3, 4, 5, 8, 9, 11

Figs 10 + 11

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RESEARCH REPORT NO. 345

UTILIZATION OF DRILLING AND RESISTIVITY EQUIPMENT IN GROUND WATER RESEARCH

by

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Southern Branch
Soil and Water Conservation Research Division
Agricultural Research Service
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October 17, 1961

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Introduction

The drilling exploration and resistivity measurements discussed in this report were conducted during the summer of 1960 in the Pigeon Roost Creek Watershed, Marshall County, Mississippi. This 117 square mile watershed lies in the North Central Plateau region of the East Gulf Coast Plain physiographic section of the Coastal Plain province.

The investigations, as part of a comprehensive water balance study, served in the testing of equipment and the development of drilling techniques. Data obtained were used in establishing preliminary structure and stratigraphic profiles, for characterizing the sediment and geologic strata, and in defining the water table and piezometric surfaces. Resistivity measurements were carried out for the comparison of resistivity and drilling methods in determination of geologic conditions.

1/ Geologist, US Sedimentation Laboratory, Southern Branch, Soil and Water Conservation Research Division, Agricultural Research Service, US Department of Agriculture, University, Mississippi, in cooperation with the University of Mississippi and Mississippi State University.

Drilling Rig

A vacuum type drilling rig was utilized because of its ability to drill in quicksands and to obtain good samples by several different means. These were particularly useful features for drilling in the Pigeon Roost Creek Watershed. This rig is mounted on skids; but the one used in this study was on a tandem trailer (figure 1). The tank shown in the pickup truck supplied water for the drilling operation and was filled by a 1½ horsepower centrifugal pump which also supplied water under pressure for cleaning equipment and mixing mud for forced and reverse water drilling. The skids are sturdy and may be used as slides to move the rig. These skids also serve as storage reservoirs for the oil used by the hydraulic system. The rig, including the mast, rotary head, draw works, and both catheads, is completely hydraulically operated.

The mast is mounted on a rotating table which permits angle drilling perpendicular to the rig (figure 2). It is also possible to angle drill parallel with the center line of the rig (figure 3). Any combination of these two is possible permitting complete rotation of the mast through 180°. The mast is 15 feet high and supports the rotary drill head, which is raised and lowered by a number 60 roller chain at speeds from 0 to 15 feet per minute with up to 2,000 pounds total pressure. The drill head, which rotates the drill stem, has speeds from 0 to 420 RPM and swings out permitting the use of the cathead to lower or remove drill stem or casing from the hole and to use the hammer to drive cores.

The drill removes cuttings from the holes in six different ways: (1) vacuum-air or vacuum-water (figure 4); (2) drive core; (3) auger drilling; (4) core drilling; (5) forced water (jetting) (figure 5); and (6) reverse water (figure 5). With the 4-cylinder, 30-horsepower, air cooled gas engine, it is possible to drill to depths of about 250 feet, depending on drilling conditions.

Disturbed or undisturbed samples can be obtained. The disturbed samples may be taken by: (1) reverse water, wherein the sample is collected in the plastic sampling tubes; (2) vacuum-air or vacuum-water, which collects and gives total recovery of the sample in the plastic tubes (figure 6); (3) forced water, whereby samples are collected in the sump tank but may not represent the total sample; (4) auger drilling, which merely collects the sample on the surface of the auger or augers it to the surface. The undisturbed samples may be taken by means of: (1) a core barrel, or (2) a split-tube drive sampler, both of which give total recovery.

The vacuum type drill rig is particularly useful in drilling quicksands. This can be accomplished by three methods: (1) vacuum drilling and driving the casing simultaneously, (2) rotating the casing under continuous pressure, or (3) vacuum drilling and driving alternately. The first method is successful if extreme care is taken not to let sand rise above the bit while driving (figure 7). This method, however, is risky in that the drill stem cannot be brought out of the hole fast enough if the sand rises above the bit while in operation. The second method involves putting a saw-tooth shoe on the casing, attaching it to the drill head, and rotating the casing while forcing it down with the drill head (figure 8). This method works until friction and weight overcome the power of the drill head. It is possible to go slightly deeper by vacuuming out the casing and breaking the sand loose below the casing shoe, but the maximum depth with this method is 40 feet. Below 40 feet it is necessary to use either the first method or vacuum drill and break the sand loose, then drive. The third method, vacuum drilling and driving alternately, requires more time, but there is less chance of getting stuck in the casing. This method consists of vacuuming the casing out by using water and vacuum, then pulling the drilling tools out of the hole and driving the casing. Usually when the casing is cleaned out this permits the sand to break loose below the casing and rise in the casing. It is this loosening action on the sand below the casing which permits driving. It has been possible to penetrate

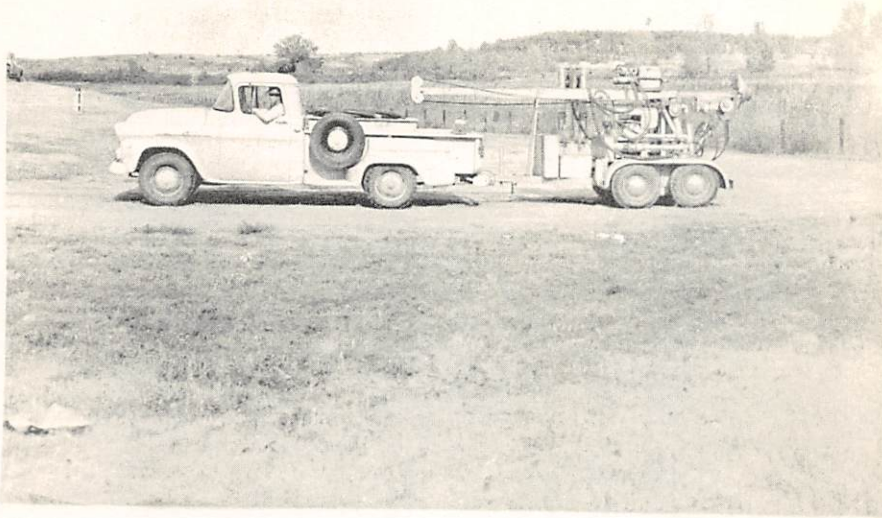


Figure 1 - The vacuum type drilling rig in the road position.

