No. ______

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

TOPICAL REPORT NO. 63

WINNIPEG AND BRANDON SHEETS, MANITOBA

Part I. An Aquifer Test, Winkler, Manitoba

Part II. A Resistivity Reconnaissance Survey at Winkler, Manitoba

BY

J. E. CHARRON AND J. E. WYDER

OTTAWA

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FOREWORD

A study of the hydrogeology of the Red River basin of Manitoba has been in progress since 1959 and was supplemented during the field season of 1962 by a resistivity survey of a certain aquifer.

One result was the disclosure of some information regarded to be of direct interest to the inhabitants of Winkler. A Topical Report seemed the quickest and most convenient means of making this information available to the parties directly concerned.

Part I

An Aquifer Test, Winkler, Manitoba

J.E. Charron

Foreword

In 1959 a groundwater study of the Red River valley was started. In a subsequent report[1] the author mentioned that "The area of approximately 48 square miles surrounding Winkler has the greatest potential groundwater resources in the Plum Coulee region. The extent of these resources could be established by a systematic drill-hole program, with the holes having a minimum depth of 160 feet and a maximum depth of 290 feet."

Purpose

In the winter of 1960-61 the town of Winkler became interested in a water supply. In the spring of 1961 the Manitoba government drilled some eight holes around Winkler, mostly to the south, in the hope of obtaining a water supply. An aquifer of sand and some gravel was encountered but only 25 gpm were available by pump test. As a follow through, in the summer of the same year, the federal government undertook a drilling program. In all thirteen holes were drilled in a line running NW of Winkler. The aquifer previously encountered by the Manitoba drilling program was traced some 7 miles to the NW of Winkler (Fig. 1). Hole #8 penetrated some 165 feet of sand and gravel.

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[1] Paper 60-22, G.S.C. Dept. of Mines and Technical Surveys, p. 39.

In the summer of 1962 a pump test was carried out to determine the quantitative and qualitative aspects of this sand and gravel aquifer.

Location

The site chosen was SE 36-3-5 west of the principal meridian some 500 feet west of hole #8. It is 2 miles west and 5 miles north of the town of Winkler, along highway #3 (Lat. 49°15', Long. 98°00').

Well Drilling

Five wells were drilled; one 6 inch and four 4 inch inside diameter wells. In the 6 inch or main well a 5 inch by 15 feet long iron screen was installed. The slot openings of the screen were #93. In each of the four observation wells a 2 inch by 4 feet long plastic screen was installed with #10 slot openings. The four observation wells were drilled 25 feet north, south, east and west of the main well (Fig. 2). Apart from a foot of top soil and some big boulders (1 foot and 2 feet across) at 10 feet below ground level, the five holes did not penetrate anything else but sand and some lenses of gravel. The drilling was done with a rotary drill by the Department of Public Works, Ottawa.

The following table gives the data on the 5 wells. All measurements were made from the top of the casing which in each case was 2½ feet above ground level.

		Main Well	Well A	Well B	Well C	Well D
Depth	-	202.0'	201.5'	201.0'	201.0'	196.5'
Diameter	-	6"	4"	4"	4"	4"
Elev. of top of casing	-		919.18'	919.77'	918.93'	918.11'
S.W.L. 10 a.m. 25-7-62	-		897.32'	897.39'	897.36'	897.40'
Elev. of screen setting (bottom of screen)	-	202.0'[1]	717.68'	718.77'	717.93'	721.68'

[1] Depth to bottom of screen not elevation.

Pump Test

Prior to the main pump test, preliminary tests were carried out to determine the final rate of pumping. At first, without a screen, the well would only yield 4 gpm; then with further development 16 gpm were available, then over 100 gpm. At that point the 15 foot screen was installed and a maximum capacity of 500 US gpm or 416 I gpm was recorded. The rate of pumping was measured through a 90° weir. A 315 cu.ft. per min. air compressor supplied the power through 127 feet of a 2" air line using the 6" casing as eductor pipe for the 72 hour pump test. Because of the preliminary pump testing all activities were stopped for two days prior to the test in order to establish natural equilibrium in the aquifer.

The pump test was started at 11.00 a.m., July 25, 1962. The drawdown was measured in the four observation wells. No measurements were obtained from the main well as the full 6 inch size of the hole was required for pumping at 416 I gpm.

The maximum drawdown after three days of pumping occurred in well A and was only 1.33 feet.

After 72 hours of pumping, recovery measurements were obtained in the same manner as for the drawdown (Fig. 2); 51 hours after pumping had stopped well A had completely recovered. Some 21 hours later the other three wells had almost but not quite fully recovered (Fig. 3).

The Hydraulic Characteristics of the Winkler Aquifer

A - Transmissibility and Storage Coefficient

A time-drawdown graph for the four observation wells was made and is shown on Fig. 4. From this, using the Jacob's Method of the Non-Equilibrium formula, the transmissibility and storage coefficient value of the aquifer was calculated.

Apart from observation well D, the drawdown and recovery values are almost identical in each well, as well as being identical one well with another. Why well D was erratic in the first 200 minutes of the pump test, is not known.

The Theis non-equilibrium time-drawdown curves could not be used to analyse this pump test for the simple reason that the largest percentage of the drawdown occurred within the first minute of the pump test and the remaining drawdown was negligible in proportion to the time. In other words, equilibrium was reached too quickly. A higher rate of pumping would have probably given better results but this would have necessitated a larger diameter well.

The aquifer was originally thought to be unconfined, but after analysing the results it would seem to be both unconfined and confined. The top part of the aquifer is considered unconfined while an analysis of the water which was pumped from a depth of 202 feet shows that the water is partly derived from the shale bedrock which would make the bottom part of the aquifer a confined aquifer.

Figure 4 shows that for each observation well two transmissibility values were obtained. One value, the largest, is for the first ± 100 minutes of the pump test while the smallest value is for the remaining ± 70 hours of the pump test and is the one chosen as being more realistic.

The difference in values is shown on the graph (Fig. 4) as a negative boundary which occurs somewhere between the 50 and 100 minute mark. In general the line drawn through the points (Fig. 4) is one that averages both the drawdown and recovery data together. Beyond the 1500 minute mark the readings are not as regular and perfect equilibrium is never reached.

The calculated transmissibility and storage coefficient values after 100 minutes of pumping are:

	Transmissibility	Storage Coefficient
Well A	752,219 gpd/ft.	0.11×10^{-5}
Well B	704,000 " "	0.28×10^{-3}
Well C	682,137 " "	0.16×10^{-3}
Well D	657,629 " "	0.18×10^{-1}

The values show local variations within the aquifer, but on the whole the values can be considered as fairly consistent with one another.

For the remainder of this report all calculations were made using the transmissibility and storage coefficient value of observation well B (T=704,000 gpd/ft. and $S=0.28 \times 10^{-3}$). It is also assumed that: the aquifer was completely penetrated; the aquifer is of infinite areal extent and homogeneous throughout; no well loss occurred; total withdrawal was from storage, that is, no recharge from rainfall or other sources took place.

$$\text{If } s = \frac{114.6\ QW(u)}{T}$$

$$\text{where } W(u) = -0.577216 - \text{In } u + u - \frac{u^2}{2x2!} + \frac{u^3}{3x3!} - \frac{u^4}{4x4!} \text{ -----}$$

$$\text{-----}\ \frac{(-1)^n u^n}{n \times n!}$$

and $u = \frac{1.56\ r^2 S}{T\ t}$

s = drawdown at any point in the aquifer.
Q = discharge of pumped well 416 I gpm.
T = Coefficient of transmissibility of the aquifer 704,000 gpdf.
t = time since pumping started in days.
r = distance from discharging well.
S = coefficient of storage of the aquifer 0.28×10^{-3}

From the above equation the performance calculated is a continuous operation at 416 I gpm. The drawdown in the main well is when

t = 1 day -------------------- s = 1.49 feet

t = 3 days ------------------- s = 1.56 "

t = 10 days ------------------ s = 1.64 "

t = 100 days ----------------- s = 1.80 "

t = 1 year (365 days) -------- s = 1.89 "

t = 100 years ---------------- s = 2.20 "

and the drawdown 1000 feet away would be when

t = 1 day -------------------- s = 0.46 feet

t = 3 days ------------------- s = 0.53 "

t = 10 days ------------------ s = 0.62 "

t = 100 days ----------------- s = 0.77 "

t = 1 year (365 days) -------- s = 0.86 "

t = 100 years ---------------- s = 1.17 "

If one doubles the rate of pumping theoretically the drawdown should also be doubled.

B - Permeability and Flow Velocity in the Winkler Aquifer

T = Km $\qquad\qquad K = \frac{Q}{IA}$

T = transmissibility in gpd/ft. = 704,000 gpdf.

K = permeability in gpd/ft^2.

m = saturated thickness of the aquifer in ft = 182 feet.

Q = Rate of discharge in gpd = 416 gpm.

A = X-sectional area of flow in ft^2 = 720,720 ft^2.

I = hydraulic gradient in ft/mile.

$$K = \frac{T}{m} = \frac{704,000}{182} = 3,868 \text{ gpd/ft}^2$$

$$I = \frac{Q}{} = \frac{599,040}{3,868 \times 720,720} = 0.000215$$

$$I = 1.14 \text{ ft/mile}$$

$$\text{If } V = \frac{KI}{6.25\theta}$$

V = Velocity in ft/day

θ = porosity in % = 34% (field test experiment)

$$V = \frac{3868 \times .000215}{6.25 \times 0.34} = 0.39 \text{ ft/day}$$

or V = 142 feet/year

C - Velocity of Groundwater Motion (Toward a discharging well in an infinite aquifer of uniform thickness).

$$V = \frac{36.7XQ}{m\theta} X \frac{I}{r}$$

V = velocity of GW at distance r in ft/day

Q = Rate of discharge in gpm = 416 gpm

m = saturated thickness of aquifer in ft = 182'

θ = porosity - % = 34%

r = distance from pumped well in feet = 25'

$$V = \frac{36.7 \times 416}{182 \times 0.34 \times 25} = 9.9 \text{ ft/day}$$

is the velocity of the groundwater at 25 feet from the pumped well during the pump test.

If the radius of the pumped well is small relative to the distance r (in this case it is 3 inches to 25 feet) then

$$tw = \frac{m \, \theta \, r^2}{73.5Q}$$

tw = time traverse to the pumped well in days.

$$tw = \frac{182 \times 0.34 \times 625}{73.5 \times 416} = 1.3 \text{ day}$$

Therefore it took the water 1.3 day to travel from the observation wells to the main well during the pump test. This shows that the velocity of the water increased as it approached the main well which was being pumped.

D - Specific Yield of the Winkler Aquifer

The specific yield of an unconfined aquifer is the storage coefficient. It is the water which can be drained from an aquifer. It is therefore a fraction of the porosity of an aquifer.

By the Remson, Lang method

$$\log V = \log \frac{Qr^2}{4T} + \frac{5.45Ts}{Q}$$

V = The volume of dewatered material in cu. ft.

Q = discharge rate of pumped well in gpd = 416 gpm

r = distance from main well to observation well in feet = 25 feet

T = transmissibility = 704,000 gpd/ft.

s = the drawdown at distance r. in feet = 1.06 feet

$$\log V = \log \frac{599,040 \times 625}{4 \times 704,000} + \frac{5.45 \times 704000 \times 1.06}{599.0 \times 0}$$

$$= \log 132.95 + 6.79$$

$$= 2.13570 + 6.79 = 8.92570$$

$$V = 842,760,000 \text{ cu. ft.}$$

If the specific yield is the volume of water pumped during the test divided by the gross volume of dewatered material within the cone of depression then

$$Sp = \frac{Qt}{7.48V}$$

Sp = specific yield

Q = discharge rate of pumped well in gpd = 416 gpm.

t = the time, in days, since pumping began = 3 days.

V = the volume of dewatered material in cu. ft. = 842,760,000 cu. ft.

$$Sp = \frac{599,040 \times 3}{7.48 \times 842,760,000} = 0.285 \times 10^{-3}$$

which is the same as the storage coefficient value and which would make this aquifer an unconfined aquifer.

If the drawdown at the main well is taken as 1.60 feet, which is an average calculated from the values obtained at the four observation wells the specific capacity of the main well is 260. The specific capacity measures the effectiveness of a well and is equal to the rate of discharge divided by the drawdown or

$$Sp\ C = \frac{Q}{s}$$

it is not a constant.

E - Spacing of Wells in the Winkler Aquifer

If

sp = permissible drawdown = 1.5 feet

T = transmissibility = 704,000 gpdf.

S = Storage coefficient = 0.28×10^{-3}

Q = 500 U.S. gpm = discharge rate of pumped well

t = time since pumping began = 0.5 day (here it is assumed the well is only pumped in the daytime and that equilibrium is reached between each pumping session).

r_1 = effective radius of pumped well = one foot

r_2 = distance from new well to well already being pumped in feet.

$$\log u_1 u_2 = -\left(\frac{spT}{264Q} + 0.501\right)$$

$$= -\left(\frac{1.5 \times 704000}{264 \times 500} + 0.501\right)$$

$$= -8.501 = 1.499 - 10$$

$$u_1 u_2 = 3.16 \times 10^{-9}$$

$$\text{But } K = \frac{1.87S}{T\ t} = \frac{1.87 \times 0.28 \times 10^{-3}}{704000 \times 0.5} =$$

$$K = 1.49 \times 10^{-6}$$

$$r_2 = \frac{u_1 u_2}{Kr_1}$$

$$r_2 = \frac{3.16 \times 10^{-9}}{1.49 \times 10^{-6} \times 1}$$

$$r_2 = 37.72 \text{ feet}$$

This would be the distance second well, pumping at the conditions given, would have to be from the main well which would also be giving the same performance, withouth affecting one another beyond the permissible drawdown.

Quality of the Water from the Winkler Aquifer

The temperature of the water was 44° Fahrenheit.

A sample of water was taken on June 28, 1962 from the 202 feet horizon after some 45,000 gallons had been pumped. The analysis of this sample, recorded below, was made by the Manitoba Health Laboratory - the lab. No. of the analysis is 7082.

Date, 21-7-62

Colour = 10

pH = 7.7

Turbidity = 15.0 ppm.

Calcium (Ca) = 171.0 ppm.

Magnesium (Mg) = 53.5 ppm.

Sodium (Na) = 200.0 ppm.

Iron (Fe) = 0.8 ppm.

Fluoride (F) = 0.92 ppm.

Bicarbonate (HCO_3) = 371.0 ppm.

Chloride (Cl) = 93.80 ppm.

Sulphate (SO_4) = 523.0 ppm.

Carbonate (CO_3) = nil

Hydroxide ($CaCO_3$) = nil

Nitrate (N) = nil

Alkalinity ($CaCO_3$) = 304.0 ppm.

Total Hardness ($CaCO_3$) = 648.0 ppm.

Total Solids = 1550.0 ppm.

Spec. Cond = 1600.0 microhmos.

From this analysis the water can be considered as extremely hard, very high in sulphates and with some iron. Its total solid value is also high enough to qualify this water, chemically speaking, as fair water, although it tasted excellent during the pump test.

A graph of this analysis shows this water is being partly derived or associated with shale and not entirely derived from the sand and gravel in which the pump test was made as would have been presupposed. This indicates that even though the sand and gravel aquifer was not totally penetrated, the bottom of each well is very close to the bedrock which is, in all probability, Cretaceous shale of the Ashville Formation. The water in the shale being under artesian pressure, would be forced up into the sand and gravel aquifer and would mix with the water above it.

Another sample was taken during the pump test after 71 hours of pumping, which means that some 1,772,160 gallons had been pumped out of the aquifer, and is presently being analysed by the Industrial Minerals Division, Department of Mines and Technical Surveys, Ottawa. This second sample was taken to check if there would be a considerable increase in salt (Na Cl) content due to a large withdrawal of water from the aquifer. This region is known to have produced many wells which at first yielded potable water but which in time became too salty for human consumption. Although the complete analysis is not yet available for this second sample of water, the salt (Na Cl) content is known and it is interesting to note that the sodium (Na) stayed the same at 200 ppm, the chloride (Cl) increased to 225 ppm which is an increase of 131.2 ppm. This may have serious consequences for a long term supply and should be studied with more detail before establishing a water supply.

