RPI - FWI - 73-15

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Fresh Water Institute

AT LAKE GEORGE

THIRTY-FIVE YEARS OF USE OF A NATURAL SAND BED FOR POLISHING A SECONDARY TREATED EFFLUENT

By

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1973

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Presented at

Rural Environmental Engineering Conference

University of Vermont

September 27, 1973

FWI Report #73-15

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INTRODUCTION

When the Lake George Village Sewage Treatment Plant was constructed in the late 1930's, laws were already in effect preventing the discharge of any sewage, raw or treated, into the waters of Lake George or into any streams discharging into this beautiful recreational lake. Therefore, extra steps were taken to provide for "complete" treatment of the sewage. The basic treatment plant is not unusual, consisting of circular Imhoff tanks providing for primary sedimentation and sludge digestion, trickling filters, and secondary sedimentation of the trickling filter effluent. The unique portion of the plant, other than its dual pumping system lifting the sewage approximately 200 feet from the collection point by the lake to the treatment plant, is the discharge of the effluent from the secondary sedimentation tanks directly onto natural sand beds without chlorination. The sand beds were determined to be "more than 25 feet in depth. "The final effluent becomes groundwater, which in all probability, seeps eventually to some water course as a highly purified liquid which cannot be identified as a sewage effluent."(5)

When the original treatment plant was designed and constructed, the population estimates for the area varied from approximately 1500 persons in winter to about 5000 at the peak of the summer season. In order to allow for this approximately three-fold change in population, the treatment system was built essentially in triplicate using one-third of the system for the winter-time flows and the entire plant for summertime flows. The present population estimates[1] being served by the treatment system are 2100 persons in winter and 12,300 in summer. Initially, there were six sand beds with a total area of approximately 72,000 square feet (6,690 square meters). Presently, there are 14 sand beds in the area where the original six were located and an additional seven sand beds at a higher elevation above the primary settling tanks. The total area of these combined beds is 6.4 acres (2.6 hectares). A general layout of the plant is shown in Figure 1.

PREVIOUS STUDIES

When the original plant was built, the primary concerns in sewage treatment were the disposal of the liquid effluent and the sanitary quality as measured by the coliform count. Twenty-five feet of soil was considered adequate to remove the coliform bacteria which also meant the absence of pathogenic bacteria. However, no tests had ever been performed to show positively the removal of coliforms by passing through the sand beds. In recent years we have realized that sanitary quality is not the only parameter by which to judge the efficiency of a treatment system. Nitrogen and phosphorus compounds are frequently limiting nutrients in a lake. Therefore, it is expedient to be sure that the inputs of nitrogen and phosphorus to Lake George are kept to a minimum. In order to determine the potential discharge of these and other substances into Lake George, studies were performed in the sand beds during the late 1960's by students at RPI. Wells were installed in beds 7, 11, and 13 (see Figure 1) at depths of 5, 10, 15, 20, and 25 ft. (1.5, 3, 4.6, 6.1, and 7.6 m). Bed No. 7 was

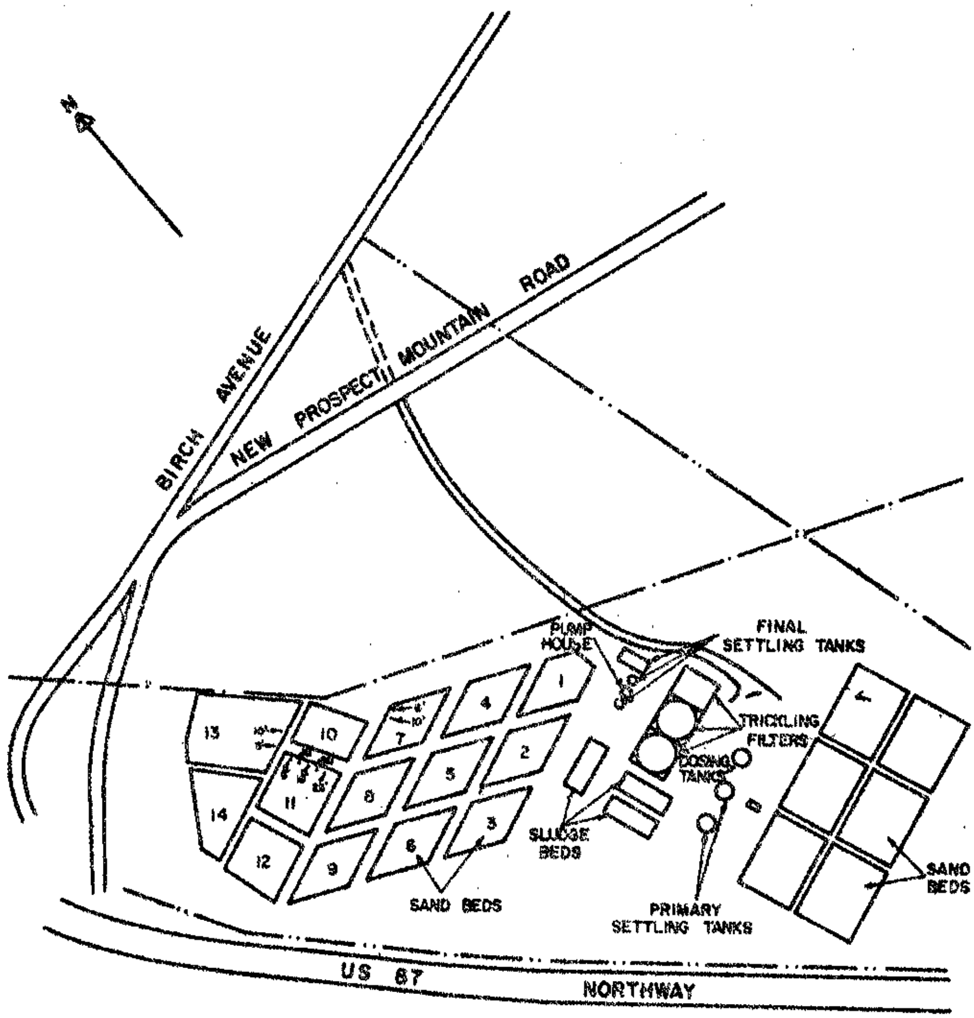


FIGURE I

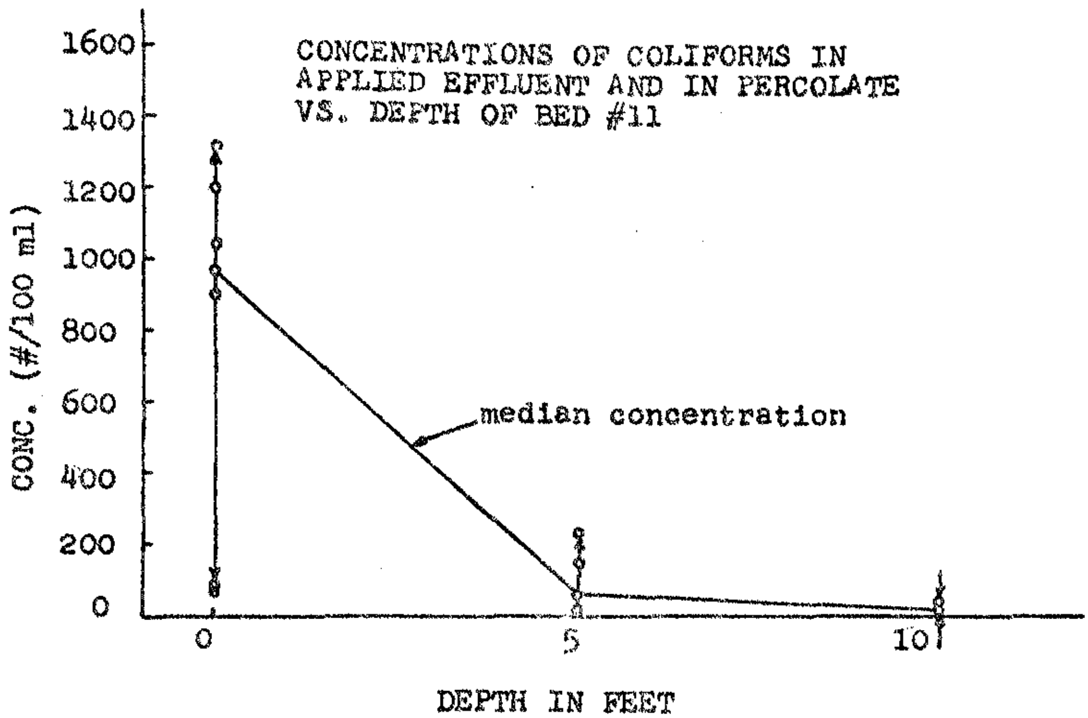
LAKE GEORGE SEWAGE TREATMENT PLANT

an extremely slow bed and took up to a week to dry. Bed 11 was a fast bed in that the water percolated away in a day or two. Bed 13 was chosen because it had had only limited use since the plant was built due to the fact that the control valve for this bed is accessible only through a manhole. Valves for the other beds are operated from above the ground.

It was found that no sample could be secured from bed 7 and that samples could be secured from the wells at the 5 and 10 ft. depths only in beds 11 and 13. It was considered that the securing of samples at the 5 and 10 ft. depths indicated a continuous water column to these depths, but that by the time the water percolated 15 ft. down into beds 11 and 13, the water became dispersed and could not be pumped directly.