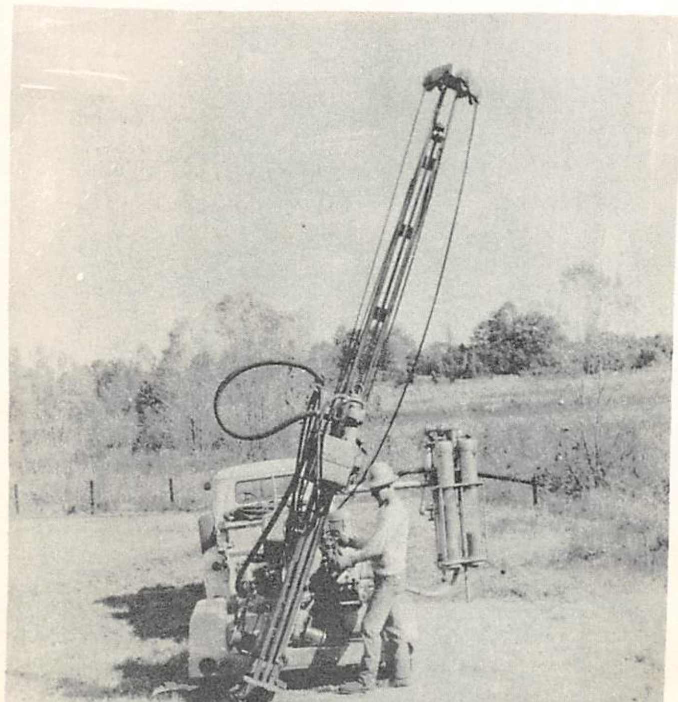


Figure 2 - Directional drilling at 20° from the perpendicular.

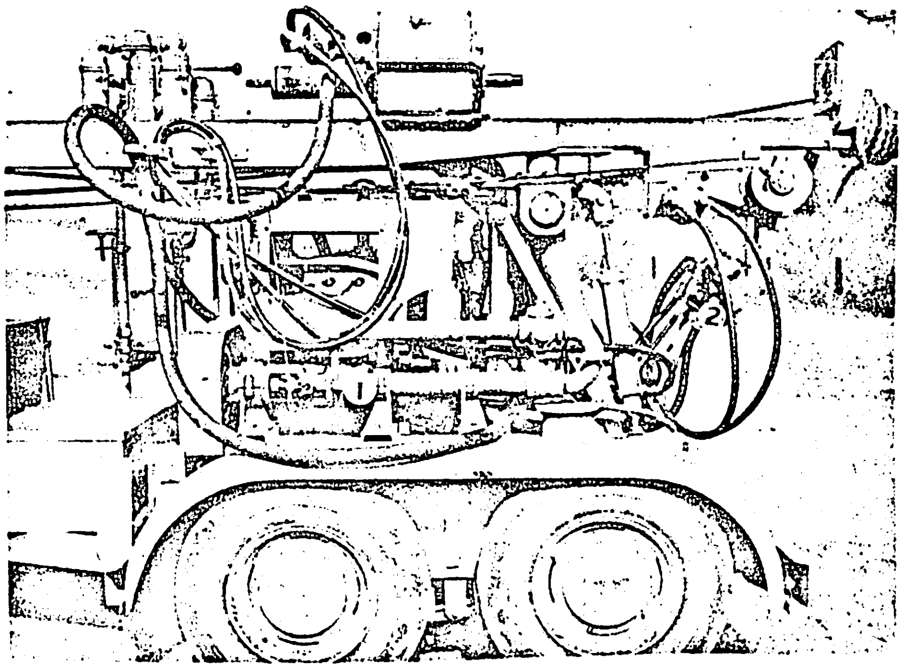


Figure 5 - Left-hand side of rig showing (1) water pump capable of pumping 10 GPM at 200 lbs. PSI and (2) hydraulic controls for operating drill rig.

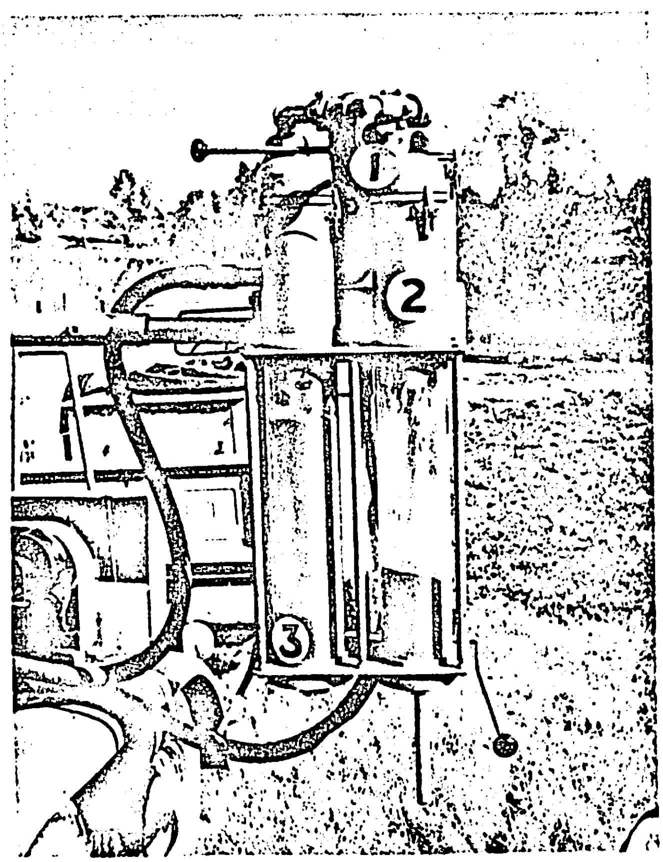


Figure 6 - Plastic sample collection tubes, which give continuous visual logs. (1) Valve handle, which permits directing samples to either of the sample tubes. (2) Primary cyclonic separator which permits air separation from the sample. (3) Plastic cylinder showing stratification.

