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RESULTS OF RESEARCH IN SAMPLING LOESSIAL SOIL FOR INPLACE UNIT WEIGHT DETERMINATIONS

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16. ABSTRACT

In the past, the USBR (Bureau of Reclamation) has used 5-inch (13-cm) diameter thin-wall push-tube sampling in loessial soil for unit weight determinations and laboratory testing. Radiographic (x-ray) photographs of push-tube samples showed patterns of concave fracturing, indicating substantial sample disturbance. In addition, sample recovery was frequently low (90 percent or less), indicating compaction of the soil samples. Because the amount of compaction was unknown, the inplace unit weights obtained from 5-inch (13-cm) diameter push-tube samples were not considered representative of in situ soil conditions. In addition, "undisturbed" specimens for laboratory testing could not be obtained from the samples.

Because of the difficulties encountered in push-tube sampling, USBR personnel evaluated several sampling techniques in loessial soil. Results of the investigation have led the USBR to use a hollow-stem auger system with liners. High-quality loessial soil samples can now be obtained for inplace unit weight determinations and laboratory testing.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. *DESCRIPTORS*-- push-tube sampling/ loessial soil/ concave fracturing/ undisturbed samples/ drill holes/ in situ soil conditions/ continuous sampling/ hollow-stem auger/ dry unit weight/ sample recovery

b. *IDENTIFIERS*-- North Loup Division/ Nebraska Projects Office/ Grand Island, Nebraska/ Twin Loups Irrigation and Reclamation Districts/ Mirdan Canal/ Davis Creek damsite

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Geotechnical Branch
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Engineering and Research Center
Denver, Colorado

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A less detailed form of this report was published in April 1987, by the American Society of Civil Engineers in Geotechnical Special Publication No. 10, *The Engineering Aspects of Soil Erosion, Dispersive Clays, and Loess.*

The research covered by this report was funded under the Bureau of Reclamation PRESS (Program Related Engineering and Scientific Studies) Project No. DR-447, "Canal Lining Performance – Loess."

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INTRODUCTION

Early in 1982, it became evident that loessial material obtained from projects in the North Loup Division was being contaminated by drilling fluid and was consolidating during the sampling process. Samples were obtained using the Pitcher sampler, which requires the use of drilling fluid. Following a brief, undocumented investigation of push-tube sampling techniques by USBR (Bureau of Reclamation) personnel, 5-inch (13-cm) diameter push-tube sampling in the dry was initiated, and samples obtained for dry unit weight testing were limited to a maximum length of 1.5 feet (0.5 m) in an attempt to recover high-quality samples. Five-inch (13-cm) diameter samples were needed to provide three specimens for triaxial shear testing and 4¼-inch (10.8-cm) diameter one-dimensional consolidation specimens. In addition to more representative testing conditions, the larger samples were required to minimize sample disturbance, which is critical in preserving the loose in situ structure of loessial soil.

As the North Loup Division investigations program continued, samples were sent to the Engineering and Research Center geotechnical laboratory for testing and radiographic (x-ray) examinations. Radiographs of the push-tube samples showed patterns of concave fracturing, perpendicular to the direction of push, in several of the loessial soil samples. Many of the concave fractures penetrated the entire sample cross section. This indicated that substantial disturbance was occurring during the push-tube sampling process. Figure 1 photographs show sample disturbance caused by the push-tube sampling process. Further analysis of 5-inch (13-cm) push-tube sampling techniques showed that sample recovery (ratio of length of recovered sample to length of push, expressed as a percent) was often low (90 percent or less), although it did not appear that any portion of the soil fell out of the tube into the drill hole. This indicated that the soil compacted during sampling. In addition, there appeared to be some sloughing of the drill hole side walls. Because of these factors, the amount of compaction could not be determined and, therefore, the inplace dry unit weights obtained from 5-inch (13-cm) push-tube samples were not considered representative of in situ soil conditions. "Undisturbed" specimens for laboratory testing could not be obtained from the push-tube samples. Ac-

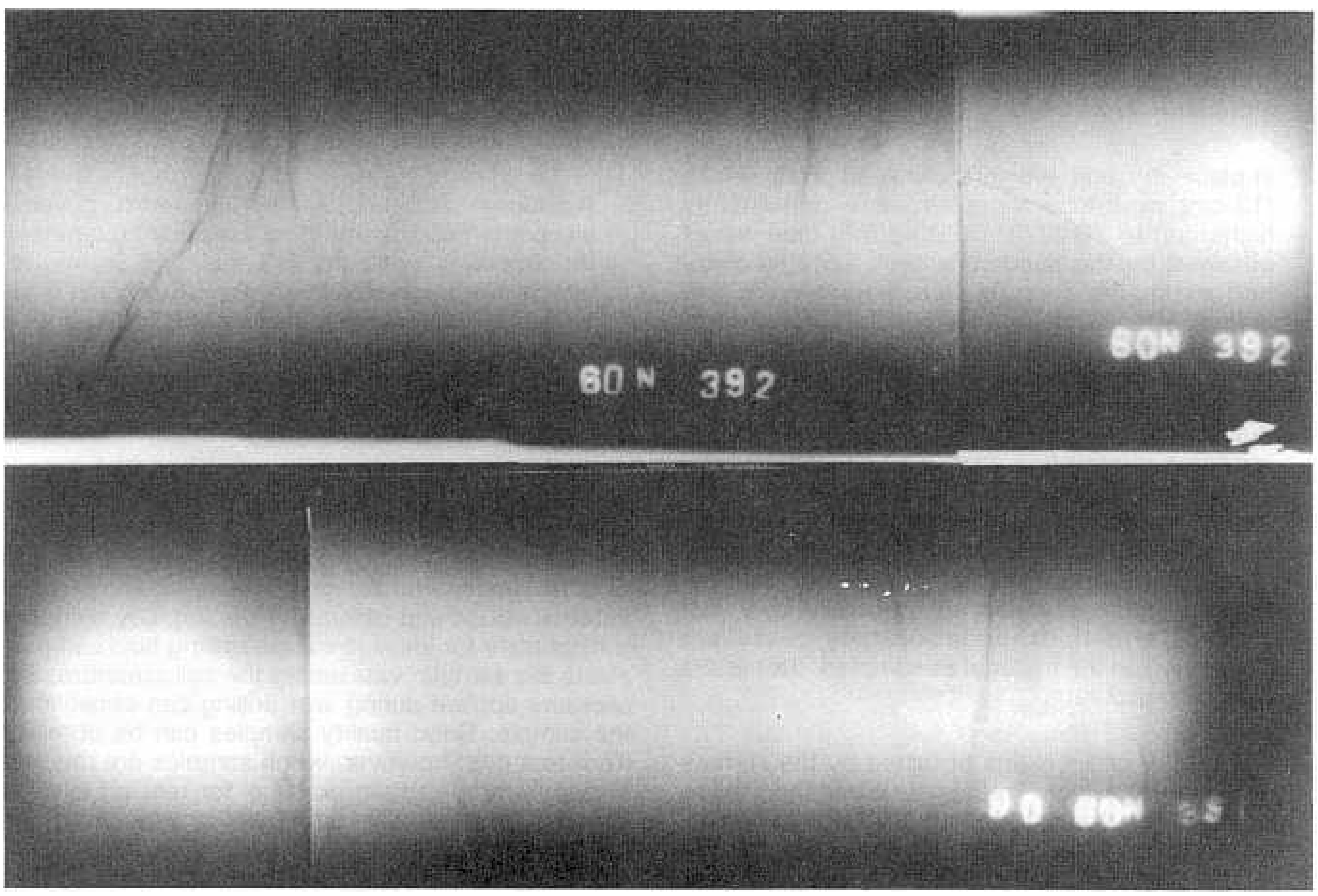

Figure 1. – Radiographic (x-ray) photographs showing disturbance of push-tube samples. P-801-D-81147

curate inplace unit weights were required for slope stability analyses and for structural settlement and foundation design analyses for canal structures. Accurate inplace unit weights were also required for determining the collapse potential of the material, which for loess is a function of dry unit weight and liquid limit [1].*

Because of the difficulty encountered in sampling loessial material, it became necessary to investigate other sampling techniques to find a more reliable method. In May 1984, an investigation program was developed for the North Loup Division to evaluate sampling techniques in loessial soil. The program was initiated by personnel from the Grand Island, Nebraska Projects Office and from the Divisions of Geology, Dam and Waterway Design, Construction, and Research and Laboratory Services at the Engineering and Research Center in Denver [2].

CONCLUSIONS AND RECOMMENDATIONS

1. In most cases, inplace dry unit weights obtained from hollow-stem auger samples were reasonably close to values obtained by the sand-cone method. Sample recovery was consistently high, and sample quality was good when the hollow-stem auger was used for sampling.

2. In-place dry unit weights obtained from 5-inch (13-cm) push-tube samples were consistently higher [up to 20 lbf/ft^3 (320 kg/m^3)] than values obtained by the sand-cone test. Low recovery and extensive sample disturbance were frequently encountered in the 5-inch (13-cm) push-tube samples. In addition, there appeared to be some sloughing of the drill hole side walls. For these reasons, there is no method to determine the amount of compaction that occurs during the push-tube sampling process. Therefore, the change in dry unit weight caused by compaction cannot be determined. Consequently, the dry unit weights obtained from push-tube samples may not be representative of actual inplace soil conditions. These samples are generally very disturbed; and if other laboratory tests are performed on the material as sampled, the results may be inaccurate.

3. Inplace dry unit weights obtained by the surface nuclear gauge were frequently lower than those obtained by the sand-cone method; however, wet unit weights obtained by the surface nuclear gauge were reasonably close to the wet unit weight values obtained by the sand-cone method. This indicates that a field correction for moisture content is necessary when using the surface nuclear gauge to provide acceptable inplace dry unit weight data.

4. In most cases, inplace dry unit weight determinations made on block samples correlated closely with data obtained by the sand-cone method.

5. The gamma-gamma density tool generally provided higher wet unit weights than the sand-cone and the nuclear gauge; however, the gamma-gamma density tool frequently indicated the zones of low unit weight material determined by sand-cone and nuclear gauge testing.

6. Current USBR practice in loessial soil requires that soil samples be obtained either as block samples from test pits or with the 6¼-inch (15.9-cm) i.d. hollow-stem auger system to ensure that the actual inplace soil conditions are represented by the samples. Because of the loose structure of loessial soil, samples obtained by the hollow-stem auger for unit weight and laboratory testing should be limited to a maximum length of 1.5 feet (0.5 m) to minimize sample disturbance. Additional studies may indicate that longer undisturbed samples can be obtained with the hollow-stem auger for laboratory testing.

7. Additional studies should be initiated to develop an economical liner meeting necessary tolerances for sampling with the 6¼-inch (15.9-cm) i.d. hollow-stem auger system. PVC (polyvinyl chloride) pipe sections were used in this investigation program; however, substantial variation in the i.d. of the pipe made it difficult to obtain a proper fit with the sampler bit.

PRACTICAL APPLICATIONS

The loose structure of loessial soil makes it difficult to obtain undisturbed samples for inplace unit weight determinations and laboratory testing. Dry sampling is necessary for loess, because drilling fluid can penetrate the sample, weakening the soil structure, and pressure applied during wet drilling can consolidate the sample. Good quality samples can be obtained from test pits; however, when samples are required at depths greater than practical for test pit excavation, different sampling methods are required. The hollow-stem auger system with liners provides a practical and economical method for obtaining good quality loess samples for unit weight determinations and laboratory testing.

*Numbers in brackets refer to entries in the bibliography.

NORTH LOUP DIVISION

The North Loup Division is a USBR project currently under construction for the Twin Loups Irrigation and Reclamation Districts in central Nebraska. The North Loup Division is a multipurpose project (fig. 2) that provides irrigation, ground-water recharge, water quality improvement, flood control, and recreation. The main purpose of the project is irrigation. When construction is completed, two dams will store 136,000 acre-feet (1.68×10^8 m^3) of water, which will be available to irrigate 53,000 acres (21,448 ha); 162 miles (261 km) of canals with capacities from 12 to 720 ft^3/s (0.3 to 20.4 m^3/s) will be used for water delivery. Canals having capacities greater than 50 ft^3/s (1.4 m^3/s) are constructed as open ditches, and those smaller are constructed as buried pipelines. In the North Loup Division, the thickness of the loess ranges from a few feet to more than 100 feet (30 m), and the average thickness is 40 to 50 feet (12 to 15 m).

GEOLOGIC AND ENGINEERING PROPERTIES

The North Loup Division lies in the heart of the Great Plains. This area is typified by ten to several hundred feet of unconsolidated Pleistocene deposits overlying horizontally bedded Tertiary and Cretaceous sediments. Surficial Pleistocene deposits include silty sands of the Sand Hills of west-central Nebraska, silts and sands of the river valleys, Aeolian silts of southern and eastern Nebraska, and glacial tills found in portions of eastern Nebraska. Canals and laterals are located within the rolling loessial hills of central Nebraska, but approximately 20 miles (32 km) to the northwest, these loessial hills change to the Sand Hills of west-central Nebraska.

Glacial ice sheets are not recognized as having advanced into this area of central Nebraska; however, their influence was recorded by alternating periods of stream downcuttings associated with glacial advances and related lowered ocean levels, by valley fillings during glacial meltbacks, and by sediment-laden streams that moved back and forth across wide expanses of the area in Pleistocene times. Flood plains of these interglacial streams are considered the sediment sources of loessial deposits.

Several recognized loesses occur in Nebraska. Peorian loess has widespread occurrence in the upper stratum and, consequently, is the material most frequently encountered during USBR construction. Peorian loess was the subject of research and testing in the monograph by Gibbs and Holland [1]. Other loesses are older and have very limited surface exposures in Nebraska; they are generally lean clays that have undergone loading and consolidation and, thus, have engineering characteristics different from those of Peorian loess.

Peorian loess was deposited during the middle Wisconsin period of the Pleistocene epoch. Loess is considered to be the product of glacial-related abrasion, which produced the rock-powder silt deposited along flood plains of rivers. This silt was subsequently transported and redeposited by wind action. Peorian loess is a buff-colored, uniformly sorted mixture composed predominantly of quartz grains in the size of silt and fine sand. Most of these grains are coated with very thin films of clay. This clay is generally montmorillonite that forms intergranular supports or braces within the structure. Calcite usually occurs in loess as distinct silt-sized grains in a finely dispersed state rather than as a cementing material. Thin clay coatings and, to a lesser extent, calcite apparently bond particles together. Upon wetting, this bond weakens causing loss of strength.