In terms of irrigation this water is classified as second class water and may not be used for all crops. The per cent sodium of the water is 40.2%, while the sodium-adsorption ratio is 3.43.

Sieve Analysis Data of Material Forming the Winkler Aquifer

During the drilling of the main well, samples were taken every 10 feet starting at 15 feet below ground level. In all 19 samples were taken. A sieve analysis of each sample was made and at the end of this report a grain size distribution diagram is included for each sample.

It is interesting to note, Fig. 5, that the grain size of 50% of the material in the main well, over a length of 26 feet, that is from 131 feet to 157 feet, is 2 millimeters or larger. Had the screen been placed at that horizon it can easily be supposed that the performance of the well would have been superior to that obtained, assuming the same conditions.

Recommendations

In 1961 the author recommended a resistivity study of many areas within the Red River Valley and the Winkler aquifer was one of them. In the summer of 1962 the Geophysics Division of the G.S.C. sent Mr. J. Wyder to do a resistivity study. The resistivity report and map is included with this report. In it the aquifer is clearly defined and it can be readily seen that there are better groundwater zones within the aquifer itself.

From the resistivity map the northern end of the aquifer looks undoubtedly to be the best source of groundwater. That groundwater could be found in sufficient quantity, closer to Winkler than the present pump test site, is readily seen. But it is believed by the writer, from his own personal experience of the area, that as one moves SE from the pump test site, say towards Winkler, the chances are greater that the water will get more and more saline because one gets closer to the Swan River sandstone, that underlies the shale, that is under artesian pressure and that yielded water containing 10,000 ppm salt (Na Cl) in a hole drilled in 1961 in SW-8-3-4W.

Assuming a groundwater supply is to be supplied by the aquifer from a well or wells situated in Sec. 36-3-5W, it is to be recommended that the depth of the wells be restricted to a maximum of 150 feet, the reason being that the higher up in the aquifer the water is being pumped from, the less is the chance of salt water, under artesian pressure, intruding from depth. At the pump test site this is easily feasible because the thickness of the aquifer is more than 200 feet and its saturated thickness is known to be more than 180 feet. Whether the water is pumped from 200 feet or less a large supply is guaranteed in any case.

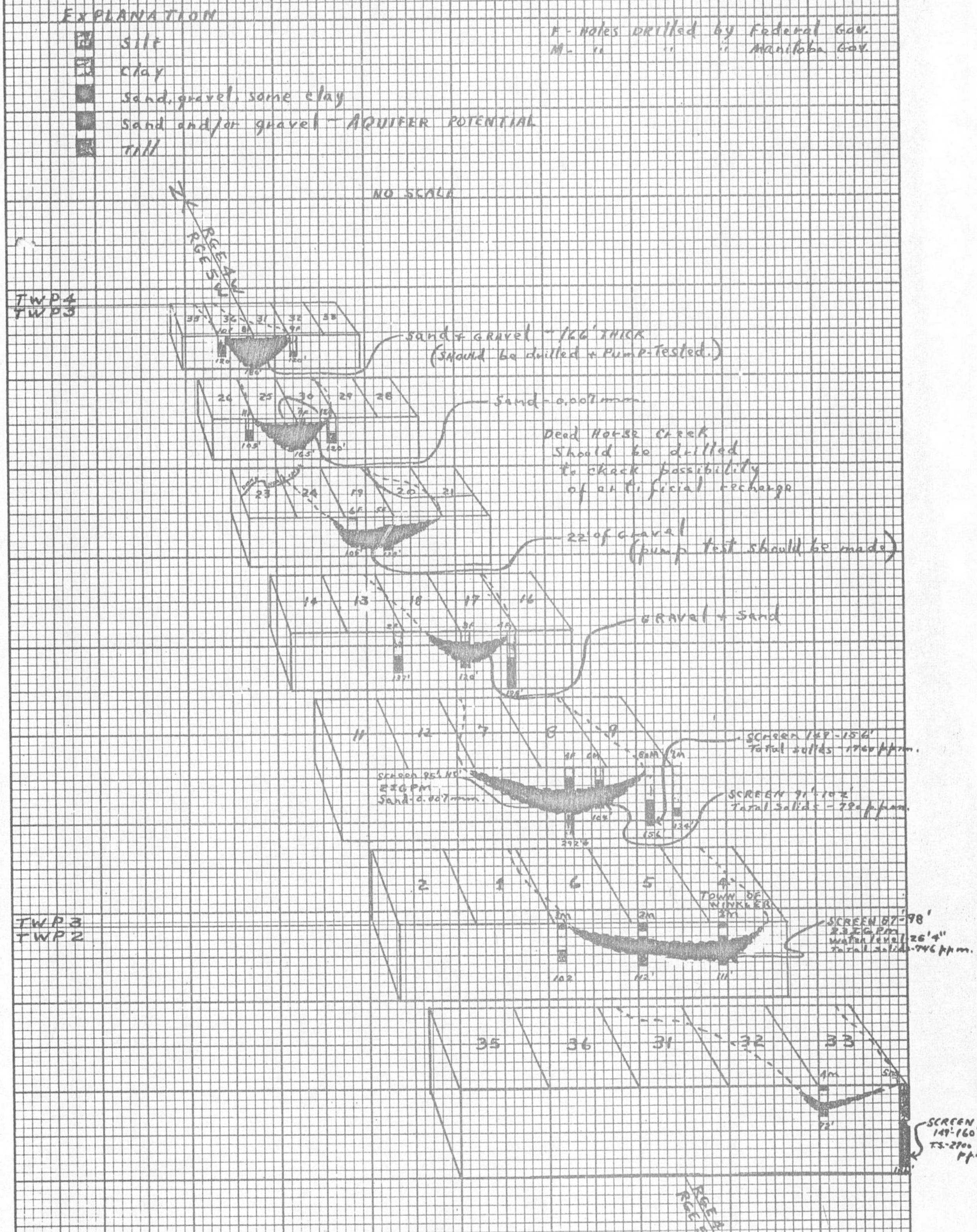
Finally the topographic map of the area shows that the aquifer is traversed in a west to east direction by Shannon Creek 1½ miles to the north of the pump test site and by Dead Horse Creek 1 mile to the south of the pump test site. Both streams are intermittent with the bottom of their beds being only a few feet above the sand and gravel aquifer. (Where highway #3 crosses Dead Horse Creek, a test hole showed only 5 feet of silt above the sand and gravel.) This is mentioned because there is an ideal situation for artificial recharge of the aquifer during spring run-off. This would help to restore the largest part of the water which is believed will be withdrawn almost entirely from storage and it should also help to hold the salt content down.

Conclusion

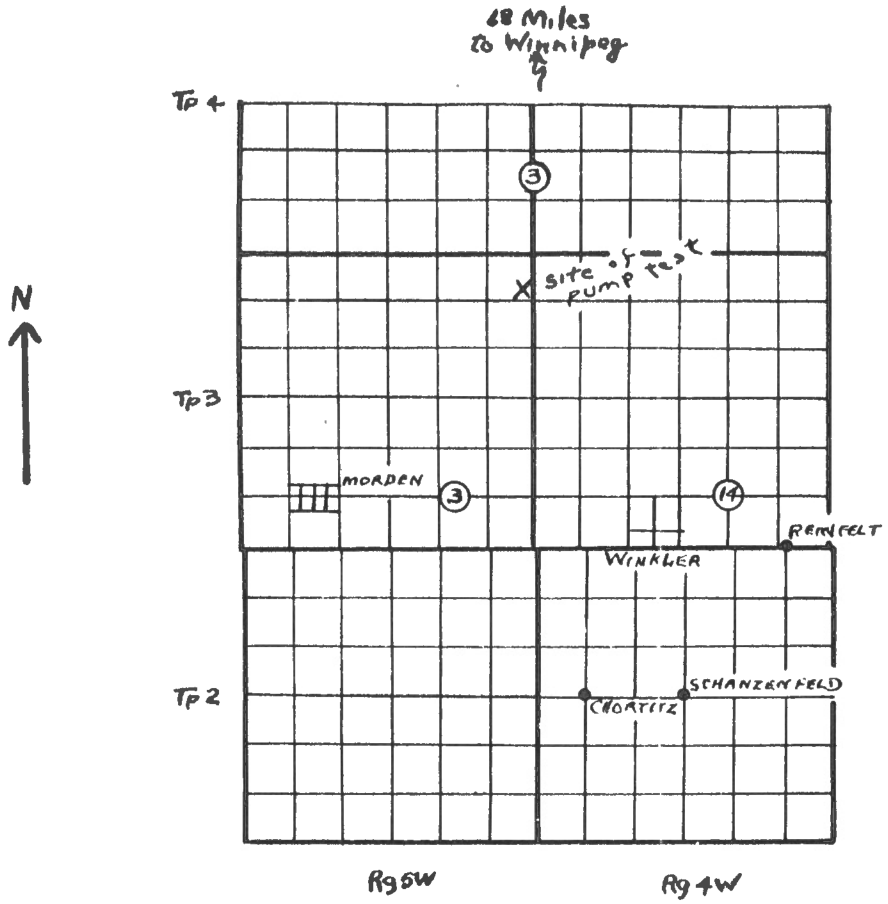
The northern end of the aquifer will yield a very good supply (one million or more gallons per day) of groundwater. What size well and screen should be used, how far from Winkler the well or wells should be, is now strictly a matter of economics and what amount of groundwater will be required from the aquifer. The results obtained from the drilling, pump testing and the resistivity study, that make up the final part of this groundwater study, were better than expected.