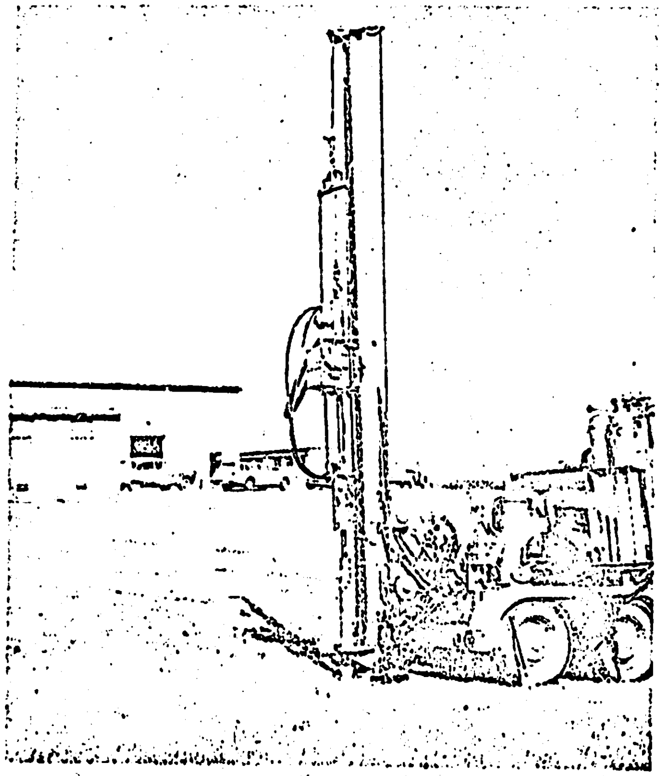


Figure 7 - Driving and drilling simultaneously. (1) Brake operating catline of left side of mast used to regulate the descent of the rotary head. (2) Casing. (3) Hammer, 140 lbs. (4) Drill-stem. (5) Cathead used to drop the hammer.

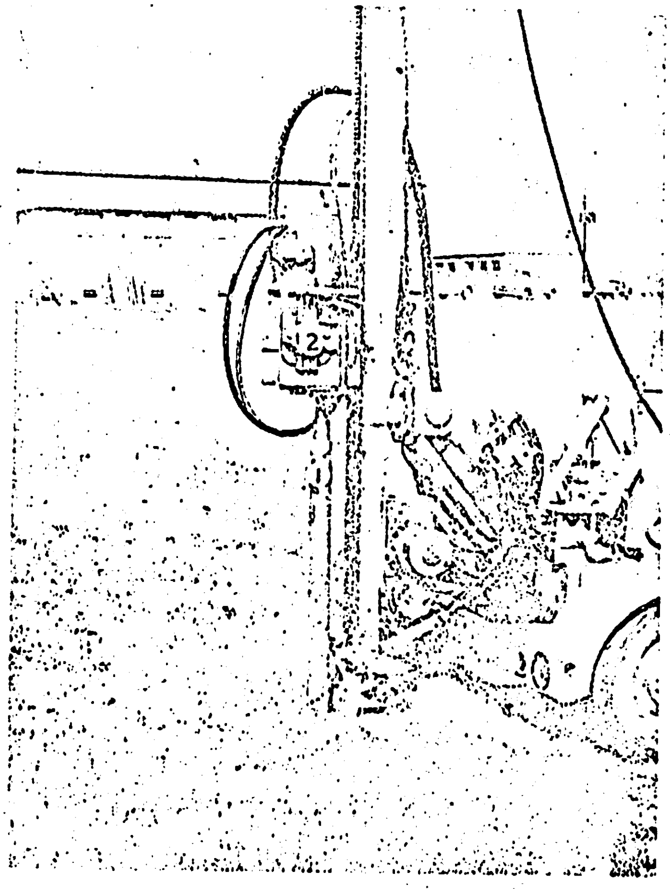


Figure 8 - Rotating and forcing casing into quicksand. (1) Casing (smooth walled) 3" ID 3¼ OD. (2) Drill-head.

approximately 100 feet of quicksands, which is about the maximum depth using present equipment and techniques.

A visible core can be obtained with vacuum air, vacuum water, and reverse water. It is also possible to obtain total recovery by the two vacuum methods. The rig will also drill by forced water and coring. The varied sampling and drilling methods make it adaptable to most drilling conditions in any area.

The rig is light and portable. Its weight, including the trailer, is about 2 tons, depending upon the equipment carried on the trailer. Approximately 15 minutes are required to ready the drill after arriving at a location because it is completely hydraulic.

The rig, as a whole, is well designed, but there is a definite need for heavier and better construction. Design alterations needed are: (1) a better system of oiling the top bearing in the drill head, (2) larger hydraulic motors to drive the catheads and the drill head, (3) a different gear ratio which would give less speed and greater power on the drill head rotation. (At present the drill head has speeds from 0 to 420 RPM. Speeds in excess of 100 RPM are too fast to be of much use. It would be desirable to have more power and less speed.) (4) a different trap door suspension on the

