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Potential Groundwater Resources in the Vicinity of Battle River Near Wetaskiwin

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by

W.A. Meneley

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INTRODUCTION

The City of Wetaskiwin is entirely dependent upon groundwater for its municipal water supply, and the continually increasing demand for water renders it imperative that a new source of supply be developed in the near future.

Intensive groundwater exploration has been carried out by Calgary Power Ltd. (who own and operate the water system), and the Research Council of Alberta to determine the feasibility of developing other aquifers as near to Wetaskiwin as possible. This report summarizes the results of exploration carried out since 1957, and provides an estimate of the probable yield of the most prolific aquifer found in the area south and east of Wetaskiwin.

HYDROGEOLOGY

The Wetaskiwin area (Fig. 1) is underlain by sedimentary rocks of the Upper Cretaceous Edmonton formation. Within the area the upper surface of the Edmonton formation is an erosional disconformity, upon which has been deposited a highly variable thickness of younger alluvial and glacial material. Both the Edmonton formation and the overlying surficial deposits may be considered to constitute a single flow medium, through which groundwater moves under the influence of gravity from topographically higher areas toward topographically lower areas, following the path which requires the minimum expenditure of energy. In the Wetaskiwin area the regional direction of groundwater movement will be eastward and northeastward from the Battle River drainage divide to the west, toward the discharge area along Battle River and Gwynne channel. Locally, tributary streams, and closed depressions will also be minor discharge areas. The groundwater flow system is recharged by precipitation in the upland areas. Near Edmonton, Farvolden (in press) determined that the recharge to the surficial deposits is in the order of three per cent of the average precipitation. Because the underlying Edmonton formation is generally less permeable, the actual recharge to the Edmonton formation is considerably less (say in the order of 1/10).

The major aquifers in the Wetaskiwin area are the Edmonton formation, and the alluvial deposits, underlying or associated with the glacial deposits.

Edmonton Formation

The Edmonton formation is made up principally of soft silty shale which encloses lenticular interbeds of poorly sorted fine-grained sandstone. Thin coal seams are also present; however, these are not important as aquifers in this area. The present water supply of the City of Wetaskiwin is obtained from a number of wells completed in the Edmonton formation. The transmissibility of this aquifer is highly variable, ranging from less than 100 gpd/ft. to a maximum value of about 1500 gpd/ft. Most of the production wells initially yield up to 25 gpm; however, the yield of individual wells tends to decline with time at a variable rate, and the useful life of a given well rarely exceeds 15 years.

Several factors contribute to the observed decline in productivity. Certainly one major factor is the mutual interference between adjacent wells in the well field. There is at present a steep cone of influence, particularly around the older part of the well field, and most of the well failures have occurred within this area. North of the city no significant

in which direction.

Have we any maps of the piezometric surface to illustrate th interference has been observed, probably because the wells are spaced at a greater distance and because production has not continued for a sufficiently long period of time. Another factor, which would permanently affect the permeability of the aquifer in the vicinity of the well, is consolidation of the aquifer due to the reduction of the fluid potential in the aquifer by pumping.

Although conclusive proof is lacking, it is almost certain that water is being withdrawn from the aquifer at a rate which is greater than the rate of recharge. Any further development of this aquifer in the vicinity of Wetaskiwin will tend to increase the amount of mutual interference between existing wells, so that each additional well completed will bring a diminishing increase in the total production from the aquifer. It is probable that the water withdrawn from this aquifer does not represent a permanent decrease in the amount of water available for utilization in the area. As soon as production from the well field ceases the water levels will gradually recover, and in time will approach the original static water level, that is, the potential distribution in the aquifer will again approach its original state. Because the economic rate of utilization temporarily exceeds the rate of recharge it is conceivable that harmful interference could be caused by depriving someone of a source of water supply. It is anticipated that this could occur only in the immediate vicinity of a production well and would continue only as long as the supply well was producing. It would thus represent a temporary lack of supply rather than a permanent deprivation of a source of water.

It is considered that the development of aquifers in the Edmonton formation in the Wetaskiwin area has nearly reached its maximum extent and that other aquifers must be developed to supply the increasing demands of the city.

Surficial Deposits

Figure 1 shows the bedrock topography of the Wetaskiwin area. This map was constructed principally from logs of seismic shot holes drilled by Texaco Exploration Company and by Imperial Oil Limited. Most of the logs obtained are of excellent quality for this source of information, a few were obviously erroneous and were discarded. The correlation between logs of the different companies and between shot hole logs and water well logs is excellent.

Red Deer Channel: The major morphologic feature of the bedrock surface is the broad, northeasterly-trending Red Deer channel. This channel is the course of a major Tertiary or early Pleistocene river, and has been traced by Farvolden (1961) from west of Innisfail to the Saskatchewan border. Within this area extensive gravel deposits averaging about 20 feet in thickness are found in the channel. In the western half of the area three distinct terrace levels can be recognized (Fig. 2). These terraces probably continue into the eastern half of the area; however, the available data are too few to permit a positive identification.

Gravel of the lowest terrace level is exposed at several locations along the Battle River in Sections 1, 12, 13, Tp. 45, R. 23, W. 4th Mer. Here the gravel is composed almost entirely of quartzite, chert, dolomite and limestone pebbles and boulders; however, a few pebbles of granitic gneisses and biotite schist can generally be found in every outcrop. At the gravel pit in Sec. 1, Tp. 45, R. 23, W. 4 the operator estimates that the gravel there averages about 85 per cent pebbles and boulders up to 5 inches in diameter and about 15 per cent sand and silt sized particles. Local areas containing finer grained material are rare. On the basis of this estimate of the grain size distribution, the permeability of the gravel determined from Hazens formula may be as high as 10,400 gpd.ft.^{2}.

