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SECOND INTERIM REPORT ON THE FEASIBILITY STUDY FOR DEWATERING THE OVERBURDEN IN GCOS LEASE 86

by

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RESEARCH COUNCIL

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SUMMARY AND CONCLUSION

The cost of dewatering the southern portion of the lease using a sump was estimated to be $337,200. The cost of dewatering the same area using wells was estimated to be $163,267. Evidently it is more economical to use wells. It is expected that a refinement of these figures will not significantly change the above conclusion.

On the basis of an electrical model of groundwater flow in the area between the Thickwood Hills and the GCOS Lease it was found that the whole lease above the Athabasca River escarpment is in a natural recharge area. Therefore, theoretically no water enters the lease from Thickwood Hills or Ruth Lake under natural conditions. A tentative groundwater flow map was constructed delineating the local flow systems. These will have to be considered when planning a dewatering program.

From a fence diagram of the lithologic variations in the overburden it is apparent that there are two main aquifers in the lease, separated by a less permeable boulder clay unit. Isopach maps of each aquifer were used to plan an aquifer testing program. The isopach maps indicate that although the aquifers are present over most of the lease area, the areas where a significant thickness of either aquifer is present are patchy. Consequently each of these areas will have to be tested and dewatered separately. The calculation of the permeability of aquifers is restricted to the results of one pump test and four bail tests. None of these were conducted in the upper aquifer. Thus permeability values are available for two areas in the lower aquifer, two areas in the boulder clay unit, and the combined permeability of the upper and lower aquifers is available for one area. The permeability of the lower aquifer was found to vary from 208 to 805 igpm/sq ft. The permeability of the boulder clay was found to vary from 0.66 to 2.38 igpm/sq ft. The combined permeability of the lower and upper aquifers in the vicinity of CH 117 is approximately 200 igpm/sq ft. The specific yield of the lower and upper aquifers in the southern part of the lease combined with the recharge during an eight month period was found to be 47 per cent. This means that out of a unit volume of sediment a volume of water equal to 47 per cent of the bulk volume has to be removed to dewater the sediment and keep it dewatered over a period of eight months.

Proposed testing program to be undertaken this winter involves a minimum number of 23 wells required at the present. However, some changes may be required during the program. An attempt has been made to anticipate some of these changes in the planning of the program (see Appendix), but it is obvious that all possible conditions cannot be foreseen.

INTRODUCTION

The first part of this report summarizes the work done during the period between November 1968 and November 1969, and the conclusions reached as a result of the newly acquired information. The second part outlines a plan for the continuation of the acquifer testing program which was started in March 1969, and had to be discontinued due to spring thaw. It states the objectives and the manner in which they will be met.

GROUNDWATER MOVEMENT

Regional Flow

Contrary to what was suggested in the previous report to GCOS (Kahil, 1968, p. 25), it is now believed that Beaver River and Ruth Lake effectively stop any water from entering the lease from the Thickwood Hills, situated to the Southwest (see Kahil 1968 p.25). This opinion is based on an electrical model of groundwater flow (Plate I) which assumes that the substratum is homogeneous and isotropic, which is not actually the case. It is believed, however, that but for slight distortions the model represents the actual groundwater movement.

An important condition indicated by the model is that the whole GCOS lease above the Athabasca River escarpment is in a regional recharge area discharging some groundwater into Ruth Lake and the major portion into the Athabasca River. Thus, from the model, it is evident that under natural conditions no water flows from Ruth Lake into the lease.

Local Groundwater Movement

A knowledge of the local groundwater movement is of extreme importance in planning the most favourable location from which to dewater an aquifer, and in predicting the effect on the water table of removing groundwater from a certain location.

Groundwater movement was studied using groundwater chemistry, water levels in wells during drilling, changes in water levels in observation wells (piezometers) during the year, electrical models, and vegetation. Combining all this information, a tentative map of groundwater recharge and discharge features (Plate 2) was prepared. This map indicates the recharge and discharge features of local flow systems which are superimposed on the regional system referred to above.

It is difficult to assess, at present, the reliability of the outlined areas because of the muskeg conditions. Although groundwater chemistry and groundwater movement have been related in many studies, no such study has ever been made in a muskeg environment which may present special problems. Because of this the use of groundwater chemistry to determine groundwater movement in a muskeg area should be used cautiously.