According to the *Earth Manual* [3], the loess encountered during construction of the North Loup Division was a clayey to silty loess containing less than 5 percent sand (usually 1 to 3 percent) and 18 to 24 percent 0.005-mm or smaller sized material. According to ASTM D 2487-85 [4], this loess is classified as silt (ML), silty clay (CL-ML) or, occasionally, lean clay (CL). The loess had a PI (plasticity index) that normally fell in the 6- to 11-percent range with an LL (liquid limit) range from 22 to 31 percent. The undisturbed dry unit weights of the loess ranged from the low 70's to low 90's lbf/ft^3 (1100 to 1400 kg/m^3), normally between 77 and 87 lbf/ft^3 (1233 and 1394 kg/m^3). The maximum unit weight of the material normally ranged from 99 to 104 lbf/ft^3 (1586 to 1666 kg/m^3), with an optimum moisture content of 19 to 20 percent. The field moisture content of the loess was highly variable and dependent on the depth of sampling, type of vegetative cover, and climatic conditions.

DISCUSSION

Two locations were selected for sampling along the alignment for Mirdan Canal, and two locations at Davis Creek damsite (fig. 2). The investigation program consisted of continuous sampling with a 6¼-inch (15.9-cm) i.d. hollow-stem auger system and continuous sampling with 5-inch (13-cm) i.d. push tubes in adjacent offset drill holes [5, 6]. Inplace moisture content and dry unit weight determinations were made on samples obtained by both drilling methods. Samples were recovered from approximately the same depth intervals in adjacent drill holes. Sample recovery was calculated for all samples. A gamma-gamma downhole density logging

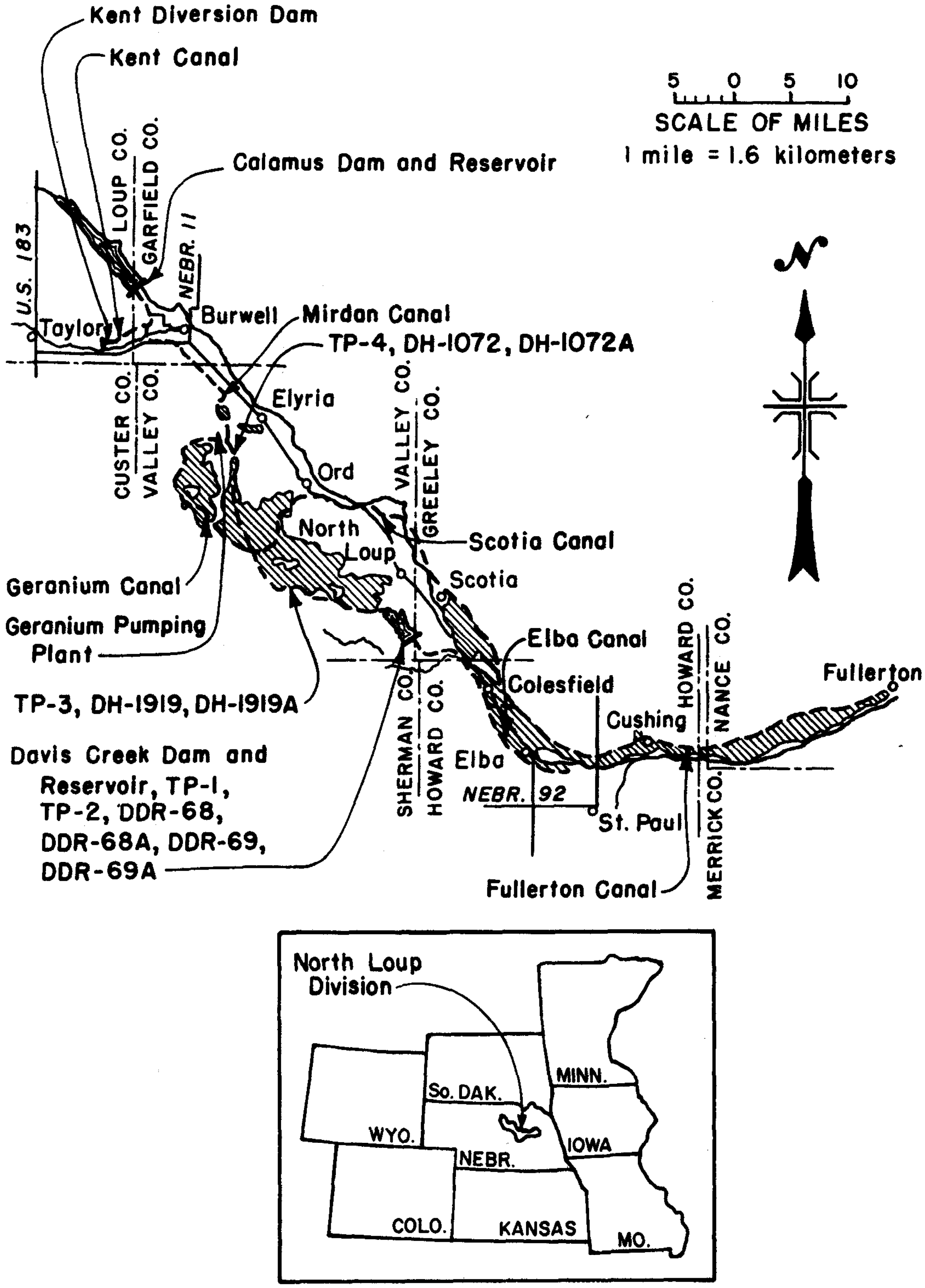

Figure 2. – Map of North Loup Division.

tool was also used in each drill hole [7]. Following completion of the geophysical logging, test pits were excavated at all four locations [8]. Locations of the eight drill holes and four test pits are shown on figure 2. Geologic logs for these locations are included in appendix A. Moisture content and dry unit weight determinations were made at frequent intervals in all test pits using both the "Field Density Test – Sand Cone" [3] and a surface nuclear moisture-density gauge. Block samples were also obtained at frequent depth intervals from each test pit for laboratory dry unit weight determinations by the mass in air – mass in water method.

Figure 3 shows a plan and profile view of a typical test pit in relation to the drill holes. The unit weights determined from the sand-cone test were used as the standard for evaluating the results of the other

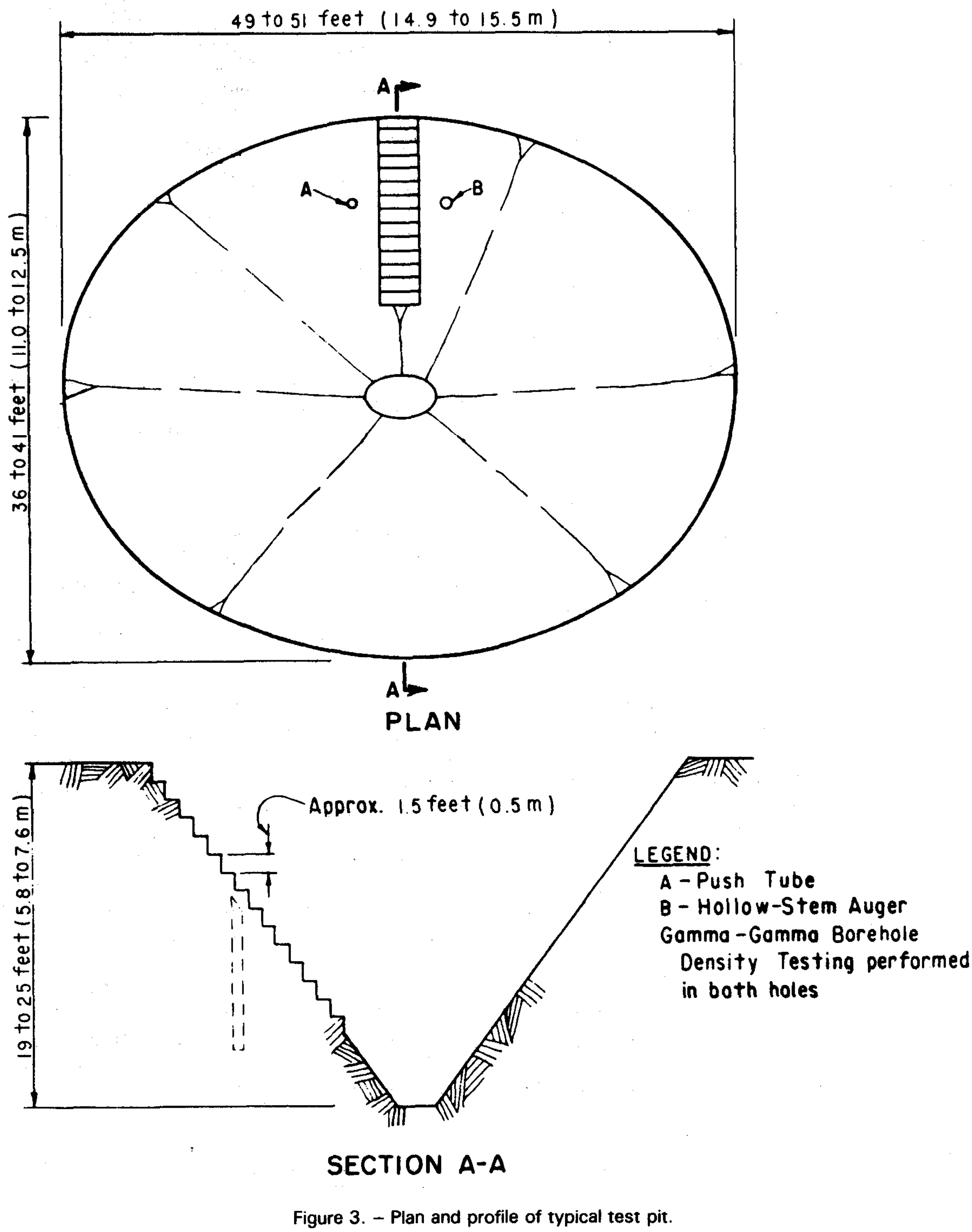

Figure 3. – Plan and profile of typical test pit.

methods investigated. This report discusses the results of the investigation program.

All laboratory and field tests were performed in accordance with procedures described in the *Earth Manual* [3], or in accordance with approved USBR test procedures.

Data acquisition was accomplished by personnel from several USBR offices. A drill crew from the Lower Missouri Region performed drilling operations with both a hollow-stem auger sampler and a push-tube sampler. Unit weight determinations were made on all samples. Test pits were excavated by a private party under contract to the Lower Missouri Region. Sand-cone testing in the test pits was performed by Grand Island Projects Office personnel. In addition, surface nuclear gauge and gamma-gamma borehole unit weight determinations were made by Engineering and Research Center personnel. To verify moisture content values obtained by the surface nuclear gauge, Mirdan Canal laboratory personnel performed independent moisture determinations. Unit weight and moisture content determinations were performed on several block samples.

Undisturbed Sampling

Hollow-Stem Auger System. – Sampling was performed using a CME-55 drill rig and a 10½-inch (27-cm) o.d. flight auger with a 6¼-inch (15.9-cm) i.d. hollow stem, one of the few such samplers available. A photograph of the drilling equipment in operation is shown on figure 4. A sketch of the hollow-stem auger system is shown on figure 5. During drilling operations, samples may be recovered using a core barrel sampler with or without liners; however, when samples are required for unit weight determinations, liners must be used. Sections of 5-inch (13-cm) i.d. PVC pipe, cut to appropriate lengths to fit the inside of the hollow-stem auger, were used as liners. A photograph of a liner made from PVC pipe is shown on figure 6.

Continuous hollow-stem auger sampling was performed in four holes (DDR-69 and -68, and DH-1072 and -1919). Moisture content and dry unit weight were determined for all samples, and sample recovery was computed. Sample recovery was consistently high in all samples from all four holes (see tables 1 through 4). A photograph of a typical soil sample obtained using the hollow-stem auger sampling method is shown on figure 7. Results of moisture content and dry unit weight determinations on samples obtained from all four auger holes are summarized in tables 1 through 4. Plots showing inplace dry unit weight versus depth are shown on figure 8.

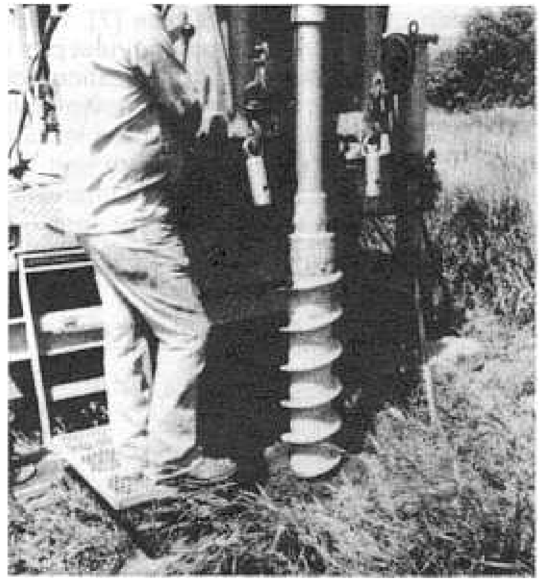

Figure 4. – Hollow-stem auger system. A 10½-inch (27-cm) o.d. flight auger with 6¼-inch (15.9-cm) i.d. hollow stem. P-801-D-81148

Initially, sampling with the hollow-stem auger system proceeded slowly, but as the drill crew became familiar with the equipment, the sampling process became quite efficient.

One problem encountered with this sampling method was that the i.d. of the PVC pipe (liner) was slightly larger than the i.d. of the sampler bit. During the investigation program, the bit diameter was modified several times; however, the i.d. of the PVC pipe varied enough so it was virtually impossible to consistently match bit diameter to pipe diameter. An unsuccessful attempt was also made to use 5-inch (13-cm) i.d. clear acrylic tubing so the core could be visually examined before extruding the sample. However, because the o.d. of the clear acrylic tubing was smaller than the i.d. of the core barrel sampler, the tubing moved to one side of the core barrel. Sample disturbance was then observed on one side of the sample in the clear acrylic liner. Because the PVC pipe fit more tightly in the barrel than the clear acrylic liner, this type of disturbance did not appear to be a problem with the PVC liners. Sampling then continued with PVC pipe as liners. Radiographic examinations of samples obtained using PVC pipe as a liner indicated minimal disturbance (i.e., no concave fractures). Further investigations are required to develop an economical liner meeting necessary tolerances for sampling with the 6¼-inch (15.9-cm) i.d. hollow-stem auger.

