

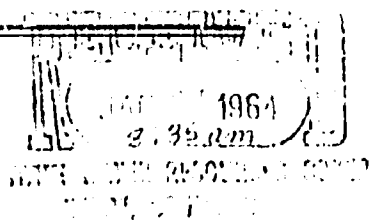
1. Considered 3-19, 1975 2199.3
2. Name of Applicant WILLIAM MINOW
3. Post Office Address TINDALL
4. Amount of water claimed 2.0
5. Source of water supply GROUNDWATER
6. Water to be used for IRRIGATION
- Acres to be irrigated 1.56
7. Water to be diverted and used in BON HOMME county
about 3 1/4 ^{4 1/4 - 5 1/2} miles of TINDALL
8. Proof of Publication Received ~~1st~~ 3-26-75
- Not Received _____
9. Application Approved _____
- Subject to _____
- Not Approved _____
- Action deferred _____

10. Remarks:

SEE LETTER

Notified of delinquent by phone on 9-1-75
1979

No. 1075-3
 Water Division No. 3 Missouri River District
 (Blanks to be Filled by the Engineer for the W. R. C.)



APPLICATION FOR PERMIT To Appropriato Water within the State of South Dakota

(NOTE—Draw a line through items not applicable.)

1. Name of applicant City of Tyndall, South Dakota
 Postoffice address Tyndall, County Bon Homme, State S. Dakota

- I. If a corporation
- (a) Name of same
 - (b) Date and place of incorporation
 - (c) Amount of capital stock
 - (d) Amount paid in
 - (e) Names and addresses of directors

(NOTE—A certified copy of articles of incorporation must accompany the application.)

II. Method of accomplishing the work and financial resources of the applicant:

(a) Method of accomplishing work (Whether by contract, employment of others, or by direct labor)
contract

(b) Cash on hand, \$ (c) Treasury stock, \$
 (d) Bonds to be issued, \$132,000 (e) Other resources, \$

2. Name of diversion work
3. Amount of water claimed cubic feet per second
4. Source of water supply Drilled well in section 21-24-60W. of 5th R.M.
5. Location of point of diversion on bank County.
6. Annual period or periods during which water is to be used all year
7. To be used for:

I. Irrigation or domestic use: Gravity, overhead sprinkling or combination system? domestic & fire protection
 (a) Number of acres to be irrigated acres.

(b) Legal subdivisions to be irrigated

(NOTE—A list of lands to be irrigated, giving each subdivision and fraction with acreage thereof, should be written here, or may be appended as a part of this application. Same must also be shown on accompanying map.)

(c) Statement as to domestic use (giving location, etc.) Domestic use for the City of Tyndall.

II. Stockwatering, mining, milling, power, fish culture, fire protection and public recreation:

- (a) Nature of use fire protection
Name any of the above uses claimed
- (b) Amount of power to be generated none horse power.
 Amount claimed for engine cooling
- (c) Location of plant
- (d) Method of developing power
- (e) Point where water will be returned to stream

Map No 711-3

8. Estimated cost of work:

(a) Head Gates, \$..... (b) Pumping plant, \$.....
(c) Fluming, \$..... (d) Canal-earth, \$..... Rock, \$.....
(e) Other structures \$..... Total, \$.....

9. Description of diversion works:

I. Nature of works: (Reservoir, dam, ditch, flume, pumping plant, etc.)

II. Dimensions of works.

(a) Dam: Height.....feet; length at bottom.....feet; length at top.....feet; thickness at bottom.....feet; thickness at top.....feet; slope at front water face.....; slope at back face.....
material used in construction.....
(b) Reservoir: Capacity when filled.....acre feet. Surface area at highwater mark.....acres.

DEPTH AT OUTLET-Feet	SURFACE AREA AT EACH DEPTH AT OUTLET--ACRES	FEET	ACRE-Feet CAPACITY

(c)* Head gate: Width.....feet; height.....feet;
Material.....
(d) Canal: Total length.....miles.

LOCATION BELOW HEADGATE	DEPTH	BOTTOM WIDTH	WIDTH AT WATER-LINE	GRADE PER MILE
At.....Mile	feet	feet	feet	feet
At.....Mile	feet	feet	feet	feet
At.....Mile	feet	feet	feet	feet
At.....Mile	feet	feet	feet	feet
At.....Mile	feet	feet	feet	feet
At.....Mile	feet	feet	feet	feet

(Give dimensions where reductions in size are made.)

10. Time required for completion of work.....one-half years.
11. Time required for complete application of water to the proposed beneficial use.....one-half years.
12. Choice of newspaper for publication of notice of intention to appropriate.....
Tyndall Tribune & Register, Tyndall, S. Dak.

STATE OF SOUTH DAKOTA }
County of Bon Homme } ss.

I, Leonard E. Chaatka, being first duly sworn on my oath depose and say: That my relation to the above described undertaking is that of owner, that I have read the above foregoing statement, examined the map accompanying the same, and that I know of my own personal knowledge that the matters therein stated and shown are true.

Signed.....
Mayor, City of Tyndall

Subscribed and sworn to before me this 23rd day of September, 1964.

Notary Public (or other qualified officer)

CITY OF
TYNDALL

R. 59 W.

R. 60 W.

T. 94 N.

SCALE 1" = 1/8 MILE

WELL LOCATION & 10" WATER LINE ROUTE
FOR CITY OF TYNDALL, S. DAKOTA

SURVEYOR'S CERTIFICATE
I, Frank J. Bohac, Registered Land Surveyor, do hereby certify that I have surveyed the well location and water line route in the manner indicated on this plat. The locations and dimensions as shown are true and correct. In witness whereof I have set my hand and seal this 15th day of Jan. 1964.

Frank J. Bohac
REGISTERED LAND SURVEYOR SEAL

STATE OF IOWA }
COUNTY OF WOODBURY } ss
On this 15th day of Jan., 1964 before me a Notary Public for said County and State personally appeared Frank J. Bohac, R.L.S., known to me to be the person described in and who executed the foregoing Surveyor's Certificate.
My Commission expires July 4, 1966

Alma M. Jacobson
NOTARY PUBLIC SEAL

Map No 711-3
(Appl. No 1075-3)

R. 60 W.

1/4 SEC. LINE

SECTION LINE

1/4 SEC. LINE

1/4 SEC. LINE

1/4 SEC. LINE

1/4 SEC. LINE

SECTION LINE

STATE HIGHWAY 377

1/4 SEC. LINE

1/4 SEC. LINE

1/4 SEC. LINE

SECTION LINE

1/4 SEC. LINE

SECTION LINE

1/4 SEC. LINE

21

22

14

15

12

7

WELL IS 40.0' NORTH OF 1/4 LINE
15.0' NORTH OF 1/4 LINE
2397.0'

P.I. STA. 24+19.0 IS 22.0' EAST
& 15.0' NORTH OF 1/4 COR.

STA. 53+60 & INTERSECTS
1/4 LINE 110' SOUTH OF 1/4 COR.

P.I. STA. 82+85.0 IS 90' WEST
& 24.5' SOUTH OF SEC. COR.

P.I. STA. 118+370

P.I. STA. 145+83.0
IS 235.6' WEST OF 1/4 COR.

P.I. STA. 164+00 IS 40.5' WEST
& 329.0' SOUTH OF 1/4 COR.

STA. 148+64.5 & INTERSECTS
1/4 LINE 153.8' NORTH OF 1/4 COR.

STA. 167+04 & INTERSECTS
1/4 LINE 277.3' OF 1/4 COR.

P.I. STA. 170+36.3 IS
44.5' EAST OF 1/4 LINE

P.I. STA. 187+56
IS 50.0' EAST &
72.0' NORTH OF 1/4 COR.

EQUATION:
STA. 187+56.8 = 187+49.9

P.I. STA. 218+94.1
100.0' SO. OF SEC. LINE

P.I. STA. 278+00
IS 140' SOUTH &
100' WEST OF 1/4 COR.

P.I. STA. 263+62
4 = 0° 25' RT

EXISTING
6" MAIN
STA. 280+72
4 = 91° 30'

10.0' SOUTH OF SEC. LINE

4 = 0° 27' RT

1/4 SEC. LINE

1/4 SEC. LINE

1/4 SEC. LINE

4 = 45° 10'

4 = 48° 57'

4 = 20° 11'

4 = 29° 01'

4 = 60° 45'

4 = 63° 23'

4 = 54° 26'

Remarks by State Water Resources Commission:

This well is located near domestic wells which may obtain water from the same aquifer. If the well covered by this permit to appropriate water depletes the domestic water supply, restrictions, to the extent necessary, of the capacity of this well or periods of operation or other arrangements may be required to protect the domestic water supply.

STATE OF SOUTH DAKOTA
County of Hughes ss.

Pierre, South Dakota, March 13, 1964

This is to certify that the foregoing application was received by the Commission at 8:35 o'clock
a.m. upon the 27th day of January, 1964

State Water Resources Commission.

By:

Durston Jones
for Chief Engineer, Executive Officer

Number of permit 1075-3

Date of first receipt of application January 27, 1964

Date of return to applicant for correction, amendments or changes required as follows: _____, 19____

Date of receipt of corrected application _____, 19____

Date from which applicant may claim right January 27, 1964

Approved March 11, 1964, Recorded in Book _____ Page 166

This is to certify that we have examined the foregoing application for a permit to appropriate water of the State of South Dakota, and we hereby grant the same as stated herein, subject, however, to the following limitations and conditions:

1st. The equivalent of at least one-fifth of the work above specified is to be completed on or before _____

June 11, 1964

2nd. The whole of said work is to be completed on or before September 11, 1964

3rd. The limit of time for proof of beneficial use of water appropriated in accordance herewith is

March 11, 1965

4th. The water appropriated shall be used for the purpose of municipal use

5th. The prior right of all persons who, by compliance with the laws of the State of South Dakota, have acquired a right to the use of water must not be injuriously affected by this appropriation.

6th. The amount of the appropriation herein granted shall not exceed 1.1 cubic feet per second; neither shall it exceed the capacity of the above described system of diversion works, nor the least amount of water that experience may hereafter indicate as necessary for the production of crops in the exercise of the best husbandry; and further, said appropriation must be limited to not more than one-seventieth (1/70) of one cubic foot of water per second of time for each acre of land to which water is actually

and beneficially applied for irrigation on or before March 11, 1965; said water to be used during the following described annual period:

continuously
Witness my hand this 13th day of March, 1964

State Water Resources Commission

By:

John Jones
Chief Engineer, Executive Officer

Certificate of Construction issued AUGUST 11, 1969

Water License issued AUGUST 11, 1969

9. (Continued)

III. Well Specifications

(a) Hole and casing

Size of drill hole or excavation 34", Depth 160 ft.

Type of casing steel
(wood, concrete, steel, etc.)

Size of casing 16", Thickness of casing .375"

Length of casing 120 ft. If collection gallery, length, size and depth of gallery

(b) Screens

Type of perforated screen Horiz. slot "Everdur"

Size of perforated screen 16", 40 ft.
(diameter) (length)

Thickness of gravel pack 9", length of gravel pack 130'

(c) Water Bearing Materials

Distance to water 25 ft. Character of water bearing materials fine sand to fine gravel (Alluvium)

Thickness of water bearing material 143 ft.

(d) Pump and Motor

Type of pump vertical turbine
(centrifugal, propeller, mixed flow, etc.)

Name of pump Fairbanks Morse, size 500 g.p.m. @ 232' TDH

Kind of motor electric
(gasoline, electric, diesel, etc.)

Horsepower 40, Name of Motor Fairbanks Motor

(e) Complete well

Capacity 500 gpm at drawdown of 30 ft. Estimated cost \$ 11,750

(f) Owner of land upon which well is located City of Tyndall
Name

Tyndall, S. Dak.
Address

(g) Distance to nearest existing wells

On same owner's property none rods. On property owned by others 80 rods

Form 15.

9

Permit No. 1075-3

Water Diversion No. 3 MISSOURI RIVER Water District

CERTIFICATE OF CONSTRUCTION

This is to Certify, That the City of Tyndall

_____ the holder _____ of
Permit No. 1075-3, issued upon Application No. 1075-3, bearing date of priority of January 27,
1964 authorizing the diversion of 1.1 cu. ft. per second of the waters of _____
ground water County of Bon Homme, State of South Dakota at _____
a point 300' E and 40' N of the center, Section 21, T94N, R60W

_____, for municipal

purposes, has 5 complied with the provisions of the laws of the State of South Dakota relating to proof of
completion of the works of diversion set out and described in said Permit; that said works are found in satisfactory
condition for diverting and conveying to the place of intended use 1.33 cu. ft. per second of water.

Date August 11, 1969

WATER RESOURCES COMMISSION

By:

J.W. GRIGGS, Executive Officer

STATE OF SOUTH DAKOTA

WATER LICENSE NO. 1075-3

(1) WHEREAS, On the 27th day of January A. D. 19 64
the City of Tyndall
made Water Right Application No. 1075-3 for a permit to use 1.1 cubic feet per second of the waters
of ground water
County of Bon Homme, State of South Dakota, for Municipal
purposes; and
(2) WHEREAS, On the 13th day of March A. D. 19 64
Permit No. 1075-3, with a date of priority of January 27, 1964
was issued to said applicant for the diversion of said water, and provided for the completion of construction of the water
supply system therein described on or before the 11th day of September A. D. 19 64 and for the
application to beneficial use of said water on or before the 11th day of March A. D. 19 65

and:

(3) WHEREAS, It is hereby certified that the applicant has complied with the provisions of the laws of the State of South Dakota
relating to completion of the construction of the water supply system and is entitled to divert 1.1 cubic feet
per second of water for beneficial use and,

(4) WHEREAS, It is hereby certified that the applicant has complied with the provisions of the laws of the State of South Dakota
relating to the application of water to beneficial use of the following extent,

to be used for municipal purposes by the City of Tyndall

(5) NOW, THEREFORE, By the virtue of the authority vested in us by the laws of the State of South Dakota, We hereby grant and confirm to the City of Tyndall

~~xxx~~
the holder _____ and owner _____ of said permit No. 1075-3 a water right, dating from January 27, 1964
to use of 1.1 cubic feet per second of the waters
of ground water
in the County of Bon Homme and State of South Dakota, or so much thereof as may be necessary for the
purposes hereinbelow mentioned, to be diverted at a point 300' E and 40' N of the Center, Section 21,
T94N, R60W

and conduct ~~xxxxxxx~~ through the city water distribution system

for the purpose of municipal use

Subject to any limitations listed in Water Right Permit No. 1075-3 and subject to the laws of the State of South Dakota.

WITNESS, My hand and seal of our office at Pierre, South Dakota
this 11th day of August A. D.
Nineteen Hundred and Sixty-nine

W. W. W. RESOURCES COMMISSION

By:

Chief Engineer, Executive Officer, J.W. GRIMES

on or before
(First Publication February 12, 1964)

APPROPRIATION OF WATER

Office of State Water Resources Commission,

Pierre, S. Dak, January 31, 1964

Notice is hereby given that the City of Tyndall ~~whose office~~
~~has made an application~~ S. Dak., has made an application in accordance with
the provisions of the water laws of South Dakota for a permit to appropriate for beneficial use 1.1
cubic feet of water per second of time from ~~the~~ ground water through the
city well, the point of diversion of which is to be located ~~on the~~
~~in the~~ SW $\frac{1}{4}$ of the NE $\frac{1}{4}$ of Section 21
Twp. 94N Range 60W. Said water to be used for the purpose of providing ~~for the~~
~~municipal supplies for the City of Tyndall~~
municipal supplies for the City of Tyndall

~~for~~ ~~purpose~~

This application will be taken up by the State Water Resources Commission at their office at Pierre for
consideration upon the 11th day of March, 1964, at 2 P. M. All interested persons
may appear and be heard.

Appropriate action will be taken by the Water Resources Commission after suitable time has elapsed for
the consideration of any or all information presented.

State Water Resources Commission

By:

CC: Mr. J. T. Trevillyan, Publisher
Tyndall Tribune and Register
Tyndall, South Dakota

BURTON F. JONES
Water Right Specialist

PROOF OF PUBLICATION

STATE OF SOUTH DAKOTA }
County BonHomme } ss.

John A. Whalen being duly sworn, deposes and says the annexed printed copy of Notice of Intention to Appropriate Water was taken from the _____
Tribune and Register a newspaper which during the whole itme of publication of said notice herein after stated, has been and is printed and published in the _____
City Tyndall of South Dakota County of BonHomme and State of South Dakota; that the said notice was published in said newspaper on the following dates:

Feb. 6, 1964

Feb. 13, 1964

Feb. 20, 1964

Feb. 27, 1964

in each and every issue of the full number thereof, the first publication being made on the 6 day of Feb. 1964 and the last publication on the 27 day of Feb. 1964 upon which days or times of publication aforesaid the newspaper was regularly published, and that during the whole time of said publication he was _____ the printer and publisher of the said newspaper.

John A. Whalen

Subscribed and sworn to before me this 27th day of February A D. 1964

Notary Public Bon Homme County, S. D.

LEGAL NOTICES

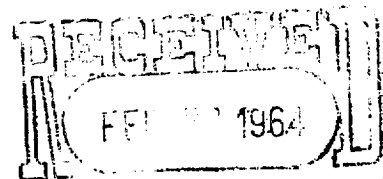
A. APPROPRIATION OF WATER

Office of State Water Resources Commission,
Pierre, S. Dak., January 31, 1964.

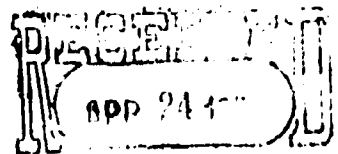
Notice is hereby given that the City of Tyndall, S. Dak., has made an application in accordance with the provisions of the water laws of South Dakota for a permit to appropriate for beneficial use 1.1 cubic feet of water per second of time from ground water through the city well, the point of diversion of which is to be located in the SW $\frac{1}{4}$ of the NE $\frac{1}{4}$ of Section 21 Twp. 94N Range 60W. Said water to be used for the purpose of providing municipal supplies for the City of Tyndall.

This application will be taken up by the State Water Resources Commission after suitable time has elapsed for the consideration of any or all information presented.

State Water Resources
Commission
BURTON F. JONES
Water Right Specialist
(Feb. 6-13-20-27)



STATE WATER RESOURCES COMMISSION
PIERRE, SOUTH DAKOTA

Permit No. 1075-3River
Water Division No. 3 Missouri Water DistrictSTATE WATER RESOURCES COMMISSION
PIERRE SOUTH DAKOTA

Notice of Application of Water to Beneficial Use

(This blank must be filled out by holder of permit and forwarded to the State Water Resources Commission at least sixty days before the time set for application of water.)

(P. O.) Tyndall, South Dakota(Date) March 20, 1964

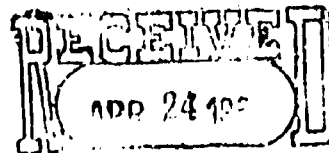
TO THE STATE WATER RESOURCES COMMISSION OF SOUTH DAKOTA, PIERRE:

DEAR SIR: Notice is hereby given that on the 20 day of May, 1964
1964, at Tyndall, South Dakota County of Bon Homme State of South Dakota,
before _____ proof will be submitted of the application to beneficial use
(Examining Engineer or Officer)
of 1.1 cubic feet per second of the waters of _____
_____ In accordance with the terms and conditions of Permit No. 1075-3
heretofore issued by the Water Resources Commission of South Dakota.

- The name and postoffice address of the person or corporation holding said permit are _____
City of Tyndall, Tyndall, South Dakota
- The use to which said water has been applied is Domestic water supply
- The amount applied to beneficial use is 1.1 cu. ft. / sec
- The place where said water is used is (if for irrigation, give full and accurate description of the lands irrigated) City of Tyndall, South Dakota
- The name of the canal or ditch or other works by which said water is conducted to such place of use is 10" Water transmission line.
- The right to take the water from such works is based upon permit No. 1075-3
- The source of supply from which such water is diverted is Tyndall City Well
- The date of priority which said user is prepared to establish is _____

(Sign) James E. [Signature]
Mayor, City of Tyndall

Permit No. 1075-3

Water Division No. 3 Missouri River Water STATE WATER RESOURCES COMM
PIERRE, SOUTH DAKOTA

NOTICE OF COMPLETION OF WORKS

This blank must be filled out by the holder of permit and forwarded to the Executive Officer at least 60 days before the time set for completion of works

(P. O.) Tyndall, South Dakota

(Date) March 20, 1961

TO THE STATE WATER RESOURCES COMMISSION
OF SOUTH DAKOTA, PIERRE:

DEAR SIR: Notice is hereby given of the completion of the works for the diversion of

1.1 cu. ft. per second of the waters of the state from
through the Tyndall City Well & Pipe line
for Domestic water supply purposes

In accordance with the terms and conditions of a certain permit heretofore issued by the Water Resources Commission of the State of South Dakota.

1. The name of the person or corporation holding said permit is City of Tyndall

2. The postoffice address of such person or the place of business of such corporation is Tyndall, S. Dak.
County of Bon Homme State of South Dakota

3. The number of such permit is 1075-3 and the date set for the completion of such work is

4. Said water to be used for May 20, 1961 purposes.

5. Said works of diversion will be fully completed on the date set for such completion, and the amount of water which said works are capable of conducting to the place of intended use, in accordance with the plans accompanying the application for such permit, is 1.1 cubic feet per second

6. The amount of land for which said water is available is 1.0 acres,
particularly described as follows: Beginning at a point 2238 ft. west of the SE corner

of the NE 1/4 of sec. 21 T. 9 N., R. 6 W., of the 5th P.M., thence North for a distance of 208 ft.; thence West for a distance of 208 ft.; thence South for a distance of 208 ft.; thence East for a distance to point of beginning.

I hereby certify that the facts set forth in the above notice are true.

James E. Chandler
Mayor, City of Tyndall

(Signature of Owners)

Permit No. 1075-3

Water Division No. 3 MISSOURI RIVER Water District

Certificate of Examination of Works

Report of Examining Engineer

To the State Water Resources Commission, Pierre, South Dakota:

Dear Sirs: I hereby certify that ~~in accordance with your letter of authorization dated~~
~~XXXX~~, I have this day made a thorough examination of the diversion works constructed by
 the City of Tyndall, of
 Bon Homme County, South Dakota, holder of Permit No. 1075-3, issued
 upon Application No. 1075-3, bearing date of priority of January 27, 1964, authorizing the
 diversion of 1.1 cu. ft. per second of the waters of 160' well for municipal
 purposes. I have to report on the condition of the same as follows:

The diversion works comprise: 160' well, 16" steel casing, Fairbanks Morse pump size
 16½" x 6" No. 2F25 3558 - Fairbanks Morse electric Motor, 40 H.P., F455952 and 10"
 main line is shown on water right map No. 711-3

and the system is in the following condition: good

The point of diversion is located 300' E. 40' N of center of Section 21, T94N, R60W

The works are capable of diverting and conveying to the place of use 1.33 cu. ft. per second of water,
 which is to be used for municipal purposes

The legal sub-divisions to be irrigated are:

comprising a total of acres of land.
 The domestic use intended comprises

The utilization for power, mining, or other beneficial uses comprises:

Witness my hand, this 17th day of June, A.D., 1969, XXX-XXXX

—SEAL—

Donald Wiscoll
 Examining Engineer
 DONALD WISCOLL, Deputy Chief Engineer
 Water Resources Commission



THORPE WELL COMPANY

157 / Ankeny, 50021 / 964-1111;
P.O. BOX 888 / ~~DEKALBA~~ IOWA 50021 / ~~DEKALBA~~ / AREA CODE 515
March 20, 1975

We dig for our business

City of Tyndall
Tyndall, South Dakota

ATTN: Mr. Schneider

Dear Sir:

In reviewing our test well and production well records, we have the following information.

The well was drilled in 1963 to a depth of 160', there is 43' of stainless steel well screen, 8" diameter. The well produced 700 G.P.M. with a 69' pumping level. The aquifer is a shallow sand and gravel the top of which is at 19' the bottom is at 160'. We have no information as to how large an area this well influences, or if any other wells in close proximity are or would influence the aquifer.

We would recommend a pumping test using what equipment is installed in the wells and observing any changes that occur.

The State Geological Survey has some information on this area and I am sure they would gladly furnish this to you.

If we can be of assistance we would be more than happy to meet with you and give you what assistance we could. Mr. Guy Lemar is very familiar with the area and I'm sure could answer most of your questions.

Sincerely,

THORPE WELL COMPANY

Neil F. Archer
General Manager

NFA:db

**M
E
C** **MUNICIPAL
ENGINEERING
CONSULTANTS, P.C.**

Box 220
Sergeant Bluff, Iowa 51054
Phone 712-943-5055

September 7, 1981

Honorable Mayor and Council
City Hall
Tyndall, South Dakota 57066

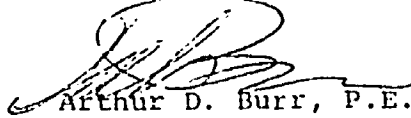
Members of the Council:

We are submitting herewith a Report on the Municipal Water Supply for the City of Tyndall, South Dakota. We sincerely hope this report will assist you in your plans for a quality municipal water supply for your City.

We wish to express our sincere appreciation to the City for the excellent cooperation in providing information for this report and the opportunity to be of service.

Sincerely,

Municipal Engineering Consultants, P.C.


Arthur D. Burr, P.E. & L.S.

ADB/lb

Enc.

SCOPE

This report presents results of engineering studies and analyses of the Tyndall Water Supply. Present demands on the system are examined and probable future demands are determined.

A recommendation is presented to provide the city with a high quality water, economically.

Estimated construction costs are included.

DESCRIPTION OF CITY

Tyndall is located in the central part of Bon Homme County approximately 30 miles west of Yankton. The City is served by State Highway #50, which runs east and west through the south part of the City. State Highway #37 runs on the west side of the City and proceeds south to Springfield.

The water, sewerage, and electricity systems are municipally owned and operated under control of the City Council.

Telephone service are provided by private utility companies.

POPULATION

Population trends in Tyndall since 1930 are illustrated in Table 1-1.

TABLE 1-1

<u>Year</u>	<u>Population</u>
1930	1287
1940	1289
1950	1292
1960	1262
1970	1245
1980	1249

Source: U.S. Census Reports

For purposes of this study, an average of the population projections has been used and extended to the year 2000. Future water supply needs recommended in this report are based upon the population projections of 1300 for the year 2000.

WATER SYSTEM

The existing water system source for Tyndall is from three wells. Two deep wells located in the City which are at a depth of 800 feet deep into the Dakota sandstones. These two wells supply an adequate quantity of water, but provide extremely poor quality of water. In 1963 the City drilled a well, 3 miles south and 4 miles west, 160 feet deep extending into the Tyndall - Scotland aquifer, which is sands and gravel.

COST ESTIMATES

Cost estimates used in this report are based on 1981 price levels and represent complete project costs. No attempt has been made to forecast inflation or deflation which may occur in the future.

Estimates assume construction under contract awarded by competitive bidding procedures and include a 10% allowance for contingencies and an 18% allowance for engineering, legal and administrative costs.

PAST WATER USE

Available water use records have been studied to determine water consumption for the past several years.

AVERAGE DAILY WATER USE

<u>Year</u>	<u>Estimated Population</u>	<u>(gpd)</u>	<u>Supply (gpcd)</u>
1974	1245	146,100	117
1978	1246	173,600	139
1979	1247	167,800	134
1980	1248	196,400	157
1981 ⁽¹⁾	1249	223,970	179

gpd - gallons per day

gpcd - gallons per capita per day

(1) - 7 months

The average daily per capita pumpage ranged from 117 to 179 gallons.

The difference between water from supply and water sold is

"Unaccounted-for-Water". To determine the Unaccounted-for-Water we used the following:

<u>Time</u>	<u>Pumped gal.</u>	<u>Sold gal.</u>	<u>%</u>
1980			
Jan. Feb. Mar.	12,021,000	8,436,800	30%
1980			
Oct. Nov. Dec.	15,414,000	11,284,700	27%

As indicated this Unaccounted-for-Water has amounted to approximately 30% of the total water pumped to the system.

Unaccounted-for-Water may be due to many factors. These include distribution losses from service and main leaks, hydrants, fire flow and flushing, net meter inaccuracies, free and unmetered services and miscellaneous losses. Leaks in distribution mains and services may result from joint failure, valve and hydrant leakage or pipe corrosion. These losses can be reduced by continuous inspection of the system for detection of leaks. Leaks should receive immediate attention as they represent loss of revenue and a potential source of system pollution.

Individual meters serving homes and businesses are often inaccurate. It is important that customer meters be maintained and tested for accuracy. It should be noted that defective meters of the type used for individual services, nearly always register low. This, along with unmetered services, result in loss of revenue and misleading Unaccounted-for-Water percentages.

PEAK WATER DEMANDS

Peak day usage during the first 7 months of this year was 335,800 gpd (280 gpm) and in 1974 it was 339,600 gpd (283 gpm). By the year 2000, it is expected that peak day use will be about 350,000 gpd (292 gpm).

FUTURE WATER USE

Future water use has been estimated to establish a guide for planning improvements. Water consumption will increase with growth in population.

It is estimated that water pumped will increase from 165 gpcd to about 200 gpcd in the year 2000. Based on these figures and a growth in population to 1,300, the average daily domestic water pumped in the year 2000, will be about 260,000 gpd.

Planning for water system improvements should envision the 260,000 gpd average usage and a peak daily usage of 350,000 gpd for requirements in the future.

EXISTING SUPPLY

Presently the City's water is supplied by two deep wells which produce from the artesian sands of the Dakota at a depth of about 800 feet. These two wells supply an adequate quantity of water, but the extremely poor quality of the water has become an increasing problem for the City. Some residents had been forced to haul water great distances to supply their household needs. The hospital reported that the water was adversely affecting the function of some hospital equipment. In 1961, an investigation of the ground water conditions in an area of 88 square miles around the City was started. This investigation consisted of the geological mapping of the area and the drilling of 29 shallow test holes by the State Geological Survey Department.

After much investigation the City of Tyndall had a well constructed in Sec. 21, T94N, R60W, and is located in the southwest corner of the northeast quarter, near the center of the section. This location is approximately three (3) miles south and four (4)

miles west of the City of Tyndall.

The well is constructed in the Tyndall-Scotland aquifer, an out-wash deposit of sands and gravels, which partly fills a pre-glacial valley extending generally northward along Emanuel Creek. The well was drilled in 1963 to a depth of 160 feet and 43 feet of stainless steel well screen of eight (8) inch diameter was installed. The well was test pumped at a rate of 700 gpm which is equal to a rate of one (1) million gallons per day, of 1.56 cubic feet per second. The reported pumping level was 69 feet below ground level and the reported specific capacity was 22 gpm per foot of drawdown at the end of 72 hours of pumping.

RAW WATER SUPPLY

The two major factors to be considered in evaluating a water supply are the quantity and quality of the water that is obtained.

There are four major water bearing aquifers available in the vicinity of Tyndall. These are in order of depth, Tyndall-Scotland sands and gravel which is what the City's existing well is into, the Niobrara, Codell and the Dakota sandstone. Each aquifer has a sufficient quantity of water to provide for the City's needs.

A sample of the existing supply was analyzed by the State Laboratory in October 1976.

A summary of the chemical analysis of each aquifer is as follows:

Test Results for:

	<u>Tyndall-Scotland</u>	<u>Niobrara</u>	<u>Oxide</u>	<u>Dakota</u>
Potassium (mg/l)	9	25	20	19
Sodium (mg/l)	37	155	356	101
Calcium (mg/l)	148	217	80	315
Magnesium (mg/l)	47	41	18	52
Iron (mg/l)	0.2	0.12	-	-
Nitrate (mg/l)	-	-	-	-
Fluoride (mg/l)	-	-	-	-
Chloride (mg/l)	7	55	174	113
Sulfates (mg/l)	510	788	410	890
Bicarbonate (mg/l)	185	295	329	147
pH	7.73	7.95	-	-
Solids (mg/l)	896	920	1,360	1,780
Hardness (mg/l)	-	-	296	1,010

Water quality criteria for public water supplies have been more or less left up to individual states to define and enforce. However, it is generally recognized that certain minerals and impurities in the water are undesirable. A few of these undesirable characteristics are as follows:

Tastes and Odors

Tastes and odors in water can be attributed to dissolved gases or organic matter in the raw water. Tastes and odors have not been a serious problem in the past.

Iron and Manganese

When iron and manganese are present in a combined total of 0.3 mg/l or more, they discolor fixtures and may affect the color and taste of water. Once established in a water distribution system, iron causes clogging of water mains, valves and meters.

Hardness

Hardness in water is due to calcium and magnesium in chemical combination with bicarbonates and sulfates. Hardness in a water supply is of concern to domestic, industrial and commercial users. Hard water requires more soap and detergent for cleansing purposes. Hard water also deposits material on surfaces which is unacceptable in certain industrial and commercial operations. Many authorities suggest that a hardness of 85 to 120 mg/l is desirable for domestic use. Some commercial processes require water with a hardness of near 0.

In 1974, the "Safe Drinking Water Act, Public Law 93-523," was signed into law.

The Act is designed to set Maximum Contaminant Levels (MCL's) of certain contaminants. These contaminants are described as "Inorganic Chemicals" such as Arsenic, Chromium, Lead, Silver, etc.; "Organic Chemicals" such as Hydrocarbons, Endrin, etc.; "Radionuclides" of natural and manmade beta activity and "Turbidity".

Included in the Act are Secondary Regulations that are to be used as guidelines on water quality. The Secondary Regulations are as follows:

<u>Constituant</u>	<u>Recommended Maximum Levels</u>
Odor	3 T.O.N.*
Manganese	0.05 mg/l
Iron	0.3 mg/l
Foaming Agents (MBAS)	0.5 mg/l
Copper	1.0 mg/l
Color	15 Color units
Chloride	250 mg/l

<u>Constituant</u>	<u>Recommended Maximum Level</u>
Sulfate	250 mg/l
Zinc	5 mg/l
Hydrogen Sulfide	0.05 mg/l
Corrosion	non-corrosive
pH	6.5 - 8.5
TDS**	500 mg/l

*Threshold Odor Number

**Total Dissolved Solids

The Safe Drinking Water Act is to be enforced by the Environmental Protection Agency in conjunction with the individual State Regulatory Agencies. A public water supply system (except regional systems) must comply with these regulations by January 1, 1981.

In comparing the secondary regulations with the chemical analysis of the existing wells, it appears that certain constituents are in excess or will exceed the MCL requirements.

Additional tests will have to be conducted to insure that present sources meet the MCL requirements.

FUTURE SUPPLY

The City currently has two wells in the Dakota sandstone which are large producers of water. The water use from these wells has been discontinued due to the undesirable quality of the water.

The Codell aquifer and the Niobrara aquifer are also capable of providing a large quantity of water. Both of these aquifers contain a high level of sodium which may cause additional problems in heart conditions.

REPRODUCTION: REDUCTION 1/5.7
ROLL NO 889
DATE MICROFILMED 1/28/82
CINEMA COPY 1/28/82

We have reviewed the study of Geology and Water Resources of Bon Homme County, Part I & II prepared by South Dakota Geological Survey, and test results from the Department of Water and Natural Resources. We also have had discussions with both departments.

From the forementioned sources, it is indicated that there is a large quantity of water in the Tyndall-Scotland aquifer and that this aquifer has a good quality of water. This aquifer is limited to an area west of Highway 37 and approximately half a mile north of Highway 50 - just north of the golf course along Emanuel Creek.

The golf course presently has a well in service located on its property. The well in the golf course is 270 feet deep with 15 feet of 16" diameter screen. The pump setting is at 240 feet with the static water level at 18 feet. The pump is rated at 400 gpm at 210 feet of head. The 50 hp submersible pump is probably capable of pumping more than 400 gpm.

The well is located 630 feet south and 450 feet west of the Northeast corner of Section 3. This positions the well 2 1/2 miles west of the water main going into the City from the existing City wells.

The pump could not be used to pump water to the City because it is not capable of pumping the head that is required. The cost of installing a transmission main from the golf course to the City would be \$105,000 and the cost of a new pump would be an additional \$10,000.

There are numerous irrigation wells in the area, several being located near the City well. [These irrigation wells are all withdrawing water from the Codell and Niobrara aquifers.]

1951
2/10/51
Reviewed by
and and placed

We have enclosed a record from the Department of Water & Natural Resources indicating that the irrigation wells are not affecting the drawdown at all. The seasonal weather seems to effect the drawdown more than the irrigation pumping in this area.

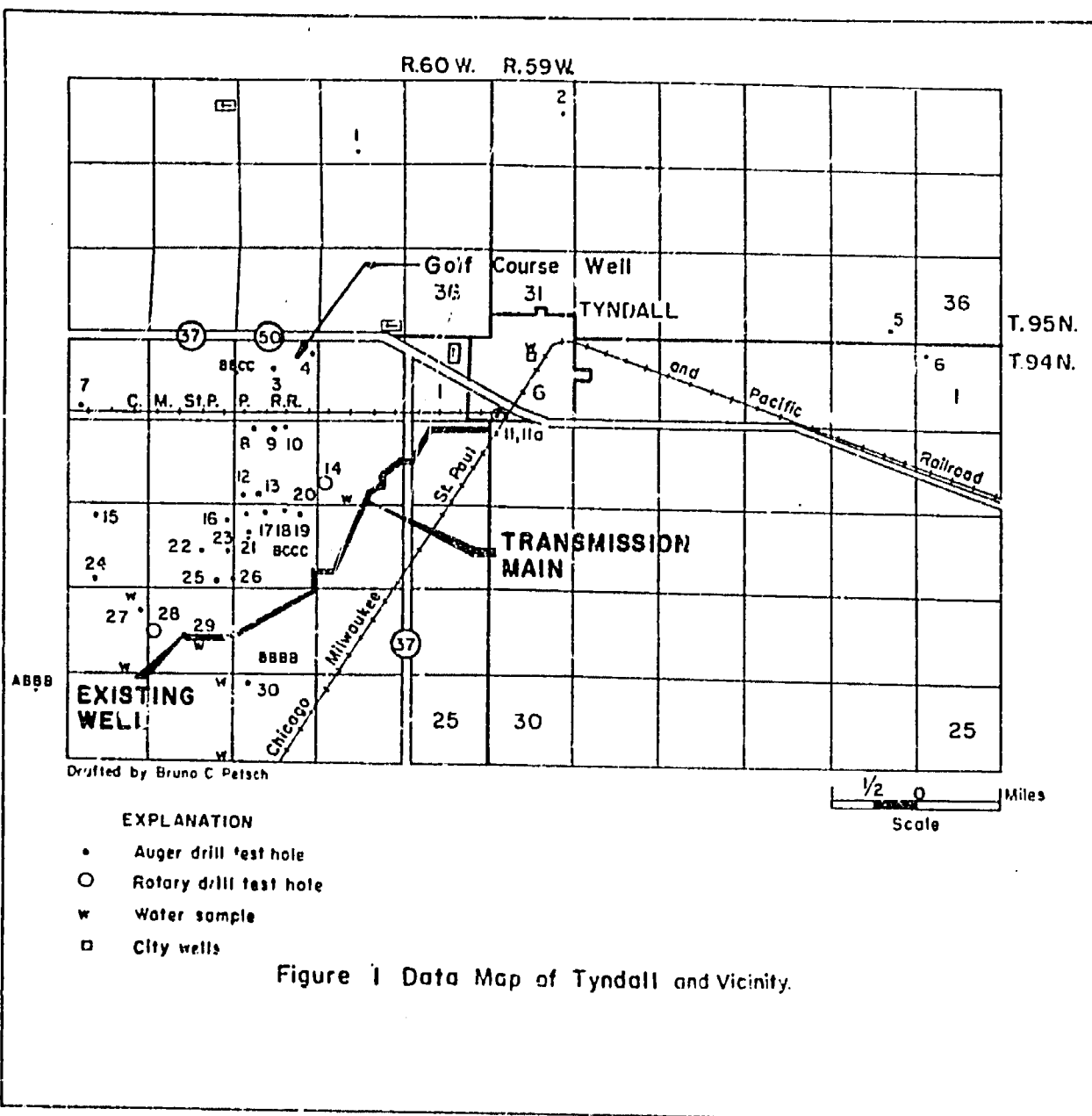
RECOMMENDATION

Considering all factors, we would recommend that the City construct another well next to the existing well in the Tyndall-Scotland sand and gravel. The new well shall have a capacity of 300 gpm. It is standard practice to place the wells 300 feet or more apart, when both wells are being pumped simultaneously. In this case, both wells will not pump simultaneously, therefore, construct the new well at the present site.

Cost Estimate

Construct the new well in the sand & gravel:

Test hole	\$ 1,500
34" dia. hole	9,000
12" casing	5,000
12" screen	2,000
Grout	500
Gravel Pack	500
Test Pump	500
Pump & Piping	10,000
	<u>\$29,000</u>
Contingencies	2,000
	<u>\$31,000</u>
Engineering, Legal and Overhead	4,000
	<u>\$35,000</u>



94-60-21PCCC. U.S. GEOLOGICAL SURVEY. S.W. OF TYNDELL. DRILLED OBSERVATION WATER TABLE WELL
 IN GLACIAL OUTWASH. DIAM 3 IN. DEPTH 64 FT. SAND POINT 59-64 FT. MP. TOP OF RECORDER PLATFORM
 LSD 1334.52 FT ABOVE MSL.
 HIGHEST WATER LEVEL 27.15 BELOW LSD, APR. 17, 1974.
 LOWEST WATER LEVEL 27.30 BELOW LSD, JUNE 27, 1968.
 RECORDS AVAILABLE: 1964-68, 1970-75.

DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL
MAY 4, 1966	24.20	MAY 11, 1967	26.01	AUG. 25, 1971	23.73	SEP. 14, 1973	22.85
MAY 5	24.12	JUNE 5	26.12	SEP. 16	24.09	OCT. 15	22.11
MAY 9	24.06	JULY 7	21.92	OCT. 8	24.35	NOV. 16	21.50
MAY 10	24.03	JULY 26	21.84	NOV. 12	24.72	DEC. 17	21.18
MAY 11	24.02	AUG. 16	23.28	DEC. 9	24.90	JAN. 17, 1974	21.86
MAY 12	24.06	SEP. 7	23.77	DEC. 29	25.10	FEB. 19	22.27
MAY 17	23.98	OCT. 3	24.16	JAN. 20, 1972	25.30	MAR. 18	21.34
MAY 24	23.99	NOV. 22	24.75	FEB. 14	25.39	APR. 17	20.16
MAY 25	24.04	DEC. 19	24.56	MAR. 7	25.11	MAY 21	21.28
MAY 26	23.97	FEB. 12, 1968	25.49	MAR. 31	25.12	JUNE 20	21.90
JUNE 6	23.97	MAR. 8	25.56	APR. 20	25.30	JULY 18	21.91
JUNE 7	23.61	APR. 2	25.79	MAY 16, 1970	23.25	AUG. 12	22.45
JUNE 14	23.77	MAY 21	26.13	JUNE 20	20.19	SEP. 16	22.96
JUNE 22	24.02	JUNE 27	27.30	JULY 26	21.84	OCT. 16	23.30
JUNE 27	24.02	AUG. 8, 1970	24.84	AUG. 24	22.37	NOV. 14	23.64
JULY 4	24.21	MAY 13	22.50	SEP. 14	22.40	DEC. 11	23.82
AUG. 4	24.49	MAY 20	22.76	OCT. 16	23.27	JAN. 16, 1975	24.18
AUG. 15	24.65	MAY 25	22.91	NOV. 16	23.73	FEB. 13	24.35
SEP. 10	24.85	MAY 31	23.00	DEC. 14	24.08	MAR. 13	24.55
SEP. 27	24.97	JUNE 5	22.47	JAN. 10, 1973	24.30	APR. 9	24.69
OCT. 18	25.15	JUNE 10	22.64	FEB. 15	22.78	MAY 14	24.74
NOV. 10	25.24	JAN. 19, 1971	25.33	MAR. 19	20.54	JUNE 10	24.86
NOV. 29	22.64	FEB. 16	25.45	MAR. 21	20.60	JULY 15	25.02
DEC. 13	24.41	MAR. 1	24.85	MAR. 30	20.72	AUG. 12	25.17
JAN. 5, 1967	24.61	APR. 12	23.10	APR. 26	21.48	SEP. 15	25.30
JAN. 31	25.46	MAY 12	23.72	MAY 17	21.85	OCT. 16	25.46
FEB. 17	25.70	JUNE 15	22.14	JUNE 18	21.87	NOV. 13	25.58
MAR. 9	25.82	JULY 8	22.87	JULY 16	21.68	DEC. 16	25.74
APR. 6	25.93	JULY 30	23.35	AUG. 15	22.34		

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY

STATION NUMBER 42564377571001 00040W21NCC

WELL SOURCE AGENCY USGS

LATITUDE 425643 LONGITUDE 6975710 WELL DEPTH 64.00 GEOLOGIC UNIT DATUM 1335.00 STATE 46 COUNTY 009

DATED LEVEL IN FEET BELOW LAND SURFACE DATUM. CALENDAR YEAR JANUARY 1975 TO DECEMBER 1975
INSTANTANEOUS OBSERVATIONS AT 1200

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	24.05	24.21	24.43	24.66	24.67	24.76	24.94	25.16	25.24	25.40	25.52	25.45
10	24.04	24.22	24.47	24.64	24.75	24.86	24.97	25.14	25.25	25.44	25.52	25.66
15	---	24.37	24.55	24.69	24.79	24.87	25.02	25.14	25.30	25.46	25.54	---
20	24.04	24.35	24.54	24.67	24.66	24.91	25.05	25.01	25.31	25.43	25.56	25.70
25	24.11	24.61	24.60	24.64	24.76	24.92	25.05	25.02	25.37	25.47	25.53	25.72
30	24.24	24.61	24.52	24.66	24.79	24.93	25.11	25.14	25.30	25.44	25.52	25.72
31	24.11	24.34	24.52	24.66	24.72	24.87	25.03	25.10	25.31	25.44	25.56	25.69

NOTE: MISSING DATA OF DEGREE EXCEEDED 200 OF YEAR

Ben H...
PROCESS DATE IS 02-24-77

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY

STATION NUMBER 425643097571001 04N60W219CCC

WELL SOURCE AGENCY USGS

LATITUDE 425643 LONGITUDE 0975710 WELL DEPTH 64.00 GEOLOGIC UNIT DATUM 1335.00 STATE 46 COUNTY 009

WATER LEVEL IN FEET BELOW LAND SURFACE DATUM, CALENDAR YEAR JANUARY 1976 TO DECEMBER 1976
INSTANTANEOUS OBSERVATIONS AT 1200

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	25.77	25.94	25.11	23.29	23.43	23.80	24.27	24.83	25.29	25.55	25.81	26.05
10	25.73	26.79	25.22	---	23.55	23.85	24.32	24.91	25.37	25.58	25.85	26.09
15	25.77	25.65	25.30	23.48	23.55	23.89	24.47	24.99	25.42	25.65	25.85	26.09
20	---	25.73	24.70	23.11	23.60	23.98	24.54	25.07	25.45	25.69	25.90	26.11
25	25.84	25.41	23.00	23.35	23.67	24.05	24.65	25.12	25.47	25.71	25.95	26.16
30	25.82	24.78	23.02	23.37	23.70	24.18	24.75	25.23	25.51	25.77	26.00	---
MONTH	25.77	25.77	24.39	23.32	23.58	23.95	24.50	25.02	25.41	25.65	25.89	26.10

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

STATION NUMBER 42543037571001 94N60W219CC
LATITUDE 425543 LONGITUDE 0975710 WELL DEPTH 64.00 GEOLOGIC UNIT
DATUM 1335.00 STATE 46 COUNTY 009

WATER LEVEL IN FEET BELOW LAND SURFACE DATUM, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
INSTANTANEOUS OBSERVATIONS AT 1200

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	25.65	26.79	25.96	26.35	27.11	26.47
2	---	---	---	---	---	---	25.64	26.74	25.96	26.34	27.11	26.49
3	---	---	---	---	---	---	25.70	26.79	25.96	26.40	27.13	26.40
4	---	---	---	---	---	---	26.67	26.79	26.96	26.43	27.13	26.90
5	25.55	25.41	26.04	26.26	26.43	26.57	26.71	26.79	26.97	26.46	27.15	26.22
6	---	---	---	---	---	---	26.72	26.74	26.94	26.51	27.17	26.23
7	---	---	---	---	---	---	26.73	26.40	26.99	26.55	27.14	26.95
8	---	---	---	---	---	---	26.74	26.40	26.94	26.61	27.20	26.95
9	---	---	---	---	---	---	26.71	26.41	26.94	26.65	27.19	26.97
10	25.59	25.43	25.14	26.27	26.44	26.58	26.59	26.41	26.94	26.60	27.22	26.24
11	---	---	---	---	---	---	26.72	26.42	27.01	26.56	27.21	27.01
12	---	---	---	---	---	---	26.74	26.44	27.02	26.64	27.44	27.01
13	---	---	---	---	---	---	26.75	26.44	27.03	26.68	27.43	27.02
14	---	---	---	---	---	---	26.73	26.44	26.94	26.73	27.41	27.04
15	25.55	25.43	25.14	26.30	26.44	26.60	26.75	26.44	26.44	26.76	27.24	27.05
16	---	---	---	---	---	---	26.74	26.44	26.79	26.77	27.27	27.06
17	---	---	---	---	---	---	26.74	26.44	26.40	26.78	27.37	27.07
18	---	---	---	---	---	---	26.74	26.45	26.69	26.79	27.43	27.07
19	---	---	---	---	---	---	26.74	26.47	26.44	26.41	27.44	27.13
20	25.54	25.41	25.11	26.33	26.51	26.60	26.77	26.47	26.32	26.44	26.44	27.11
21	---	---	---	---	---	---	26.79	26.47	26.24	26.44	27.54	27.14
22	---	---	---	---	---	---	26.79	26.47	26.33	26.47	27.54	27.14
23	---	---	---	---	---	---	26.79	26.47	26.34	26.44	27.64	27.14
24	---	---	---	---	---	---	26.79	26.43	26.27	26.44	27.74	27.14
25	25.71	25.49	25.14	26.37	26.51	26.62	26.79	26.43	26.14	27.01	27.74	27.14
26	---	---	---	---	---	---	26.79	26.43	26.10	27.03	27.77	27.14
27	---	---	---	---	---	---	26.79	26.43	26.11	27.04	27.74	27.14
28	---	---	---	---	26.56	---	26.79	26.43	26.19	27.04	27.43	27.16
29	---	---	---	---	---	---	26.79	26.43	26.24	27.04	27.47	27.17
30	---	26.00	---	---	---	---	26.79	26.44	26.29	27.04	27.47	27.17
31	25.77	---	25.27	26.40	---	26.64	---	26.44	---	27.04	27.47	---
MAX	25.77	25.00	26.27	26.40	26.55	26.64	26.79	26.45	27.03	27.04	27.27	27.17
MIN	25.55	25.41	26.04	26.26	26.43	26.54	26.55	26.79	26.10	26.44	26.24	26.47



United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
P. O. Box 1412
Huron, South Dakota 57350
April 24, 1975

RECEIVED

APR 26 1975

**DEPT. OF NATURAL
RESOURCE DEVELOPMENT**

Mr. Don Driscoll, Director
Division of Water Rights
Department of Natural Resource Development
State Office Building
Pierre, South Dakota 57501

Dear Don:

Enclosed is the water level information for well number 94N60W21BCCC
which you requested per phone conversation today.