The use of groundwater level changes with depth (Kahil, 1968, p. 20) and of water level changes in time may be the most suitable method at the present for determining groundwater flow. In this study an insufficient number of wells have been drilled to use this method effectively on the scale that is desired. Increasing the number of areas where this type of information is available is one of the objectives of the test drilling program proposed in the second part of this report.

The adequacy of an electric model to determine the direction of groundwater flow is limited by the fact that it considers the substratum as homogeneous and isotropic. In the GCOS lease there is a sharp contrast in permeability between the boulder clay unit and the boulder sand or sand units (Kahil, 1968). Thus the effectiveness of the electric model as a tool for outlining local flow systems is greatly reduced.

Plants have been used as indicators of groundwater discharge areas in numerous studies; however, none of these were in a muskeg environment. It is therefore necessary first to learn which plants are indicative of groundwater discharge in such an environment before they can be used as indicators. An attempt has been made in this study to recognize plants that are indicators of groundwater discharge but the conclusions of this aspect of the study have to be verified before the method can be used as a tool. This has not been done. In view of these considerations, the map of groundwater recharge and discharge areas (Plate 2) should be considered tentative.

DELINEATION OF AQUIFERS

The lithologic descriptions of the core holes drilled by GCOS and the Alberta Government in the lease, as well as the observation wells (piezometers) drilled in March and April of 1968, were used to construct a fence diagram of the

GCOS lease (not included in this report). In this fence diagram the stratigraphic units defined by Linkens (1965) were not used for various reasons. The most important ones are: That the stratigraphic units may not constitute hydraulic units, i.e. water will flow freely from a boulder sand to a sand and back to the boulder sand; that it is probable that one stratigraphic unit will not have a uniform permeability; and that portions of the boulder clay which are sandy would otherwise be ignored. This would underestimate the area to be dewatered and the volume of water to be removed.

The fence diagram constructed revealed three aquifers separated in most cases by a clay layer. The upper and lower aquifers are the most widespread, extending throughout most of the lease. The intermediate aquifer is present in the northwest and southeast part of the lease. It is thin and patchy and therefore will be ignored from further discussion for the present.

Using the same information that was used to construct the fence diagram, two isopach maps were made. One of the lower aquifer, which mostly includes the A1, B1, E units and the McMurray Formation (Plate 3), and one of the upper aquifer which includes mostly the A2, B3 units (Plate 4). The areas of contact between the two aquifers, and the area where neither of the aquifers are present are marked on the maps.

In the above discussion it has been assumed that the boulder clay unit is impermeable; however, this is not always the case (Kahil, 1968, p. 13). Because of this the upper and lower aquifers may be hydraulically connected in more areas than those indicated in Plates 3 and 4. This is both advantageous and disadvantageous for, on one hand, if the aquifers are hydraulically connected over a large area it would be possible to drain both aquifers by removing water from the lower one, thus reducing the number of installations required to dewater the overburden. On the other hand, if the boulder clay is permeable it would have to be dewatered, thus increasing the total volume of water to be removed from the overburden.

For the proper planning of a dewatering program it is essential to determine the permeability of the boulder clay unit and of the two aquifers. As the permeability of each hydrologic unit may be different in different parts of the lease, it should be tested in each area when a significant thickness of aquifer is present. This is to be accomplished through pump tests and the proper location of observation wells, as is indicated in the second portion of this report.

AQUIFER TESTS

The information available on permeability of the aquifers in the lease area is derived from one pump test conducted by GCOS in January and February of 1967, and bail tests conducted on four observation wells undertaken in March and April 1969.

Analysis of the Pump Test Conducted on Core Hole 117

During the pump test, which continued with interruptions for 28,990 minutes (approximately 20 days), CH 117 was pumped at approximately 65 igpm. Water levels were recorded during drawdown and recovery in CH 117 and two observation wells. One observation well was located 12 feet from the pumped well (observation well 1) and the other 29 feet from the pumped well (observation well 2).

According to the geologist's lithologic log of CH 117, 22 feet of the lower aquifer and 22 feet of the upper aquifer are penetrated by the well. Thus the results of this test will give a combined permeability of both aquifers. The lithologic logs for the observation wells are not available so these wells will be considered to have similar logs as CH 117.