Push Tubes. – Following completion of each hole drilled with the hollow-stem auger system, an adjacent hole (offset several feet) was drilled using 5-inch

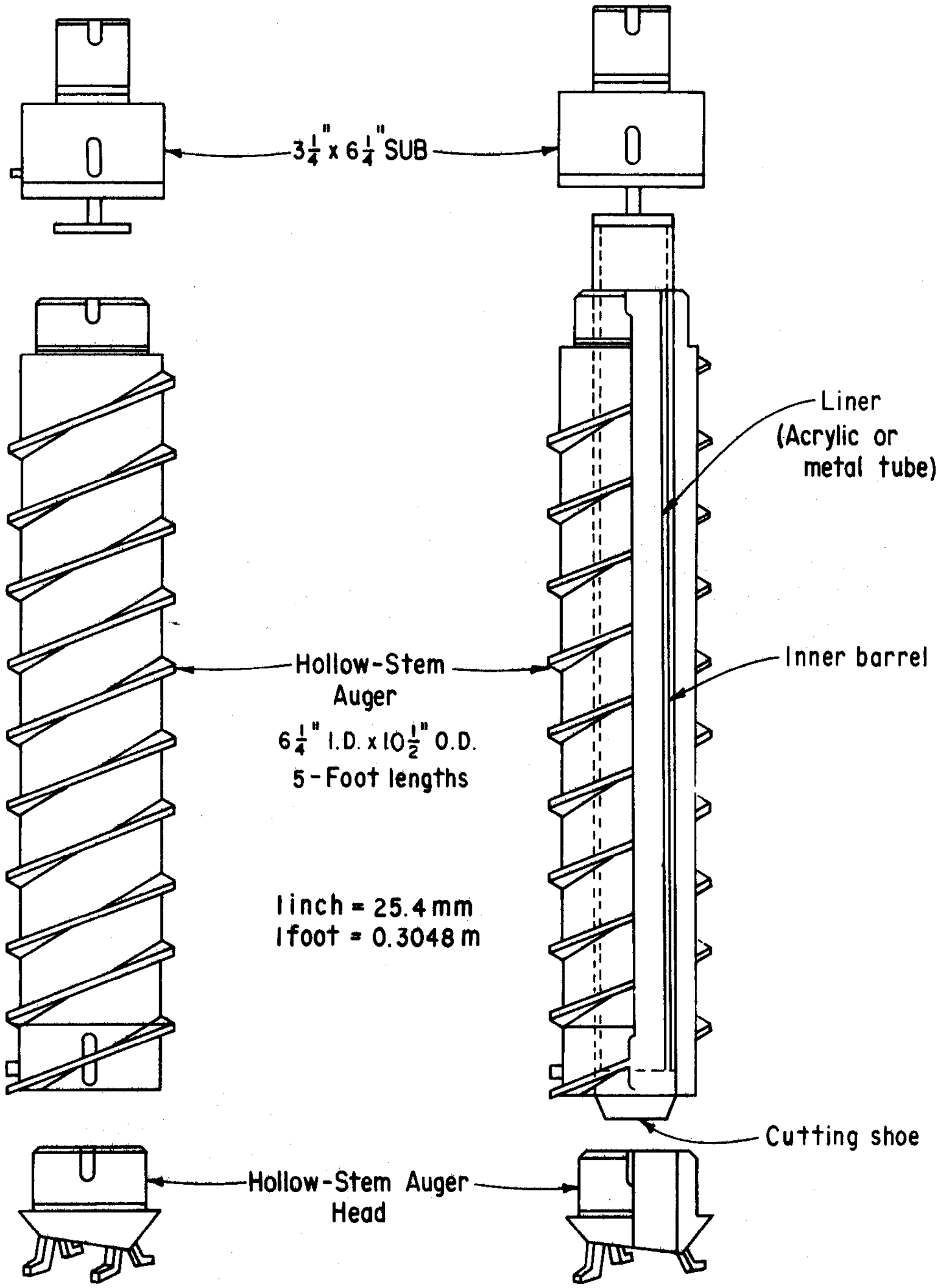

Figure 5. – Sketch of hollow-stem auger system.

(13-cm) i.d. push tubes and a Failing 1500S drill rig. Photographs of the drilling equipment are shown on figures 9 and 10.

Continuous sampling was performed throughout the depth of all four push-tube holes (DDR-68A and -69A and DH-1919A and -1072A), and push-tube samples were taken at approximately the same depth intervals sampled with the hollow-stem auger system. Moisture content and dry unit weight were determined on all samples obtained. Sample recovery was computed for all samples.

Sample disturbance was observed, and sample recovery was consistently low (see tables 1 through 4). Radiographic examination of several push-tube samples indicated that substantial disturbance occurred during the sampling process. Figure 11 is a photograph of concave fracturing of a loessial soil sample obtained with the push tube. This type of fracturing is frequently encountered in loessial soil samples when push tubes are used for sampling. At the discretion of the driller, the penetration rate of the push-tube sampler was greatly reduced during a portion of this investigation program in an attempt to improve sample quality and recovery. Even at slower penetration rates, sample disturbance was observed and sample recovery was low.

The results of moisture content and dry unit weight determinations made on samples from all four push-

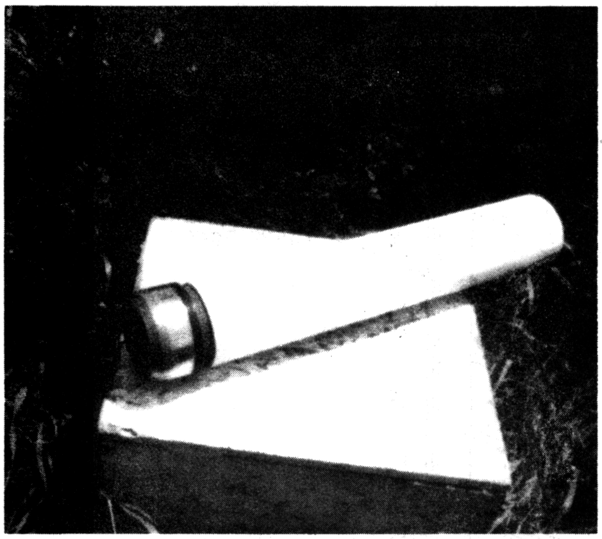

Figure 6. – Liner made from cut section of 5-inch (13-cm) i.d. PVC pipe. P-801-D-81149

tube holes are summarized in tables 1 through 4. Plots showing dry unit weight versus depth are shown on figure 8.

Geophysical Borehole Unit Weight Logging

After completion of the sampling with the hollow-stem auger and push tubes, seven of the eight drill holes were geophysically logged. Drill hole DDR-69A caved in before geophysical logging could be performed. A brief explanation of the borehole unit weight logging technique provided by the Geophysics Section is included in appendix B.

Inplace wet unit weights were determined at frequent depth intervals. These results are summarized in tables 5 through 8 and on plots of inplace wet unit weight versus depth (fig. 12). Because only wet unit weight determinations can be obtained by geophysical borehole logging, these results are compared only with the wet unit weights obtained by other sampling and testing methods.

Inplace Unit Weight Testing

Test Pits. – Four test pits (TP-1 through -4) were excavated using an Insley H-600 backhoe. Total depths of the test pits ranged between approximately 19 and 25 feet (6 and 8 m). The test pits were excavated to full depth in an arc around the drill holes. Locations of the test pits in relation to the drill holes are shown on the geologic logs (app. A). Benches were excavated down one slope of each test pit at approximately 1.5-foot (0.5-m) depth intervals for field unit weight (sand-cone) testing, surface nuclear moisture-density gauge testing, and

Figure 7. – Typical soil sample obtained using the hollow-stem auger. P-801-D-81150

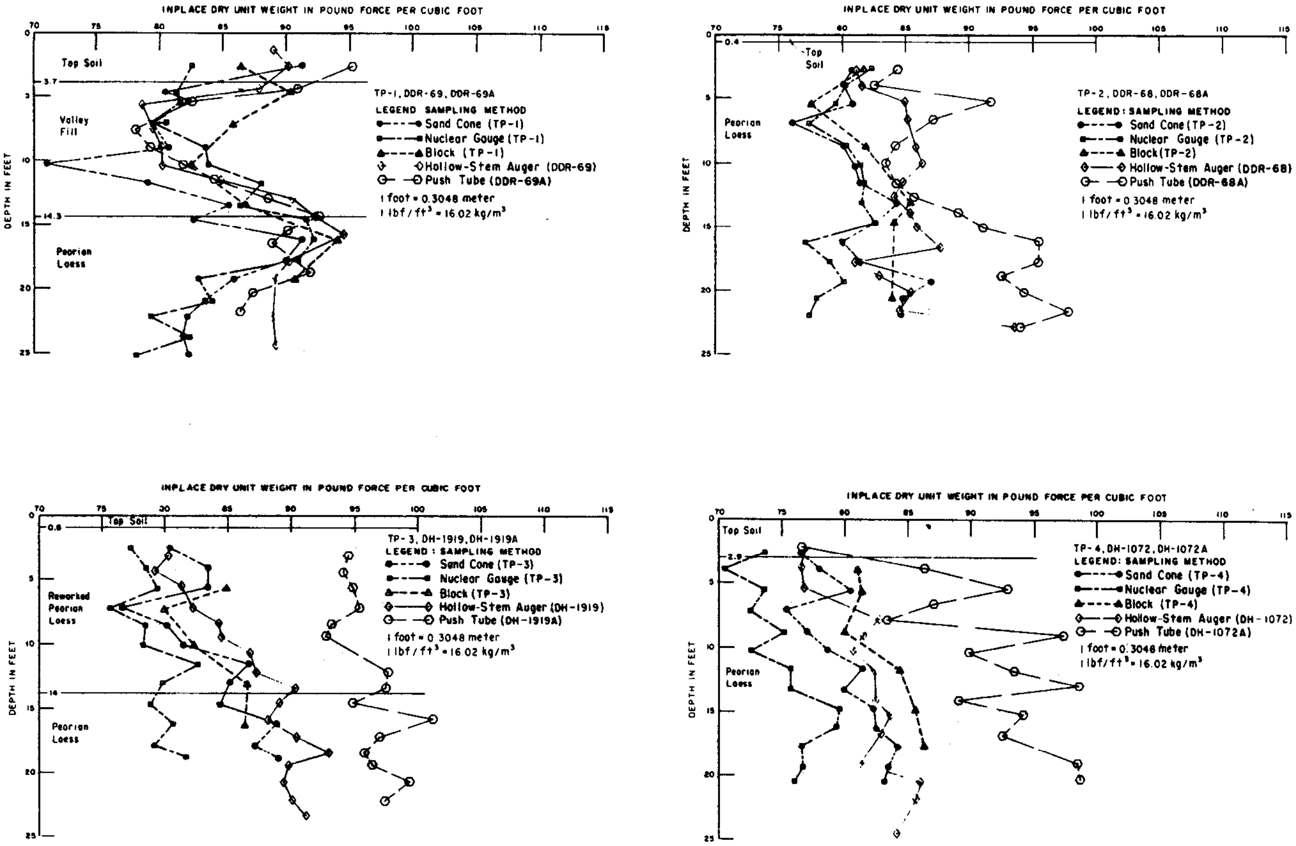

Figure 8. – Inplace dry unit weight versus depth.

block sampling. Figure 3 is a sketch and figure 13 is a photograph of an excavated test pit. Inplace moisture content and dry unit weight determinations were made on each bench by the sand-cone method and by nuclear gauge. Block samples were also obtained at frequent depth intervals in all test pits for laboratory moisture content and dry unit weight determinations by the mass in air–mass in water method.

Surface Nuclear Gauge. – Nuclear gauge moisture content and unit weight tests were performed on each bench in all four test pits at approximately 1.5-foot (0.5-m) depth intervals. A Troxler 3411B single-probe nuclear gauge was used for testing (fig. 14). The gauge was adjusted once at each test pit to correct for sidewall proximity effects. Three 1-minute counts were taken at each location. The three readings were averaged to obtain the final reading. Results of nuclear gauge testing are summarized in tables 1 through 4 and on the plots shown on figure 8.

Because the moisture content is a factor in obtaining correct inplace dry unit weights, ovendried moisture content values were used. When possible, moisture content determinations from the sand-cone test were used; however, in several instances, separate moisture content determinations were required because of the length of time between nuclear gauge and sand-cone testing. Moisture contents cf ovendried specimens and the wet unit weight values obtained by the nuclear gauge were then used to calculate inplace dry unit weights for the nuclear gauge. These results are summarized in tables 9 through 12 and on figure 15.

Inplace wet unit weights obtained by the nuclear gauge were also compared with wet unit weights obtained by the sand-cone and gamma-gamma density tool testing. These results are summarized in tables 5 through 8 and plotted on figure 12.

Field Unit Weight (Sand-Cone) Tests. – A sand-cone test was performed on each bench in all test pits following the test with the surface nuclear gauge. Results from the sand-cone tests are summarized in tables 1 through 4 and on the plots shown on figure 8. The sand-cone test was used as the standard, and data from all other test methods were compared with results from the sand-cone test.

Block Samples. – Small block samples having an approximate average volume of 0.14 ft³ (4000 cm³) were obtained from benches at frequent depth intervals in every test pit. The block samples were

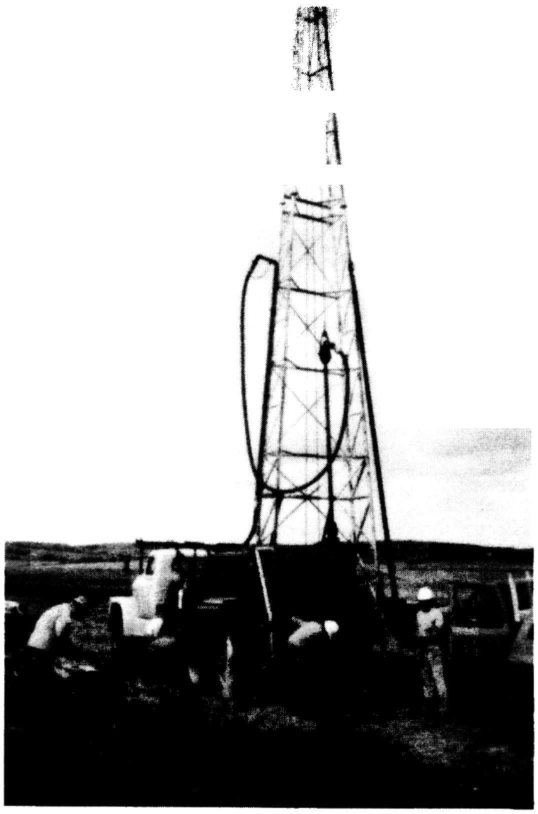

Figure 9. – Failing 1500S drill rig used for push-tube sampling. P-801-D-81151

Figure 10. – Closeup of Failing 1500S drill rig during push-tube sampling. P-801-D-81152

Figure 11. – Concave fracturing of loessial soil sample caused by push-tube sampling. P-801-D-81153

waxed at the site and then transported to the laboratory for moisture content and dry unit weight determinations by the mass in air–mass in water method. These test results are summarized in tables 1 through 4 and on the plots shown on figure 8.

RESULTS OF SAMPLING INVESTIGATION

Inplace Dry Unit Weight Versus Depth

Tables 1 through 4 and figures 8 through 11 summarize inplace dry unit weights determined from 5-inch (13-cm) i.d. push-tube samples, 6¼-inch (15.9-cm) i.d. hollow-stem auger samples, block samples, sand-cone testing, and surface nuclear gauge testing.

Davis Creek Damsite. – Inplace dry unit weights obtained from TP-1, DH-69, and DH-69A at Davis Creek damsite produced comparable data for most sampling intervals for all five methods (see table 1 and fig. 8). The geologic log at this location indicated topsoil from the ground surface to a depth of 3.7 feet (1.1 m), valley fill between depths of 3.7 and 14.3 feet (1.1 and 4.4 m), and Peorian loess between depths of 14.3 and 25.1 feet (4.4 and 7.7 m).