A test hole drilled by Calgary Power Ltd. in the N.E. 1/4, Sec. 9, Tp. 45, R. 23, W. 4th Mer. encountered 19 feet of sand and gravel in the lowest terrace. The following aquifer coefficients were determined by means of a short pumping test: transmissibility approximately 6000 gpd/ft, storage coefficient, approximately 2×10^{-4}. This would give a value of $\frac{6000}{19} = 315$ gpd/ft^2 for the field permeability, which may be considered a representative value for a sandy gravel aquifer. A clean well sorted gravel such as that encountered in section 1, is considered to have a field permeability of about 3300 gpd/ft^2.

The water in the Red Deer channel gravels is extremely hard (about 550 ppm) and may contain up to 2 ppm iron; it would therefore require treatment before it could be used as a source for a municipal water supply. In addition, the water may contain a significant percentage of sodium bicarbonate, sodium sulphate, and sodium chloride if the direction of groundwater movement is upward from the underlying Edmonton formation. No information is available regarding the fluoride concentration of this water.

From Figure 1 it is apparent that the gravel deposits of the lowest terrace of the Red Deer channel lie at an elevation lower than Battle River for a distance of several miles. Wells completed in these gravels adjacent to Battle River would obtain water from the river by induced infiltration, which would be naturally filtered in percolating through the gravel. Thus, a large quantity of water could be obtained, which would require neither chemical nor bacteriological treatment prior to utilization.

Figure 3 shows a longitudinal profile along the Battle River from the east boundary of the Hobbema Indian Reserve, to the confluence of the Battle River and Gwynne channel. The Red Deer channel and Battle River have convergent gradients and the

Battle River flows directly over the lowest terrace gravel in sections 1, 12, and 13, Tp. 45, R. 23, W. 4th Mer. (Site 2); this is obviously the most favorable area in which to explore for an induced infiltration water supply. Upstream from this site it may also be possible to obtain induced infiltration supplies provided that the material lying between the channel of Battle River and the underlying gravel is sufficiently permeable. Downstream, the limit of economic development would occur when an insufficient thickness of gravel remains below river level.

A detailed refraction seismic survey was carried out at Site 2 (Fig. 4) to determine the thickness of gravel lying below the river here. The survey was correlated with three points at the south end of the traverse; however, no control tie-in is presently available at the north end of the traverse. Three distinct velocity layers could be identified at some stations; at others only the minimum possible depth to the third layer could be computed. On the basis of seismic velocities, and geologic control, the upper layer is composed of topsoil, silt, and possibly unsaturated gravel, having a velocity of about 1000 ft/sec. The second layer (v = 5000 ft/sec) is believed to represent gravel, and the third layer (v = 9000 ft/sec) is considered to be the Edmonton formation. If this interpretation is correct then there should be an average thickness of about 30 feet of gravel lying below the Battle River (Fig. 5). This is in agreement with the available geologic evidence, but conflicts with the estimate of a maximum depth of gravel below river level of 10 to 15 feet in the gravel pit previously mentioned. On the basis of the seismic profile (Fig. 5) the base of the channel gravel and the water level of the Battle River are converging at about 7 feet/mile. On this gradient the base of the channel gravel should be exposed at river level in the vicinity of the bridge in the S.E. 1/4, Sec. 25, Tp. 45, R. 23, E. 4th Mer. Inspection of outcrops at this location revealed a bed of gravel extending downward for an unknown distance below river level. Some but not all seismic shot hole logs report up to 20 feet of gravel, at or slightly below river level. The northern extent of possible induced infiltration sites cannot be reliably predicted until further exploration is carried out.

Another seismic profile was run across the Battle River at Site 3, along the road following the east boundary of section 28, and in Sec. 34, Tp. 44, R. 23, W. 4th Mer. The results, however, were inconclusive as the gravel, if present, occurs at too great a depth to be detected with the available velocity contrast. The maximum depth of resolution at the site is less than the estimated depth of the gravel based on seismic shot hole logs. Additional information can be obtained only by drilling.

Other Surficial Aquifers: Several narrow, steep sided bedrock channels are also found in the area. These are found at both a higher and lower bottom elevation than the Red Deer channel, and some cut obliquely across its course. All of them are considered to post-date the Red Deer channel, and are considered to be stream trenches probably of at least slightly different ages. These stream trenches are much smaller than the Red Deer channel, and the information available is insufficient to determine the extent of coarse granular fill material in each one. It is apparent, however, that the stream trench alluvial deposits in this area are neither as well sorted nor as extensive as the gravel deposits of the Red Deer channel.

One stream trench deposit along Battle River in Secs. 6, 7, 17, and 18, Tp. 46, R. 22, W. 4th Mer. (termed Site #1) was investigated in detail first by a refraction seismic survey, and later by test drilling. The seismic survey failed to disclose the presence of gravel because of an apparent velocity inversion at a depth of 44 feet. A test hole drilled in Lsd. 16, Sec. 7, Tp. 46. R. 22, W. 4th Mer. encountered sand and gravel from 44 to 64 feet. A pumping test indicated that the transmissibility of this aquifer is about 1200 gpd/ft. The pump test was not continued for a sufficiently long period to prove whether a direct hydrologic connection exists between the gravel and the Battle River; however, the static water level is only slightly above the river level at that location, which suggests that a direct connection does exist. Nevertheless the transmissibility is too low to permit any large-scale induced infiltration supply to be developed. Although the evidence from only one hole cannot be considered as conclusive, the unfavorable results obtained together with the high cost of additional test drilling (because of difficult access to this reach of the river) render further exploration of this site uneconomic at this time.