The equation used to interpret pump tests, requires continuous pumping of the well during the test. It is unfortunate that this condition was not met during this test. Because of this, the only portion of the test that can be used is the recovery portion. Although this portion of the test should provide as accurate a result as the drawdown portion, it is desirable to calculate the permeability from both portions of the test so as to cross check the results.

The average permeability calculated from the recovery data for the aquifer around CH 117 was found to be 208 igpm/sq.ft. The results of the calculations are summarized in table 1.

Bail Test Analyses

The main practical difference between a bail test and a pump test is that bail tests are usually run for shorter periods of time than pump tests. Thus the permeability values determined from the bail test reflect the local conditions around the well, while those determined from a pump test are representative of a larger area around the well.

It is unfortunate that at the time the test holes were being drilled and bail tested, the author was unable to supervise the operations, consequently, some of the bail test results are slightly uncertain. In the case of P 19 the observation well was bail tested twice. The first time bailing was interrupted because of some mechanical malfunction and therefore the well was bailed for an insufficient length of time. The second bail test was begun before the well had fully recovered. This factor introduces an error in the analysis of the data because of assumptions made in the derivation of the equation used. The results from the bail test on P 34 do not plot along a smooth curve, thus their interpretation is questionable. The bail tests conducted on P 29 and P 39 were conducted properly and the permeability values calculated from these date from these tests are reliable.

PERMEABILITY OF HYDRAULIC UNITS

The permeability of the hydraulic units discussed below are those determined from the tests that have been conducted to the present on each unit. It should be remembered that the permeabilities discussed are valid only for the particular unit at and surrounding the location of the well on which the test was conducted. The permeability values calculated in one area of an aquifer should not be applied in another portion of the aquifer without great caution, for it is not known at the present to what extent the various hydraulic units are homogeneous.

Lower Aquifer

Only two tests were conducted on the lower aquifer alone, namely the bail tests on P 19 and P 39. The results from P 19 (second bail test) indicate that the lower aquifer has a permeability of 805 igpm/sq ft and the results from P 39 indicate a permeability of 208 igpm/sq ft.

Boulder Clay Unit

Two bail tests were conducted in the C unit. One of these tests was conducted on P 29 and the other on P 34. The test conducted on P 29 yielded a permeability of 6.9 igpm/sq ft for the sediment surrounding the well. The permeability calculated from the results of the bail test on P 34 is 2.38 igpm/sq ft. It should be remembered that the data from the latter bail test are not reliable for reasons given above, therefore the permeability value should be used cautiously.

Upper Aquifer

The upper aquifer was never tested individually and its permeability is therefore not known.

Combined Upper and Lower Aquifers

As was previously mentioned CH 117 penetrates both the upper and lower aquifers; therefore the pump test conducted on the well yields data on the combined permeability of both aquifers. The average permeability for the upper and lower aquifer in the area surrounding CH 117 and its two associated observation wells is 208 igpm/sq ft.

SPECIFIC YIELD

The specific yield of a sediment is the quantity of water that has to be removed from a unit volume of sediment to dewater it by gravity drainage.

An attempt was made to calculate the specific yield of the combined lower and upper aquifers by comparing the volume of water pumped from the sump between March 16 and November 15, 1968, and the volume of sediments dewatered (Fig. 3). They indicate that out of each unit volume of sediment a volume of water equal to 47 per cent of the unit volume can be removed. This figure is very close to the maximum porosity theoretically possible for a sediment composed of uniform spheres and in cubical arrangement. As the sediment is not composed of perfect spheres and is not arranged in that fashion, this figure is above that theoretically possible. Thus this figure cannot really represent the specific yield of the lower and upper aquifers. It is believed to represent the specific yield plus the induced recharge entering the aquifer. Thus this figure represents the amount of water that needs to be removed from a unit volume of sediment to keep it dewatered over a period of eight months. Until this figure is verified by other means it should be used with caution, for delineating the volume of sediment dewatered is only approximate and is susceptible to errors.