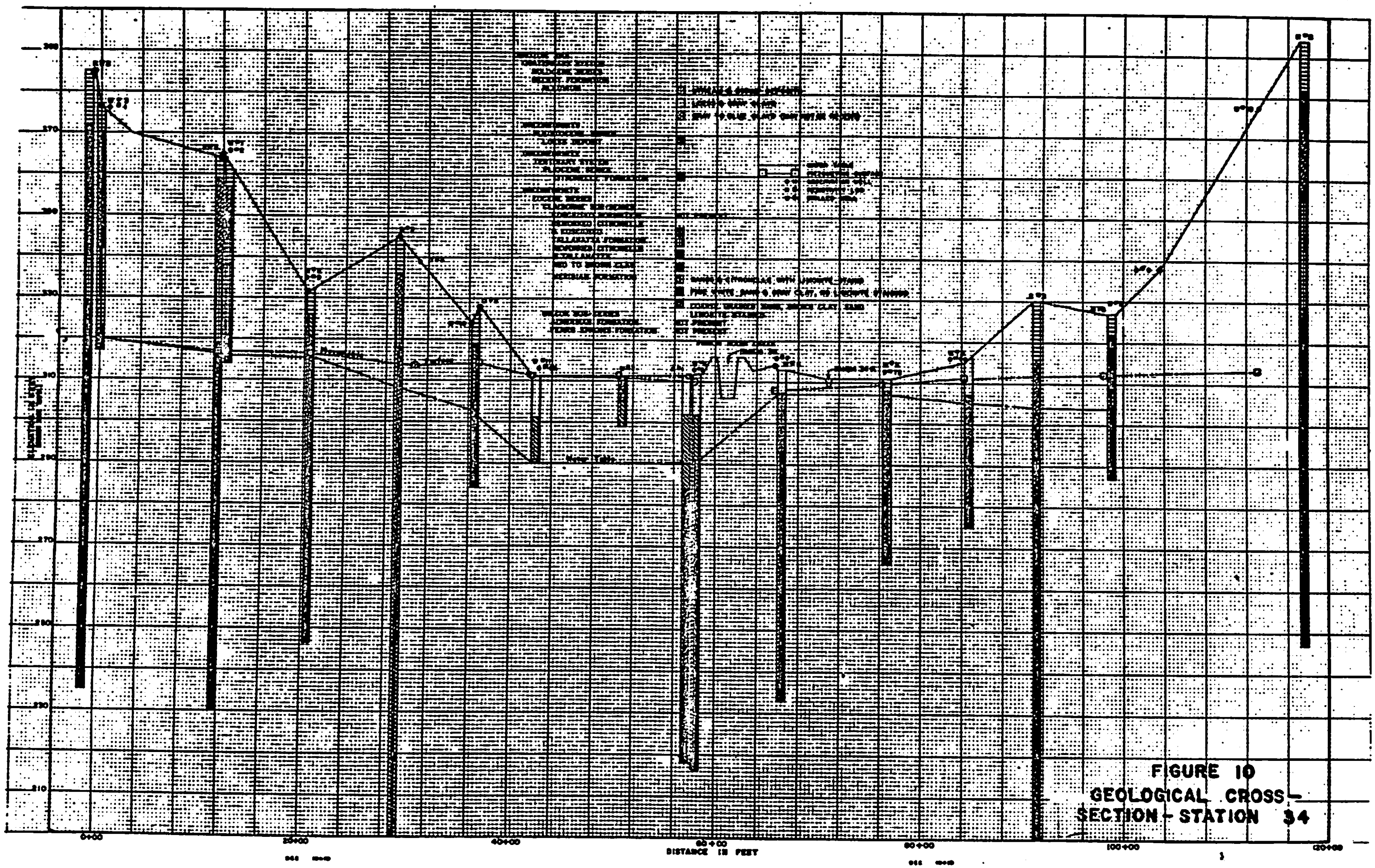


FIGURE 10
GEOLOGICAL CROSS-SECTION - STATION 34