FIG. 2. FEDERAL + PROVINCIAL
DRILLING PROGRAM 1961
WINKLER MANITOBA

BLOCK DIAGRAM

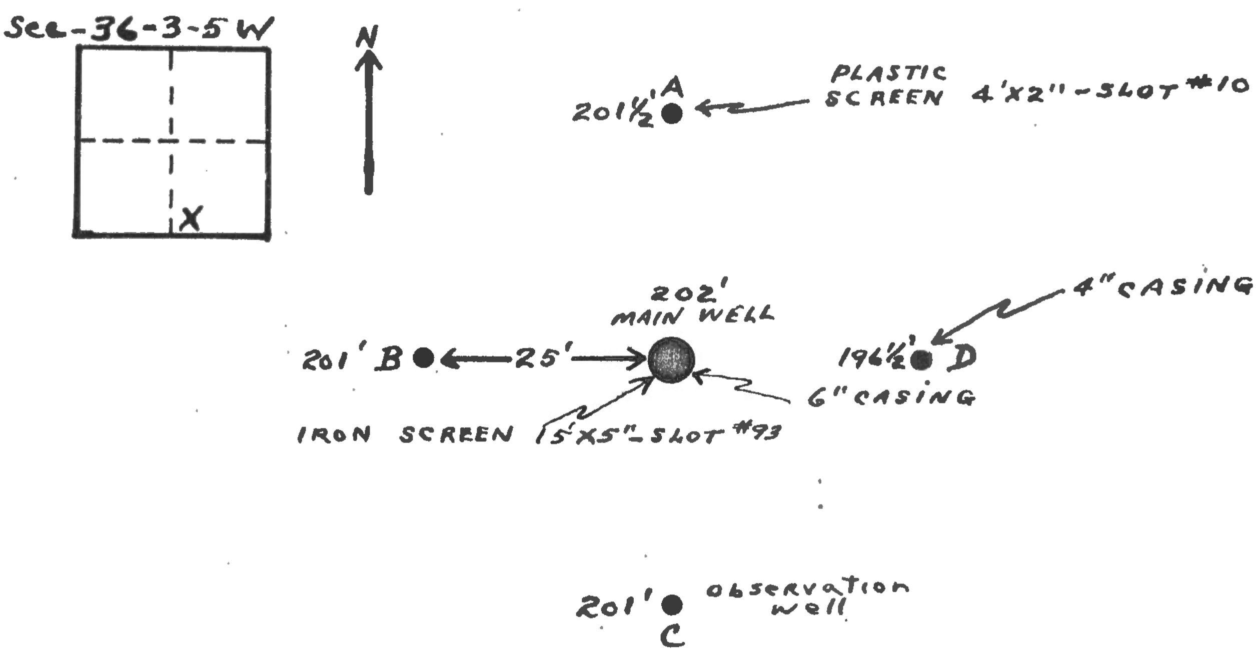


by - J. E. Charron
Ground water Section
1961



Scale : 1" = 4 Miles

LOCATION MAP



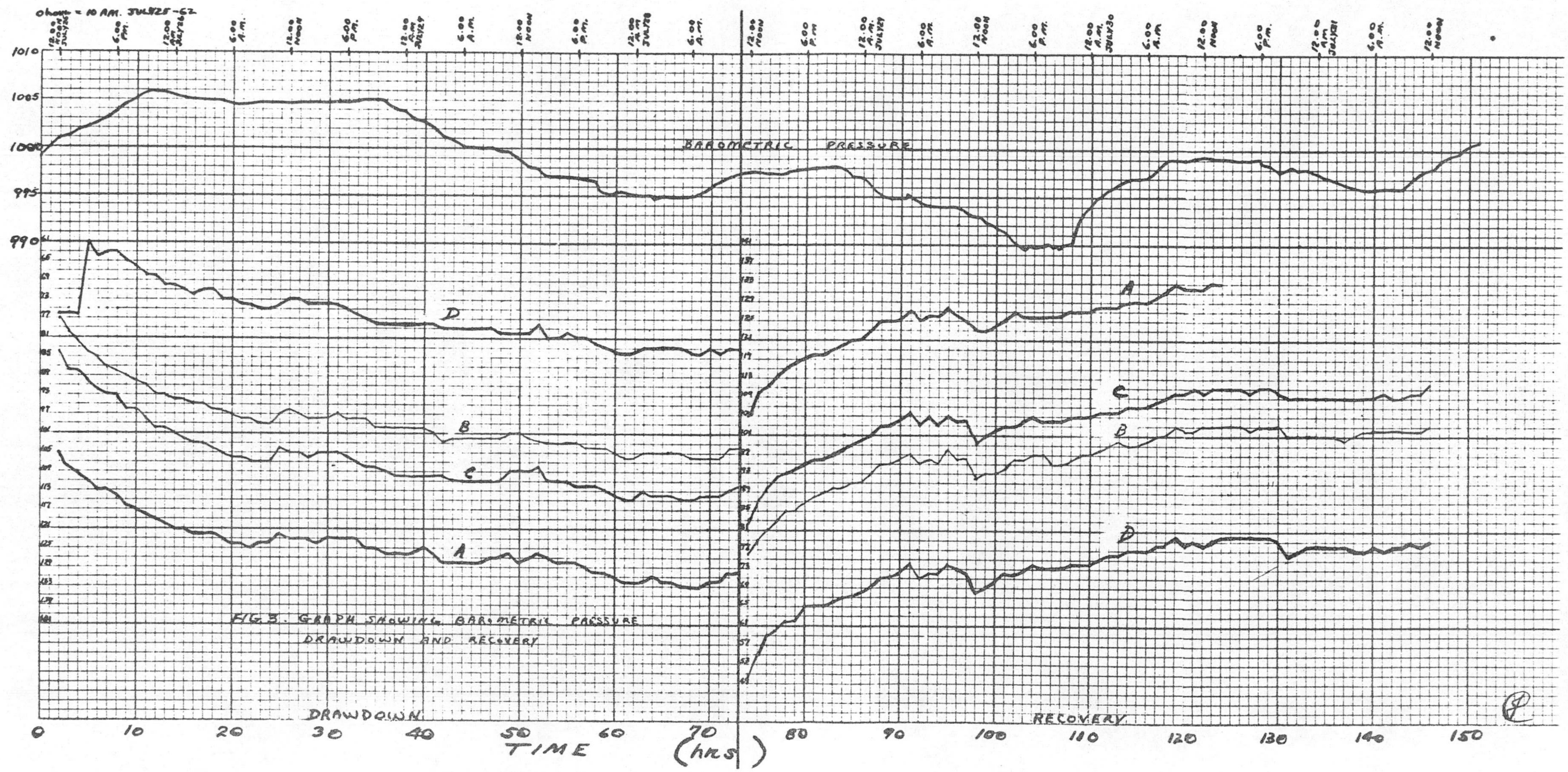


FIG. 3. GRAPH SHOWING BAROMETRIC PRESSURE DRAWDOWN AND RECOVERY

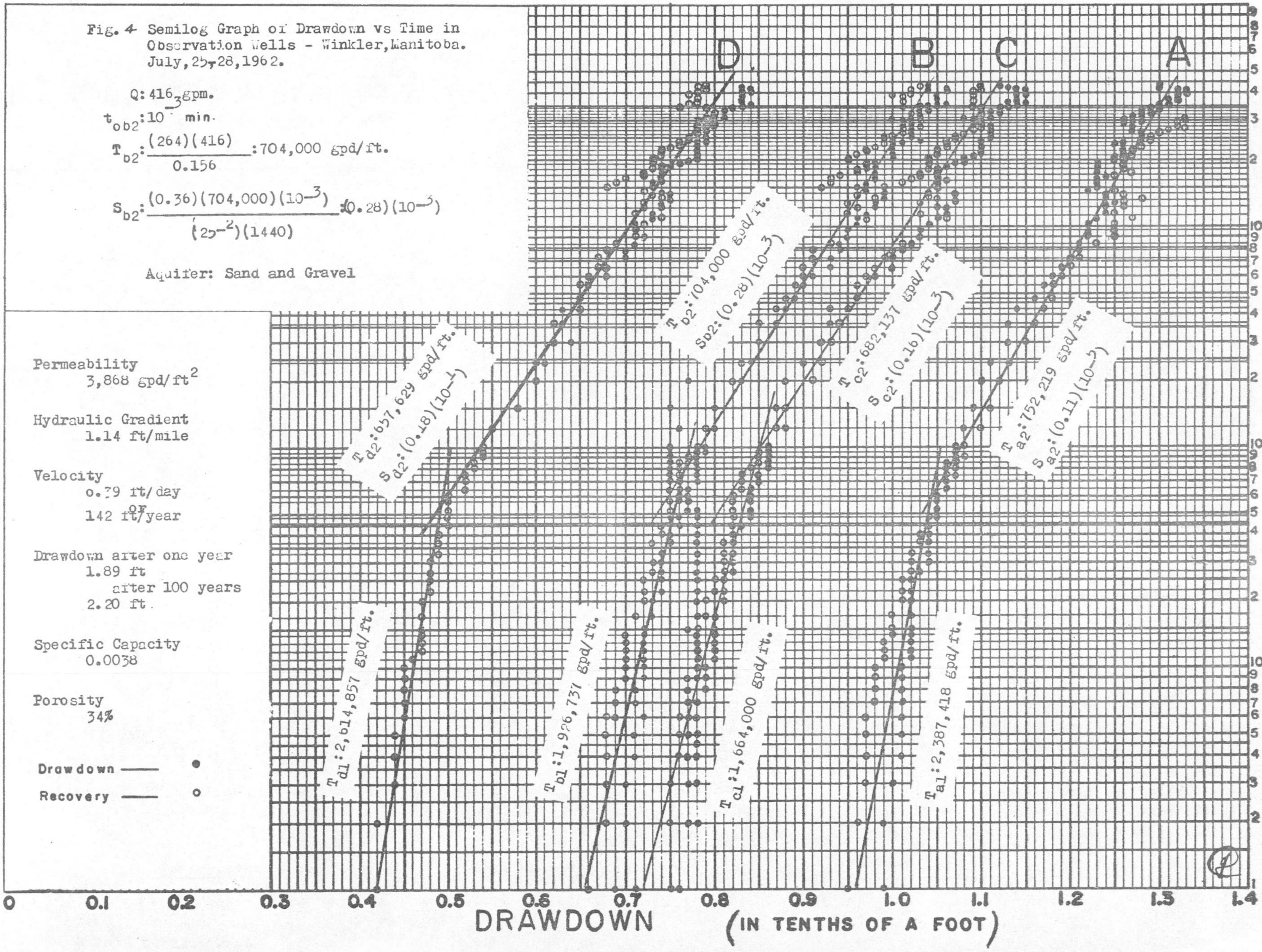


Fig. 4 Semilog Graph of Drawdown vs Time in Observation Wells - Winkler, Manitoba. July, 25-28, 1962.

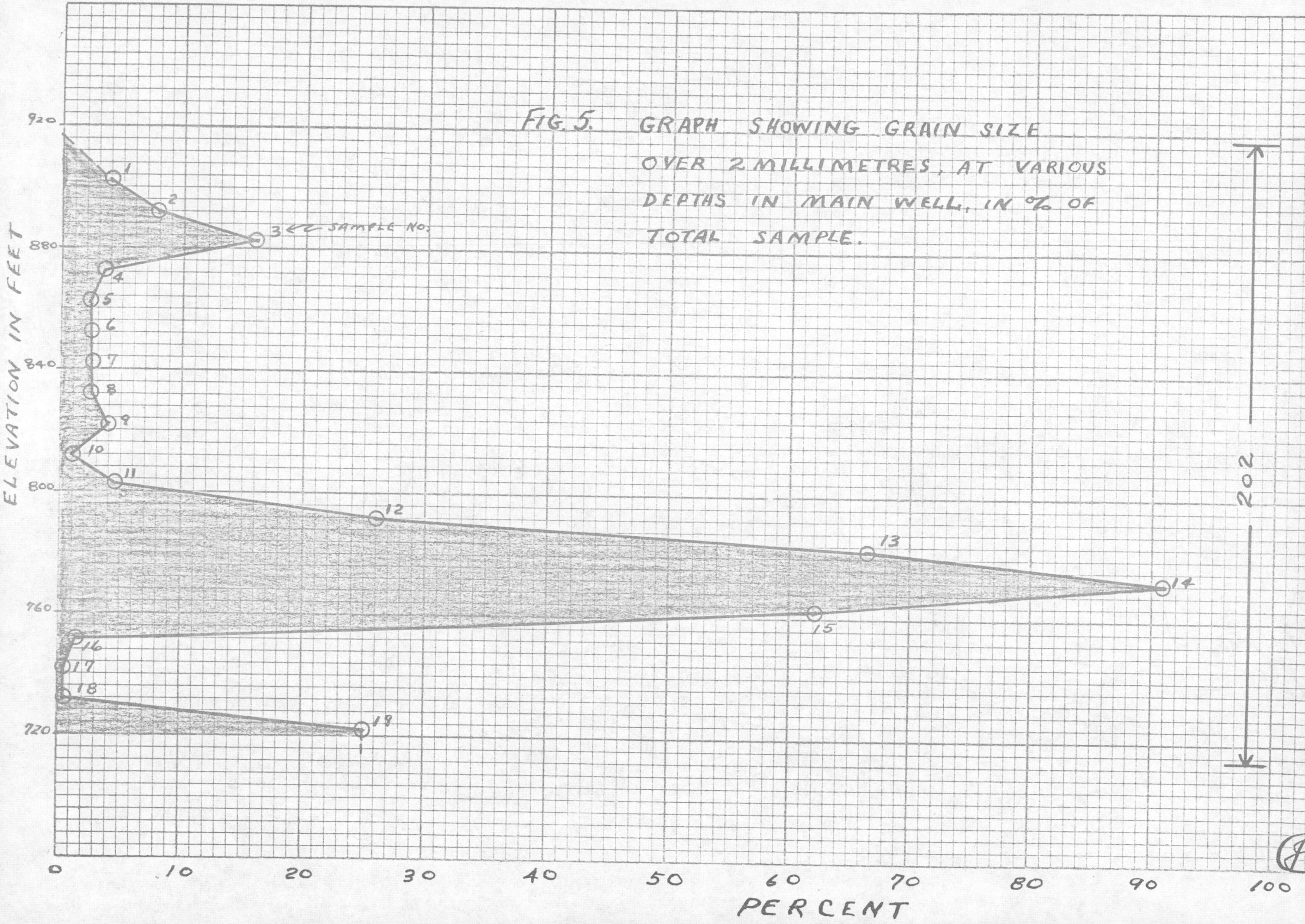
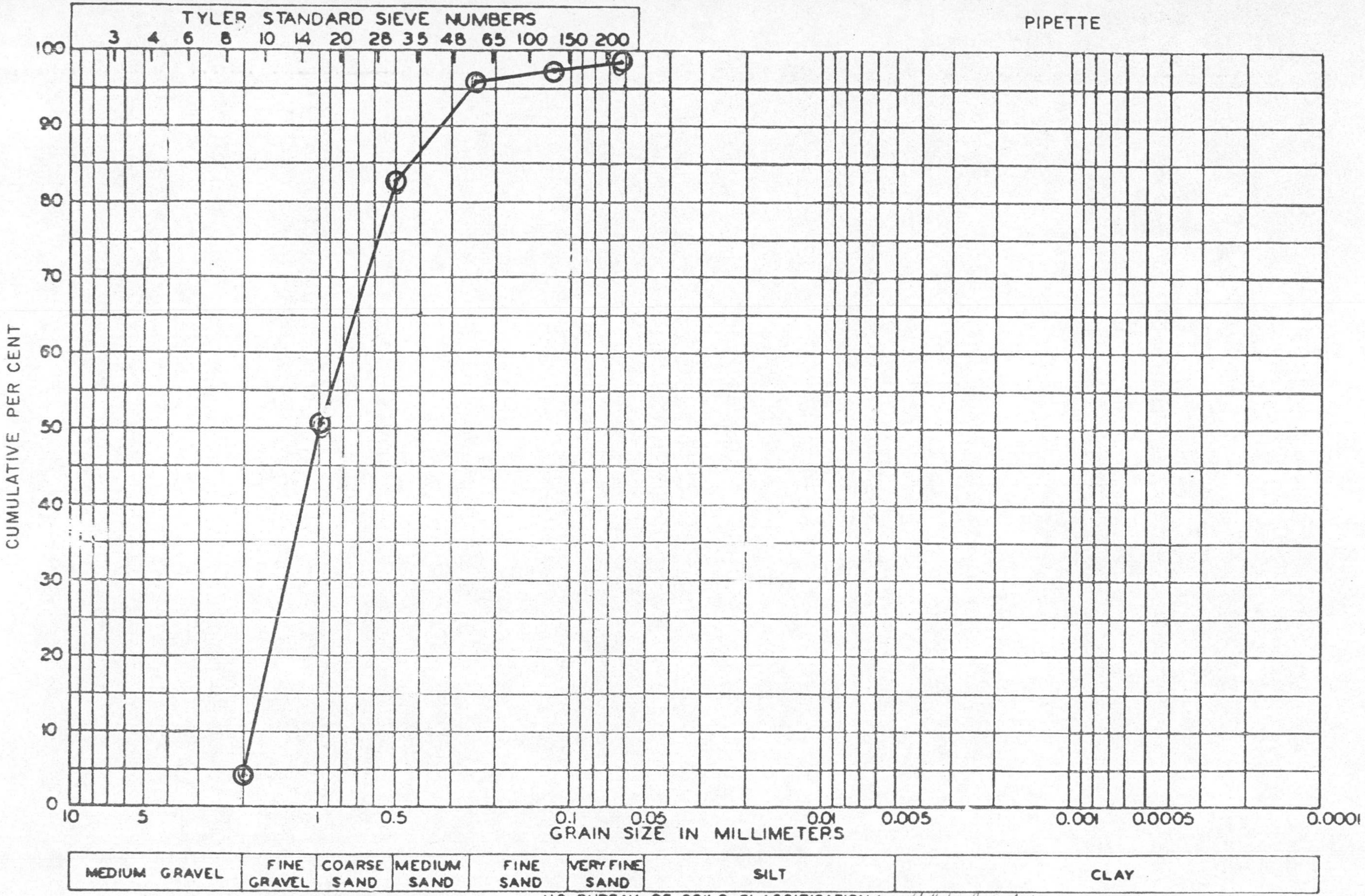


FIG. 5. GRAPH SHOWING GRAIN SIZE OVER 2 MILLIMETRES, AT VARIOUS DEPTHS IN MAIN WELL, IN % OF TOTAL SAMPLE.