Table 1. Permeability values of the hydraulic units in the GCOS Lease

Well number	Date and type of test	Type of data	Producing horizon	Duration of pumping or bailing (min.)	Transmissivity (igpm/ft)	Permeability (igpm/sq ft)
CH 117	Jan.-Feb. 1967 pump test	recovery	upper & lower aquifers	28,990	9,040	203
Observation well #1 to CH 117	Jan.-Feb. 1967 pump test	recovery	upper & lower aquifers	28,990	6,870	151
Observation well #2	Jan.-Feb. 1967 pump test	recovery	upper and lower aquifers	28,990	12,250	269
P19 (second bail test)	March 24, 1969 bail test	recovery	lower aquifer (A_1)	173	42,000	805
P29	April 2, 1969 bail test	drawdown recovery	boulder clay boulder clay	37.2	37 34	0.72 0.66
P34	April 3, 1969 bail test	drawdown	boulder clay	10	87	2.38
P39	April 3, 1969 bail test	recovery	lower aquifer (B_1)	55	3,960	208

COMPARISON OF DEWATERING COSTS USING A SUMP VERSUS WELLS

In an attempt to compare the cost of using wells as opposed to a sump for dewatering the overburden, the number of wells and spacing required to duplicate the effect of the sump presently in the southern portion of the lease was calculated. This portion of the lease was chosen because the permeability and specific yields of aquifer are best known and because actual costs of dewatering by the use of a sump are known. A summary of the cost involved in each scheme and the total cost are given in Table 2.

The wells in the second dewatering scheme are arranged in two rows, one offset from the other to form triangular cells. The spacing between the wells is 400 feet and they are arranged along the length of the present sump, which was estimated to be about 9,600 feet long. With this number of wells pumping at approximately 100 gpm for one half year the total volume removed is 1,260,000,000 gallons of water. This compares with 523,000,000 imperial gallons pumped from the sump over a 12-month period. Thus, with this arrangement and number of wells more overburden is dewatered than with the sump.

The above arrangement was chosen because it is preferable to GCOS to pump only during the warm period.

If it is possible to pump during the whole year then an even greater amount of overburden may be dewatered using only 30 wells arranged in a row along the sump, and pumping at 100 gpm. This would reduce the total cost to $132,284 and the volume of water pumped would increase to 1,575,000,000 imperial gallons.

It is obvious from these calculations that it is cheaper to dewater the overburden using wells. It should be remembered that the calculations above are based on one pump test which was not conducted properly, and on a questionable figure for specific yield and induced recharge. However, an error of 50% would have to have been made in the calculations and cost estimates of the scheme using wells before the cost of the two methods approach one another.

Another advantage of using wells is that the scheme is more flexible. In the scheme presented here all wells were pumped at the same time in order to duplicate the effect of the sump. This would be unnecessary, for the dewatering could procede

Table 2. Estimate of cost for dewatering a portion of the southern part of the GCOS Lease using two different schemes

Estimate of the cost of dewatering the overburden using a sump:	
Cost of excavating 1,232,000 cubic yards of sediment at 27¢ per cubic yard	$303,300
Cost of operating pump for 12 months at $3/hour	25,500
Cost of operator at $700 a month	8,400
Total cost	$337,200
Estimate of the cost of dewatering the overburden using wells:	
Cost of drilling 48 wells approximately 60 feet deep at $12/foot (8 inch casing)	$ 34,560
Cost of 48 submersible pumps capable of pumping 100 igpm at $1,500 per completeunit	72,000
Cost of operating pumps for 1/2 year at 1¢ per horsepower per hour (3 hp motors needed)	6,307
Cost of 12 operators (one operator to 4 pumps) at $700 a month	50,400
Total cost	$163,267

just ahead of the overburden removel, thus greatly reducing the number of pumps, amount of casing and screen required, and reducing the operating costs per year, as these can be recovered and reused while the sump cannot. Also, by dewatering only a portion of the overburden the induced recharge is reduced, and therefore the amount of water to be removed is decreased.

PROPOSED TESTING PROGRAM

The proposed testing program is designed to provide information necessary for the formulation of a realistic dewatering scheme. The main aims of the testing program are:

1. The determination of well interference. In order to do that needed are:
   a) Regional values of transmissivity permeability, and specific yield.
   b) Field determinations of the shape and expansion of the cone of depression.

Determination of areas from which water is induced to the wells, and the amount of water induced.

Distribution of a set of wells for monitoring.

To achieve these aims the following steps should be taken. Test holes should be drilled at key positions. During the drilling a detailed description of the lithology should be made. The water level should be measured every ten feet and any time there is a sudden change in water level. Each well should be cased and bail tested to determine the permeability of the sediment. During the bail test the well should be bailed at about 20 igpm and for approximately two hours. If it is bailed at a lower rate the bailing should be continued for a longer period of time. This, however, is not recommended. At each location where there is a great thickness of highly permeable aquifer, as indicated by the lithologic logs and bail tests, a pump test should be conducted. The rate at which the well will be pumped during the pump test and the length of time it will be pumped will have to be determined separately for each case. From the available information it is probable that the pumping rate will be approximately 200 igpm for a duration of about one week.