Sincerely,

Wendell Bradford

Wendell Bradford
Hydrologic Technician

Enclosure

90-60-218CCC. U.S. GEOLOGICAL SURVEY. S.W. OF TYNDILL. DRILLED OBSERVATION WATER TABLE WELL
 IN GLACIAL OUTWASH. DIA. 3 IN, DEPTH 64 FT, SAND POINT 59-64 FT. MP, TOP OF RECORDER PLATFORM
 HIGHEST WATER LEVEL 20.19 BELOW LSD, JUNE 20, 1972,
 LOWEST WATER LEVEL 27.30 BELOW LSD, JUNE 27, 1968.
 RECORDS AVAILABLE 1968-69, 1970-73.

DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL
MAY 4, 1966	24.20	DEC. 13, 1966	24.41	MAY 25, 1970	22.91	MAY 16, 1972	23.50
MAY 5	24.12	JAN. 5, 1967	24.61	MAY 31	23.00	JUNE 20	20.19
MAY 9	24.04	JAN. 31	25.46	JUNE 5	22.47	JULY 26	21.84
MAY 10	24.03	FEB. 17	25.70	JUNE 10	22.64	AUG. 24	22.37
MAY 11	24.02	MAR. 9	25.82	JAN. 19, 1971	25.33	SEP. 14	22.80
MAY 12	24.00	APR. 6	25.43	FEB. 16	25.45	OCT. 16	23.27
MAY 17	23.99	MAY 11	26.01	MAR. 9	24.85	NOV. 16	23.73
MAY 24	23.99	JUNE 5	26.12	APR. 12	23.10	DEC. 14	24.08
MAY 25	24.04	JULY 7	21.92	MAY 12	23.72	JAN. 10, 1973	24.30
MAY 26	23.97	JULY 26	21.84	JUNE 15	22.14	FEB. 15	22.78
JUNE 6	23.97	AUG. 16	23.28	JULY 8	22.87	MAR. 19	20.54
JUNE 7	23.81	SEP. 7	23.77	JULY 30	23.35	MAR. 21	20.60
JUNE 14	23.77	OCT. 3	24.16	AUG. 25	23.73	MAR. 30	20.72
JUNE 22	24.02	NOV. 22	24.75	SEP. 16	24.09	APR. 26	21.48
JUNE 27	24.02	DEC. 19	24.56	OCT. 8	24.35	MAY 17	21.85
JULY 8	24.21	FEB. 12, 1968	25.49	NOV. 12	24.72	JUNE 18	21.87
AUG. 4	24.49	MAR. 8	25.56	DEC. 9	24.90	JULY 16	21.68
AUG. 15	24.65	APR. 2	25.79	DEC. 29	25.10	AUG. 15	22.34
SEP. 10	24.85	MAY 21	26.13	JAN. 20, 1972	25.30	SEP. 14	22.85
SEP. 27	24.97	JUNE 27	27.30	FEB. 14	25.39	OCT. 15	22.11
OCT. 18	25.15	APR. 8, 1970	24.84	MAR. 7	25.11	NOV. 16	21.50
NOV. 16	25.24	MAY 13	22.50	MAR. 31	25.12	DEC. 17	21.18
NOV. 29	22.64	MAY 20	22.76	APR. 20	25.30		

19-10681

19--; Records available

-from recorder graph)

water level on 5th, 10th, 15th, 20th, 25th, and end of each month

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7261

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1974-76

INDEXED BY BCIC S.W. Tyndell

-19-; Records available.

- (from recorder graph)

[illegible]

WATER SUPPLY REVIEW
THE CITY OF TYNDALL
TYNDALL, SOUTH DAKOTA

MAY, 1975

by

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LAYNE WESTERN COMPANY, INC.

WATER SUPPLY REVIEW
THE CITY OF TYNDALL
TYNDALL, SOUTH DAKOTA

MAY, 1975

INTRODUCTION

The Hydrologist was contacted by Mr. R. J. Zieser, City Attorney for the City of Tyndall, South Dakota, with respect to reviewing the ground water situation for water supply and determine whether a potential conflict with an application for irrigation in the vicinity may exist. The data was received from several sources and are enclosed in the Appendix for information.

The purpose of the review by the Hydrologist at this time, was to determine the overall general resource capability and whether additional uses and of what magnitude might impose a threat to the supply of the City of Tyndall, South Dakota. This information was gleaned from the enclosed material.

GEOLOGIC SETTING

The City of Tyndall has a well located in Sec. 21, T. 94N., R.60W., and is further located in the southwest corner of the northeast quarter, near the center of the section. This location is approximately three (3) miles south and four (4) miles west of the City of Tyndall.

The well is constructed in the Tyndall-Scotland aquifer which is an out-wash deposit of sands and gravels which partly fills a pre-glacial valley extending generally northward along Emanuel Creek. Little information exists about the recharge mechanism and sources of recharge to this aquifer but some circumstantial evidence and data does exist. A hydrograph of water level observed in a nearby well from the period beginning May, 1966 through June of 1968, indicates that periods of runoff flow along the Emanuel Creek do recharge the aquifer to some extent. It has also been the experience of the Hydrologist that rainfall and other forms of precipitation in the area contribute to some extent to the overall recharge of the aquifer system.

Exploratory test hole drilling and survey work was accomplished by Layne-Minnesota Company in 1962. Copies of the test hole boring logs and electric logs made at that time, with a sketch of the approximate location of each boring, is attached for its information. The actual well was drilled in 1963 to a depth of 160 feet and installed was 43 feet of stainless steel well screen of eight (8) inch diameter. The well was test pumped at a rate of 700 gpm which is the equivalent rate of one (1) million gallons per day, or 1.56 cubic feet per second. The reported pumping level was 69 feet below ground level and the reported specific capacity was 22 gpm per foot of drawdown at the end of 72 hours of testing. Analysis of the data by U. S. Geological Survey indicates a transmissivity of 210,000 gpd per foot width of aquifer material with a coefficient of storativity of 0.20. The average hydraulic conductivity was 216 feet per day, which is actually a velocity and converts to the equivalent of 1,600 gpd, per square foot of material. From the maps indicated, the most permeable portion of this aquifer is less than one-half mile wide and extends in length for about a four (4) mile reach along the Emanuel Creek. Thinner sections of the same aquifer material exists on either side of the deeper portion which have a lower transmissivity of 20,500 gpd per foot width of aquifer material but are important catchment areas of local recharge in the area.

HYDROLOGIC SETTING

In order to better understand the terms and expressions used in hydrology, the Hydrologist will take license to utilize a very simple analogy to explain the principal functions involved.

Visualize a 1,000 gallon horse tank with a 10 gpm hose running into the tank and the tank is spilling over. Obviously, the tank would spill over at a rate of 10 gpm. One could install a pump with a capacity of 500 gpm and pump from the tank for approximately two (2) minutes before the storage of the tank would be exhausted. If the pump were shut off just prior to the tank being completely exhausted, and the tank allowed to stand for 100 minutes, it would be refilled by the 10 gpm supply to overflowing again. This process could be repeated after full recovery had been allowed and the impression that a 500 gpm rate could be attained from this supply, would be misleading. The fact would be that the recharge rate was only 10 gpm but higher pumping rates are possible from the storage of the system providing sufficient recharge and recovery time is allowed to exist between pumping cycles.

The Tyndall-Scotland aquifer setting in the vicinity of the City of Tyndall wells, has exactly the same situation. Utilizing the calculations of transmissivity of 210,000 gpd per foot width of aquifer for a one-half mile width in the vicinity of the well field, and with an average hydraulic gradient of three (3) feet per mile gives an indicated flow of 315,000 gpd. Utilizing the additional flow in the outlying portions of the aquifer on either side of the deep channel, adds another 123,000 gpd of flow approximately. Therefore, it is estimated that the total recharge to the aquifer system is approximately 438,000 gpd which is the equivalent rate of flow from the hose to the tank. The storage capacity of the aquifer in the vicinity of the wells which was taken to be an area of approximately one-half mile wide and one mile long and 130 feet deep, was 1.8 billion gallons. The normal usable supply from an aquifer system is approximately 50 percent of its storage capacity which is 900 million gallons of water in storage in the aquifer tank. Obviously, more storage than this exists in the entire Tyndall-Scotland aquifer system but outlying reaches are beyond the capacity and the influence of the City wells.

WATER USE INVENTORY

From the information submitted by the City Auditor, it appears that a total of 53,329,000 gallons of water was used by the City in 1974. The yearly total converts to an average annual day use of 146,104 gpd. This is 33 percent or one-third of the recharge rate estimated for the aquifer system. Obviously, this is not the only use being made of water from the system. There are many domestic and ranch wells in the area and there may be some other irrigation wells in the area. The Hydrologist leaves to others, to estimate the average annual usage being made of water in the vicinity. Obviously on an annual basis, there is sufficient allowance and recharge supply to allow the use of water by others.

An analysis was made of the peak weekly use, which was 2,377,000 gallons. This converted to the equivalent average daily rate during that period of 339,572 gpd of water use. Even peak day pumpage during a week of high use, was below the apparent recharge rate to the aquifer system.

It has been reported that the City of Tyndall, South Dakota has a permit issued in 1964 for water usage up to 1.1 cubic feet per second which is the equivalent of 494 gpm or 711,000 gpd of use. It is not understood whether this is a peak rate limitation or an average annual usage. It is assumed from the experience of the Hydrologist that this is probably a peak day use limitation. If so, the peak day use during the week of highest usage was 48 percent of the permit rate.

Eased on the reported population of the City of Tyndall of 1262, the peak day usage during the maximum week of use, was the equivalent of 269 gpd per person. The average annual usage per person was 115.8 gpd. It appears, that per capita usage for the City of Tyndall, is in line with normal averages for the area.

SUMMARY AND CONCLUSIONS

It was found that the City of Tyndall, South Dakota has a well, or wells, located in the Tyndall-scotland aquifer system which is located several miles southwest of the City. A review of the geologic data available to the Hydrologist, suggests the average recharge rate to the aquifer system being utilized is approximately 438,000 gpd of flow. It was further estimated that the volume of water in storage within the area of influence of the City well was approximately 1.8 billion gallons, of which, it was estimated that the usable supply was approximately 900 million gallons.

It was reported that the City used 53,328,000 gallons of water in 1974. This was the equivalent average rate of 146,104 gpd, on an annual basis. This is 33 percent of the estimated recharge to the aquifer system. No information was available on the usage being made by others in the vicinity.

It is the conclusion of the Hydrologist that the recharge to the aquifer system may be sufficient to support some additional usage in the area.

RECOMMENDATIONS

It should be recognized that the estimates of recharge were made on very limited data available from the aquifer system. Of equal importance to the inventory of usage from the area is a continuous record or periodic record of water levels in more than one point covering the aquifer area. It is therefore, recommended that the City of Tyndall and other water users that may be involved from the same aquifer system, install miniature wells or piezometers which would have steel or plastic casing and should extend well down into the middle of the sand and gravel formation zones. The bottom 20 feet of the piezometers should be slotted and should be of suitable diameter to obtain a water quality sample when needed. Normal minimum diameter of these piezometers is two (2) inch. Water levels should be measured at least quarterly or once every three months and carried out over a period of several years.

Should observations show the mean sea level elevation of the static water level decline below elevation 1,300 feet, for a period of more than two (2) years, this would indicate overdraft and overpumping of the aquifer system. This would be the equivalent of drawing upon the storage of the aquifer system in excess of the recharge rate. Some draft upon the storage of the aquifer system is desirable to make room for recharge of fresher and better quality of water.

The City of Tyndall

TYNDALL, SOUTH DAKOTA 57056

from the office of: _____ City Auditor

April 4, 1975

Mr. Carl E. Huzman
Hydrology Consultant
Layne-Western Company, Inc.
1010 West 39th Street
Kansas City, Missouri 64111

Dear Mr. Huzman:

A reply to your letter which you sent Mr. Zieser, asking for all information obtainable in regard to the well in discussion.

Enclosed herewith is some of the information we could obtain.

The records of the resistivity survey on the five or six test holes made by Layne-Western Co., Inc. was not to be found, at least not in our records, do have some information which is enclosed from Thorpe Well Co. who was awarded the contract to dig the well.

Daily log of water pumped is not kept but attached is a weekly log of water pumped each week and the total pumped for the year 1974.

The permit issued to the City of Tyndall, was for 1.1 cubic feet of water persecond, permit issued 1964.

Also enclosed a Geological survey of our county with information on our well, which may be of some value to you, should you need some questions answered after reading through the survey, call Cleo M. Christensen, Vermillion, S. Dak., telephone number 605 624-4471 who seems to have considerable knowledge about the aquafer our well is located.

I hope this information is of some value to you, should you^{have}/any questions feel free to call this office, number 605 589-3481.

Sincerely yours,

Laddie Schneider
Laddie Schneider
City Auditor

Hospital - Auditorium - Carnegie Library - Parks - Swimming Pool - Schools

Weekly Log 1974

1-4-74	701,000	6-28-74	1,517,000
1-11-74	747,000	7-5-74	1,653,000
1-18-74	734,000	7-12-74	1,632,000
1-25-74	689,000	7-20-74	2,377,000
2-1-74	668,000	7-26-74	1,615,000
2-8-74	658,000	8-2-74	1,587,000
2-15-74	649,000	8-9-74	1,209,000
2-22-74	675,000	8-16-74	^{filled} fresh pond 2,376,000
3-1-74	682,000	8-23-74	1,321,000
3-8-74	738,000	8-30-74	1,441,000
3-15-74	614,000	9-6-74	1,669,000
3-22-74	634,000	9-13-74	1,145,000
3-29-74	692,000	9-20-74	1,026,000
4-5-74	645,000	9-27-74	1,110,000
4-12-74	683,000	10-4-74	943,000
4-19-74	822,000	10-11-74	1,010,000
4-26-74	776,000	10-18-74	919,000
5-3-74	973,000	10-25-74	1,099,000
5-10-74	1,030,000	^{filled} pond 11-1-74	722,000
5-17-74	757,000	11-12-74	1,480,000
5-24-74	1,081,000	11-15-74	328,000
5-31-74	958,000	11-22-74	768,000
6-7-74	1,003,000	11-29-74	766,000
6-14-74	961,000	12-6-74	785,000
6-21-74	1,158,000	12-13-74	734,000

12-20-74	787,000
12-27-74	760,000
1-3-75	827,000

Total gallons
53,328,000



THORPE WELL COMPANY

157 / Ankeny, 50021 / 964-1111
P.O. BOX 111 / DES MOINES, IOWA 50301 / 964-1111 / AREA CODE 515
March 20, 1975

We dig for our business.

City of Tyndall
Tyndall, South Dakota

ATTN: Mr. Schnider

Dear Sir:

In reviewing our test well and production well records, we have the following information.

The well was drilled in 1963 to a depth of 160', there is 43' of stainless steel well screen, 8" diameter. The well produced 700 G.P.M. with a 69' pumping level. The aquifer is a shallow sand and gravel the top of which is at 19' the bottom is at 160'. We have no information as to how large an area this well influences, or if any other wells in close proximity are or would influence the aquifer.

We would recommend a pumping test using what equipment is installed in the wells and observing any changes that occur.

The State Geological Survey has some information on this area and I am sure they would gladly furnish this to you.

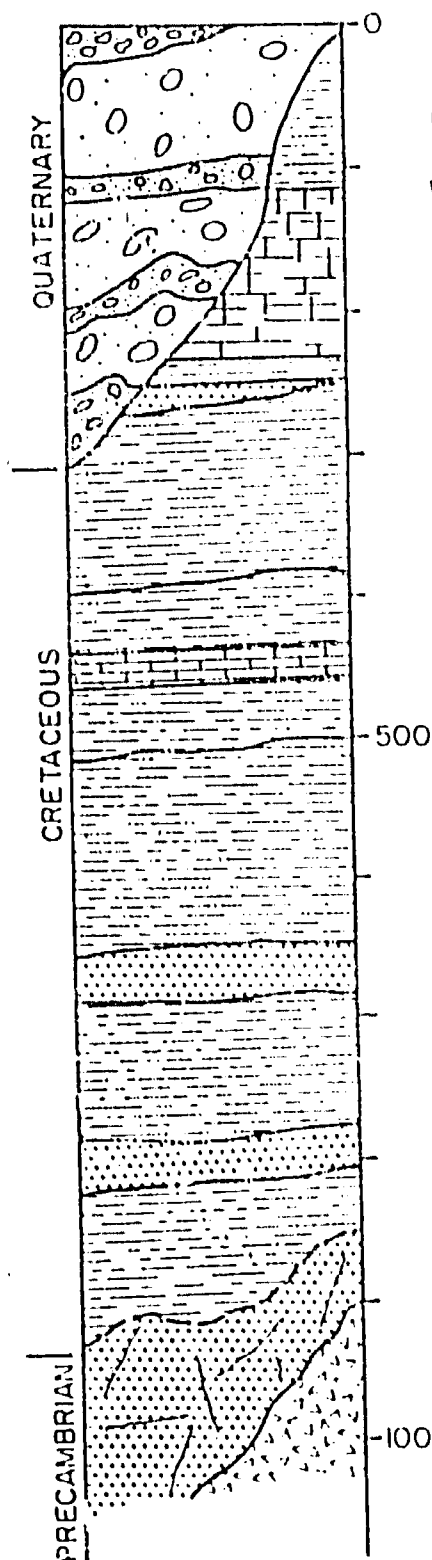
If we can be of assistance we would be more than happy to meet with you and give you what assistance we could. Mr. Guy Lemar is very familiar with the area and I'm sure could answer most of your questions.

Sincerely,

THORPE WELL COMPANY

Neil F. Archer
General Manager

NFA:db



GEOLOGY AND WATER RESOURCES OF BON HOMME COUNTY SOUTH DAKOTA

Part II; Water Resources

by
Donald G. Jorgensen
United States Geological Survey

*Prepared in cooperation with the
South Dakota Geological Survey,
County of Bon Homme, and
Fort Randall Conservancy Sub-District.*

Bulletin 21
SOUTH DAKOTA GEOLOGICAL SURVEY

1000 1971

STATE OF SOUTH DAKOTA
Richard Kneip, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

BULLETIN 21
GEOLOGY AND WATER RESOURCES OF
BON HOMME COUNTY, SOUTH DAKOTA
Part II: Water Resources

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Science Center
University of South Dakota
Vermillion, South Dakota
1971

CONTENTS

	Page
Abstract	1
Introduction	2
Water resources	6
Surface water	6
Missouri River	12
Choteau Creek	12
Emanuel Creek	12
Lewis and Clark Lake	13
Lake Henry	13
Other surface-water bodies	13
Ground water	13
Alluvial aquifers	14
Till aquifer	14
Shallow outwash aquifers	15
Choteau aquifer	15
Hubonmix aquifer	15
Tyndall-Scotland aquifer	20
Niobrara aquifer	20
Codell aquifer	25
Aquifers in the Dakota Formation	33
Water quality	39
Surface water	46
Ground water	53
Summary	60
Selected references	61

ILLUSTRATIONS

	Page
Figure 1. Map showing physiographic divisions of eastern South Dakota and location of Bon Homme County	3
2. Generalized geologic map	4
3. Map showing altitude of the upper surface of the Cretaceous bedrock	5
4. Diagram of well-numbering system	7
5. Simplified diagram of the hydrologic cycle	8
6. Map of the drainage areas	9
7. Graph showing variation of mean annual flood with drainage area	11
8. Graph showing variation of flood discharge with recurrence interval	11
9. Hydrograph showing annual changes of water level in a well tapping the till aquifer	16
10. Hydrograph showing monthly changes of water level in a well tapping the till aquifer	17
11. Map showing areal extent and thickness of the Choteau aquifer	18
12. Hydrograph of water level in a well tapping the Choteau aquifer	19
13. Map showing areal extent and potentiometric contours of the Hubonnix aquifer	21
14. Map showing areal extent, thickness and potentiometric contours of the Tyndall-Scotland aquifer	22
15. Hydrograph of water level in a well tapping the Tyndall-Scotland aquifer	23
16. Geohydrologic section of the Tyndall-Scotland aquifer	24
17. Map showing areal extent and altitude of the upper surface of the Niobrara Marl	26
18. Map showing depth to the Niobrara Marl	27
19. Hydrograph of the water level in a well tapping the Niobrara aquifer	28
20. Map showing potentiometric contours of the Niobrara aquifer	29

Illustrations—continued.	Page
Figure 21. Map showing depth to the Codell aquifer	30
22. Map showing altitude of the upper surface of the Codell aquifer	31
23. Hydrograph of the water level in a well tapping the Codell aquifer	32
24. Map showing potentiometric contours of the Codell aquifer	34
25. Diagram of formations and composite electric log at well 95-60-34ccac	35
26. Map showing altitude of the upper surface of the upper Dakota aquifer	36
27. Map showing depth to the upper Dakota aquifer	37
28. Hydrograph of the water levels of the lower Dakota aquifer at Tyndall and Springfield	38
29. Hydrograph of the potentiometric level in a well tapping the lower Dakota aquifer	38
30. Map showing potentiometric contours of the lower Dakota aquifer	40
31. Diagram for classification of irrigation water	44
32. Graph showing relation of dissolved solids to discharge in Choteau Creek	45
33. Graph showing relation of dissolved solids to discharge in Emanuel Creek	47

TABLES

Table 1. Drainage areas	10
2. Monthly mean discharge of Choteau Creek	12
3. Monthly mean discharge of Emanuel Creek	13
4. Significance for domestic use of common chemical constituents and physical properties of water	41
5. Rating of irrigation water for various crops on the basis of boron concentration	48
6. Selected chemical analyses of water from Choteau Creek	49
7. Selected chemical analyses of water from Emanuel Creek	50

Tables—continued.	Page
Table 8. Water quality of Missouri River at Yankton, South Dakota	51
9. Selected chemical analyses of water from Lake Henry	52
10. Summary of chemical analyses of water from the till aquifer	54
11. Summary of chemical analyses of water from the Choteau aquifer	55
12. Summary of chemical analyses of water from the Tyndall-Scotland aquifer	56
13. Summary of chemical analyses of water from the Niobrara aquifer	57
14. Summary of chemical analyses of water from the Codell aquifer	58
15. Summary of chemical analyses of water from the lower Dakota aquifer	59

Geology and water resources of Bon Homme County,
South Dakota
Part II, Water Resources

by
Donald G. Jorgensen

ABSTRACT

Bon Homme County, an agricultural county in southeastern South Dakota, has an area of 570 square miles and a population of 8,707. Sands and sandstones of Tertiary age, sands and gravels, till, and loess of Pleistocene age, and alluvium of Holocene age overlie the Cretaceous bedrock strata throughout nearly the entire county.

Water from Lewis and Clark Lake and the Missouri River has a low sodium hazard and a medium salinity hazard. It is suitable for domestic and stock uses and for irrigation with only moderate leaching of the soil. The water is used by the city of Springfield and also to a limited extent for irrigation.

The quality of water from Emanuel and Choteau Creeks varies with the rate of discharge in the creeks. In general, the water has a high salinity hazard at low flows and should not be used for irrigation on soils with poor drainage. However, the water is suitable for stock use.

In Lake Henry the quality of water varies with both the season of the year and the volume of water in the lake. In particular, the water has a low sodium hazard and a variable high to very-high salinity hazard. The water is not suitable for irrigation under ordinary conditions. However, in general, the water is suitable for domestic and stock uses.

Alluvial and surficial outwash aquifers supply ground water for domestic and stock use. Shallow wells finished in these aquifers produce 3 to 10 gpm (gallons per minute).

Widespread till deposits usually yield water with a low sodium hazard and a very high salinity hazard. This water is not suitable for irrigation under ordinary conditions. At certain locations in the till the water has excessively high sulfate and dissolved solids concentrations and may not be suitable for domestic use. However, the water is suitable and is commonly used for stock watering. Wells finished in the aquifer yield from 1 to 5 gpm.

Three extensive glacial outwash aquifers are present in the county. The 32-square mile Choteau aquifer is adjacent to Choteau Creek. The Tyndall-Scotland aquifer underlies an area of more than 90 square miles and extends from near Springfield to near Scotland. The Hubonmix aquifer in northwestern Bon Homme County has an areal extent of about 36 square miles. Water from these three aquifers usually has a low sodium hazard and a high salinity hazard. Therefore it should be used for irrigation only on land which has good soil drainage. The water, in general, is suitable for domestic and stock uses. At locations where these aquifers contain more than 50 feet of saturated aquifer material, properly constructed wells should produce more than 100 gpm.

The Codell Sandstone Member of the Carlile Shale, a bedrock aquifer that commonly yields "soft" water, is widely used as a source of domestic water. Water from this aquifer usually has a very high sodium hazard and a high salinity hazard. It is unsuitable for irrigation but is usually suitable for domestic and stock uses.

The Niobrara Marl and the sandstone layers of the Dakota Formation are also bedrock aquifers. Water from these aquifers generally has a low sodium hazard and a high salinity hazard; it should be used only on land which has good soil drainage. The water, in general, is suitable for domestic and stock uses. Properly constructed wells at certain locations in the Niobrara aquifer will produce more than 100 gpm, and properly constructed wells in the lower Dakota aquifer may produce as much as 900 gpm.

INTRODUCTION

The increasing use of water and the increasing awareness of the importance of water resources in Bon Homme County and in other South Dakota counties have created the need and desire to evaluate the water resources of the State. The purpose of this investigation is to identify and evaluate the water resources of Bon Homme County. The significant findings and the data obtained will be useful in planning the orderly development of the water resources.

The study was started in 1965 as a part of the program of the U. S. Geological Survey, the South Dakota Geological Survey, Bon Homme County, and the Fort Randall Conservancy Sub-District. This is the fifth in a series of such cooperative county-wide studies. The author is indebted to the residents of the county for their help and especially to Kenneth Karanda, who supplied many valuable well logs.

Method of investigation.—The investigation included the collecting of well data, test drilling, measuring water levels and stream flow, sampling and chemical analyses of waters, and determining altitudes by spirit-level and altimeter surveys. The data were studied to determine the source, movement, quantity, and quality of the ground and surface waters in the county. The accuracy of maps and of other interpretations based on altitude determinations is plus or minus 10 feet. Geological mapping was done by the South Dakota Geological Survey.

Geography.—Bon Homme County is located in southeastern South Dakota. It has an area of approximately 570 sq mi (square miles) and a population of 8,707 (1970 census). Five municipalities, Tyndall, population 1,262; Springfield, population 1,194; Scotland, population 1,077; Avon, population 637; and Tabor, population 378, are located in the county. About 97 percent of the land in the county is in farms. More than half of the farms are primarily engaged in raising livestock, and about one-third are small grain or row crop farms.

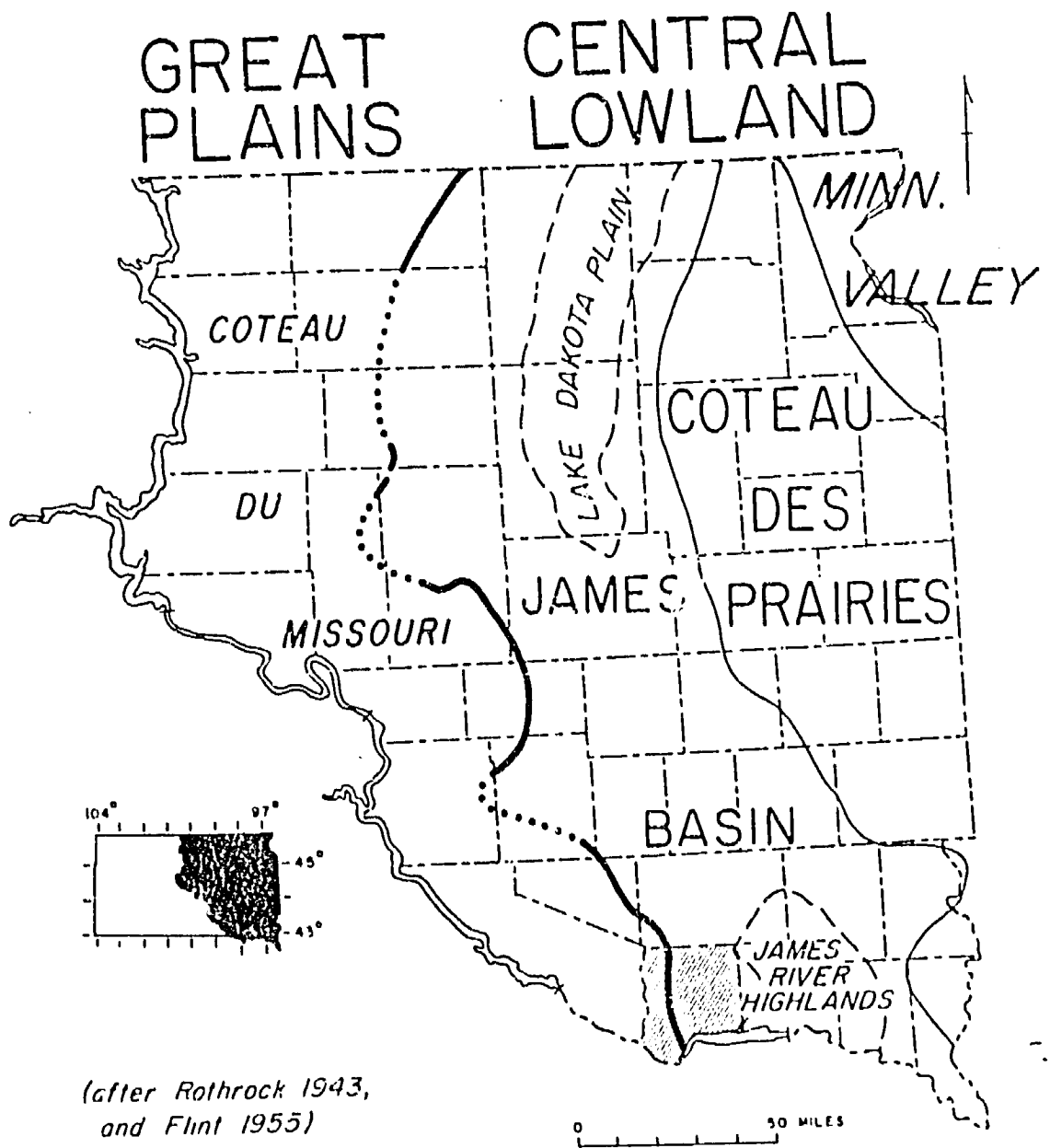
Physiography.—The county, as shown on figure 1, is part of two physiographic provinces, the Great Plains and the Central Lowland. The dissected glacial uplands west of Emanuel Creek are part of the glaciated Missouri Plateau section of the Great Plains Province (Fenneman, 1946) and the low-lying land east of Emanuel Creek is part of the James Basin of the Central Lowland Province. The James River Highlands in the southeast corner of the county is a part of the James Basin. The Missouri River flood plain, which is approximately 1 mile wide on the South Dakota side of the Missouri River, has now been submerged by the water in Lewis and Clark Lake, above Gavins Point Dam, except for small areas along the river in the southwest corner of the county. The flood plain is defined by bluffs 200 to 300 feet high in the southeast and southwest corners of the county, and by bluffs 25 to 100 feet high in the south-central part of the county.

Altitudes of land surface in the county range from approximately 1,210 feet on the Missouri River flood plain to approximately 1,950 feet on three hills of the glacial upland in the northwest corner of the county.

Geology.—The surficial deposits, except for the exposed bedrock strata, are glacial drift, alluvium, colluvium, and eolian materials (Christensen, in preparation). Figure 2 is a generalized geologic map of the surficial deposits of Bon Homme County.

Exposed bedrock consists of the Tertiary age Ogallala sands and sandstones¹, and the Pierre Shale and Niobrara Marl of Cretaceous age. The configuration of the upper surface of the Cretaceous age bedrock is shown in figure 3. Unexposed bedrock formations of Cretaceous age include the Carlile Shale, Greenhorn Limestone, Graneros Shale, and Dakota

¹ Stratigraphic nomenclature used in this report follows that of the South Dakota Geological Survey, which differs somewhat from the usage adopted by the U. S. Geological Survey.



 Bon Homme County

Figure 1. Map showing physiographic divisions of eastern South Dakota and location of Bon Homme County.

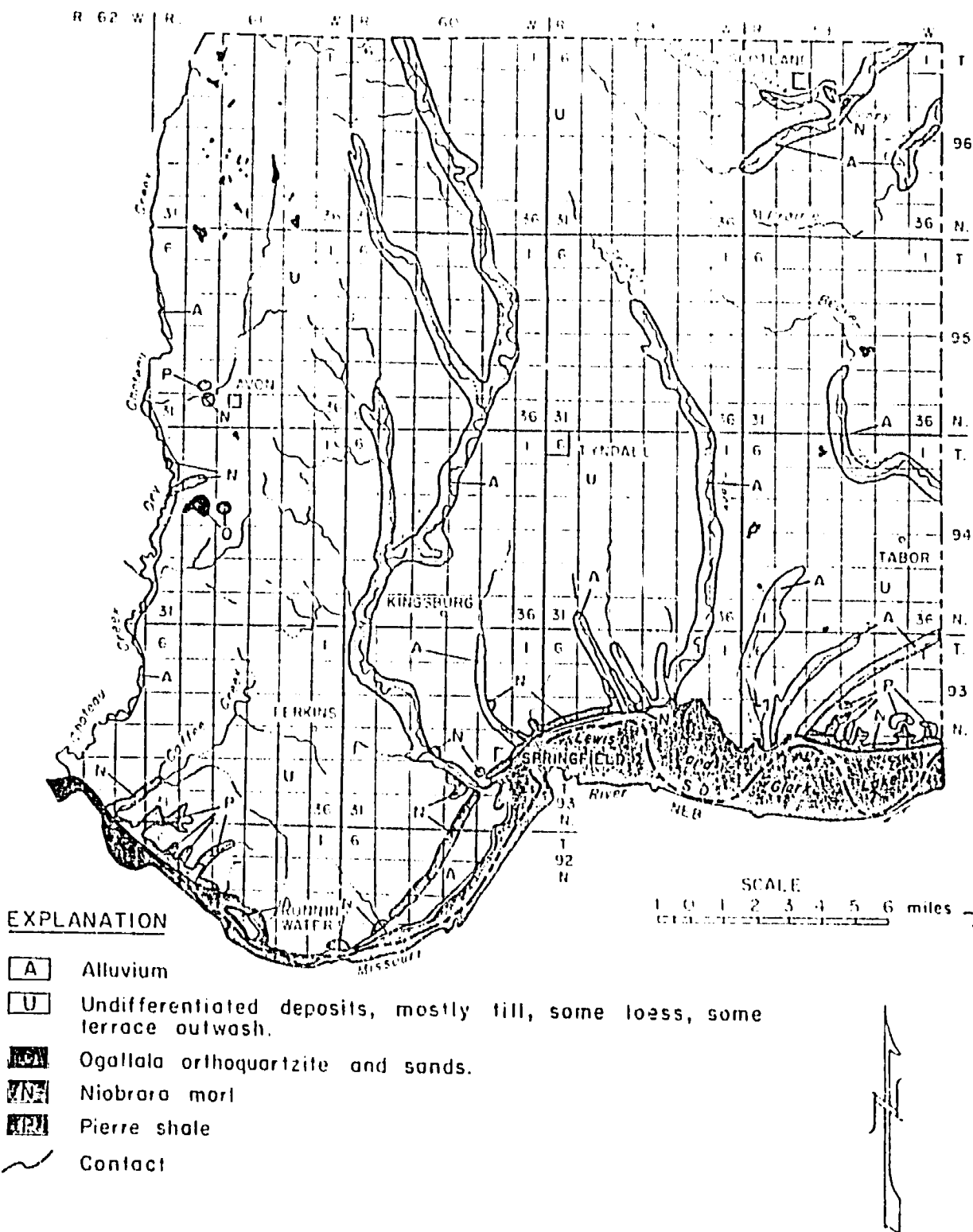
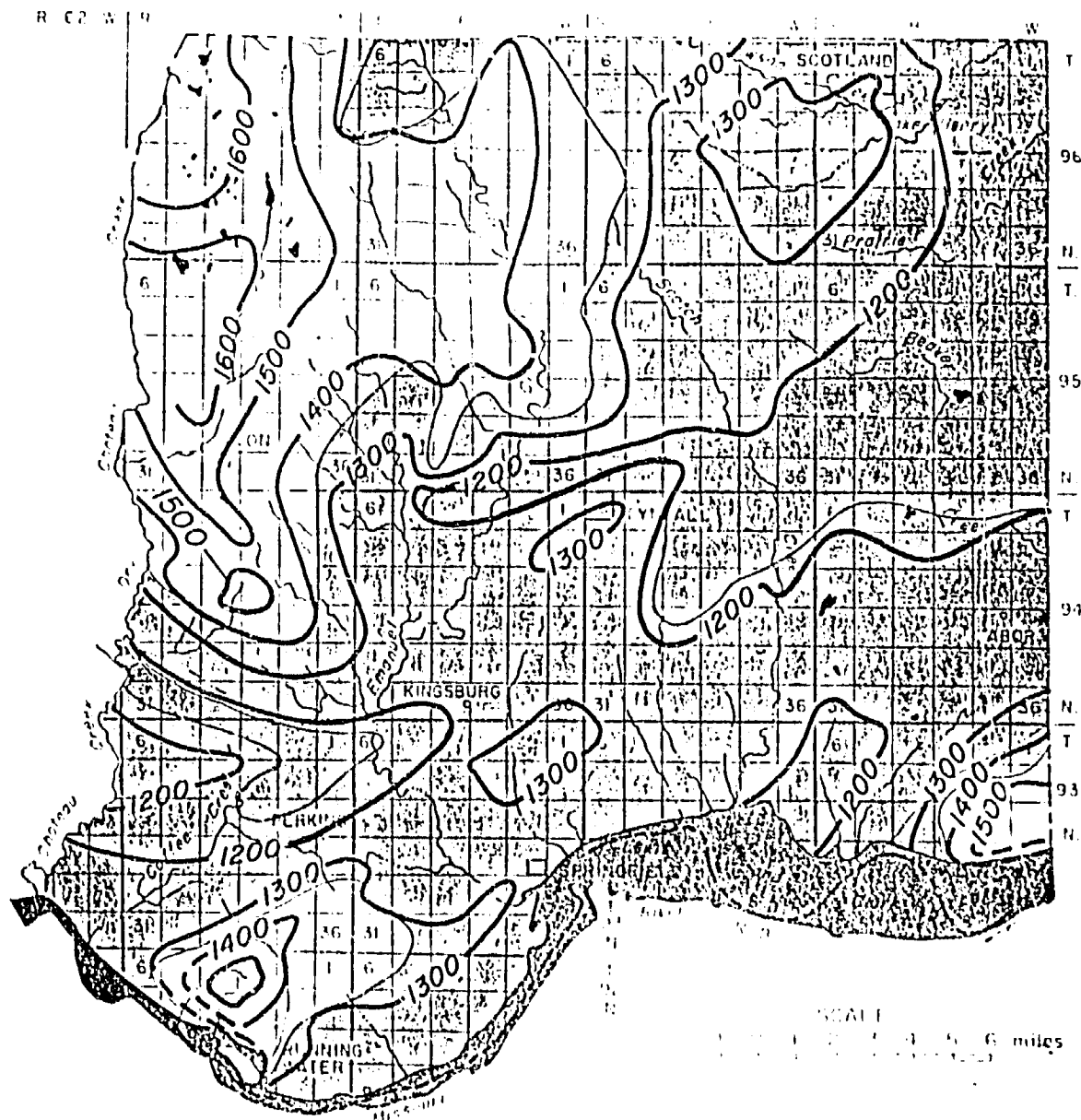
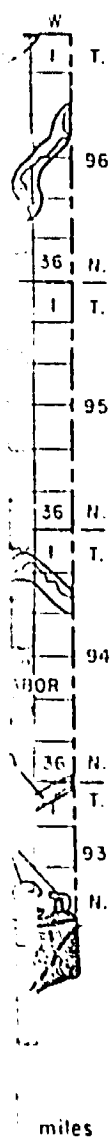


Figure 2. Generalized geologic map.

After Christensen, Part I, (in preparation)



-  Pierre Shale
-  Niobrara Marl
-  Carlile Shale

-1300- Bedrock contour shows altitude of top of Cretaceous rocks. Dashed where approximately located. Contour interval = 100 feet. Datum is mean sea level.

Figure 3. Map showing altitude of the surface of the Cretaceous bedrock.

Formation. The Dakota lies unconformably on the Sioux Quartzite "basement" rock of Precambrian age.

Climate.—U. S. Weather Bureau meteorological records (1967) for Tyndall indicate that the average annual temperature is 9.3° Celsius (48.7°F) and the average annual precipitation is 22.46 inches. The average dates of the last spring and first fall frosts are May 4 and September 30 (Pengra, 1957b). The average dates of the first spring and first fall occurrence of a "killing frost," which is -2°C (28°F) or lower, at Tyndall are April 26 and October 10 (Pengra, 1956a).

Previous investigations.—Previous geologic or hydrologic investigations in the county include water-supply studies for the cities of Tyndall (Bruce, 1962) and Scotland (Christensen, 1963). Simpson (1960) mapped the geology of the Yankton area, including a part of Bon Homme County.

Well-numbering system.—The location of wells, test holes, and other items is described according to the numbering system shown in figure 4. The first segment indicates the township, the second the range, and the third the section in which the well, test hole, or other feature is located. The lowercase letters following the section number indicate the position of the well in the section. The first letter denotes the quarter section, the second letter the quarter-quarter section, the third letter the quarter-quarter-quarter section, the fourth letter the quarter-quarter-quarter-quarter section (2½-acre tract). The subdivisions of a section are lettered a, b, c, and d in a counterclockwise direction, starting in the northeast quarter. If more than one well is listed in a 2½-acre tract, consecutive numbers starting with 1 are added to the well numbers. Thus well 93-58-15babb (fig. 4) is in the NW¼, NW¼, NE¼, NW¼ of section 15, Township 93 North, Range 58 West.