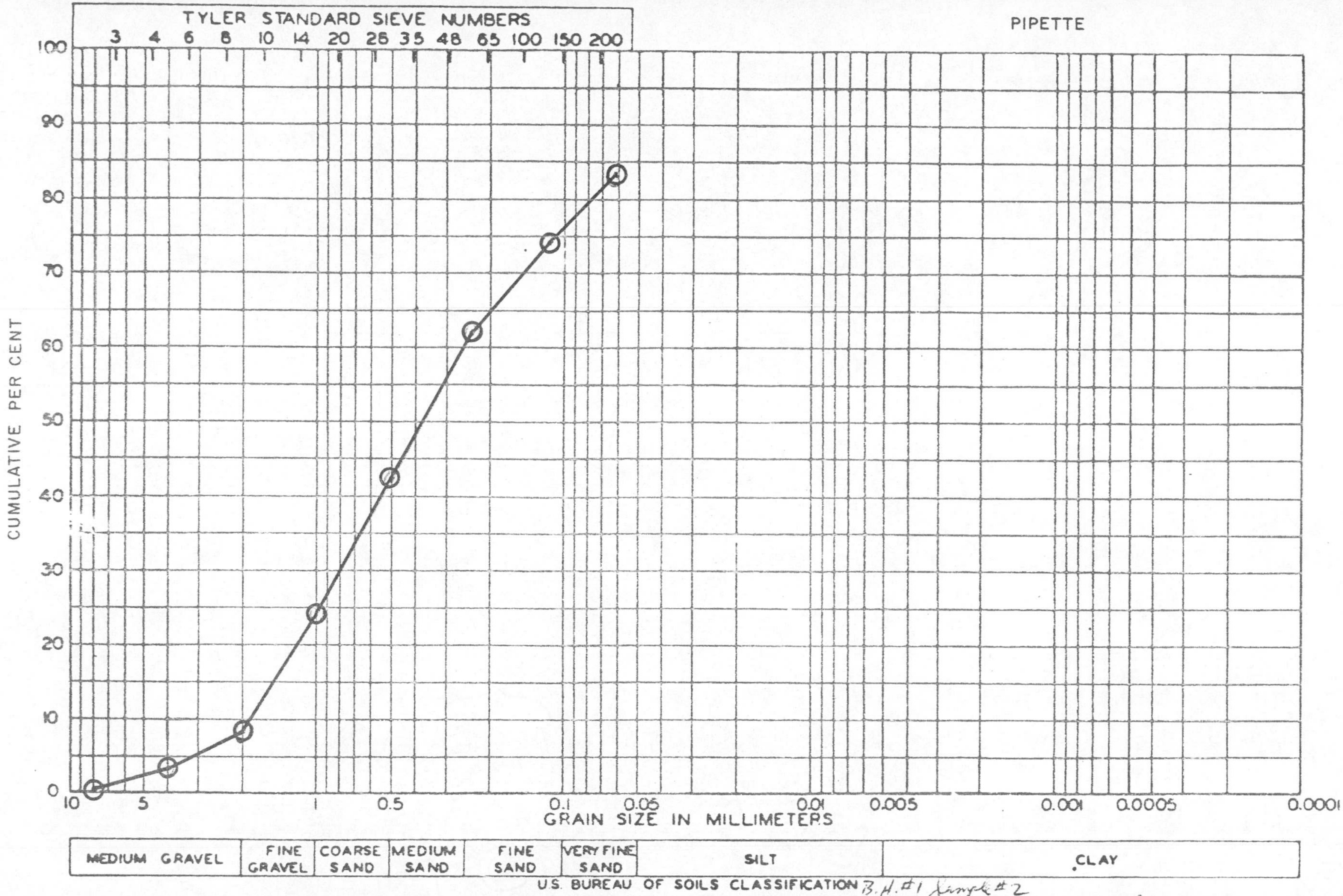


U.S. BUREAU OF SOILS CLASSIFICATION *Bore Hole #1 Sample #3*

PROJECT *WINKLER PUMP TEST* FIELD SAMPLE NO. *59-18-1* SAMPLE NO. *PL-1910*

DEPTH *15'* ELEVATION *902.14* REMARKS *SUB-SIEVE AVER. SIZE = 11.2 MICRONS*

GRAIN SIZE DISTRIBUTION DIAGRAM

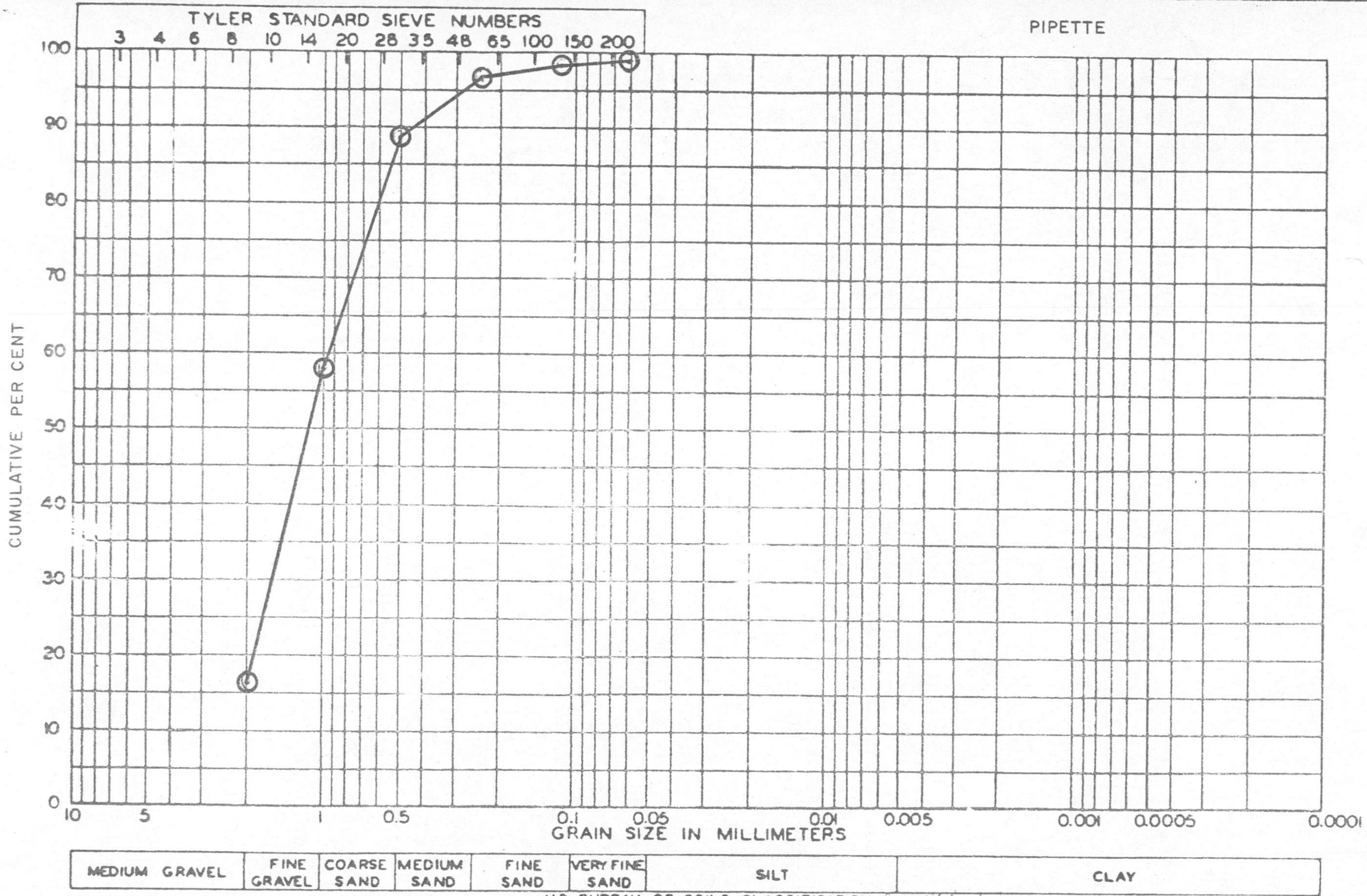


B.H. #1 Sample #2

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-2 SAMPLE NO. PL-1911

DEPTH 25' ELEVATION 892.14 REMARKS SUB-SIEVE AVER. SIZE = 6.35 MICRONS

GRAIN SIZE DISTRIBUTION DIAGRAM

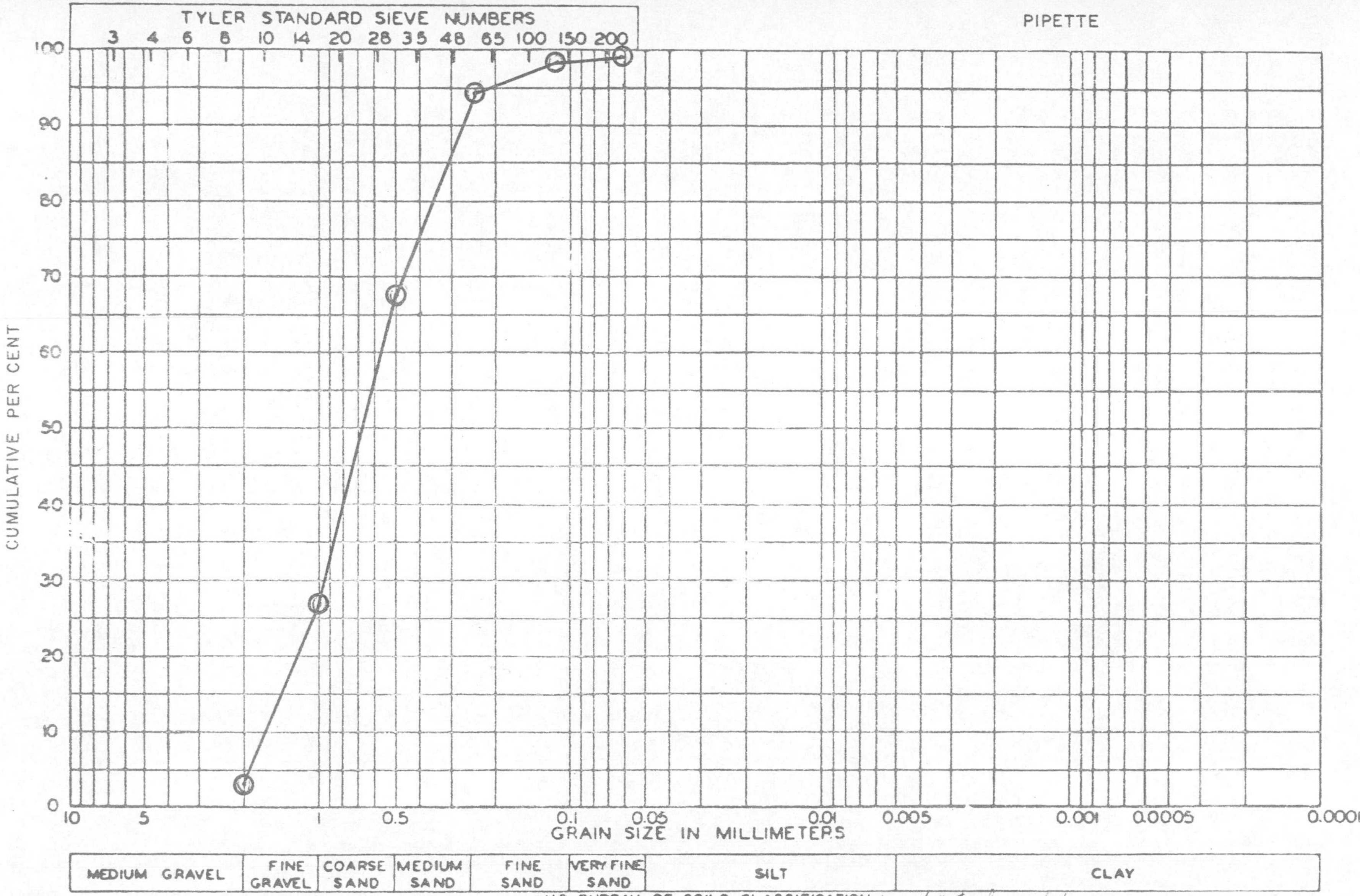


Bore Hole #1 Sample #3

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-3 SAMPLE NO. PL-1912

DEPTH 35' ELEVATION 882.14 REMARKS SUB-SIEVE AVER. SIZE = 9.2 MICRONS

GRAIN SIZE DISTRIBUTION DIAGRAM

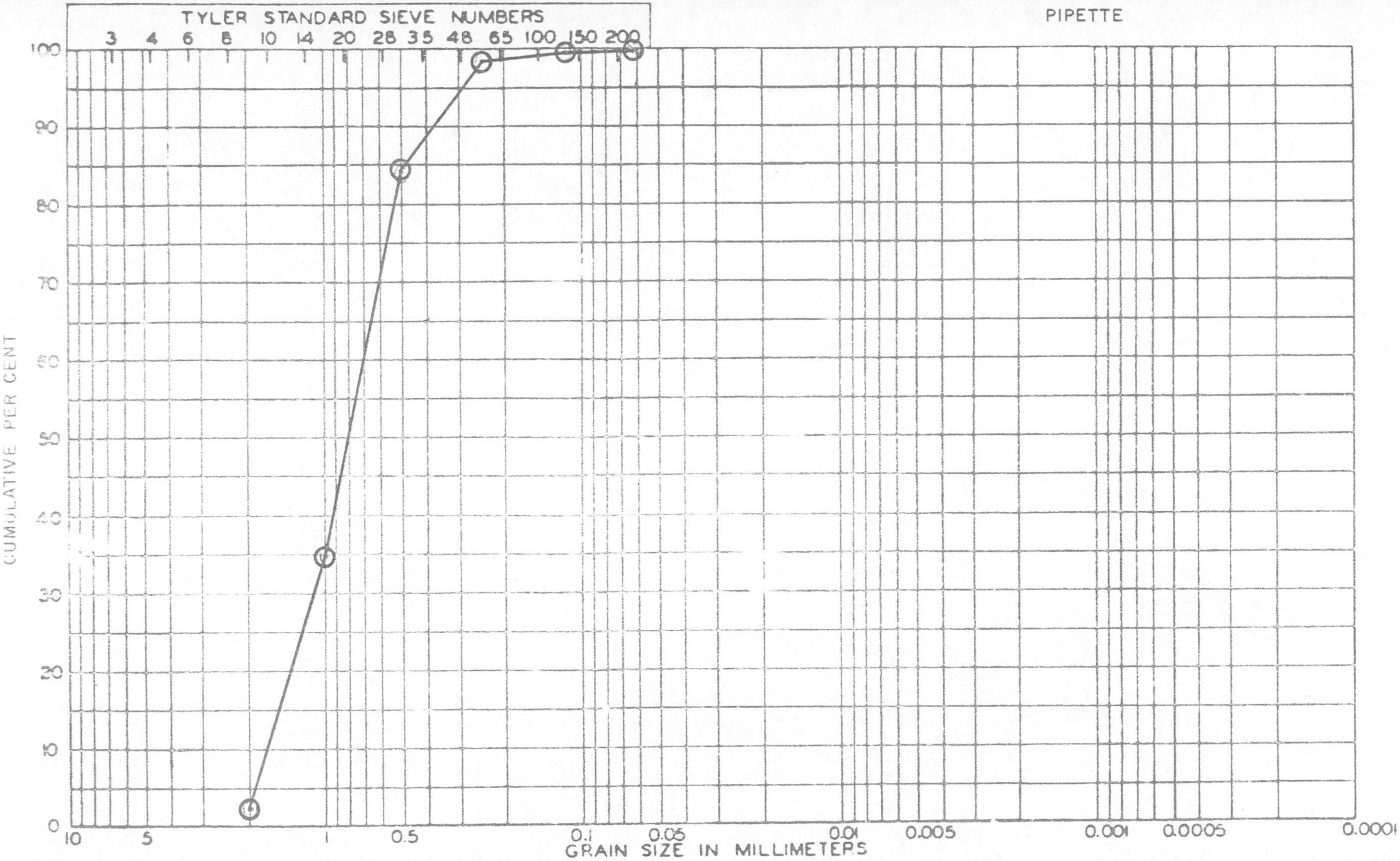


Core Hole #1 Sample #4

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-4 SAMPLE NO. PL-1917

DEPTH 45 ELEVATION 872.14 REMARKS Sub-SIEVE AVER. SIZE = 8.5 MICRONS

GRAIN SIZE DISTRIBUTION DIAGRAM



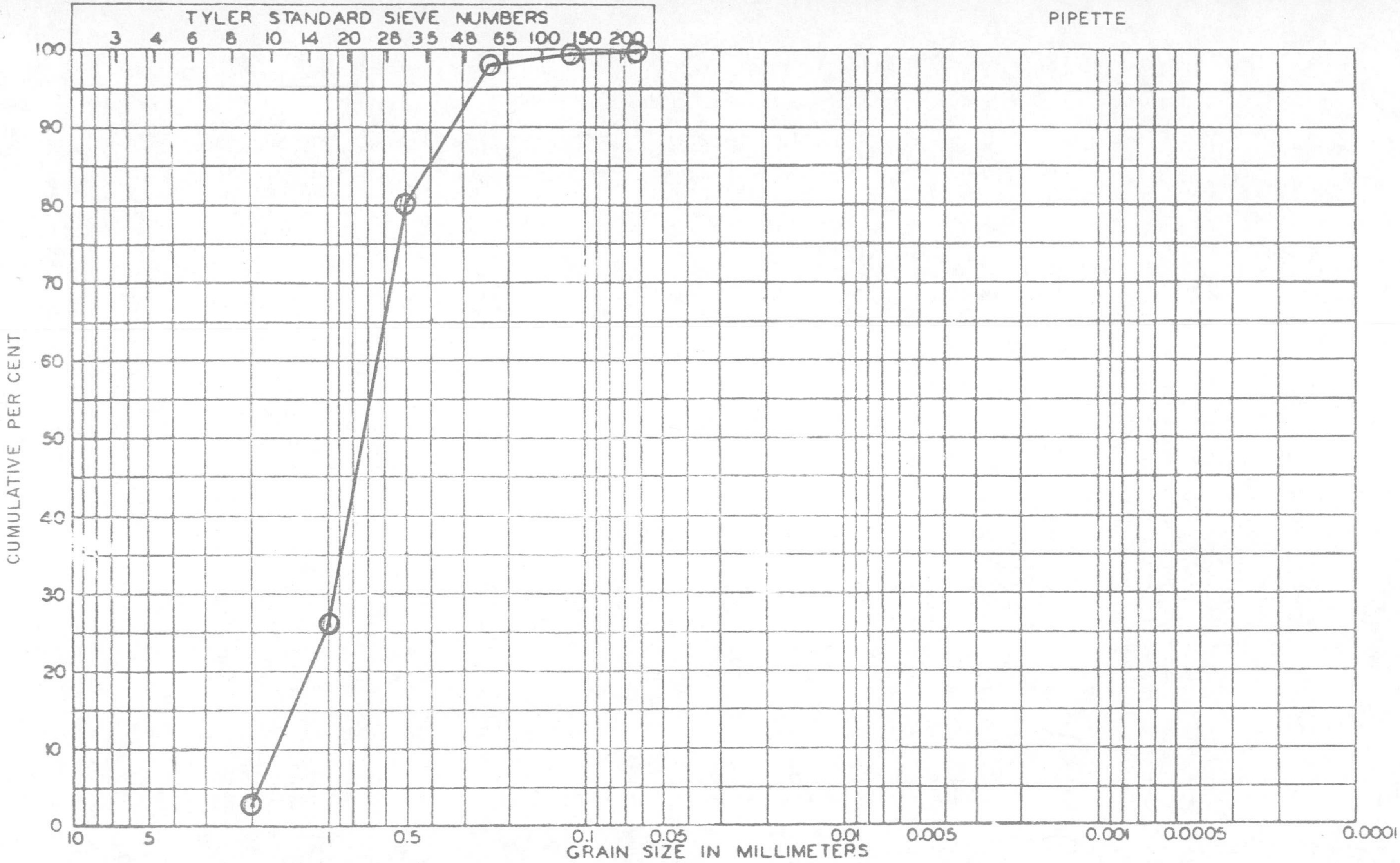
MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