The appendix is a table of the proposed locations for the test holes to be drilled within the lease, along with an explanation of purpose of each test hole. In addition to these wells approximately six additional wells will be required for observation wells for pump tests. The test drilling program is designed from the available information; therefore it may be modified as it progresses and more information is made available. The testing program was developed by dividing the lease into general partitions and an order of importance placed on each partition. The orders were based on the volume of aquifer available and on the anticipated time the problem would be encountered. Thus emphasis was placed on areas in which overburden would be removed in the near future and areas where large volumes of water may have to be removed. The areas that had a high order of importance are to be studied in more detail than areas having a low order of importance.

REFERENCES CITED

Kahil, Alain, 1968, Interim report on the feasibility study for dewatering the overburden in GCOS Lease 86. Unpublished report to Great Canadian Oil Sands Ltd., 39 p.

Linkens, W.M.J. 1965, Final report on the overburden - Lease 4, Athabasca River area, Alberta, Canada. Unpublished report to Great Canadian Oil Sands Ltd, 46 p.

APPENDIX

Observation well number	Total depth (feet)	Aquifer(s) thickness (feet) lower	upper	Slotted interval from (feet)	to (feet)	total (feet)	Remarks
P47*	50	24	3	26	50	25	This well is to determine the effect of the new sump. This area being far from the sump may have to be dewatered separately. Depending on permeability and thickness of the aquifer, P48 will be drilled.
P48*	50	8	3	?	?	10	This well to be drilled if P47 indicated the aquifers to have a high permeability. Purpose: To check the thickness of the lower aquifer, to serve as an observation well for a possible pump test, and to monitor the effect of the sump.
P49*	44	35	2	9	44	37	Purpose: To determine the presence of 37 feet of aquifer that appears to be there and to determine its permeability.
P50*	40	19	3	?	?	19	This hole is to be drilled if P49 indicated that the area warrants further study. Purpose: To determine if there is a connection between P49 and P50. If there is, then the area north of P49 should be dewatered along with this area before overburden removal gets to this area. This well is also to be used to determine permeability of material.
P51*	10	-	10	5	10	5	Well to be drilled only in upper aquifer to determine if boulder clay allows water to flow through it. Also to determine permeability of upper aquifer.
P52*	24	0	20	10	24	14	To investigate the presence of 20 feet of lower aquifer and its permeability. If aquifer is present and is permeable then P53 should be drilled.
P53*	24	0	20	10	24	14	To be drilled only if results from P52 justify it. Purpose: To delineate aquifer and observation well for possible pump test.
P63*	20	-	20	10	20	10	To determine the thickness and permeability of the lower aquifer.

*Location plotted on Plate 3.

— within NTS 74D (Waterways) sheet

Observation well number	Total depth (feet)	Aquifer(s) thickness (feet)		Slotted interval			Remarks
		lower	upper	from (feet)	to (feet)	total (feet)	
P54*	47	0	20	25	47	22	This well is to be drilled if P52 indicates a permeable aquifer. It is to be used to determine the permeability of the aquifer and as an observation well if a pump test is warranted.
P55*	40	23	12	20	40	20	This well should be sealed between the upper and lower aquifer, so as to pump only the lower aquifer. It is to be used to determine the permeability of the lower aquifer.
P56*	15	-	12	5	12	7	This well is to be drilled only to clay. It is to determine the permeability of the upper aquifer, and to check the permeability of the boulder clay by pumping P55 and noting any drop in water level in P56.
P57*	57	27	8	47	57	10	To check the presence of 27 feet of upper aquifer and its permeability.
P58*	58	10	8	48	58	10	To determine thickness and permeability of lower aquifer. This area is supposed to be water bearing.
P59*	34	-	30	15	30	15	To determine the thickness and permeability of the upper aquifer.
P60*	21	11	10	5	20	15	To determine presence of both aquifers and their combined permeability. Also to be used as an observation well for a pump test.
P61*	60	3	55	40	60	20	To determine the thickness and permeability of aquifers and as an observation well for a pump test.
P62*	62	-	62	40	62	20	To determine the thickness and permeability of the lower aquifer and as an observation well for a pump test.

