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THE GROUNDWATER POTENTIAL OF ALLUVIAL TERRACES, ALONG THE WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA

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Alberta
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THE GROUNDWATER POTENTIAL OF ALLUVIAL TERRACES, ALONG THE WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA

Introduction

This report deals in part with information obtained from groundwater investigations carried out by the Research Council of Alberta during the summer of 1960, of a general study to evaluate:

1. The groundwater potential of possible alluvial terrace aquifers, along the major drainage ways in the Peace River district.

2. The relationship between river flow and groundwater recharge or discharge of alluvial terraces. For this purpose, observation wells were established.

3. Hydrologic methods and best method of approach in solving for aquifer coefficients in unconfined aquifers adjacent to perennial streams.

4. The drilling techniques and well completion practices in sand and gravel alluvial terraces.

The information contained below is from the Research Council of Alberta Test Site #1, Wapiti River, Grovedale Bridge, south of Grande Prairie, Alberta. It is hoped that this data will aid in evaluating the groundwater potential in this area.

Location and Description of Area Tested

R.C.A. test site #1 is located on a recent alluvial terrace on the south side of the Wapiti River (centre south side Sec. 23, Tp. 70, R. 6, W. 6th Mer.). The test site is approximately 7 miles south of the centre of the City of Grande Prairie, Alberta (N.W. cor. Sec. 24, Tp. 71, R. 6, W.6th Mer.). The site was quite accessible as a small camping park had been recently established, and access roads were provided.

In order to establish the geologic and hydrologic conditions of the terraces, 4 test holes were drilled with a rotary drilling rig by Independent Drilling and Exploration Co. Ltd. of Edmonton.

The alluvial terrace at this locality consisted of a surface coverir of sand, silt and clay which overlaid approximately 15 feet of water-saturated coarse gravels. A pumping test site was established here.

See attached sketch for pump test site location and layout.

See appendix for test hole logs.

Pump Test Results

General Statement:

For test purposes a test pump (Pomona little Chief) was installed in a well with 4 1/4" I.D. black insert joint water well casing. The casing was slotted the saturated length of the aquifer with 1/4" slots. The pumping test was run for 26 hours at a rate of 70 gallons per minute August 20 and 21, 1960. Water-level measurements were made with a steel tape of both drawdown and recovery in observation wells spaced around the pumping well (see attached sketch, Fig. 1). The water from the pumping well was discharged through pipe to the Wapiti River.

Three water samples were taken of the pumping well during the test. Temperature measurements were made on both the well and Wapiti River waters. See section on water quality.

AQUIFER COEFFICIENTS AND HYDROLOGIC BOUNDARIES

The following aquifer coefficients were to be determined.

T, The coefficient of transmissibility of an aquifer is defined as the rate of flow of water in gallons per day which passes through a vertical strip of an aquifer one foot wide, with a unit hydraulic gradient. Stated in another way, the transmissibility is the product of the thickness, m, and the permeability, p, of the aquifer.

S, The coefficient of storage may be defined as the amount of water, in cubic feet, that will be released from storage in each vertical column of an aquifer with a height equal to the thickness of the saturated portion of the aquifer and a base one foot square when the hydrostatic head is lowered one foot.

Transmissibility Determination by standard methods

Obs. Well, 40' east

T = 38,200 gals/ft/day - Theis method
T = 41,000 gals/ft/day - Jacob method

Obs. Well, 100' west

T = 44,500 gals/ft/day - Theis method
T = 46,000 gals/ft/day - Jacob method

Obs. Well, 100' south

T = 44,500 gals/ft/day - Theis method
T = 68,400 gals/ft/day - Jacob method

Average T, Theis = 42,400 gals/ft/day

Average T, Jacob = 51,800 gals/ft/day

Average T, both methods = 47,100 gals/ft/day

The average T for both methods was used in all calculations

Since T = Pm T = 47,100 gals/ft/day

m = 15' P = 3,140 gals/ft^2/day

P = Permeability (average)

Permeability determined from the Dupuit free Aquifer equation:

P = 3,420 gals/ft^2/day, which compares very closely
T = 51,300 gals/ft/ day which is slightly higher by this method.