U.S. BUREAU OF SOILS CLASSIFICATION

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-5 SAMPLE NO. PL-1915'

DEPTH 55 ELEVATION 862.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM



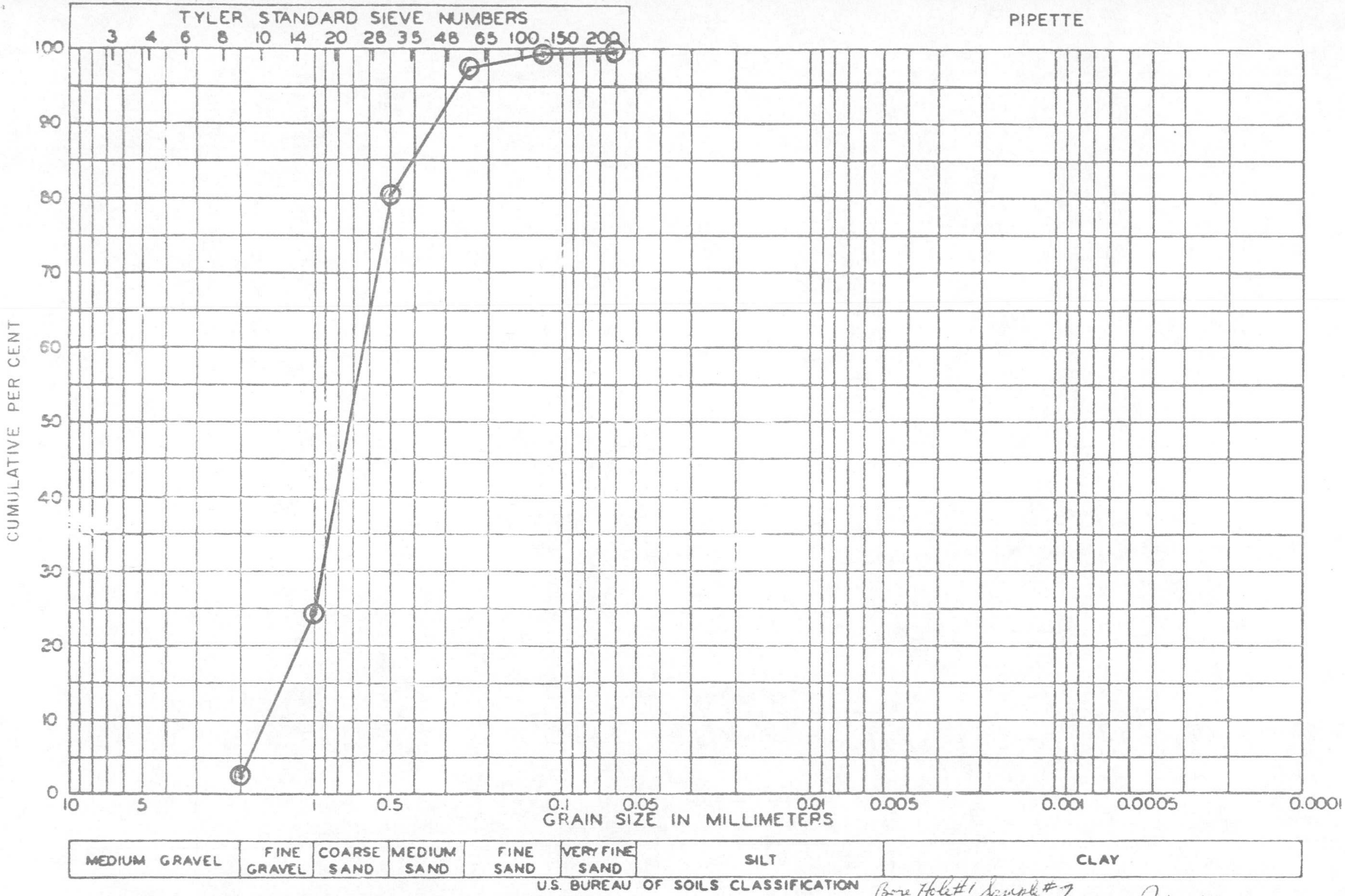
MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

U.S. BUREAU OF SOILS CLASSIFICATION *Bore Hole #1 Sample #6*

PROJECT *WINKLER PUMP TEST* FIELD SAMPLE NO. *59-18-6* SAMPLE NO. *PL-1919*

DEPTH *65'* ELEVATION *852.14* REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

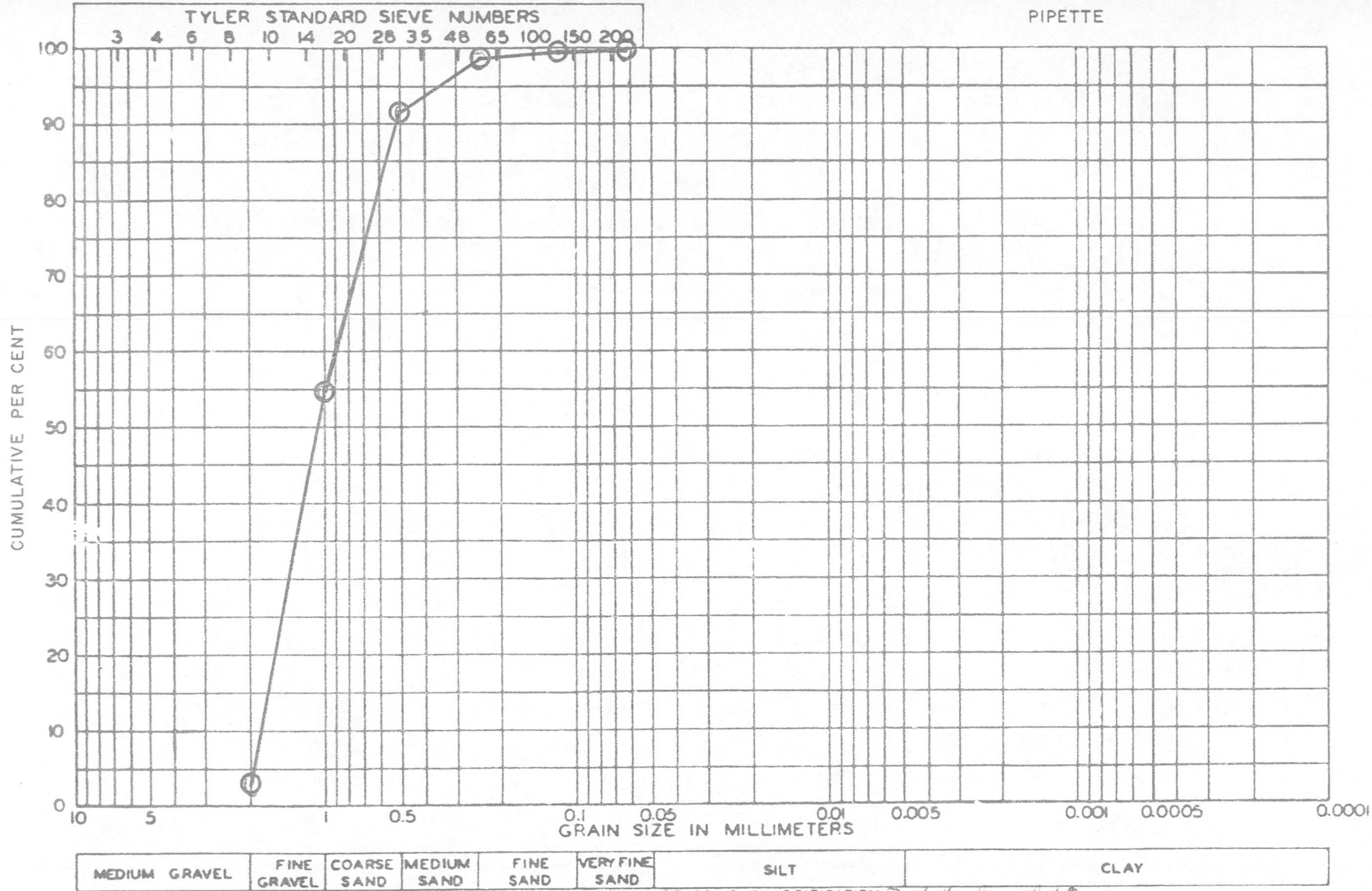


Bore Hole #1 Sample #7

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-7 SAMPLE NO. PL-1913

DEPTH 75' ELEVATION 842.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

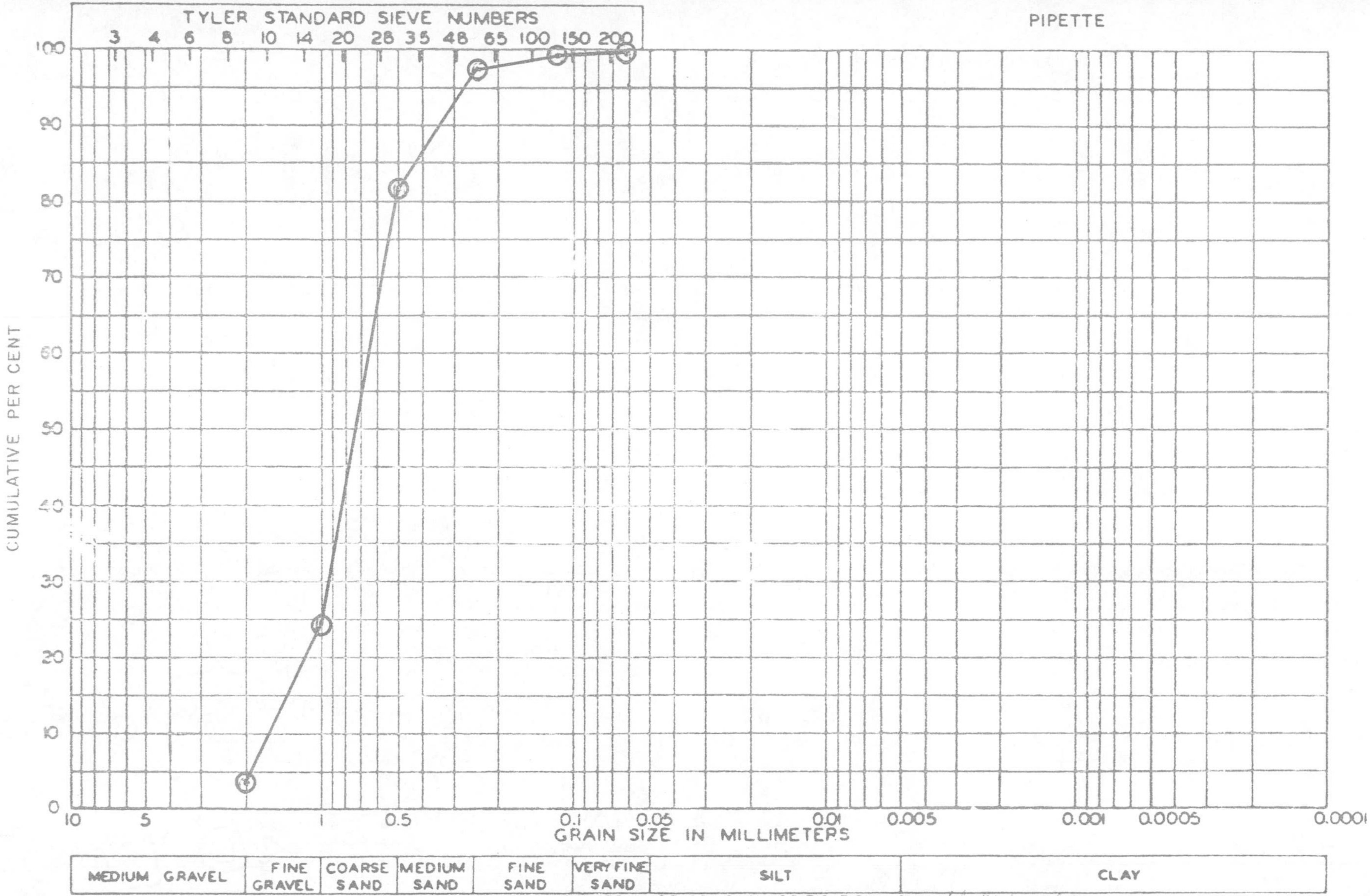


B.H. #1 Sample #8

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-8 SAMPLE NO. PL-1924

DEPTH 85' ELEVATION 832.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

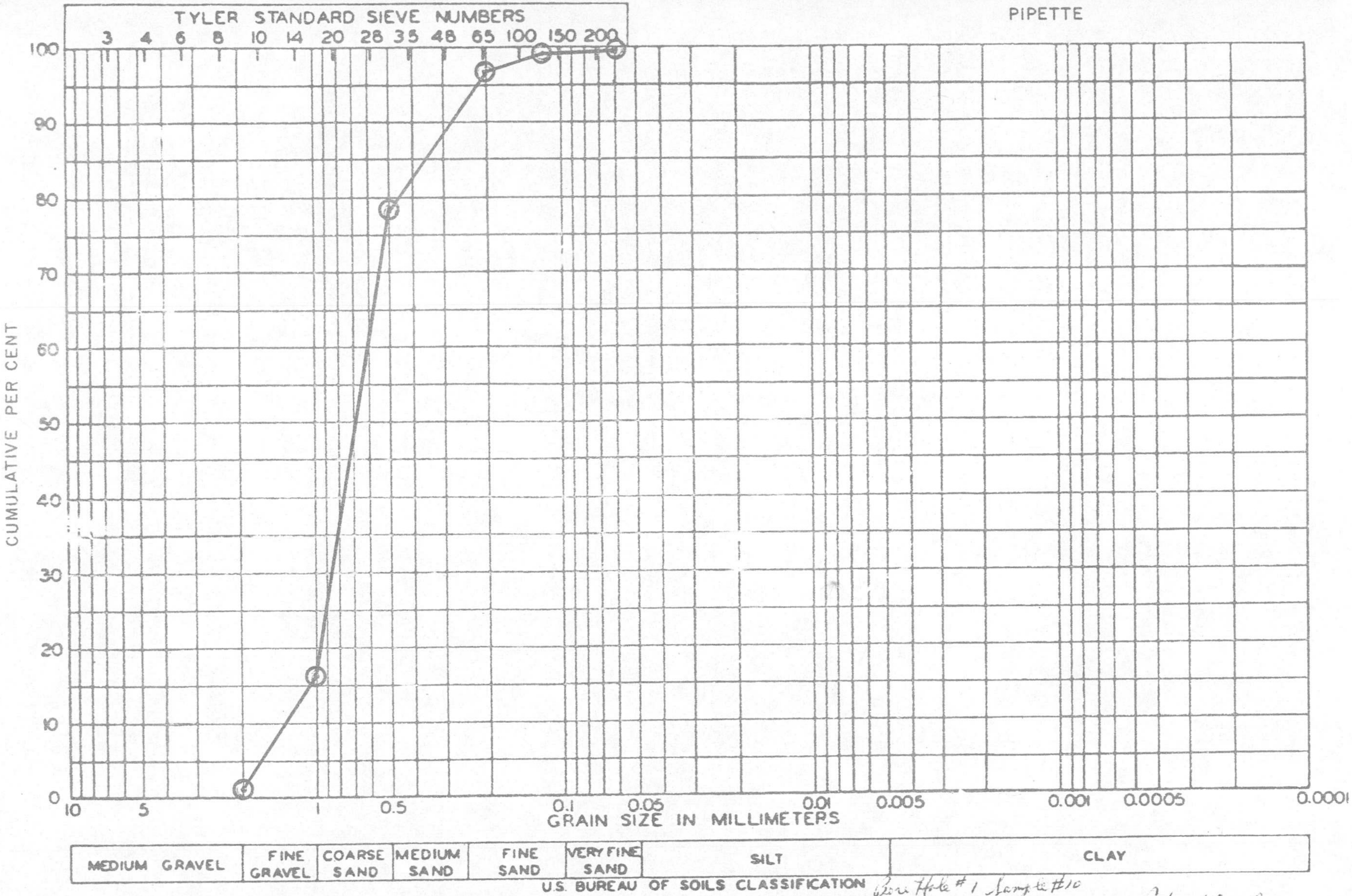


U.S. BUREAU OF SOILS CLASSIFICATION *Bore Hole #1 Sample # 9*

PROJECT *WINKLER PUMP TEST* FIELD SAMPLE NO. *59-18-9* SAMPLE NO. *PL-1914*

DEPTH *95'* ELEVATION *822.14* REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