Inplace dry unit weights obtained in Peorian loess from TP-2, DH-68, and DH-68A at the Davis Creek damsite show comparable values for four of the five methods (see table 2 and fig. 8). The 5-inch (13-cm) diameter push-tube samples generally showed higher

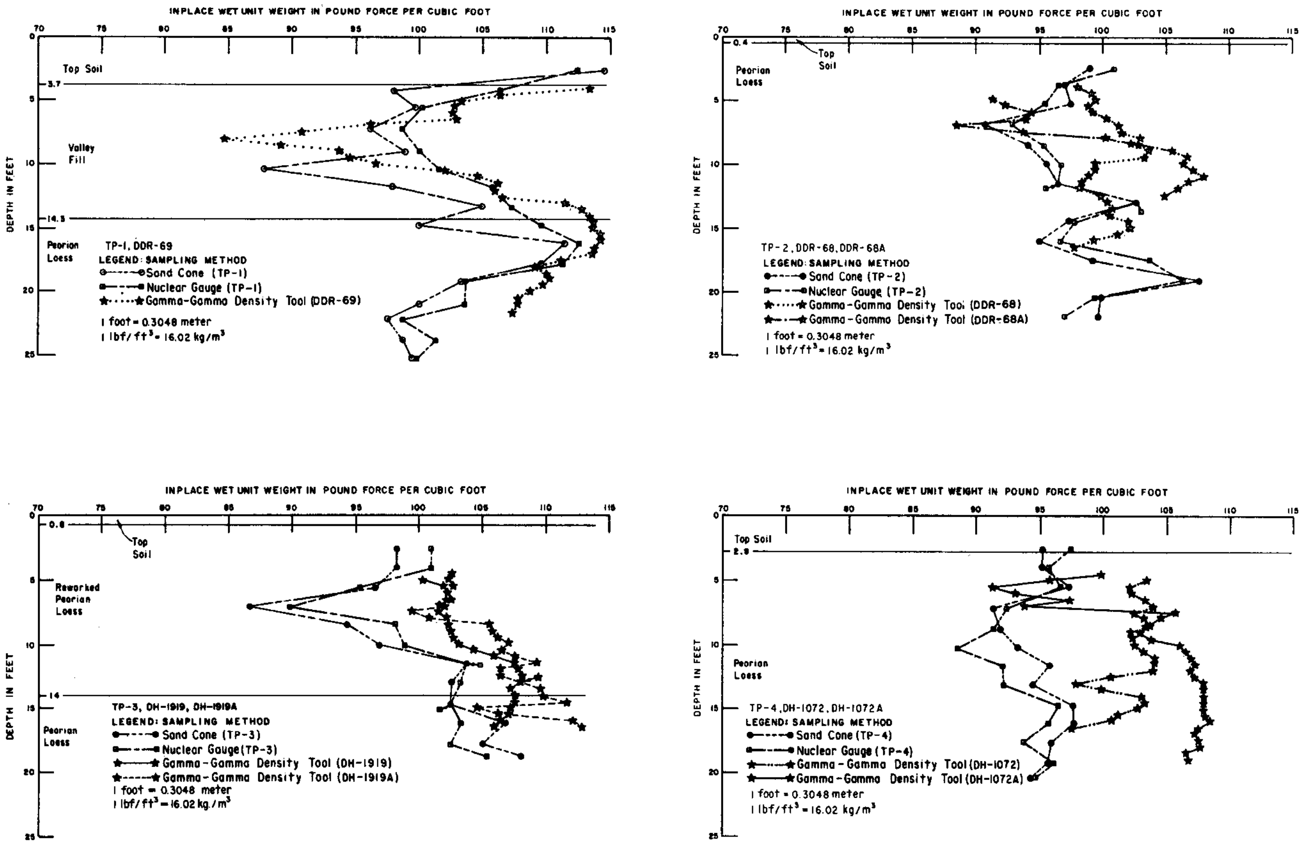

Figure 12. – Inplace wet unit weight versus depth.

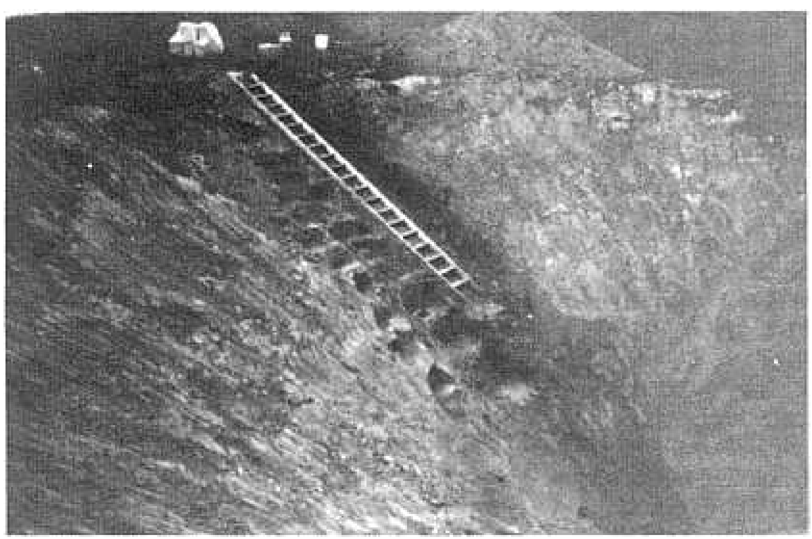

Figure 13. – Typical test pit configuration. P-801-D-81154

inplace dry unit weights than samples obtained by the other methods. Several of the push-tube samples showed extensive disturbance when observed visually and examined radiographically. Concave fracturing was typically encountered (see the photograph on fig. 11) in these samples. Sample recovery was low for many of the push-tube samples (see table 2), indicating that compaction may have caused the increased unit weight.

Mirdan Canal. – Inplace dry unit weights obtained in Peorian loess from TP-3, DH-1919, and DH-1919A

Figure 14. – Troxler 3411B nuclear gauge. Used for moisture and unit weight determinations. P-801-D-81155

(located along the Mirdan Canal alignment) show comparable values for sand-cone testing, hollow-stem auger samples, and block samples (see table 3 and fig. 8). Again, samples obtained with the 5-inch (13-cm) push tubes showed consistently higher inplace dry unit weights than those obtained by the sand-cone method. Low sample recovery (see table 3) and extensive sample disturbance were frequently encountered with the push-tube samples, indicating compaction during the sampling process. At this location, inplace dry unit weights obtained by the surface nuclear gauge were lower than those obtained by the sand-cone method; however, wet unit weights obtained by the surface nuclear gauge were comparable with those obtained by the sand-cone method (fig. 8). This indicates that a field correction for moisture content is necessary when using the surface nuclear gauge.

Inplace dry unit weights obtained from TP-4, DH-1072, and DH-1072A (also located in Peorian loess along the Mirdan Canal alignment) show comparable values for sand-cone testing, hollow-stem auger samples, and block samples (see table 4 and fig. 8). Again, samples obtained with the 5-inch (13-cm) push tubes were disturbed and the sample recovery was low (see table 4). Consistently higher inplace dry unit weights were obtained from the 5-inch (13-cm) push-tube samples than from the other methods, indicating compaction during the sampling process. Inplace dry unit weights obtained from the surface nuclear gauge were again consistently lower than those obtained by the sand-cone method; however, the wet unit weights were comparable with those obtained by the sand-cone method (fig. 8). This indicates that a field correction for moisture content is necessary when using the surface nuclear gauge.

When comparing results of inplace dry unit weight versus depth at all four locations (fig. 8), results generally indicate that the inplace dry unit weights obtained by the sand-cone method, and from the hollow-stem auger, and block samples are comparable. Inplace dry unit weights obtained from the 5-inch (13-cm) push-tube samples were consistently higher [up to 20 lb/ft^3 (320 kg/m^3)] than values obtained by the sand-cone method. Low recovery (tables 1 through 4) and extensive sample disturbance were frequently encountered in the 5-inch (13-cm) push-tube samples, indicating compaction during the sampling process. Because the amount of compaction that occurred during the push-tube sampling process was unknown, the change in the unit weight values caused by the compaction also could not be determined. Therefore, dry unit weight values obtained from push-tube samples may not be representative of in situ soil conditions. In most cases, inplace dry unit weights determined from hollow-stem auger samples were reasonably close to values obtained by the sand-cone method. Sample recovery was high (tables 1 through 4), and quality was good when the hollow-stem auger was used.

Plots showing inplace dry unit weights determined from hollow-stem auger and push-tube samples versus inplace dry unit weights obtained by the sand-cone method are shown on figures 16 and 17. Unit weights determined from samples of valley fill and Peorian loess are plotted separately.

Inplace dry unit weights obtained by the surface nuclear gauge were frequently lower than values obtained by the sand-cone method; however, inplace wet unit weights obtained by the surface nuclear gauge were reasonably close to inplace wet unit weight values obtained by the sand-cone method. This indicates that a field correction for moisture content is necessary when using the surface nuclear gauge. As part of this investigation program, moisture content samples were obtained for ovendrying at all locations where the surface nuclear gauge was used. Ovendried moisture contents and inplace wet unit weights obtained from the nuclear gauge were used to compute inplace dry unit weights determined by the nuclear gauge and are summarized on the plots shown on figure 15. These inplace dry unit weight values were generally comparable with those obtained by the sand-cone method.

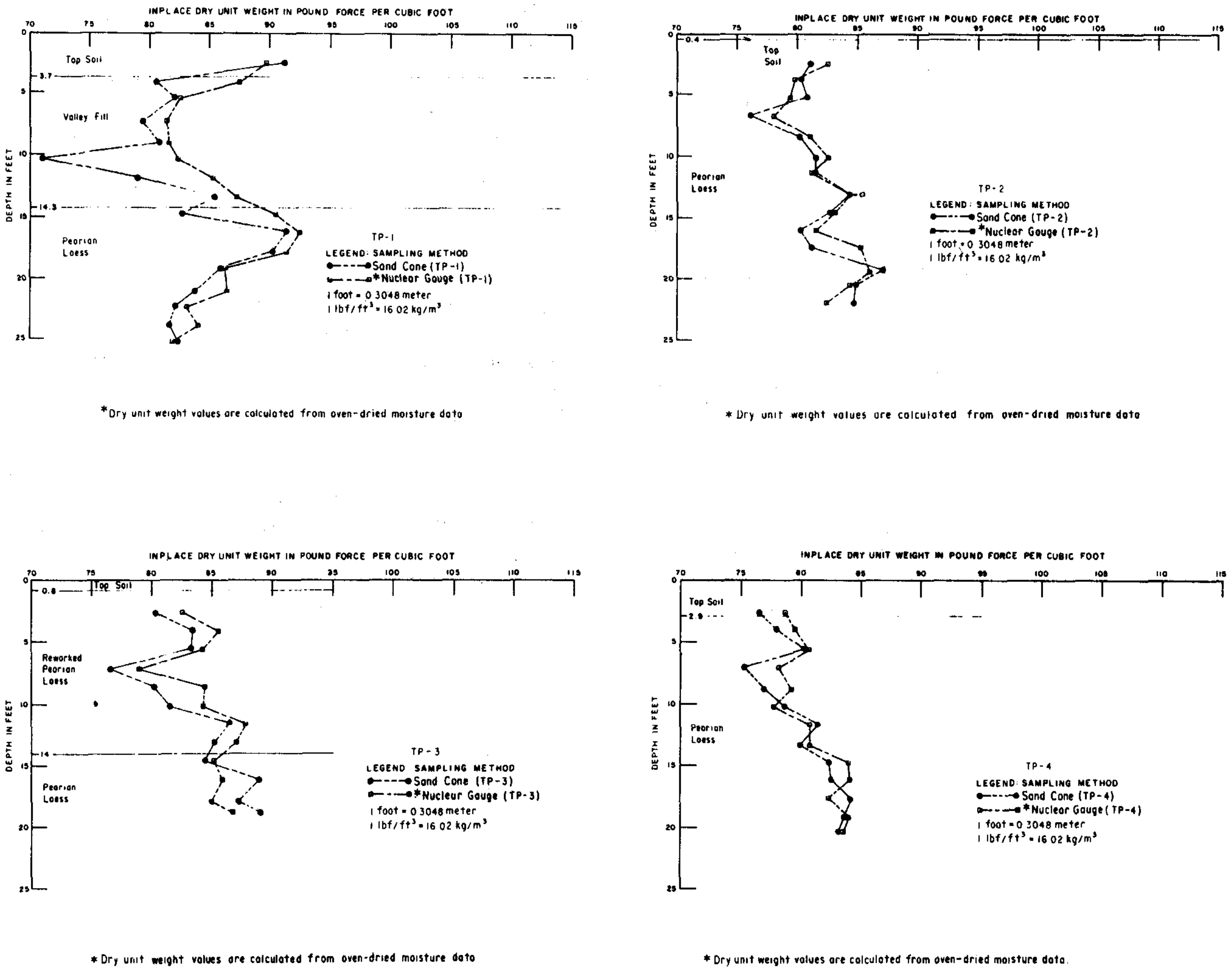

Figure 15. – Inplace dry unit weight versus depth – nuclear gauge. Dry unit weight values are calculated from ovendried moisture data.

SUMMARY

1. An investigation program to evaluate methods of determining inplace dry unit weight in loessial soil was developed and initiated by personnel from the Kansas-Nebraska Projects Office and from the Divisions of Geology, Dam and Waterway Design, Construction, and Research and Laboratory Services at the Engineering and Research Center in Denver.

2. Two locations at the Davis Creek damsite and two locations along the Mirdan Canal alignment were selected for testing. The investigation program involved continuous sampling with a 6¼-inch (15.9-cm) i.d. hollow-stem auger sampler and continuous sampling with a 5-inch (13-cm) push-tube sampler. Inplace dry unit weight and moisture content were determined on samples obtained by both drilling methods at approximately the same depth intervals. Recovery was computed for all samples. A gamma-gamma downhole density tool was then used in each drill hole. Following completion of the geophysical downhole unit weight testing, test pits were excavated at all four sites. Sand-cone and surface nuclear gauge tests were made at frequent intervals in all test pits. Block samples were also obtained at frequent intervals in each test pit.

3. The sand-cone method was used as the standard for evaluating all inplace dry unit weight test data. Data from this investigation program provide trends produced by each sampling and testing method. There is some variation in the location and depth intervals of the samples tested.