Storage Coefficient

The storage coefficient varies considerably with time, especially in the early stages of the pumping test, but in the case of unconfined aquifers such as the alluvial terraces, as time increases the storage coefficient eventually equals the specific yield.

Specific yield for coarse gravels

20% $\therefore S = .20$

This value is used to replace S (storage coefficient) in all calculations.

The saturated thickness (m) of the gravels was approximately 15.0' on August 17, 1960.

The values for both the transmissibility and storage coefficient can be considered to be very good. Based on these values predictions can be made about the performance of an aquifer.

Drawdown and Interference Calculations for estimations of future water levels

In determining the drawdown in and near a pumping well the following equations are used:

$$s = \frac{114.6}{T} Q \; W(u)$$

s = drawdown in feet
Q = pumping rate in gpm
S = storage coefficient

$$u = \frac{1.56 . r^2}{Tt} S$$

r = distance from pumping well to observation well
t = time since pumping started

(The relationship between u and W(u) is given in standard tables)

By means of these equations the drawdown at any moment at any distance from a pumped well can be calculated.

1) Test well pumping @ 200 gpm. at test site #1

Drawdown Table - 200 gpm. after one day

Distance from pumping well r feet	r^2	u	W(u)	Drawdown in feet after one day
1	1	6.40×10^{-6}	11.38	5.52
10	100	6.40×10^{-4}	6.78	3.30
100	10,000	6.40×10^{-2}	2.23	1.08
200	40,000	2.65×10^{-1}	1.01	0.49
300	90,000	5.95×10^{-1}	0.46	0.24
500	250,000	1.65	0.09	0.04
1,000	1,000,000	6.40	-	-

Drawdown Table - 200 gpm. after 2 years

Distance from pumping well r feet	r^2	u	W(u)	Drawdown in feet after two years
1	1	9.51×10^{-9}	17.89	8.68
10	100	9.51×10^{-7}	13.29	6.45
100	10,000	9.51×10^{-5}	8.68	4.22
200	40,000	3.82×10^{-4}	7.30	3.55
300	90,000	8.60×10^{-4}	6.48	3.25
500	250,000	2.38×10^{-3}	5.46	2.65
1,000	1,000,000	9.51×10^{-3}	4.09	1.99

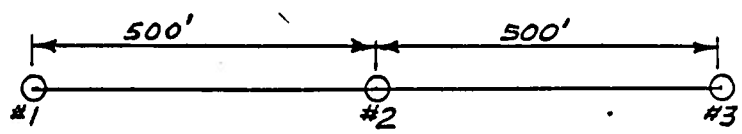
See attached graphical representation.

WELL FIELD DESIGN

Interference Calculations, based on 3 wells spaced in a linear arrangement 500' apart parallel to the Wapiti River - each producing at a measured rate of 200 gallons/min. after oneday and two years.

This is using 15' of water-saturated gravels - 15' was total available drawdown during the test at test site #1.

Let #1 well of test site #1 be the central well (#2) of arrangement.



To be added to calculations - recharge amount of recovery - to be determined

To be subtracted - well loss.

INTERFERENCE TABLE - after one day

Interfering with	Well #1 Distance	Well #1 Interference	Well #2 Distance	Well #2 Interference	Well #3 Distance	Well #3 Interfe
Well #1			500	0.04	1,000	
Well #2	500	0.04			500	0.(
Well #3	1,000	-	500	0.04		
Total Interference		0.04		0.04		0.(
Own Drawdown		3.48		3.48		3.4
Recharge	?	?	?	?		
Well Loss	-	--	-	-	-	
Total Drawdown		3.52 ≠		3.56 ≠		3.3

INTERFERENCE TABLE - after two years

Interfering with	Well #1 Distance	Well #1 Interference	Well #2 Distance	Well #2 Interference	Well #3 Distance	Well #3 Interfer
Well #1			500	2.65	1,000	1,9
Well #2	500	2.65			500	2.6
Well #3	1,000	1.99	500	2.65		
Total Interference		4.64		5.30		4.6
Own Drawdown		6.78		6.78		6.7
Recharge	?	?	?	?	?	
Well Loss	-	-	-	-	-	
Total Drawdown		11.42 ≠		12.08 ≠		11.42

temperature measurements indicate no recharge.