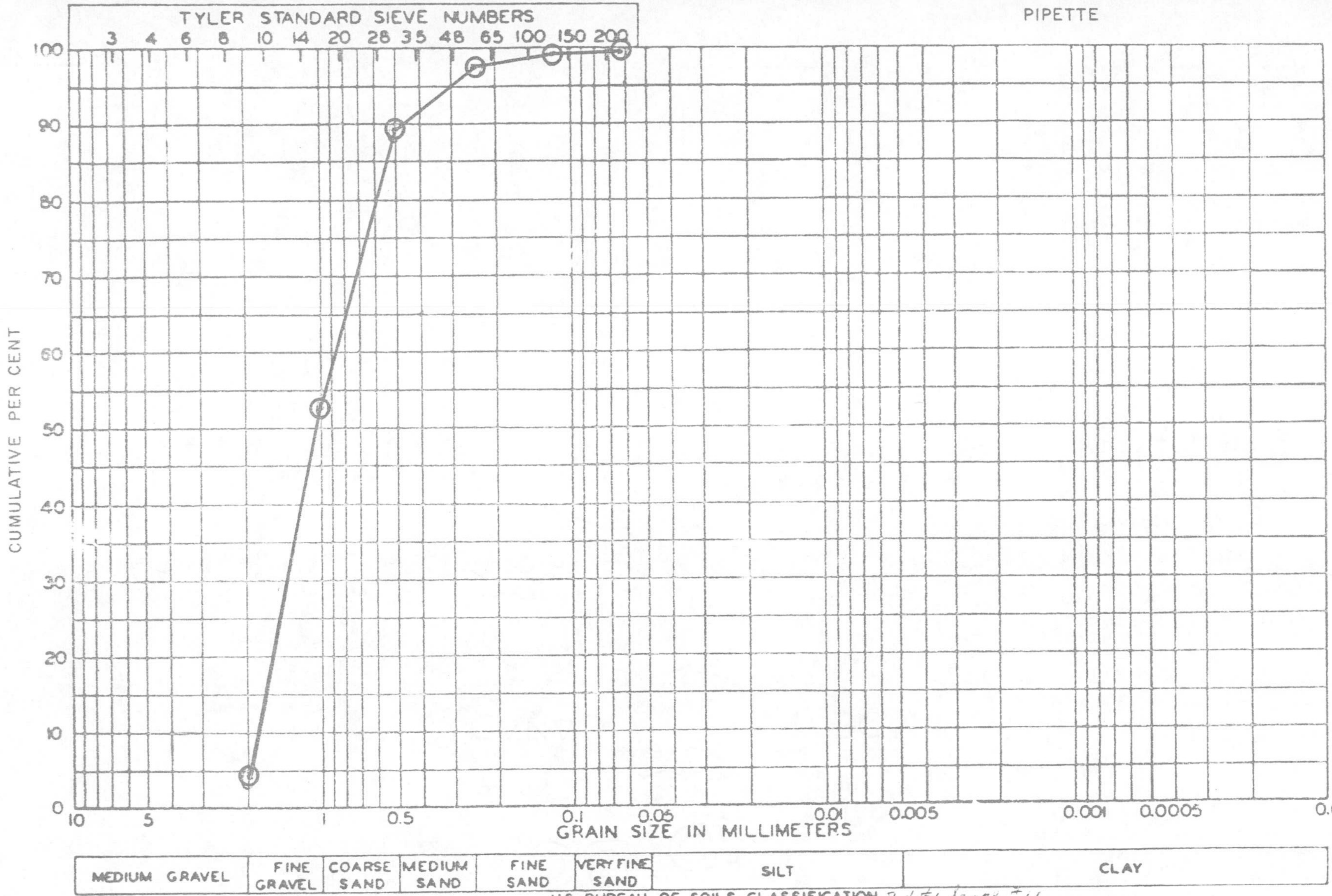


Bore Hole #1 Sample #10

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-10 SAMPLE NO. PL-1909

DEPTH 105' ELEVATION 812.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

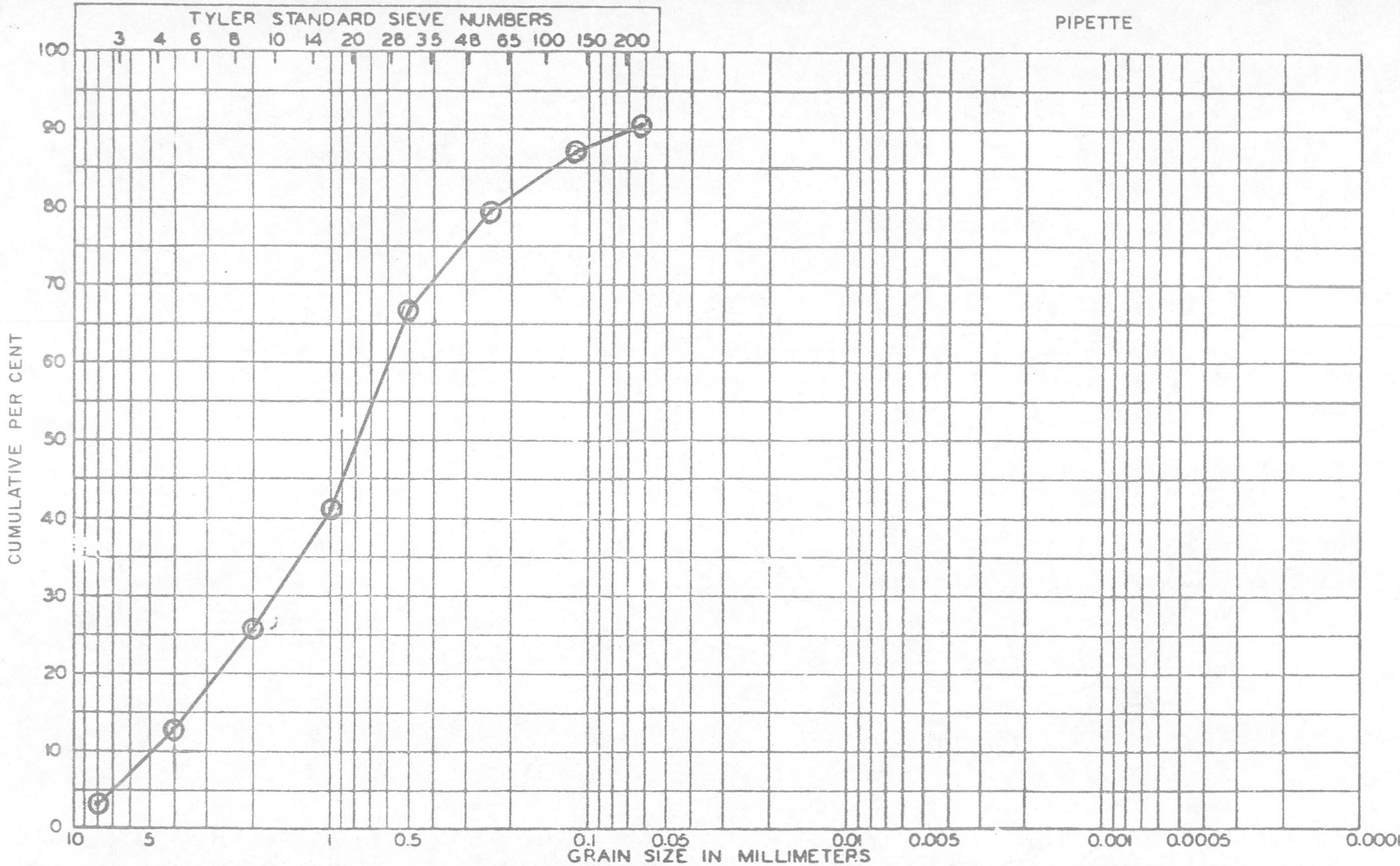


U.S. BUREAU OF SOILS CLASSIFICATION B.H. #1 Sample #11

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-11 SAMPLE NO. PL-1918

DEPTH 115' ELEVATION 802.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM



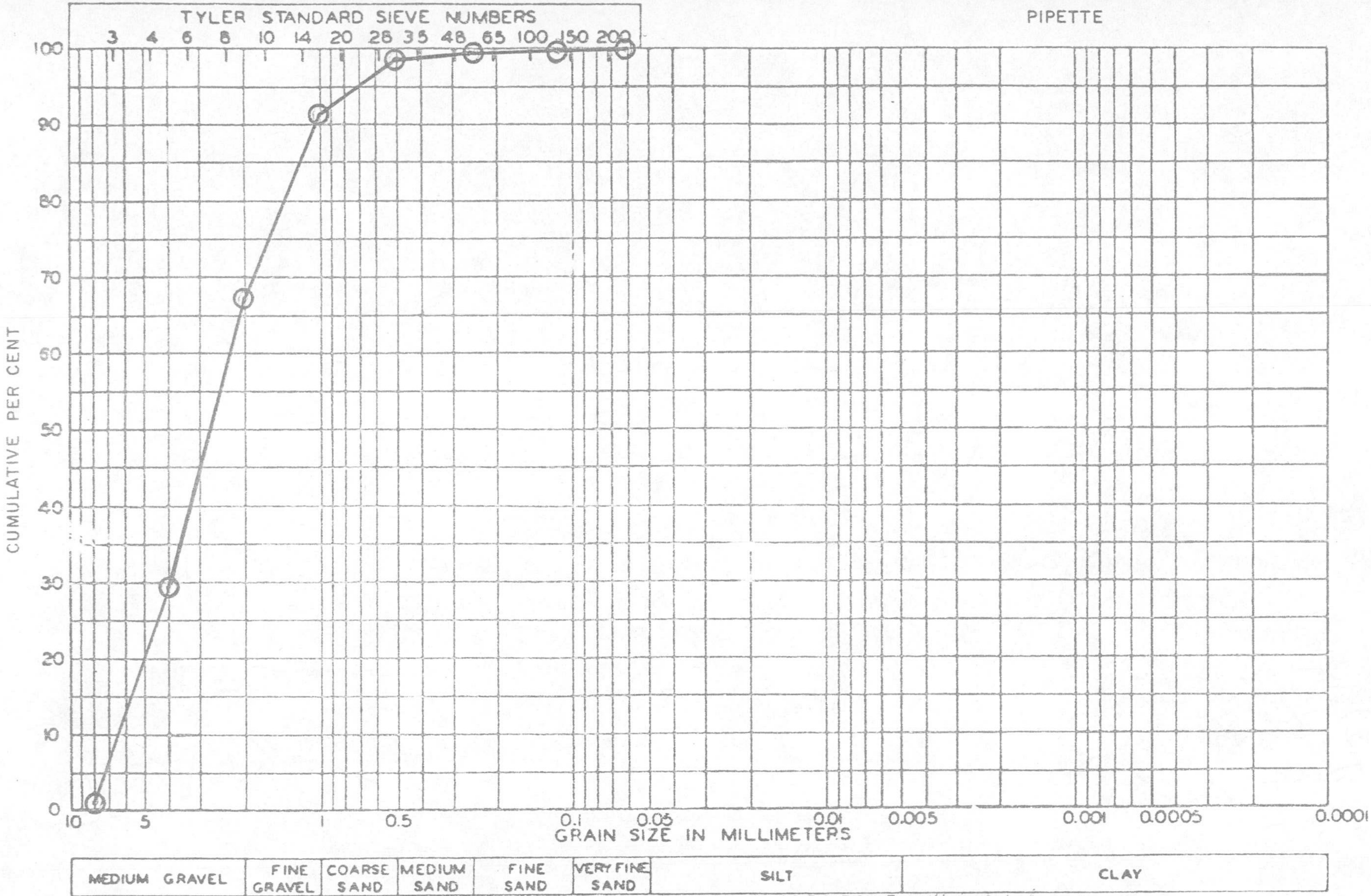
MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