There are several other stream trenchs in the area; however, none of these are located adjacent to a perennial source of recharge, and because their sand and gravel deposits are of limited areal extent, the volume of water in storage in these aquifers is very limited. Consequently, the stream trench deposits in the area do not constitute high capacity aquifers, and further exploration is not recommended.

Isolated sand and gravel lenses occur within the till and minor outwash and aeolian sand deposits overlie the till in this area; however, they lack sufficient size and/or permeability to warrant any serious exploration for a large industrial water supply.

Summary: The gravel deposits associated with the Red Deer channel offer the best possibility for development of a large quantity of water for municipal and industrial purposes. At Site 2, and for an indeterminate distance upstream and downstream, the optimum geologic conditions exist for obtaining water by induced infiltration from the Battle River. The maximum capacity of an induced infiltration development at this site will be limited only by the permeability of the gravel, and by the average minimum discharge of Battle River.

CLIMATOLOGY AND STREAMFLOW ANALYSIS OF THE BATTLE RIVER BASIN

The Battle River, a major tributary of the North Saskatchewan River, drains about 100,000 square miles of the plains area of central Alberta. It rises in the upland area west of Pigeon Lake, but east of the foothills physiographic province. Thus its entire flow is dependent upon the amount of precipitation which falls on the plains.

The flow is made up of surface runoff from snow melt and rainfall, and the groundwater discharge to the river. The peak runoff occurs during the early spring when the accumulated precipitation from several months is discharged during a relatively short period. Thereafter the discharge declines rapidly, reaching a minimum discharge equal to the groundwater discharge minus surface evaporation from the stream (and its associated lakes). Meyboom (1961) has divided the groundwater contribution to streamflow into three components, contact springs and artesian leakage (here grouped together for convenience) and bank storage discharge. Artesian leakage makes up a small relatively constant component of the baseflow (about 27 per cent in the Calgary area), while bank storage discharge constitutes the most significant (73 per cent) baseflow contribution. Bank storage is the temporary storage of water in permeable material adjacent to the river during the maximum river stage. This water is gradually discharged back to the river after the river stage declines. It thus acts to stabilize the streamflow. The Battle River, however, flows over directly permeable gravel only for a short distance in the vicinity of Site 2, and possibly for a short distance in the vicinity of Hardisty. While there may be highly significant amounts of bank storage at those locations, the overall contribution of bank storage to the baseflow of the river is negligible. This is evident from the minimum discharge which provides a crude estimate of the baseflow of Battle River. At Ponoka, the Battle River was dry at various times during the record period, while at Unwin, which would include the groundwater contribution from almost the entire Battle River basin, the minimum recorded flow is only 7 cfs. (basin storage discharge which is all g.w. flow.

The existing streamflow data are too few to permit any quantitative estimate of the reliability of the Battle River as a source of supply for an induced infiltration development at Site 2. The streamflow, however, is directly related to precipitation so that a longer term estimate of the flow characteristics may be obtained by correlating the available discharge records to the precipitation records available for the period 1883 to 1960 at Edmonton.

The cumulative departure from the mean annual precipitation at Edmonton are plotted against time on Figure 6. Upward trending limbs of the curve denote periods of above-normal precipitation, while downward trending limbs of the curve indicate that the precipitation was below normal. The cumulative departures from the mean annual streamflow are also plotted in the same manner, both for the Ponoka gauging station and for the Unwin gauging station, and arbitrarily translated to nearly superimpose on the precipitation curve. The discharge and precipitation departure curves correlate reasonably well. From the known records at Ponoka it is possible to determine that following two years of sub-normal precipitation, the mean monthly discharge of the river will approach zero for one or more consecutive months of the following year. Then from the precipitation records, it is possible to estimate that the Battle River at Ponoka has been dry for one or more months during 18 of the past 77 years. Because the long-term fluctuations in precipitation are not normally distributed about the mean, it is not possible to predict the true frequency of occurrence of this phenomena, nevertheless this estimate is much closer to the true probability of zero discharge than the estimate obtained from 18 years of records at the Ponoka gauging station.

It is certain that the Battle River cannot be relied on as a continuous source of water for an induced infiltration installation.

On the other hand, there is no evidence to suggest that the Battle River has been totally dry for a period as long as one year. The minimum annual discharge recorded at Ponoka is about 8000 acre-feet/year. If an induced infiltration supply is designed so that it can operate for one year on water in storage in the aquifer, then it is probable that there will be adequate discharge during any given two year period to permit continued operation at the rate designed on this basis.

PROBABLE YIELD OF THE RED DEER CHANNEL AQUIFER AT SITE 2

The exploration carried out to date has been sufficient to delineate the most favorable geologic environment for a large capacity induced infiltration installation. Some hydrologic data have already been obtained during the course of exploration and some from published literature. The objective of this chapter is to estimate on the basis of the available information, the possible yield of the Red Deer channel aquifer at this location, to assess the possible economic advantages that could accrue from its development.

Several assumptions which significantly affect the final answer must be made. If the overall economic assessment of the project is favorable then these assumptions must be verified as soon as possible, before proceeding with the final development. The ultimate feasibility of the project must be re-evaluated as new information becomes available. The amount of money committed for further pre-development investigation must be sufficient to obtain decisive results, but should never exceed the economic worth of the prospect at any particular stage of its development.

