----------	----------	----------	----------
Dry unit weight.......g per cc..	2	1.29	1.38	1.34
Specific gravity..............	2	2.76	2.77	2.77
Porosity.......percent..	2	50.2	53.3	51.8
Acid solubility.......do....	2	7.8	7.9	7.9
Liquid limit..............	2	84	90	87
Sand-silt-clay				
Permeability:				
Vertical.......gpd per sq ft..	10	0.0004	0.009	0.003
Horizontal.......gpd per sq ft..	14	.0003	.3	.04
Dry unit weight.......g per cc..	16	1.54	1.84	1.73
Specific gravity..............	16	2.71	2.75	2.73
Porosity.......percent..	16	32.6	44.0	36.5
Acid solubility.......do....	8	7.5	19.1	12.0
Liquid limit..............	8	33	58	38
Silty clay				
Permeability:				
Vertical.......gpd per sq ft..	9	0.0002	0.004	0.001
Horizontal.......gpd per sq ft..	10	.0005	.006	.002
Dry unit weight.......g per cc..	17	1.34	1.70	1.56
Specific gravity..............	17	2.68	2.79	2.72
Porosity.......percent..	17	36.8	50.4	42.8
Acid solubility.......do....	10	7.2	11.9	9.5
Liquid limit..............	12	38	68	54
CORE HOLE 7S/1E-16C6				
Sand (including gravel)				
Permeability:				
Vertical.......gpd per sq ft..	----------	----------	----------	----------
Horizontal.......gpd per sq ft..	3	0.4	190	60
Dry unit weight.......g per cc..	3	1.65	1.69	1.67
Specific gravity..............	3	2.72	2.79	2.76
Porosity.......percent..	3	37.9	40.4	39.5
Acid solubility.......do....	1			12.2
Liquid limit..............	----------	----------	----------	----------
Silty sand				
Permeability:				
Vertical.......gpd per sq ft..	2	0.004	0.03	0.02
Horizontal.......gpd per sq ft..	3	.001	.07	.03
Dry unit weight..............	3	1.73	1.91	1.83
Specific gravity..............	3	2.71	2.76	2.74
Porosity.......percent..	3	30.5	36.2	33.1
Acid solubility.......do....	2	11.0	13.5	12.3
Liquid limit..............	1	----------	----------	24
Sand-silt-clay				
Permeability:				
Vertical.......gpd per sq ft..	10	0.0001	0.005	0.001
Horizontal.......gpd per sq ft..	12	.0002	.01	.002
Dry unit weight.......g per cc..	12	1.59	1.88	1.76
Specific gravity..............	12	2.70	2.79	2.74
Porosity.......percent..	12	31.6	41.1	35.6
Acid solubility.......do....	5	12.7	18.4	15.5
Liquid limit..............	7	25	33	31
Clayey silt				
Permeability:				
Vertical.......gpd per sq ft..	4	0.0001	0.007	0.002
Horizontal.......gpd per sq ft..	7	.0002	.01	.002
Dry unit weight..............	7	1.59	1.80	1.65
Specific gravity..............	7	2.68	2.80	2.76
Porosity.......percent..	7	34.8	42.1	40.3
Acid solubility.......do....	2	11.4	16.1	13.8
Liquid limits..............	2	41	50	46

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