These calculations do not allow for any recharge - this relationship will have to be determined as outlined.

It can be seen from the above that if a minimum saturated thickness of the gravel of 15 feet is maintained, there should be ample water.

Well Completion - to reduce well loss

In unconsolidated sands and gravels such as are found in the alluvial terraces along the Wapiti River at the Grovedale Bridge, the proper way to complete a well is to install a well screen opposite the water-saturated portion of the aquifer.

A 6" slot #50 well screen of the Johnson Everdur type should be installed opposite coarse and very coarse gravel. In the case of 15 feet of water-saturated gravels, a 15-foot 6" screen which will provide 1395 square inches of opening - which is several times that of a slotted casing.

The advantages of well screen over slotted well casing are several:

1) In slotted casing the high entrance velocity of the water will deposit part of its mineral content on and around the well - this will severely limit production and will eventually have to be removed by acid treatment, which in turn corrodes the casing. Because of the large open area of the screen the entrance velocity is reduced to such an extent that encrustation is unlikely to occur. If any treatment is necessary, well screens usually have considerably more resistance against this treatment than ordinary water-well casing.
2) The "well loss" with a screen will be 6 to 10 times less than if the well is finished with slotted casing. This will mean a considerable reduction of cost in pumping per day.

Well Loss

The actual drawdown in a pumped well is slightly more than the calculated drawdown due to head loss during flow of water into the well.

This "well loss" is generally the result of poor well construction. In a properly-screened well the well loss can be reduced to 5 to 15 per cent of the calculated drawdown. This loss has to be added to the total drawdown calculations to determine the correct actual drawdown.

Hydrologic Boundaries and Conditions

The pumping test at test site #1 was not carried out long enough to establish clearly the effective recharge of infiltrated water from the river to well.

Several discharge boundaries were noted - which usually show up in the early stages of pumping tests in unconfined aquifers.

Probable permeability boundaries that were noted:

1) effect of cone of influence with intersection of alluvial terrace gravels with bedrock wall to south of pumping test site

2) minor effect of cone influence with intersection of alluvial terrace gravels - with perennial stream (Wapiti).

The pumping test was not carried out long enough in the trial run to establish clearly the boundaries, and it appears a minimum pumping test period of at least 48 hours is needed.

To be determined

1) Relationship between groundwater level in alluvial terraces and fluctuations in Wapiti River level at various times of the year -

At certain times of the year alluvial terraces might be effluent into the river;

At certain times of the year alluvial terraces might be influent.

The maximum and minimum water levels have to be established so that a minimum saturated thickness of the alluvial terrace gravels can be established.

Rate of induced infiltration to be determined

This can be done by:

1) Establishing a water-level recorder, Stevens & Leupold F.M. monthly type, in the pumping well of test site #1. This well was left open for this purpose.

2) Establishing a system of measuring the stream flow of the Wapiti River. Water-level measurements should be made daily.

3) The observation well location should be surveyed in, and its elevation with regard to sea level established. Similarly, stream-flow records should be made from a known elevation.

In this way the water-level recorder measurements and stream flow measurements can be correlated.

The above has to be done before any accurate estimation of the saturated thickness at various times of the year of the alluvial terrace can be made for well design purposes.

See attached folder containing elevations established on the Grovedale Bridge at the Wapiti by the Department of Highways.

To Evaluate Alluvial Terraces

1) During the pumping test - Test Site #1, August 20-21, 1960 - the approximate saturated thickness of the gravels was approximately 15 feet. This thickness can vary because at different times of the year the alluvial terrace (an unconfined aquifer)i

1) hydraulically connected with the Wapiti River;

2) receives groundwater recharge from the steep banks of the Wapiti - i.e. surface run-off, etc., which is captured by the pervious gravels.

3) Piezometric surface of Wapiti formation is effluent towards the river.

4) Resulting piezometric surface is slightly higher than river level at certain times of the year (exact relationship to be established).