Well Field Design

A water supply capable of meeting the municipal and industrial water requirements of Wetaskiwin must be capable of supplying several million gallons of water per day. Let us design a well field that is capable of yielding up to 10 mgd. The geologic environment dictates that the well field must be located in Sec. 1, Tp. 45, R. 23, W. 4th Mer. The streamflow analysis indicates that the well field may have to derive water from storage in the aquifer for a period as long as one year.

The following assumptions are necessary to permit the well field design:

1. the saturated thickness of the aquifer is 30 feet, and the maximum permissible drawdown in any well is 20 feet, or 67% of the aquifer thickness;

2. the field permeability is about 3300 gpd/ft^2, so that the aquifer transmissibility is about 100,000 gpd/ft.;

3. that the specific yield of the aquifer is =0.20, and assuming gravity drainage will be essentially complete in a time of less than 365 days;

4. the critical design is for the maximum period during which the water will have to be withdrawn from storage in the aquifer, and that this will never exceed 365 days.

5. the configuration of the cone of influence surrounding each production well may be reliably predicted from the Theis equation if the configuration is determined only after production has continued for a year.

From the well field design calculations (Appendix I) a well field made up of four wells equally spaced 1,500 feet apart, 100 feet away from Battle River, may be expected to produce in the order of 4 mgd. for a period of one year, if there is no flow in the Battle River during this period. If a daily minimum flow of 17 cfs were maintained in the river by some form of stream regulation then the same well field should be capable of yielding in the order of 9 mgd. From the same analysis a single well at this location would yield 1.4 mgd and 2.3 mgd., respectively.

It should be pointed out that if the flow regulation were maintained at a higher level, then additional wells could be completed in the same area, to increase the capacity of the well field to the sustained minimum flow of the river.

Probable Water Quality

Water from the Red Deer channel gravel aquifer would require considerable treatment to remove excess hardness and iron before it could be utilized in a municipal water supply system. The Battle River, however, carries water which is chemically suitable, but would require treatment to remove organic turbidity and possibly bacterial contamination. The ideal situation would be to obtain water from the river by induced infiltration, thereby obtaining a natural removal of organic color and bacterial contamination, and at the same time capturing water which is chemically suitable without the expense of treatment.

It is certain that so long as there is water in the Battle River the chemical quality of water obtained by induced infiltration will approach the chemical quality of the river water. The water produced from storage in the aquifer when the river is dry will be of poorer quality because under these conditions the quality of the water produced will tend to approach the quality of water naturally discharged from the gravel aquifer and the underlying Edmonton formation.

It is considered that some provision for treating the water to reduce the hardness and iron concentration will be required as an integral part of the proposed induced infiltration installation. The only way that this could be eliminated would be to provide the upstream storage necessary to ensure that there would always be a measurable minimum flow in the river.

Summary

The Red Deer channel aquifer in the vicinity of Site 2 is capable of yielding about 4 mgd to four vertical wells completed adjacent to the Battle River. The water produced from this well field may be expected to be a quality approaching that of river water, provided that there is water in the river. If, however, the river is dry, then the water quality will approach the quality of water found in the Red Deer channel gravel. If the flow in Battle River could be regulated to provide a minimum daily flow of 17 cfs, then the same well field design would be capable of yielding about 9 mgd, and no water quality problem would exist.

Imperial Oil Limited obtain water from the Red Deer River at Red Deer by induced infiltration to supply their secondary recovery operations in the Joffre field. Initially, considerable bacterial contamination was found in the induced water as the wells are located within 100 feet of the centre of the river and their wells are located about one mile downstream from the City of Red Deer sewage outfall. As pumping continued the bacterial contamination steadily decreased and now presents no problem.

At the present time, a chlorine treatment of 14 ppm is adequate to provide the desired chlorine residual in the input water at the extreme end of their distribution system. It appears, therefore, that even if the wells are located as close as 100 feet from the river no difficulty will be experienced with the bacterial quality of the water in the proposed system.

VERIFICATION OF THE DESIGN CRITERIA AT SITE 2

The following critical assumptions, used in the well field design, must be evaluated before any decision is taken to proceed with development of this aquifer:

1. The thickness of gravel, determined by seismic work at Site 2, must be verified by test drilling. This should be done in the vicinity of station 54, at station 42, and at station 68 to evaluate critical assumptions in the seismic interpretation.

2. The transmissibility of the gravel should be determined, in detail at one location, and approximated at sufficient other locations to obtain an estimate of the variability of the gravel permeability. At one location a full-scale pump test should be carried out, with a large diameter production well and at least three observation wells. At the other locations, one observation well would be sufficient. During the full-scale pump test, the water discharged should be conveyed at least 2000 feet away from the pumping well, and if possible discharged so that it will not directly recharge the gravel. This test should be run for a period of about a week, to determine the transmissibility, and the specific yield of this aquifer. It will also establish the significance which will have to be attached to "delayed yield" in this aquifer, the lag in the gravity drainage of the part of the cone of influence de-watered during pumping. The desired information

can be obtained only during a period when the Battle River is dry, because the effects will be obscured by recharge if there is any water in the river. In contrast, the other locations may be tested when there is water in the river since at those locations only the transmissibility will be determined. At these sites the water should be discharged through a pipeline directly back to the river.

3. The water level recorder and staff gauge should be transferred to a better location than they are in at present. One of the test holes drilled during the above testing program would be ideal for observation well purposes. If possible the site selected for the observation well should be located close to the river, at a location which will be as far as possible from the possible production wells. The correlation established between the river stage and the well water level could be used to establish the time at which zero discharge in the river begins.