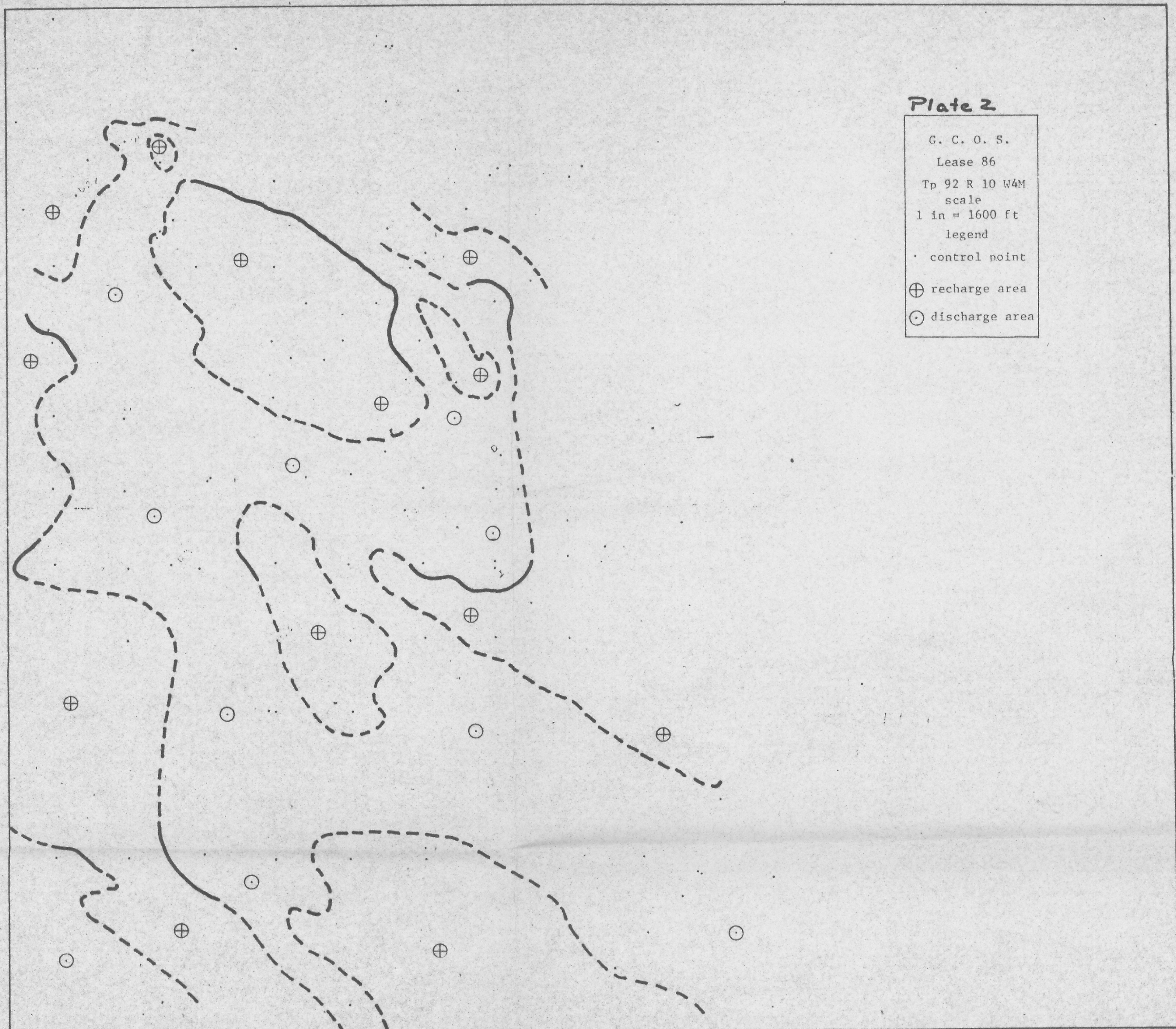
Plate 2
G. C. O. S.
Lease 86
Tp 92 R 10 W4M
scale
1 in = 1600 ft
legend
control point
recharge area
discharge area