U.S. BUREAU OF SOILS CLASSIFICATION B.H.#1 Sample #12

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-1812 SAMPLE NO. PL-1922

DEPTH 125' ELEVATION 792.14 REMARKS SUB-SIEVE AVER. SIZE = 6.7 MICRONS

GRAIN SIZE DISTRIBUTION DIAGRAM

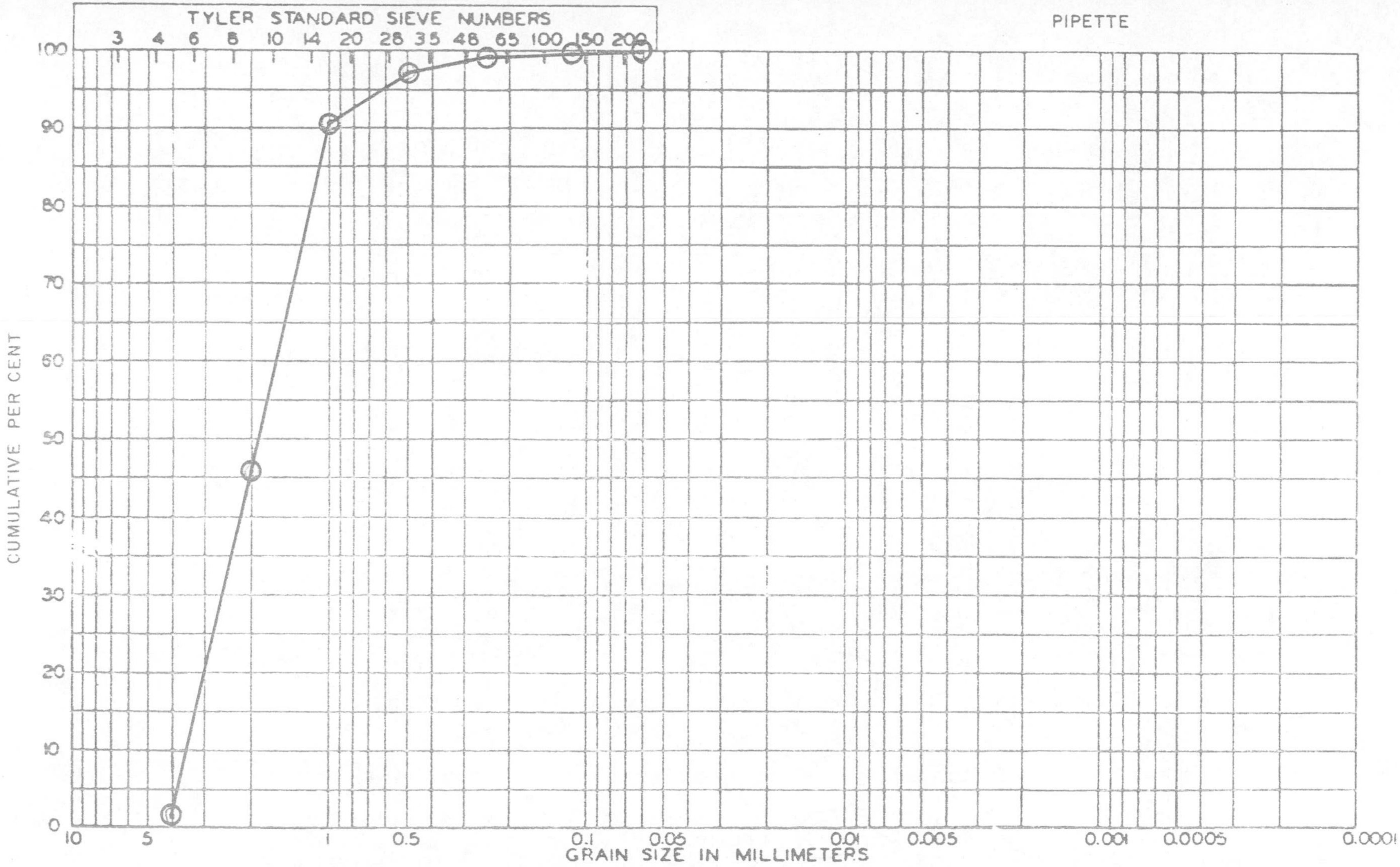


U.S. BUREAU OF SOILS CLASSIFICATION Bore Hole #1 Sample #13

PROJECT W INKLER PUMP TEST FIELD SAMPLE NO. 59-1813 SAMPLE NO. PL-1921

DEPTH 135' ELEVATION 782.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

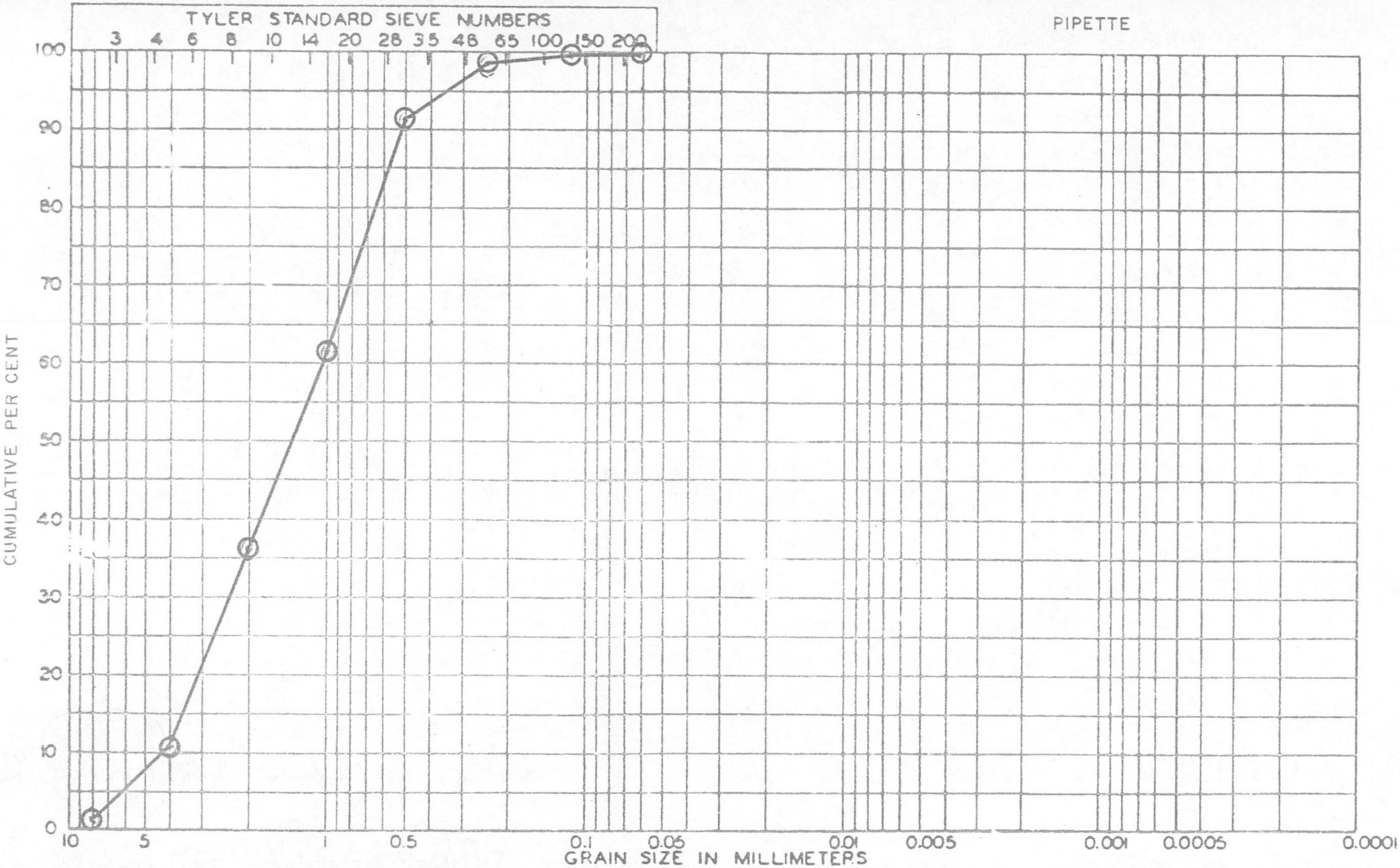


U.S. BUREAU OF SOILS CLASSIFICATION B.H.#1 Sample #14

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-1814 SAMPLE NO. PL-1923

DEPTH 145' ELEVATION 772.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM



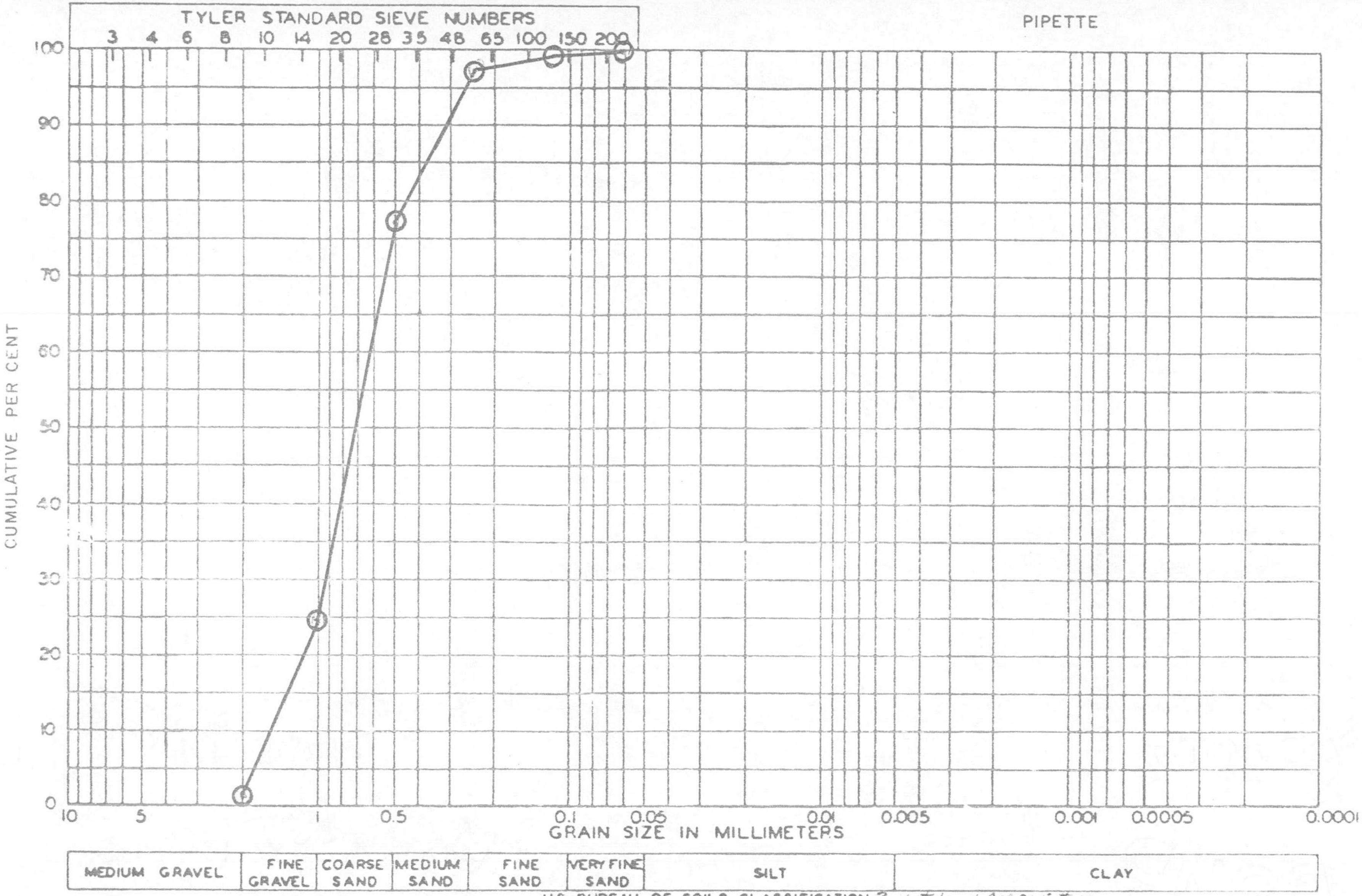
MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