4. Samples of well water should be taken at intervals during the full-scale pumping test to determine the average quality of groundwater discharge from this aquifer. In addition, samples of water from Battle River should betaken monthly, at the bridge on the south boundary of Section 1, and at the bridge in Section 25, Tp. 45, R. 23, W. 4. These samples should be analyzed by a commercial laboratory which can determine Ca, Mg, Na + K, $CO_3 + HCO_3$, SO_4, and Cl, separately. From these analyses the annual variation in river water quality, and the percentage of groundwater discharge in the streamflow can be determined by the analysis of the two-component mixture by the method outlined by Piper (1944).

5. If the feasibility of treating water for the municipal water supply is demonstrated then it may be necessary to carry out test drilling along the proposed pipeline route to

determine how much water can be developed from the Red Deer channel gravels along the way, and what the probable water quality will be. The existing analysis of the water from the lowest terrace is singularly bad, it is felt that the overall water quality may be better; however, this could only be determined by analysis of water obtained after a longer period of pumping.

6. The preliminary design must be re-evaluated as new information becomes available to determine the ultimate productivity of this aquifer and its economic worth.

7. The legal problems arising from the diversion of water from Battle River should be taken under consideration at an early date. In connection with this, records of the quality of sewage effluent discharged back to the river will constitute important evidence regarding the downstream effects of any diversion. It is certain that the major portion of water diverted will be diverted at the peak river stage, initially from bank storage recharge, and later from a decrease in the bank storage discharge. It is also certain that production from the aquifer during periods when the river is dry will increase the bank storage capacity, and this propensity for recharge will be satisfied during the peak stream discharge.

8. The economic feasibility of this project must be continually re-evaluated as new information becomes available. If at any stage of development, the new information renders the project unfeasible, then a similar regional exploration program should be undertaken in the vicinity of Pigeon Lake, which is the only other perennial body of water in the area. In this connection it would be advisable to determine whether any lake level records are being maintained, and if not, to establish a regular program of water level measurements.

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APPENDIX I

Well Field Design Calculations

A. All Production Obtained from Storage

T - *transmissibility* = 100,000 gpd/ft

Specific yield = 0.20

Time = t = 365 days

Maximum drawdown
= s_{max} = 20 ft.

From the Theis Equation

$$s = \frac{114.6\,Q}{T}\,W(u), \quad \text{and} \quad u = 1.56\frac{r^2 S}{Tt}$$

Design a well field in which each production well will have an effective radius r_c = 1.0

$$\text{at } r_c: \quad u = \frac{1.56\,r^2 S}{Tt} = \frac{1.56\,(1)^2 \times 2.0 \times 10^{-1}}{1 \times 10^5 \times 3.65 \times 10^2} = 8.55 \times 10^{-9}$$

at the end of 365 days pumping.

Then from Theiss curve tables when u = 8.55×10^{-9}, W(u) = 17.99

$$\text{so:} \quad Q = \frac{s_{max}\,T}{114.6\,(Wu)} = \frac{2.0 \times 10 \times 1 \times 10^5}{1.146 \times 10^2 \times 1.799 \times 10} = 970 \text{ gpm.}$$

∴ Safe production rate for a single well = 970 gpm. = 1.4 mgd.

assuming that well losses are negligible.

Now determine the radius r_c where $u = 0.02$ at $t = 365$ days.

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

$$r_c = \frac{2 \times 10^{-2} \times 1 \times 10^{5} \times 3.65 \times 10^{2}}{1.56 \times 2 \times 10^{-1}}$$

$$= 2.34 \times 10^{6}$$

$$r_c = 1530 \text{ feet}$$

Now the drawdown after one year of pumping at a rate of 970 gpm at this radius may be determined:

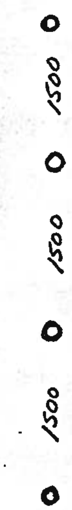
where $u = 0.02$ $W(u) = 3.35$

$$s = \frac{114.6\ Q\ W(u)}{T} = \frac{114.6 \times 970 \times 3.35}{100{,}000} = 3.7'$$

Thus the line for Q = 970 gpm may be plotted on Figure 7. Beyond 1530' the drawdown is approximate.

Now consider a 4 well field with the wells equally spaced on a north-south line, each producing at 970 gpm.

The total drawdown in each well will be the algebraic summation of the self-caused drawdown and the interference drawdown of each of the other wells in the field. Because their cones of interference are individually identical to that of a single well the drawdown for a given radius can be directly determined from Figure 7. Obviously the center wells will have the greatest drawdown.



Consider Well #2 in a 4 well field at a spacing of 1600'.

$\Delta s_t = 20 + 2(3.7) + 1(2.1)$

$\Delta s_t = 29.5.$ This is excessive.

∴ Safe production rate must be reduced.

By the previous method the drawdowns at $r = 1$ and $r = 1500$ ' were determined for $t = 365$ days for pumping rates of 800 gpm and 700 gpm.

Consider 4 wells pumping at 700 gpm each at a spacing of 1500 feet in Well #2

$\Delta s_t = 14.4 + 2(2.7) + 1(1.6)$

$\Delta s_t = 21.4$ feet <u>Acceptable</u>

The well field should provide 4 x 700 = 2800 gpm for a period of one year, assuming that no recharge occurs during that period. This is a daily production of about 4 mgd.

One Well: Q_{max} = 1.4 mgd.

Four Wells Q_{max} = 4 mgd.