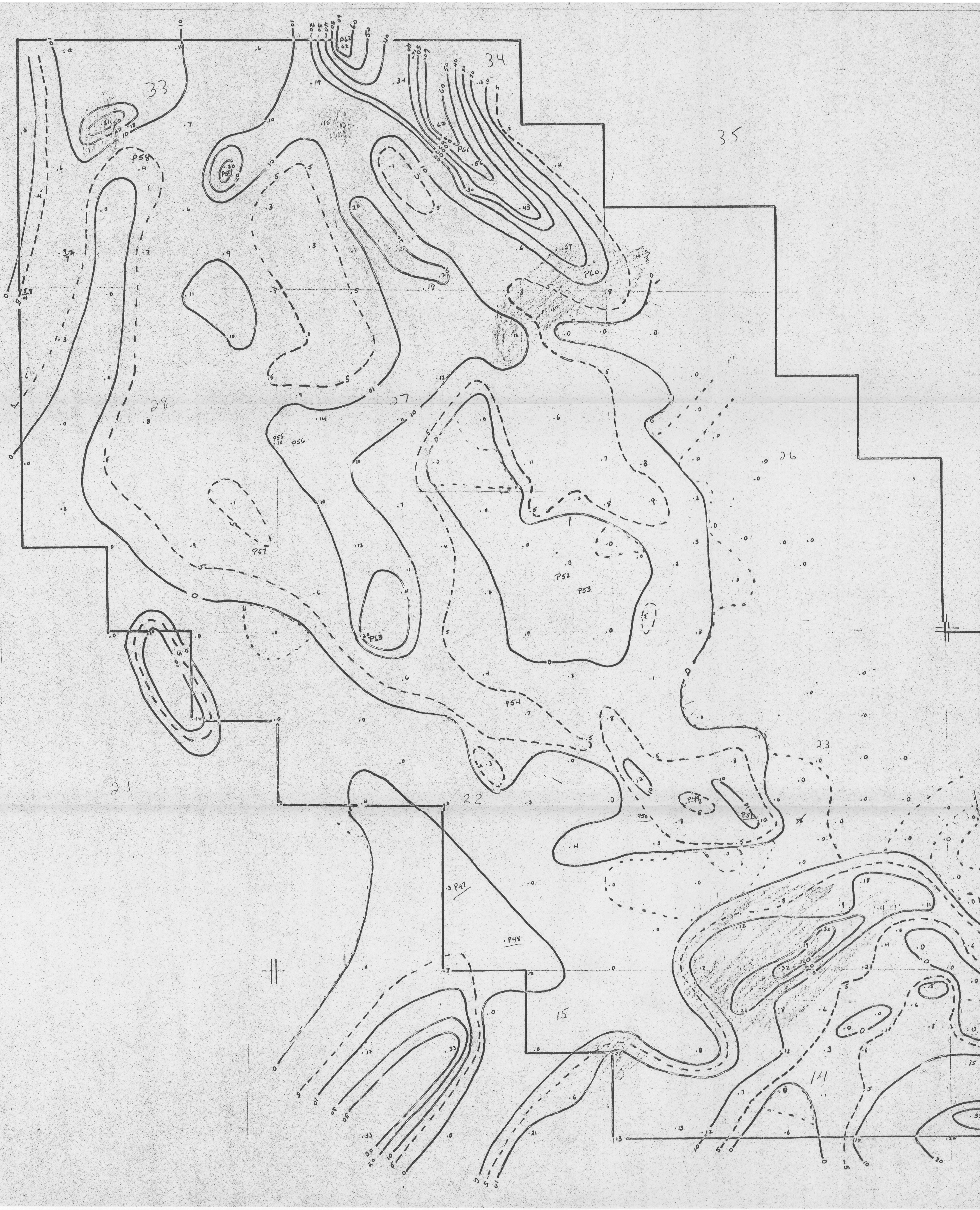

Plate 3

Geology Series
Isopach
upper aquifer
($A_2 + B_2 + B_3$)

Horiz Scale 1" = 800'
CI = 10 ft.

$\frac{1}{3}$ 2 This symbol indicates 1' of aquifer separated by 2' of aquiclude from 3' of aquifer

area of contact bet. upper and lower aquifers

area with no aquifers

Draughted by Alain Kahil
Oct. 1969


Geology Serie
Isopach of lower aquifer
(A, + B, + McMurray fm devoid of oil)
Horiz. scale 1" = 800'
CI = 10 ft.
area of contact between upper + lower aquifer
area with no aquifers

Plate 4