The results of these studies are summarized in Figures 2 through 10.[2] Figure 2 shows the concentration of coliforms in the applied effluent and in the percolate at the 5 and 10 ft. depths in beds 11 and 13. It may be seen that essentially all of the coliforms are removed in the first five feet of the bed depth. The similar BOD removal is shown in Figure 3. The influent BOD which varied at about 40 mg/l was reduced to less than 8 mg/l at the 5 ft. depth and to less than 2 mg/l at the 10 ft. depth. This indicates very satisfactory BOD removal. The chloride concentration with depth in the two beds is shown in Figure 4. Essentially there is no significant reduction in the removal of chlorides with depth. The overall reduction with 10 ft. of depth in bed 11 was 5% whereas in bed 13 it was 10%. The organic nitrogen content is shown in Figure 5. It may be seen that essentially

Figure 2


CONCENTRATIONS OF COLIFORMS IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11
CONC. (#/100 ml)
1600
1400
1200
1000
800
600
400
200
0
median concentration
0
5
10
DEPTH IN FEET

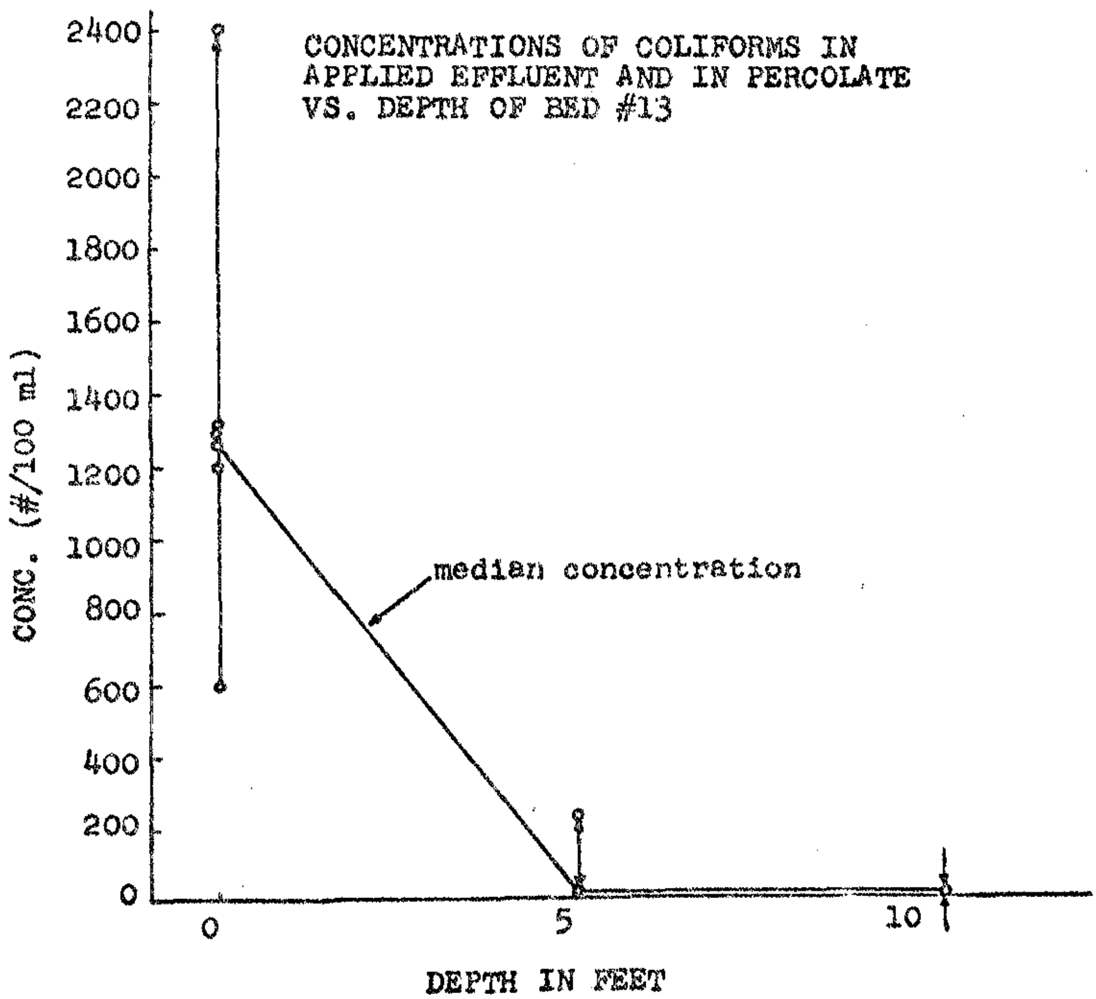
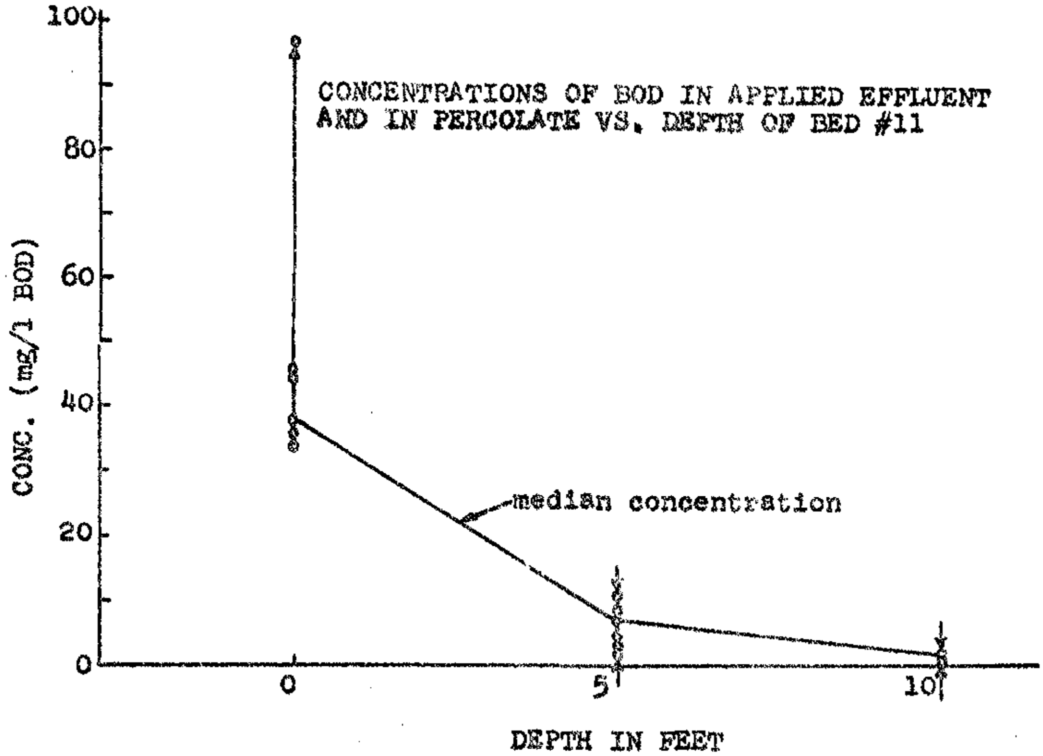

CONCENTRATIONS OF COLIFORMS IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13
CONC. (#/100 ml)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
median concentration
0
5
10
DEPTH IN FEET

Figure 3


CONCENTRATIONS OF BOD IN APPLIED EFFLUENT
AND IN PERCOLATE VS. DEPTH OF BED #11
CONC. (mg/1 BOD)
100
80
60
40
20
0
median concentration
0
5
10
DEPTH IN FEET