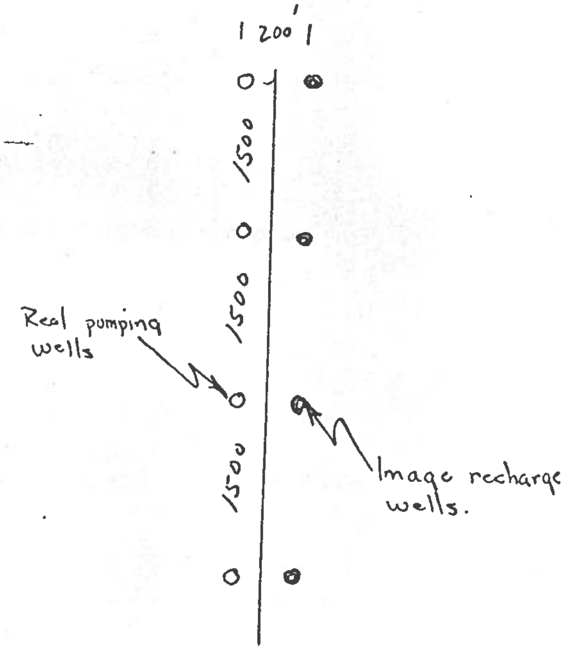
This, of course, assumes that there will be sufficient bank storage recharge in the following year to eradicate the cone of influence created by the above production. This would occur if 5400 ac. feet of water were intercepted from Battle River, after it had been dry for a year.

B. All Production Obtained by Induced Infiltration

Assume that the Battle River will flow at some finite rate at all times. Determine the maximum production rate from a 4 well field, with wells spaced at 1500 feet.

To do this the river must be considered as a line source of recharge. Because the primary objective is to obtain the maximum amount of river water, let us place the 4 production wells as near to the river as possible, say 100 feet.

The line source of recharge may be replaced by 4 imrage recharge wells, recharging at the same rate as the production wells are pumping. Each production well and its recharge image may be considered as an independent unit, because with this well fjeld arrangement the drawdown and recharge from the other real and image wells will effectively cancel each other.



For each well unit:

say $Q = 700$ gpm.

then Δs_t = self-caused dd - induced recharge

$\Delta s_t = 14.4 - 6.0 = 8.8$ feet.

$Q = 1600$ gpm.

$\Delta s_t = 33 - 13.6 = 19.4'$. Acceptable.

Now at any time t, because u is already ≤ 0.02, the rate of drawdown will be the same in the real well and in the image well, therefore any increase in drawdown will cause an equal increase in recharge, and there will be no increase in the observed drawdown. The total production from the well field would be

$4 \times 1600 = 6400 \text{ gpm} \approx 9 \text{ mgd}$.

Now 1 mgd = 1.86 cfs

So at 9 mgd the minimum daily flow entering Site 2 would have to exceed 17 cfs.

1 mgd = 3.68 ac. ft.

at 9 mgd. for 1 year = 12,000 ac. ft.

This would require useable storage of a magnitude sufficient so that at least 12,000 ac. feet would be available for infiltration at Site 2.