WATER RESOURCES

Water resources include all water that can be used, whether it occurs in the air, on the ground, or in the ground. All water in Bon Homme County is of atmospheric origin. Precipitation or the condensation of water vapor in the form of rain, snow, dew, or frost is the source of both ground water and surface water. Surface water is water that runs over the land or is stored on the land surface. Water which infiltrates into the ground to the zone of saturation is termed ground water. Some water is transpired by plants or evaporates and returns to the atmosphere. The continual cyclic movement of water is termed the hydrologic cycle. Figure 5 is a simplified sketch of the hydrologic cycle showing precipitation returning to clouds (vapor) by means of evapotranspiration from plants, soil, and surface-water bodies (rivers, lakes, etc.).

Surface Water

Surface water is the water on the surface of the earth. It includes the water in lakes, ponds, reservoirs, rivers, creeks, etc. Runoff is that part of the precipitation that appears in surface streams. Amount of runoff is a function of many variables including precipitation, size and slope of drainage area, and soil permeability. The drainage areas and the main surface-water bodies in the county are shown in figure 6. The approximate sizes and the names of the drainage areas are listed in table 1.

Magnitude and the frequency of flooding is a characteristic of a stream that is of special importance to anyone who utilizes the flood plain. Flood-frequency studies are used to predict the occurrence and magnitude of floods. Patterson (1966, p. 3-11) developed regional flood-frequency curves applicable to Bon Homme County. The method is based on two sets of curves and can be used to estimate the magnitude of floods that have recurrence intervals of 1.1 to 50 years. Recurrence interval is the average interval of time within which the given flood will be equaled or exceeded once. A flood having a recurrence interval of 10 years is one that has a 10 percent chance of occurring in any year; likewise a 50-year flood

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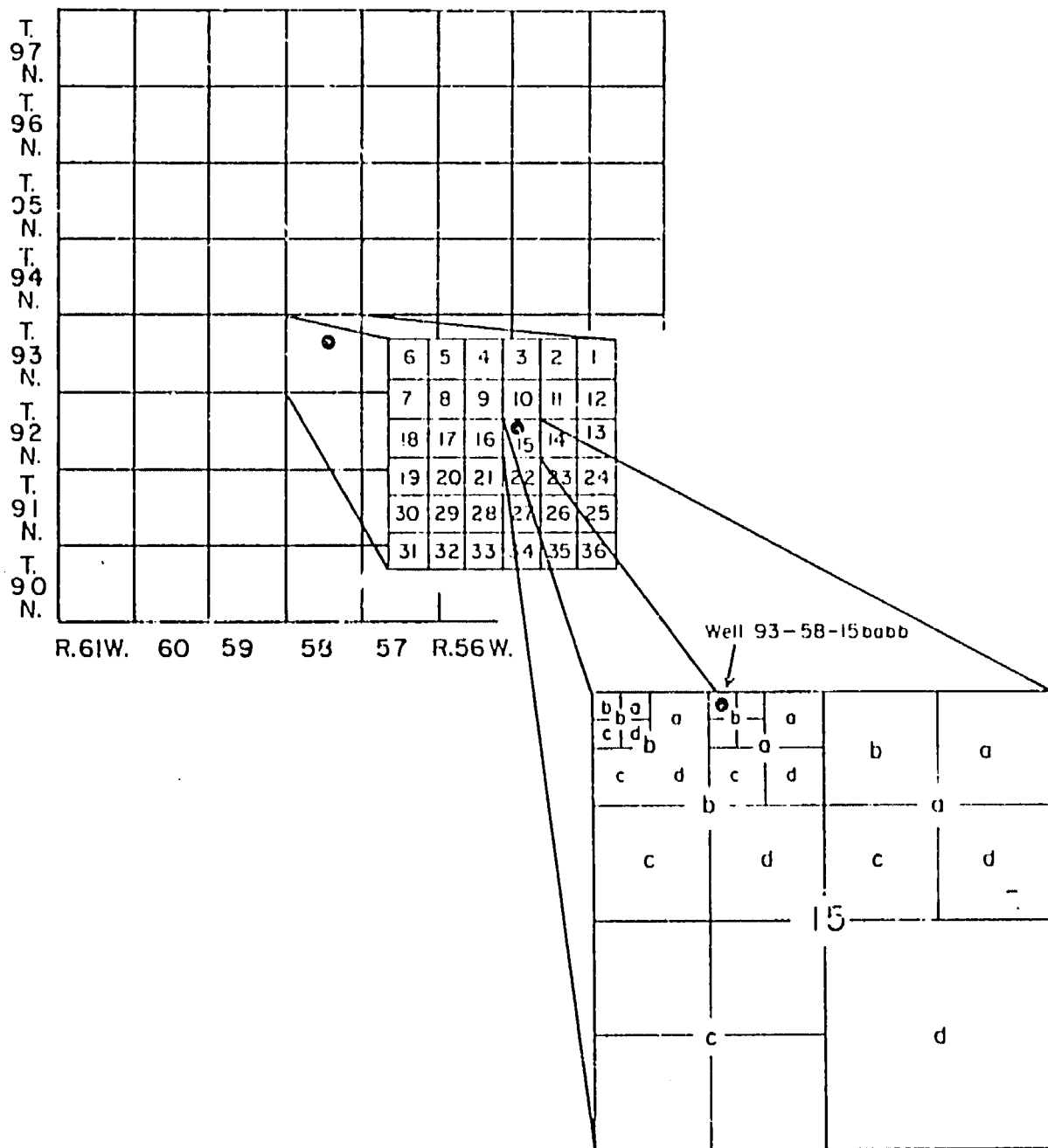


Figure 4. Diagram of well-numbering system.

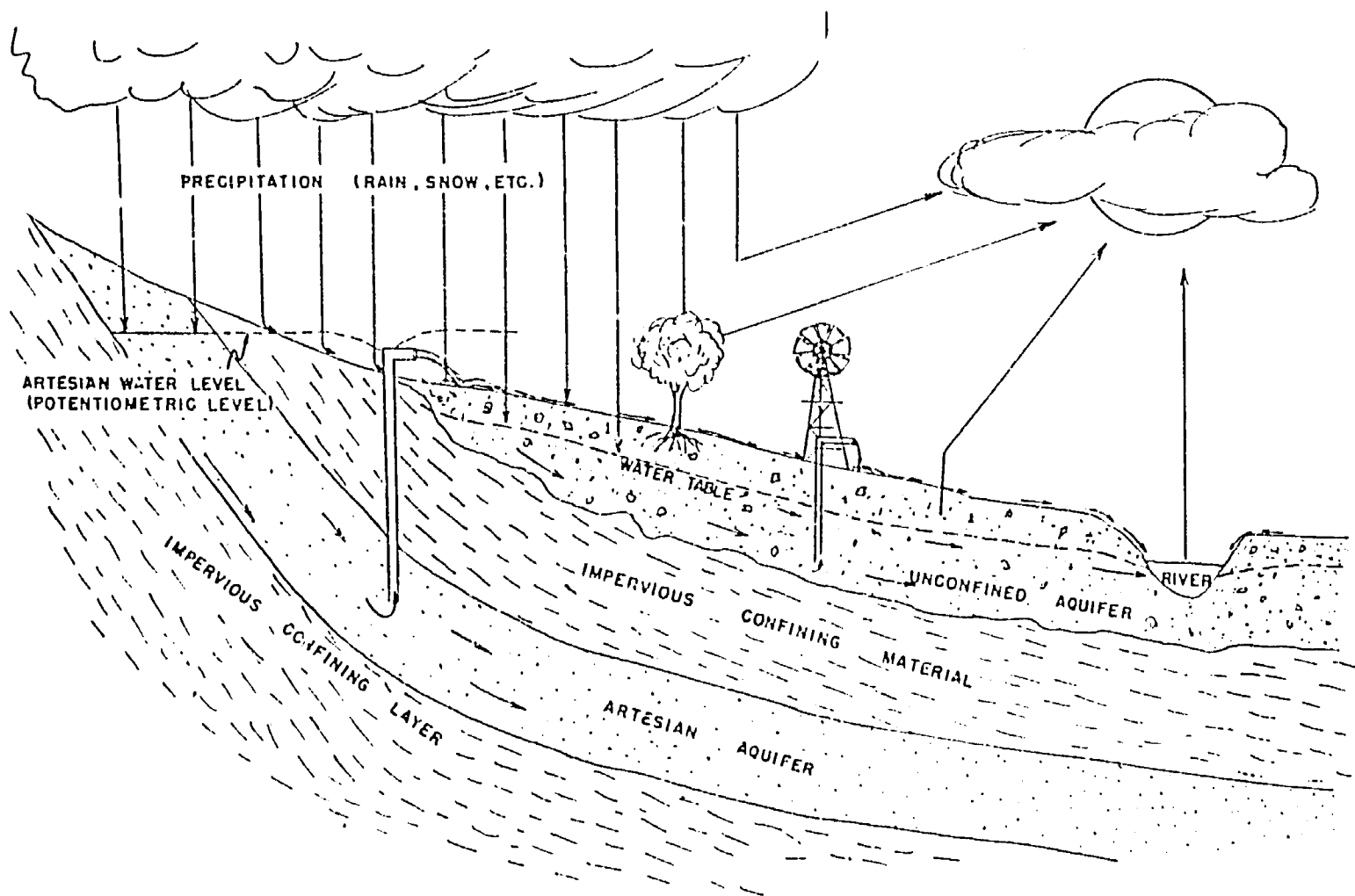
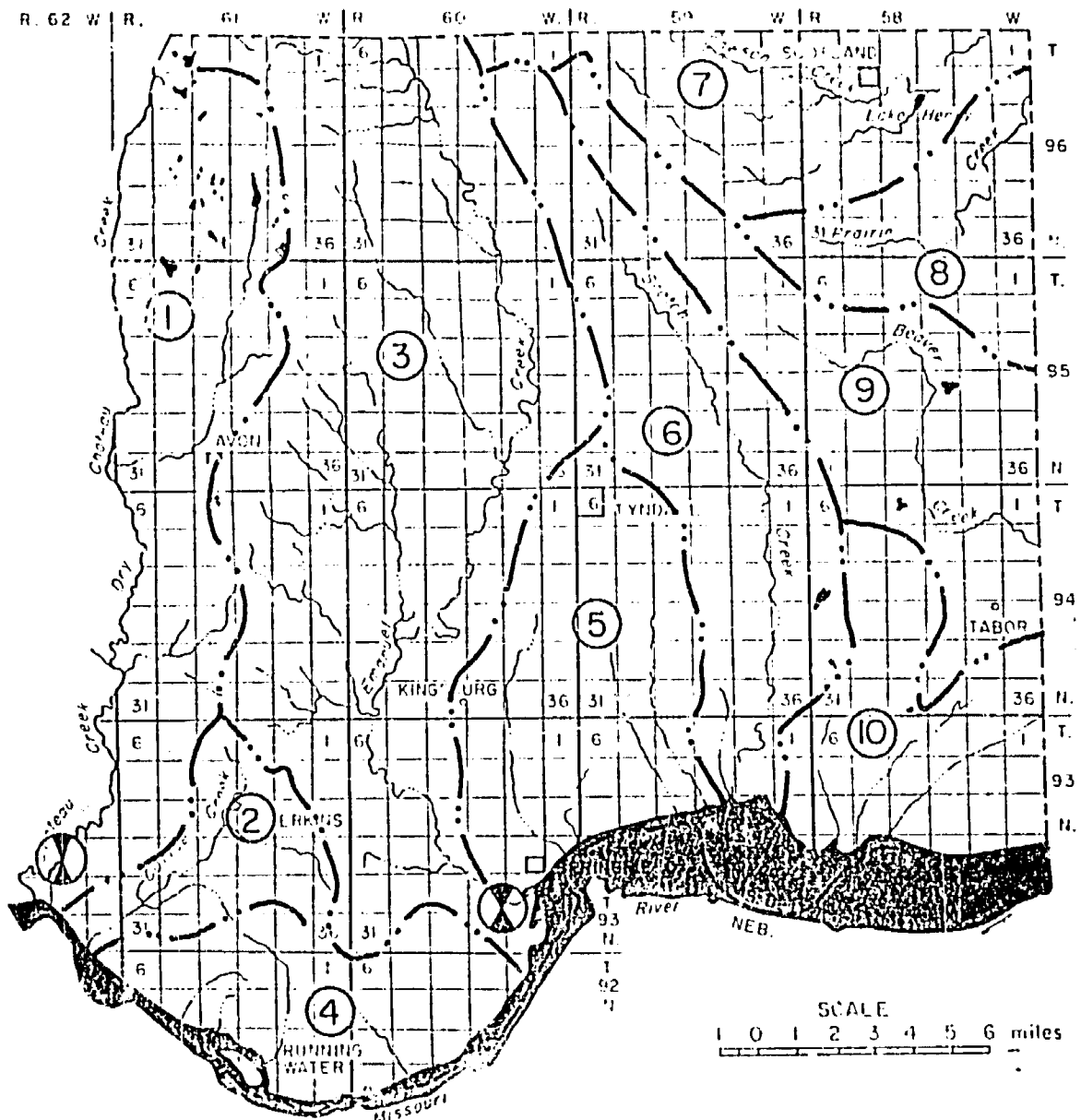


Figure 5 -- Simplified diagram of the hydrologic cycle



- ②
Drainage area identification number (see table 1).
- ⊗
Stream gaging station.
- — — — —
Drainage divide.

Figure 6. Map of drainage areas

Table 1.—Drainage areas

(See fig. 6)

Number	Name	Drainage area (sq mi)	
		Total	Bon Homme County
1	Choteau Creek	613	69½
2	Coffee Creek	19½	19½
3	Emanuel Creek	182	154
4	Unnamed	36	36
5	Unnamed	54	54
6	Snatch Creek	63	63
7	Dawson Creek	76	44½
8	Prairie Creek	39	30
9	Beaver Creek	146	57
10	Unnamed	42½	42½

has a 2 percent chance of occurring in any year. One flood-frequency curve (fig. 7) relates the size of the drainage area to the mean annual flood. Mean annual flood for a gaging station is, by definition, the 2.33-year flood from the graphic-frequency curve defined by points which are referred to the same base-time period. Other flood-frequency curve (fig. 8) shows the relation between the ratio of discharge to mean annual flood and the recurrence interval.

Procedure for using these curves in determining the discharge of a 10-year flood at the mouth of Snatch Creek is as follows:

1. Determine the size of the drainage area. (Snatch Creek has a drainage area of 63 sq mi.)
2. Determine the discharge in cubic feet per second (cfs) of the mean annual flood for this size drainage area from figure 7. (The discharge for the mean annual flood for 63 sq mi is 620 cfs.)
3. Determine the ratio of the flood of the selected recurrence interval to the mean annual flood from figure 8. (The ratio for a flood with a 10-year recurrence interval to the mean annual flood is 2.7.)
4. Multiply the discharge obtained from the mean annual flood curve (fig. 7) by the ratio obtained from the frequency curve (fig. 8) to obtain the discharge of the flood in cubic feet per second. (The discharge of the 10-year flood at the mouth of Snatch Creek is 620 times 2.7, which is 1,670 cfs.)

Another useful runoff characteristic is the total annual runoff in acre-feet that can be expected. An acre-foot is a unit for measuring volume of water, and is equal to the quantity of water required to cover 1 acre to a depth of 1 foot (43,560 cubic feet). The probability that annual runoff in acre-feet per square mile (acre-ft per sq mi) will equal or exceed the stated amount is given below:

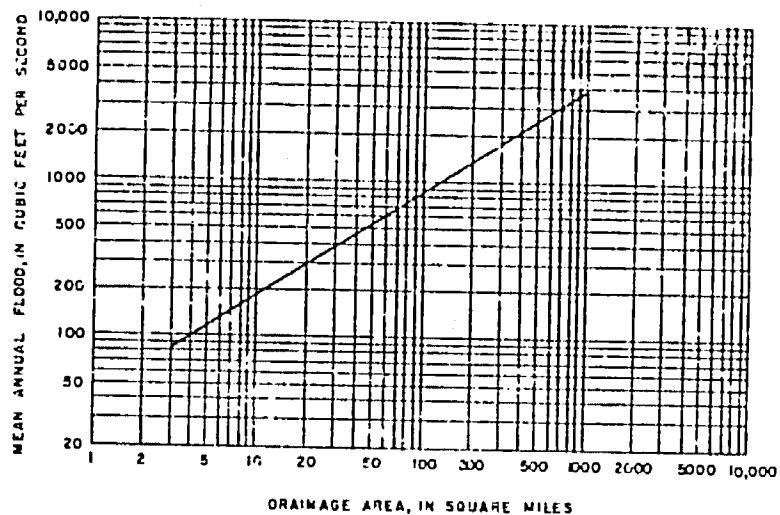


Figure 7. --Variation of mean annual flood with drainage area (after Patterson, 1966)

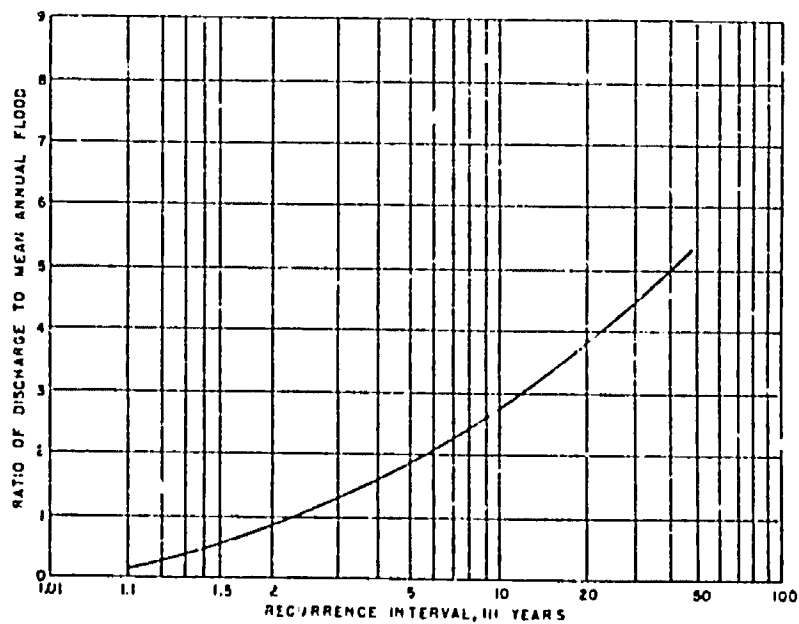


Figure 8.-- Variation of flood discharge with recurrence interval (after Patterson, 1965)

Probability (percent)	Runoff (acre-ft per sq mi)
10	200
25	100
50	60
75	30
90	20

Average runoff is 80 acre-ft per sq mi which is considerably larger than the 50 percent probability of 60 acre-ft per sq mi annual runoff. To determine the annual runoff for any probability, multiply the runoff figure listed above by the drainage area. For example, to determine the annual runoff that will be equaled or exceeded 10 percent of the time for Emanuel Creek, multiply the drainage area of 182 sq mi, as listed in table 1, by 200 acre-ft per sq mi, as listed above, thus obtaining a value of 36,400 acre-ft.

Missouri River

The Missouri River is the largest stream in the area. Discharge of the Missouri River has been measured below Fort Randall Dam since 1947. Flow had been regulated by Fort Peck Dam in Montana prior to 1952 and by Fort Randall Dam thereafter. Average discharge for the period of record (U. S. Geological Survey, 1968) is 22,890 cfs. Maximum discharge during the period of record was 447,000 cfs on April 12, 1952. Water, other than that from Lewis and Clark Lake, is unused in Bon Homme County.

Choteau Creek

Choteau Creek drains 613 sq mi in Davison, Aurora, Douglas, Charles Mix, and Bon Homme Counties. The 69.5 sq mi part of the drainage area in Bon Homme County consists of dissected till plains and a well-defined flood plain along the lower reaches of Choteau Creek. A gaging station was established for this study at 93-62-23bdd to determine amount of flow in the creek. Monthly mean discharges are listed in table 2. The maximum peak discharge for the period May 16, 1966 to October 31, 1968 was 3,140 cfs (gage height, 9.11 ft) at 1200 hours on June 19, 1967. The minimum discharge for the same period was 0.60 cfs on September 5, 1966. It is believed that the flood on June 19, 1967, has been exceeded only once in the last 20 years. A flood at a gage height of about 11 feet occurred in March 1962. Base flow of Choteau Creek is ground water derived from the Choteau aquifer.

Water is unused except as stock water in a few small dugouts and small stock dams.

Table 2.—Monthly mean discharge of Choteau Creek
(units of discharge are cfs)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1966									6.44	1.84	1.34	0.72
1967	1.08	1.68	1.8	2.28	2.36	3.14	2.61	2.54	180	27.2	64.5	3.50
1968	2.61	1.87	2.21	2.11	2.35	2.35	4.03	1.31	1.43	6.32	1.76	8.88

Emanuel Creek

Emanuel Creek has a drainage area of 182 sq mi, 154 of which is in Bon Homme County. The creek, which drains an area of till plains, flows into Lewis and Clark Lake. Its lower

reaches are characterized by a small but well-defined flood plain. A gaging station was established for this study at 93-60-27dbb. Monthly mean discharges are listed in table 3. Source of base flow is springs that discharge water from the Tyndall-Scotland and Niobrara aquifers.

Maximum discharge for the period May 16, 1966, to October 31, 1967, was 1,590 cfs (gage height, 7.11 ft) on June 19, 1967, at 14:45 hours. Minimum discharge for the same period was 1.16 cfs on September 12, 1966. Several floods have been observed by local residents in the last 20 years at crests 2 to 3 feet above the peak recorded on June 19, 1967.

Water is unused except as stockwater in a few small dugouts and stock dams.

Table 3.—Monthly mean discharge of Emanuel Creek
(units of discharge are cfs)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1966									3.59	1.66	1.97	1.50
1967	2.26	2.72	3.00	3.18	3.32	4.06	3.06	3.01	125	9.13	7.33	2.24

Lewis and Clark Lake

Lewis and Clark Lake is formed by Gavins Point Dam, which is on the Missouri River 7½ miles east of the southeast corner of the county. Storage began in July 1955. Normal maximum capacity below altitude 1,208.0 ft is 477,000 acre-ft. Water is used primarily for downstream navigation, recreation, power, and flood control. Four residents in the county have used the water for irrigation. The city of Springfield used an estimated 207 acre-ft of this water for domestic purposes in 1963.

Lake Henry

Lake Henry is formed by impoundment of water behind a small dam located on Dawson Creek at 96-58-9. The lake is used for recreation.

Other Surface-Water Bodies

There are many small lakes and ponds in the county. Most of the lakes are less than 4 feet deep, and commonly dry up during periods of drought. These lake areas are a habitat for wildlife, but are not otherwise used. The many small dams and dugouts in and along the creeks have little storage and do not hold water permanently.

Ground Water

Definitions

Ground water is that water which occurs beneath the surface of the ground in the saturated zone. The ground is said to be saturated when all the voids are filled with water. A soil or rock material that yields water to wells or springs at a sufficient rate to be used as a water supply is called an aquifer. If ground water is confined it is said to be under artesian conditions. If ground water is only under atmospheric pressure, it is unconfined, or it is said to be under water-table conditions. Artesian and water-table conditions are shown graphically in figure 5.

The level to which water will rise in a well is termed the potentiometric level. The potentiometric level is the water surface at atmospheric pressure. For water-table conditions, this surface (water table) is within the aquifer; whereas, for artesian conditions it is an imaginary surface above the aquifer. The shape of the water table or potentiometric

surface is the configuration of water surface slopes resulting from water movement between areas of recharge (water entering the aquifer) and areas of discharge (water leaving the aquifer).

Porosity is the ratio of the volume of voids to the total volume of a rock or rock material. The greater the porosity of an aquifer, the larger the amount of water that can be stored in the aquifer. The amount of water that can be drained from a unit volume of aquifer material by gravity is called its specific yield. However, not all of the water will drain by natural gravitational force because some water adheres to the pore walls; the quantity of water per unit volume retained in this manner is termed its specific retention. Therefore, specific retention plus specific yield is equal to the effective porosity of a saturated material.

Storage coefficient (S) is the volume of water that an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. For an unconfined aquifer, the value of S is the same as its specific yield. Typical storage coefficient values range from 0.1 to 0.3 for unconfined aquifers and from 0.0005 to 0.005 for confined aquifers.

Hydraulic conductivity (K), expressed in terms of feet per day (ft per day), represents the rate at which water will pass through an area of 1 square foot of water-bearing material at unit head. Rate of water movement through a material may also be discussed in terms of permeability (P) expressed in gallons per day per square foot (gpd per ft²) at unit head. The relation between hydraulic conductivity in feet per day and permeability in gallons per day per square foot is $P=0.134K$.

Transmissivity (T) is an expression of the water transmitting capability of the entire thickness of an aquifer. It is equal to the average hydraulic conductivity times the aquifer thickness. Transmissivity of an aquifer can be expressed in units of square feet per day (ft² per day) or in units of volume such as gallons per day per foot (gpd per ft). Transmissivity values in square feet per day are converted to values in gallons per day per foot by multiplying by 7.48.

Well yield is a function of transmissivity; other factors being equal, the larger the transmissivity the larger the yield. If an aquifer has uniform permeability, a well constructed in the portion of the aquifer that has the largest saturated thickness will produce the most water.

To describe an aquifer in any detail it is necessary to determine its size, thickness, amount of water in storage, and hydraulic conductivity. A water-level map or map of the potentiometric surface is important because it describes the altitude of the water surface at a particular time and place. The water-level or potentiometric map, together with hydrographs of the water level in particular wells, are very useful in defining areas and types of recharge and discharge for the aquifer.

Alluvial Aquifers

Stream-deposited sediment (alluvium) is found along stream channels in the county. Most alluvium consists of silty clay, clayey silt, and some sand. Figure 2 shows the location and extent of alluvial deposits in Bon Homme County. Alluvial deposits have low permeabilities and do not yield water rapidly. Thus, small yields of 3 to 10 gpm (gallons per minute) are normally obtained from wells finished in the alluvium. One gpm approximately equals 1/449 cfs.

Recharge to the alluvial aquifers is by infiltration of precipitation, seepage from streams, and subsurface inflow; discharge is by evapotranspiration, seepage to streams, and subsurface outflow. The aquifers are of minor importance to the county as only 5 to 10 stock wells are finished in them.

Till Aquifer

Till is an unstratified heterogeneous deposit of glacial debris consisting of clay and silt with some sand, gravel, and cobbles. It is the predominant surficial deposit in the county (fig. 2) and underlies most of the surficial alluvial and glacial outwash deposits. In Bon Homme County, till has a low permeability and is a poor aquifer because it yields water

slowly. Recharge to the till is from precipitation, and discharge is by evapotranspiration, subsurface outflow into more permeable aquifers, and pumping.

Figure 9 shows that water levels in the till have not changed appreciably since 1936. In constructing this graph, water levels measured during the 4th quarter of the calendar year were plotted. Water levels at this time of year are more stable and are the best indication of long-term water-level changes. Most of the long-term changes in water level are the result of long-term weather variations; that is, a greater depth to water is the result of drought conditions; a lesser depth is the result of "wet" conditions.

Figure 10 shows the seasonal water-level fluctuation. The rise of the water level in May 1967 occurred when the ground frost melted and allowed snowmelt and rain to recharge the aquifer. The rise of the water level in July 1967 was the result of infiltration of rainwater to the saturated zone. Declining water levels resulted from the loss of water by evapotranspiration, by drainage to other deposits, and by pumping.

The till aquifer is used extensively as a stock-water source because wells drilled at almost any location will yield from 1 to 5 gpm. In 1968, the 150 wells producing from the till furnished an estimated 180 acre-ft of water.

Shallow Outwash Aquifers

Sand and gravel deposited by glacial melt water is called outwash. Most outwash deposits are porous and permeable and, therefore, are good aquifers if they have sufficient saturated thickness. Shallow outwash deposits are present below the thin alluvial cover along Dawson, Prairie, Snatch, Emanuel, and Dry Choteau Creeks (fig. 2). These aquifers do not have adequate saturated thickness to yield large volumes of water. Even though yields are low, more than 50 shallow wells, which produce 1 to 10 gpm, have been constructed. These wells in 1968 withdrew an estimated 65 acre-ft of water, most of which was used by livestock.

Choteau Aquifer

Those glacial outwash sand and gravel deposits (fig. 11), which underlie the surficial alluvium along Choteau Creek and extend eastward beneath the surficial till layer, are collectively termed the Choteau aquifer. The aquifer has a 32-sq mi area within the county, and a much larger areal extent in adjacent counties. Maximum known thickness is 170 feet at 94-61-19adec. About 10 sq mi of the aquifer, as shown in figure 11, has a saturated thickness of 50 feet or more.

A 12-hour aquifer test at the site of well 94-16-19cccc indicated a transmissivity of 200,000 gpd per ft and an estimated storage coefficient of 0.2.

Recharge to the aquifer is by subsurface inflow, direct precipitation, seepage from Choteau Creek and Dry Choteau Creek, and percolation through the till cover. Limited water-level observations indicate water movement is from Choteau Creek toward Emanuel Creek. Water-level maps of the Niobrara and Codell aquifers, which are contiguous with the Choteau aquifer, indicate that there is little or no water movement between these aquifers within Bon Homme County.

Figure 12 shows the rise of water level in well 94-61-19cccc due to seepage from Dry Choteau Creek. The abrupt rise of the water table in June and July 1967 is largely the result of water seepage from Dry Choteau Creek. Lowering of the water table during the first half of August mostly results from spreading of the ground-water mound that was built up during the time when the aquifer was being recharged.

Natural discharge from the aquifer is by subsurface outflow, evapotranspiration, and loss to Choteau and Dry Choteau Creek. In 1968 the water stored in the Bon Homme County part of the aquifer was estimated to be 120,000 acre-ft. Only 20 to 30 wells, which in 1968 withdrew an estimated 28 acre-ft of water, are finished in the aquifer. Properly constructed wells in the area with the greatest saturated thickness as shown in figure 11 should produce water at rates exceeding 450 gpm.

Hubonnix Aquifer

The Hubonnix aquifer of silty sand and gravel is located in the northwest corner of the

county. This aquifer has an area of about 26 sq mi; however, its exact extent is poorly defined. The outwash deposit is normally 10 to 30 feet thick and is overlain by as much as 200 feet of till. Maximum known thickness is 53 feet at well 96-60-5bbbc.

Only a few domestic and stock wells are finished in the aquifer; many wells extend through the outwash to the deeper Codell aquifer. Properly constructed wells at locations with more than 50 feet of saturated sand and gravel should produce water at rates in excess of 100 gpm. At certain locations, wells that tap the aquifer flow. Figure 13 shows the known area and the potentiometric surface of the aquifer.

Tyndall-Scotland Aquifer

The Tyndall-Scotland aquifer is an outwash deposit of sand and sands and gravels that partly fills a preglacial valley extending generally northward from about 3 miles northwest of Springfield to west of Tyndall, then eastward and northeastward out of the county east of Scotland (fig. 14). This outwash is the most extensive in the county. The aquifer underlies an area of 90 sq mi within the county and includes an area of 25 sq mi with a saturated thickness greater than 50 feet. (See fig. 14.) The outwash is buried beneath the till, except for a small area where it is overlain by surficial alluvium along Emanuel Creek (fig. 2) where it crops out.

Water in the aquifer is under artesian conditions at most places; however, water-table conditions exist locally. Rise of the water level in well 94-60-21bccc, which is located about 300 feet from Emanuel Creek, indicates that recharge takes place when there is flow in Emanuel Creek. (See fig. 15.) The effect of recharge is so pronounced at this location that it suggests the possibility of artificially recharging the aquifer by water-spreading methods. Most recharge is by percolation of water through the overlying till or alluvium. Possibly some recharge is by underflow from bedrock aquifers at some of the locations where they are in contact with the Tyndall-Scotland aquifer.

The Tyndall municipal well (94-60-21accc) can produce more than 700 gpm and has a specific capacity of 22 gpm per ft of drawdown after 72 hours of continuous pumping. An aquifer test made by pumping this well indicates a transmissivity of 210,000 gpd per ft and a storage coefficient of 0.2. A test hole at the site penetrated 130 feet of saturated material; thus, the average hydraulic conductivity is 216 ft per day (1,600 gpm per ft²). gpd

A 12-hour aquifer test at well 94-60-20decd indicated a transmissivity of 20,500 gpd per ft. Relatively low transmissivity at this site as compared to the transmissivity at well 94-60-21accc is due to a decrease in saturated thickness.

Areas underlain by more than 50 feet of saturated aquifer material are shown in figure 14. These areas offer the most promising sites for properly constructed wells that might produce from 100 to 900 gpm.

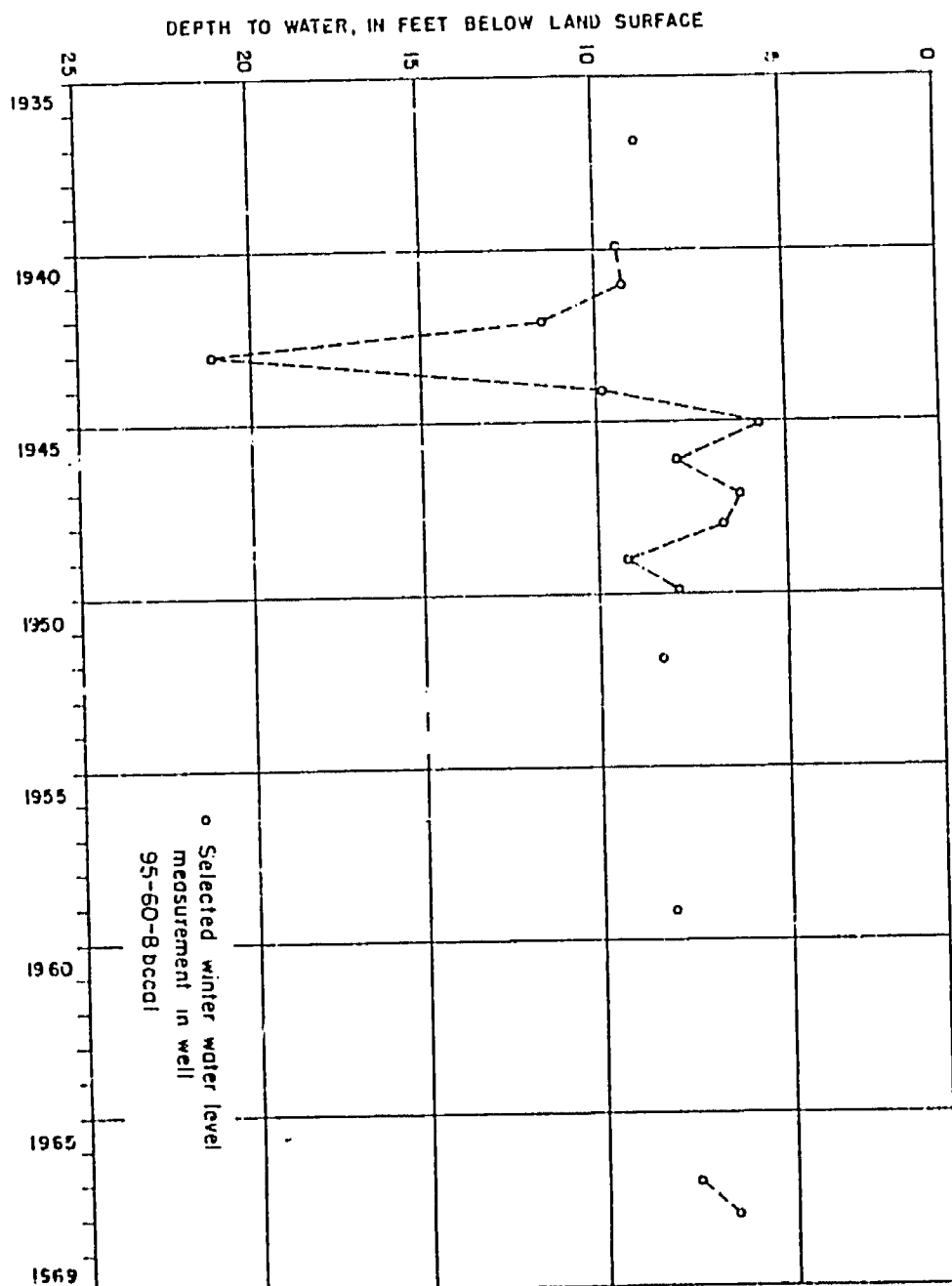
Discharge from the aquifer is largely from springs in the outcrop area along the lower reaches of Emanuel Creek as shown in figure 16. This discharge constitutes most of the base flow at the Emanuel Creek gaging station at 93-60-27d. Study of daily discharge records at this site indicates that the ground-water discharge from the outwash was approximately 3 cfs (1,000 gpm). Discharge is also by evapotranspiration, by pumping, and at certain locations by seepage into the contiguous bedrock aquifers. Discharge is also by subsurface flow out of the county near Scotland to the James River trench; such discharge occurs east of a ground-water divide 6 to 10 miles east of Tyndall. Some discharge is to the Niobrara and Codell aquifers; specifically this occurs 2 to 3 miles northeast of Tyndall and probably along a line between 94-60-4 to 95-59-28.

Pumpage in 1968 from the one municipal well and the 80 or more domestic wells in the aquifer was about 244 acre-feet, or only about 0.06 percent of the estimated 440,000 acre-feet of water stored in the aquifer within the county.

Niobrara Aquifer

The Niobrara Marl, locally called the "chalk rock," consists of nearly horizontal layers of calcareous shale, chalk, and chalky limestone. Thickness of the formation ranges from 0, where it has been completely removed by erosion, to about 205 feet in the northwest corner of the county.

Figure 9.-- Hydrograph showing annual changes of water level in a well tapping the till aquifer.



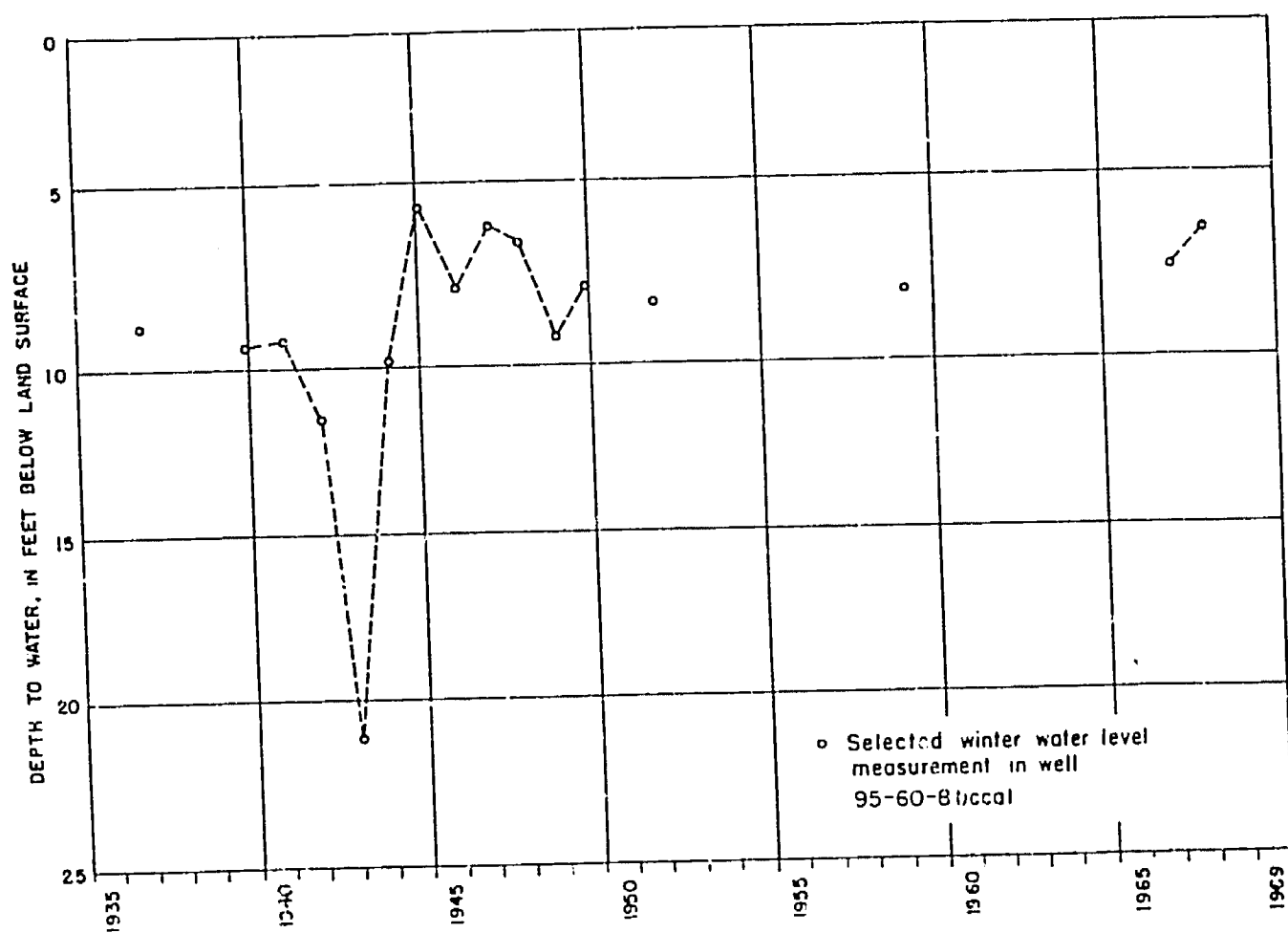


Figure 9.-- Hydrograph showing annual changes of water level in a well tapping the till aquifer.

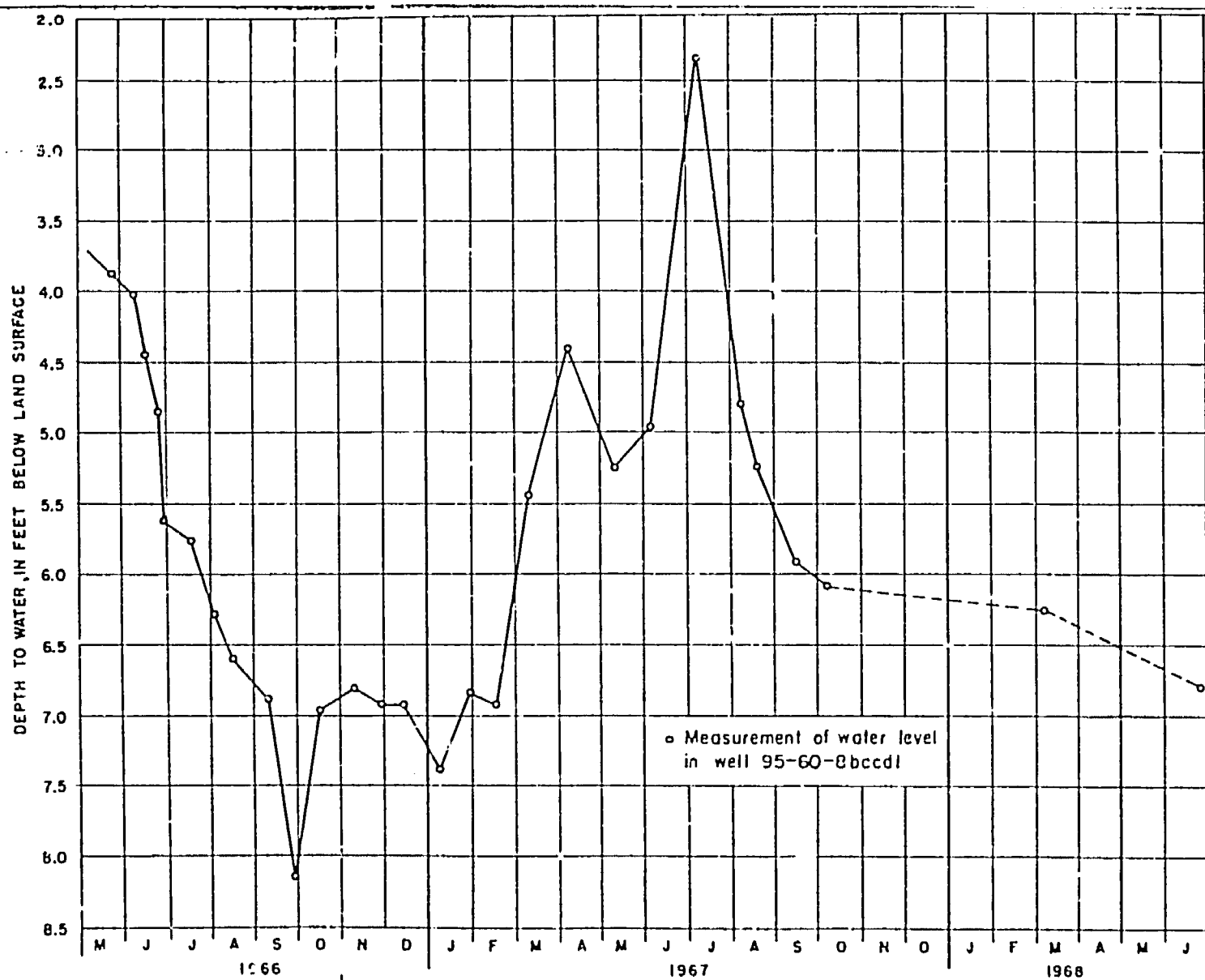


Figure 10. -- Hydrograph showing monthly changes of water level in a well tapping the till aquifer.



EXPLANATION

- Approximate aquifer boundary.
- Aquifer thickness greater than 50 feet.
- Aquifer thickness less than 50 feet.
- Location of observation well.

Figure II. Map showing areal extent and thickness of the Choteau aquifer.