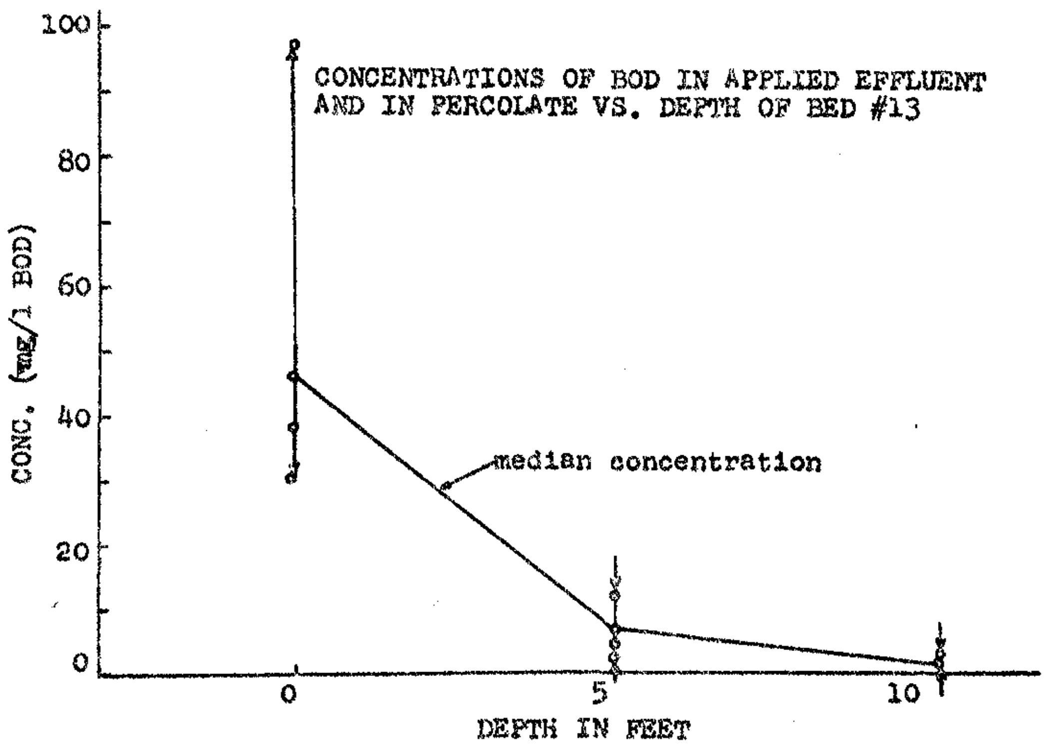
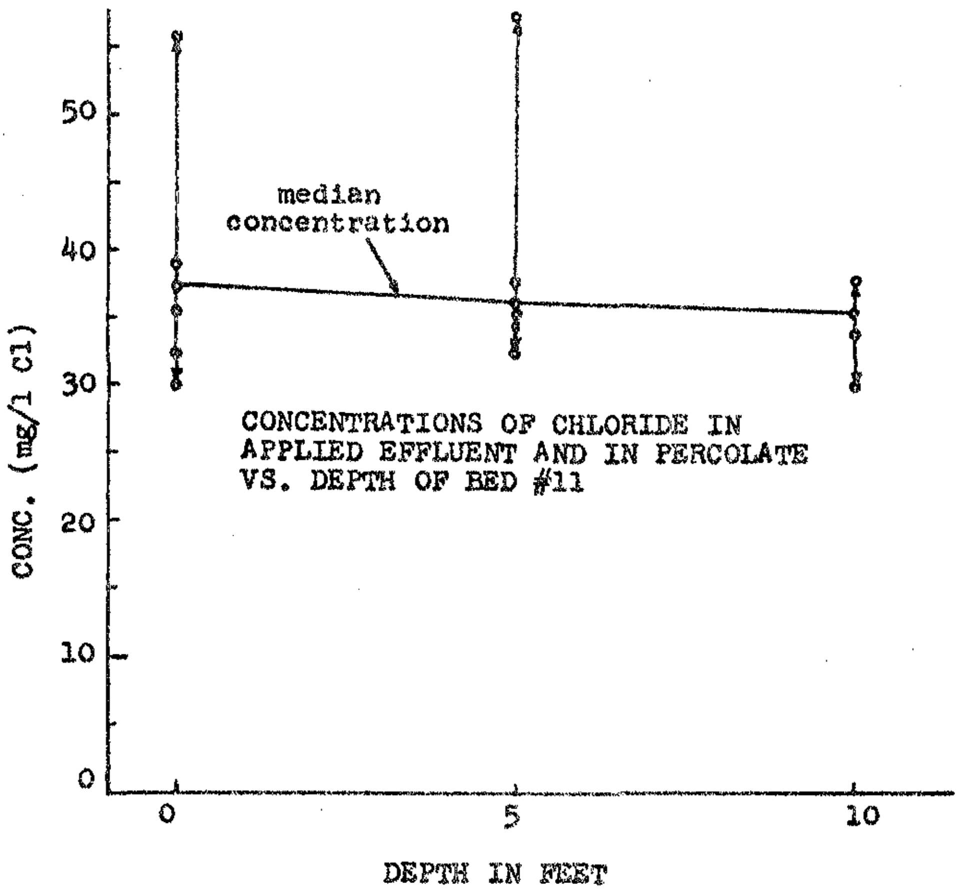
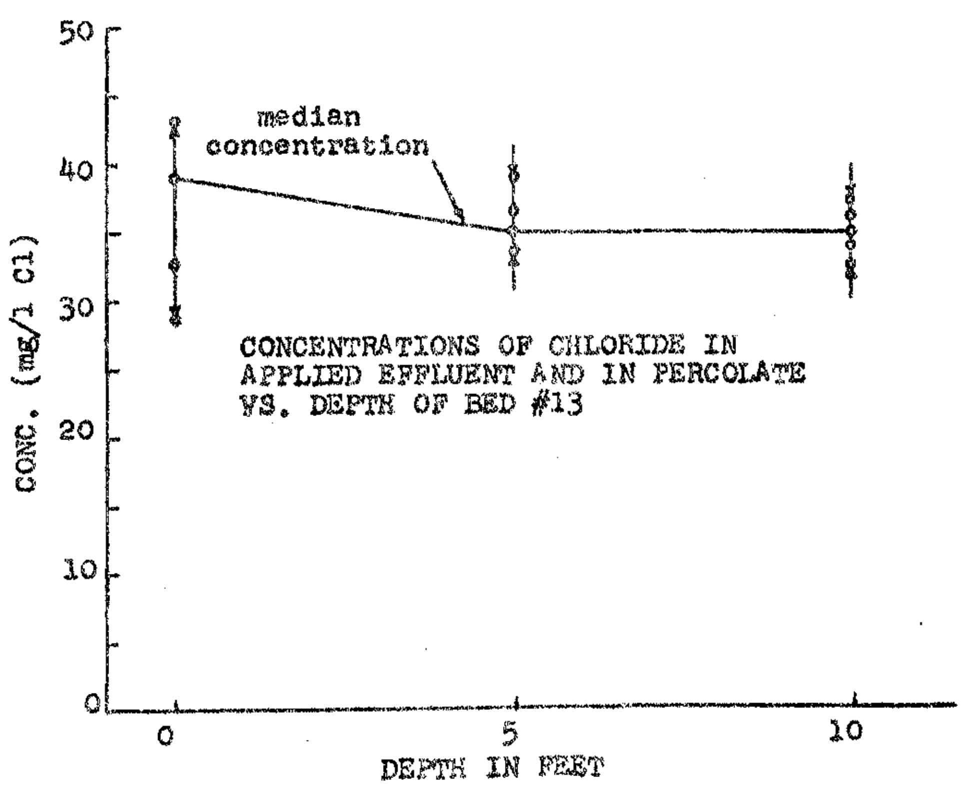

CONCENTRATIONS OF BOD IN APPLIED EFFLUENT
AND IN PERCOLATE VS. DEPTH OF BED #13
CONC. (mg/1 BOD)
100
80
60
40
20
0
median concentration
0
5
10
DEPTH IN FEET

Figure 4

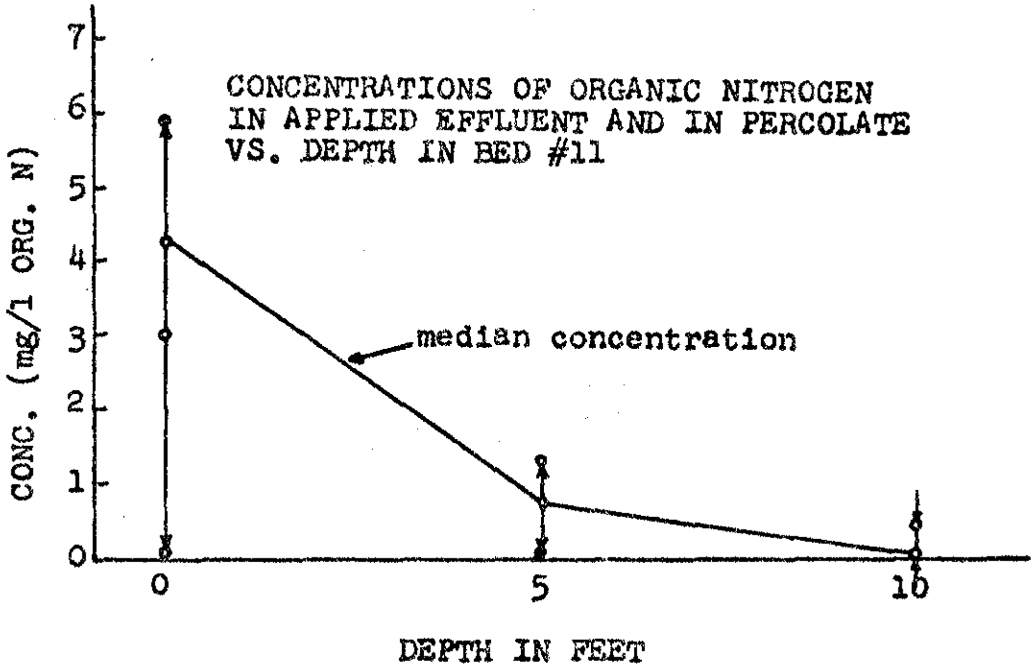


median
concentration
CONCENTRATIONS OF CHLORIDE IN
APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #11
CONC. (mg/l Cl)
0
10
20
30
40
50
0
5
10
DEPTH IN FEET

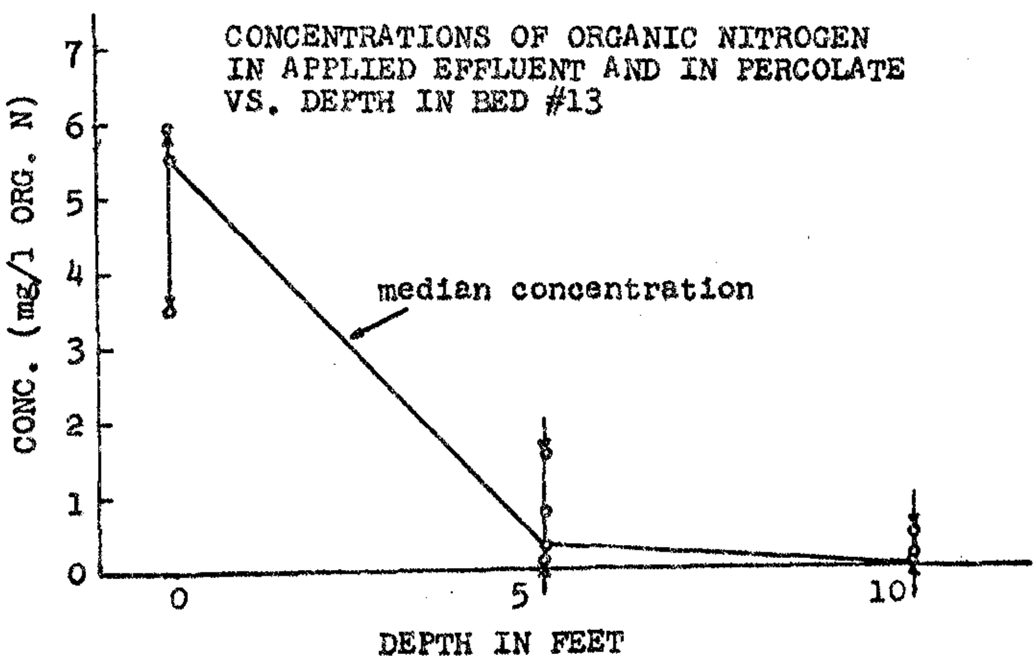


median
concentration
CONCENTRATIONS OF CHLORIDE IN
APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #13
CONC. (mg/l Cl)
0
10
20
30
40
50
0
5
10
DEPTH IN FEET