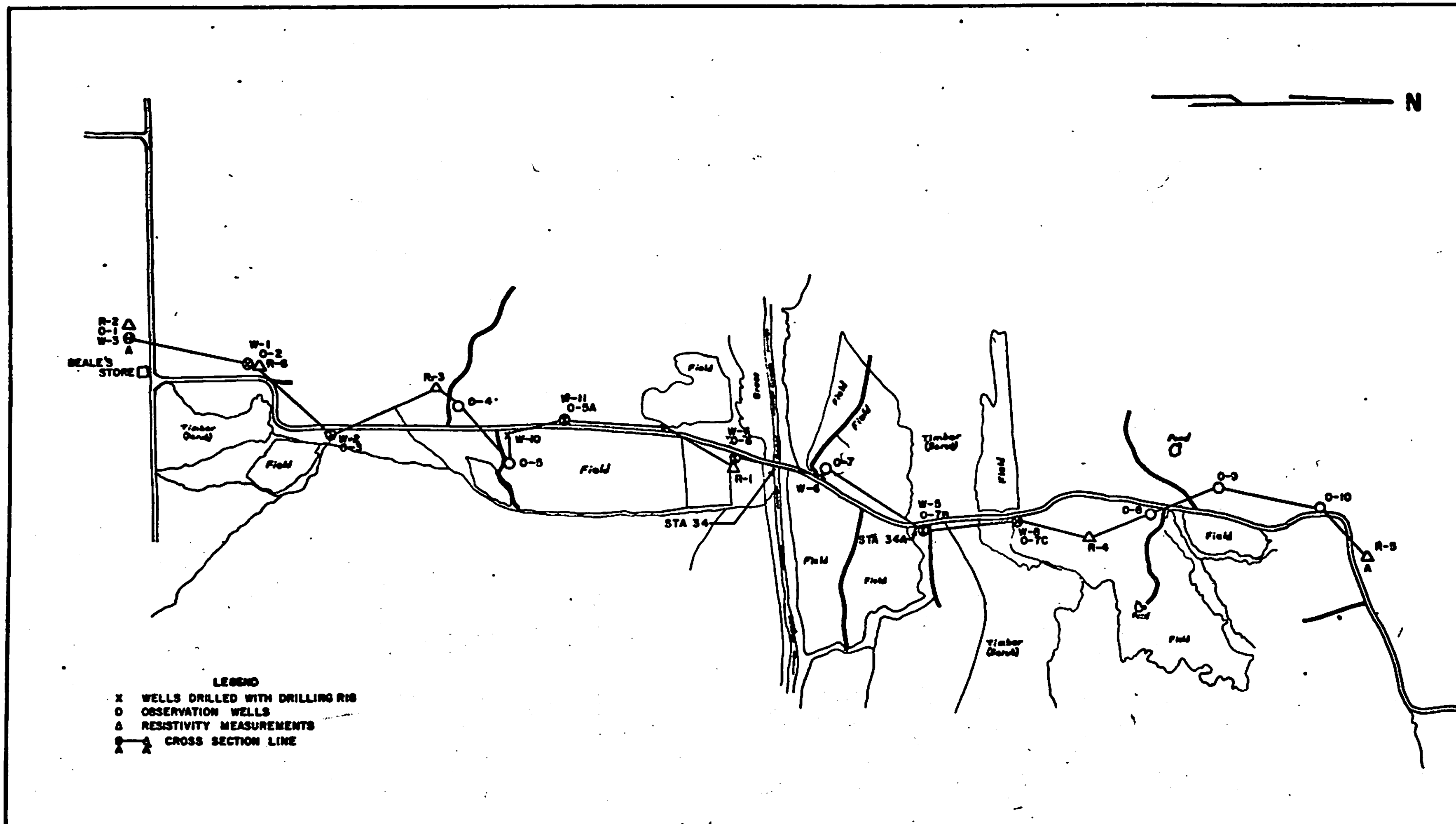
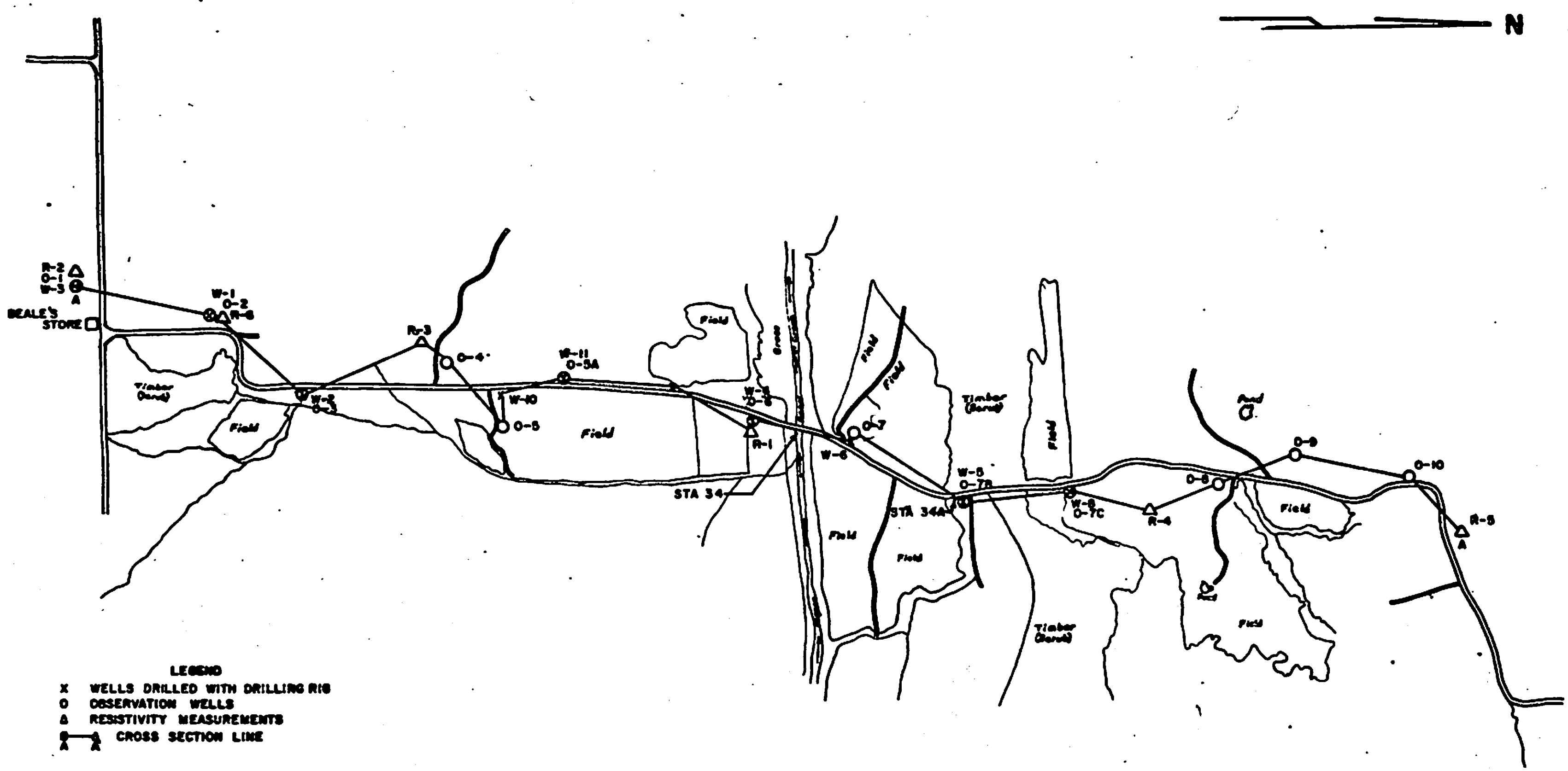