U.S. BUREAU OF SOILS CLASSIFICATION Bore Hole #1 Sample #15

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-15 SAMPLE NO. PL-1920

DEPTH 155' ELEVATION 762.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

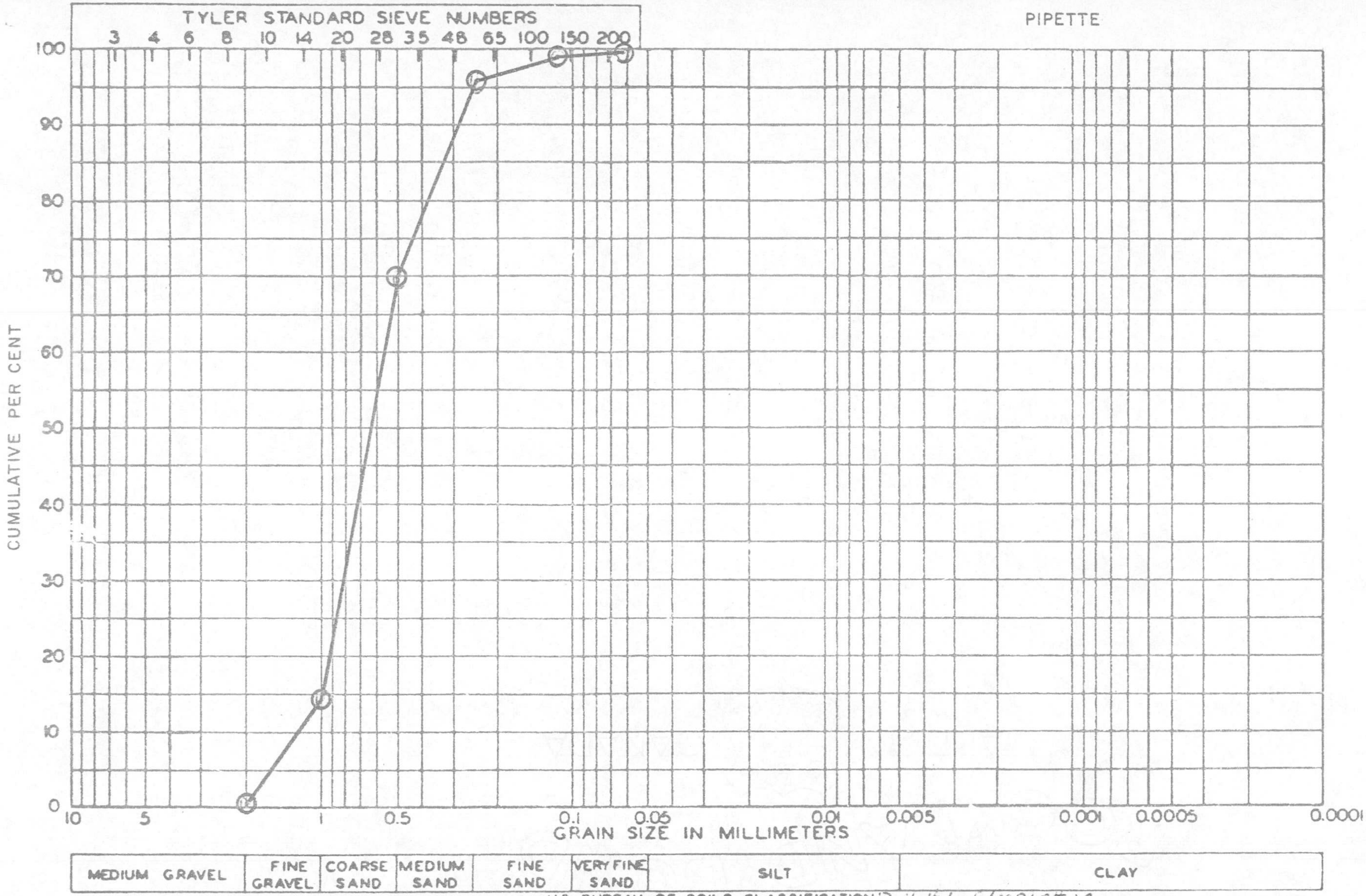


U.S. BUREAU OF SOILS CLASSIFICATION B.H. #1 SAMPLE #16

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-16 SAMPLE NO. PL-1927

DEPTH 165' ELEVATION 752.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

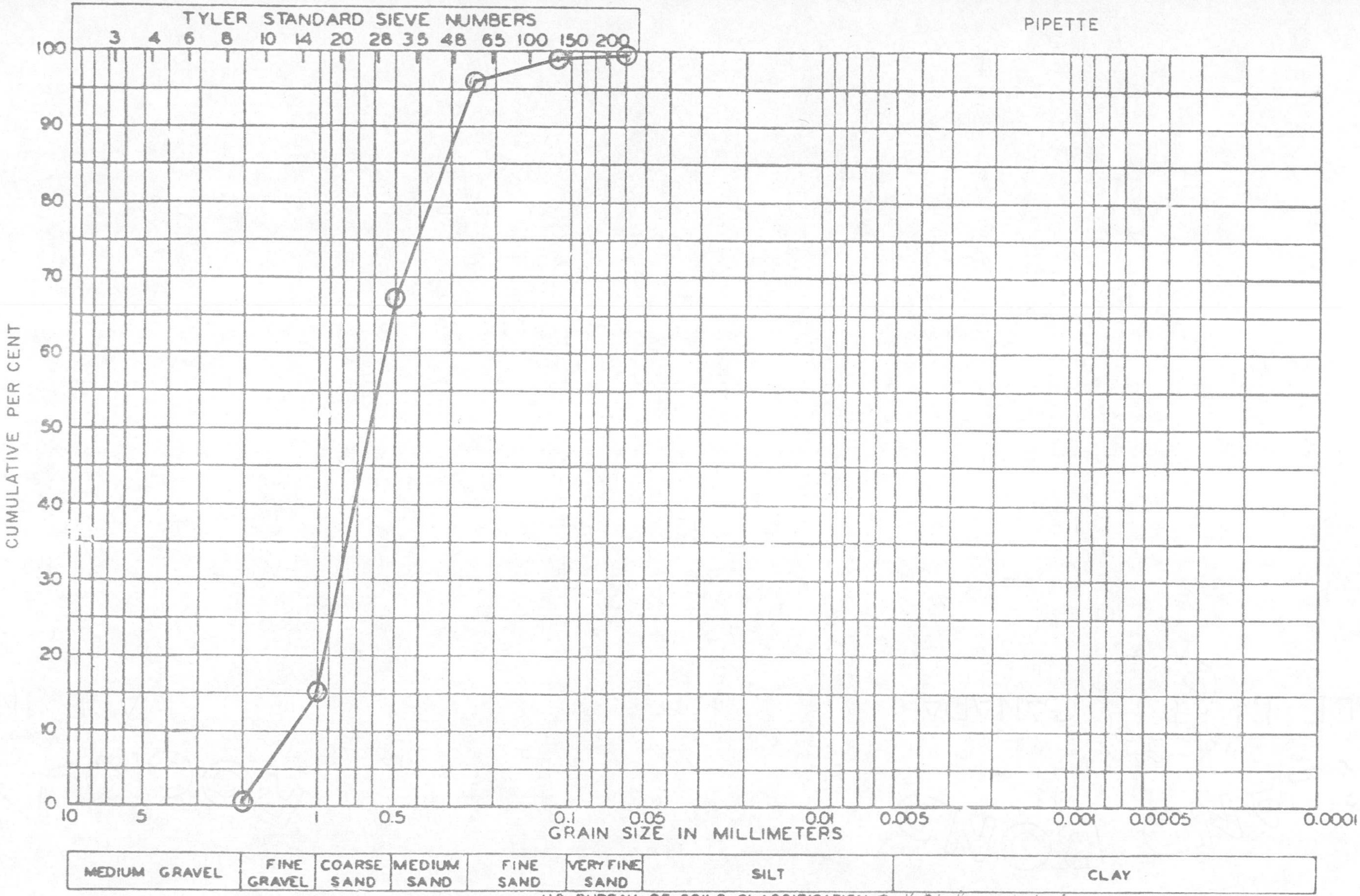


B.H. #1 SAMPLE #17

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-17 SAMPLE NO. PL-1925

DEPTH 175' ELEVATION 742.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM

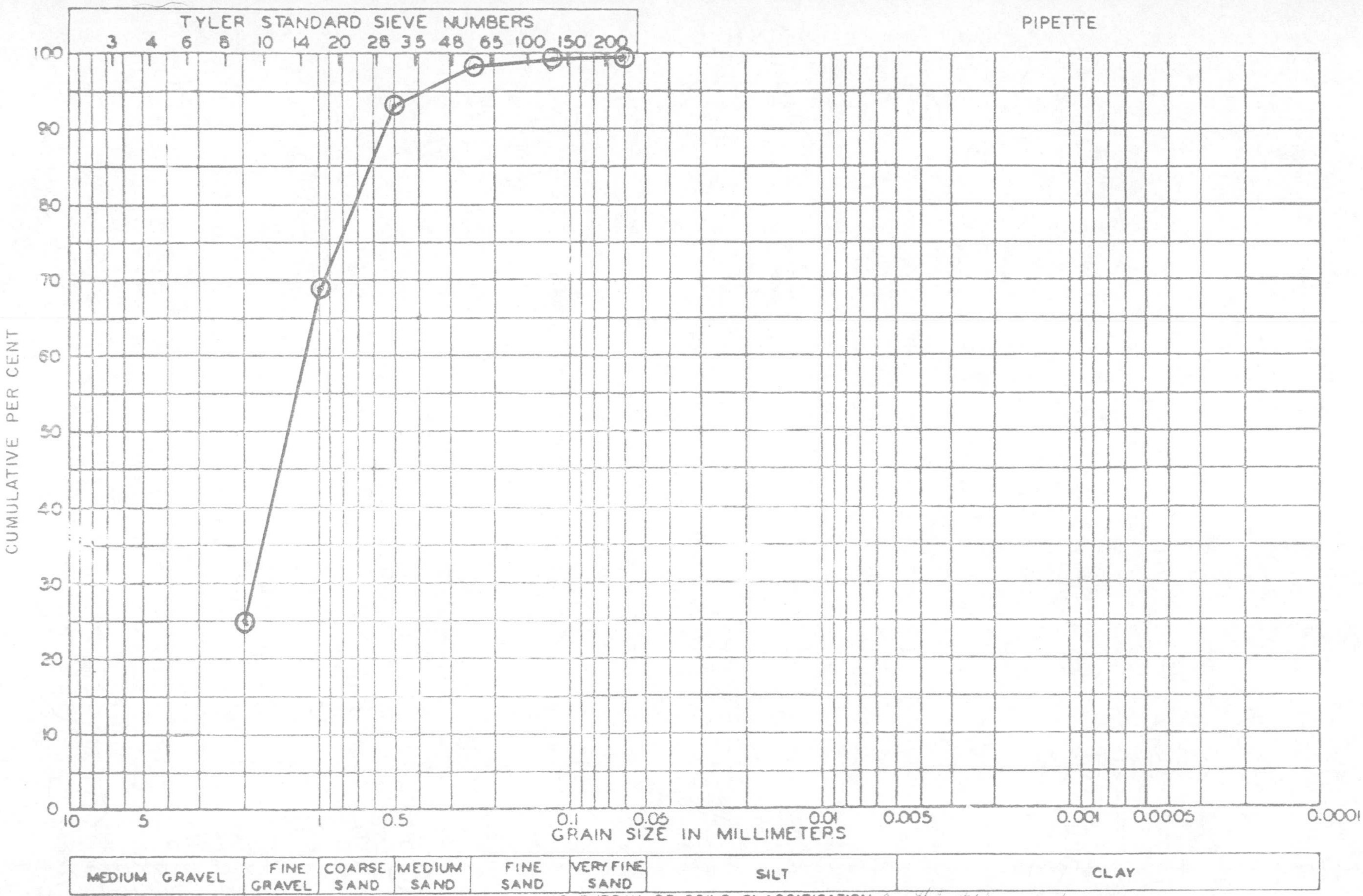


U.S. BUREAU OF SOILS CLASSIFICATION B H. #1 Sample #18

PROJECT WINKLER PUMP TEST FIELD SAMPLE NO. 59-18-18 SAMPLE NO. PL-1926

DEPTH 185' ELEVATION 732.14 REMARKS

GRAIN SIZE DISTRIBUTION DIAGRAM



Bore Hole #1 Sample #19

PROJECT *WINKLER PUMP TEST* FIELD SAMPLE NO. *5 9-18-1* SAMPLE NO. *PL-1916*

DEPTH *195'* ELEVATION *722.14* REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

Part II

RESISTIVITY RECONNAISSANCE SURVEY AT WINKLER, MANITOBA

J.E. Wyder

Introduction

On November 20, 1961, Mr. J.E. Charron of the Groundwater Section sent a memo outlining in detail 11 sites in southern Manitoba where he thought surface resistivity surveys might outline subsurface aquifers, to Mr. G.D. Hobson of the Seismic and Resistivity Section. Mr. Hobson brought the memo to my attention and together we concluded that the proposed sites seemed to be in areas where surface resistivity methods could be successfully applied. Further studies of the suggested sites brought out the fact that possibly 3 of the suggested areas were connected by one aquifer.

Field work has proven that two of the three sites are probably located on one aquifer, while the third site constitutes a small but separate aquifer. The body of this report is concerned with the larger of the two aquifers which is approximately 14 miles long by 1/8 mile to 2 miles wide. The aquifer strikes NW-SE through the town of Winkler, Manitoba (see fig. 1).

Principles and methods of electrical surface resistivity surveys

The resistivity of a substance is defined as its resistance to an electric current flowing between opposite faces of a unit cube of the material. Resistivity values are commonly expressed in the units of ohm-centimeters or ohm-meters and less commonly in ohm-feet

The success of resistivity surveys depends upon the presence of a difference in resistivities between any two adjacent layers of rocks (including sediments). Generally, the less the resistivity contrast between rock types the less definitive the resistivity surveys.

Surface resistivity techniques are based upon the measurement of potential (voltage) fields associated with a flow of current in the earth. For ease of interpretation and for convenience, a known current is caused to flow into the ground. Thus two quantities are known - the magnitude of the current introduced into the ground and the value of the associated potential field, on the ground surface, at certain known points relative to the current electrodes.

The electric current is generally introduced into the ground through metal stakes called current electrodes. The potential measurements are generally made between two porous pots containing a metallic salt in solution. These are called potential electrodes or simply "pots".

If values of current and voltage are known, it is theoretically possible to calculate the resistivity of the underlying material by using the formula:

$$\rho = C \frac{V}{I}$$

where

ρ = resistivity of the material

V = potential measured

I = current flowing in the material

C = (constant of proportionality (dependent upon relative (distances between current and (potential electrodes

If, however, the current is caused to flow in two or more rock types then a quantity called "apparent resistivity" is obtained by substituting current and potential values into the above formula. The apparent resistivity of two materials will vary between the true values of resistivity for each rock type.

In order to simplify the theoretical interpretation of resistivity fields results, the geophysicist arranges the four electrodes in one of many possible geometrical electrode arrangements. The word "configuration" is often used in place of electrode arrangement.

Two general methods of conducting resistivity surveys are employed. In "constant depth profiling", the distances between adjacent electrodes in the configuration are kept constant. The configuration as a whole is then moved along the surface of the ground. "Constant depth profiling" is often used to locate horizontal changes in the resistivity of the ground. A second method of resistivity surveying utilizes the fact that as the relative distance between the current electrodes is increased an increasing amount of current will normally flow deeper beneath the ground surface. Thus, theoretically, by progressively increasing the distance between current electrodes, it is possible to determine the variation of resistivity with depth. This method of resistivity surveying is often referred to as "vertical depth profiling" or "electric drilling".

The Wenner electrode arrangement was used for both constant depth profiles and vertical depth profiles. A Wenner configuration consists of placing the four electrodes in a straight line with the distances between any two adjacent electrodes being equal. The distance between any two adjacent electrodes is referred to as the "a-span" of the Wenner configuration.

Constant depth profiles (with a = 100') with station centres 300 feet apart were used to delineate the boundaries of the aquifer. After the aquifer had been located, vertical depth profiles (a = 3' to 1000') were completed at selected points both within and outside the suspected aquifer boundaries.

Equipment

Resistivity equipment operates on either direct current (DC) or alternating current (AC) principles. Although AC equipment is less subject to electric noise problems, DC equipment is capable of deeper penetration, for a given power, than AC equipment. Both types of equipment have approximately the same initial cost ($600 to $1500) and both types are commercially available. Most, if not all commercial equipment, is portable.

The equipment used by the Geophysics Division was conceived, developed and constructed by members of the staff of the Saskatchewan Research Council. The equipment, which operates on DC principles, and is not commercially available, consists of an instrument console and two dual power-operated reels, all of which are mounted in a modified one-ton truck.

Interpretation and discussion of results

Equi-resistivity contours, obtained by plotting constant depth probe profiles, outlined a zone of high resistivity gravel, sand, and silt in an environment of low resistivity clay. A one week drilling program, near the end of the field season, substantiated the resistivity survey results.

Constant depth probe profiles oriented in an east-west direction, were completed at one mile intervals along the main axis of the aquifer. This control is probably not sufficient for the purposes of drilling water wells. If a land owner wishes to drill a well he should, possibly using figure 1 as a guide, complete a detailed resistivity survey of his land in order to locate the areas where he is most likely to find gravel and sand and any associated water. The constant depth probe profiles in this survey would be sensitive to resistivity changes to a depth of from 50 to 75 feet. Hence if deeper aquifers exist, they would not have been detected.

It should be realized that the resistivity boundaries displayed in figure 1 are, in general, not sharp. The boundaries actually represent transition zones which may be several tens of feet wide. A preliminary qualitative interpretation of figure 1 follows:

1. Material with resistivity values between 30 ohm-feet and 60 ohm-feet
   - possibly areas of silty clay and sandy silt, capable of low yields of water
2. Material with resistivity values between 60 ohm-feet and 200 ohm-feet
   - possibly areas of sandy silt to sand to gravelly sand, capable of moderate yields of water
3. Material with resistivity values greater than 200 ohm-feet
   - these are possibly areas of gravel capable of yielding large volumes of water at high pumping rates

The over-all picture of high resistivity values at the northern end of the anomaly, grading into much lower resistivity values at its southern extremity, suggests two important features about the aquifer:

(1) The aquifer material probably grades from coarse boulder gravel in the north to fine silty clay in the south. The grain size of the aquifer material will probably dictate the rate at which water can be pumped - the smaller the individual particles the lower the pumping rate.

(2) The aquifer reaches the surface at its northern end but is probably at least 50 feet below surface at its southern extremity.

Analyses of vertical depth profiles suggest that there may be as much as 280 feet of water-bearing gravel in section 1, tp. 4, rge. 5 WPM and as little as 5 feet of water-bearing silty clay in section 14, tp. 2, rge. 4 WPM.

The previous discussion has been based on the assumption that the anomalous area is one continuous aquifer. This is not necessarily true and only further drilling and resistivity surveys will prove or disprove the assumption.

There is no reason to believe that if the aquifer is continuous, all the water in it is potable. The small anomaly at the southern end may be caused by saline water in a gravel and/or sand layer more than 50 feet below surface.

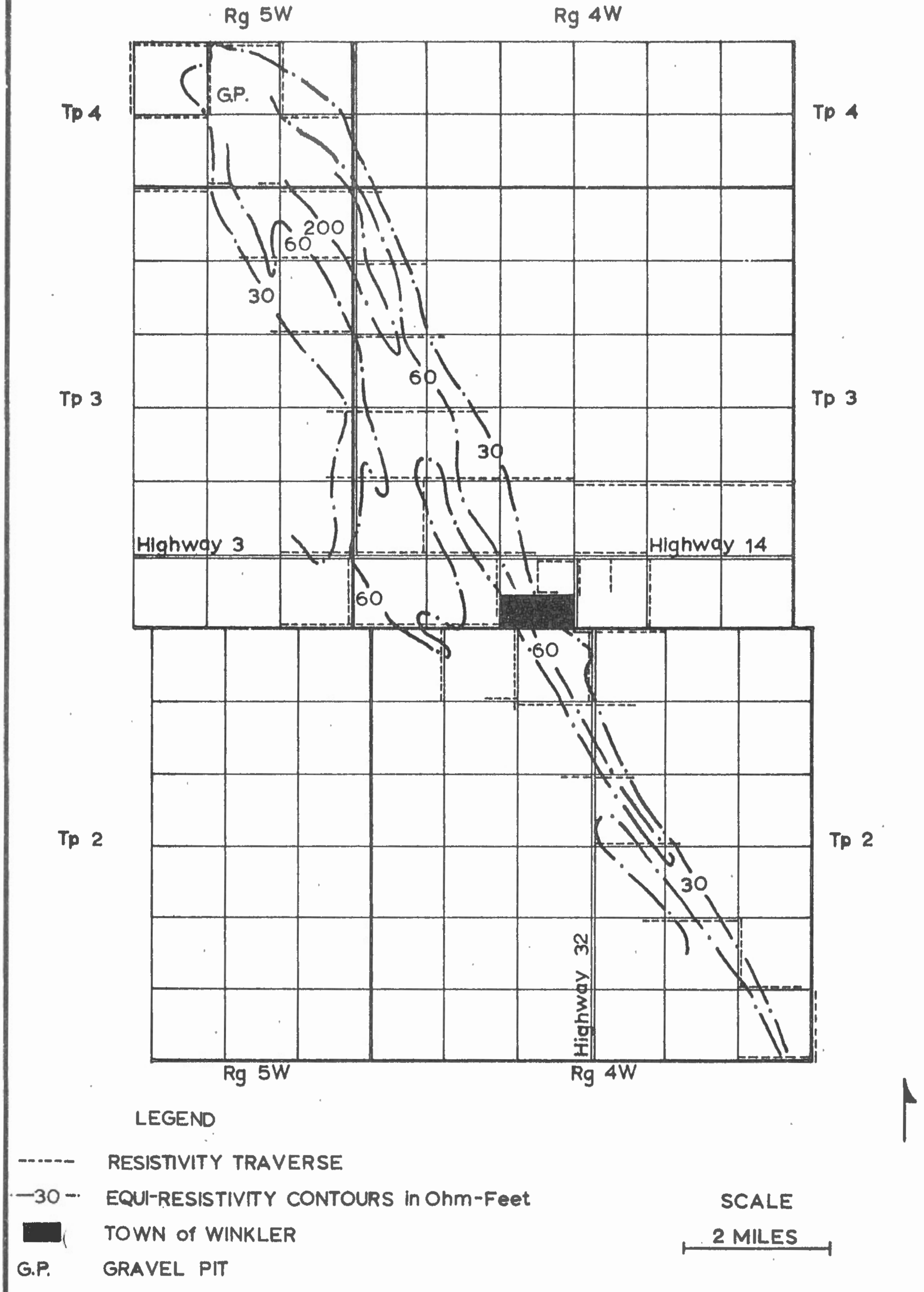
It has been shown by drilling that some of the high resistivity anomalies located within the area of the aquifer are water-barren sand and gravel deposits. These deposits are all associated with topographic highs which represent ancient beaches. Other regions of high resistivity values not associated with topographic highs may also prove to be water-barren. This fact points out two very important concepts for interpreting resistivity data:

(1) At the moment there is no known commercially available resistivity equipment capable of detecting water directly. Rather, all known equipment is capable only of designating areas or zones most likely to contain water.

(2) In general, resistivity surveys and the results of those surveys are almost valueless unless definite geologic control is established, either by drill-holes or some other technique. This fact cannot be over-emphasized and must be considered if any amount of quantitative information is to be extracted from resistivity survey results.

J.E. Wyder.

October 30th, 1962.



TOPICAL REPORT NO. 63

FIGURE 1– PART 2