Figure 5



CONCENTRATIONS OF ORGANIC NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #11
median concentration
CONC. (mg/l ORG. N)
0
1
2
3
4
5
6
7
0
5
10
DEPTH IN FEET

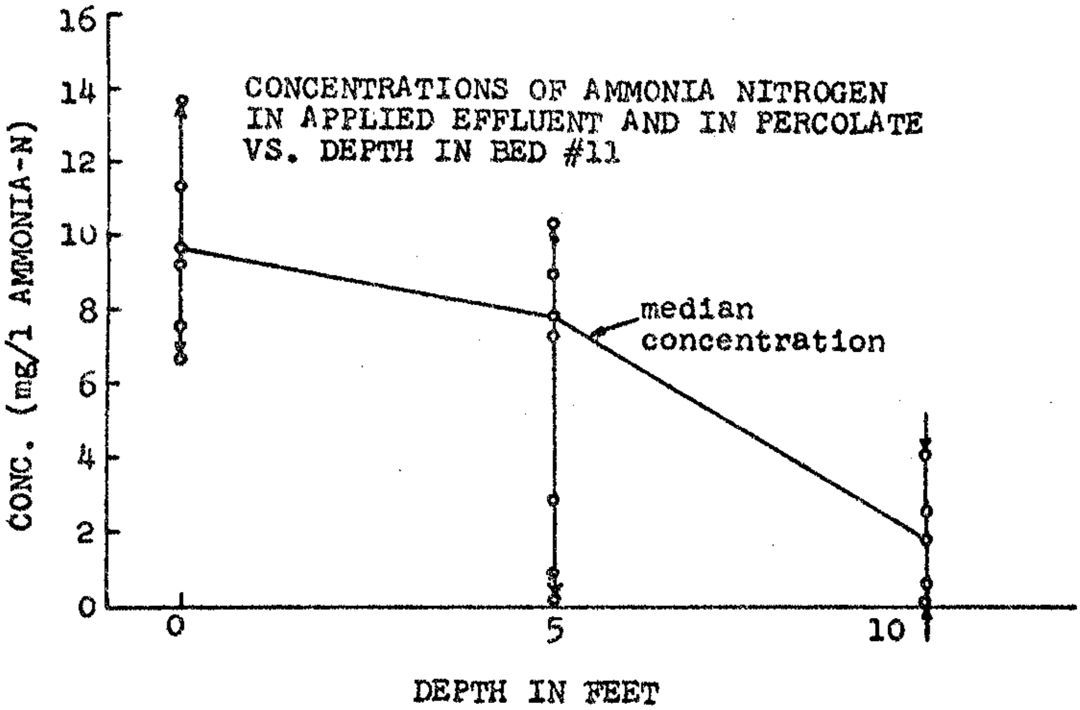


CONCENTRATIONS OF ORGANIC NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #13
median concentration
CONC. (mg/l ORG. N)
0
1
2
3
4
5
6
7
0
5
10
DEPTH IN FEET

all of the organic nitrogen was removed within the first 10 ft. of the filter bed. The ammonia nitrogen, on the other hand, as shown in Figure 6, was removed only to an extent of about 80% in the first 10 ft. of the sand beds. Since the removal appears to be nearly linear, it may be estimated that nearly complete ammonia removal could be accomplished with an additional 5 ft. of depth of sand or 15 ft. total. Whereas the results of the nitrate determination varied considerably (Figure 7), the concentration did appear to increase slightly with depth. There was no quantitative balance between the reduction of ammonia and organic nitrogen and the increase in nitrate nitrogen. However, it may be concluded that there is an overall oxidation process involved in converting organic and ammonia nitrogen to nitrate.

The phosphorus analyses were the only ones which showed a significant difference between beds 11 and 13. The polyphosphate concentration in the two beds is summarized in Figure 8. There seems to be some significant reduction in polyphosphates in the first 5 ft. of bed 11 but little further reduction between 5 and 10 ft. in bed 11. Bed 13 showed no significant change in polyphosphate concentration. The orthophosphate, on the other hand (Figure 9), showed no reduction with depth in bed 11 and even a slight increase at the 5 ft. depth. In bed 13, which was little used, there was a significant reduction in the first 5 ft. but no further reduction in the second 5 ft. of bed depth. The total phosphate results are similar to those of the orthophosphate, as shown in Figure 10, It was concluded that, for the depths studied, bed 11, which had received considerable use,

Figure 6


CONCENTRATIONS OF AMMONIA NITROGEN
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #11
median
concentration
CONC. (mg/1 AMMONIA-N)
DEPTH IN FEET
0
2
4
6
8
10
12
14
16
0
5
10

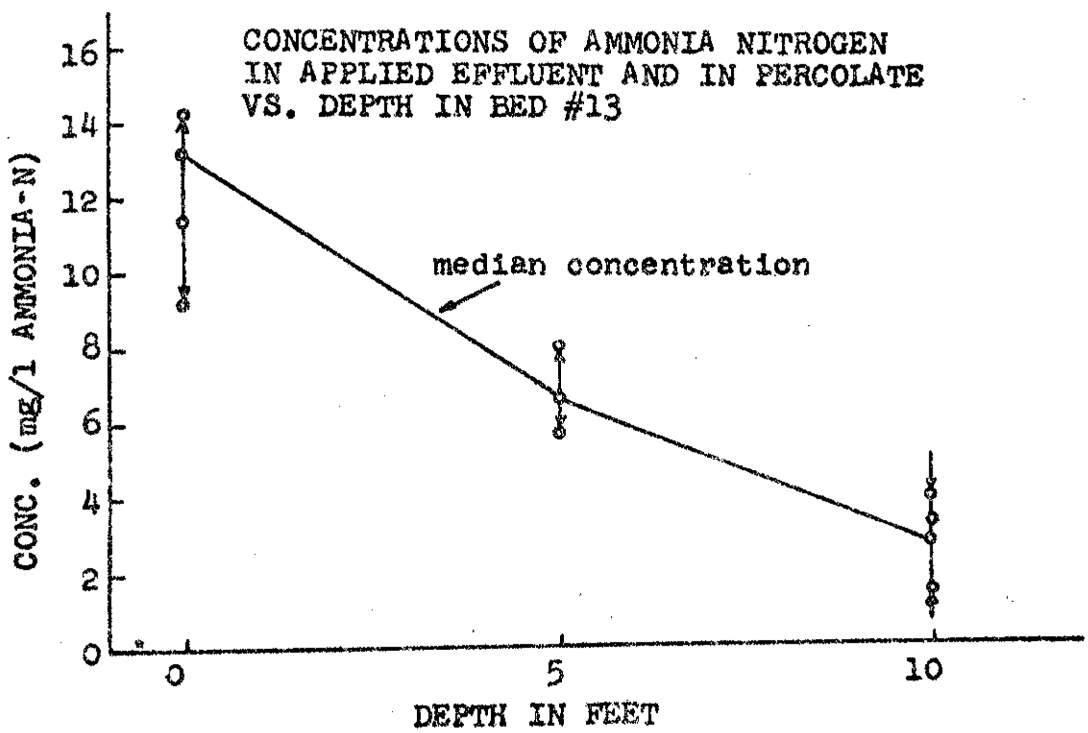
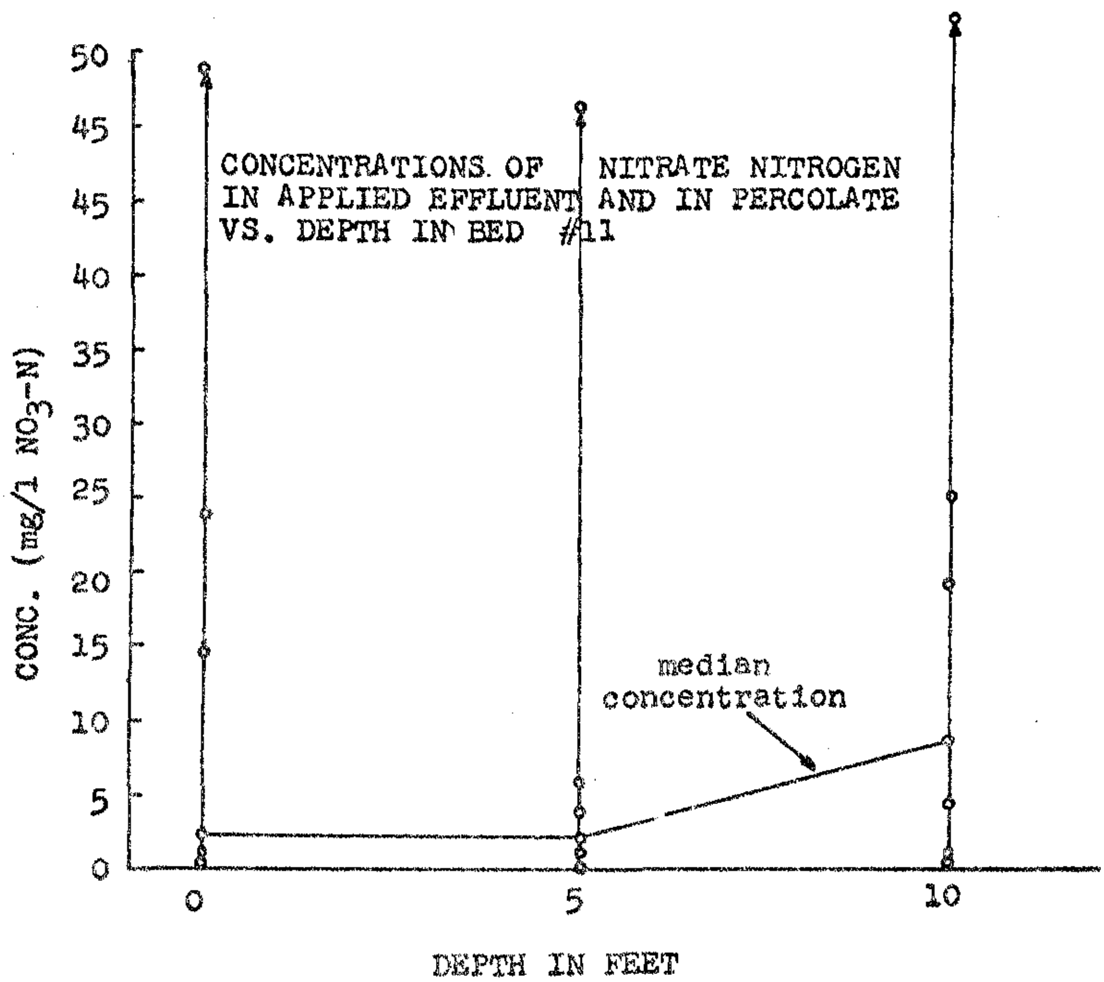
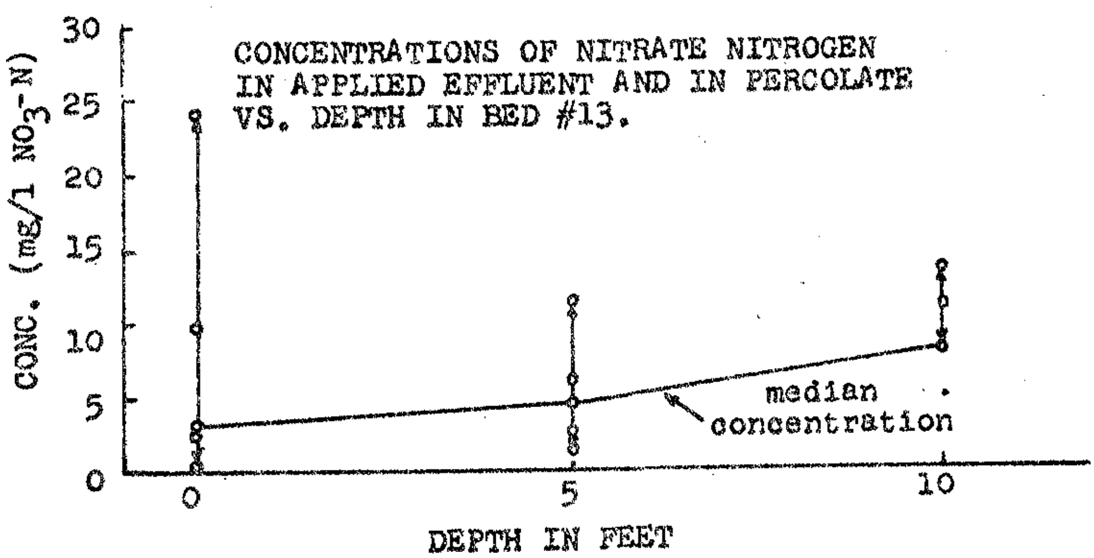