1. The Research Council of Alberta established an observation well at test site #1 as part of a program to determine the relationship between stream flow and groundwater recharge or discharge of alluvial terraces along major drainage channels.

2. This test site was drilled at the most accessible site.

To evaluate the terrace fully for eventual water well production for a community such as Grande Prairie the following must be evaluated:

1) the thickness of the alluvial terrace on the south side of the river - see attached sketch for proposed drilling site.

2) the thickness of alluvial terraces on the north side of the river - see sketch for proposed drilling sites.

3) This can be done by test drilling.

From Research Council Test Site #1 the saturated thickness of the gravels was approximately 15 feet on August 20 and 21, 1960.

It has been established from the pump test at Research Council Site #1 that the average transmissibility was 47,100 gallons/ft/day and the resultant average permeability P in gallons/ft^2/day = 3,140.

We have the simple relationship that

$$T = Pm$$

where

T = transmissibility

P = Permeability

m = saturated thickness of aquifer

∴ doubling the saturated thickness of the aquifer

$$T = 3,140 \times 30$$

$$T = 94,200 \text{ gallons/ft/day}$$

Actually in the case of an unconfined aquifer, doubling the saturated thickness slightly more than doubles the transmissibility.

Maximum production from 15 feet of saturated gravels was 335 gallons/min. if well was 100 per cent efficient.

∴ maximum production from 30 feet of saturated gravels will be in the order of 1,340 gallons/min. if well was 100 per cent efficient.

This increase in production obtainable from one well by doubling the thickness of the saturated gravels I think fully warrants a thorough test-drilling and pumping test program for the terraces on both sides of the river (as outlined) if any large supply of water is desired.

See attached appendixes for:

1) Pumping test requirements
2) Water quality
3) Test-drilling procedure
4) Logs of test holes

See Fig. 1 - location sketch
Fig. 2 - graphical results of pumping test.

Sgd.

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October 12, 1960.

Appendix I

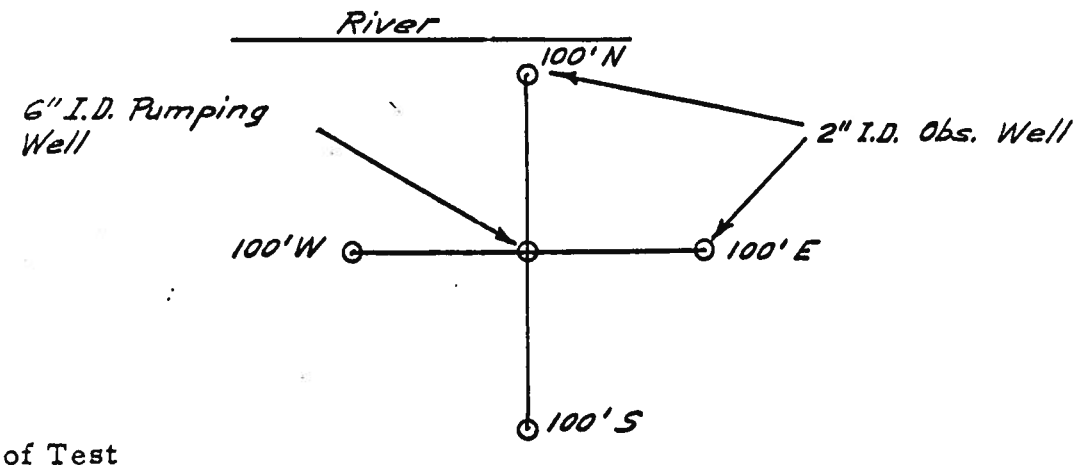
Test Site - Pump testing

The minimum requirements to obtain the necessary information for well design in alluvial terrace gravels appear to be:

One pumping well and
four observation wells.

See sketch for distance.

No observation well should be closer to the pumping well than 1.5 m. to 2.0 m. where m = saturated thickness of aquifer.



Length of Test

1) Minimum of 48 hours a well if possible.

2) Rate - pumped at least 200 gpm. at a constant rate.

3) Temperature readings of water taken throughout test.