FIGURE 11
LOCATION MAP OF GEOLOGICAL CROSS SECTION
STATION 34, PIGEON ROOST CREEK
MARSHALL COUNTY, MISSISSIPPI



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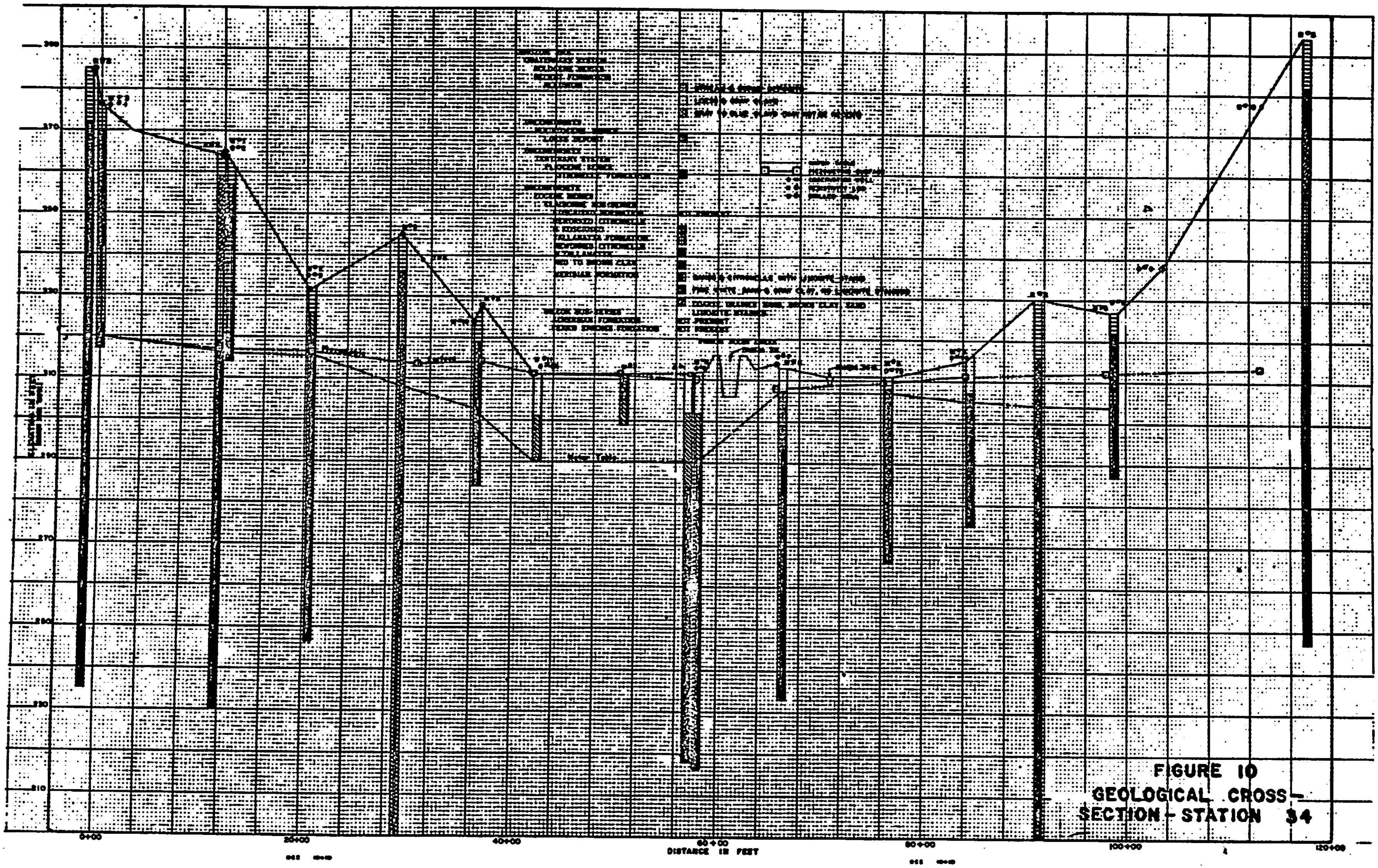

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Figure 3 - Angle drilling parallel with center line of drill rig, 40° from the perpendicular.

Figure 4 - Right-hand side of rig showing (1) high velocity vacuum air pump capable of pulling up to 7,500 F.P.M. and (2) air filter system.

bottom of the plastic sample tubes, (5) a better clutch system on the high velocity vacuum pump and one that permits changing to water with greater ease, (6) a hook to hold the drill head back to prevent it from swinging over the hole when it is in the out-position, (7) a guard to keep the hydraulic hoses from hooking on the back of the mast when in the out-position, and (8) a change of the air-cooled gasoline motor into such a position as to enable the operator to change the oil without the oil running all over the rig and also permit the oil plug to be removed easier.

Modifications will be made on the local drill rig to increase its efficiency. It is planned to design a gravel trap which can be attached to the drill head to separate the gravel (Citronelle) from the sand, silt, and clay before it goes into the rubber hose to the cyclones. The gravel in the Pigeon Roost Creek area has a diameter that permits it to go through the bit and up the drill stem, but not through the hose to the cyclones. It is not possible to grind the gravel before it goes into the bit because the sediments are not consolidated. When the gravel is forced into the walls of the drill hole, it will not stay. Therefore, a great deal of drilling time is lost cleaning the hoses and unplugging the cyclones.