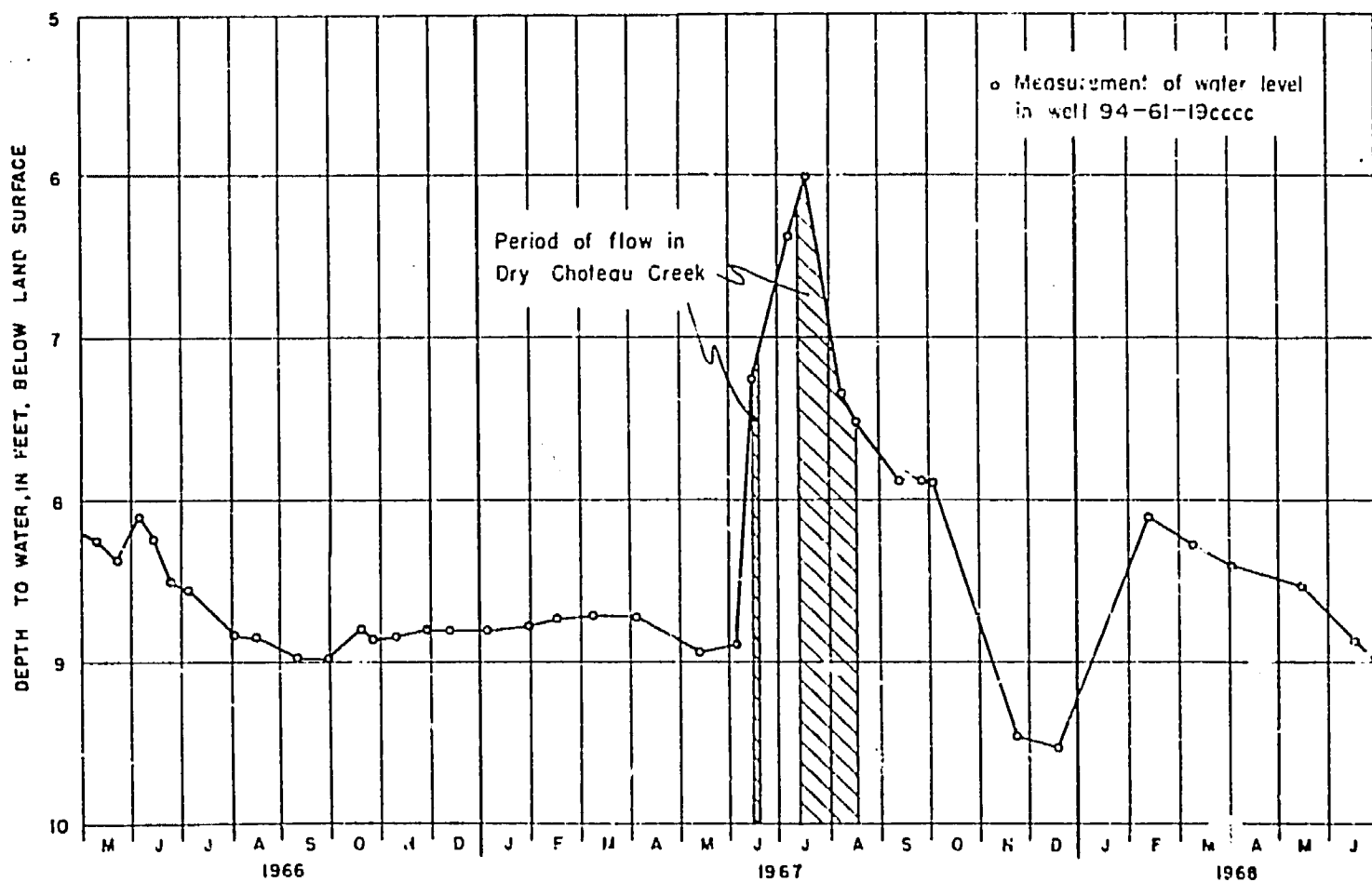
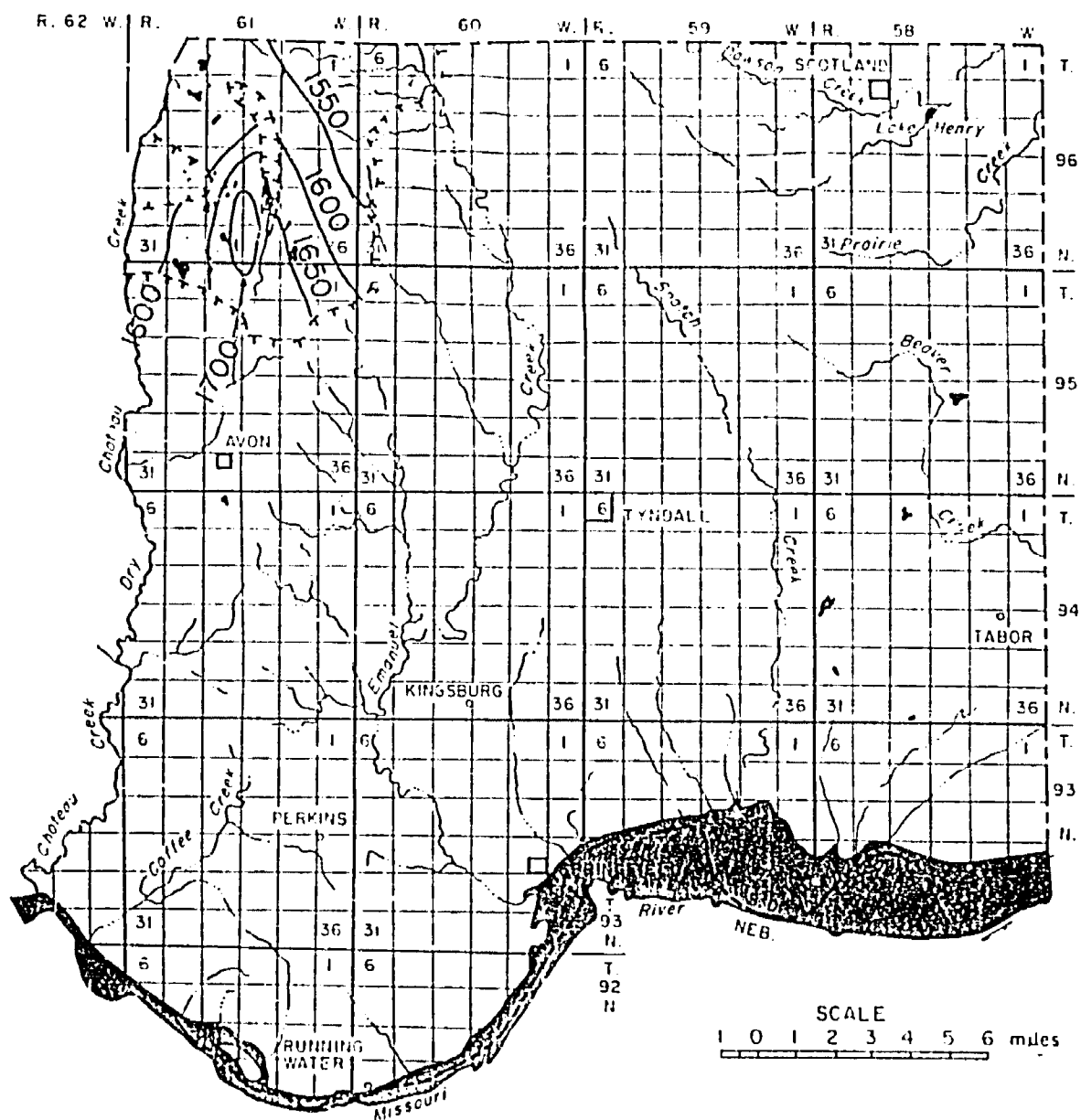


Figure 12. -- Hydrograph of water level in a well tapping the Choteau aquifer.



EXPLANATION

- Approximate aquifer boundary
- 1600 ----- Approximate potentiometric contour shows altitude of potentiometric surface 1966-67.
- Contour interval 50 feet.
- Datum is mean sea level.



Figure 13. Map showing areal extent and potentiometric contours of the Hubonmix aquifer.

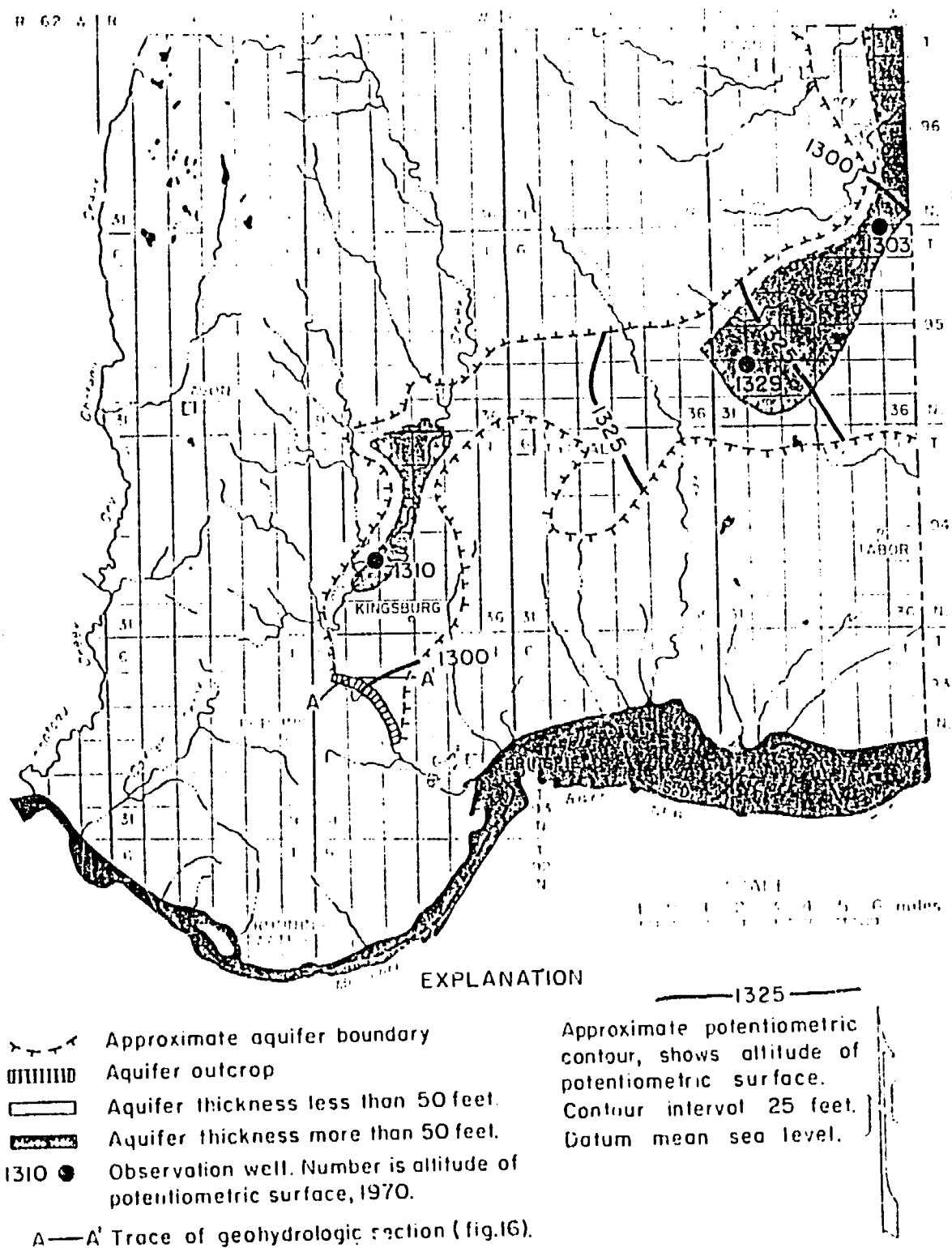


Figure 14. Map showing areal extent, thickness, and potentiometric contours of the Tyndall-Scotland aquifer.

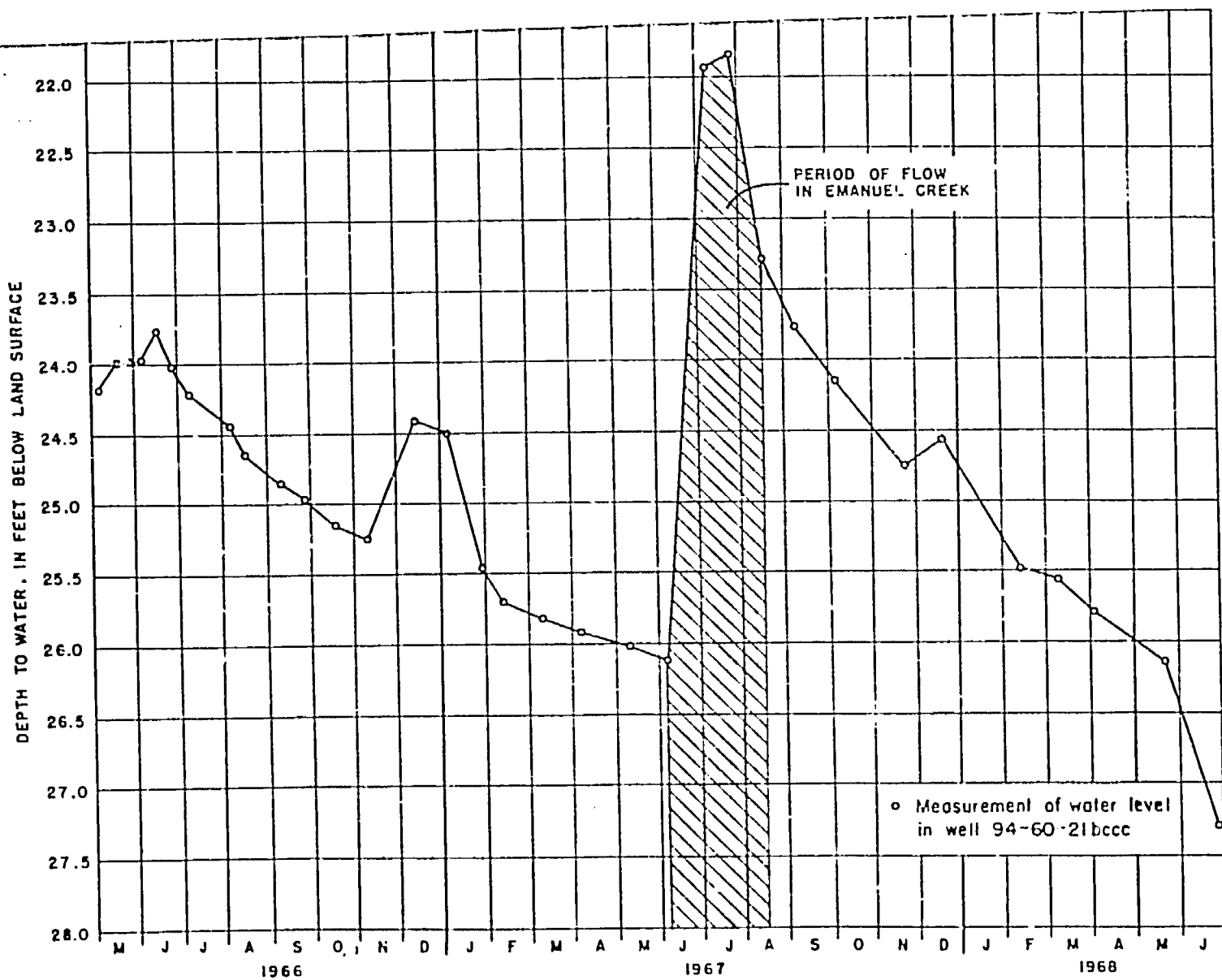


Figure 15 -- Hydrograph of water level in a well tapping the Tyndall-Scotland aquifer

Figure 16.-- Geohydrologic section of the Tyndall-Scotland aquifer.

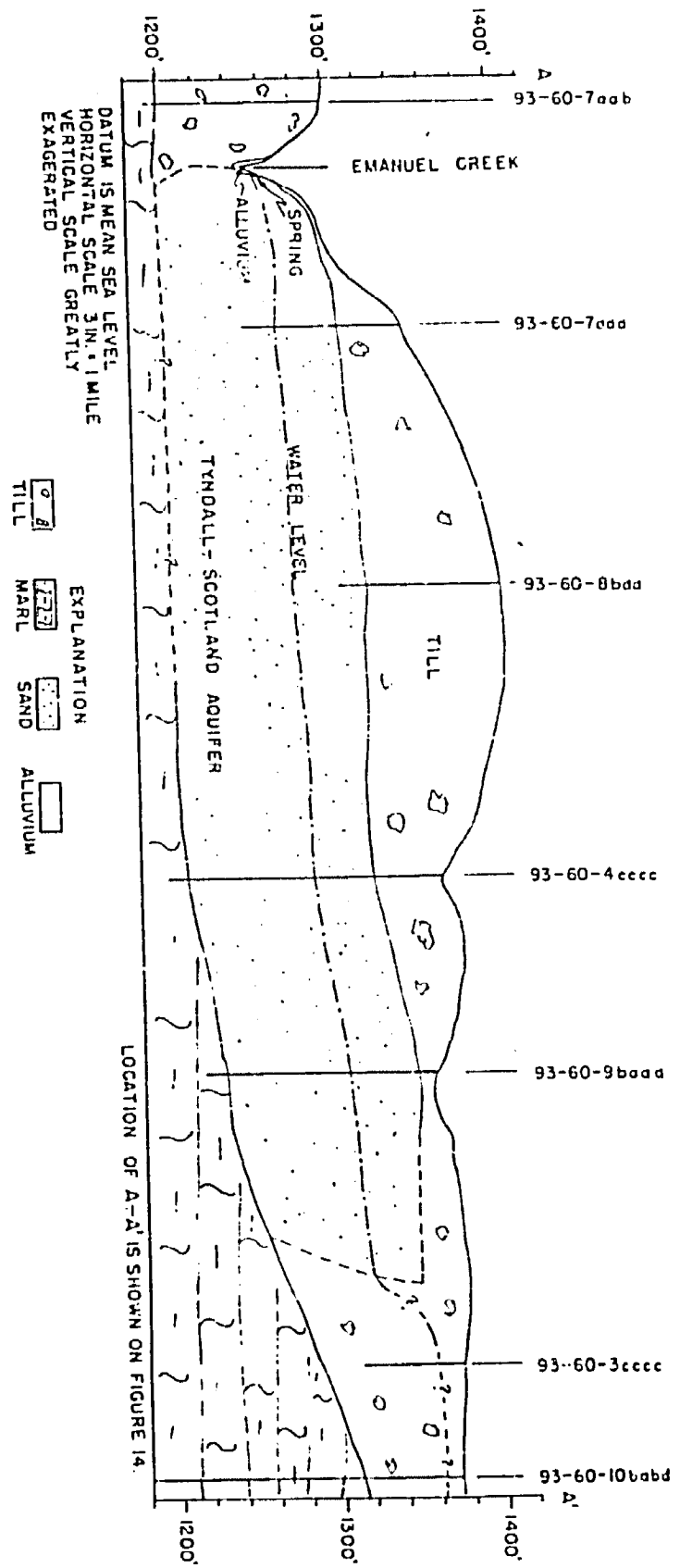


Figure 17 shows the altitude of the upper surface (top) of the Niobrara Marl. Depth to the top of the formation can be calculated by subtracting the altitude of the top of the formation from the altitude of the ground surface. For example, to determine the depth to the top of the Niobrara Marl at Perkins, subtract 1,200 feet from 1,451 feet (land-surface altitude). Thus at Perkins the top of the "chalk rock" is 251 feet below land surface.

In figure 18 the contours show the depth below ground level to the top of the formation. For example, the depth to the marl at Perkins is more than 200 feet but less than 300 feet. Either figure 17 or figure 18 can be used to estimate the depth to the top of the formation; however, if the altitude of the land surface is known, the calculated depth to the formation using data from figure 17 will probably be more accurate than the depth as shown in figure 18.

Water at some locations in the Niobrara aquifer is under artesian conditions; however, at most locations it is under water-table conditions.

Water levels measured in well 93-61-28cdac, as shown in figure 19, had only minor fluctuations during the period of measurement indicating nearly equal amounts of recharge and discharge.

Shape and altitude of the potentiometric surface and the direction of water flow are shown in figure 20. The figure also shows that the subsurface flow probably discharges from the aquifer near Scotland and that subsurface flow from the Tyndall-Scotland aquifer probably occurs in the area about 2 miles northeast of Tyndall. In addition figure 20 indicates that the Missouri River valley is the major discharge area. Many of the springs are in the bluffs of the Missouri River valley where water in the Niobrara aquifer emerges at the land surface.

Most recharge to the aquifer is by subsurface inflow and by percolation through the overlying till, outwash, or shale deposits.

Pumpage of water from municipal wells at Scotland and Tabor and an estimated 225 domestic and stock wells was about 438 acre-ft in 1968. Well yields range from 2 to 100 gpm. Maximum yield that can be obtained from this aquifer is unknown; however, it probably is in excess of 200 gpm and less than 700 gpm. In other counties, yields larger than 450 gpm have been obtained, but porosity, specific yield, and permeability vary so greatly that local values can be determined only by an aquifer test. However, test drilling indicates that, in general, the most favorable locations for the construction of wells that might produce more than 100 gpm are in areas where the depth from the land surface to the top of the aquifer is less than 100 feet.

Codell Aquifer

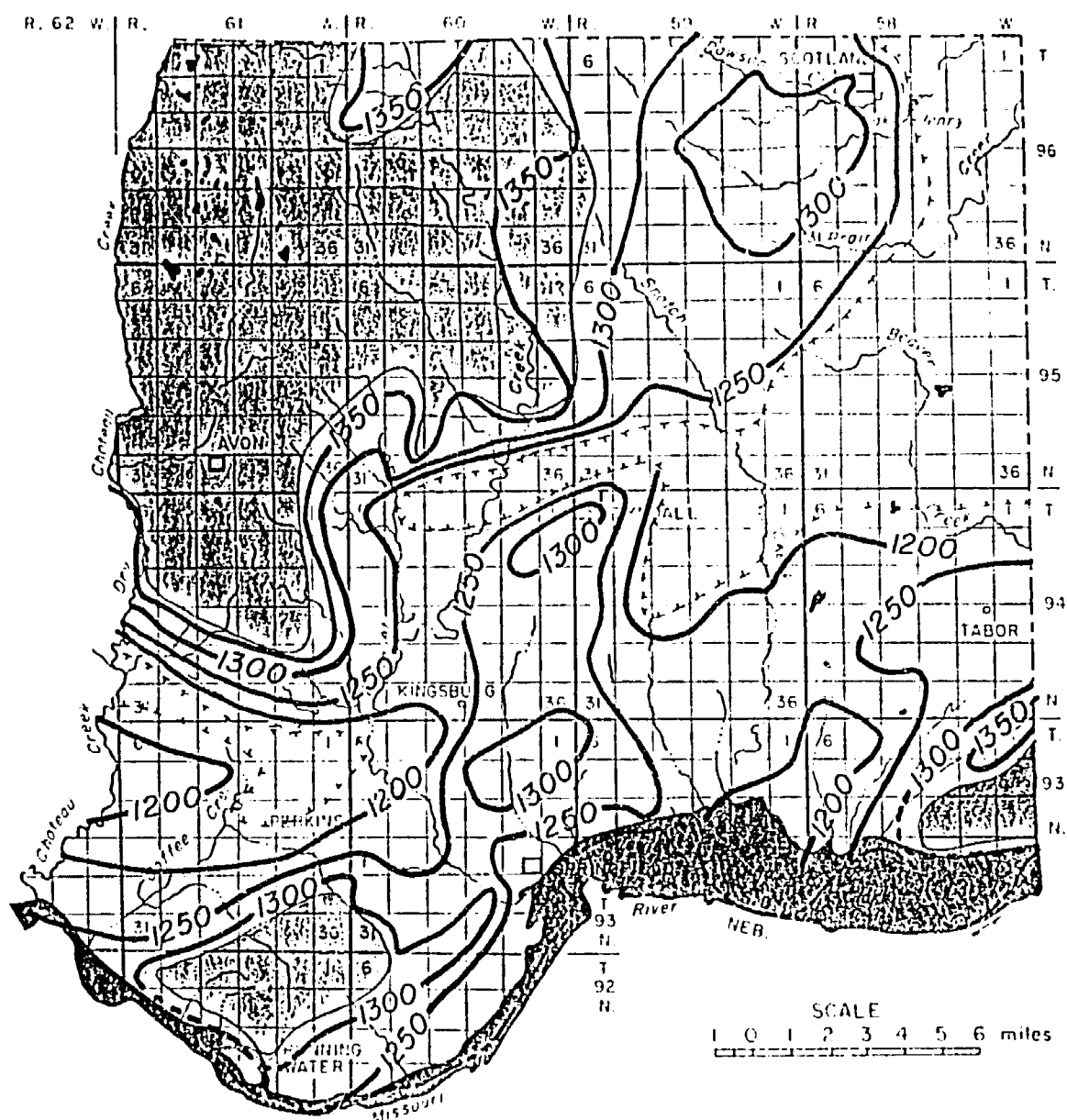
The Codell Sandstone Member of the Carlile Shale in Bon Homme County is siltstone to fine-grained sandstone. This unit is locally called the "soft-water sandstone" because it yields characteristically soft water. The aquifer is present in the subsurface of the entire county except for a part of the Tyndall-Scotland bedrock valley, where it has been removed by erosion (fig. 21). Where present, the sandstone is overlain by 5 to 30 feet of impermeable shale and underlain by 130 to 160 feet of nearly impermeable shale. The sandstone layer ranges in thickness from 0 to 100 feet and is commonly about 25 feet thick.

Depth below land surface to the top of the aquifer ranges from approximately 100 to 900 feet. Figure 22 shows the altitude of the upper surface of the sandstone. Either figure 21 or figure 22 may be used to estimate the depth to the aquifer.

The sandstone is saturated and the water is under artesian conditions. Hydrograph of the water level in well 93-61-15ddbb (fig. 23) shows neither a continuous rising nor a continuous declining trend. Fluctuations were less than 1 foot in magnitude during this period of record, indicating that the rates of recharge and discharge were uniform and nearly equal.

Discharge from the aquifer is largely by well pumpage and by subsurface outflow to the Missouri River trench. Discharge by subsurface outflow to the Tyndall-Scotland aquifer may also occur north of a possible ground-water divide in the Tyndall-Scotland aquifer east of Tyndall.

Recharge is mostly by subsurface inflow from outside the county. Some recharge is from



EXPLANATION

----- Approximate aquifer boundary.

 Formation not eroded.

 Formation partly eroded.

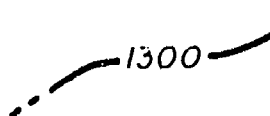
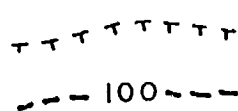
 1300 — Structure contour, shows altitude of top of Niobrara Marl. Dashed where approximately located. Contour interval 50 feet. Datum is mean sea level.

Figure 17. Map showing areal extent and altitude of the upper surface of the Niobrara Marl.



Approximate aquifer boundary.

Line of equal approximate depth to top of Niobrara Marl.

Contour interval 100 feet.

Datum is land surface.

Figure 18. Map showing depth to the Niobrara Marl.

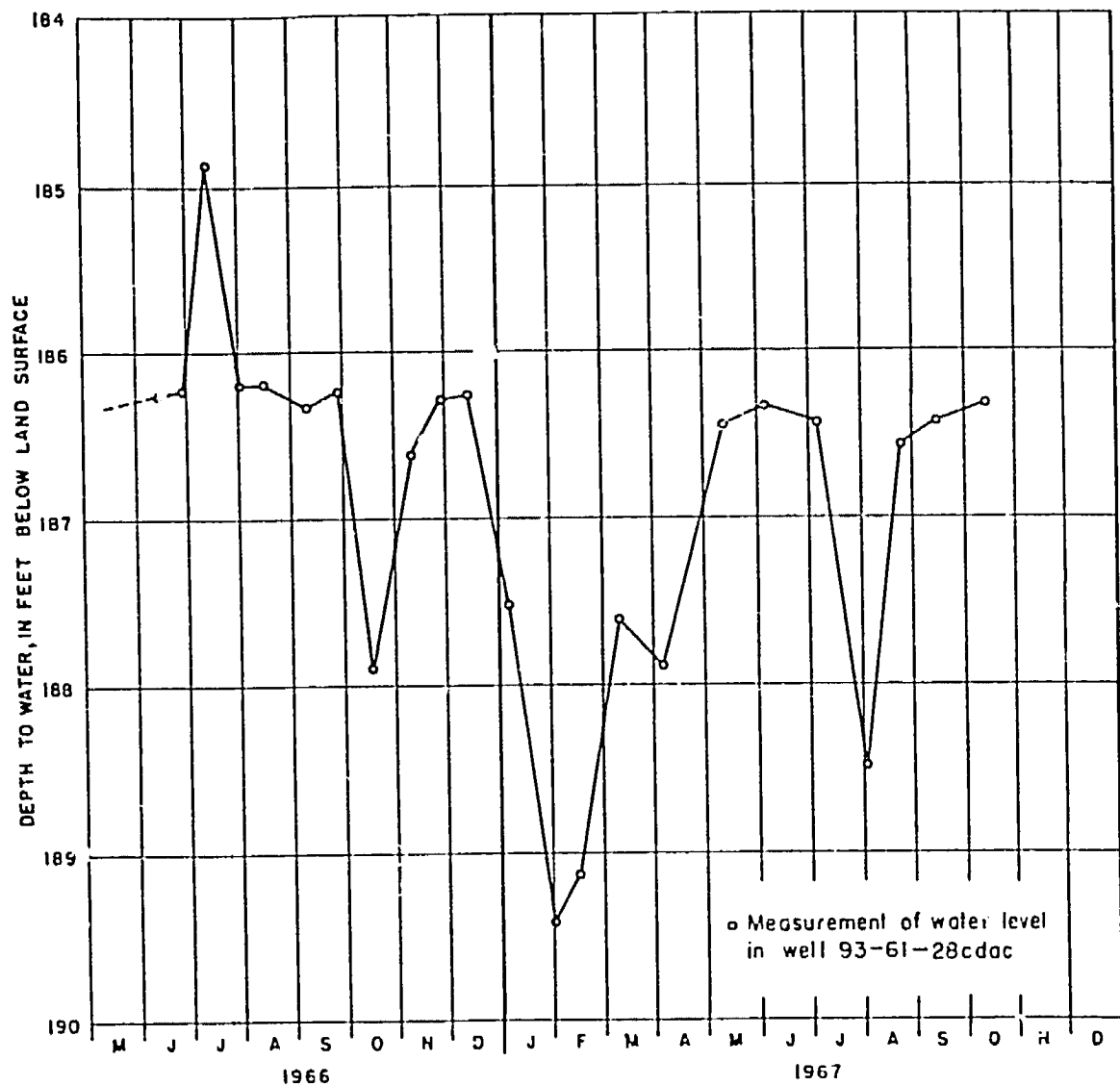
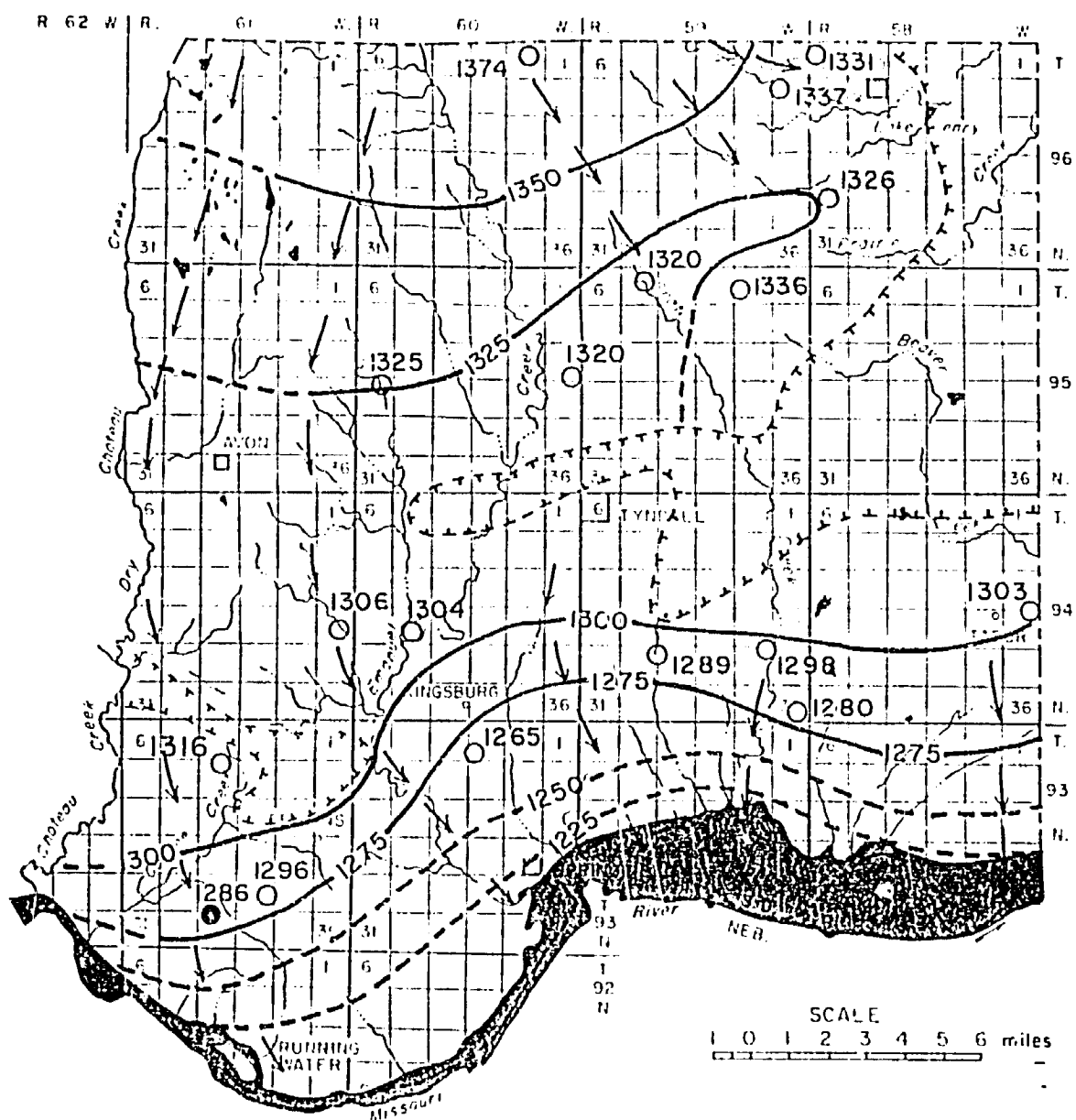
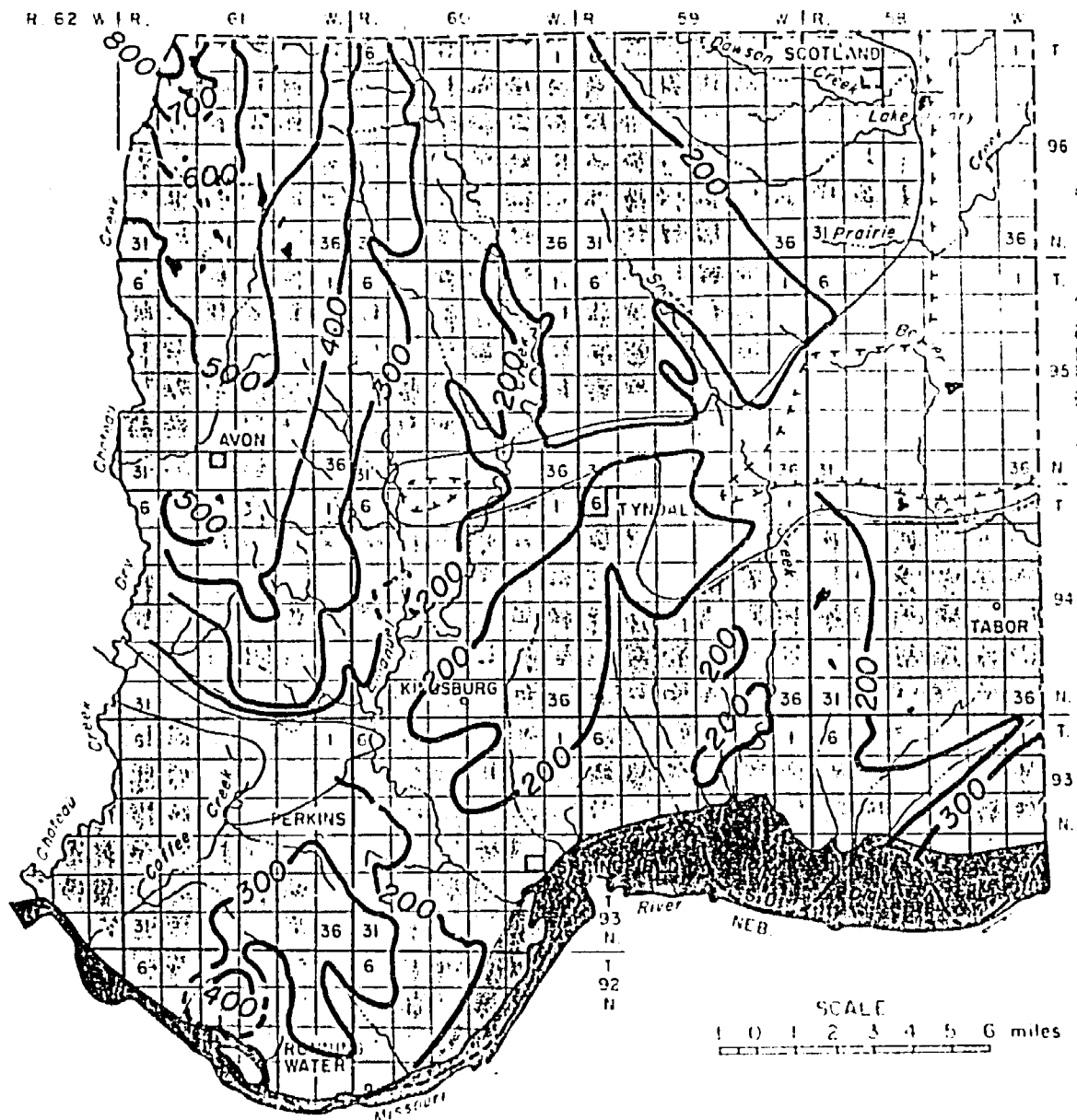


Figure 19 -- Hydrograph of the water level in a well tapping the Niobrara aquifer.



- Approximate aquifer boundary
- 1325 — Potentiometric contour shows altitude of potentiometric surface. Dashed where approximately located. Contour interval 25 feet. Datum mean sea level.
- 1374 Well
- 1286 Observation well
- Number is altitude of potentiometric surface in 1966-67.
- → → Direction of water movement.

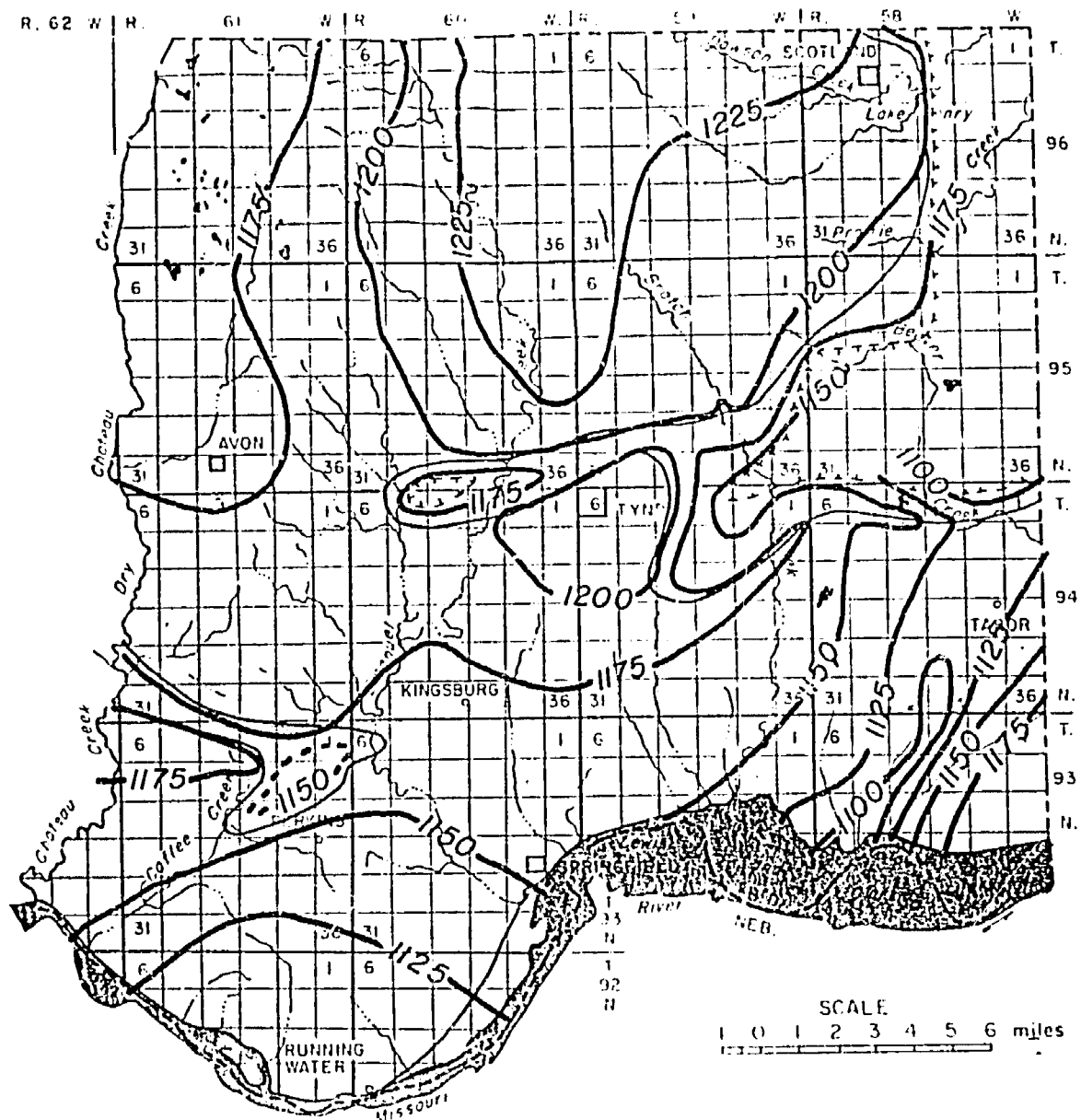
Figure 20. Map showing potentiometric contours of the Niobrara aquifer.



EXPLANATION

- Approximate aquifer boundary.
- Aquifer partly eroded.
- Aquifer not eroded.
- 300 — Line of equal depth to top of Codell aquifer
Dashed where approximately located. Contour interval 100 feet. Datum is mean sea level.

Figure 21. Map showing depth to the Codell aquifer.



EXPLANATION

- Approximate aquifer boundary.
- Aquifer partly eroded.
- Aquifer not eroded.
- 1150 — Structure contour, shows altitude of top of Codell aquifer. Dashed where approximately located. Contour interval 25 feet. Datum is mean sea level.

Figure 22. Map showing altitude of the upper surface of the Codell aquifer.

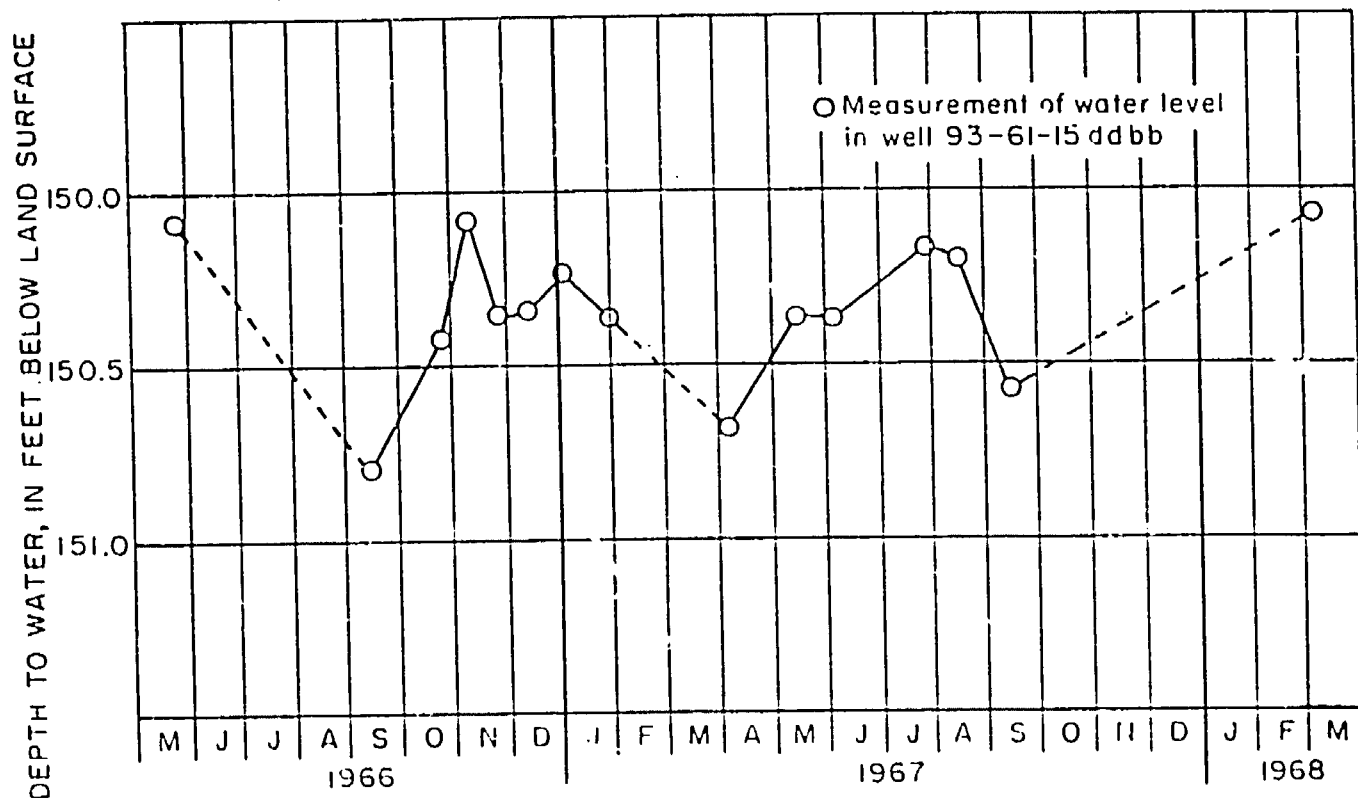


Figure 23. Hydrograph of the water level in a well tapping the Codell aquifer.

the Tyndall-Scotland aquifer and occurs at a location about 3 miles northeast of Tyndall and from a source associated with the anomalous high in the potentiometric surface at 94-61-13. (See fig. 24.) The anomaly may be the result of recharge from the Tyndall-Scotland aquifer at 95-60-32 where the glacial outwash is contiguous with the Codell Sandstone Member. (See fig. 21.) At some locations water from the artesian aquifers of the Dakota Formation leaks through broken casing into the Codell aquifer; however, the amount of water recharging the aquifer in this manner is small.

An 8-hour aquifer test in the Avon municipal well indicated a transmissivity of 400 gpd per ft and an approximate storage coefficient of 0.001.

Yields from domestic and stock wells range from 2 to 5 gpm. The public-supply well at Avon produces 90 gpm, and two public-supply wells at Tripp, 4 miles north of the county, produce 80 and 100 gpm. Total pumpage in 1968 from the estimated 465 wells tapping the aquifer was about 609 acre-ft and was used largely for domestic purposes.

Aquifers in the Dakota Formation

The sandstone layers of the Dakota Formation underlie the entire county and constitute two aquifers. These layers are composed of poorly consolidated, fine- to medium-grained sandstone.

Relation of the Dakota sandstone layers to each other and to the overlying and underlying formations is illustrated in figure 25. Figure 25 also shows a composite electric log; the formations and the sandstone layers are easily identified by their characteristic traces of spontaneous potential and resistivity on the electric log. The upper sandstone layer, which is an aquifer and locally is called the "first flow," is termed the upper Dakota aquifer in this report. The lower sandstone layers also are an aquifer, which locally is called the "second flow," and in this report is termed the lower Dakota aquifer.