CONCENTRATIONS OF AMMONIA NITROGEN
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #13
median concentration
CONC. (mg/1 AMMONIA-N)
DEPTH IN FEET
0
2
4
6
8
10
12
14
16
0
5
10

Figure 7

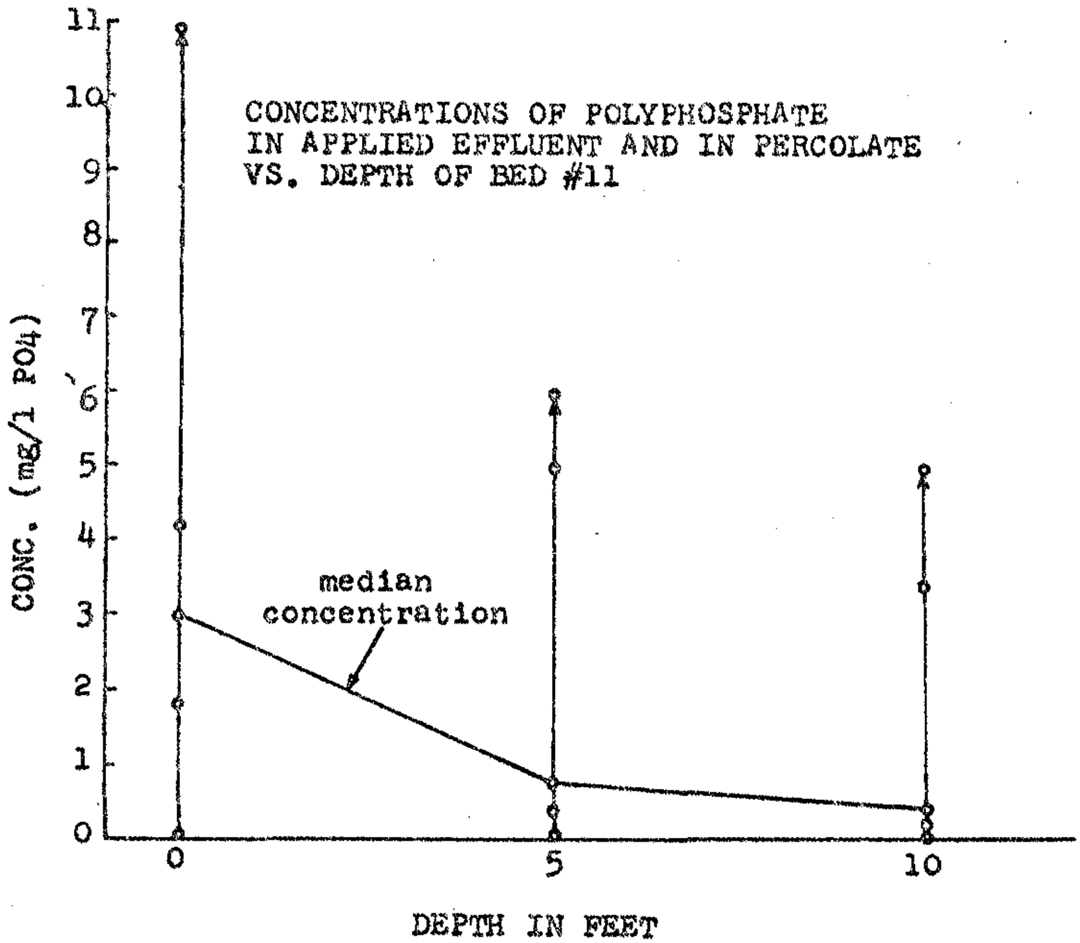


CONCENTRATIONS OF NITRATE NITROGEN
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #11
median
concentration
CONC. (mg/1 NO3-N)
50
45
45
40
35
30
25
20
15
10
5
0
0
5
10
DEPTH IN FEET



CONCENTRATIONS OF NITRATE NITROGEN
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #13.
median
concentration
CONC. (mg/1 NO3-N)
30
25
20
15
10
5
0
0
5
10
DEPTH IN FEET

Figure 8


CONCENTRATIONS OF POLYPHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #11
median
concentration
CONC. (mg/1 PO4)
0
1
2
3
4
5
6
7
8
9
10
11
0
5
10
DEPTH IN FEET