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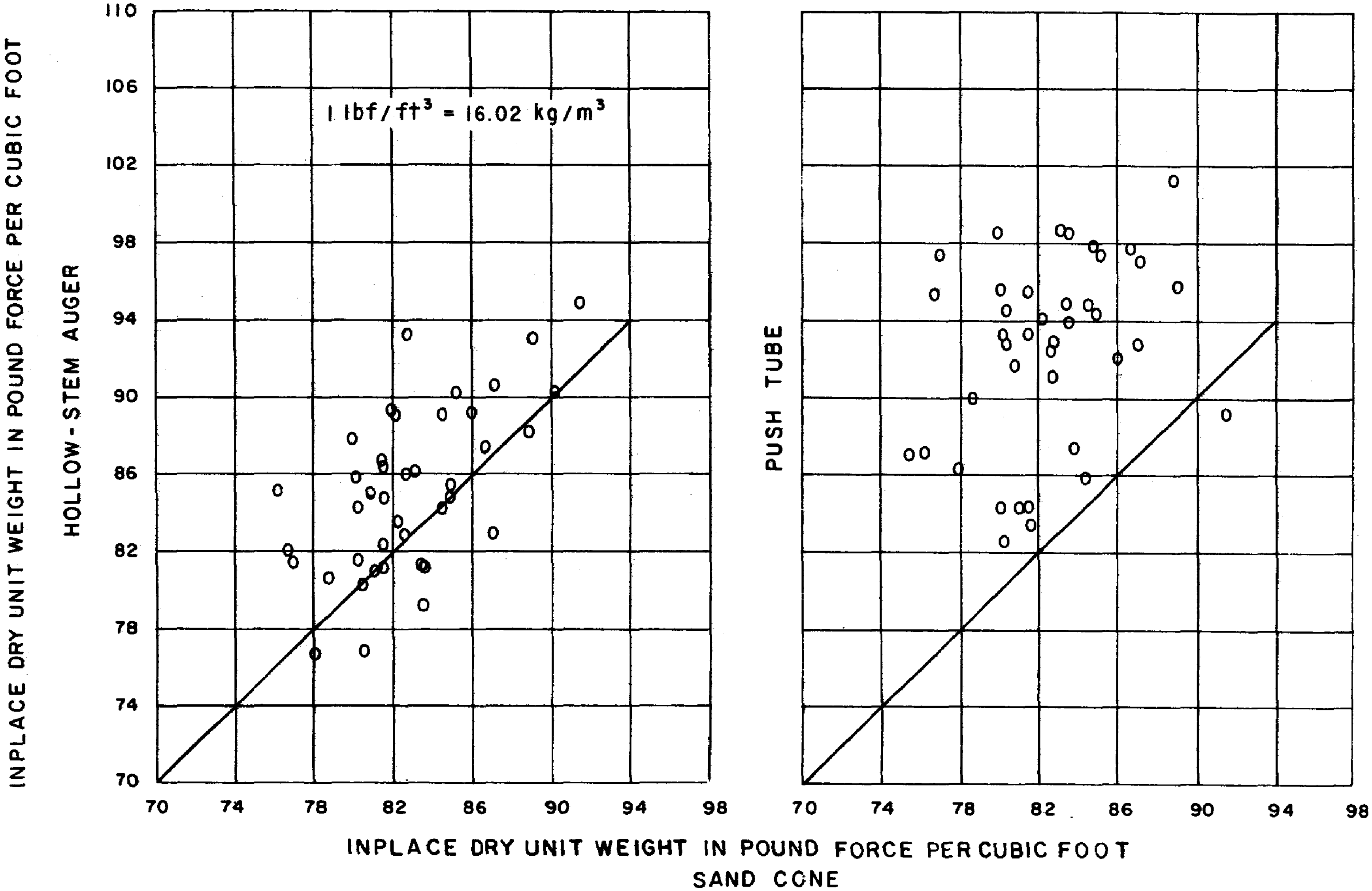


Figure 16. – Inplace dry unit weight by hollow-stem auger and push tube versus inplace dry unit weight by sand cone – Peorian loess.

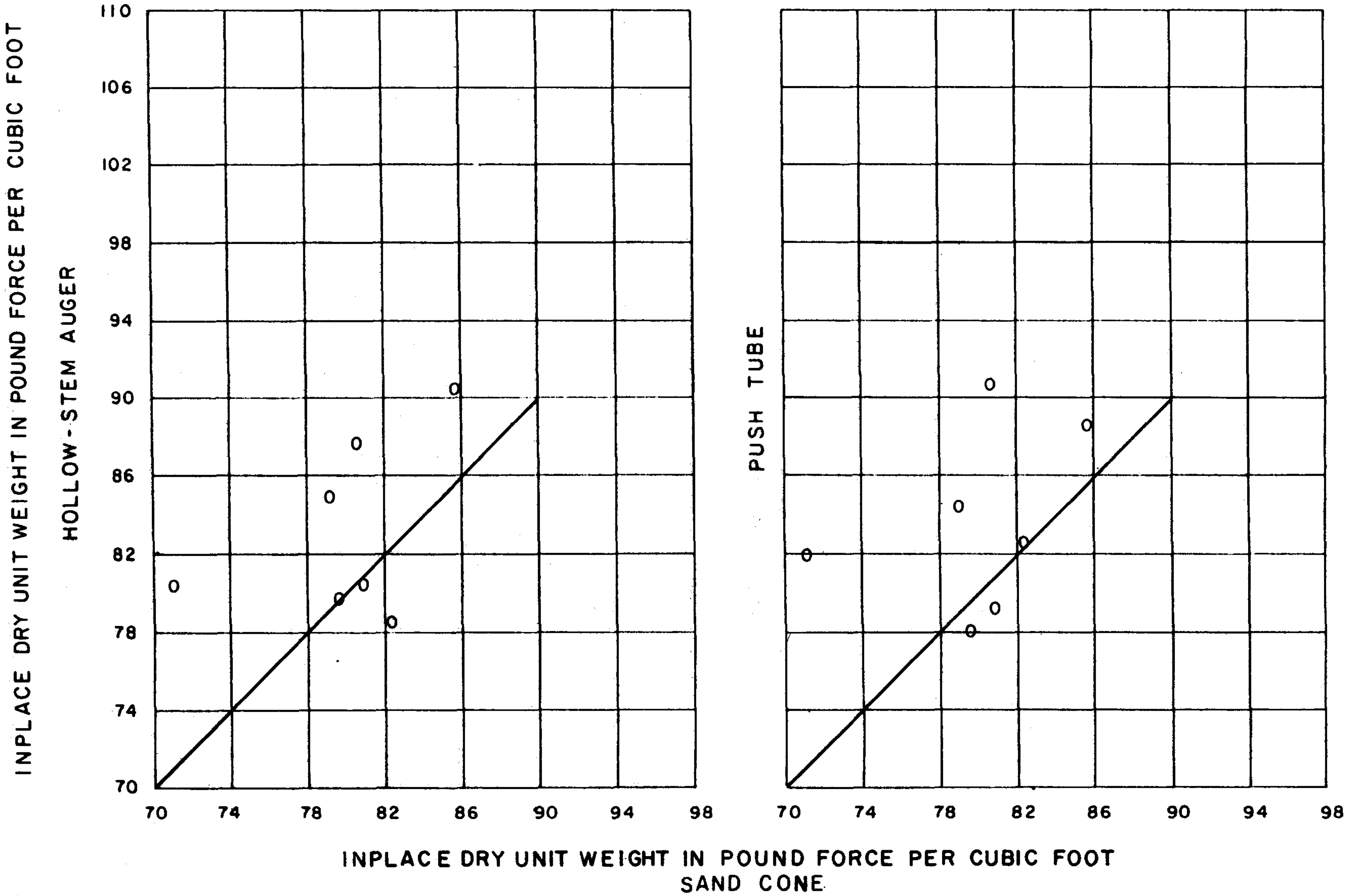


Figure 17. – Inplace dry unit weight by hollow-stem auger and push tube versus inplace dry unit weight by sand cone – valley fill.

Table 1. – Summary of inplace moisture and unit weight values (TP-1, DDR-69, DDR-69A).

Project: Pick-Sloan Missouri Basin Program | Feature: Davis Creek Dam | Conversions: 1 foot = 0.3048 meter, 1 lbf/ft³ = 16.018 46 kg/m³

Identification				Test pit TP-1									Drill hole DDR-69				Drill hole DDR-69A			
				Sand cone			Nuclear gauge			Block			Hollow-stem auger				Push tube			
Geol. formation, ft	Project test No.	Avg. depth, ft	Depth, ft	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %
		1.2	0.4-1.9										111.2	25.0	89.0	100				
Topsoil		2.6	1.9-3.4										111.0	23.3	90.1	100	118.0	24.1	95.1	73
0.0-3.7	1-16	2.6	2.1-3.1	114.4	25.3	91.3	112.4	36.1	82.6	106.5	23.3	86.4								
		4.2	3.4-4.9										106.7	21.6	87.7	100	109.7	20.8	90.8	100
	1-15	4.3	3.8-4.8	97.9	21.5	80.6	106.3	31.0	81.2	109.1	20.7	90.4								
		5.7	4.9-6.5										96.7	23.2	78.5	100				
		5.9	4.9-6.9														100.8	22.1	82.6	100
	1-14	5.6	5.1-6.1	99.8	21.2	82.3	100.1	22.5	81.7											
		7.2	6.5-8.0										97.6	22.6	79.6	100				
	1-13	7.3	6.8-7.8	96.1	20.9	79.5	98.6	24.1	79.5	103.1	20.2	85.8								
Valley fill		7.7	6.9-8.5														99.9	27.9	78.1	98
	1-12	9.0	8.5-9.5	98.9	22.4	80.8	100.0	19.5	83.7				99.9	24.4	80.3	100	99.4	25.5	79.2	90
		10.2	9.5-11.0														101.1	23.4	81.9	100
		10.4	9.7-11.0										96.5	20.1	80.3	100				
	1-11	10.4	9.9-10.9	87.8	23.5	71.1	101.5	21.0	83.8	100.3	21.7	82.4								
		11.6	11.2-12.3										102.3	20.3	85.0	100	99.4	17.6	84.5	100
	1-10	11.9	11.0-12.3	97.9	23.7	79.1	105.6	19.9	88.1											
		12.9	12.3-13.5										106.8	17.9	90.5	100	103.9	17.1	88.7	100
	1-9	13.4	12.9-13.9	105.0	22.7	85.6	107.1	23.7	86.6	107.1	23.2	86.9								
14.3		14.2	13.5-14.8														109.4	17.9	92.8	100
		14.3	13.5-15.1										109.5	17.5	93.2	100				
	1-8	14.8	14.3-15.3	100.0	20.8	82.8	109.5	19.5	91.6											
		15.4	14.8-15.9														107.4	19.0	90.3	96
		15.8	15.1-16.6										112.1	18.3	94.8	100				
	1-7	16.3	15.8-16.8	111.4	21.7	91.5	112.6	22.1	92.2	113.8	21.1	94.0								
		16.4	15.9-16.9														105.0	17.9	89.1	68
		17.6	16.6-18.5										105.2	16.5	90.3	100				
	1-6	17.8	17.3-18.3	109.5	21.5	90.2	111.3	22.4	91.0											
		18.6	17.6-19.5														108.8	18.1	92.1	100
		19.2	18.5-20.0										103.7	16.2	89.3	100				
	1-5	19.2	18.7-19.7	103.3	20.1	86.0	103.4	24.6	83.1	108.0	19.2	90.6								
Peorian		20.2	19.5-21.0														102.3	17.0	87.4	97
loess		20.8	20.0-21.5										102.8			100				
	1-4	21.0	20.5-21.5	100.0	19.4	83.8	103.4	22.9	84.2											
		21.8	21.0-22.5														101.5	17.2	86.6	80
		22.5	21.5-23.5										105.5	18.4	89.1	100				
	1-1	22.3	21.8-22.8	97.5	18.7	82.2	98.6	24.0	79.5											
	1-2	23.8	23.3-24.3	98.7	20.5	81.9	101.3	22.9	82.4											
		24.5	23.7-25.3										105.3	17.9	89.3	100				
	1-3	25.2	24.7-25.7	99.4	20.7	82.3	99.0	26.6	78.2											
		26.0	25.3-26.6										104.9	18.1	88.8	100				
		27.4	26.6-28.1										105.5	17.9	89.5	100				
		28.9	28.1-29.7										106.1	18.0	89.9	100				
		30.5	29.7-31.1										105.9	16.6	90.8	100				
		34.2	33.4-35.0										111.8	8.8	102.8	91				
		36.0	35.0-37.0										115.7	10.6	104.6	100				

Table 2. – Summary of inplace moisture and unit weight values (TP-2, DDR-68, DDR-68A).

Project: Pick-Sloan Missouri Basin Program — Feature: Davis Creek Dam — Conversions: 1 foot = 0.3048 meter, 1 lbf/ft³ = 16.018 46 kg/m³

Identification				Test pit TP-2									Drill hole DDR-68				Drill hole DDR-68A			
				Sand cone			Nuclear gauge			Block			Hollow-stem auger				Push tube			
Geol. formation, ft	Project test No.	Avg. depth, ft	Depth, ft	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %
Topsoil 0.0-0.4		2.6	1.9-3.4										97.3	20.1	81.0	100	100.3	18.8	84.4	73
	2-16	2.5	2.0-3.0	99.0	22.2	81.0	100.9	22.6	82.3	99.9	22.3	81.7								
	2-15	3.9	3.4-4.4	97.0	20.9	80.2	96.5	20.2	80.3				97.7	19.6	81.6	100	99.5	20.4	82.6	100
		5.2	4.4-5.9										101.4	19.3	85.0	100	109.6	19.3	91.8	83
	2-14	5.4	4.9-5.9	97.4	20.3	80.9	95.5	20.1	79.6	93.0	20.0	77.5								
		6.6	5.9-7.4										100.6	18.0	85.2	100	102.7	17.8	87.2	100
	2-13	6.9	6.4-7.4	90.7	19.0	76.2	92.8	19.8	77.5											
		7.8	7.4-8.1													*				*
	2-12	8.6	8.1-9.1	94.1	17.6	80.1	95.3	18.9	80.2	98.3	20.0	81.9								
		8.6	8.1-9.2										100.1	16.6	85.8	100	98.2	16.5	84.3	95
		10.0	9.2-10.7										101.2	17.0	86.4	100	98.0	17.3	83.5	97
	2-11	10.1	9.6-10.6	95.6	17.1	81.6	96.7	19.2	81.1											
		11.4	10.7-12.1										99.2	16.9	84.8	100	98.1	16.1	84.4	100
	2-10	11.5	11.0-12.0	96.4	18.3	81.5	96.3	17.7	81.8											
Peorian		12.6	12.1-13.2										98.8	17.3	84.2	100	100.0	16.5	85.8	55
loess	2-9	13.1	12.6-13.6	102.6	21.5	84.4	102.5	25.4	81.7	101.3	18.5	85.5								
		13.8	13.2-14.3										99.9	17.0	85.4	100	103.6	16.0	89.3	100
	2-7	14.6	14.1-15.1	97.3	17.5	82.8	97.6	18.1	82.6	98.8	17.3	84.2								
		15.0	14.3-15.8										100.6	17.0	86.0	100	106.5	16.9	91.1	77
	2-6	16.1	15.6-16.6	95.0	18.6	80.1	96.6	25.3	77.1											
		16.6	15.8-17.3										103.8	18.2	87.8	100	111.7	16.7	95.6	77
	2-5	17.6	17.1-18.1	99.2	21.8	81.5	103.8	31.2	79.1											
		17.8	17.3-18.3										94.9	17.1	81.8	100	111.9	17.2	95.5	85
		18.8	18.3-19.4										99.0	19.3	83.0	100	108.1	16.7	92.7	90
	2-8	19.2	18.7-19.7	107.6	23.6	87.1	106.3	32.5	80.2											
		20.1	19.4-20.8										100.2	17.2	85.5	100	110.0	16.4	94.4	69
	2-4	20.6	20.1-21.1	99.9	17.6	84.9	99.4	27.3	78.1	99.4	18.3	84.0								
		21.6	20.8-22.3										98.4	16.1	84.7	100	114.1	16.5	97.9	83
	2-3	22.0	21.5-22.5	99.8	17.7	84.8	97.0	25.1	77.5											
		22.8	22.3-23.3										93.8	17.9	79.6	100	110.4	17.5	94.0	90

* Sample too small to provide representative unit weight.