The upper sandstone, which is about 20 feet thick, contains water under artesian pressure; however, the water is under less artesian pressure than the water in the lower sandstones. Wells tapping the upper Dakota aquifer yield less water than wells tapping the lower sandstones because the upper Dakota aquifer has a lower transmissivity and has less pressure. Altitude of the top of the upper Dakota aquifer is shown in figure 26 and the depth below land surface to the top of the upper Dakota aquifer is shown in figure 27. The depth to the top of the lower Dakota aquifer can be estimated by adding 90 feet to the depth to the top of the upper Dakota aquifer.

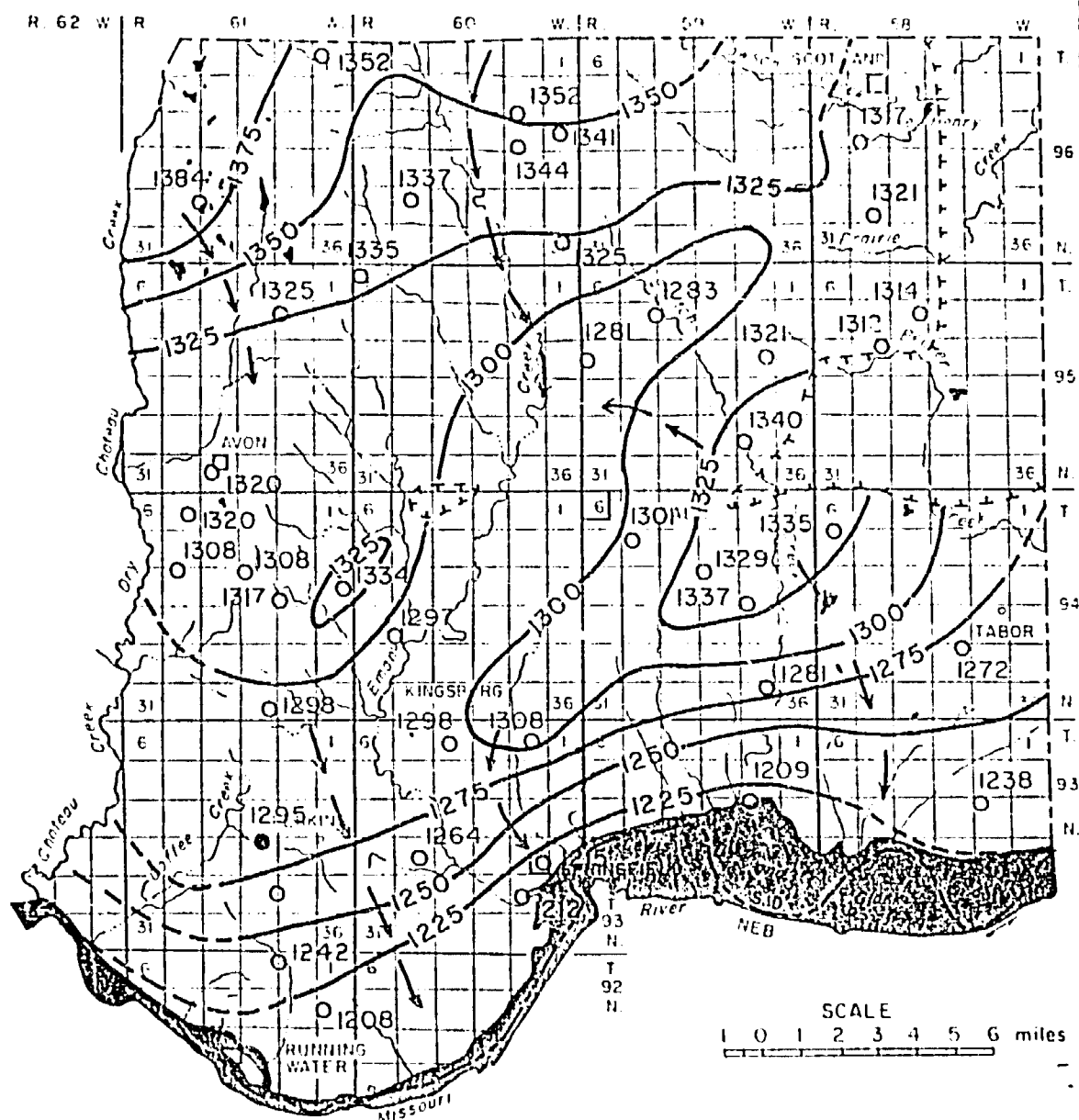
Aggregate thickness of the lower Dakota aquifer is not constant because of the uneven surface of the underlying Sioux Quartzite, and because of possible variations in deposition. At well 93-60-10d the total thickness of the aquifer is 217 feet.

Several studies have been made of the artesian conditions in the Dakota Formation. Studies, which include those by Darton (1896 and 1909), Barkley (1952), Davis, Dyer, and Powell (1961), and Dyer and Goehring (1965), document the declining potentiometric surfaces of the aquifers in the Dakota.

Figure 28 shows the decline of pressure (lowering of the potentiometric surface) in the lower Dakota aquifer. The water level in wells finished in the upper Dakota aquifer has decreased more rapidly than the water level in wells finished in the lower Dakota aquifer. Recently, the pressure has stabilized or increased slightly in the lower Dakota aquifer. Large pressure decrease in the past occurred during a time when many wells were allowed to flow uncontrolled. As the pressure decreased the number of flowing wells decreased, thus reducing the volume of discharge and causing a change in the rate of pressure decline.

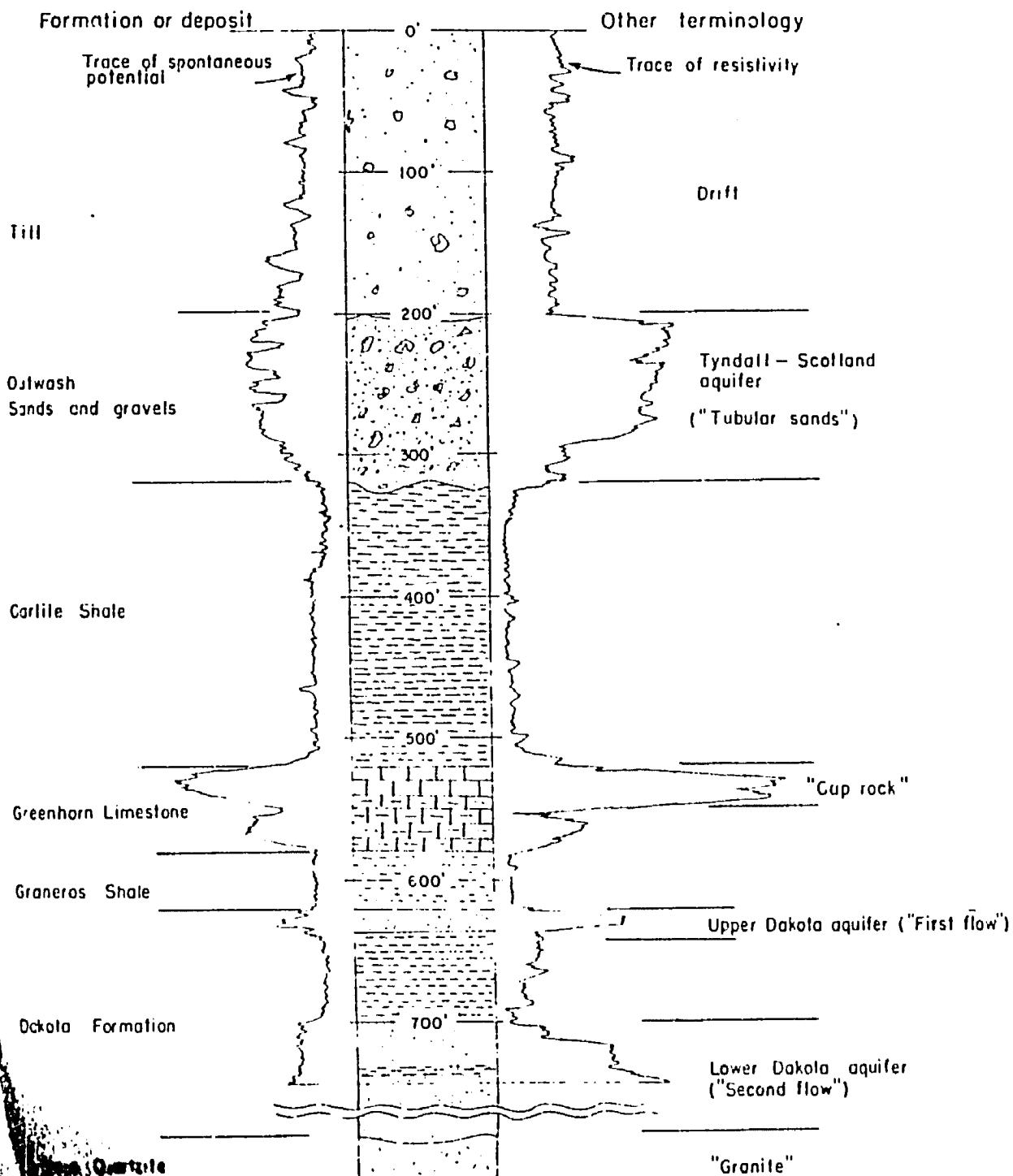
Figure 29 shows some pressure variations which may indicate a seasonal water-level trend. An increase of pressure occurred in the spring of 1967 and possibly again in the spring of 1968. However, because the accuracy of the measurement is $\pm \frac{1}{2}$ pound per square inch (1.15 ft) the existence of the seasonal variation cannot be positively ascertained. Abrupt rise of the potentiometric level in August 1966 occurred when the normal free flow of 250 gpm from the well was terminated. Specific capacity of the well is 14.7 gpm per foot of drawdown indicating that if the well was pumped it could produce water at a rate of approximately 900 gpm.

Discharge from the aquifer is by subsurface outflow, flow from wells, and well pumpage;



- Approximate aquifer boundary
- 1275 ——— Potentiometric contour shows altitude of potentiometric surface. Dashed where approximately located. Contour interval 25 feet. Datum is mean sea level.
- 1320 Well
- 1295 Observation well
- Number is altitude of potentiometric surface in 1966-67.
- ← — — — Direction of water movement.

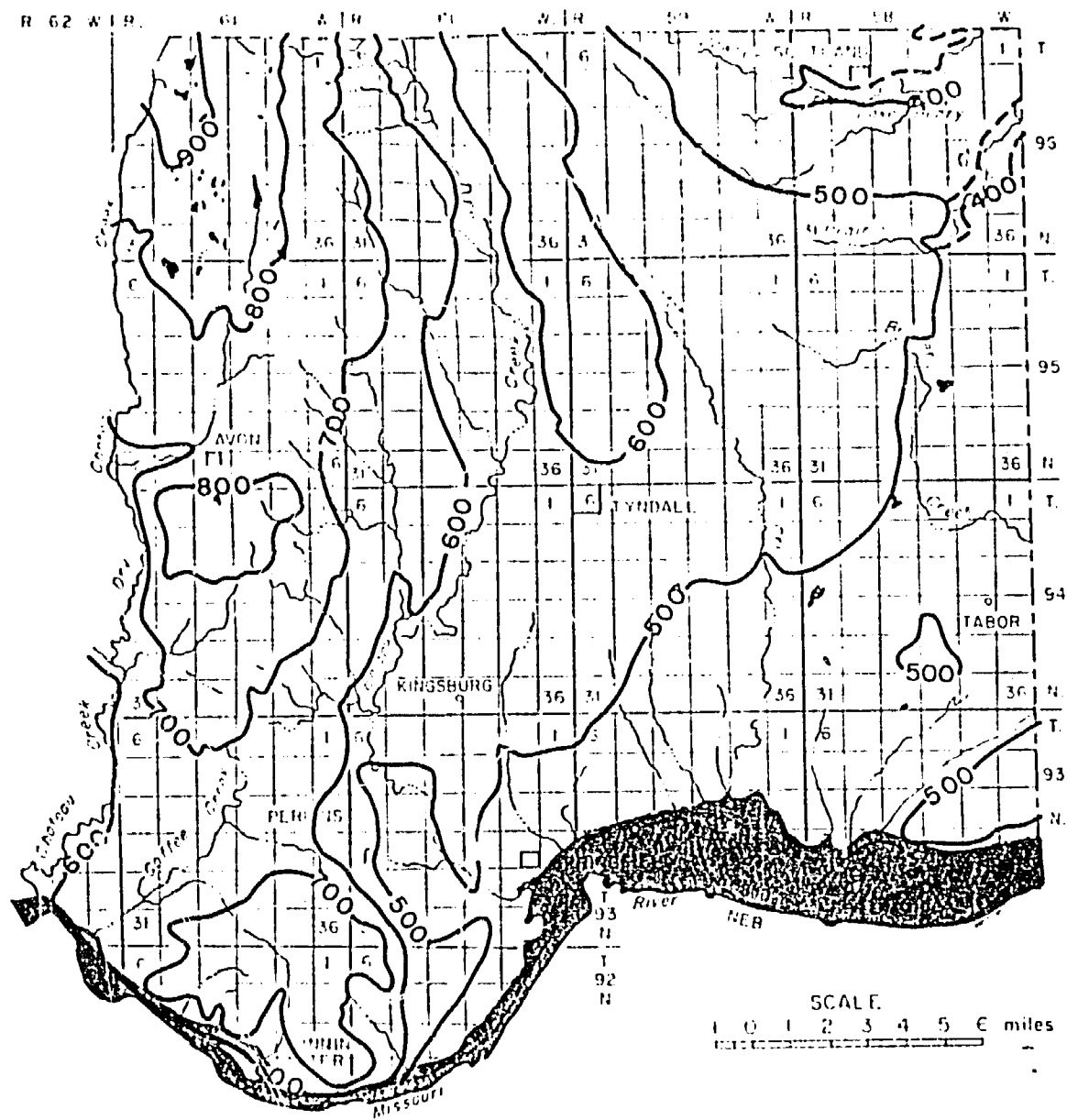
Figure 24. Map showing potentiometric contours of the Codell aquifer.



Page 25 -- Diagram of formations and composite electric log at well 95-60-34ccac



Figure 26. Map showing altitude of the upper surface of the upper Dakota aquifer.



— 400 — Line of equal depth to top of upper Dakota aquifer.
Dashed where approximately located.
Contour interval 100 feet.

Datum is land surface.

Figure 27. Map showing depth to the upper Dakota aquifer.

Figure 28. Hydrograph of the water levels of the lower Dakota aquifer at Tyndall and Springfield.

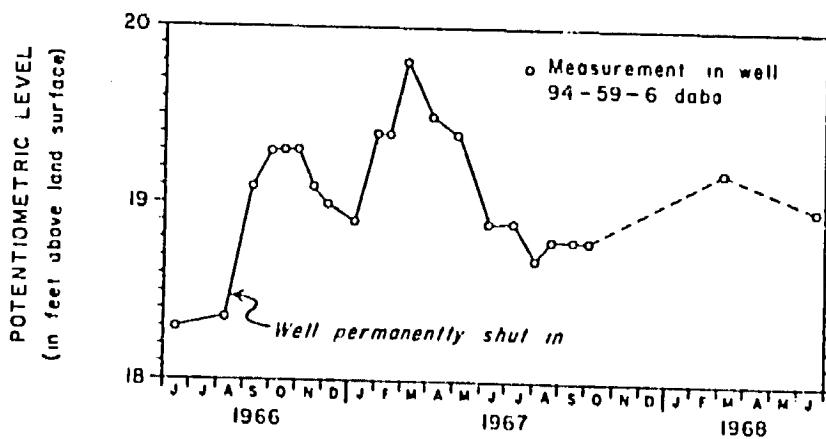
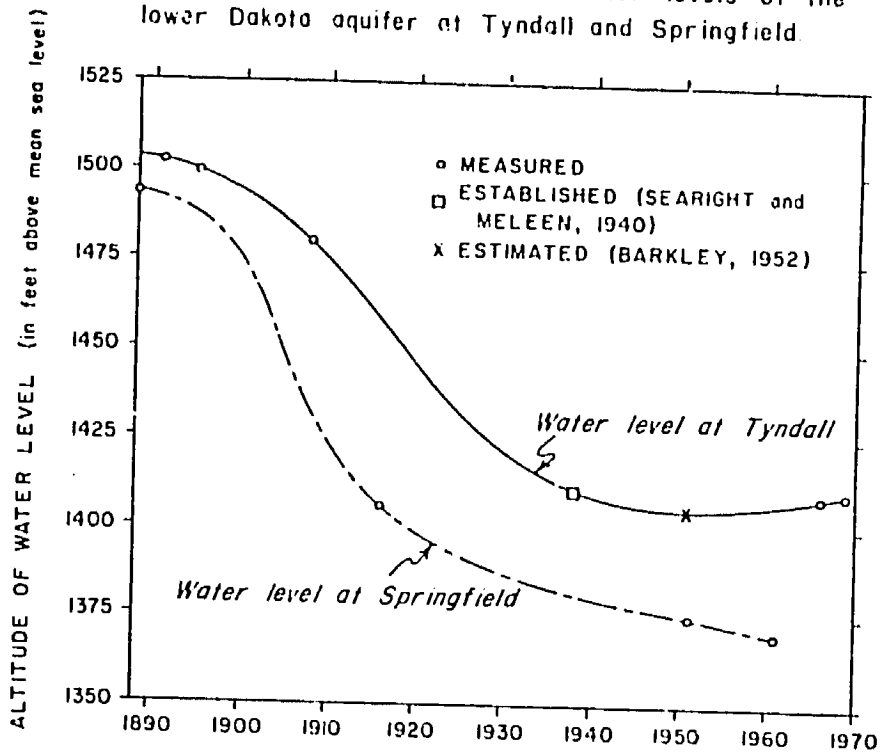


Figure 29. Hydrograph of the potentiometric level in a well tapping the lower Dakota aquifer.

recharge, however, is entirely from subsurface inflow. Because of the variable thickness of the aquifer, and because the storage coefficient is undetermined, the volume of water in storage was not estimated.

Approximately 190 flowing wells which tap the Dakota aquifers in the county discharged an estimated 1,290 acre-ft of water in 1968. Only 269 acre-ft of water was used beneficially; the rest flowed to waste. Figure 30 shows the area where wells will flow, the contours on the potentiometric surface, and the direction of water movement in the lower Dakota aquifer.

Water Quality

Suitability of water for a given use is determined by its chemical and physical properties. Water suitable for one use may not be suitable for another. For example, water suitable for stock may be undesirable for both irrigation and domestic use. Some of the factors that affect the chemical and physical properties of water are climate, geology, topography, and man's activities such as irrigation, drainage, and waste disposal.

This report emphasizes properties associated with inorganic constituents that influence the suitability of water for domestic, livestock, and irrigation uses. All concentrations except pH are reported in milligrams per liter (mg/l). Units of milligrams per liter are very nearly equivalent to parts per million (ppm) and are regarded as equivalent in this report.

Chemical constituents that are often measured to evaluate water for domestic use are listed in table 4. Limits of concentration recommended by U. S. Public Health Service, 1962, for some constituents for domestic use are also included in table 4. These recommended limits are hereinafter referred to as "Federal drinking water standards."

A water-classification system for livestock use is given below (South Dakota Agricultural Experiment Station, 1959, p. 10):

Dissolved solids (mg/l)	Class
0- 999	Excellent
1,000-3,999	Good
4,000-6,999	Satisfactory
7,000 and over	Unsatisfactory

Most livestock can tolerate water of higher mineral content than humans.

Selenium is toxic even in small quantities and when present in some soils can adversely affect livestock health. Certain pea-type plants of the genus *Astragalus*, such as the well-known locoweed, remove selenium from the soil and water and concentrate it within their tissues. Animals grazing on these plants may suffer from the ailment called "blind stagger" (Hem, 1959). In Bon Homme County, Cretaceous-age strata, which are in part aquifers that are known to contain selenium, are the Pierre Shale, the Niobrara Marl, the Carlile Shale, the Greenhorn Limestone, and the Graneros Shale (Koch, 1967, p. 971). The county agent generally is aware of selenium poisoning and should be consulted whenever a new source of water is to be used for irrigating forage crops or pastures.

Several methods of classification of water for irrigation are in use. For these classifications it is assumed that the water will be used under average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate, and salt tolerance of the crop. Large deviations from the average of one or more of these factors may make it unsafe to use water that would be safe under average conditions.

Method of classification most often used is based on the irrigation hazards of salinity and sodium. This method is described fully by Wilcox (1955). A measure of the salinity of the water is its specific conductance. Specific conductance of a water is easily measured with use of a conductance meter which indicates the ease (conductivity) of electrical flow in the water. Units of measurement of EC (specific electrical conductance) are micromhos per centimeter (μm per cm) at 25°C; however, in reports of the U. S. Geological Survey the term "centimeter" is commonly omitted. A measure of sodium hazard is the sodium-adsorption ratio (SAR). The larger the SAR ratio the greater the sodium hazard. The

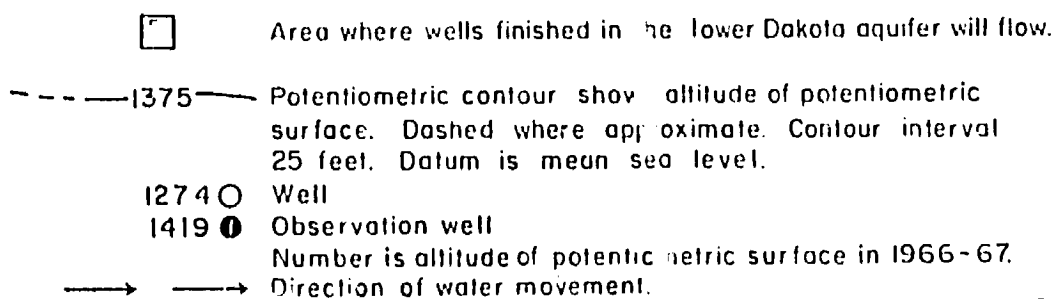


Figure 30. Map showing potentiometric contours of the Lower Dakota aquifer.

Table 4 -Significance for domestic use of common chemical constituents and physical properties of water.

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in amounts less than 25 mg/l. However, waters draining from deposits high in silicate minerals particularly feldspars, often contain as much as 60 mg/l.	Forms hard scale in pipes and boilers. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. Usually less than 1 mg/l in alkaline surface water. Higher amounts occur in acid waters from mine drainage or other sources.	More than about 0.3 mg/l stains laundry and utensils reddish-brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing, and other processes. Federal drinking water standards state that iron should not exceed 0.3 mg/l.
Manganese (Mn)	Dissolved from some rocks and soils. Usually less than 1 mg/l in alkaline surface waters. Large concentrations often associated with high iron content and with acid waters.	Same objectionable features as as iron. Causes dark brown or black stains. Federal drinking water standards provide that manganese should not exceed 0.05 mg/l.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all rocks and soils, but especially from limestone, dolomite, gypsum, and gypsiferous shale.	Causes most of the hardness and scale-forming properties of water; soap consuming. (See hardness.)
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in sewage, industrial waste, and waste brines.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks and soil materials such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonate of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts,

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Table 4--continued.

Constituent or physical property	Source or cause	Significance
	Usually present in drainage from mines and in some industrial wastes.	sulfate in combination with other ions gives a bitter taste to water and may cause a laxative effect. Federal drinking water standards recommend that sulfate content should not exceed 250 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in waste brines and some other industrial wastes.	Chloride in large amounts and in combination with sodium gives salty taste to drinking water and increases the corrosiveness of water. Federal drinking water standards recommend that the chloride content should not exceed 250 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Present in salt water from oil wells, and industrial waste from processing of insecticides, disinfectants and preservatives.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. Federal drinking water standards recommend that fluoride content be between 0.8 and 1.3 mg/l for Bon Homme County.
Nitrate (NO_3)	Decaying organic matter, sewage, and nitrates in soil and fertilizer.	Concentrations much greater than the local average may suggest pollution. More than about 45 mg/l nitrate may cause methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter.	Water with large concentrations of dissolved solids often taste. Federal drinking water standards recommend that the dissolved solids should not exceed 500 mg/l unless mineralized supplies are not available.
Hardness as CaCO_3	In most waters nearly all the hardness is due to calcium and magnesium. Metallic cations	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale

Table 4--continued.

Constituent or physical property	Source or cause	Significance
	except alkali metals also cause hardness.	in boilers, water heaters, and pipes. Waters of hardness up to 60 mg/l are considered soft; 61 to 120 mg/l, moderately hard; 121 to 200 mg/l, hard; more than 200 mg/l, very hard.
Specific conductance	Mineral content of the water.	Specific electrical conductance (EC) is a measure of the ability of the water to conduct an electric current. Varies with temperature, concentration, and degree of ionization of the constituents.
Hydrogen ion concentration(pH)	Acids, acid-generating salts, and dissolved carbon dioxide lower the pH; carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutral solution. Values higher than 7.0 indicate increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions, corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Color	Natural color is usually associated with swamp drainage, and is often the result of decomposition products of vegetal material.	Color affects the use of water for dyeing, textiles, food processing, ice making, and is esthetically unpleasant.

sodium-adsorption ratio is calculated by the equation:

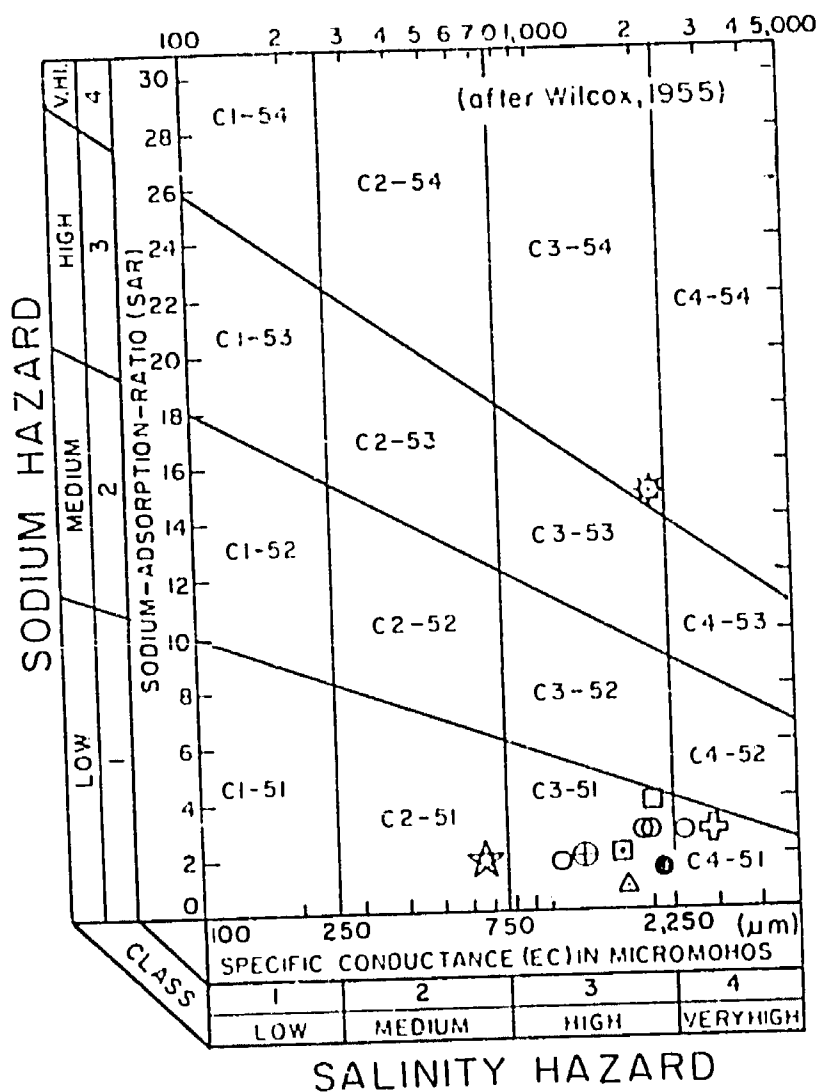
$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

in which the concentrations of sodium (Na^{+}), calcium (Ca^{++}), and magnesium (Mg^{++}) are given in millequivalents per liter (meq/l). Millequivalents per liter may be calculated by dividing the constituents molecular weight by the ionic charge or valence.

The irrigation water classification method based on EC and SAR uses a diagram as is shown by figure 31. For example, the average SAR and EC for the analyses of Codell aquifer water are 15 and 2,030 μ m respectively. These values are used as coordinates and define a point in the C3-S4 area of the diagram.

Significance of the classes of water shown on figure 32 is summarized as follows (Wilcox 1955):

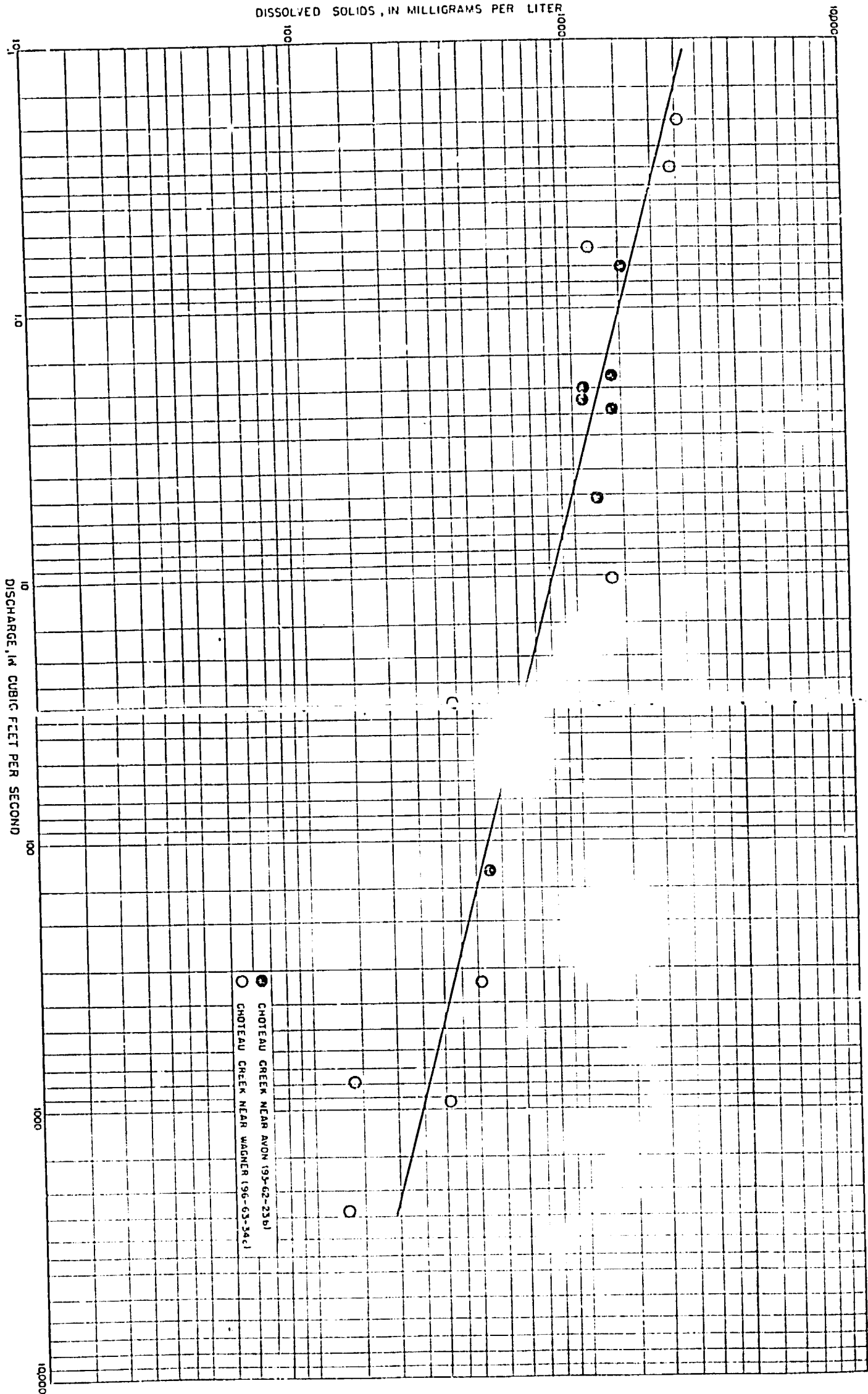
Low-salinity water (C1) can be used for irrigation with most crops on most soils, with little likelihood that a salinity problem will develop. Some leaching is required; however, this generally occurs under normal irrigation practices except in soils of extremely low permeability.



- ⊕ Hubonmix-aquifer water
- Average Choteau-aquifer water
- △ Average Tyndall-Scotland-aquifer water
- ⊕ Average Ill-aquifer water
- Average Niobrara-aquifer water
- ⊗ Average Codell-aquifer water
- Average Dakota-aquifer water
- Seasonal analysis of water from Lake Henry
- ☆ Discharge-weighted average of Missouri River water from October 1, 1957–September 30, 1958 at Yankton, South Dakota.

Figure 31. Diagram for classification of irrigation water.

DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER



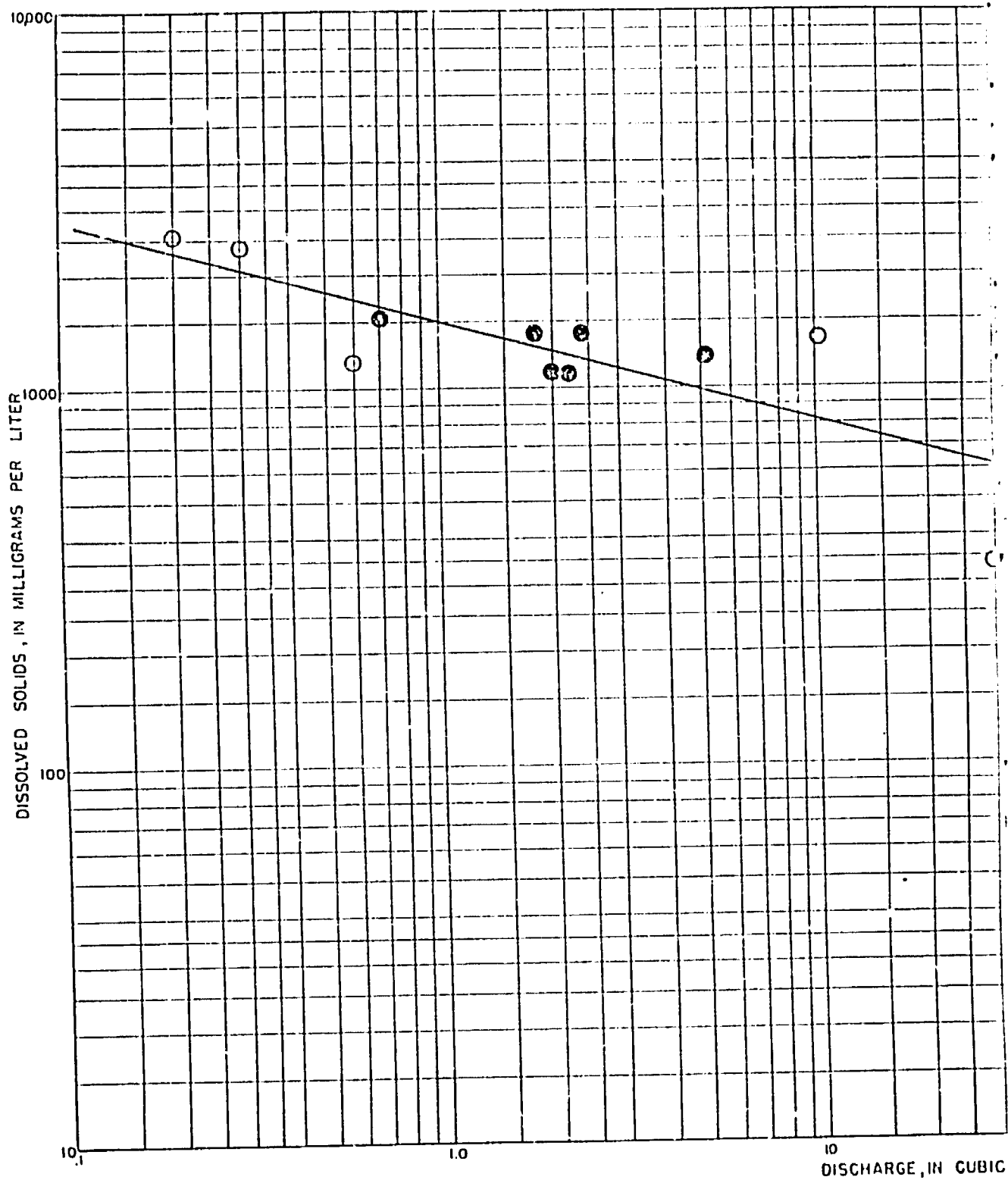
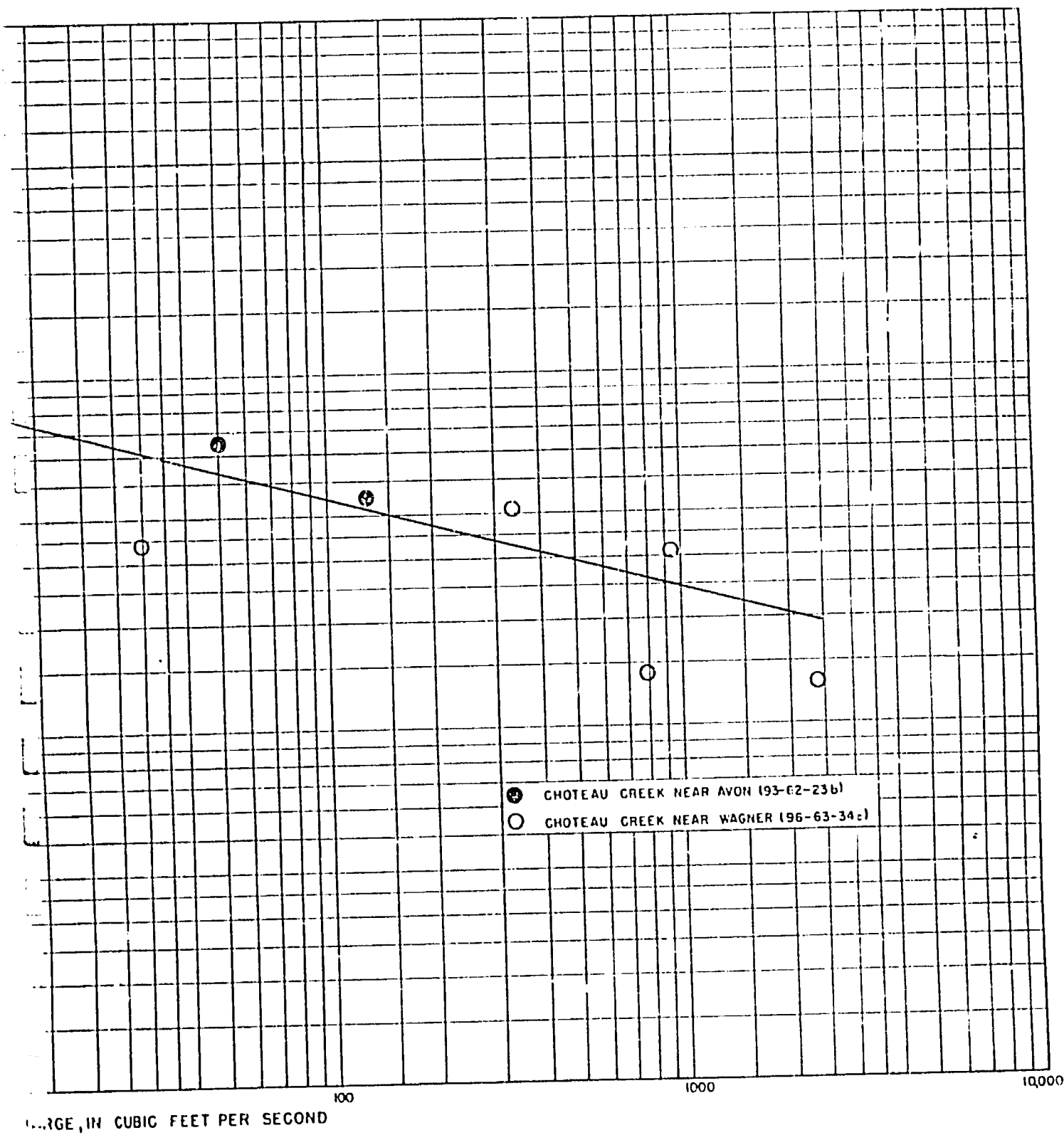


Figure 32 ----- Graph showing relation of dis



relation of dissolved solids to discharge in Choteau Creek

Medium-salinity water (C2) can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown on most soils without special practices for salinity control.

High-salinity water (C3) can not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerances should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but it may be used occasionally under special circumstances. If this water is used, the soils must be permeable, the drainage must be adequate, the quantity of irrigation water applied must be in excess so as to provide considerable leaching, and very salt-tolerant crops should be grown.

Classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may suffer injury as a result of sodium accumulation in plant tissue when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

Low-sodium water (S1) can be used for irrigation on most soils with little danger of harm. However, sodium-sensitive crops may be injured by accumulation of sodium concentrations.

Medium-sodium water (S2) presents appreciable sodium hazard in fine-textured soils of high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils that have good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and requires good drainage, high leaching rates, and addition of organic matter. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium.

Very high sodium water (S4) is generally unsatisfactory for irrigation except at low and perhaps medium salinity where the solution of calcium from the soil or the use of gypsum or other amendments may make the use of these waters possible.

Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of C1-S3 and C1-S4 waters. For calcareous soils with high pH values or for noncalcareous soils, the sodium status of waters in classes C1-S3, C1-S4, and C2-S4 may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2-S3 and C3-S2 waters are used.

Classification of water for irrigation based on the concentration of boron is also useful. Boron, even in small quantities, is toxic to some types of plants. Some crops, including most deciduous fruit and nut trees and beans are sensitive to boron; most small grains, potatoes, and some vegetables are semitolerant; alfalfa and most root vegetables are tolerant. Permissible boron concentrations are shown in table 5 (Ilem, 1959, p. 245).

Surface Water

Quality of surface water varies widely within the same stream and from one stream to another. Variations in quality are due to the type of soil that the water contacts, length of contact time, past use of the water, amount and source of base flow, amount of storm runoff, and many other factors. These variations can be described in terms of maximum and minimum concentrations, frequency of occurrence of specific concentrations, and their duration. A computation of average quality for a year from an analysis of daily samples has limited value; however, a discharge-weighted quality computation is meaningful in anticipating the quality of water in a reservoir.