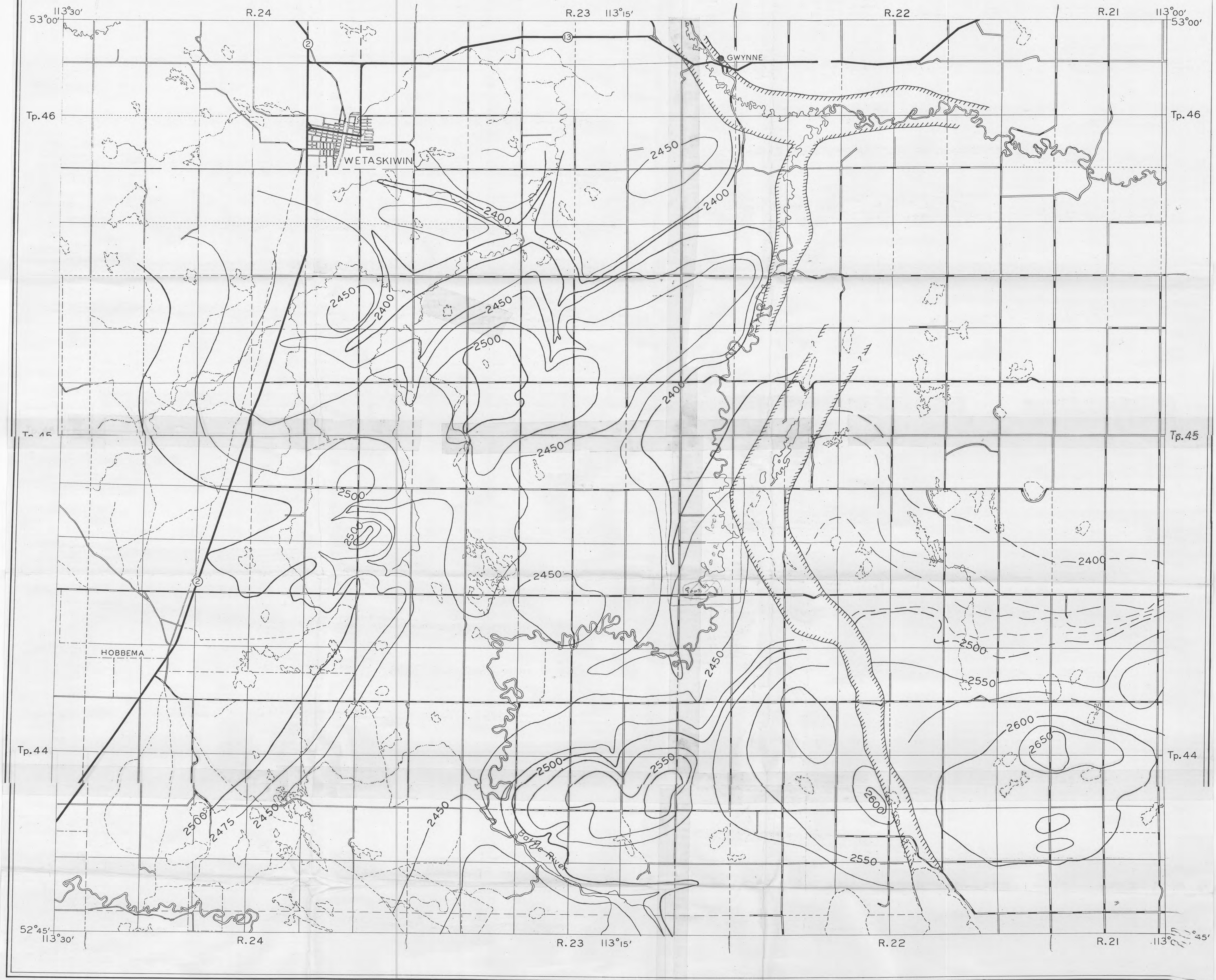


Figure 1

WETASKIWIN AREA

WEST OF FOURTH MERIDIAN

LEGEND

Scale in miles

1 0 1 2 3

Hard surface

Loose surface

Loose surface (dry weather)

Contour on bedrock surface

Contour on bedrock surface, position uncertain

Approximate boundary of stream trenches

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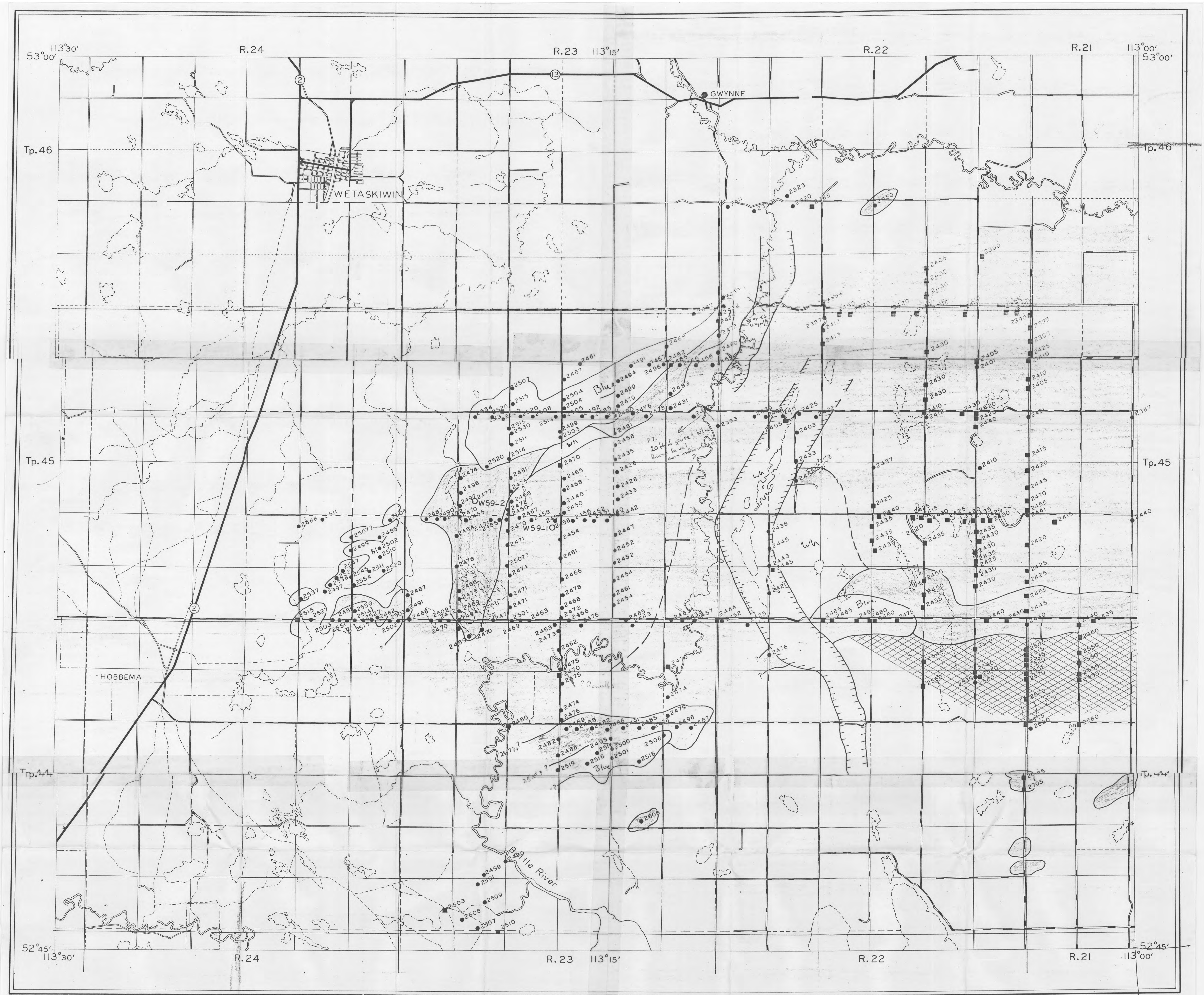

Basal Gravel Deposits
Associated with the
RED DEER CHANNEL

Residual remments of high level gravels

1 Terrace

2 Terrace — RED DEER Channel

3 Terrace

Texaco shot hole elevation is top of basal gravel ● 2545

I.O.L. shot hole elevation is top of basal gravel ■ 2605

Limit of post channel erosion

Figure 2

WETASKIWIN AREA

WEST OF FOURTH MERIDIAN

LEGEND

Scale in miles

1 0 1 2 3

Hard surface

Loose surface

Loose surface (dry weather)