Table 3. – Summary of inplace moisture and unit weight values (TP-3, DH-1919, DH-1919A).

Project: Pick-Sloan Missouri Basin Program   Feature: Mirdan Canal   Conversions: 1 foot = 0.3048 meter, 1 lbf/ft³ = 16.018 46 kg/m³

Identification				Test pit TP-3									Drill hole DH-1919				Drill hole DH-1919A			
				Sand cone			Nuclear gauge			Block			Hollow-stem auger				Push tube			
Geol. formation, ft	Project test No.	Avg. depth, ft	Depth, ft	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %	Wet unit wt, lbf/ft³	Moisture content, %	Dry unit wt, lbf/ft³	Sample recovery, %
Topsoil 0.0-0.8	3-16	2.5	2.0-3.0	98.2	22.1	80.4	100.9	30.6	77.3											
↑		3.1	2.4-3.8										96.6	20.4	80.3	100	112.9	19.5	94.5	72
	3-15	4.1	3.6-4.6	98.2	17.6	83.5	100.9	28.5	78.6											
		4.4	3.8-5.0										95.7	20.8	79.2	78	112.2	19.2	94.1	74
		5.7	5.0-6.4										96.5	18.6	81.4	100	112.1	18.1	94.9	72
	3-14	5.7	5.2-6.2	96.5	15.8	83.4	95.2	19.5	79.4	96.4	13.5	84.9								
		7.2	6.4-7.9										96.2	17.2	82.1	100	113.2	18.6	95.4	136*
Re-	3-13	7.2	6.7-7.7	86.7	13.1	76.7	89.9	18.9	75.6	92.4	15.5	80.0								
worked		8.4	7.9-8.9										99.1	17.6	84.3	100	111.9	20.0	93.2	105*
Peorian	3-12	8.6	8.1-9.1	94.2	17.4	80.2	98.1	24.9	78.5											
loess		9.4	8.9-10.0										99.7	17.8	84.6	100	111.1	19.7	92.8	95
	3-11	10.1	9.6-10.6	96.9	19.0	81.5	98.8	26.3	78.2	98.0	18.9	82.4								
		10.8	10.0-11.5										103.1	18.7	86.8	100				0**
	3-10	11.6	11.1-12.1	103.7	19.5	86.7	103.7	25.3	82.7											
		12.2	11.5-13.0										105.0	20.3	87.3	100	118.9	21.7	97.7	90
	3-9	13.1	12.6-13.6	102.5	20.4	85.2	103.3	29.3	79.9	103.3	19.3	86.6								
↓		13.4	13.0-13.8										108.3	19.9	90.4	100	118.6	21.7	97.4	106*
14.0		14.6	13.8-15.4										107.5	20.4	89.2	97	114.6	20.8	94.9	81
↑	3-8	14.7	14.2-15.2	102.4	21.2	84.5	102.4	29.7	78.9											
		15.9	15.4-16.4										105.3	19.5	88.1	100	123.4	21.8	101.3	100
	3-7	16.2	15.7-16.7	106.8	20.2	88.9	103.3	28.1	80.7	104.4	20.8	86.4								
Peorian		17.2	16.4-17.9										109.2	20.7	90.5	100	118.6	22.2	97.0	93
loess	3-6	17.9	17.4-18.4	105.0	20.4	87.2	102.4	29.0	79.3											
		18.4	17.9-18.9										112.2	20.6	93.0	100	116.1	21.2	95.8	105*
	3-5	18.8	18.3-19.3	108.0	21.4	89.0	105.3	28.6	81.8											
		19.4	18.9-20.0										108.4	20.7	89.9	100	117.3	21.7	96.4	100
		20.8	20.0-21.5										108.8	21.5	89.5	100	121.4	22.0	99.5	87
		22.2	21.5-23.0										110.4	22.5	90.1	100	119.3	22.6	97.3	100
↓		23.5	23.0-23.9										110.4	21.0	91.2	100				

* Possibly picked up material that caved in from the side of the hole.
** Lost sample down hole.

Table 4. – Summary of inplace moisture and unit weight values (TP-4, DH-1072, DH-1072A).

Project: Pick-Sloan Missouri Basin Program — Feature: Mirdan Canal — Conversions: 1 foot = 0.3048 meter, 1 lbf/ft^3 = 16.018 46 kg/m^3

Identification				Test pit TP-4									Drill hole DH-1072				Drill hole DH-1072A			
				Sand cone			Nuclear gauge			Block			Hollow-stem auger				Push tube			
Geol. formation, ft	Project test No.	Avg. depth, ft	Depth, ft	Wet unit wt, lbf/ft^3	Moisture content, %	Dry unit wt, lbf/ft^3	Wet unit wt, lbf/ft^3	Moisture content, %	Dry unit wt, lbf/ft^3	Wet unit wt, lbf/ft^3	Moisture content, %	Dry unit wt, lbf/ft^3	Wet unit wt, lbf/ft^3	Moisture content, %	Dry unit wt, lbf/ft^3	Sample recovery, %	Wet unit wt, lbf/ft^3	Moisture content, %	Dry unit wt, lbf/ft^3	Sample recovery, %
Topsoil		2.2	1.5-3.0										94.1	22.4	76.9	100	93.3	21.6	76.7	80
0.0-2.9	4-16	2.6	2.1-3.1	95.2	24.5	76.5	97.4	31.9	73.8											
		3.8	3.0-4.6										92.9	21.3	76.6	100	104.1	20.6	86.3	75
	4-15	4.0	3.5-4.5	95.1	21.9	78.0	95.6	35.5	70.5	98.2	21.2	81.0								
		5.4	4.6-6.1										91.7	19.3	76.9	99	111.4	20.0	92.9	77
	4-14	5.6	5.1-6.1	97.3	21.1	80.4	96.6	31.0	73.7	97.9	20.3	81.4								
		6.6	6.1-7.2													0*	103.5	18.9	87.1	91
	4-13	7.1	6.6-7.6	91.2	21.0	75.4	92.3	27.4	72.5											
		7.8	7.2-8.5										96.3	16.5	82.7	100	100.3	20.3	83.4	77
	4-12	8.8	8.3-9.3	91.9	19.3	77.0	91.3	21.3	75.3	94.4	18.0	80.0								
		9.0	8.5-9.5										93.7	15.0	81.5	100	115.5	18.6	97.4	100
		10.2	9.5-11.0										92.6	14.8	80.7	100	105.3	17.1	89.9	70
	4-11	10.2	9.7-10.7	93.2	18.4	78.7	88.4	21.7	72.6											
		11.8	11.0-12.5										93.9	14.0	82.4	100	108.4	16.1	93.4	67
	4-10	11.7	11.2-12.2	95.7	17.5	81.5	92.1	21.5	75.8	98.6	16.8	84.4								
		13.0	12.5-13.4														114.5	16.1	98.6	100
	4-9	13.3	12.8-13.8	94.4	18.0	80.0	92.1	21.7	75.7											
Peorian		14.0	13.4-14.5										94.8	14.9	82.5	100	102.7	15.6	88.9	91
loess	4-8	14.8	14.3-15.3	97.5	18.5	82.3	96.4	21.0	79.7	100.4	17.1	85.7								
		15.2	14.5-16.0										95.5	14.1	83.7	100	107.9	14.7	94.1	73
	4-7	16.2	15.7-16.7	97.6	18.1	82.6	95.6	20.3	79.4											
		16.8	16.0-17.5										94.9	14.4	83.0	100	105.9	14.5	92.5	87
	4-6	17.7	17.2-18.2	96.0	13.9	84.3	93.7	22.0	76.7	103.3	19.5	86.4								
		18.0	17.5-18.5													0*				0*
		19.0	18.5-19.6										93.3	14.8	81.3	100	112.9	14.6	98.5	91
	4-5	19.3	18.8-19.8	95.6	14.3	83.6	96.0	25.0	76.8											
		20.2	19.6-20.9														113.2	14.7	98.7	85
		20.4	19.6-21.1										98.5	14.5	86.1	100				
	4-4	20.4	19.9-20.9	94.2	13.2	83.2	94.5	24.2	76.1							100				
		21.8	21.1-22.6										98.3	14.6	85.8	100				
		23.1	22.6-23.6													116**				
		24.4	23.6-25.1										97.0	15.2	84.2	100				

* Lost sample down hole.
** Sample disturbed.

Table 5. – Summary of inplace wet unit weight values (TP-1, DDR-69, DDR-69A). Sheet 1 of 2.

Project: Pick-Sloan Missouri Basin Program
Feature: Davis Creek Dam

Conversions: 1 foot = 0.3048 meter, 1lbf/ft³ = 16.018 46 kg/m³

Identification			Wet unit weight values (lbf/ft³)						
			TP-1			Drill hole DDR-69		Drill hole DDR-69A	
Project test No.	Average depth, ft	Depth, ft	Block	Sand cone	Nuclear	Gamma-gamma	Hollow-stem auger	Gamma-gamma*	Push tube
	1.2	0.4-1.9					111.2		
	2.6	1.9-3.4					111.0		118.0
1-16	2.6	2.1-3.1	106.5	114.4	112.4				
	4.2	3.4-4.9					106.7		109.7
1-15	4.3	3.8-4.8	109.1	97.9	106.3				
	4.0	4.0				113.4			
	4.5	4.0				106.3			
	5.7	4.9-6.5					96.7		
1-15	5.9	4.9-6.9							100.8
	5.0	5.0				103.3			
1-14	5.6	5.1-6.1		99.8	100.1				
	5.5	5.5				102.8			
	6.0	6.0				102.7			
	6.5	6.5				102.9			
	7.2	6.5-8.0					97.6		
1-13	7.3	6.8-7.8	103.1	96.1	98.6				
	7.7	6.9-8.5							99.9
	7.0	7.0				96.0			
	7.5	7.5				90.8			
	8.0	8.0				84.6			
	8.5	8.5				89.1			
1-12	9.0	8.5-9.5		98.9	100.0		99.9		99.4
	9.0	9.0				93.7			
	9.5	9.5				94.5			
	10.2	9.5-11.0							101.1
	10.4	9.7-11.0					96.5		
1-11	10.4	9.9-10.9	100.3	87.8	101.5				
	10.0	10.0				96.5			
	10.5	10.5				102.0			
	11.0	11.0				104.3			
	11.6	11.0-12.3					102.3		99.4
1-10	11.9	11.4-12.4		97.9	105.6				
	11.5	11.5				106.1			
	12.0	12.0				105.8			
	12.9	12.3-13.5					106.8		103.9
	12.5	12.5				106.5			
	11.5	11.5				106.1			
	12.0	12.0				105.8			
	12.9	12.3-13.5					106.8		103.9
	12.5	12.5				106.5			
1-9	13.4	12.9-13.9	107.1	105.0	107.1				
	13.0					111.3			
	13.5	13.5				112.8			
	14.2	13.5-14.8							109.4
	14.3	13.5-15.1					109.5		
	14.0	14.0				113.3			
1-8	14.8	14.3-15.3		100.0	109.5				
	14.5	14.5				113.6			
	15.4	14.8-15.9							107.4
	15.0	15.0				113.4			
	15.8	15.1-16.6					112.1		
	15.5	15.5				114.2			
1-7	16.3	15.8-16.8	113.8	111.4	112.6				
	16.4	15.9-16.9							105.0
	16.0	16.0				114.2			
	16.5	16.5				113.8			
	17.6	16.6-18.5					105.2		
	17.0	17.0				113.6			
1-6	17.8	17.3-18.3		109.5	111.3				
	17.5	17.5				111.1			
	18.6	17.6-19.5							108.8

* The gamma-gamma density tool was not used because the hole closed up.

Table 5. – Summary of inplace wet unit weight values (TP-1, DDR-69, DDR-69A). Sheet 2 of 2.

Project: Pick-Sloan Missouri Basin Program
Feature: Davis Creek Dam

Conversions: 1 foot = 0.3048 meter, 1lbf/ft³ = 16.018 46 kg/m³

Identification			Wet unit weight values (lbf/ft³)						
			TP-1			Drill hole DDR-69		Drill hole DDR-69A	
Project test No.	Average depth, ft	Depth, ft	Block	Sand cone	Nuclear	Gamma-gamma	Hollow-stem auger	Gamma-gamma*	Push tube
	18.0	18.0				109.0			
	18.5	18.5				110.0			
	19.2	18.5-20.0					103.7		
1-5	19.2	18.7-19.7	108.0	103.3	103.4				
	19.0	19.0				110.1			
	19.5	19.5				109.7			
	20.2	19.5-21.0							102.3
	20.0	20.0				108.8			
	20.8	20.0-21.5					102.8		
	20.5	20.5				107.9			
1-4	21.0	20.5-21.5		100.0	103.4				
	21.0	21.0				107.9			
	21.8	21.0-22.5							101.5
	21.5	21.5				107.3			
	22.5	21.5-23.5					105.5		
1-1	22.3	21.8-22.8		97.5	98.6				
1-2	23.8	23.3-24.3		98.7	101.3				
	24.5	23.7-25.3					105.3		
1-3	25.2	24.7-25.7		99.4	99.0				

* The gamma-gamma density tool was not used because the hole closed up.

Table 6. – Summary of inplace wet unit weight values (TP-2, DDR-68, DDR-68A).