Quality of water in both Choteau Creek and Emanuel Creek varies inversely with discharge. Low mineral concentrations occur during periods of high discharge when most of the flow is surface runoff. High mineral concentrations occur during periods of low discharge when most of the base flow is ground water. Figure 32 shows the discharge-dissolved solids relation for Choteau Creek, and figure 33 shows this same relation

DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER

10000

1000

100

10

10

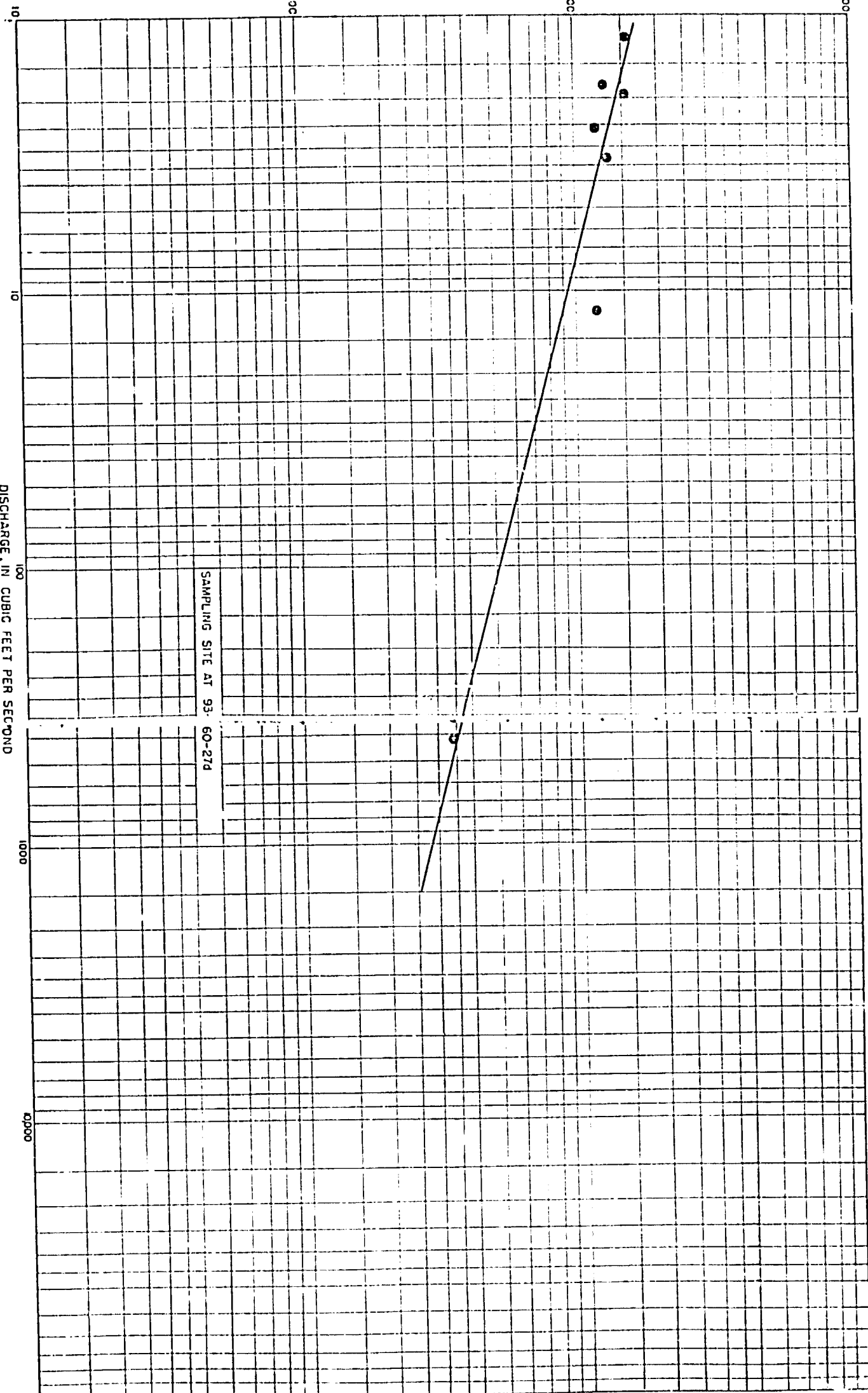
100

1000

10000

DISCHARGE, IN CUBIC FEET PER SECOND

SAMPLING SITE AT 93-60-274



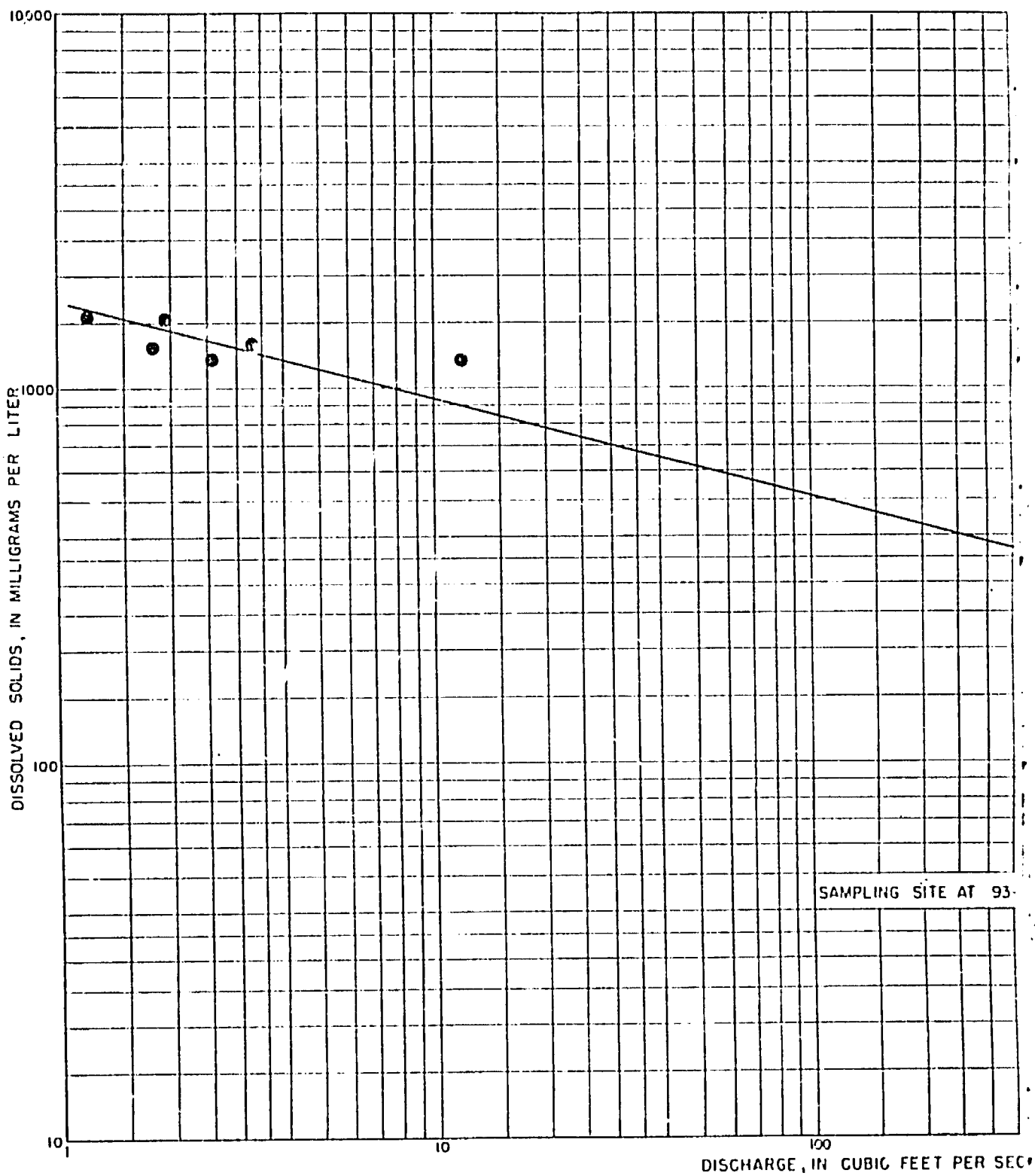
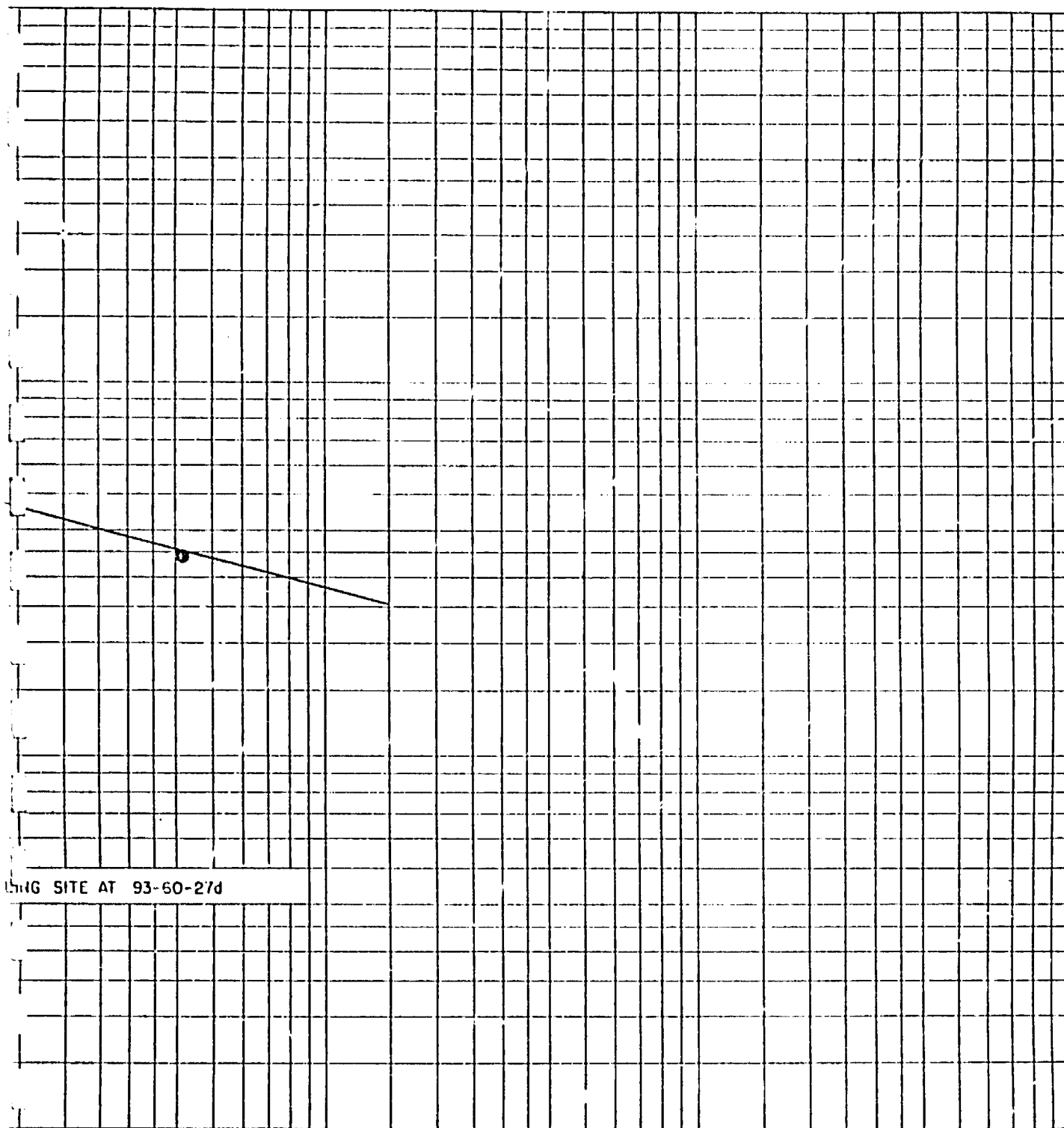


Figure 33 - - - - Graph showing relation of dissolve



ING SITE AT 93-60-27d

FEET PER SECOND

1000

10000

tion of dissolved solids to discharge in Emanuel Creek

Table 5.--Rating of irrigation water for various crops on the basis of boron concentration (after Hem, 1959).

Classes of water		Sensitive crops (mg/l)	Semitolerant crops (mg/l)	Tolerant crops (mg/l)
Rating	Grade			
1	Excellent	<0.33.....	<0.67.....	<1.00.....
2	Good	.33 to .67	.67 to 1.33	1.00 to 2.00
3	Permissible	.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	>1.25.....	>2.50.....	>3.75.....

for Emanuel Creek. No relation between season and mineral composition of water was found. Tables 6 and 7 list chemical analyses at various rates of discharge for Choteau and Emanuel Creeks. In general, the water at discharges of less than 8 cfs from either creek is unsatisfactory for irrigation because of its high dissolved solids and salinity. These creeks are not considered as sources of irrigation water because they seldom have flows exceeding 8 cfs. Water in either creek is suitable for stock use and could be used for domestic purposes although the concentrations of dissolved solids, sulfate and iron at commonly occurring discharge rates may exceed those recommended in the Federal drinking water standards.

Quality of the water in Lewis and Clark Lake was monitored from July 1, 1964 to June 30, 1966 at Gavins Point Dam, 9 miles east of Bon Homme County, by a continuous recorder operated by the Bureau of Sport Fisheries (written commun.). The results were:

Constituent or Property	Range
Conductivity	650-840 micromhos
Turbidity	10-675 mg/l
Bicarbonate	144-180 mg/l of HCO_3
Dissolved oxygen	5.4-14.0 mg/l

Quality of water discharged from the lake measured at Yankton, 12 miles east of the southeast corner of Bon Homme County, for the 1958 water year is shown in table 8 (U. S. Geological Survey, 1962).

Although some differences between the quality of water in the Missouri River above Springfield, and in Lewis and Clark Lake below Springfield is observable, the differences are not of such a magnitude to appear significant.

Water from Lewis and Clark Lake and the Missouri River is of good quality for domestic and stock use, and is classified as C2-S1 (low sodium hazard and medium salinity hazard) for irrigation. (See fig. 31.) The water is suitable for most plants and requires only moderate leaching of the soil to prevent sodium build-up.

Quality of water in Lake Henry, a reservoir on Dawson Creek, may be similar to the quality of water that would be expected if a reservoir was constructed on Emanuel or Choteau Creek. The variation of the quality is seasonal and is due to the processes of dilution and distillation. That is, when surface water of low mineral content flows into the lake it dilutes the more mineralized lake water. During the growing season, transpiration removes nearly pure water and leaves a concentrated mineral solution behind; during winter months, freezing at the surface concentrates the minerals in the unfrozen water beneath the ice. Table 9 shows that dissolved-solids content decreased with the rising lake level except for the February 4, 1965 analysis which shows the increased concentration caused by

Table 6.--Selected chemical analyses of water from Choteau Creek.
(All concentrations in mg/l--all samples collected at 93-62-23b)

Date	9-8-66	6-7-67	7-7-67
Discharge (cfs)	0.62	130	50.3
Gage height (ft)	1.00	2.20	1.56
Iron (Fe)	.03	.32	.70
Calcium (Ca)	232	76	123
Magnesium (Mg)	44	14	27
Sodium (Na)	86	17	4
Potassium (K)	17	10	18
Bicarbonate (HCO_3)	259	161	273
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	680	120	104
Chloride (Cl)	38	12	30
Nitrate (NO_3)	.0	.0	2.5
Selenium (Se)			.001
Dissolved solids	1,540	452	664
Ca, Mg hardness as CaCO_3	762	249	420
Noncarbonate hardness as CaCO_3	350	117	196
SAR	1.4	.5	.9
EC in μm	1,700	560	900
pH	7.6	7.0	7.3
Temperature in $^{\circ}\text{C}$	20	17	
Remarks	base flow		

Table 7.--Selected chemical analyses of water from Emanuel Creek
(All concentrations in mg/l--all samples collected at 93-60-27d)

Date	9-8-66	6-7-67	7-7-67
Discharge (cfs)	1.19	415	11.8
Gage height (ft)	.10	3.86	.80
Iron (Fe)	.00	.60	.00
Calcium (Ca)	244	64	194
Magnesium (Mg)	32	4.8	56
Sodium (Na)	130	6.3	67
Potassium (K)	20	7.7	15
Bicarbonate (HCO_3)	324	151	263
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	730	60	504
Chloride (Cl)	38	4.0	25
Nitrate (NO_3)	2.7	4.0	16
Selenium (Se)			.005
Dissolved solids	1,580	332	1,200
Ca, Mg hardness as CaCO_3	745	180	716
Noncarbonate hardness as CaCO_3	477	0	500
SAR	2.2	.2	1.1
EC in μm	1,960	377	1,530
pH	7.5	7.2	
Temperature in $^{\circ}\text{C}$	24	17	
Remarks	base flow		

Table 8.-Water quality of Missouri River at Yankton, South Dakota

LOCATION.-At gaging station at Meridian Highway Bridge on U. S. Highway 81 in Yankton County, 5.8 miles upstream from James River, and 6.1 miles downstream from Gavins Point Dam.

DRAINAGE AREA.-379,500 square miles, approximately.

RECORDS AVAILABLE.-Chemical analyses: October 1950 to September 1951; October 1956 to September 1958.

Water temperatures: October 1956 to September 1958.

EXTREMES, 1957-58.-Dissolved solids: Maximum, 489 mg/l Oct. 1-31; minimum 377 mg/l May 25 to Apr. 17.

Hardness: Maximum, 236 mg/l Oct. 1-31; minimum, 154 mg/l Mar. 26 to Apr. 17.

Specific conductance: Maximum daily, 772 μ m in Oct. 1; minimum daily, 537 μ m Apr. 6, 7.

Water temperatures: Maximum 27°C (81°F) Aug. 19; minimum, 1°C (33°F) on many days during December to February.

EXTREMES, 1956-58.-Dissolved solids: Maximum, 559 mg/l Aug. 29 to Sept. 30, 1957; minimum 327 mg/l Mar. 16-31, 1957.

Hardness: Maximum, 259 mg/l Aug. 29 to Sept. 30, 1957; minimum, 168 mg/l Mar. 16-31, 1957.

Specific conductance: Maximum daily, 839 μ m Aug. 24-25, Sept. 5-8, 1957; minimum daily 479 μ m in Mar. 30, 1957.

Water temperatures: Maximum 27°C (81°F) Aug. 19, 1958; minimum, freezing point on many days during winter months.

REMARKS.-Daily samples for chemical analyses composited by discharge. Records of specific conductance of daily samples available at USGS office, Lincoln, Nebraska.

Chemical analyses, in mg/l, water year October 1957 to September 1958

Date of collection	Mean dis-charge (cfs)	Silica (SiO ₂)	Iron (Fe)	Cal-cium (Ca)	Mag-nes-ium (Mg)	So-dium (Na)	Po-tas-sium (K)	Bicar-bonate (HCO ₃)	Sul-fate (SO ₄)	Chlo-ride (Cl)	Fluoride		Ni-trate (NO ₃)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as CaCO ₃		Sul-phate-reduc-tion ratio	Specific conduct-ance EC in μ m	pH	
											(F)	(F)			Milli-grams per liter	Tons per acre-foot	Tons per day	Cal-cium, mg/l	Non-car-bon-ate				
Oct. 1-31, 1957	28,120	10	0.04	64	19	71	5.6	191	209	12	0.6	0.4	0.19		489	0.57	37,130	236	79	2.0		748	7.7
Nov. 1-30	11,900	13	.02	63	17	64	5.2	185	190	10	.7	.5	.14		466	.63	14,850	228	76	1.8		696	7.3
Dec. 1-31	8,351	18	.01	59	18	60	4.9	200	180	11	.5	1.2	.07		453	.62	10,210	222	58	1.8		678	7.4
Jan. 1-31, 1958	8,803	13	.01	61	17	58	5.3	182	174	10	.5	1.2	.12		440	.60	10,400	222	73	1.7		661	7.2
Feb. 1-28	6,695	13	.01	60	17	55	5.0	185	167	9.8	.5	.6	.10		442	.60	10,380	221	69	1.6		674	7.3
Mar. 1-25	8,206	13	.01	52	15	22	4.3	172	169	9.0	.5	1.2	.13		377	.56	9,170	207	64	1.7		627	7.6
Mar. 26-Apr. 17	20,820	14	.00	51	16	42	4.7	166	140	7.7	.5	1.2	.08		377	.51	21,190	194	58	1.4		576	7.5
Apr. 18-May 12	24,920	11	.04	56	17	54	4.7	176	164	9.4	.5	1.2	.10		411	.56	27,650	210	66	1.6		677	7.4
May 13-31	26,530	9.5	.04	54	13	55	4.6	172	167	9.2	.5	.2	.11		411	.56	29,500	208	67	1.6		639	7.3
June 1-30	27,950	9.6	.01	53	18	60	4.7	162	184	8.9	.4	.6	.12		425	.58	32,070	206	73	1.8		652	7.0
July 1-31	25,970	7.7	.00	56	17	60	5.2	168	195	8.9	.5	.1	.19		445	.61	31,200	211	73	1.8		675	7.2
Aug. 1-31	26,220	8.5	.00	56	18	61	6.0	174	194	9.0	.5	.8	.16		456	.62	34,740	215	72	1.8		673	7.0
Sept. 1-30	28,910	8.6	.00	58	19	63	5.2	187	201	10	.5	.4	.15		470	.64	36,690	224	71	1.8		699	7.2
Weighted average	19,720	10	0.01	57	18	60	5.1	177	185	9.6	0.5	0.7	0.14		443	0.60	23,590	216	71	1.8		671	

² Represents 100 percent of runoff for water year October 1957 to September 1958.

Table 9.--Selected chemical analyses of water from Lake Henry.
(All concentrations in mg/l--all samples collected at 96-58-9d)

Date	10-24-64	2-4-65	5-17-65	9-6-65
Gage height (ft)	9.86*	9.99*	8.80*	7.97*
Iron (Fe)	.06	.09	.01	.05
Manganese (Mn)	.19	1.4	.29	.09
Calcium (Ca)	128	160	111	88
Magnesium (Mg)	119	156	112	71
Sodium (Na)	185	225	166	98
Potassium (K)	18	21	17	17
Bicarbonate (HCO_3)	168	239	172	178
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	867	1,150	744	432
Chloride (Cl)	107	139	115	71
Fluoride (F)	.4	.4	.3	.3
Nitrate (NO_3)	1.5	4.8	1.5	.3
Phosphorous as PO_4	.56	1.4	0.44	1.2
Phosphate (PO_4)	.36	1.4	.37	1.2
Boron (B)	.68	.69	.58	.37
Dissolved oxygen (DO)	11.8	.3	8.4	8.3
Dissolved solids	1,520**	1,980**	1,350**	936
Ca, Mg hardness as CaCO_3	868	1,040	737	511
Noncarbonate hardness as CaCO_3	670	844	569	310
SAR	2.8	3.0	2.7	1.09
EC in μm	2,060	2,520	1,920	1,300
pH	8.5	7.8	8.5	8.4
Temperature in $^{\circ}\text{C}$	10	2	19	19

*Depth below reference mark 1.

**Calculated

freezing. The quality of water of Lake Henry and other selected lakes is discussed fully by Petri and Larson (1968).

Figure 31 indicates that the classification of the water for irrigation has a low sodium hazard and high to very high salinity hazard; therefore, the water should not be used on soils that are not permeable or adequately drained. The water is suitable for stock use. However, it is not recommended for domestic use because it has concentrations of manganese, sulfate, and dissolved solids that exceed the limits specified by Federal drinking water standards.

Ground Water

Summaries of the results of 109 "complete" chemical analyses are shown in tables 10 through 15. The tables list the number of determinations for each constituent, the maximum and minimum values for each constituent, and the average ($\bar{X}$). A measure of dispersion of data from the mean is the standard deviation (s) and is defined as the positive square root of the sum of squares of the deviations of the observations from the arithmetic mean divided by one less than the total number of observations. Values of s and $\bar{X}$ listed in tables 10 through 15 were determined numerically. The curve defined by plotted points on normal probability paper was used to determine the probability of a value being equal or exceeded. That is, the values listed under 25 percent, 50 percent, and 75 percent in table 8 indicate that the probability of the listed value being equaled or exceeded is 25 percent, 50 percent, and 75 percent, respectively. The 50 percent value is the median or middle value of the group. Neither standard deviation nor probability was determined if less than four observations were available.

Ground water from the Choteau, Tyndall-Scotland, Niobrara, Codell, and the upper and lower Dakota aquifers is suitable for domestic use; although, all of the aquifers yield water with one or more undesirable characteristics. As an example, water from the Choteau, Tyndall-Scotland, Codell, and the upper and lower Dakota aquifers can be expected to have excessively high sulfate and dissolved solids concentrations as compared to those recommended in Federal drinking water standards. Water from the till may not be suitable for domestic use because it has concentrations of sulfate and dissolved solids which often greatly exceed Federal drinking water standards.

Water from all aquifers sampled is classified as satisfactory to excellent for livestock.

Figure 31 shows the irrigation classification for the average values of conductivity and sodium-adsorption ratio for waters from each aquifer. Water from the Choteau, Tyndall-Scotland, Niobrara, and Dakota aquifers is classified as C3-S1 (low sodium hazard and high salinity hazard), and thus should not be used for irrigation on soils with restricted drainage, even though sodium build-up would not be a problem. Water from the Codell aquifer is classified as C3-S4 (very-high sodium hazard and high salinity hazard) and is generally unsatisfactory for irrigation because of the likelihood of crop damage by sodium build-up especially on poorly drained soil. Water from the till aquifer is classified as C4-S1 (low sodium hazard and very-high salinity hazard) and is not suitable for irrigation under ordinary conditions.

Chemical analysis of a water sample from well 96-61-29 (deca finished in the Hubonmix aquifer) is as follows: calcium=128 mg/l; magnesium=20 mg/l; potassium=28 mg/l; bicarbonate=98 mg/l; carbonate=0 mg/l; sulfate=628 mg/l; chloride=17 mg/l; nitrate=8.4 mg/l; boron=1.0 mg/l; EC=1,440 μ m; and SAR=2.2. As only one sample was obtained from this aquifer no confident statement can be made about the chemical quality of the water from the aquifer. All chemical analyses of water samples collected are listed in part III, the basic-data report for this investigation.

Average boron concentration of water samples from the till, Tyndall-Scotland, Niobrara, Codell, and Dakota aquifers did not exceed that recommended for irrigation of semitolerant crops (Hem, 1959). Not enough boron analyses were available for the Choteau aquifer water to permit an evaluation of the boron hazard and no boron determination was made of the water sample from the Hubonmix aquifer.

Mixing of natural waters caused by recharge of water from one aquifer to another occurs at several places within the county. Recharge to both the Niobrara and the Codell aquifers from the Tyndall-Scotland aquifer is indicated by the nearly identical water levels and the

Table 10.-Summary of chemical analyses of water from the till aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average (X)	Median, (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	16	555	154	325	318	117	400	235
Magnesium (mg)	16	662	25	180	.....	.....	235	55
Sodium (Na)	16	486	41	222	220	124	310	130
Potassium (K)	16	40	1.4	18	18	11	25	12
Bicarbonate (HCO ₃)	16	735	122	329	305	174	450	160
Carbonate (CO ₃)	15	9	0	1	.....	.....	...	.....
Sulfate (SO ₄)	16	2,680	450	1,380	1,340	687	1,820	850
Chloride (Cl)	16	386	4.0	85	.....	.....	110	28
Boron (B)	5	1.6	1.2	1.4	1.4	.55	1.5	1.2
Dissolved solids	16	7,220	1,030	3,080	2,880	1,610	3,950	1,800
Mg/Ca hardness as CaCO ₃	16	4,000	480	1,610	1,480	986	2,000	950
Noncarbonate hardness as CaCO ₃	16	3,510	296	1,360	1,300	969	1,900	700
EC in μ m	16	7,380	1,370	3,270	3,080	1,450	3,850	2,300
SAR	16	5.6	.6	3.0	2.7	1.8	4.0	1.4

Table 11.-Summary of chemical analyses of water from the Choteau aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average ($\bar{X}$)	Median (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	4	248	128	160	160	51	215	105
Magnesium (Mg)	4	30	19	24	24	3.8	27	21
Sodium (Na)	4	225	38	126	125	66	177	73
Potassium (K)	4	28	9.4	19	19	6.7	19	13
Bicarbonate (HCO_3)	4	372	97	198	197	105	289	107
Carbonate (CO_3)	4	0	0	0	0	0	0	0
Sulfate (SO_4)	4	630	500	568	570	61	623	517
Chloride (Cl)	4	49	10	30	31	17	46	16
Boron (B)	1	.....	.....	1.0	.....	.....	.....	.....
Dissolved solids	3	1,340	1,140	1,220	.....	.....	.....	.....
Mg-Ca hardness as CaCO_3	4	718	400	500	503	127	574	432
Noncarbonate hardness as CaCO_3	4	492	284	358	368	83.5	433	303
EC in μm	4	1,630	1,440	1,520	1,530	71	1,580	1,470
SAR	4	4.0	.6	2.3	2.3	1.2	3.2	1.3

Table 12.-Summary of chemical analyses of water from the Tyndall-Scotland aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average (X)	Median (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	6	293	108	172	170	62	210	130
Magnesium (Mg)	6	43	20	35	36	7.5	42	30
Sodium (Na)	6	474	18	128	.....	.....	50	20
Potassium (K)	4	22	6.9	14	14	6.7	19	9
Bicarbonate (HCO ₃)	4	281	146	186	162	110	176	148
Carbonate (CO ₃)	4	13	0	3	.....	.....	.....	.....
Sulfate (SO ₄)	6	770	260	520	515	202	650	380
Chloride (Cl)	6	119	3.0	36	27	38	15	39
Boron (B)	3	2.7	.9	1.8	.....	.....	.....	.....
Dissolved solids	6	1,840	664	1,210	1,220	428	1,520	930
Mg, Ca hardness as CaCO ₃	5	872	450	609	600	151	460	740
Noncarbonate hardness as CaCO ₃	4	501	330	384	362	71.9	387	337
EC in μ m	3	2,080	857	1,590	.....	.....	.....	.....
SAR	5	3.0	.3	1.0	.....	.....	1.2	.5

Table 13.-Summary of chemical analyses of water from the Niobrara aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average ($\bar{X}$)	Median (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	25	433	80	241	235	93	300	170
Magnesium (Mg)	25	129	19	55	52	33	80	23
Sodium (Na)	22	384	24	209	215	118	310	120
Potassium (K)	22	56	6.2	26	26	9.9	30	21
Bicarbonate (HCO_3)	26	471	112	289	288	115	370	205
Carbonate (CO_3)	26	18	0	1	.....	.....	.....	.....
Sulfate (SO_4)	26	1,435	300	891	900	282	1,110	690
Chloride (Cl)	26	235	6	53	38	61	60	15
Boron (B)	11	2.4	0.93	1.7	1.8	0.46	2.1	1.5
Dissolved solids	26	2,800	759	1,860	1,880	483	2,200	1,550
Mg, Ca hardness as CaCO_3	26	1,610	300	827	820	349	1,040	600
Noncarbonate hardness as CaCO_3	26	1,230	156	593	600	308	805	395
EC in μm	20	3,020	985	2,160	2,180	515	2,510	1,850
SAK	20	8.6	.5	3.8	3.8	2.4	5.3	2.2

Table 14.—Summary of chemical analyses of water from the Codell aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average ($\bar{X}$)	Median (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	33	344	10	80	.....	.....	126	18
Magnesium (Mg)	33	67	1.0	18	.....	.....	26	6
Sodium (Na)	30	494	13	356	356	105	416	297
Potassium (K)	33	55	1.4	20	20	11	26	14
Bicarbonate (HCO_3)	33	501	66	329	325	113	403	203
Carbonate (CO_3)	33	67	0	12	.....	.....	19	.....
Sulfate (SO_4)	33	1,550	44	410	.....	.....	650	80
Chloride (Cl)	31	420	3	174	180	142	295	65
Boron (B)	2	2.1	1.1	1.6	.....	.....	.....	.....
Dissolved solids	33	2,360	440	1,360	1,330	472	1,650	1,010
Mg, Ca hardness as CaCO_3	33	1,390	37	296	.....	.....	500	64
Noncarbonate hardness as CaCO_3	33	1,180	0	175	.....	.....	240	.....
EC in μm	32	3,000	581	2,030	2,090	468	2,550	1,640
SAR	31	30	.4	15	16	9.6	21	10

Table 15.—Summary of chemical analyses of water from the lower Dakota aquifer
(All concentrations in mg/l)

Constituent or property	Number of deter- minations	Maximum	Minimum	Average (X)	Median (50%)	Standard deviation (s)	25%	75%
Calcium (Ca)	24	415	206	315	320	73	366	273
Magnesium (Mg)	24	82	19	52	54	18	66	42
Sodium (Na)	23	202	42	101	102	34	122	82
Potassium (K)	22	22	14	19	19	1.8	20	18
Bicarbonate (HCO ₃)	23	205	97	147	145	26.3	164	126
Carbonate (CO ₃)	23	0	0	0	0	0	0	0
Sulfate (SO ₄)	24	1,450	538	890	899	240	1,060	899
Chloride (Cl)	23	160	57	113	118	36.0	144	91
Boron (B)	3	2.8	1.0	1.7	.....	.....	.....	.....
Dissolved solids	23	2,230	1,210	1,780	1,830	364	2,130	1,530
Mg, Ca hardness as CaCO ₃	24	1,330	620	1,010	1,010	246	1,170	855
Noncarbonate hardness as CaCO ₃	22	1,200	525	868	880	77.2	1,000	760
EC in μ m	19	2,650	1,510	2,040	1,540	378	2,320	1,750
SAR	17	3.3	.4	1.4	1.4	.6	1.7	1.1

similar quality of water from wells that are finished in these aquifers at locations in Township 94 North and Range 60 West.

An apparent chemical anomaly exists at the municipal well in the Codell aquifer at Avon where the hardness of water is considerably greater than the hardness of water in the Codell aquifer from nearby wells (Jorgensen, 1968). Increased hardness of the water at Avon is due to mixing of Dakota and Codell waters. Dakota water, which is under greater artesian pressure than Codell water, flows into the Codell aquifer through a rupture in the casing of an abandoned Dakota well. Many other cases of water mixing as the result of well-casing failures exist in the county, but the quantity of water involved is not as large as at Avon and the effects upon water quality are probably very localized.

SUMMARY

Water from Lewis and Clark Lake and from the Missouri River is suitable to use for irrigation, domestic, and stock purposes. The water has a low sodium hazard and a medium salinity hazard, and thus is suitable for irrigation use in soils with only moderate leaching.

Quality of water in Lake Henry is variable. This variation is seasonal and is due to the processes of evaporation, transpiration, freezing, and dilution. Because the water has a high to very-high salinity hazard, it should not be used on soils that are not permeable or well drained. The water is not recommended for domestic use because at times it is very high in dissolved solids; however, the water is suitable for stock use.

Limited information about the quality and quantity of the water in Choteau and Emanuel Creek indicates that the mineral concentration decreases as the rate of discharge increases. Water in the creeks is, in general, unsatisfactory for irrigation at commonly occurring low flow rates because of its high salinity. The water is suitable for domestic and stock use; however, at commonly occurring discharge rates the concentrations of iron, sulfate, and dissolved solids may exceed Federal drinking water recommendations.

Water from the alluvium and the shallow outwash aquifers is used as stock water. Wells finished in these aquifers yield water at rates of 1 to 10 gpm.

Till-aquifer water has a low sodium and a high salinity hazard; therefore, it is not suitable for irrigation under ordinary conditions. The aquifer yields water to wells at most locations at rates of 1 to 5 gpm. Most of the water is used for livestock.

Available quality-of-water data for the Tyndall-Scotland, Choteau, and Hubonmix aquifers indicates that these waters have a low sodium hazard and a high salinity hazard. Therefore, the waters are suitable for irrigation on soil with good drainage. Water from these aquifers is largely used for domestic and stock purposes. Properly constructed wells tapping these aquifers at locations at which the saturated aquifer thickness is more than 50 feet should yield water at rates in excess of 100 gpm.

The Niobrara aquifer can be expected to yield water with a low sodium hazard and a high salinity hazard which is suitable for irrigation on soils with good drainage. Yields of wells that are finished in the aquifer range from 2 to 100 gpm. Sites at which wells might produce more than 100 gpm can probably be found by drilling and aquifer testing.

The Codell aquifer yields relatively "soft" water which is widely used for domestic purposes. The water has a very high sodium hazard and a high-salinity hazard and is unsuitable for irrigation. Wells finished in the aquifer produce water at rates from 2 to 100 gpm.

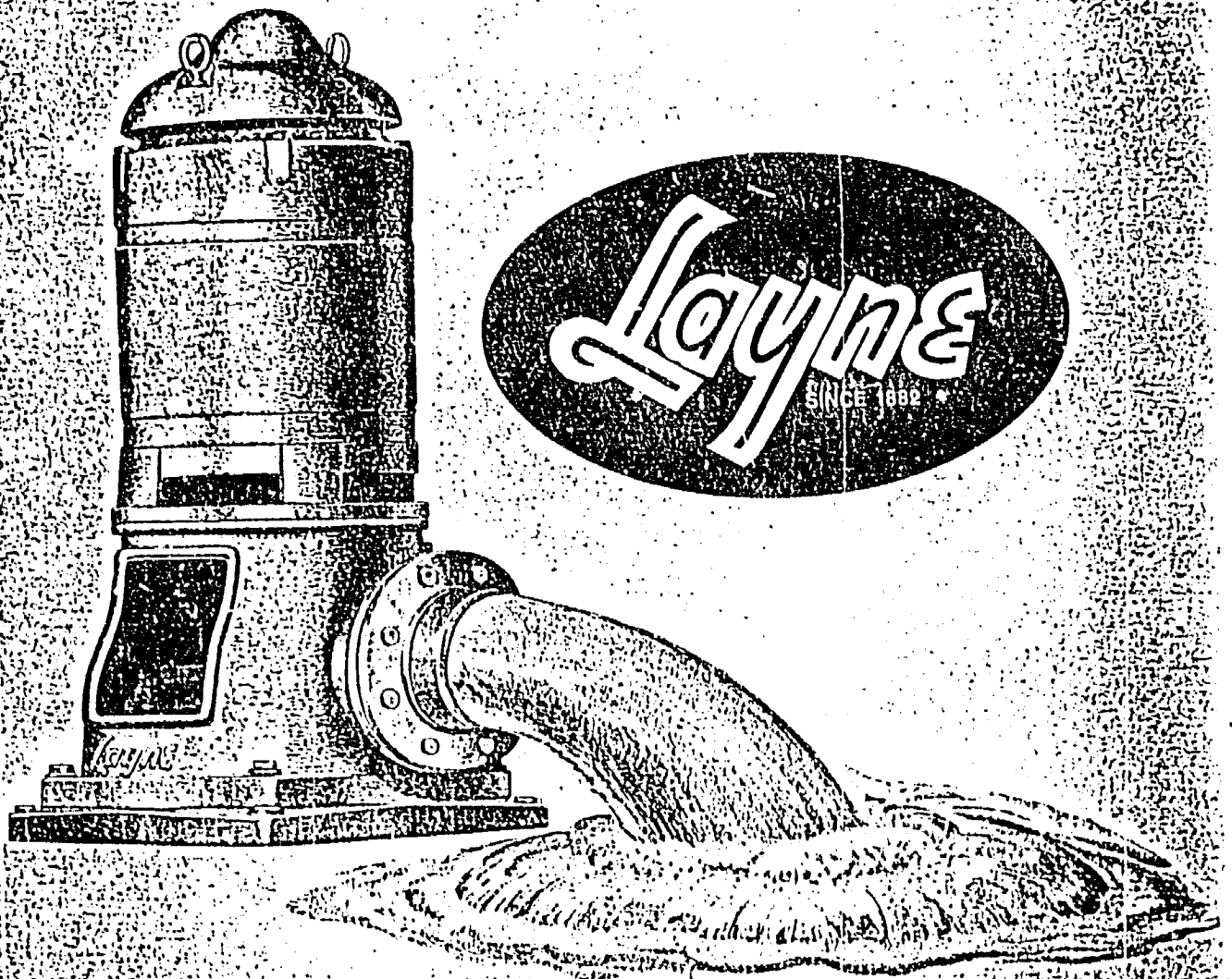
The upper and lower Dakota aquifers yield water which has a low-sodium and a high salinity hazard. The water is suitable for irrigation on land with good soil drainage. Properly constructed wells tapping the lower Dakota aquifer could produce up to about 900 gpm.

Water suitable for domestic use can be expected from wells tapping the Choteau, Tyndall-Scotland, Niobrara, Codell, and the upper and lower Dakota aquifers. However, all the aquifers can be expected to supply water that has concentrations of dissolved solids and sulfate in excess of those recommended in the Federal drinking water standards.

Water from all aquifers sampled is classified as satisfactory to excellent for livestock.

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LAYNE-MINNESOTA CO.

3147 California St. N. E.
Minneapolis, Minnesota

ARK THE MAN



FROM LAYNE

LAYNE-MINNESOTA CO.

3147 CALIFORNIA ST. N. E. • MINNEAPOLIS 19, MINN. • STERLING 1-9553

AFFILIATES • LAYNE & BOWLER, INC. • GENERAL FILTER COMPANY

March 8, 1962

The Honorable Mayor
and City Council
Tyndall, South Dakota

Re: Report on Test Drilling
Tyndall, South Dakota

Gentlemen:

Under contract dated November 28, 1961 between the City of Tyndall and the Layne-Minnesota Co., we have drilled a series of test holes in the outwash area of Emanuel Creek which lies approximately 3 to 6 miles southwest of Tyndall. Five test wells were drilled, the approximate location of which is shown on the accompanying location map. Test Wells #1, #2 and #5 were electric logged and formation samples subjected to laboratory analyses. Electric log was not run on Test Holes #3 and #4 and laboratory analyses were not run on samples therefrom. Logs of all test wells are attached, together with electric logs of three of the wells.

Sieve tests were run on typical samples from the test wells, and flow tests were run on those typical samples which would be below the pumping level of a producing well at that site. The electric log was used as an additional guide in selection of samples to be tested in the laboratory. Laboratory Report of Sieve Analyses for samples from Test Holes #1, #2 and #5 are attached. The wide variation in critical size of the sample material at different levels indicates the widely varying conditions under which the outwash and alluvium was deposited. Because the median size of all sand samples varies from .008" to .023" in the test holes drilled, it is obvious that great care must be taken in the design and construction of the permanent well to assure stability.

Flow tests were run on samples from Test Wells #1, #2, and #5. Production wells would be possible at those sites with range in probable capacities as shown. The capacity figures do not include well losses and are maximums to maintain laminar flow in the well. Figures do not take into consideration the transmissibility of the over-all formation or effects of boundaries which can only be determined by actual pumping test on a producing well with meterably water level measurements in two or more observation wells.

WATER WELLS • PUMPS • WATER TREATMENT



WORLD'S LARGEST WATER SUPPLY EQUIPMENT MANUFACTURER

March 4, 1962

Tyndall, South Dakota

Probable Capacity of well

Test Hole #1	-	310 to 520 g.p.m.
Test Hole #2	-	410 to 685 g.p.m.
Test Hole #5	-	555 to 925 g.p.m.

As stated before, the above figures do not include well or formation losses. There are, of course, human errors in sampling and testing which are not subject to evaluation. The above figures do, however, give a good picture of the comparative production abilities of producing wells at the sites indicated and a fair basic evaluation of the well capacities which can be anticipated.

All calculations of capacity were made on basis of a gravel well 34" diameter surrounding a 12" diameter screen with flow rate less than the velocity which would cause turbulent flow. The length of the screen and depth of screen setting are such as will obtain maximum producing capacity of the well with allowances for calculated drawdown.

	<u>Length of Screen</u>	<u>Depth</u>
Test Hole #1	30 ft.	35 to 115 ft.
Test Hole #2	40 ft.	100 to 160 ft.
Test Hole #5	50 ft.	115 to 160 ft.

Because of the extremely fine sand which is encountered at various levels in the test holes, it is recommended that the double gravel filter type will be used for permanent well installations. Water samples from the test holes showed considerable amounts of iron. Iron, in combination with the salts in hard waters, can present maintenance of flow problems especially in wells pumped at high capacity. The rate of plugging is in proportion to the amount of iron, the pH and alkalinity of the water and the velocity through the formation, gravel pack and screen. If turbulent flow is attained, the rate of plugging increases with the square of the velocity. Thus it is obvious that as these depositions are made the voids are reduced in size, the velocity increased and the rate of plugging accelerated - a vicious cycle. As a well plugs it becomes increasingly difficult to induce cleaning materials through the screen. Acids, polyphosphate, chlorine and other well cleaning solutions follow the path of least resistance and do not reach the areas where needed most.

March 8, 1962

PAGE NO. 3

Tyndali, South Dakota

We, therefore, recommend that a treatment coil of non-corrosive material be installed about the full length of the screen in the outer perimeter of the gravel wall. This will provide a means to apply chlorine and well cleaning solutions to the outer wall of the gravel pack without removing the pumping equipment. The ease with which the operation can be performed will be conducive to maintenance of maximum specific capacity.

Recommended Specifications

The following suggested specifications cover our recommendations for the permanent well, or wells, in the Fraapuel Creek outwash area:

Well Design - An open hole 34 inches in diameter shall be drilled from the surface to through the water-bearing formation anticipated at a total depth of _____ ft. The well may be drilled by any standard drilling method. If cable tool equipment is used, the casings shall be removed as the gravel wall and permanent casing is placed, and shall remain the property of the Contractor. Temporary casings, if used, may not be left in the well; the permanent outer casing must be cemented into native material by filling the annular space between the temporary and permanent casing with cement grout as the temporary casing is removed. Graveling between the temporary casing and the screen and inner casing shall be a progressive operation with extreme care being used to prevent sloughing of the native formation.

If rotary or reverse rotary method is used drilling fluid will be kept at a minimum specific gravity and commercial drilling clays, if used, shall be of the thin cake type easily removable with detergents and/or wetting agents. The Contractor shall be prepared to demonstrate these characteristics to the satisfaction of the engineer.

After the 34 inch diameter hole is drilled, the 12 inch diameter screen, inner casing and treatment coil with riser to the surface hole shall be placed concentric with the 34" diameter; a double gravel wall installed about the screen grading from fine next to the formation to coarse next to the screen. This double wall of filter gravel may be placed by preforming the coarse filter material on the screen before lowering in the well, or by use of a divider casing which shall be withdrawn as the gravels are placed.



March 8, 1962

Tyndall, South Dakota

The graveling shall be continued from the bottom to a point _____ ft. from the surface at which time the 24 inch diameter permanent outer casing shall be installed and cemented into the 34 inch open hole for its entire length. Ballast gravel will then be placed between the casings to the surface.

Casing - The outer casing shall be 24 inch outside diameter Schedule 40 with .375" wall and shall weigh 94.62 lbs. per ft. plain end. The inner casing shall be 12-3/4 inch outside diameter Schedule 40 with .375" wall and shall weigh 49.56 lbs. per ft. All casing shall be plain end for field butt welding.

Screen - The well screen shall be of the shutter type with horizontal shutters designed for gravel wall type construction. It shall be minimum 12 inch inside diameter and formed from No. 304 stainless steel plate with no metal removed. The screen shall have a yield strength in excess of 60,000 pounds with not more than 0.2 percent permanent deformation and with openings no less than .085 inch.

Gravel - Gravel for the gravel wall well shall be quartz and shall contain no more than two percent (2%) calcium. The gravel in contact with the formation shall be sized to withhold 90% of the native material. The gravel next to the screen shall be sized to withhold 100% of the outer gravel. In no case shall the sieve size which passes be more than double the sieve size which retains the filter media.

Cemented Casing - The annular space between the 34 inch drilled hole and the 24 inch permanent casing shall be filled with cement grout for its entire length. Cement must be placed from the bottom up to the surface by pumping or by continuous tremie.

Well Test - After the well has been completed, cleared and completely developed a vertical turbine deep well test pump shall be installed and a test run. The well test shall be conducted for a period of _____ hours with readings taken by a representative of the Contractor and the engineer every



LAYNE-MINNESOTA CO.

March 8, 1962

PAGE NO. 5

Tyndall, South Dakota

hour. The test pump shall have a capacity of 600 g.p.m. at a pumping level of 100 ft. and shall be equipped with gate valve for adjusting capacity and calibrated orifice or other acceptable device for measuring flow.

Respectfully submitted,

LAYNE-MINNESOTA CO.

F. W. Voedtsch
Vice President

CS

USE THE MAIL



FROM LAYNE

Loynes

Water Wells • Pumps • Water Treatment

Well Specifications
at #5 Test Well

GRAVEL WALL WELL for

TYNDALL, SOUTH DAKOTA

Method of Installation

Well to be drilled 34 inch diameter through the formation to be developed anticipated at an approximate depth of 160 ft.

Screen to be set opposite water-bearing strata concentric with open hole with blank casing extending to the surface. Graded gravel to be pumped into place to form a gravel filter about the screen and to 100 feet from the surface.

Outer casing 24 inch diameter to be grouted in open hole and graveling continued between casings to the surface.