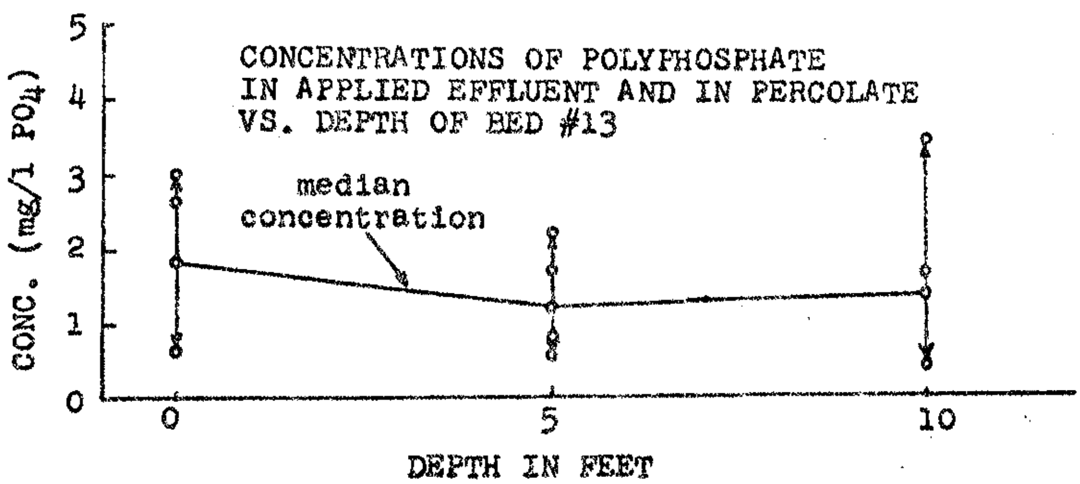
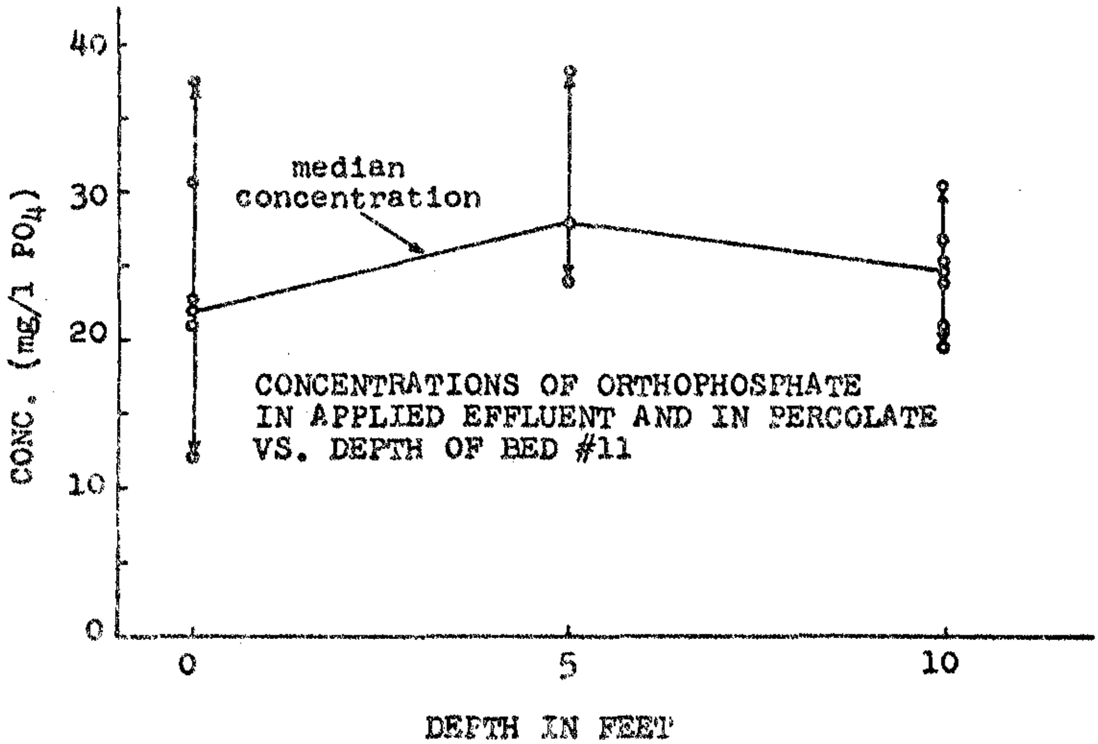

CONCENTRATIONS OF POLYPHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #13
median
concentration
CONC. (mg/1 PO4)
0
1
2
3
4
5
0
5
10
DEPTH IN FEET

Figure 9


40
30
20
10
0
CONC. (mg/1 PO_4)
median
concentration
CONCENTRATIONS OF ORTHOPHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #11
0
5
10
DEPTH IN FEET

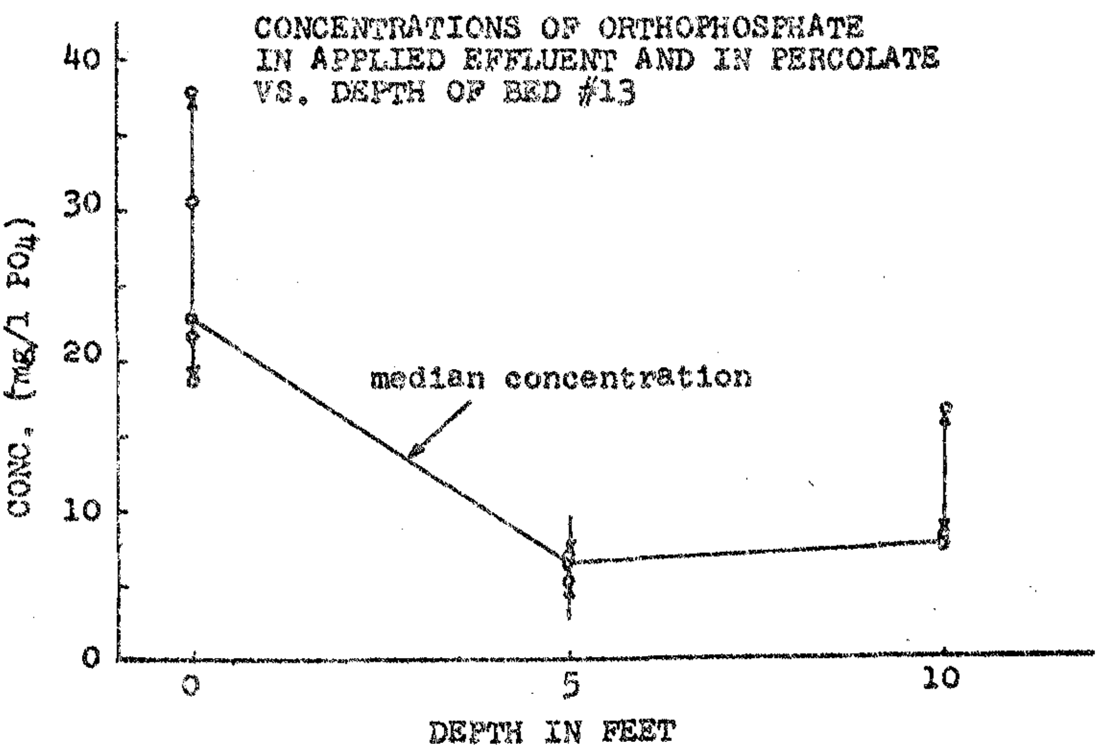
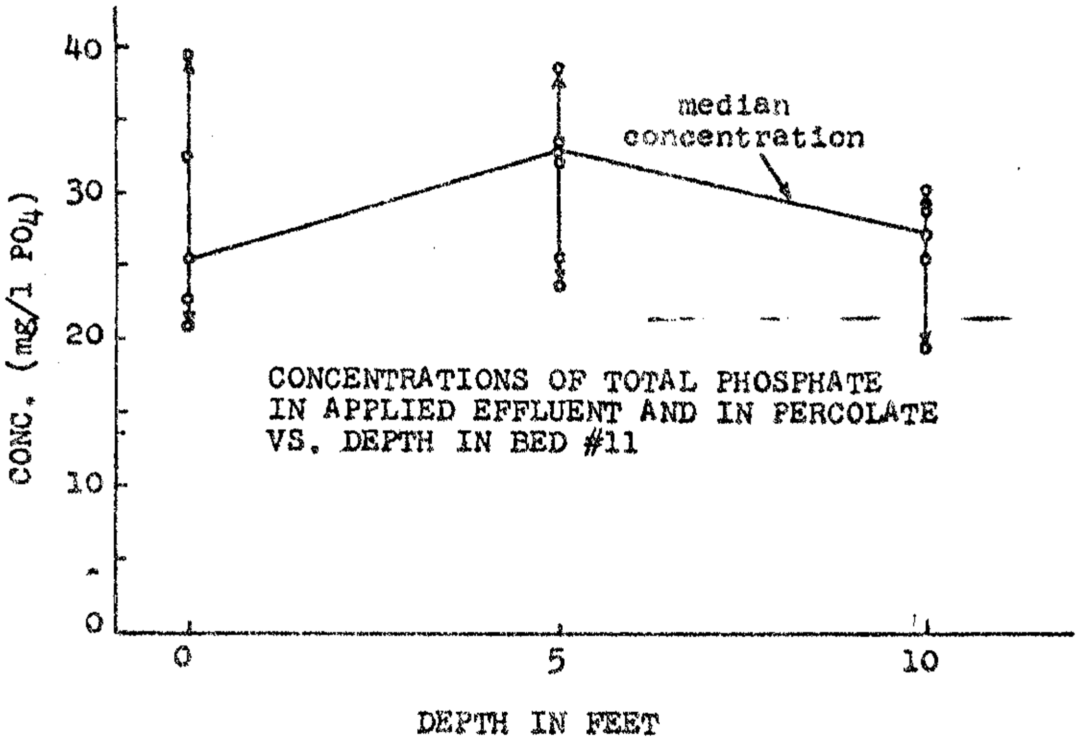
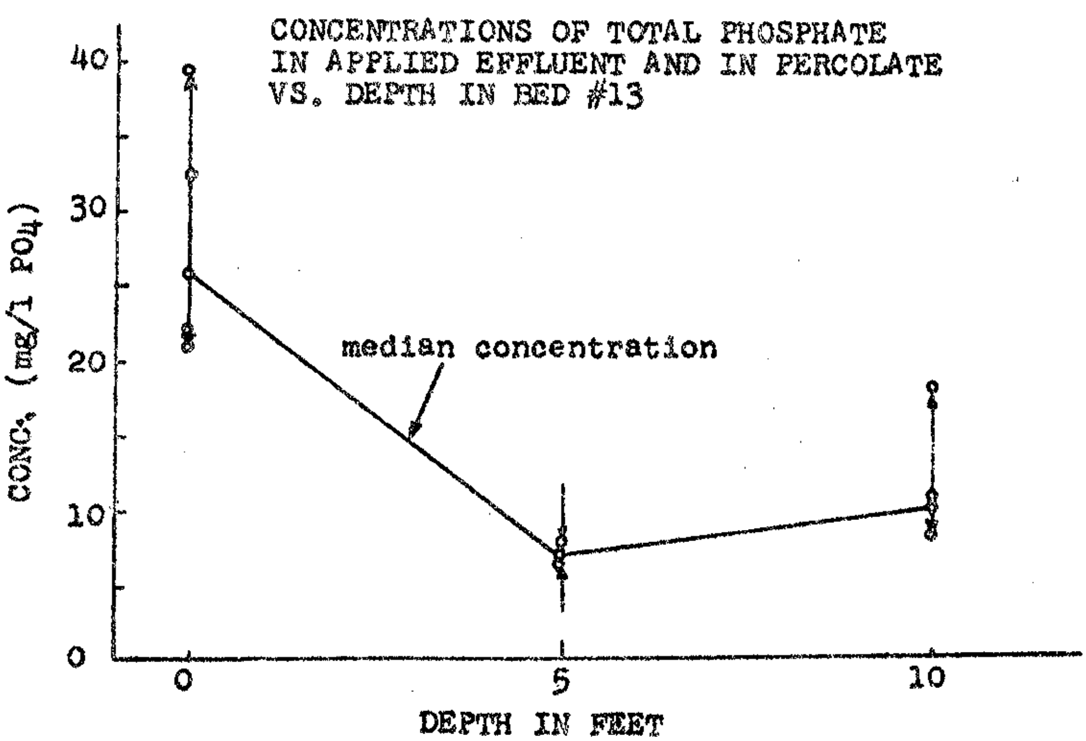