Project: Pick-Sloan Missouri Basin Program
Feature: Davis Creek Dam

Conversions: 1 foot = 0.3048 meter, 1 lbf/ft³ = 16.018 46 kg/m³

Identification			Wet unit weight values (lbf/ft³)						
			TP-2			Drill hole DDR-68		Drill hole DDR-68A	
Project test No.	Average depth, ft	Depth, ft	Block	Sand cone	Nuclear	Gamma-gamma	Hollow-stem auger	Gamma-gamma	Push tube
	2.6	1.9-3.4					97.3		100.3
2-16	2.5	2.0-3.0	99.9	99.0	100.9				
2-15	3.9	3.4-4.4		97.0	96.5		97.7		99.5
	4.0	4.0				98.0			
	5.2	4.4-5.9					101.4		109.6
	4.5	4.5				99.1			
2-14	5.4	4.9-5.9	93.0	97.4	95.5				
	5.0	5.0				99.4		91.3	
	5.5	5.5				98.8		92.3	
	6.6	5.9-7.4					100.6		102.7
	6.0	6.0				99.3		94.3	
2-13	6.9	6.4-7.4		90.7	92.8				
	6.5	6.5				100.3		93.8	
	7.0	7.0				101.2		88.4	
	7.5	7.5				101.4		93.7	
	8.0	8.0				103.0		100.3	
2-12	8.6	8.1-9.1	98.3	94.1	95.3				
	8.6	8.1-9.2					100.1		98.2
	8.5	8.5				102.9		102.2	
	9.0	9.0				103.6		105.4	
	10.0	9.2-10.7					101.2		98.0
	9.5	9.5				103.3		106.6	
2-11	10.1	9.6-10.6		95.6	96.7				
	10.0	10.0				99.4		106.4	
	10.5	10.5				99.4		107.1	
	11.4	10.7-12.1					99.2		98.1
	11.0	11.0				98.8		108.0	
2-10	11.5	11.0-12.0		96.4	96.3				
	11.5	11.5				98.3		106.8	
	12.0	12.0				98.1		105.8	
	12.6	12.1-13.2					98.8		100.0
	12.5	12.5				99.9		104.9	
2-9	13.1	12.6-13.6	101.3	102.6	102.5				
	13.0	13.0				100.4			
	13.8	13.2-14.3					99.9		103.6
	13.5	13.5				100.8			
	14.0	14.0				100.6			
2-7	14.6	14.1-15.1	98.8	97.3	97.6				
	15.1	14.3-15.8					100.6		106.5
	14.5	14.5				102.0			
	15.0	15.0				102.1			
	15.5	15.5				101.1			
2-6	16.1	15.6-16.6		95.0	96.6				
	16.6	15.8-17.3					103.8		111.7
	16.0	16.0				99.2			
	16.5	16.5				97.7			
2-5	17.6	17.1-18.1		99.2	103.8				
	17.8	17.3-18.3					94.9		111.9
	18.8	18.3-19.4					99.0		108.1
2-8	19.2	18.7-19.7		107.6	106.3				
	20.1	19.4-20.8					100.2		110.0
2-4	20.6	20.1-21.1	99.4	99.9	99.4				
	21.6	20.8-22.3					98.4		114.1
2-3	22.0	21.5-22.5		99.8	97.0				
	22.8	22.3-23.3					93.8		110.4

Table 7. – Summary of inplace wet unit weight values (TP-3, DH-1919, DH-1919A).

Project: Pick-Sloan Missouri Basin Program
Feature: Mirdan Canal

Conversions: 1 foot = 0.3048 meter, 1lbf/ft³ = 16.018 46 kg/m³

Identification			Wet unit weight values (lbf/ft³)						
			TP-3			Drill hole DH-1919		Drill hole DH-1919A	
Project test No.	Average depth, ft	Depth, ft	Block	Sand cone	Nuclear	Gamma-gamma	Hollow-stem auger	Gamma-gamma	Push tube
3-16	2.5	2.0-3.0		98.2	100.9				
	3.1	2.4-3.8					96.6		112.9
3-15	4.1	3.6-4.6		98.2	100.9				
	4.4	3.8-5.0					95.7		112.2
	4.5	4.5						102.6	
	5.0	5.0				100.3		102.3	
	5.7	5.0-6.4					96.5		112.1
3-14	5.7	5.2-6.2	96.4	96.5	95.2				
	5.5	5.5				101.9		102.7	
	6.0	6.0				102.1		102.3	
	7.2	6.4-7.9					96.2		113.2
	6.5	6.5				102.4		102.1	
3-13	7.2	6.7-7.7	92.4	86.7	89.9				
	7.0	7.0				101.6		102.0	
	7.5	7.5				101.5		99.4	
	8.4	7.9-8.9					99.1		111.9
	8.0	8.0				102.1		100.8	
3-12	8.6	8.1-9.1		94.2	98.1				
	8.5	8.5				102.2		105.5	
	9.4	8.9-10.0					99.7		111.1
	9.0	9.0				102.3		105.7	
	9.5	9.5				102.6		106.1	
3-11	10.1	9.6-10.6	98.0	96.9	98.8				
	10.0	10.0				103.1		107.0	
	10.8	10.0-11.5					103.1		
	10.5	10.5				104.2		106.5	
	11.0	11.0				105.8		107.5	
3-10	11.6	11.1-12.1		103.7	103.7				
	11.5	11.5				107.4		109.2	
	12.2	11.5-13.0					105.0		118.9
	12.0	12.0				107.7		106.4	
	12.5	12.5				108.1		106.4	
3-9	13.1	12.6-13.6	103.3	102.5	103.3				
	13.0	13.0				108.0		108.0	
	13.4	13.0-13.8					108.3		118.6
	13.5	13.5				107.1		109.5	
	14.6	13.8-15.4					107.5		114.6
	14.0	14.0				107.4		109.7	
3-8	14.7	14.2-15.2		102.4	102.4				
	14.5	14.5				107.4		111.6	
	15.0	15.0				107.2		104.6	
	15.9	15.4-16.4					105.3		123.4
	15.5	15.5				107.0		106.3	
3-7	16.2	15.7-16.7	104.4	106.8	103.3				
	16.0	16.0				106.4		112.1	
	17.2	16.4-17.9					109.2		118.6
	16.5	16.5				105.9		112.8	
3-6	17.9	17.4-18.4		105.0	102.4				
	18.4	17.9-18.9					112.2		116.1
3-5	18.8	18.3-19.3		108.0	105.3				
	19.4	18.9-20.0					108.4		117.3
	20.8	20.0-21.5					108.8		121.4
	22.2	21.5-23.0					110.4		119.3
	23.4	23.0-23.9					110.4		

Table 8. – Summary of inplace wet unit weight values (TP-4, DH-1072, DH-1072A).

Project: Pick-Sloan Missouri Basin Program
Feature: Mirdan Canal

Conversions: 1 foot = 0.3048 meter, 1lbf/ft³ = 16.018 46 kg/m³

Identification			Wet unit weight values (lbf/ft³)						
			TP-4			Drill hole DH-1072		Drill hole DH-1072A	
Project test No.	Average depth, ft	Depth, ft	Block	Sand cone	Nuclear	Gamma-gamma	Hollow-stem auger	Gamma-gamma	Push tube
	2.3	1.5-3.0					94.1		93.3
4-16	2.6	2.1-3.1		95.2	97.4				
	3.8	3.0-4.6					92.9		104.1
4-15	4.0	3.5-4.5	98.2	95.1	95.6				
	4.5	4.5						99.9	
	5.4	4.6-6.1					91.7		111.4
	5.0	5.0				103.4		95.7	
4-14	5.6	5.1-6.1	97.9	97.3	96.6				
	5.5	5.5				102.0		91.2	
	6.0	6.0				102.1		93.0	
	6.6	6.1-7.2							103.5
	6.5	6.5				103.3		97.3	
4-13	7.1	6.6-7.6		91.2	92.3				
	7.0	7.0				103.9		93.7	
	7.8	7.2-8.5					96.3		100.3
	7.5	7.5				102.3		105.7	
	8.0	8.0				103.2		104.5	
4-12	8.8	8.3-9.3	94.4	91.9	91.3				
	8.5	8.5				103.6		103.3	
	9.0	8.5-9.5					93.7		115.5
	9.0	9.0				102.1		102.8	
	9.5	9.5				102.2		103.7	
	10.2	9.5-11.0					92.6		105.3
4-11	10.2	9.7-10.7		93.2	88.4				
	10.0	10.0				102.4		106.0	
	10.5	10.5				103.1		106.4	
	11.0	11.0				104.0		106.9	
	11.8	11.0-12.5					93.9		108.4
4-10	11.7	11.2-12.2	98.6	95.7	92.1				
	11.5	11.5				104.0		107.2	
	12.0	12.0				103.8		106.9	
	12.5	12.5				100.5		107.1	
	13.0	12.5-13.4							114.5
4-9	13.3	12.8-13.8		94.4	92.1				
	13.0	13.0				97.8		107.9	
	14.0	13.4-14.5					94.8		102.7
	13.5	13.5				99.9		107.9	
	14.0	14.0				103.0		107.9	
4-8	14.8	14.3-15.3	100.4	97.5	96.4				
	14.5	14.5				103.2		108.0	
	15.2	14.5-16.0					95.5		107.9
	15.0	15.0				102.7		107.9	
	15.5	15.5				101.1		108.0	
4-7	16.2	15.7-16.7		97.6	95.6				
	16.0	16.0				100.7		108.4	
	16.8	16.0-17.5					94.9		105.9
	16.5	16.5				97.5		107.5	
	17.0	17.0						107.2	
4-6	17.7	17.2-18.2	103.3	96.0	93.7				
	17.5	17.5						107.5	
	18.0	18.0						107.6	
	18.5	18.5						106.4	
	19.0	18.5-19.6					93.3		112.9
4-5	19.3	18.8-19.8		95.6	96.0				
	20.2	19.6-20.9							113.2
	20.4	19.6-21.1					98.5		
4-4	20.4	19.9-20.9		94.2	94.5				
	21.8	21.1-22.6					98.3		
	24.4	23.6-25.1					97.0		

Table 9. – Summary of nuclear gauge data* (TP-1).

Project: Pick-Sloan Missouri Basin Program — Feature: Davis Creek Dam

Identification: Project test No.	Identification: Average depth, ft	Identification: Depth, ft	Nuclear gauge wet unit weight, lbf/ft³	Ovendried moisture content, %	Dry unit weight using ovendried moisture content, lbf/ft³
1-16	2.6	2.1-3.1	112.4	25.3	89.7
1-15	4.3	3.8-4.8	106.3	21.5	87.5
1-14	5.6	5.1-6.1	100.1	21.2	82.6
1-13	7.3	6.8-7.8	98.6	20.9	81.6
1-12	9.0	8.5-9.5	100.0	22.4	81.7
1-11	10.4	9.9-10.9	101.5	23.5	82.2
1-10	11.9	11.4-12.4	105.6	23.7	85.4
1-9	13.4	12.9-13.9	107.1	22.7	87.3
1-8	14.8	14.3-15.3	109.5	20.8	90.6
1-7	16.3	15.8-16.8	112.6	21.7	92.5
1-6	17.8	17.3-18.3	111.3	21.5	91.6
1-5	19.2	18.7-19.7	103.4	20.1	86.1
1-4	21.0	20.5-21.5	103.4	19.4	86.6
1-1	22.3	21.8-22.8	98.6	18.7	83.1
1-2	23.8	23.3-24.3	101.3	20.5	84.1
1-3	25.2	24.7-25.7	99.0	20.7	82.0

* Dry unit weight values are calculated from ovendried moisture data.

Table 10. – Summary of nuclear gauge data* (TP-2).

Project: Pick-Sloan Missouri Basin Program — Feature: Davis Creek Dam

Identification: Project test No.	Identification: Average depth, ft	Identification: Depth, ft	Nuclear gauge wet unit weight, lbf/ft³	Ovendried moisture content, %	Dry unit weight using ovendried moisture content, lbf/ft³
2-16	2.5	2.0-3.0	100.9	22.2	82.6
2-15	3.9	3.4-4.4	96.5	20.9	79.8
2-14	5.4	4.9-5.9	95.5	20.3	79.4
2-13	6.9	6.4-7.4	92.8	19.0	78.0
2-12	8.6	8.1-9.1	95.3	17.6	81.0
2-11	10.1	9.6-10.6	96.7	17.1	82.6
2-10	11.5	11.0-12.0	96.3	18.3	81.4
2-9	13.1	12.6-13.6	102.5	21.5	84.4
2-7	14.6	14.1-15.1	97.6	17.5	83.1
2-6	16.1	15.6-16.6	96.6	18.6	81.5
2-5	17.6	17.1-18.1	103.8	21.8	85.2
2-8	19.2	18.7-19.7	106.3	23.6	86.0
2-4	20.6	20.1-21.1	99.4	17.6	84.5
2-3	22.0	21.5-22.5	97.0	17.7	82.4

* Dry unit weight values are calculated from ovendried moisture data.

Table 11. – Summary of nuclear gauge data* (TP-3).

Project: Pick-Sloan Missouri Basin Program — Feature: Mirdan Canal

Identification			Nuclear gauge wet unit weight, lbf/ft³	Ovendried moisture content, %	Dry unit weight using ovendried moisture content, lbf/ft³
Project test No.	Average depth, ft	Depth, ft			
3-16	2.5	2.0-3.0	100.9	22.3	82.5
3-15	4.1	3.6-4.6	100.9	17.9	85.6
3-14	5.7	5.2-6.2	95.2	13.0	84.2
3-13	7.2	6.7-7.7	89.9	13.8	79.0
3-12	8.6	8.1-9.1	98.1	16.4	84.3
3-11	10.1	9.6-10.6	98.8	17.4	84.2
3-10	11.6	11.1-12.1	103.7	18.0	87.9
3-9	13.1	12.6-13.6	103.3	18.7	87.0
3-8	14.7	14.2-15.2	102.4	20.3	85.1
3-7	16.2	15.7-16.7	103.3	20.2	85.9
3-6	17.9	17.4-18.4	102.4	20.4	85.0
3-5	18.8	18.3-19.3	105.3	21.4	86.7

* Dry unit weight values are calculated from ovendried moisture data.

Table 12. – Summary of nuclear gauge data* (TP-4).

Project: Pick-Sloan Missouri Basin Program — Feature: Mirdan Canal

Identification			Nuclear gauge wet unit weight, lbf/ft³	Ovendried moisture content, %	Dry unit weight using ovendried moisture content, lbf/ft³
Project test No.	Average depth, ft	Depth, ft			
4-16	2.6	2.1-3.1	97.4	23.7	78.7
4-15	4.0	3.5-4.5	95.6	20.1	79.6
4-14	5.6	5.1-6.1	96.6	19.8	80.6
4-13	7.1	6.6-7.6	92.3	18.2	78.1
4-12	8.8	8.3-9.3	91.3	15.3	79.2
4-11	10.2	9.7-10.7	88.4	13.6	77.8
4-10	11.7	11.2-12.2	92.1	14.0	80.8
4-9	13.3	12.8-13.8	92.1	14.0	80.8
4-8	14.8	14.3-15.3	96.4	14.8	84.0
4-7	16.2	15.7-16.7	95.6	13.5	84.2
4-6	17.7	17.2-18.2	93.7	13.9	82.3
4-5	19.3	18.8-19.8	96.0	14.3	84.0
4-4	20.4	19.9-20.9	94.5	13.2	83.5

* Dry unit weight values are calculated from ovendried moisture data.