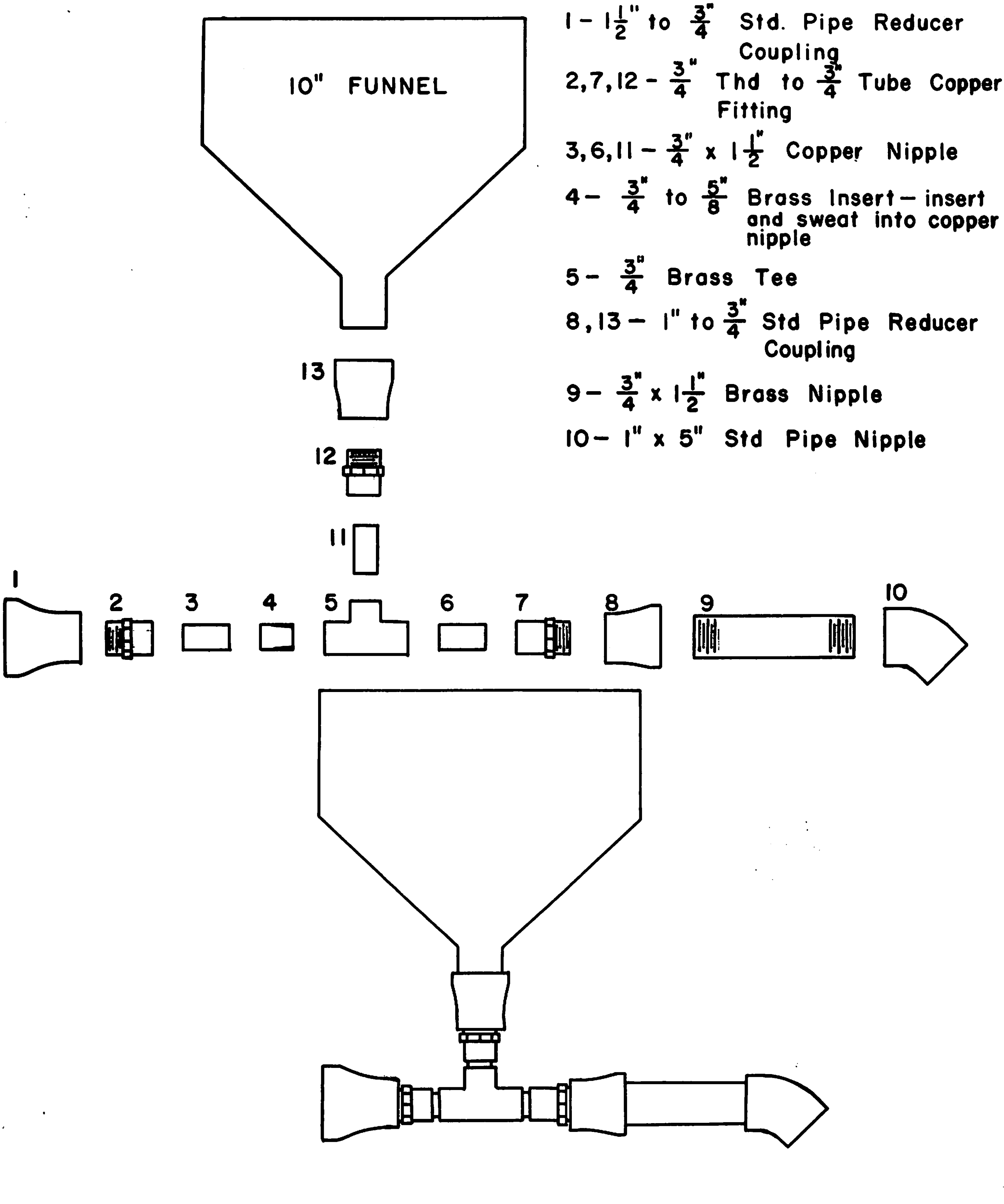
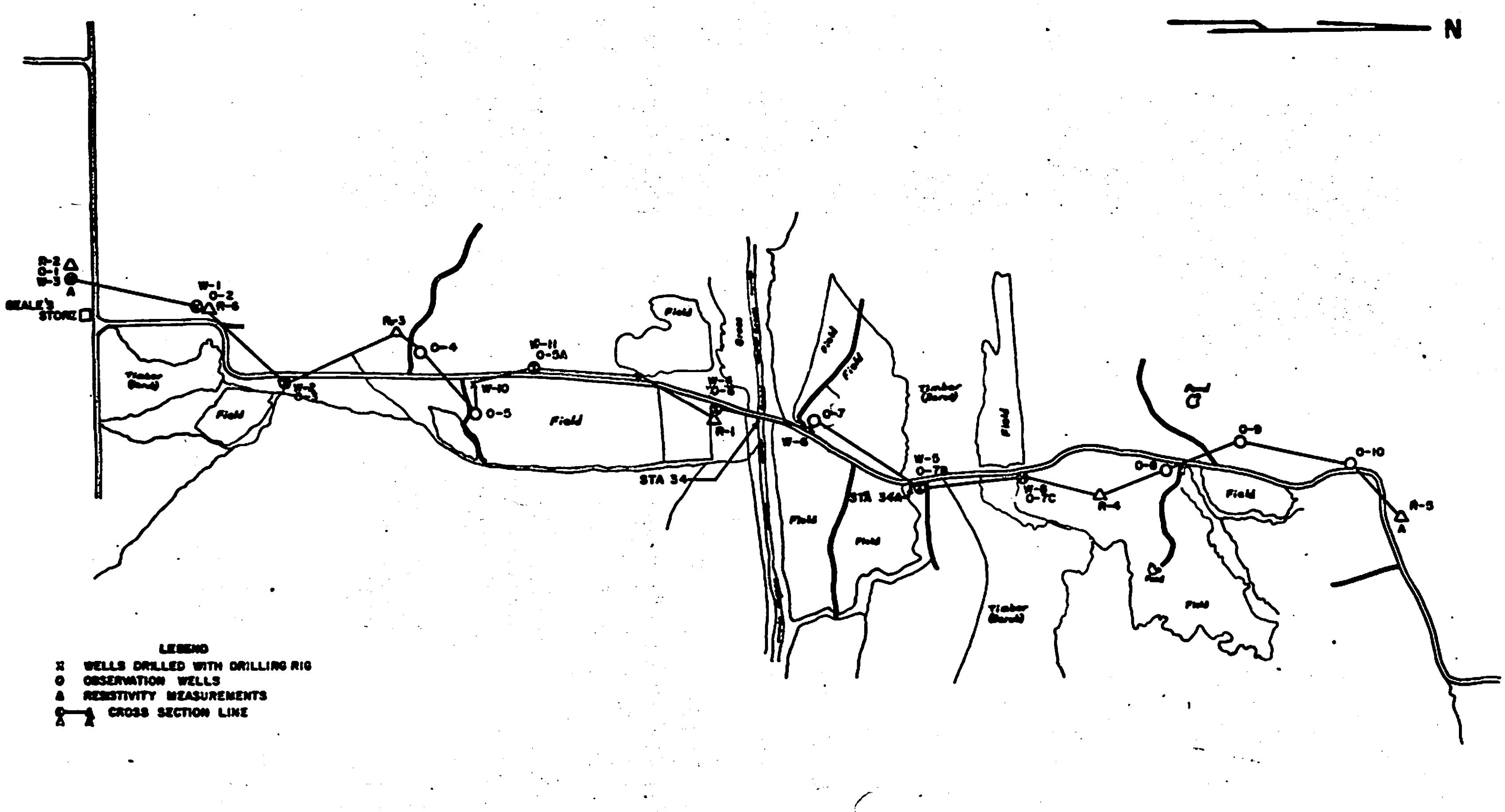


FIGURE 9 - MUD MIXING NOZZLE



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saving in time and money.

Drilling Program

Due to the flexibility of the drill rig it is possible to adapt it to a varied program of aquifer-streamflow investigations, and to develop geological and ground water interpretations usable in planning Watershed Protection and Flood Prevention programs.

Drilling, obtaining good samples, and logging holes drilled in quicksand have been the major problem in the ground water investigations in the Pigeon Roost Creek Watershed. Drilling sites located on the upland present very little or no problem until Meridian sands are contacted. It is these water-saturated sands that form the major portion of the quicksand in this area. Sites located in the valley also have valley fill material which may act in the same manner as the Meridian, since it is composed of well-graded sub-angular Eocene sands, clays, and silts.

Drilling during the summer of 1960 was successful to depths of 100 feet in quicksands which is about the maximum depth they could be drilled with the vacuum drill rig. All of the drilling sites completed during the summer were located on a section across Pigeon Roost Creek bottom at gaging Station directly into the Meridian. In either case, it is possible that water is moving both influently and effluently depending on the channel reach and stream stage, but primarily into the alluvium due to the artesian pressure within the Meridian.