RED DEER CHANNEL

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Figure #3

Proposed Sites 8 to 10 mls. E. & S. of City

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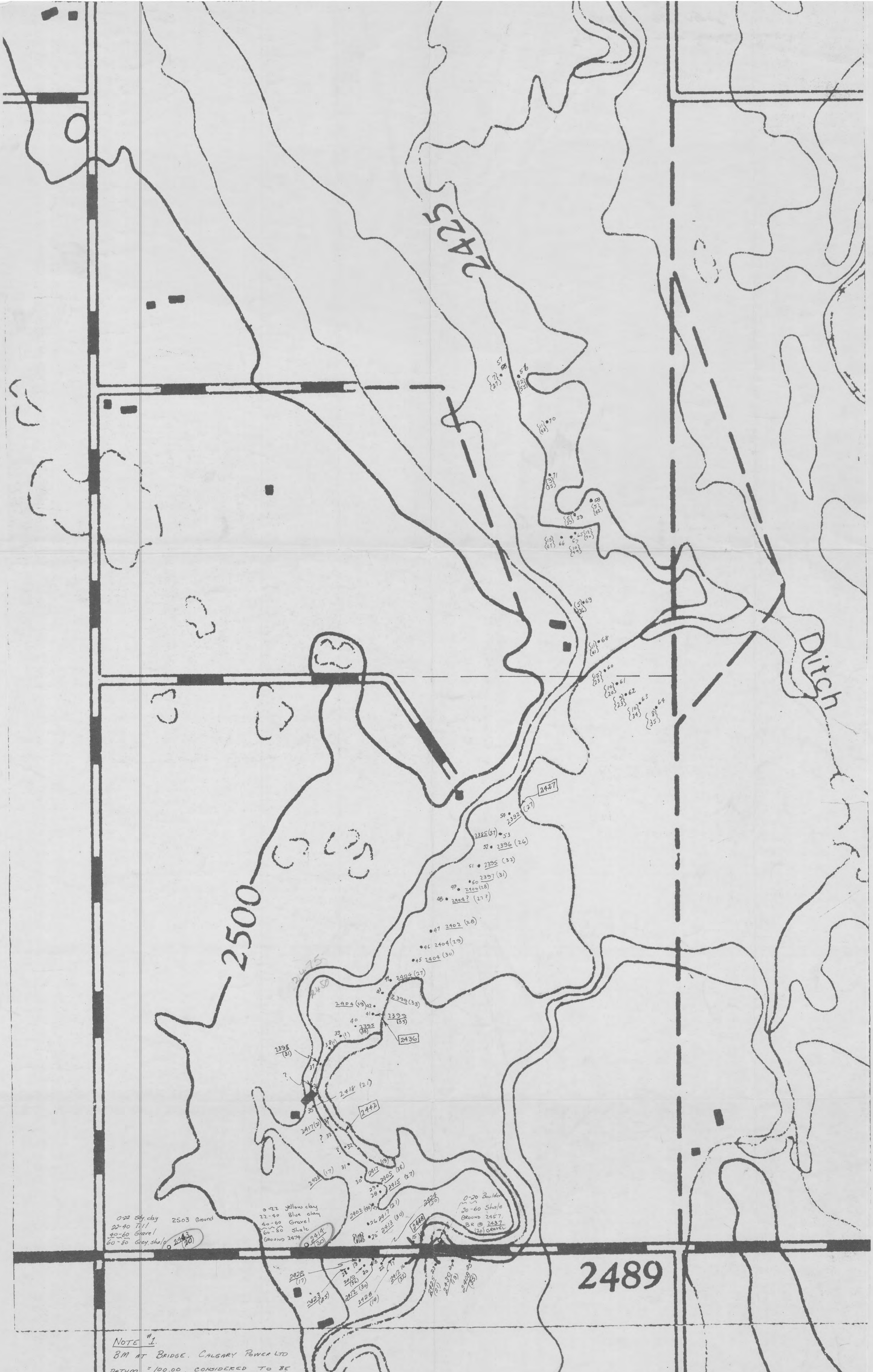

NOTE #1.
BM AT BRIDGE. CALGARY POWER LTD
DATUM = 100.00, CONSIDERED TO BE
AT GEODETIC DATUM = 2460'

FIGURE 4.

WETASKIWIN AREA

REFRACTION SEISMIC SURVEY
SITE #2
SECTIONS 1 & 12, TP 45, R. 23, W 4 mer.

LEGEND

- o — SEISMIC SHOT HOLE LOG.
- o 2463/(20) — " " " " BEDROCK ELEVATION AND GRAVEL THICKNESS
- 31 • — REFRACTION SEISMIC STATION WITH LOCATION NUMBER
- 31 • 2475/(15) — REFRACTION SEISMIC STATION, SHOWING BEDROCK ELEVATION, AND THICKNESS OF GRAVEL PRESENT
- 66 • {8/30} — REFRACTION SEISMIC STATION, NO ELEVATION SHOWING DEPTH TOP, AND TO BASE OF GRAVEL.
- [2442] — ELEVATION OF WATER LEVEL IN BATTLE RIVER JUNE 9, 1961.

1. Gravel: Commonly 20ft thick
2. Results. (i) Acceptable in South part of area
   (ii) Unacceptable from ½ ml N. to N. of area due to poor correlation between hammer seismic & drilling information

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OFR 1961-4 #5 of 5