APPENDIX A

GEOLOGIC LOGS OF DRILL HOLES

7-1337 (6-76)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Undisturbed Density Program PROJECT: North Loup Division STATE: Nebraska
HOLE NO.: DDR-69 LOCATION: Lt Abut - Davis Creek GROUND ELEV.: see below DIP (ANGLE FROM HORIZ.): 90°
COORDS. N. 638,099 E. 2,206,627
BEGUN: 5/17/84 FINISHED: 6/19/84 DEPTH OF OVERBURDEN: unknown TOTAL DEPTH: see below BEARING: ----
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not Encountered LOGGED BY: Prince, Kehler, Cast LOG REVIEWED BY: Cast, Tuttle

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)
10½" AUGER (0–36.9')	100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 91

HOLLOW STEM AUGER

Elevation: 2006.8

Date Begin: 5/17/84 Finished: 5/21/84

Drill Rig: CME 55

Driller: M. Kocian

Drill Method: 0-36.9', 10½" auger with 6¼" hollow stem and 5" inner tube; 5" PVC liners used for continuous densities.

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)
5" PUSH (0–23.5')	100, 100, 100, 66, 100, 100, 100, 100, 100, 100, 0, 100, 93, 100, 95

5" PUSH TUBE

Elevation: 2006.8

Date Begin: 5/22/84 Finished: 5/22/84

Drill Rig: Failing 1500S

Driller: M. Kocian

Drill Method: 0-23.5', 5" push tube; 0% clearance

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

Off-Set Hole: 5/21/84 off-set 8' NW from auger hole and sampled with 5" push tube and Porta-drill 521. Matching densities were taken to compare results between the two drill rigs.

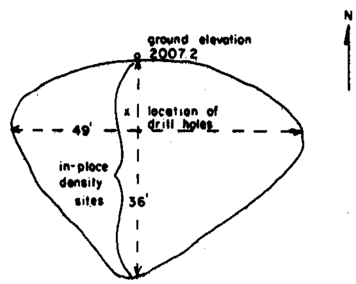
TEST PIT /

Excavated: 6-19/84 Ground Elevation: 2007.2

Method: Contract; Insley H-600 Backhoe to 25.1'

Sampling: In-place densities at 1.5' intervals by sand cone, nuclear and block sample methods. See sheet 2 of 2 for data.

Completion: Backfilled



CLASSIFICATION AND PHYSICAL CONDITION

TOPSOIL

0-3.7 LEAN CLAY, approx. 95% fines with low to medium plasticity, low toughness, medium to high dry strength, and 5% fine sand, maximum size fine sand; moist; dark brown-black; numerous fine roots; no reaction with HCl. (CL)

VALLEY FILL

3.7-14.3 SILT, approx. 95% fines with no to low plasticity, no toughness, low dry strength and 5% fine sand; maximum size fine sand; moist; tan with small amount of black mottling; a few 2-3" diameter, topsoil filled, animal burrows; a few root holes in lower 2'; numerous lime veinlets; strong reaction with HCl. (ML)
NOTE! Contact with underlying loess slopes to south and occurs at a depth of 23 feet on the south wall.

PEORIAN LOESS

14.3-25.1 SILT, approx. 100% fines with no to low plasticity, no toughness, low dry strength, and trace of fine sand; moist; light yellow-gray with rust streaking; several rust nodules to ½", can crush with fingers; numerous root holes, lime streaks and lime veinlets throughout; rust commonly associated with root holes; lime streaks and veinlets primarily vertical; strong reaction with HCl. (ML)

FEATURE: Undisturbed Density Program PROJECT: N.L. Division NE

Figure A-1. – Geologic log of drill hole. Sheet 1 of 4.

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Undisturbed Density Program	PROJECT: North Loup Division		STATE: Nebraska
HOLE NO.: DDR-68	LOCATION: Rt Abut - Davis Creek; COORDS. N. 637,150 E. 2,204,732	GROUND ELEV.: see below	DIP (ANGLE FROM HORIZ.): 90°
BEGUN: 6/7/84	FINISHED: 6/22/84	DEPTH OF OVERBURDEN: unknown	TOTAL DEPTH: see below; BEARING: ----
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not Encountered	LOGGED BY: Prince, Kehler, Cast		LOG REVIEWED BY: Cast, Tuttle

HOLLOW STEM AUGER

TYPE AND SIZE OF HOLE: 10½" AUGER

CORE RECOVERY (%): *, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

Elevation: 2095.8

Date Begin: 6/7/84 Finished: 6/7/84

Drill Rig: CME 55

Driller: M. Kocian

Drill Method: 0-23.4', 10½" auger with 6¼" hollow stem and 5" inner tube; 5" PVC liners used for continuous densities.

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

5" PUSH TUBE

TYPE AND SIZE OF HOLE: 5" PUSH

CORE RECOVERY (%): *, 73, 100, 83, 100, [illegible], 95, 97, 100, 55, 100, 77, 77, 85, 95, 69, 83, 90

Elevation: 2095.8

Date Begin: 6/7/84 Finished: 6/8/84

Drill Rig: Failing 1500S

Driller: M. Kocian

Drill Method: 0-23.4', 5" push tube; 0% clearance

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

* - not recorded

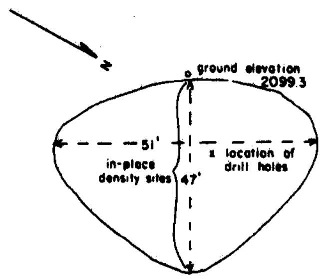
TEST PIT 2

Excavated: 6/19/84 Ground Elevation: 2099.3

Method: Contract; Insley H-600 Backhoe to 22.5'

Sampling In-place densities at 1.5' intervals by sand cone, nuclear and block sample methods. See sheet 2 of 2 for data.

Completion: Backfilled



CLASSIFICATION AND PHYSICAL CONDITION

TOPSOIL

0-0.4 LEAN CLAY, approx. 100% fines with low plasticity, low toughness, medium dry strength and trace of fine sand; maximum size fine sand; moist; black; numerous fine roots; no reaction with HCl. (CL)

PEORIAN LOESS

0.4-22.5 SILT, approx. 100% fines with no to low plasticity, no toughness, low dry strength, and trace of fine sand maximum size fine sand; moist; light yellow gray with rust streaking; decayed/iron replaced, soft, vegetation remains in discontinuous layers 1/8-3/4" thick; numerous fine root holes throughout; scattered worm tubes; open 4-6" areas (animal burrows?) at 7.5' and 21.5'; occasional small snail shell; scattered lime nodules to ½"; indistinct bedding indicated by vegetation layers; fine roots in upper 15'; moderate to strong reaction with HCl. (ML)

FEATURE: Undisturbed Density Program PROJECT: N.L. Division STATE: NE SHEET 1 OF 2 HOLE NO. DDR-68

Figure A-1. – Geologic log of drill hole. Sheet 2 of 4.

7-1337 (8-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Undisturbed Density Program — PROJECT: North Loup Division — STATE: Nebraska

HOLE NO.: 1919 — LOCATION: Sta. 1919+00 - Mirdan 3rd — COORDS. N. ... E. ... — GROUND ELEV.: see below — DIP (ANGLE FROM HORIZ.): 90°

BEGUN: 6/6/84 — FINISHED: 6/22/84 — DEPTH OF OVERBURDEN: unknown — TOTAL DEPTH: see below — BEARING: ----

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not Encountered — LOGGED BY: Prince, Kehler, Cast — LOG REVIEWED BY: Cast, Tuttle

TYPE AND SIZE OF HOLE: 10½" AUGER (0–30 ft scale: 10, 20, 30)

CORE RECOVERY (%): *, 100, 78, 100, 100, 100, 100, 100, 100, 100, 97, 100, 100, 100, 100, 100, 100, 100

HOLLOW STEM AUGER

Elevation: 2194.5

Date Begin: 6/6/84 Finished: 6/6/84

Drill Rig: CME 55

Driller: M. Kocian

Drill Method: 0-23.9', 10½" auger with 6¼" hollow stem and 5" inner tube; 5" PVC liners used for continuous densities.

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

TYPE AND SIZE OF HOLE: 5" PUSH (0–30 ft scale: 10, 20, 30)

CORE RECOVERY (%): *, 72, 74, 72, 73, 100, 95, *, 90, 100, 81, 100, 93, 100, 100, 87, 100

5" PUSH TUBE

Elevation: 2194.5

Date Begin: 6/7/84 Finished: 6/7/84

Drill Rig: Failing 1500S

Driller: M. Kocian

Drill Method: 0-23.0', 5" push tube; 0" clearance.

Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

* - not recorded

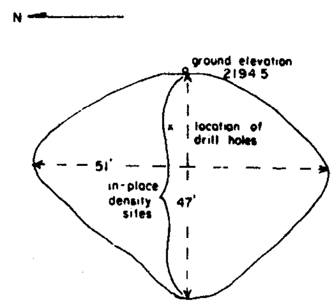
TEST PIT 3

Excavated: 6/20/84 Ground Elevation: 2194.5

Method: Contract; Insley H-600 Backhoe to 19.3'

Sampling: In-place densities at 1.5' intervals by sand cone, nuclear and block sample methods. See sheet 2 of 2 for data.

Completion: Backfilled



CLASSIFICATION AND PHYSICAL CONDITION

TOPSOIL

0-0.8 LEAN CLAY, approx. 95% fines with low plasticity, low toughness, medium dry strength and 5% fine sand; maximum size fine sand; moist; black; numerous roots to ¼" in diameter; no reaction with HCl. (CL)

REWORKED PEORIAN LOESS

0.8-14± SILT, approx. 100% fines with no to low plasticity, no toughness, low dry strength, and trace of fine sand, maximum size fine sand; moist; light yellow-gray with small amount of black mottling; scattered paper thin bedding of gray-brown silt; moderate to strong reaction to HCl. (ML)

PEORIAN LOESS

14-19.3 SILT, approx. 100% fines with no to low plasticity, no toughness, low dry strength, and trace of fine sand; maximum size fine sand; moist; light yellow-gray with numerous rust streaks; numerous root holes, a few are silt filled; moderate to strong reaction with HCl. (ML)

FEATURE: Undisturbed Density Program — PROJECT: N.L. Division — STATE: NE — SHEET 1 OF 2 — HOLE NO. 1919

Figure A-1. – Geologic log of drill hole. Sheet 3 of 4.

7-1337 (8-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE Undisturbed Density Program PROJECT North Loup Division STATE Nebraska

HOLE NO. 1072 LOCATION Sta. 1072+00 - Mirdan 2nd COORDS. N. ... E. ... GROUND ELEV. see below DIP (ANGLE FROM HORIZ.) 90°

BEGUN 6/4/84 FINISHED 6/25/84 DEPTH OF OVERBURDEN unknown TOTAL DEPTH see below BEARING ----

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not Encountered LOGGED BY Prince, Kehler, Cast LOG REVIEWED BY Cast, Tuttle

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	HOLLOW STEM AUGER
10½" AUGER	*, 100, 100, 100, 0, 100, 100, 100, 100, 0, 100, 100, 100, 0, 100, 100, 100, *, 100	Elevation: 2190 Date Begin: 6/4/84 Finished: 6/4/84 Drill Rig: CME 55 Driller: M. Kocian Drill Method: 0-25.1', 10½" auger with 6¼" hollow stem and 5" inner tube; 5" PVC liners used for continuous densities. Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit. * - not recorded

Depth scale: 10, 20, 30

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	5" PUSH TUBE
5" PUSH	*, 80, 75, 77, 91, 77, 100, 70, 67, 100, 91, 73, 87, 0, 91, 85, 0	Elevation: 2190 Date Begin: 6/5/84 Finished: 6/5/84 Drill Rig: Failing 1500S Driller: M. Kocian Drill Method: 0-23.7', 5" push tube, 0' clearance. Completion: Geophysically logged (Gamma-Gamma and Caliper) by personnel from E&R Center. Hole destroyed by test pit.

Depth scale: 10, 20, 30

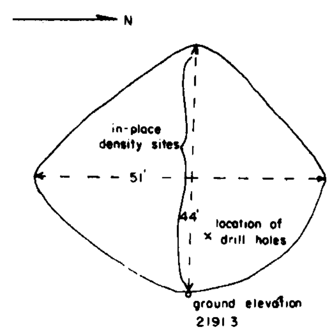
TEST PIT 4

Excavated: 6/20/84 Ground Elevation: 2191.3

Method: Contract; Insley H-600 Backhoe to 20.9'

Sampling: In-place densities at 1.5' intervals by sand cone, nuclear and block sample methods. See sheet 2 of 2 for data.

Completion: Backfilled



CLASSIFICATION AND PHYSICAL CONDITION

TOPSOIL

0-2.9 LEAN CLAY, approx. 95% fines with low to medium plasticity, low toughness, medium dry strength and 5 fine sand; maximum size fine sand; moist; black; numerous roots; no reaction with HCl. (CL)

PEORIAN LOESS

2.9-20.9 SILT, approx. 100% fines with no to low plasticity, no toughness, low dry strength, and trace of fine sand; maximum size fine sand; moist; light yellow-gray with rust streaks; lime mottling common in upper 5 feet; scattered root holes and discontinuous layers of decayed vegetation 0.01' thick; a few soft, iron nodules to ½"; upper 7' of material soft and crumbly; moderate to strong reaction with HCl. (ML)

FEATURE Undisturbed Density Program PROJECT N.L. Division STATE NE SHEET 1 OF 2 HOLE NO. 1072

Figure A-1. – Geologic log of drill hole. Sheet 4 of 4.

APPENDIX B

BOREHOLE DENSITY LOGGING

Borehole compensated densities are produced through the use of two collimated detectors at different spacings from a gamma ray source. The source and detectors are pressed against the side of the hole to reduce the gap and improve accuracy. The detector nearest the source is more severely influenced by borehole rugosity and mud-cake than the far detector. The difference in response of the two detectors is used to compensate for errors in density estimates caused by mud-cake and rugosity. Compensation is based on a "spine and ribs" plot, in which the count rate of the near detector is plotted against the count rate of the far detector for a series of densities, gaps, and mud-cake thicknesses. The line drawn through points representing zero gap and zero mud-cake is called the spine, and the curves drawn through points representing different gaps and mud-cake thicknesses for specified densities are called the ribs. Corrected densities are calculated for each detector correcting for hole diameter and borehole fluid. The two densities are then used to determine a compensated density by an algorithm developed from the "spine and ribs" plot.

The borehole compensated density probe uses a 125-cm, Cesium 137 radioactive source. The near detector is a small geiger tube (diameter 0.7 cm and active length 10 cm) with inorganic quenching gas and a platinum-coated cathode. The far detector is a sodium iodide crystal (diameter 1.27 cm and length 3.81 cm) coupled to a photomultiplier tube. Center-to-center spacing between the source and the near and far detectors is 17 and 37 cm, respectively. The pulses from the two detectors are sent up the logging cable, time averaged by two rate meters, and recorded on two channels of a strip chart recorder in the logging truck. Compensation is accomplished by an off-line computer after the logs are digitized.

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-822A, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.