CONCENTRATIONS OF ORTHOPHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH OF BED #13
40
30
20
10
0
CONC. (mg/1 PO_4)
median concentration
0
5
10
DEPTH IN FEET

Figure 10



40
30
20
10
0
CONC. (mg/1 PO_4)
median
concentration
CONCENTRATIONS OF TOTAL PHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #11
0
5
10
DEPTH IN FEET



CONCENTRATIONS OF TOTAL PHOSPHATE
IN APPLIED EFFLUENT AND IN PERCOLATE
VS. DEPTH IN BED #13
40
30
20
10
0
CONC. (mg/1 PO_4)
median concentration
0
5
10
DEPTH IN FEET

had reached a saturation point for adsorption of phosphorus, whereas bed 13, which had received little use, still had an active phosphorus adsorption capacity.

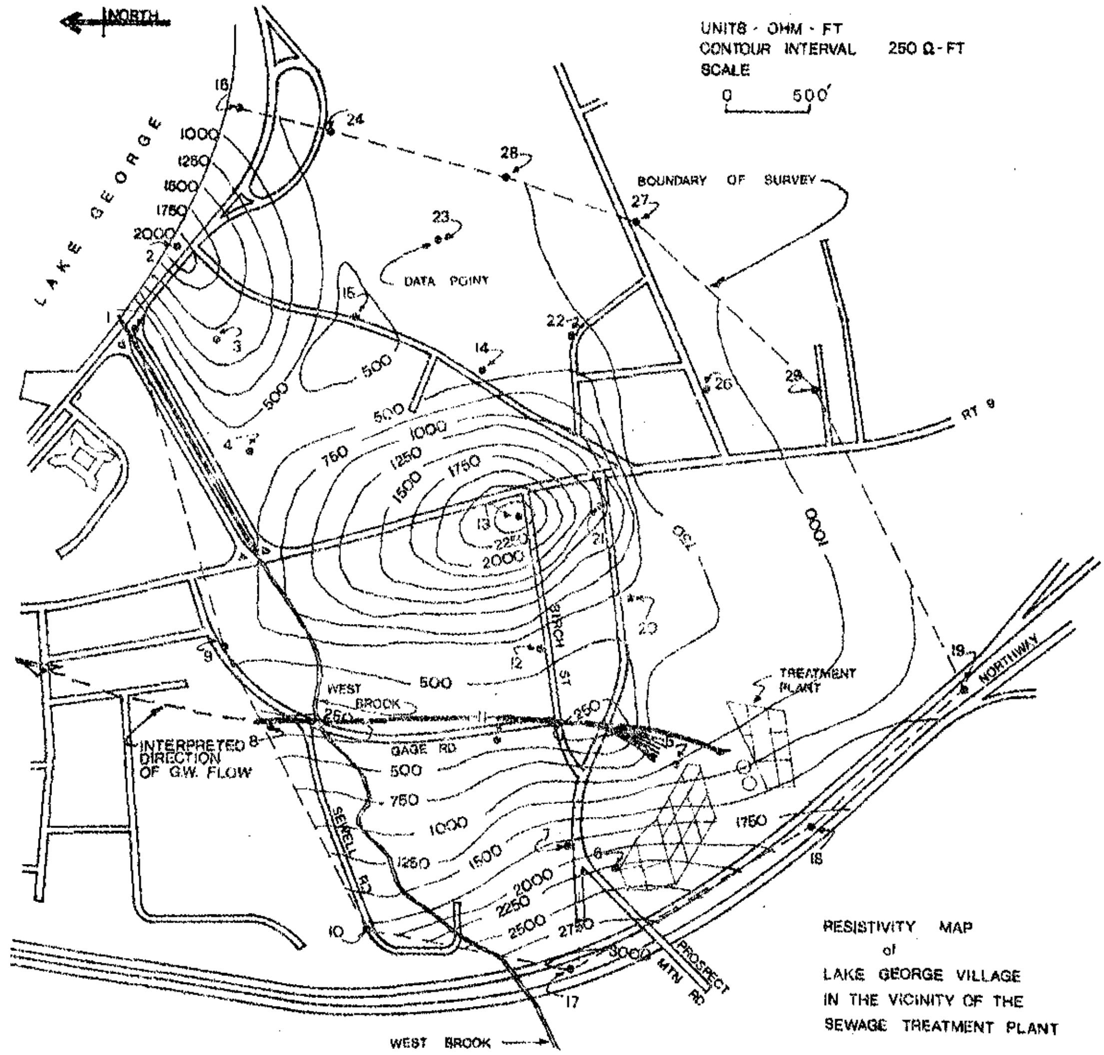
The original plan for the previously described studies was to install a series of wells in and around the treatment plant in order to determine the direction of flow of the treated effluent which was applied to the percolation bed. However, it was realized that this would involve a large number of wells and was deemed infeasible at that time. In another attempt to determine the flow of the effluent through the ground, resistivity studies were performed in the area around the sewage treatment plant.[3] The results showed (Figure 11) that the path of least resistance flowed first in a slightly eastward direction and then turned northward along Gage Road to West Brook. The resistivity studies had to be discontinued beyond this point due to interferences caused by the underground piping of houses located across West Brook.

Gage Road crosses West Brook approximately 2000 ft. (600 m) north of the lower sand beds of the treatment plant. The lower beds, 13 and 14, are 472 ft. above mean sea level (amsl), whereas West Brook is at 339 ft. amsl where it passes under Gage Road. The level of the surface of Lake George is 319 ft. $\pm$ 1 ft amsl. There is a steep hill on Gage Road in the immediate vicinity of West Brook. The hill is approximately 60 ft. in height above the surface of West Brook.

PRESENT STUDIES

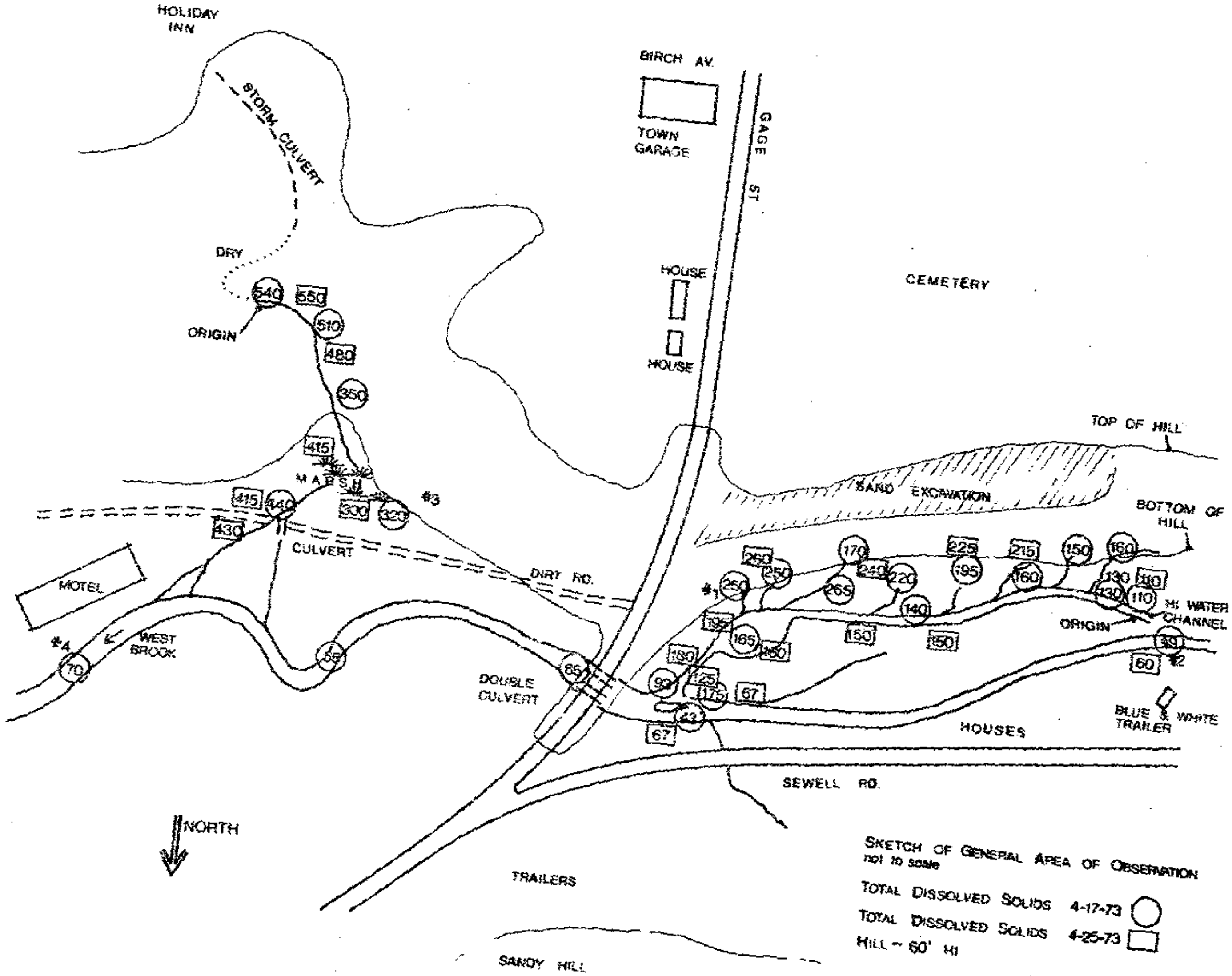
On April 17 and 25, 1973 walking surveys were made of the