4) Water samples taken regularly throughout test.

5) Static levels of wells determined prior to test.

6) Pumping well should have water-level measured during test, i.e. air line gauge (both drawdown and recovery)

7) Observation wells should have water-level measurements made - both drawdown and recovery.

8) Discharge of pumping water into the river so that none leaks back into the aquifer; if it does it will give erroneous drawdown and recovery readings.

9) Observation well and pumping well should be surveyed in with a known elevation

Properly carried out the above should give all the necessary information regarding proper well field design and completion.

Appendix II

Test Hole Logs

Wapiti River - Grovedale Bridge - Site #1

Test Hole #1 - Pumping Well

0 - 8.5	Silt, sand, minor clay
8.5 - 26.0	Gravel, coarse, minor sand
26.0 - 29.0	Gravel, coarse to medium
29.0 - 36.0	Shale, grey, Wapiti Formation (Bedrock)

Test Hole #2 - 40' East obs. well

0 - 13	Silt, sand and clay
13 - 18	Gravel (coarse) boulders
18 - 24	Gravel (coarse)
24 - 29.5	Gravel
29.5 - 30.0	Shale, grey, Wapiti Formation

Test Hole #3 - 100' West, obs. well

0 - 12.5	Silt and clay
12.5 - 28.0	Gravel (coarse)
28.0 - 35.0	Shale, grey, Wapiti Formation

Test Hole #4 - 100' south obs. well

0 - 13.0	Silt and clay
13.0 to 28.5	Gravel
28.5 - 30.0	Shale, grey, Wapiti Formation

Test Drilling

Test drilling was carried out using a Mayhew 1000 rotary drill. It was found to be most satisfactory drilling in the gravels if certain procedures were followed:

1) When commencing drilling, the drilling fluid which is just normally clear water had drilling mud added to it, 1 or 2 bags of Polygel or Supercol or some similar mud. To thicken the mud a small amount of lime was normally added.

2) Drilling the pumping well 6 7/8" roller rock bits were used. Drilling was commenced with the drilling fluid as above. The drilling rig pumps circulating the drilling fluid were hardly used at all as the mud column was used to hold back the coarse gravel as it was drilled through. When the gravels were drilled through into the bedrock the drill stem was pulled out still not disturbing mud in the hole and 4 1/2" OD water-well casing, slotted, run in. Then and only then after the casing was set the heavy thick drilling mud was bailed and thoroughly flushed out.

If larger diameter wells are desired, larger rock bits should be used and same procedure followed.

The time to drill was 2 days through 25 pf. gravel in this way.

Observation Wells

For water level measurement to observe drawdown and recovery measurements for test purposes to save time 4 3/4" rock bits were used to drill a 4 3/4" hole. Drilling procedure was the same for the pumping well except with the smaller hole the drilling was speeded up immensely. 2" I.D. black pipe was used for the observation wells. The pipes were slotted the full length of the saturated portion of the aquifer. After dropping the pipe in the holes the mud was bailed and flushed

Two observation wells drilling through 25 feet of coarse gravel were drilled each day if the above procedure was followed.

Water Quality and Temperature

Water samples were taken ~~throughout~~ at the beginning and end of the pumping test - River temperature also taken.

1) August 17, 1960 - Water from pumping well at 4:05 p.m.

Temperature = 4.5°C or 40.1°F

River water temperature = 17.5°C or 63.5°F at 4:20 p.m. 10' from river bank.

2) August 20 - Water sample - pumping well at 10:15 a.m. Temperature 2 4.5°C or 40.1°F.

3) August 21 - Water sample, pumping well at 11:15 a.m. Temperature = 4.5°C or 40.1°F.

Comparison of Water Quality in Parts per Million (Provincial Analysis)

Nature of Constituents	Wapiti River April 7/59	Well Samples #1 Aug.17/60	#2 Aug. 20/60	#3 Aug. 21/60
Total Solids	162	896	844	876
Ignition Loss	34	208	232	214
Hardness	85	390	380	405
Sulphates	38	63	100	129
Chlorides	nil	2	3	3
Alkalinity	95	630	585	595
Nature of Alkalinity	Bicarb of Na, Ca & Mg			
Nitrites	trace	trace *	nil	nil
Nitrates	0.5	2.0	nil	nil
Iron	0.7	6.0	4.5	4.5
Soda - grams/gal		24.8	15.2	12.10

* well just developed

When percolating through the gravels the river water picks up calcium and magnesian bicarbonates which results in a higher alkalinity of the infiltrated water. Chlorides are also higher.