The piezometric rises were determined by drilling holes through the clay and loess cover, determining at what depth water was contacted, and then measuring the height to which it rose in the well. There was no rise in areas where the old channel lay directly on the Meridian because of the lack of a sealer bed.

The valley fill at Station 34 lies directly on the water-saturated Meridian sands with no seal between it and the Meridian. It would, therefore, be very hard to determine the amount of water loss from the watershed in valley fill at Station 34. Water is permeating into and out of the Meridian in the areas where the sealer bed is absent. However, it may be possible to determine the ground water loss and balance the water budget from a portion of the Pigeon Roost Creek Watershed at some up-valley location where a sealer bed is found to be present over the entire valley width.

A proposed application for the well rig is the development of a method for determining in-place permeability by the use of a small well point. The rig has supplied the means for field testing such a well point and also supplied high velocity air for the draw-down in laboratory studies conducted during the winter months. By using high velocity air it was possible to maintain a small, well-controlled hydraulic head on the well point. In most cases it was found desirable to keep the head to 6 inches or less. The water removed to maintain this head was then trapped in the cylinders shown in figure 6. By measuring the quantity of water, knowing the hydraulic head, length of time pumped, and the effective area of the well point, it seems possible to compute in-place permeabilities. A later publication will cover this method of in-place permeability determinations.

Resistivity measurements were made for comparison with the visual well logs in connection with the drilling program. At Station 34 on Pigeon Roost Creek, both resistivity and drilling logs were obtained at several locations, and a good correlation existed between the data obtained.

Possible applications of the resistivity measurements in the Pigeon Roost Creek area would be in measuring thickness of sediments in old channels and dams, channel locations, ground water studies, and other geological investigations (3).

Acknowledgments

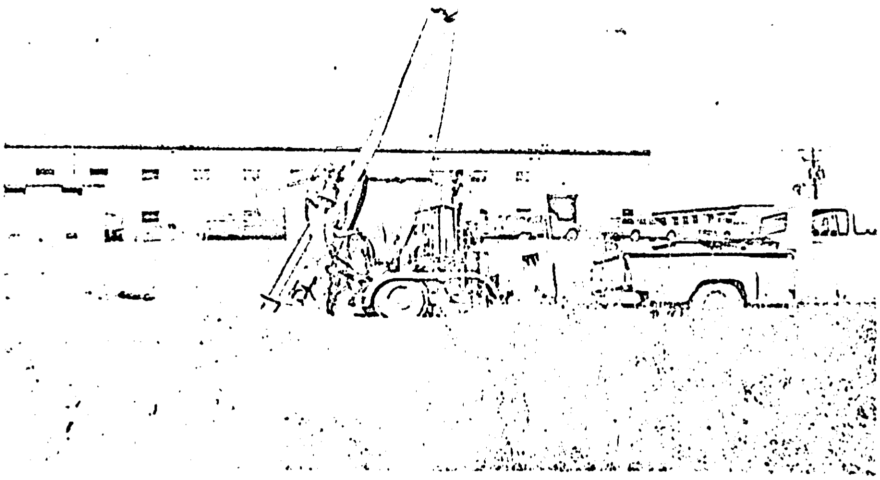
Base flow measurements were conducted by Messrs. Farris E. Dendy and Andrew J. Bowie, and assistance in the design and construction of the mud mixer was given by Mr. James C. Hartsfield. All are members of the US Sedimentation Laboratory staff.

LITERATURE CITED

(1) Evans, Norman A., "Stratum Survey Techniques for Drainage Investigation on Irrigated Lands," Colorado State University Experiment Station, Technical Bulletin Number 67, December 1958.

(2) Moore, R. W., "An Empirical Method of Interpretation of Earth's Resistivity Measurements," American Institute of Mining and Metallurgical Engineers, Volume 164, pp. 197-244 (1945).

(3) Tapp, William N., "Resistivity Method Scans Geologic Conditions," The Johnson National Drillers Journal, September-October, pp. 3-6 (1960).



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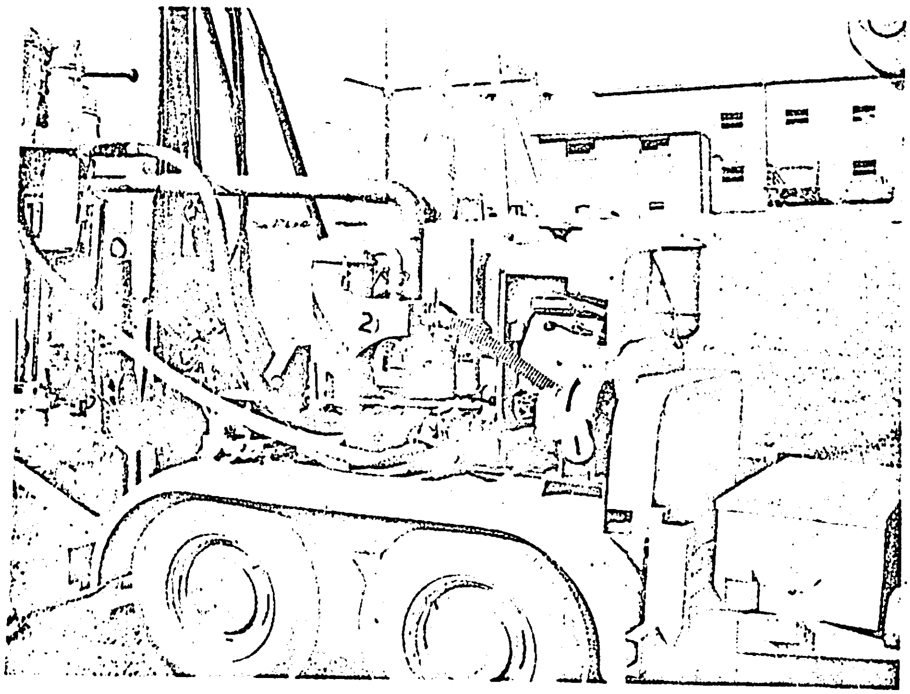

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