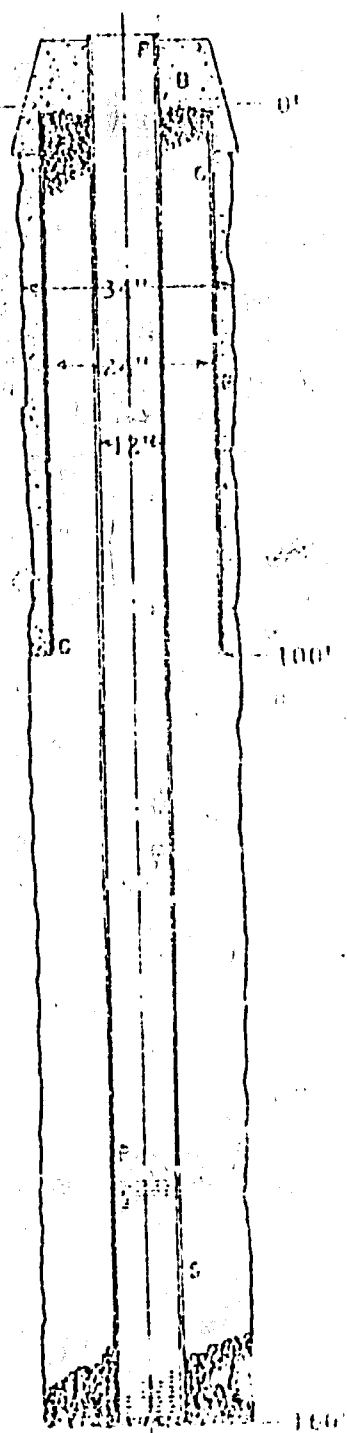
Material

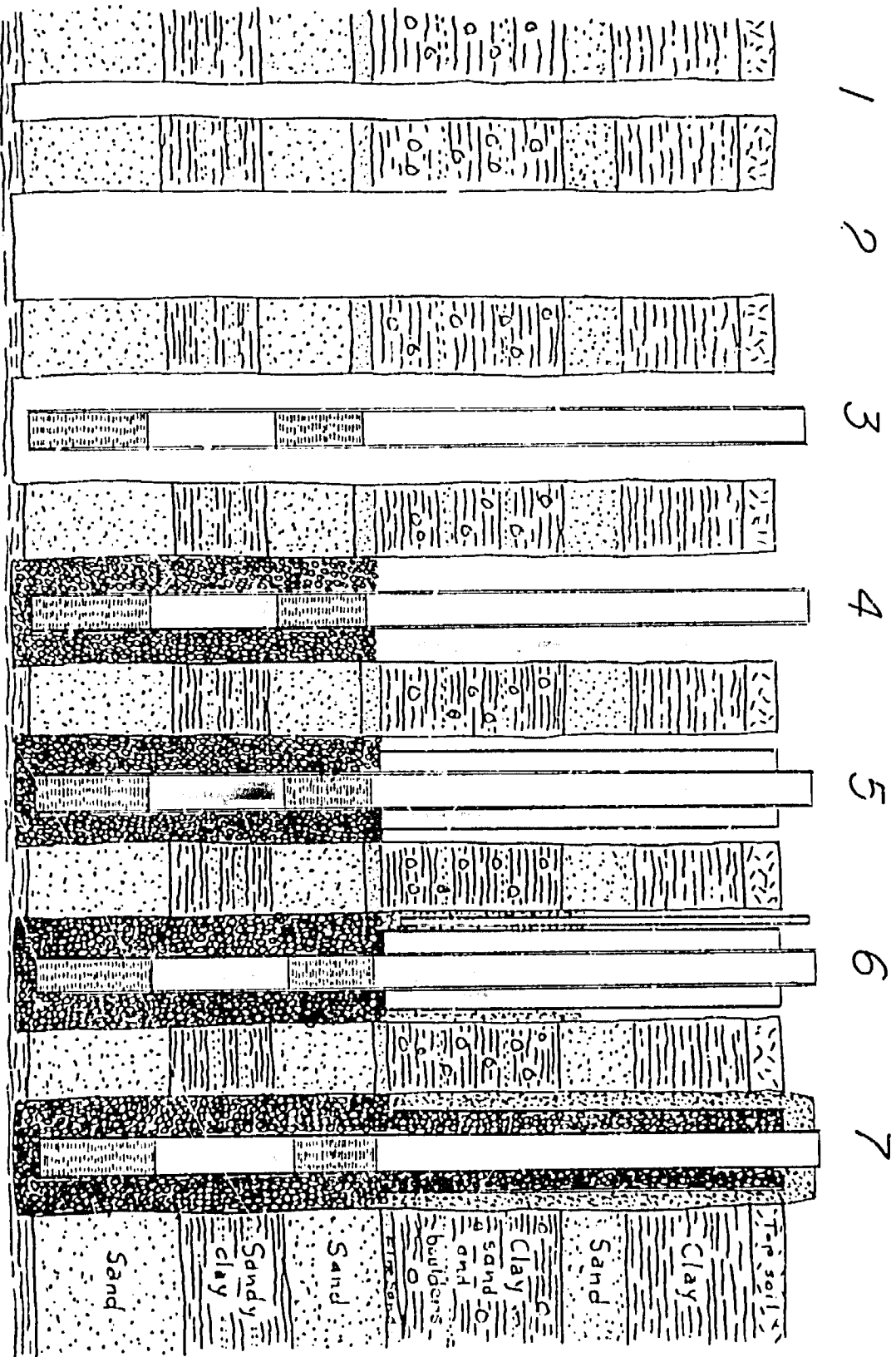
- C. 100 feet of 24 inch diameter steel pipe
- P. 119 feet of 12 inch diameter steel pipe
- S. 50 feet of 12 inch diameter Loynes Shutter

Screen made of Stainless Steel

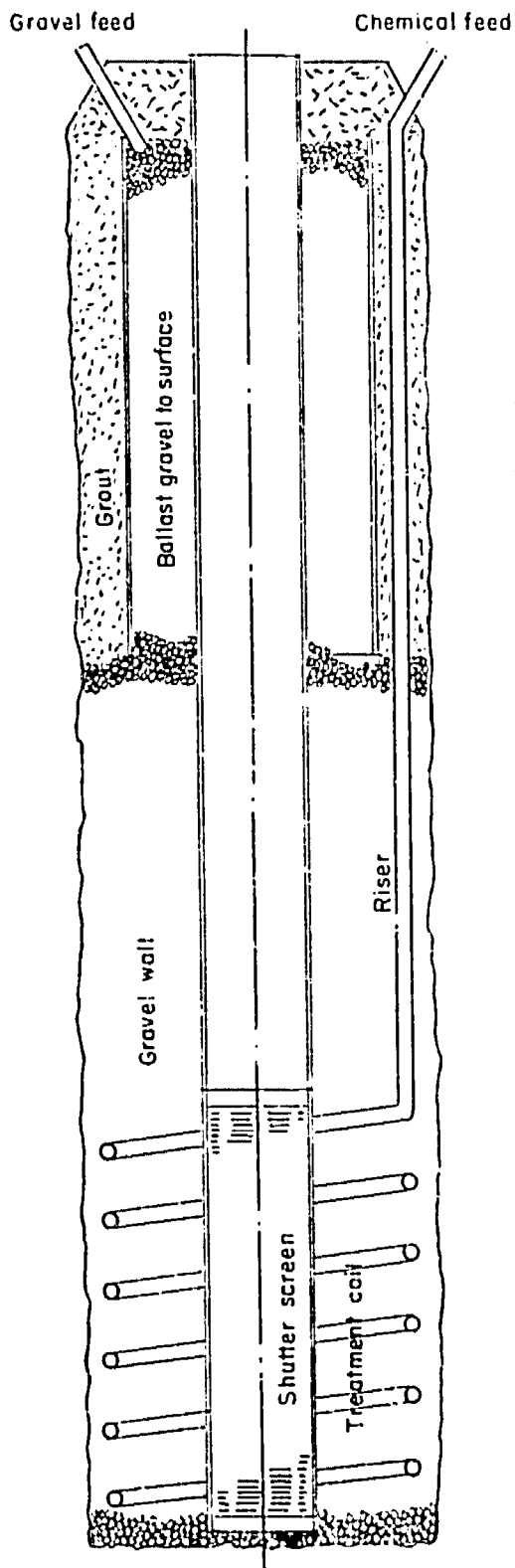
G. Concrete Grout

P. Gravel Pump





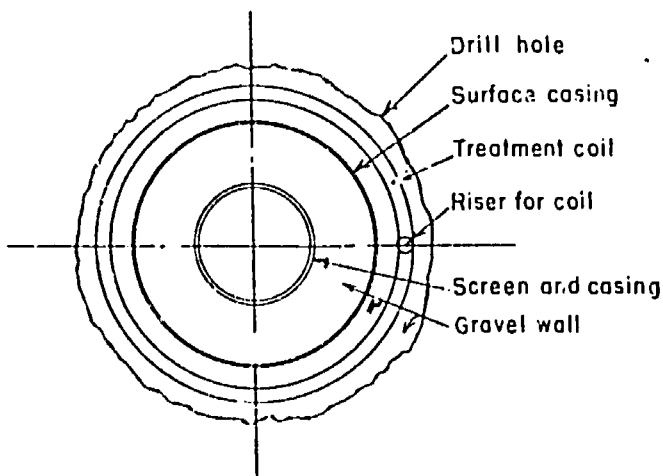
STEPS IN THE CONSTRUCTION
OF A LAYNE GRAVEL WALL WELL
REVERSE ROTARY METHOD



Layne

GRAVEL WALL WELL with TREATMENT COIL

Well to be drilled by any standard method to provide large diameter hole completely penetrating the water bearing formation. A coil made of non-corrosive tubing shall be placed about the screen with riser extending to the surface prior to placement of the gravel wall. The bottom end of the coil shall be closed. A series of properly sized and spaced holes shall be drilled in the coil to provide equal distribution of treatment liquid to the extremity of the gravel wall.



World's Largest Water Developers

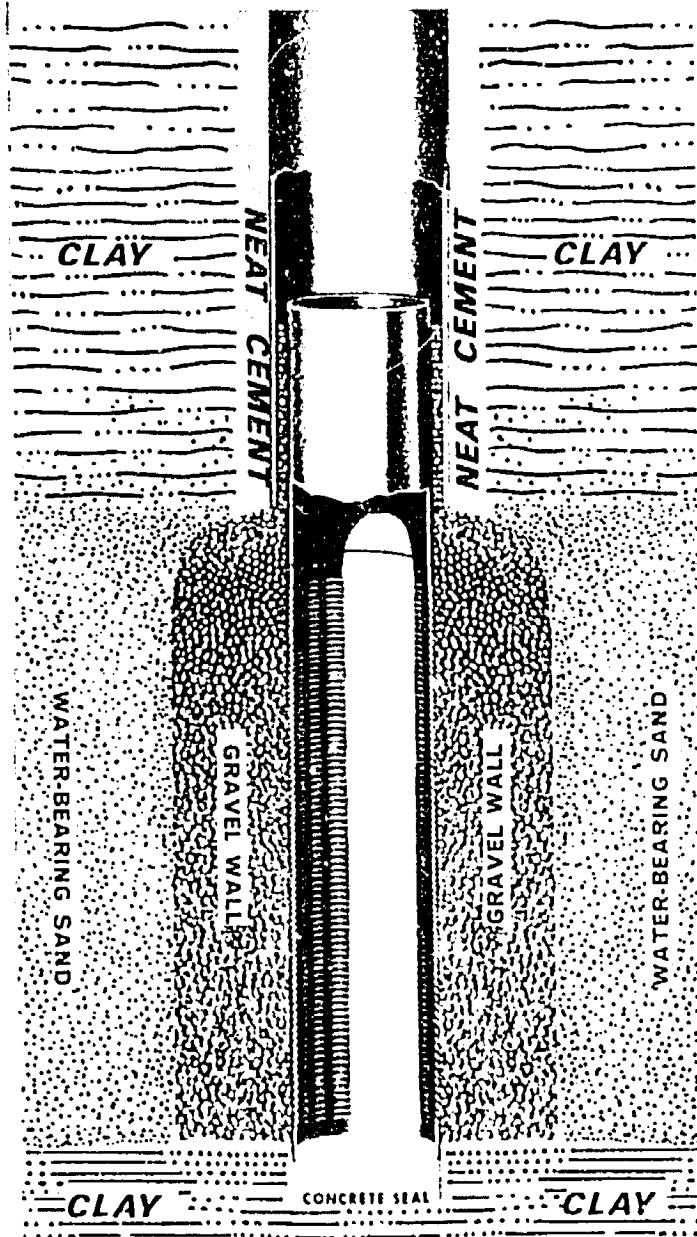
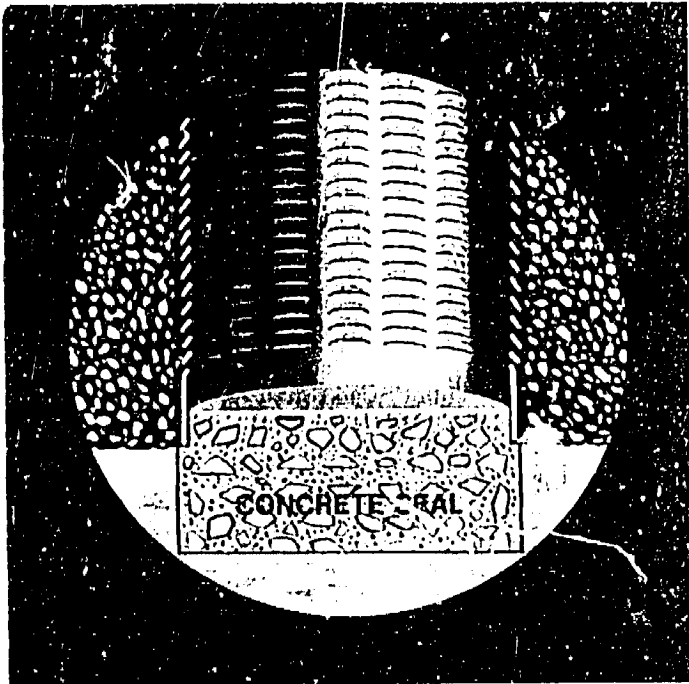
BULLETIN 900

Layne

Water Screen for Gravel Wall Wells

WORLD'S MOST COMPLETE WATER SERVICE ORGANIZATION





Shutter Screen

The basis for an efficient, economical well

The purpose of a shutter screen is to permit the free flow of water from water-bearing formations into the well proper. The screen retains gravel which, properly selected for size, prevents in-flow of sands.

The use of fine mesh sand screens effectively holds back sand particles but correspondingly reduces intake of water, drawdown is greater, pumping head is increased and overall pumping costs become excessive and impractical.

Coarse mesh sand screens simply swap these problems for others, as they permit sand seepage and continuous screen abrasion. The result of constant abrasion is an eventual failure of the screen.

Layne Shutter Screen construction provides extra failure resistance without additional cost or loss of opening area.

The Layne gravel wall well using the Layne Shutter Screen results in a well which operates efficiently and economically.

Optimum conditions are achieved by the use of the proper screen opening, properly selected and sized gravel, to form the gravel wall (or envelope)—see illustration—providing much greater contact area with the water-bearing sands, and increasing the efficiency of the well.

This produces the most efficient type of well, guaranteeing maximum water production at minimum operating and maintenance costs.

This method . . . conceived, pioneered and developed by Layne, has been imitated and copied, but never equalled or surpassed.

CROSS-SECTION OF GRAVEL WALL WELL WITH THE LAYNE SHUTTER SCREEN IN PLACE

The Layne Underreamed Gravel Wall Well, using the Layne Shutter Screen, is the most efficient ground water producing unit in existence.

The water-bearing formation is underreamed after the permanent upper casing is set in place. The screen of the proper diameter and length is centered in the large diameter of the underreamed hole. Selected and graded gravel is placed about the screen, resulting in a gravel envelope held in place by a long-lasting screen, designed to allow the maximum flow of water.

Unsurpassed Construction

The Layne Shutter Screen is a product of Layne's creative research and engineering. Years of development and field testing, together with new materials and methods, make this the most advanced screen available today.

The superiority of the Layne Shutter Screen stems from its simplicity. This screen is unique because it is made completely from one piece of cylindrical stock. *Nothing is added—nothing is removed.*

The openings are die punched into the walls of the cylinder by a special process which incorporates the cut portion into a vital and integral part of the finished screen. This cut portion, the louver, is expanded and extended—upward and outward—forming an arch over the opening, of which it still remains a continuous part. This construction feature strengthens the screen and affords protection to the openings during graveling and development of the well.

There are no "separate parts" to the Layne Shutter Screen. There are no wires welded to rods to initiate corrosion. In fact, there are no rods, reinforcing bars, buttons, or wire lugs to become loose or to interrupt water flow. Louvers are shaped to create an upward flow as water enters the well. This bridges gravel away from the mouth to allow a free area for the full extent of the opening and provides a reduction in entrance velocity. The gravel wall makes possible the use of larger openings, thereby increasing water intake. The net result is less drawdown, reduced total pumping head and lower pumping costs.

Materials

Because water conditions vary and corrosive properties may cause injury to standard metals, Layne produces shutter screens in a variety of materials, each having a specific immunity to particular corrosive agents.

Stainless Steel—AISI Type 304 (18-8), hot rolled, annealed and pickled. No. 1 finish. Composition: 18-20% chromium, 8-12% nickel, 2% manganese and small amounts of carbon, phosphorus, sulphur and silicon. This type of stainless steel is very resistant to all corrosion and is recommended when unusually severe conditions exist. No type 304 Stainless Steel Layne Shutter Screen has ever failed from corrosion in any Layne Gravel Wall Well.

Armco Iron—a uniform iron of high chemical purity, remarkably free from rust-promoting properties. This freedom from impurities insures greater resistance to rust and corrosion.

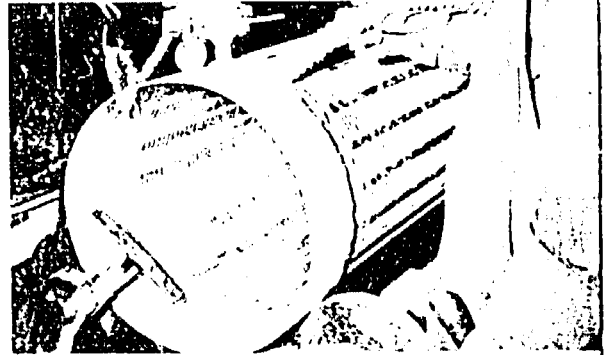
Everdur—an alloy containing approximately 90% pure copper, 1% manganese and 3% silicon. The strength of this alloy approaches that of steel, yet has all the corrosion-resisting properties of pure copper. It has a tensile strength and elastic limit equal to low and medium carbon steels.

Monel Metal (Special Order)—Type No. 25, cold rolled, ASTM Specification B127-411, Class A. Composition: 67% nickel, 30% copper, 1.4% iron, 1% manganese and traces of silicon, carbon and sulphur.

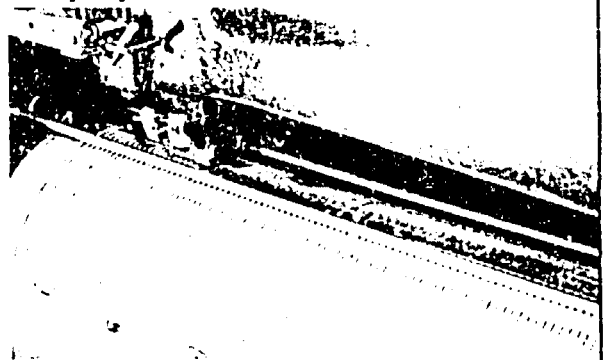


Smooth interior facing permits non-sag use of tools within screen's diameter during the development of the well, unitary construction allows trouble-free cleaning. Layne Shutter Screen design and engineering has gained fame for Layne Gravel Wall Wells throughout the world.

All seams and joints (in assembling field sections) are electric welded. The weld has unusual strength and resists shock and corrosion.

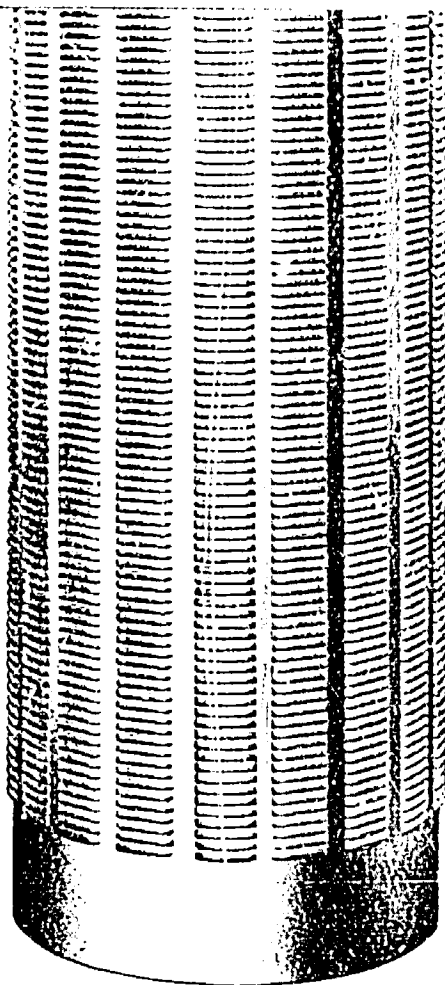


Heavy power presses cut, stamp and form louver openings in the shutter screen. Precision dies maintain uniformity of openings, angle and curvature of louvers.



Layne shutter screen is made in uniform 5 foot lengths. These are welded together in 10, 15 or 20-foot sections for proper field length.





Shutter Screen

for water wells

Sizes

Layne shutter screens come in a variety of standard lengths and diameters designed to fill individual well design requirements easily and economically.

Length: Sections 5 ft. each. Assembled and delivered in 10, 15 and 20 ft. field lengths.

Diameter: 6 inch minimum; 48 inch maximum. Larger sizes available on special order.

Joints: Butt band welded into field lengths for welding at well site, screw coupled or riveted for joining field lengths, are also available.

Louvers are made by die punching rows of openings in a cylindrical tube of the required material. No material is removed from the cylinder. The louvers are pushed outward and upward, forming an arch. This provides added strength as well as affording protection to the openings during graveling and well development.

Advantages: Uniform Louver openings offer lower inlet velocities, increased water intake, reduced pumping head and reduced drawdown.

World's Most Complete Water Service Organization

The Layne organization is first in the field—because over 75 years of pioneering and leadership around the world have provided on-the-job experience dealing with every water problem known to man.

Layne and its associate companies offer complete water service, from initial geological studies through drilling, well and pump installation to service and maintenance. Back of this service is the Layne Research Division, constantly developing new methods, better ma-

terials and greater economies. The services of Layne Research are always available to Layne customers.

A complete staff of hydrologists, engineers, consultants, technicians and field crews are available for any phase of ground water development.

LAYNE SERVICES DO NOT REPLACE, BUT RATHER CO-ORDINATE WITH THOSE OF CONSULTING, PLANT OR CITY ENGINEERS.



Layne & Bowler, Inc.

General Offices and Factory, Memphis, Tenn. 38103
Layne Associates Companies Throughout the World

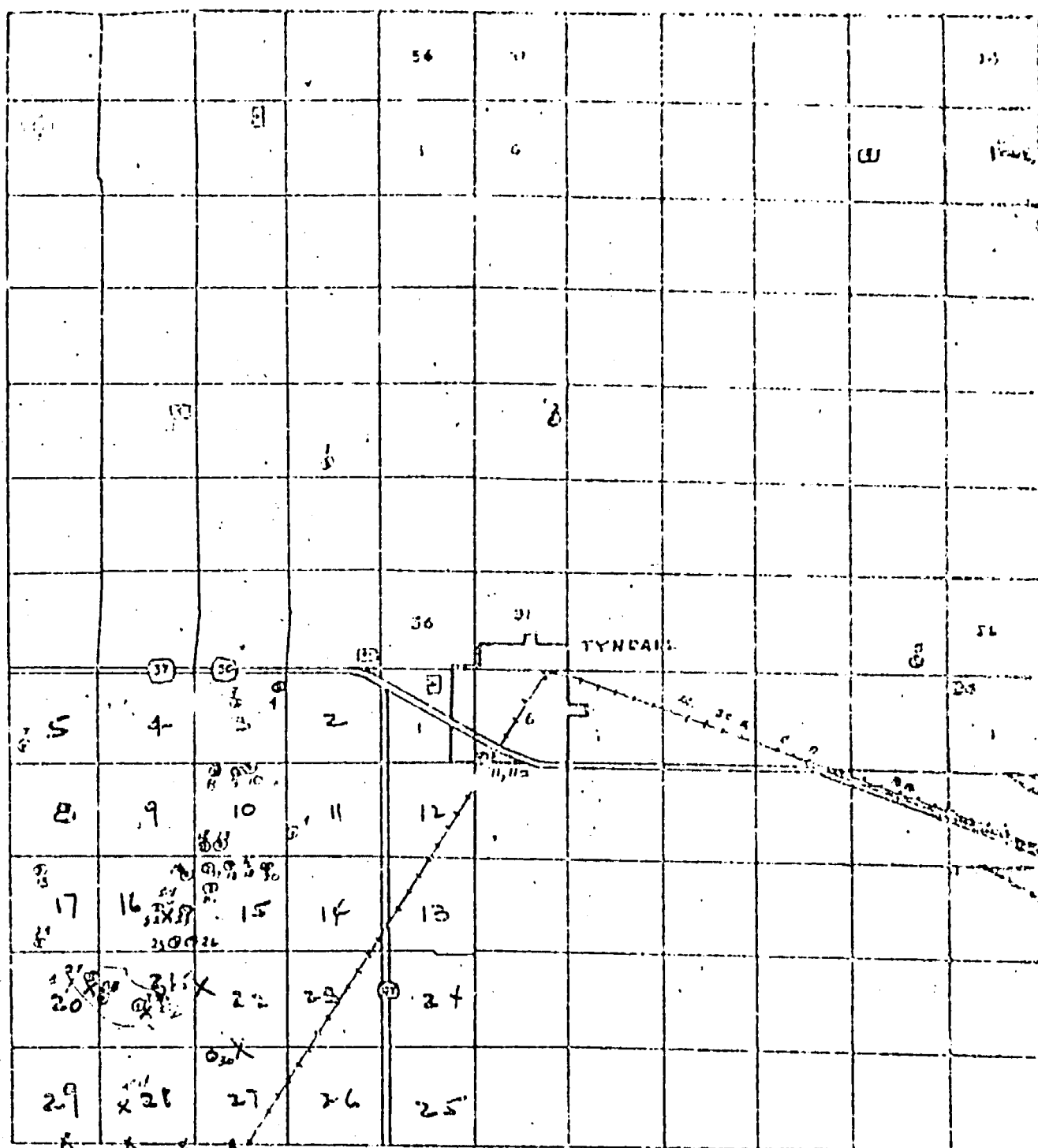


Figure 2 Data Map of Tyndall and Vicinity
by
R. L. Bruce
1961

Scale in miles
0 1/2 1

LAYNE - MINNESOTA CO.

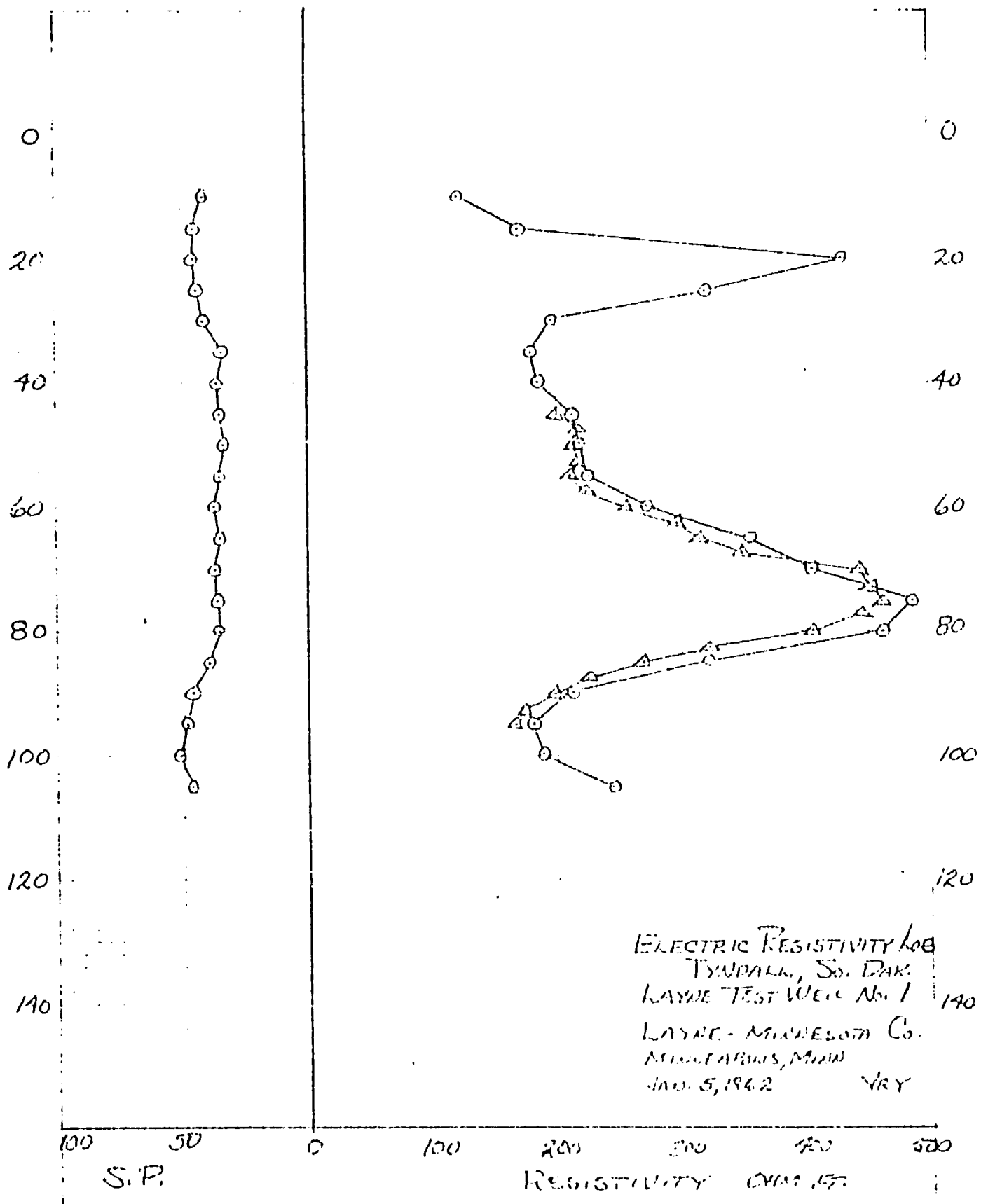
FIELD REPORT OF TEST HOLE

Name of Job CITY OF TYNDALL Test Hole No. 1
 Address Tyndall, South Dakota Depth 135'
 Date 1/3/62 - 1/4/62

LOG				PERMEABILITY DATA		
From	To	Material	Sample Taken	Hydrometer Reading	Fluid Loss inches	Remarks
0	9'	Top soil & leamy clay				
9	15	Sand & gravel M-F				Soft
15	25	Sand & gravel M-F				Soft
25	35	Sand fine gravel M-F				Soft
35	45	Sand, gravel M-F				Soft
45	55	Sand, gravel M-F				Soft
55	65	Coarse sand, gravel M-F				Soft
65	75	Fine sand				Soft, clean & clear
75	85	Fine sand				Firm, clean & clear
85	95	Fine sand				Firm, clean & clear
95	100	Fine & coarse sand				Clean & brownish
100	110	M. to F. sand				Clean & brownish
110	116	M. to F. sand				Clean & brownish
116	123	Bluish G. Clay				Hard blue gray
123	124	Clay & sandy				Softer ^{blue} /gray
124	125	Clay & sandy				Softer ^{blue} /gray
125	130	Clay & sandy				Hard ^{blue} /gray
130	135	Clay & sandy				Hard blue gray

Size of Pit: Length 8 ft. Width 6 ft. Depth 4 ft.
 Static Water Level ft. below ground level. Diameter of well 7 7/8 in.
 Was well pumped Yield g p.m. Water sample
 Depth of screen setting ft. Size of gravel used

Date 1/4/62 Driller Jerry Bonnell



ELECTRIC RESISTIVITY log
TYNDALL, S.D. DAK.
LAYNE TEST WELL No. 1
LAYNE - MINNEAPOLIS CO.
MINNEAPOLIS, MINN.
JAN. 5, 1962 VRY

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. J
 Address Tyndall, South Dakota Depth of Sample 15 - 25
 Date _____

Largest Particle _____
 Recommended size gravel _____ in to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.250	60	1	.5	.5		
6	.132	10	19	8.1	8.6		
8	.093	20	31	13.3	21.9		
12	.065	30	29	12.4	34.3		
16	.046	40	34	14.6	48.9		
20	.0328	60	38	16.3	65.2		
30	.0232	80	36	15.5	80.7		
40	.0164	100	27	11.6	92.3		
50	.0116	150	10	4.3	96.6		
70	.0085	200	2	.8	97.4		
100	.0058	300	2	.8	98.2		
200	.0029	600	3	1.3	99.5		
Per	0000	Per	1	.5	100.0		
	Total		223	100.0			

Sample obtained by -- rotary under pressure, cable tool, caisson rig
 Porosity _____ % Permeability _____

Test Driller _____ Lab Test by _____
 Date _____ Data _____

LABORATORY REPORT OF SIEVE ANALYSIS

Largest Particle _____
Recommended size gravel _____ in. to _____ in.
Remarks _____

Sample obtained by— rotary under pressure, cable tool, caisson rig.

Test Driller _____ Lab. Test by _____
Date _____ Data _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 1

Address Tyndall, South Dakota Depth of Sample 40 - 60

Date

Largest Particle

Recommended size gravel in. to in.

Remarks

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3	1	.5	.5		
6	.132	6	15	8.5	9.0		
8	.093	8	38	17.2	26.2		
12	.065	10	37	13.7	39.6		
16	.046	14	23	10.8	50.4		
20	.0328	20	20	7.4	59.8		
30	.0232	28	21	9.9	69.7		
40	.0164	35	26	12.5	82.2		
50	.0116	48	21	9.9	92.1		
70	.0082	65	10	4.7	96.8		
100	.0058	100	3	1.4	98.2		
200	.0029	200	2	.9	99.1		
Pan	.0000	Pan	2	.9	100.0		
Total				100.0			

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity % Permeability

Test Driller Lab. Test by

Date Date

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 1
 Address Tyndall, South Dakota Depth of Sample 60 - 95
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8	3	1.8	1.8		
12	.065	10	4	2.4	4.2		
16	.045	14	6	3.5	7.7		
20	.0328	20	9	5.3	13.0		
30	.0232	28	13	7.6	20.6		
40	.0164	35	24	14.1	34.7		
50	.0116	48	40	23.5	58.2		
70	.0082	65	39	22.9	81.1		
100	.0058	100	22	12.9	94.0		
200	.0029	200	8	4.7	98.3		
Pan	.0000	Pan	2	1.3	100.0		
Total			170	100.0			

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 1
 Address Tyndall, South Dakota Depth of Sample 35 - 116
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	3	1.5	1.5		
8	.093	8	8	4.3	5.8		
12	.065	10	32	17.0	22.8		
16	.046	14	46	24.5	47.3		
20	.0328	20	37	19.7	67.0		
30	.0232	28	15	8.0	75.0		
40	.0164	35	9	4.8	79.8		
50	.0116	40	11	5.9	85.7		
70	.0082	65	13	6.9	92.6		
100	.0058	100	3	1.3	97.4		
200	.0029	200	4	2.1	99.5		
Pan	.0000	Pan	1	.5	100.0		
	Total		188	100.0			

Sample obtained by-- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

FIELD REPORT OF TEST HOLE

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth 189'
 Date 1/18/62

LOG				PERMEABILITY DATA		
From	To	Material	Sample Taken	Hydrometer Reading	Fluid Loss inches	Remarks
0	15	Sand, gravel				Dry
15	25	Sand, finer				Dry - Br.
25	35	Sand, finer				Dry - Br.
35	45	Sand				Soft clean (w)
45	50	Sand, finer				Soft - Br.
50	55	Sand, coarse				Soft - Br.
55	60	Sand, coarse				Soft - Br.
60	65	Sand, coarse				Soft - Br.
65	70	Sand, coarse				Soft - Br.
70	75	Sand, coarse				Soft - Br.
75	80	Sand, coarse				Soft - Br.
80	85	Sand, fine				Soft
85	90	Sand, fine				Soft - White
90	95	Sand, fine				Soft - White
95	100	Sand, fine				Soft - White
100	105	Sand, fine				Soft - White
105	110	Sand, fine				Soft - White
110	115	Sand, fine				Soft - White
115	120	Sand, fine				Soft - White
120	125	Sand, fine				Soft - White
125	130	Sand, fine				Firm - White

Size of Pit: Length 10 ft. Width 4 ft. Depth 5 ft.
 Static Water Level ft. below ground level. Diameter of well 7 7/8 in.
 Flow rate pump gpm. Water sample
 Depth of screen setting 105 ft. Size of gravel used

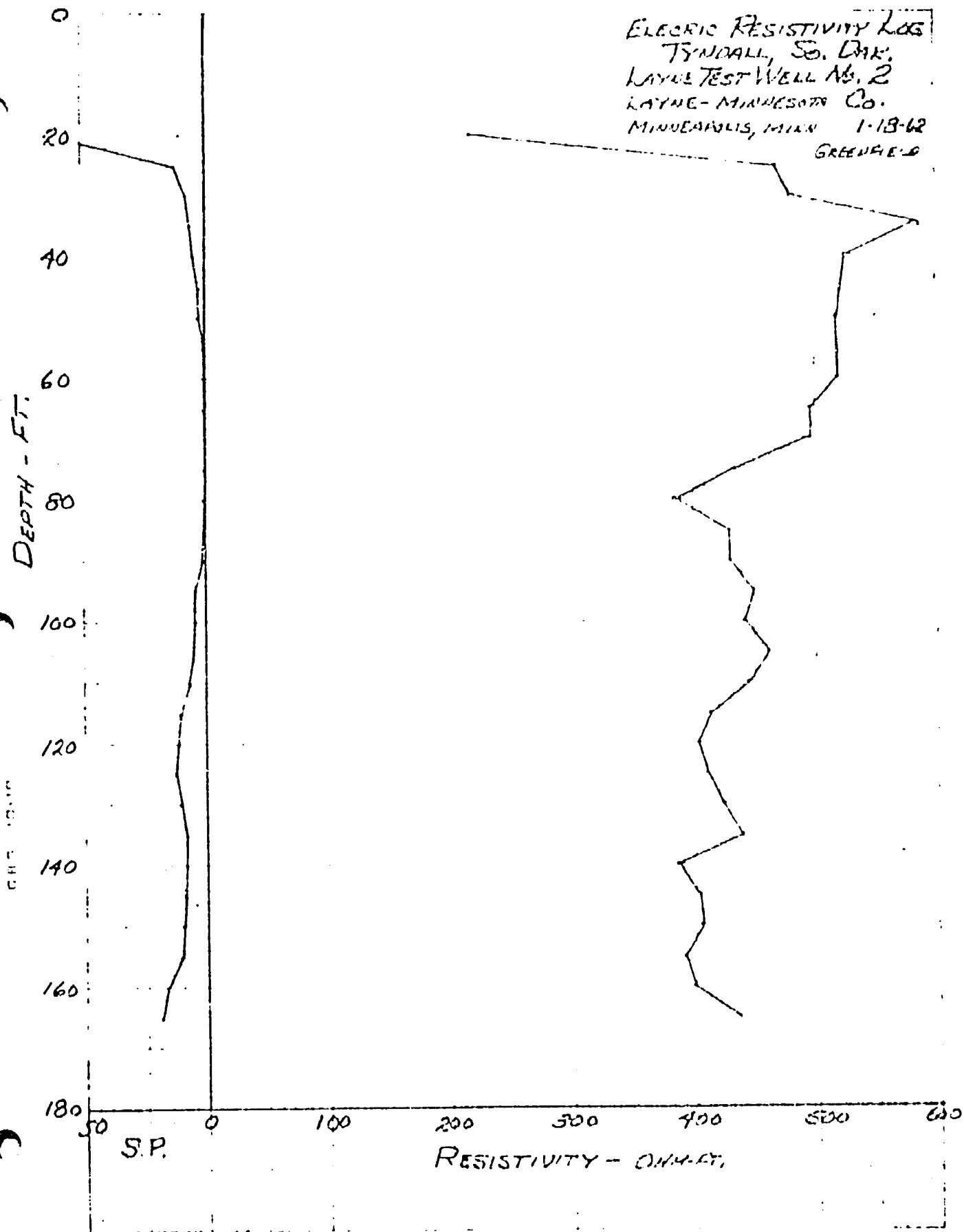
Date 1/18/62 Driller Jerry Bonnell

FIELD REPORT OF TEST HOLE

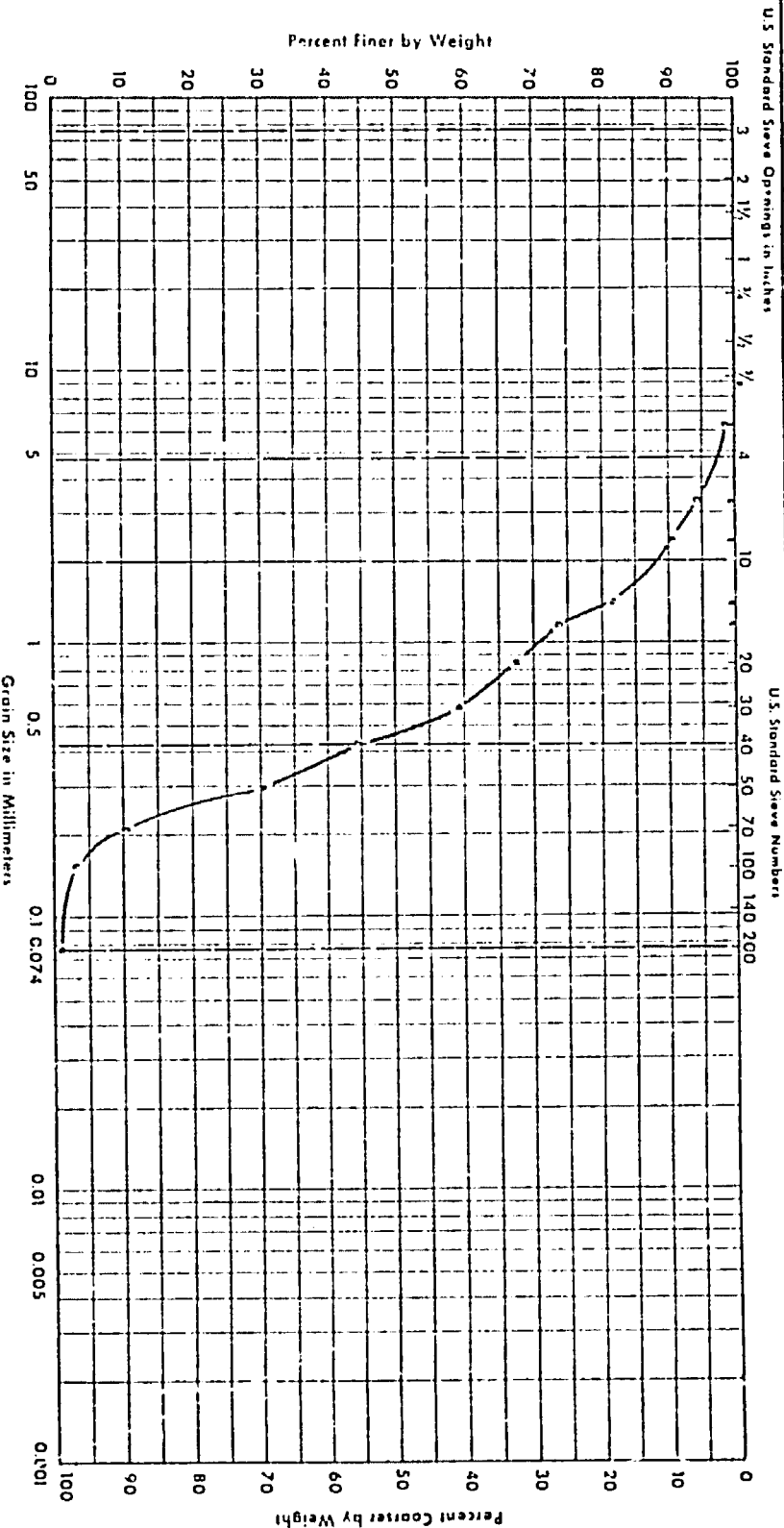
[illegible]

Size of Pit: Length 10 ft. Width 4 ft. Depth 5 ft.
 Static Water Level _____ ft. below ground level. Diameter of well 7 7/8 in.
 Was well pumped _____ Yield _____ g.p.m. Water sample _____
 Depth of screen setting 105 ft. Size of gravel used _____
 Date 1/18/62 Driller Jerry Bonnell

ELECTRIC RESISTIVITY LOG
TYNDALL, SO. DAK.
LAYNE TEST WELL NO. 2
LAYNE-MINNESOTA CO.
MINNEAPOLIS, MINN 1-18-62
GREENFIELD



GRAIN SIZE ANALYSIS



LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TINDALL Test Hole No. 2
 Address TINDALL, South Dakota Depth of Sample 25 - 35
 Date _____

Largest Particle _____ in.
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves .9090907		Total Percent		Remarks
U.S. No.	Opening inches	Mech	Grains	Percent	On	Passing	
	.250	3	1	1.8	1.8		
6	.132	6	4	3.6	3.4		
8	.093	8	5	4.5	9.9		
12	.065	10	9	8.3	18.1		
16	.046	14	9	6.3	24.3		
20	.0328	20	4	7.3	31.6		
30	.0232	28	3	7.3	40.9		
40	.0164	35	16	14.5	55.4		
50	.0116	40	16	14.5	69.9		
70	.0082	65	22	20.9	89.9		
100	.0058	100	2	7.3	97.2		
200	.0029	200	2	1.9	99.1		
Pan	.0000	Pan	1	.9	100		
	Total		110				

Sample obtained by — rotary under pressure, cable tool, auger or rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 35 - 45
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3	0				
6	.132	6	1	.7	.7		
8	.093	8	2	1.4	2.1		
12	.065	10	6	4.3	6.4		
16	.046	14	6	4.3	10.7		
20	.0328	20	5	3.6	14.3		
30	.0232	28	5	3.6	17.9		
40	.0164	35	15	10.9	28.7		
50	.0116	48	29	20.1	56.8		
70	.0082	65	37	26.6	83.4		
100	.0058	100	17	12.2	95.6		
200	.0029	200	5	3.6	99.3		
Pan	.0000	Pan	1	.8	100		
	Total		139				

Sample obtained by— rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2

Address Tyndall, South Dakota Depth of Sample 45-50

Date

Largest Particle

Recommended size gravel in. to in.

Remarks

Tyler Standard Screen Scale Sieves √2 or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.250	3					
6	.132	6					
8	.093	8					
12	.063	10	1	.9	.9		
16	.046	14	1	.9	1.8		
20	.0328	20	1	.9	2.7		
30	.0232	28	1	.9	3.6		
40	.0164	35	6	5.7	9.3		
50	.0116	48	22	20.8	30.1		
70	.0082	65	40	37.9	68.0		
100	.0058	100	26	24.5	92.5		
200	.0029	200	7	6.6	99.1		
Pan	.0000	Pan	1	.9	100.0		
	Total		106				

Sample obtained by— rotary under pressure, cable tool, caisson rig.

Porosity % Permeability

Test Driller Lab. Test. by

Date Date

Percent finer by Weight

511 T

Project: CITY OF YANBAIL

laboratory: KANSAS CITY, MO.

Date Tested:

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No 2

Address Tyndall, South Dakota Depth of Sample 50 - 55

Date _____

Largest Particles _____

Recommended size gravel _____ in. to _____ in.

Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.250	60	2	2.1	2.1		
6	.132	10	14	14.7	16.8		
8	.093	20	9	9.5	26.3		
12	.065	30	10	10.5	36.8		
16	.046	40	2	2.5	46.3		
20	.0328	60	7	7.4	53.7		
30	.0232	80	5	5.3	59.0		
40	.0164	100	6	6.3	65.3		
50	.0116	150	10	10.5	75.8		
70	.0082	200	12	12.6	88.4		
100	.0058	300	8	8.4	96.8		
200	.0029	600	2	2.1	98.9		
Pan	.0000	Pan	1	1.1	100.0		
	Total		95				

Sample obtained by -- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job TYNDALL CITY OF Test Hole No. 2

Address Tyndall, South Dakota Depth of Sample 55 - 60

Date

Largest Particle in. to in.

Recommended size gravel in. to in.