When the water is made to move faster and the pumping is carried on continuously these high amounts are believed to decrease rapidly and tend to approach the average chemical quality of the river.

Temperature of infiltrated water

The temperature of the river water and well water were quite different as of August 17, 1960.

The well water was 40.1°F
The river water was 63.5°F

The usual temperature range of groundwater will be far less extreme than that of the river water which will probably range from 32°F in the winter to 68 or 70°F in the summer.

The expected temperature of the groundwater should be in the range from 36°F to approximately 50°F.

This can be accurately determined by pump testing and keeping a close check on the river water throughout the year.

The well water will probably be coolest during spring and early summer and warmer during the fall and early winter.

Kazman (1948)* pointed out that the relationship of the temperature of surface water and infiltrated water is quite complex and listed the following important points:

1) Mixing of groundwater with infiltrated water
2) Admixture of river water of different temperature, while enroute to the well
3) The heat storage of the aquifer and underlying rocks
4) The conduction of heat upward and laterally within the aquifer due to temperature gradients.

As a result of these processes the aquifer produces water that is cooler than the warmest river water but warmer than the river lows.

Temperature and Viscosity of Water

As a result of the temperature fluctuation the coefficient of viscosity of water will decrease from a summer high to a winter low and will result in a longer flux of water towards the well in winter months - which phenomenon may cause the calculated drawdown in the wells to be slightly less in the order of 0.5'.

* R.G. Kazman (1948): River infiltration as a source of groundwater supply; Trans. Am. Soc. Civil Eng., Vol. 113, p. 404 - 424.

SUMMARY OF MAIN POINTS TO EVALUATE ALLUVIAL TERRACES - WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA - TO OBTAIN A LARGE SUPPLY OF GROUNDWATER

1. Establish a water-level recorder to measure the fluctuations in the level of the watertable in the alluvial terrace at the Wapiti River - Grovedale Bridge, and determine its relation to variation in stream flow of the Wapiti River.

2. Establish a system of measurements (daily) of stream flow of the Wapiti River, at the Grovedale Bridge.

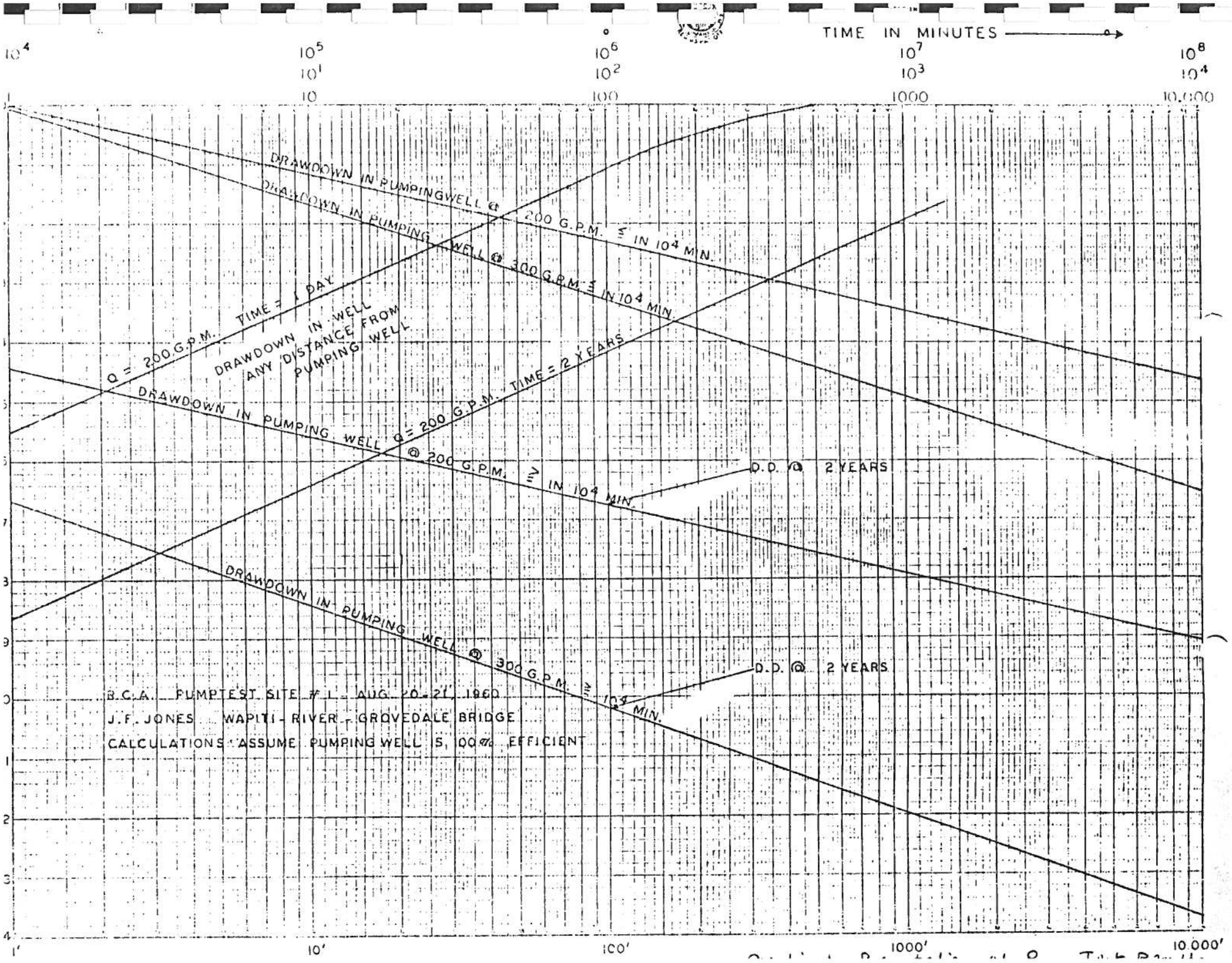
3. Collect water samples and take temperature readings of the Wapiti River on a monthly basis for a minimum period of one year.

4. Test drill the alluvial terraces to determine the maximum saturated thickness of the gravels.

5. Pump test the alluvial terrace gravels as outlined. Take water samples and temperature readings of water from pumping well.

6. The above-mentioned carried out will give the necessary information to design a well or well field to supply a large amount of groundwater.

7. Based on present information and saturated thickness of the alluvial terrace gravels as of August 20 and 21, 1960, determined at test site #1, 3 wells, 500 feet apart pumping at 200 gpm. will produce 864,000 gallons per day. This can be increased by adding additional wells.


TIME IN MINUTES
10^4
10^5
10^6
10^7
10^8
10^1
10^2
10^3
10^4
10
100
1000
10,000
DRAWDOWN IN PUMPINGWELL @ 200 G.P.M. = IN 10^4 MIN.
DRAWDOWN IN PUMPING WELL @ 300 G.P.M. = IN 10^4 MIN.
Q = 200 G.P.M. TIME = 1 DAY
DRAWDOWN IN WELL ANY DISTANCE FROM PUMPING WELL
DRAWDOWN IN PUMPING WELL Q = 200 G.P.M. TIME = 2 YEARS
DRAWDOWN IN PUMPING WELL @ 200 G.P.M. = IN 10^4 MIN.
D.D. @ 2 YEARS
DRAWDOWN IN PUMPING WELL @ 300 G.P.M. = 10^4 MIN.
D.D. @ 2 YEARS
B.C.A. PUMPTEST SITE # 1 - AUG. 20-21, 1960
J.F. JONES WAPITI - RIVER - GROVEDALE BRIDGE
CALCULATIONS ASSUME PUMPING WELL IS 100% EFFICIENT
1'
10'
100'
1000'
10,000'