Remarks

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3	3	2.4	2.4		
6	.132	6	19	15.2	17.6		
8	.093	8	12	9.6	27.2		
12	.065	10	11	8.8	36.0		
16	.046	14	10	8.0	44.0		
20	.0328	20	7	5.6	49.6		
30	.0232	28	6	4.8	54.4		
40	.0164	35	8	6.4	60.8		
50	.0116	48	13	10.4	71.2		
70	.0082	65	18	14.4	85.6		
100	.0058	100	13	10.4	96.0		
200	.0029	200	4	3.2	99.2		
Pan	.0000	Pan	1	.8	100.0		
	Total		125				

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity % Permeability

Test Driller Lab. Test by

Date Date

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 69 - 65
 Date

Largest Particle
 Recommended size gravel in. to in.
 Remarks

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3	4	3.1	3.1		
6	.132	6	13	10.2	13.3		
8	.093	8	12	9.4	22.7		
12	.065	10	11	8.6	31.3		
16	.046	14	10	7.8	39.1		
20	.0328	20	7	5.5	44.6		
30	.0232	28	5	3.9	48.5		
40	.0164	35	10	7.8	56.3		
50	.0116	48	16	12.5	68.8		
70	.0082	65	22	17.2	86.0		
100	.0058	100	14	10.9	96.9		
200	.0029	200	3	2.3	99.2		
Pan	.0000	Pan	1	0	100.0		
	Total		128				

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity % Permeability

Test Driller Lab. Test by
 Date Date

LABORATORY REPORT OF SIEVE ANALYSIS

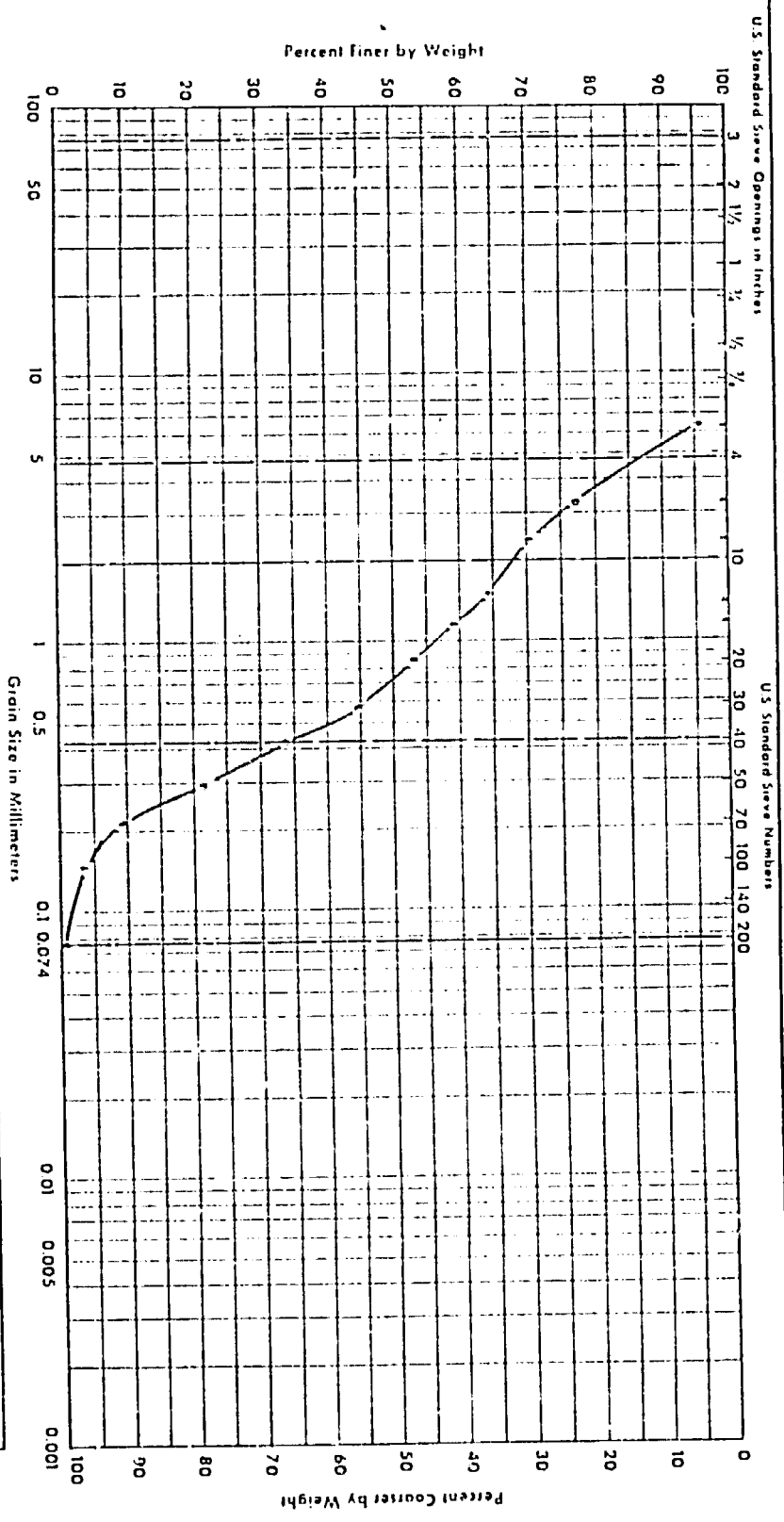
Largest Particle _____
Recommended size gravel _____ in. to _____ in.
Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3	7	5.7	5.7		
6	.132	6	17	15.6	21.3		
8	.093	8	9	7.4	28.7		
12	.065	10	12	9.8	38.5		
16	.046	14	10	8.2	46.7		
20	.0328	20	8	6.6	53.3		
30	.0232	28	8	6.6	59.9		
40	.0164	35	13	10.7	70.6		
50	.0116	48	13	10.7	81.3		
70	.0082	65	13	10.7	92.0		
100	.0058	100	3	6.6	98.6		
200	.0029	200	3	1.4	100.0		
Pan	.0000	Pan	--				
	Total		127				

Porosity _____ % Permeability _____

Test Drive _____ Lab. Test by _____
Date _____ Date _____

GRAIN SIZE ANALYSIS



LABORATORY REPORT OF SIEVE ANALYSIS

Largest Particle _____
Recommended size gravel _____ in. to _____ in.
Remarks _____

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TINDALL Test Hole No. 2

Address Tindall, South Dakota Depth of Sample 20 - 25

Date

Largest Particle

Recommended size gravel in. to in.

Remarks

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3	2	1.8	1.8		
6	.132	6	13	11.3	13.3		
8	.093	8	8	7.1	20.4		
12	.063	10	6	5.3	25.7		
16	.046	14	5	4.4	30.1		
20	.0328	20	4	3.5	33.6		
30	.0232	28	7	6.2	39.8		
40	.0164	35	20	17.7	57.2		
50	.0116	48	23	19.5	77.0		
70	.0082	65	16	14.1	91.1		
100	.0050	100	8	7.1	98.2		
200	.0029	200	2	1.8	100.0		
Pan	.0000	Pan	--				
	Total		113				

Sample obtained by -- rotary under pressure, cable tool, calson rig.

Porosity % Permeability

Test Driller Lab. Test by

Date Date

LABORATORY REPORT OF SIEVE ANALYSIS

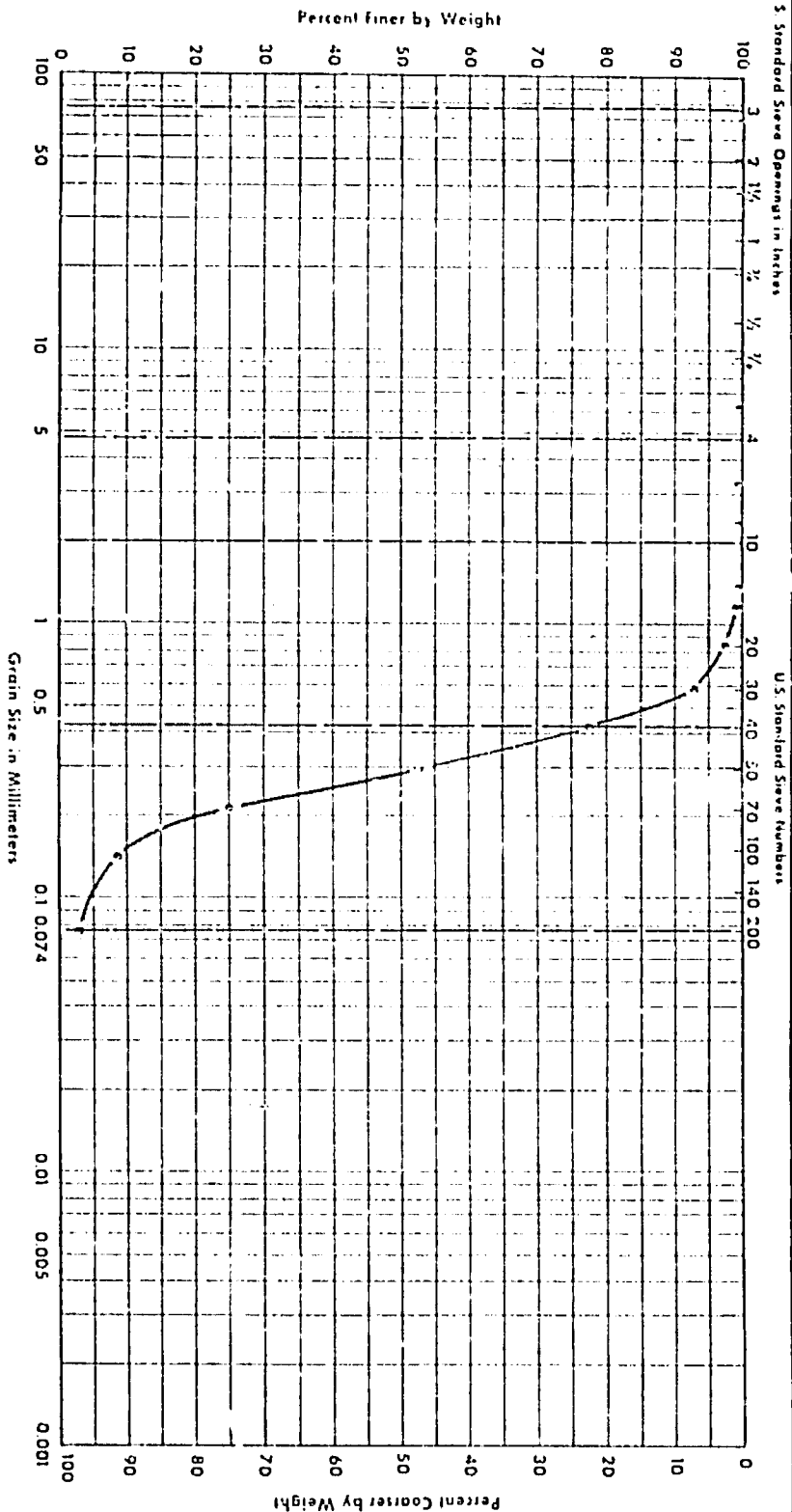
Largest Particle _____
Recommended size gravel _____ in. to _____ in.
Remarks _____

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
Date _____ Data _____

GRAIN SIZE ANALYSIS



LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 100 - 105
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8					
12	.065	10					
16	.046	14	1	1.1	1.1		
20	.0328	20	2	2.2	3.3		
30	.0232	28	4	4.3	7.6		
40	.0164	35	15	16.3	23.9		
50	.0116	48	22	23.9	47.8		
70	.0082	65	25	27.2	75.0		
100	.0058	100	16	17.4	92.4		
200	.0029	200	3	5.4	97.8		
Pan	.0000	Pan	2	2.2	100.0		
	Total		92				

Sample obtained by -- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 105-110
 Date _____

Largest Particle _____ in.
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8					
12	.065	10					
16	.046		1	.9	.9		
20	.0328		2	1.9	2.8		
30	.0232	20	5	4.6	7.4		
40	.0164	35	12	16.7	24.1		
50	.0116	48	27	25.0	49.1		
70	.0082	65	32	23.6	72.7		
100	.0058	100	17	15.7	88.4		
200	.0029	200		5.6	100.0		
Pan	.0000	Pan	-				
	Total		108				

Sample obtained by — rotary under pressure, cable tool, colason rig.
 Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2

Address Tyngsboro, South Dakota Depth of Sample 118 - 115

..... Data

Longest Particle _____

Recommended size gravel _____ in. to _____ in.

Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	Remarks
	.263	3					
6	.132	6					
8	.093	8					
12	.065	10					
16	.046	14					
20	.0320	20	3	3.2	3.3		
30	.0232	28	4	4.3	7.5		
40	.0164	35	9	9.6	17.1		
50	.0116	48	18	19.1	36.2		
70	.0082	65	26	27.7	63.9		
100	.0058	100	20	21.3	85.2		
200	.0029	200	11	11.7	96.9		
Pan	.0000	Pan	3	3.1	100.0		
	Total		94				

Sample obtained by— rotary under pressure, cable tool, calsson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 112 - 120
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieve $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8					
12	.065	10					
16	.046	14					
20	.0328	20	2	1.9	1.9		
30	.0232	28	4	3.7	5.6		
40	.0164	35	13	12.0	17.6		
50	.0116	40	11	13.4	31.0		
70	.0082	65	39	27.8	61.3		
100	.0050	100	24	22.2	87.0		
200	.0029	200	18	11.1	98.1		
Fun	.0000	Fun	2	1.9	100.0		
	Total		109				

Sample obtained by — rotary under pressure, cable tool, calson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job _____ CITY OF TYNDALL _____ Test Hole No. 2
 Address _____ Tyndall, South Dakota _____ Depth of Sample 120-125
 _____ Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

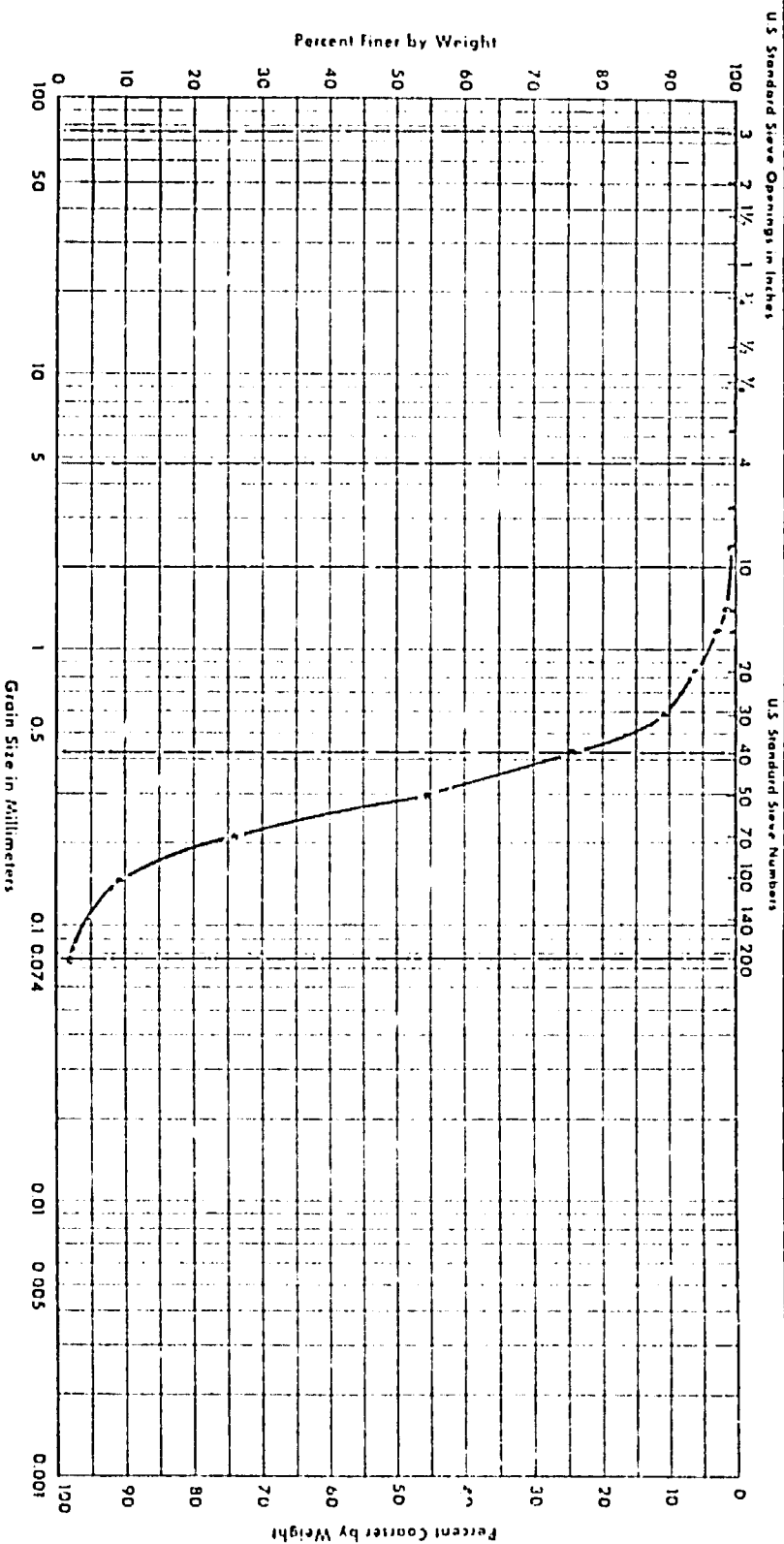
Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	263	3					
6	.132	6					
8	.093	8					
12	.065	10	5	2.8	2.8		
16	.046	14	6	3.3	6.1		
20	.0328	20	8	4.4	10.5		
30	.0232	28	16	8.9	19.4		
40	.0164	35	29	16.1	35.5		
50	.0116	40	38	21.1	56.6		
70	.0082	65	43	23.9	80.5		
100	.0058	100	25	13.9	94.4		
200	.0029	200	10	5.6	100.0		
Pan	.0000	Pan	--				
	Total		180				

Sample obtained by -- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

GRAIN SIZE ANALYSIS



LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 125 - 130
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8	1	.6	.6		
12	.065	10	2	1.1	1.7		
16	.046	14	3	1.7	3.4		
20	.0328	20	5	2.9	6.3		
30	.0232	28	8	4.6	10.9		
40	.0164	35	23	13.1	24.0		
50	.0116	48	37	21.1	45.1		
70	.0082	65	51	29.1	74.2		
100	.0058	100	30	17.1	91.3		
200	.0029	200	13	7.4	98.7		
Pan	.0000	Pan	2	1.3	100.0		
	Total		175				

Sample obtained by— rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job _____ CITY OF TYNDALL _____ Test Hole No. 2
 Address _____ Tyndall, South Dakota _____ Depth of Sample 130 - 135
 _____ Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	1	.5	.5		
8	.093	8	1	.5	1.0		
12	.065	10	2	1.1	2.1		
16	.046	14	8	4.3	6.4		
20	.0328	20	12	6.5	12.9		
30	.0232	28	19	10.3	23.2		
40	.0164	35	28	15.2	38.4		
50	.0116	48	37	20.1	58.5		
70	.0082	65	43	23.4	81.9		
100	.0058	100	23	12.5	94.4		
200	.0029	200	9	4.9	99.3		
Pan	.0000	Pan	1	.7	100.0		
	Total		184				

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 135 - 140
 Date _____
 Largest Particle _____ in. to _____ in.
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	2	3.1	2.1		
8	.093	8	1	1.0	3.1		
12	.065	10	3	3.1	6.2		
16	.046	14	6	6.2	12.4		
20	.0328	20	8	8.3	20.7		
30	.0232	28	7	7.1	27.8		
40	.0164	35	10	10.4	38.4		
50	.0116	48	16	16.7	55.1		
70	.0082	65	22	22.9	78.0		
100	.0058	100	15	15.6	93.6		
200	.0029	200	5	5.2	98.8		
Pan	.0000	Pan	1	1.2	100.0		
	Total		96				

Sample obtained by— rotary under pressure, cable tool, calisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job _____ CITY OF TYNDALL _____ Test Hole No. 2
 Address _____ Tyndall, South Dakota _____ Depth of Sample 140 - 145
 _____ Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mosh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	1	.5	.5		
8	.093	8	10	4.7	5.2		
12	.065	10	12	5.7	10.9		
16	.046	14	11	5.2	16.1		
20	.0320	20	15	7.1	23.2		
30	.0232	28	19	9.0	32.2		
40	.0164	35	25	11.8	44.0		
50	.0116	48	35	16.6	60.6		
70	.0082	65	43	21.4	82.0		
100	.0058	100	37	11.8	93.8		
200	.0029	200	11	5.2	99.0		
Pan	.0000	Pan	2	1.0	1.0		
	Total		711				

Sample obtained by — rotary under pressure, cable tool, casing rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 145 - 150
 Date _____

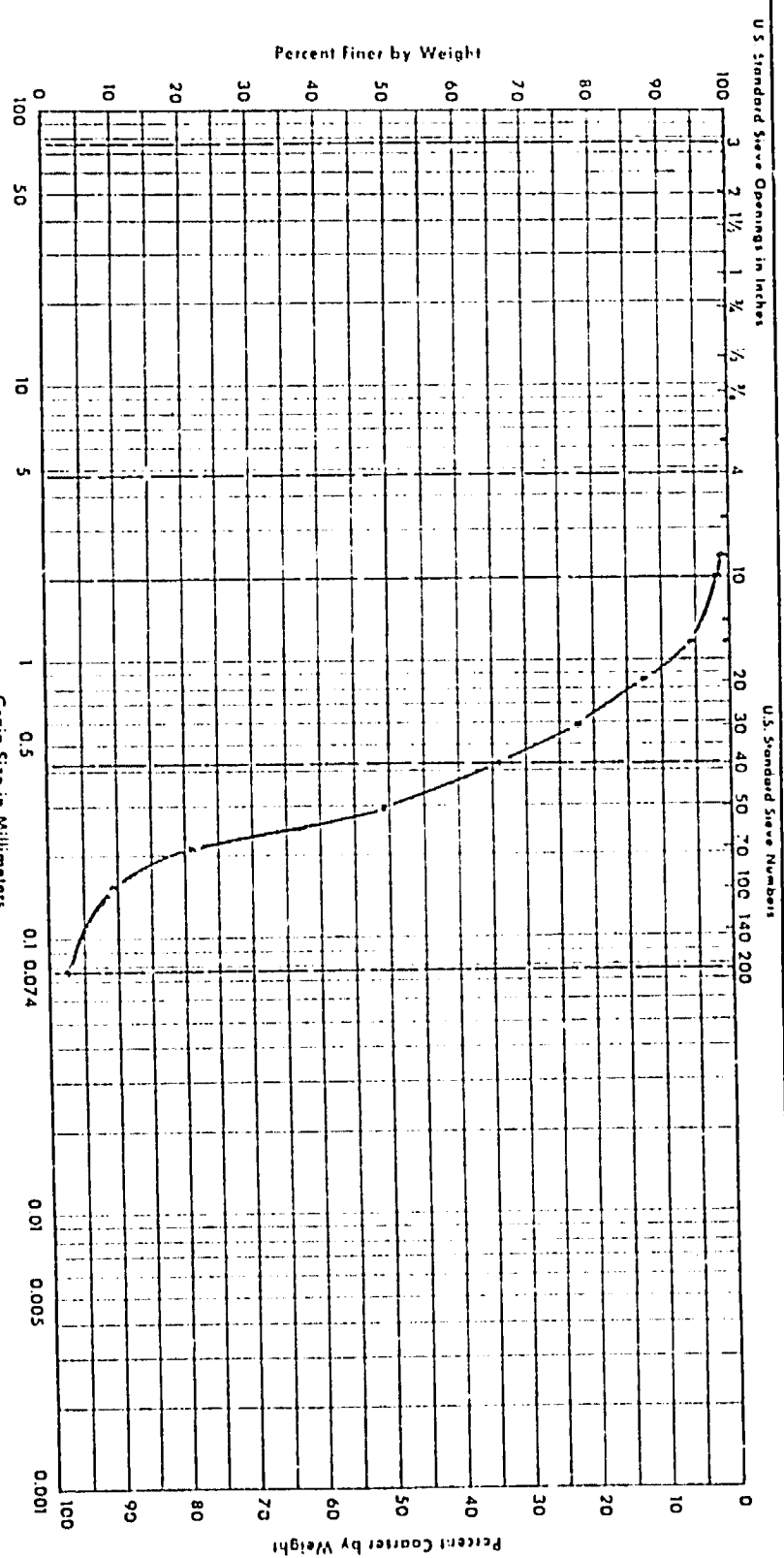
Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	1	1.1	1.1		
8	.093	8	1	1.1	2.2		
12	.065	10	1	1.1	3.3		
16	.046	14	2	2.1	5.4		
20	.0328	20	5	5.3	10.7		
30	.0232	28	8	8.5	19.2		
40	.0164	35	11	11.7	30.9		
50	.0116	48	18	19.1	50.0		
70	.0082	65	24	25.5	75.5		
100	.0058	100	17	18.1	93.6		
200	.0029	200	5	5.3	98.9		
Pan	.0000	Pan	1	1.1	100.0		
	Total		74				

Sample obtained by — rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____



LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 150 - 155
 Date _____
 Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8	1	.6	.6		
12	.063	10	2	1.2	1.8		
16	.046	14	6	3.7	5.5		
20	.0328	20	13	8.1	13.6		
30	.0232	28	15	9.3	22.9		
40	.0164	35	18	11.2	34.1		
50	.0116	40	27	16.8	50.9		
70	.0082	60	45	26.0	78.9		
100	.0058	100	19	11.8	90.7		
200	.0029	200	12	7.5	98.2		
Pan	.0000	Pan	3	1.8	100.0		
Total			161				

Sample obtained by — rotary under pressure, cable tool, colson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 155 - 160
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.253	3					
6	.132	6					
8	.093	8	1	.7	.7		
12	.065	10	2	1.5	2.2		
16	.046	14	10	7.3	9.5		
20	.0328	20	15	10.9	20.4		
30	.0232	28	13	9.5	29.9		
40	.0164	35	13	9.5	39.4		
50	.0116	48	19	13.9	53.3		
70	.0082	65	38	27.7	81.0		
100	.0058	100	17	12.4	93.4		
200	.0029	200	8	5.9	99.3		
Pan	.0000	Pan	1	.7	100.0		
	Total		137				

Sample of _____ in. by — rotary under pressure, cable tool, caisson rig.
 Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 160 - 165
 Date

Largest Particle
 Recommended size gravel in. to in.
 Remarks

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	9	2	1.1	1.1		
12	.065	10	16	8.6	9.7		
16	.046	14	21	11.3	21.0		
20	.0328	20	26	14.0	35.0		
30	.0232	28	19	10.2	45.2		
40	.0164	35	15	8.1	53.3		
50	.0116	48	23	11.8	65.1		
70	.0082	65	32	17.2	82.3		
100	.0050	100	23	12.4	94.7		
200	.0029	200	9	4.8	99.5		
Pan	.0000	Pan	1	.5	100.0		
	Total		186				

Sample obtained by — rotary under pressure, cable tool, calzeon rig.

Porosity % Permeability

Test Driller Lab. Test by

Date Date

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 165 - 170
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8					
12	.065	10	3	1.6	1.6		
16	.046	14	4	3.1	4.7		
20	.0328	20	10	7.9	12.6		
30	.0232	28	13	10.2	22.8		
40	.0164	35	14	11.0	33.8		
50	.0116	48	21	16.5	50.3		
70	.0082	65	35	27.6	77.9		
100	.0058	100	12	15.0	92.9		
200	.0029	200	8	6.3	99.2		
Pan	.0000	Pan	1	.8	100.0		
	Total		127				

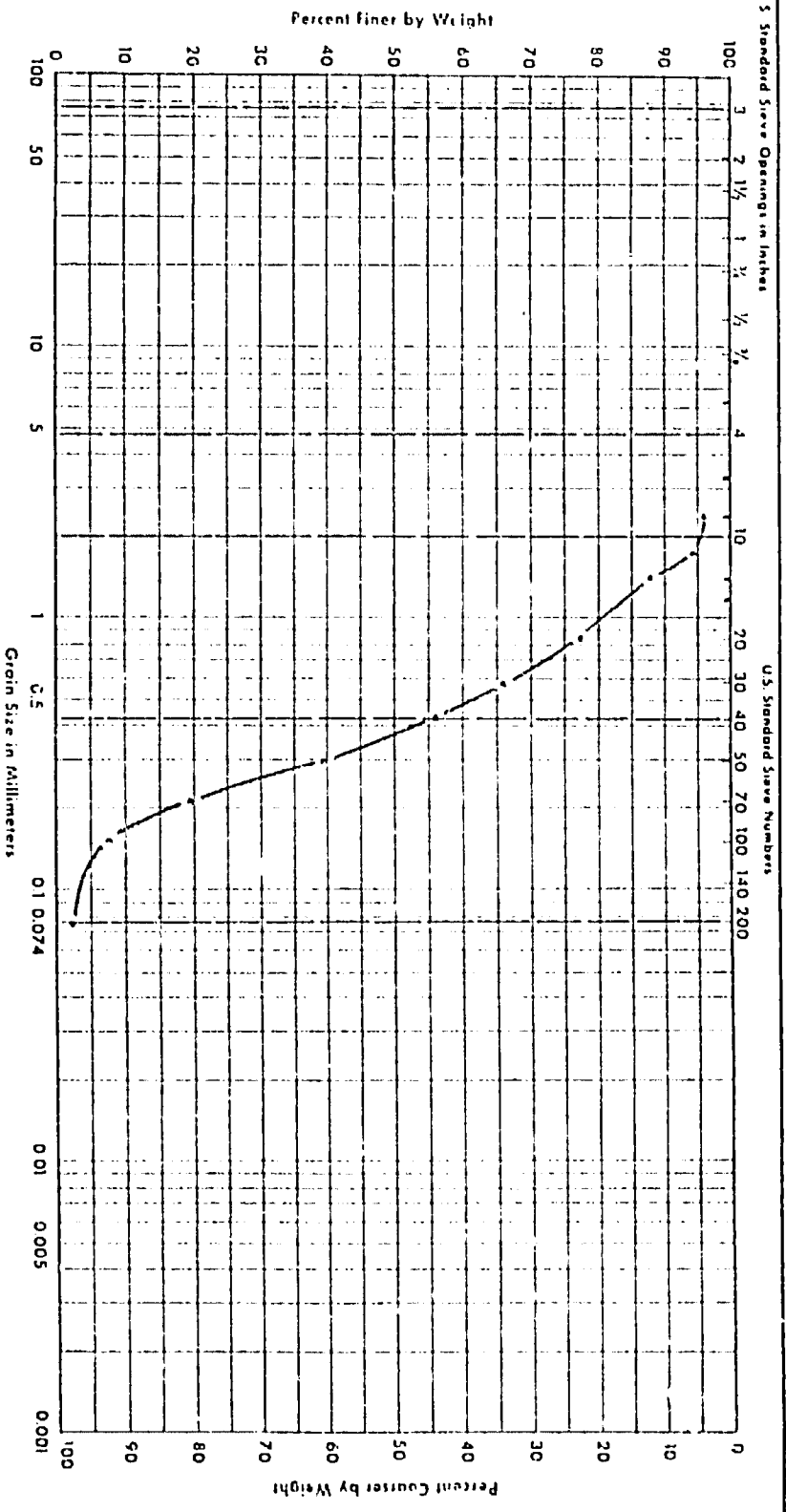
Sample obtained by -- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

GRAIN SIZE ANALYSIS



LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2
 Address Tyndall, South Dakota Depth of Sample 170 - 175
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.263	3					
6	.132	6					
8	.093	8	1	.4	.4		
12	.065	10	13	5.5	5.8		
16	.046	14	19	8.0	13.9		
20	.0328	20	23	9.7	23.6		
30	.0232	28	26	11.0	34.6		
40	.0164	35	24	10.2	44.8		
50	.0116	48	37	15.7	60.5		
70	.0082	65	42	20.3	80.8		
100	.0058	100	29	12.3	93.1		
200	.0029	200	13	5.5	98.6		
Pan	.0000	Pan	3	1.4	100.0		
	Total		236				

Sample obtained by — rotary under pressure, cable tool, colson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

FIELD REPORT OF TEST HOLE

Name of Job CITY OF TYNDALL Test Hole No. 3
 Address Tyndall, South Dakota Depth 105'
 Date 1/23/62

LOG				PERMEABILITY DATA		
From	To	Material	Sample Taken	Hydrometer Reading	Fluid Loss inches	Remarks
0	5	Top soil - heavy				Black
5	10	Top soil - heavy, sandy				Lighter color
10	15	Sandy clay & sand				
15	20	Sand fine to coarse & blue clay				Fine & coarse
20	25	Clay blue-gray				Gray & sticky
25	30	Clay blue-gray				Gray & sticky
30	35	Clay blue-gray				Gray & sticky
35	40	Clay blue-gray				Gray & sticky
40	45	Clay blue-gray				Gray & sticky
45	50	Clay blue-gray				Gray & sticky
50	55	Coarse sand & fine				Fairly clean
55	60	Sand fine - soft				Clean soft
60	65	Sand, very fine - soft				Clean soft
65	70	Sand, very fine - soft				Clean soft
70	75	Sand, very fine - soft				Clean soft
75	80	Sand, very fine - soft				Clean soft
80	81	Sand, very fine - soft				Clean soft
81	85	Clay & sand				Med. dirty gray
85	90	Clay & sandy				Med. dirty gray
90	95	Clay & sandy				Blue gray
95	105	Clay - dry				White & light gray

Size of Pit: Length 11 ft. Width 4 ft. Depth 4 1/2 ft.
 Static Water Level _____ ft. below ground level. Diameter of well 7 7/8 in.
 Was well pumped _____ Yield _____ g.p.m. Water sample _____
 Depth of screen setting _____ ft. Size of gravel used _____

Date 1/23/62

Driller Jerry Bonnell

LAYNE & MINESOTA CO

FIELD REPORT OF TEST HOLE

Name of Job. CITY OF ETHEL Test Hole No. 1
 Address Trinity R. South Dakota Depth 220'
 Date 1/30/62

LOG				PERMEABILITY DATA		
From	To	Material	Sample Taken	Hydrometer Reading	Fluid Loss inches	Remarks
0	10	Top soil & clay				Dry clay yellow
10	20	Clay & some sandy clay				Dry clay yellow
20	30	Clay & some sandy clay				Dry clay yellow
30	40	Clay & some sandy clay				Dry clay yellow
40	50	Clay & some sandy clay				Dry clay yellow
50	60	Clay, fine sandy clay soft				Brown & yellow
60	70	Very fine sand				Brown & yellow
70	80	Very fine sand				Brown & yellow
80	90	Very fine sand				Brown & yellow
90	100	Very fine sand				Brown & yellow
100	110	Very fine sand				Brown & yellow
110	120	Very fine sand				Brown & yellow
120	130	Very fine sand				Brown & yellow
130	140	Very fine sand				Brown & yellow
140	150	Very fine sand				Brown & yellow
150	160	Very fine sand				Brown & yellow
160	170	Very fine sand				Clear color
170	180	Very fine to med. sand				Clear
180	190	Very fine to med. sand				Clear
190	200	Fine, med. to coarse				Clear
200	210	Fine, med. to coarse				Clear
210	215	Fine, med. to coarse				Clear
215	220	Fine, med. to coarse - clay hard & dry, some				

Size of Pit: Length 6 ft. Width 6 ft. Depth 5 ft.
 Static Water Level ft. below ground level. Diameter of well 7.7/8 in.
 Was well pumped Yield g.p.m. Water sample
 Depth of screen setting ft. Size of gravel used
 Date 1/30/62 Driller Henry Fossall

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 4
 Address Tyndall, South Dakota Depth of Sample 179 - 210
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
	.263	3					
6	.132	6	2	1.0	1.0		
8	.093	11	4	2.1	3.1		
12	.065	10	16	8.2	11.3		
16	.046	14	24	12.4	23.7		
20	.0328	20	27	13.9	37.6		
30	.0232	28	27	13.9	51.5		
40	.0164	35	32	16.5	68.0		
50	.0116	48	28	14.4	82.4		
70	.0082	65	19	9.9	92.2		
100	.0058	100	10	5.2	97.4		
200	.0029	200	4	2.1	99.5		
Pan	.0000	Pan	1	.5	100.0		
	Total		194	100.0			

Sample obtained by — rotary under pressure, cable tool, caisson rig

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO

FIELD REPORT OF TEST HOLE

Name of Job _____ CITY OF TYNDALL _____ Test Hole No. 5
 Address _____ Tyndall, South Dakota _____ Depth 170
 Date 2/2/62

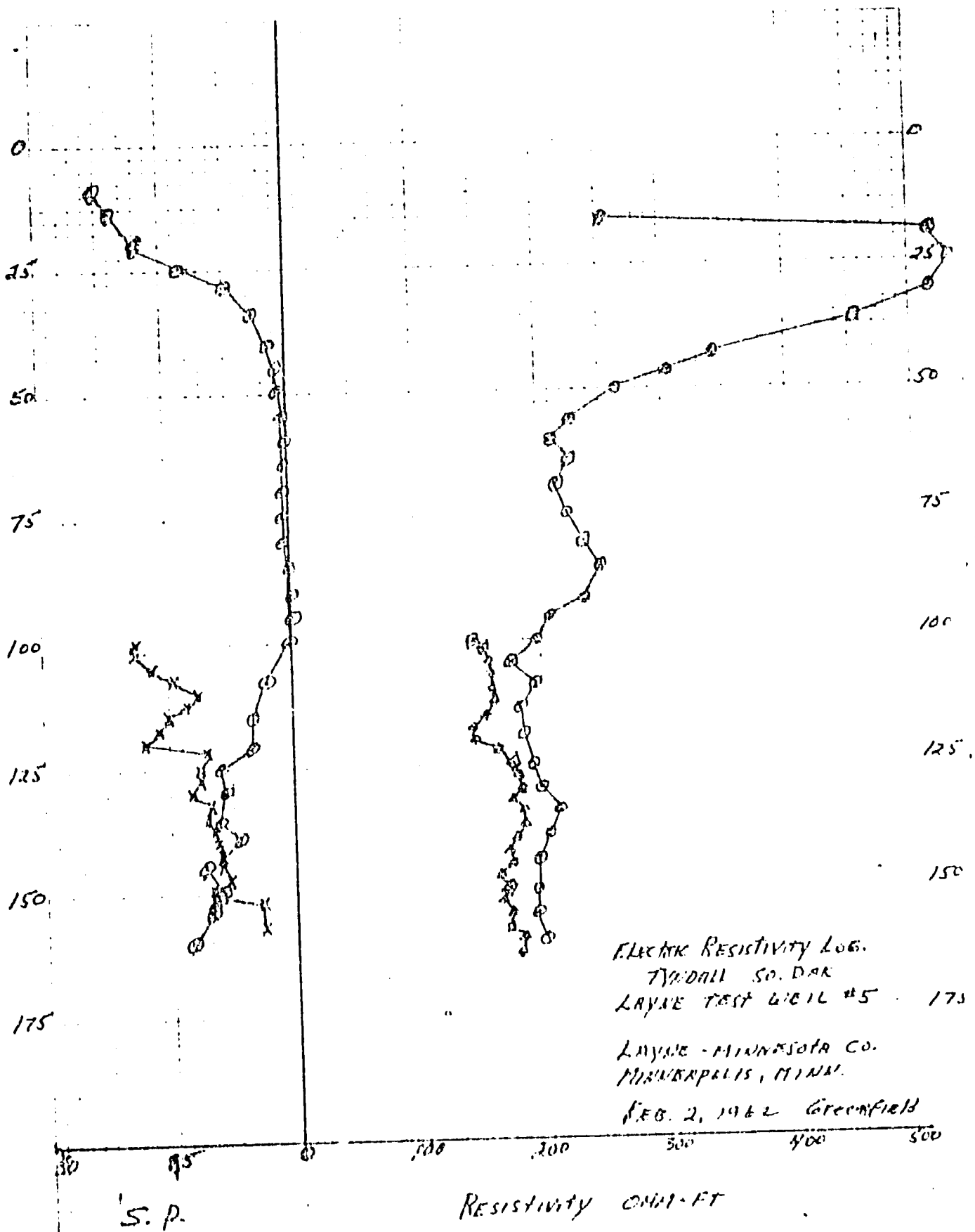
LOG				PERMEABILITY DATA		
From	To	Material	Sample Taken	Hydrometer Reading	Fluid Loss inches	Remarks
0	5	Top soil & clay				
5	17	Sand & gravel				Dry, dirty
17	25	Fine sand				Brown & clear
25	30	Fine sand				Brown & clear
30	35	Fine sand				Brown & clear
35	40	Fine sand				Brown & clear
40	45	Fine sand				Brown & clear
45	50	Fine sand				Brown & clear
50	60	Fine sand & med. to fine				Some hard cemented streaks
60	70	Fine sand & med. to fine				"
70	80	Fine sand				" 89ft
80	90	Fine sand				"
90	100	Fine sand				"
100	120	Fine sand				"
120	130	Fine sand				"
130	140	Fine sand				"
140	150	Fine sand & med. to fine				Green, clear & soft
150	160	Gravel, sand, clay & coal				Green, trace clay
160	170	Coarse sand, clay & coal				Gray & brown

Size of Pit: Length _____ ft. Width _____ ft. Depth 4 1/2 ft.
 Static Water Level _____ ft. below ground level. Diameter of well 7 1/8 in.
 Was well pumped _____ Yield _____ g.p.m. Water sample _____
 Depth of screen setting _____ ft. Size of gravel used _____

Date 2/2/62 Driller Jerry Benson

BU-ONE DISTURBANCE CO.
MADE IN U.S.A.

BU-ONE DISTURBANCE CO.
MADE IN U.S.A.



ELECTRIC RESISTIVITY LOG.
TYNDALL SO. DAK
LAYNE TEST WELL #5 175

LAYNE - MINNESOTA CO.
MINNEAPOLIS, MINN.

FEB. 2, 1962 Greenfield

RESISTIVITY OHM-FT

S. P.

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 5

Address Tyndall, South Dakota Depth of Sample 100-110

Date

Largest Particle

Recommended size gravel in. to in.

Remarks

Tyler Standard Screen Scale Sieves No. $\sqrt{2}$ or 11.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
3	.250	3					
6	.132	6					
10	.093	10					
12	.065	12					
16	.046	16					
20	.0320	20					
30	.0232	30	2	1.7	1.7		
40	.0164	40	2	1.7	3.4		
50	.0116	50	35	28.9	32.3		
70	.0082	70	44	36.4	68.7		
100	.0059	100	28	23.1	91.8		
200	.0029	200	9	7.4	99.2		
Pan	.0000	Pan	1	.8	100.0		
Total			121	100.0			

Sample obtained by— rotary under pressure, cable tool, caisson rig.

Porosity % Permeability

Test Driller Lab. Test by

Date Date

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 5

Address Tyndall, South Dakota Depth of Sample 19-229

Date _____

Largest Particle _____

Recommended size gravel _____ in. to _____ in.

Remarks _____

Tyler Standard Screen Scale Sieves √2 or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
	.250	#30					
6	.132	#60					
8	.093	#80					
12	.065	#100		.7	.7		
16	.046	#140		1.5	2.2		
20	.0328	#200		9.6	11.8		
30	.0232	#280		12.5	24.3		
40	.0164	#350		18.4	42.7		
50	.0116	#480		21.3	64.0		
70	.0082	#650		21.3	85.3		
100	.0058	100	16	11.8	97.1		
200	.0029	200	3	2.2	99.3		
Pan	.0000	Pan	1	.7	100.0		
Total			136	100.0			

Sample obtained by— rotary under pressure, cable tool, calson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LABORATORY REPORT OF SIEVE ANALYSIS

Largest Particles _____
Recommended size gravel _____ in. to _____ in.
Remarks _____

Sample obtained by— rotary under pressure, cable tool, calson rig.
Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 5
 Address Tyndall, South Dakota Depth of Sample 130-140
 Date _____

Largest Particle _____
 Recommended size gravel _____ in. to _____ in.
 Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ for 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Per cent	On	Passing	
3	.250	60					
6	.132	100					
8	.093	20	1	.6	.6		
12	.065	25	2	1.3	1.7		
16	.046	35	7	3.9	5.6		
20	.032	45	14	7.0	13.4		
30	.023	65	15	8.3	21.7		
40	.015	100	24	13.3	35.0		
50	.011	150	34	18.9	53.9		
70	.008	250	42	23.3	77.2		
100	.005	350	28	15.6	92.8		
200	.002	600	12	6.7	99.5		
Pan	.000		1	.5	100.0		
Total			180	100.0			

Sample obtained by — rotary under pressure, cable tool, casing rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____
 Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 5

Address Tyndall, South Dakota Depth of Sample 140-150

Date _____

Largest Particle _____

Recommended size gravel _____ in. to _____ in.

Remarks _____

Tyler Standard Screen Scale Sieves $\sqrt{2}$ or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mesh	Grams	Percent	On	Passing	
3	.250	60					
6	.132	120					
8	.093	20	3	1.4	1.4		
12	.065	30	11	5.1	6.5		
16	.046	40	24	11.3	17.7		
20	.032	60	46	21.4	39.1		
30	.023	80	48	22.3	61.4		
40	.016	100	35	16.3	77.7		
50	.011	150	21	9.8	87.5		
70	.008	250	15	7.0	94.5		
100	.005	400	9	4.2	98.7		
200	.002	800	3	1.3	100.0		
Pan	.000	Pan	--	--			
Total			7.15	100.0			

Sample obtained by -- rotary under pressure, cable tool, caisson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____

LAYNE - MINNESOTA CO.

LABORATORY REPORT OF SIEVE ANALYSIS

Name of Job CITY OF TYNDALL Test Hole No. 2

Address Tyndall, South Dakota Depth of Sample 130-160

Date _____

Largest Particle _____

Recommended size gravel _____ in. to _____ in.

Remarks _____

Tyler Standard Screen Scale Sieves No. 2 or 1.414			Weights On or Between Sieves		Total Percent		Remarks
U.S. No.	Opening inches	Mash	Grams	Percent	On	Passing	
3	.250	3	1	.5	.5		
6	.132	6	4	2.0	2.5		
8	.093	8	13	6.5	9.0		
12	.065	10	25	13.4	21.4		
16	.046	14	28	13.9	35.3		
20	.0328	20	25	12.4	47.7		
30	.0232	28	27	13.4	61.1		
40	.0164	35	26	12.9	74.0		
50	.0116	48	22	10.9	84.9		
70	.0082	65	16	8.0	92.9		
100	.0058	100	10	5.0	97.9		
200	.0029	200	3	1.5	99.4		
Pan	.0000	Pan	1	.6	100.0		
Total			201	100.0			

Sample obtained by — rotary under pressure, cable tool, calson rig.

Porosity _____ % Permeability _____

Test Driller _____ Lab. Test by _____

Date _____ Date _____