Figure 11


NORTH
UNITS - OHM - FT
CONTOUR INTERVAL 250 Ω - FT
SCALE
0 500'
LAKE GEORGE
BOUNDARY OF SURVEY
DATA POINT
RT 9
BIRCH ST
WEST BROOK
GAGE RD
INTERPRETED DIRECTION OF G.W. FLOW
SEWELL ST
TREATMENT PLANT
NORTHWAY
PROSPECT MTN RD
WEST BROOK
RESISTIVITY MAP
of
LAKE GEORGE VILLAGE
IN THE VICINITY OF THE
SEWAGE TREATMENT PLANT

southern banks of West Brook at the base of the steep hill as shown in Figure 12. West Brook flows in an easterly direction at this point into Lake George approximately 1/2 mile farther downstream. Immediately west of Gage Road, there is a small tributary which flows into West Brook. The flow from this small stream was estimated to be in the order of one-half million gallons per day. Observation was made of the source of this tributary and it was found that all of the water comes out of the ground at the base of the aforementioned hill on the south side of West Brook up to a level of approximately 5 ft. above the level of West Brook. During these surveys, the conductivity of the water emanating from the ground at the base of the hill was considerably higher than that in West Brook. Also, the conductivity in West Brook was measurably increased from a point above the influent of this tributary to a point below it. Proceeding eastward from Gage Road, slightly farther downstream, additional seepage was noted coming from the base of the hill and flowing into West Brook. A small intermittent stream was followed part way up a small valley which proceeds up to the rear of a motel. The water in this ditch was extremely high in dissolved solids. It must be pointed out that there is a highway department garage located on the top of the hill just above this intermittent stream. It was these findings which prompted the more detailed studies which are contained in this report.

In response to the recommendation of the Village engineer, Rist-Frost Associates, funds were provided by the Village of Lake George and with the aid of manpower from the New York State De-



HOLIDAY INN
STORM CULVERT
DRY
ORIGIN
540
650
510
480
350
415
MARSH
415
440
430
300
320
#3
CULVERT
DIRT RD.
MOTEL
#4
70
WEST BROOK
55
65
DOUBLE CULVERT
BIRCH AV.
TOWN GARAGE
GAGE ST.
HOUSE
HOUSE
CEMETERY
TOP OF HILL
SAND EXCAVATION
BOTTOM OF HILL
#1
250
250
260
195
165
160
130
93
125
175
43
67
67
170
240
265
220
140
150
225
195
150
215
160
150
160
130
110
130
110
HI WATER CHANNEL
ORIGIN
30
60
#2
BLUE & WHITE TRAILER
HOUSES
SEWELL RD.
NORTH
TRAILERS
SANDY HILL
SKETCH OF GENERAL AREA OF OBSERVATION
not to scale
TOTAL DISSOLVED SOLIDS 4-17-73
TOTAL DISSOLVED SOLIDS 4-25-73
HILL ~ 60' HI

Figure 12

partment of Environmental Conservation, wells were located in and around the area as shown in Figure 13. Well 1 is in approximately the center of the lower seepage bed No. 4. Well 2 is located approximately halfway down the steep portion of the slope just south of West Brook and west of Gage Road. Well 3 actually consists of three wells, A, B, and C and just recently Well 3D has been installed. The three wells secure water from three different depths: Well 3A being very near to the surface, 3B being approximately 11 ft. deep and Well 3C being 21 ft. deep. Wells 3 are located adjacent to where there is a significant seepage of water from the base of the hill close to West Brook. Well 4, intended to be installed upstream from all potential sources of groundwater contamination, north of West Brook, near Sewell Road and close to the Northway, was never installed due to encountering rocks before water level was reached. Well 5 is located near the center of upper sand bed No. 3. Well 6 is located just south of Prospect Mountain Road, slightly west of the entrance road to the sewage treatment plant. There are no wells numbered 7, 8, and 9. Well 10 is located in the field slightly east of the sewage treatment plant and was intended to represent uncontaminated groundwater. The samples designated West Brook upstream were taken where Sewell Road crosses West Brook and the samples designated West Brook downstream were taken sufficiently far downstream from Wells 3 in order to insure adequate mixing of the drainage which enters West Brook near Wells 3. Specific data for the wells are summarized in Table 1 and Figure 14. Approximate surface, groundwater and bedrock elevations of several

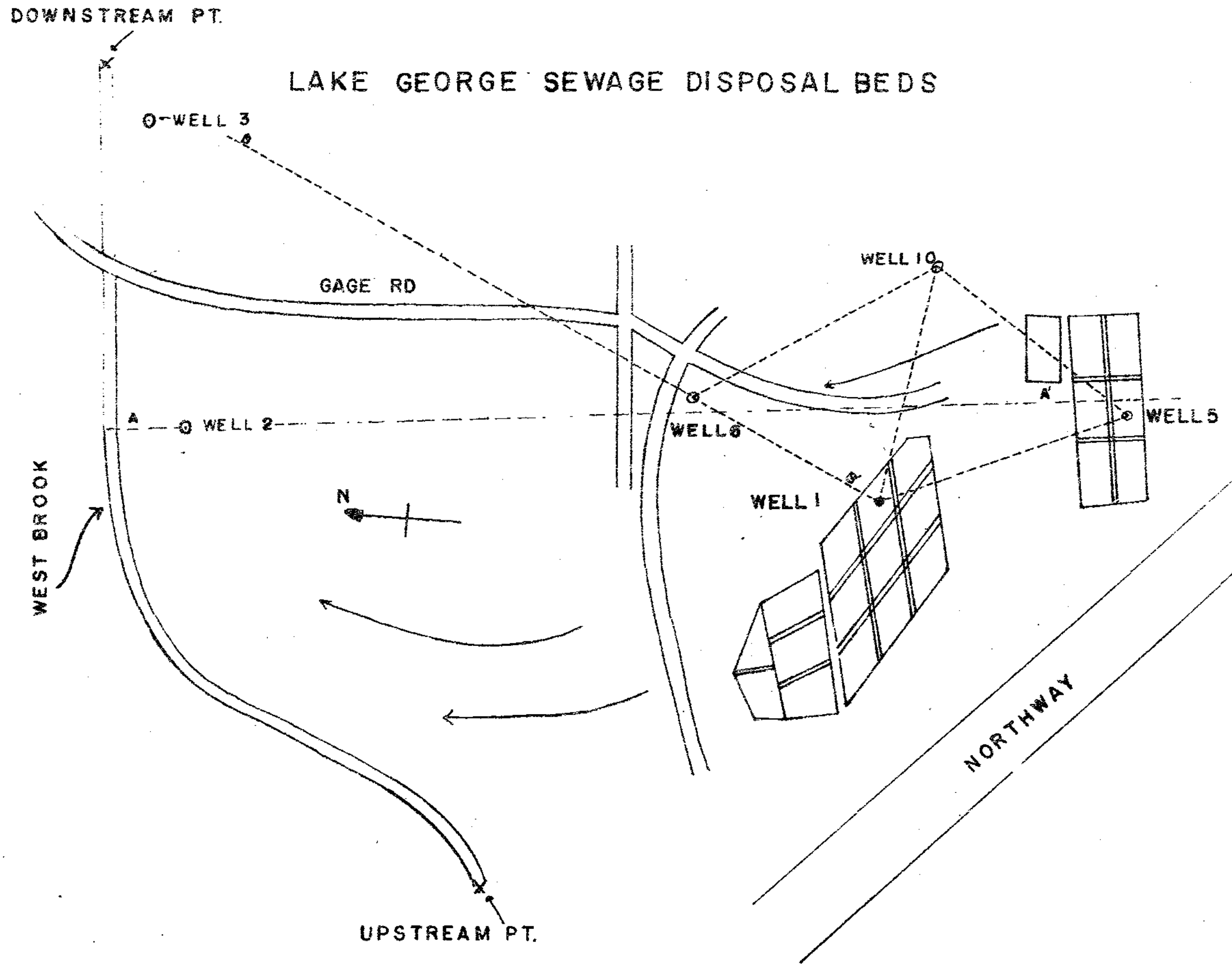

DOWNSTREAM PT.
LAKE GEORGE SEWAGE DISPOSAL BEDS
O-WELL 3
GAGE RD
WELL 10
WELL 6
A
WELL 2
A'
WELL 5
WELL 1
N
WEST BROOK
NORTHWAY
UPSTREAM PT.

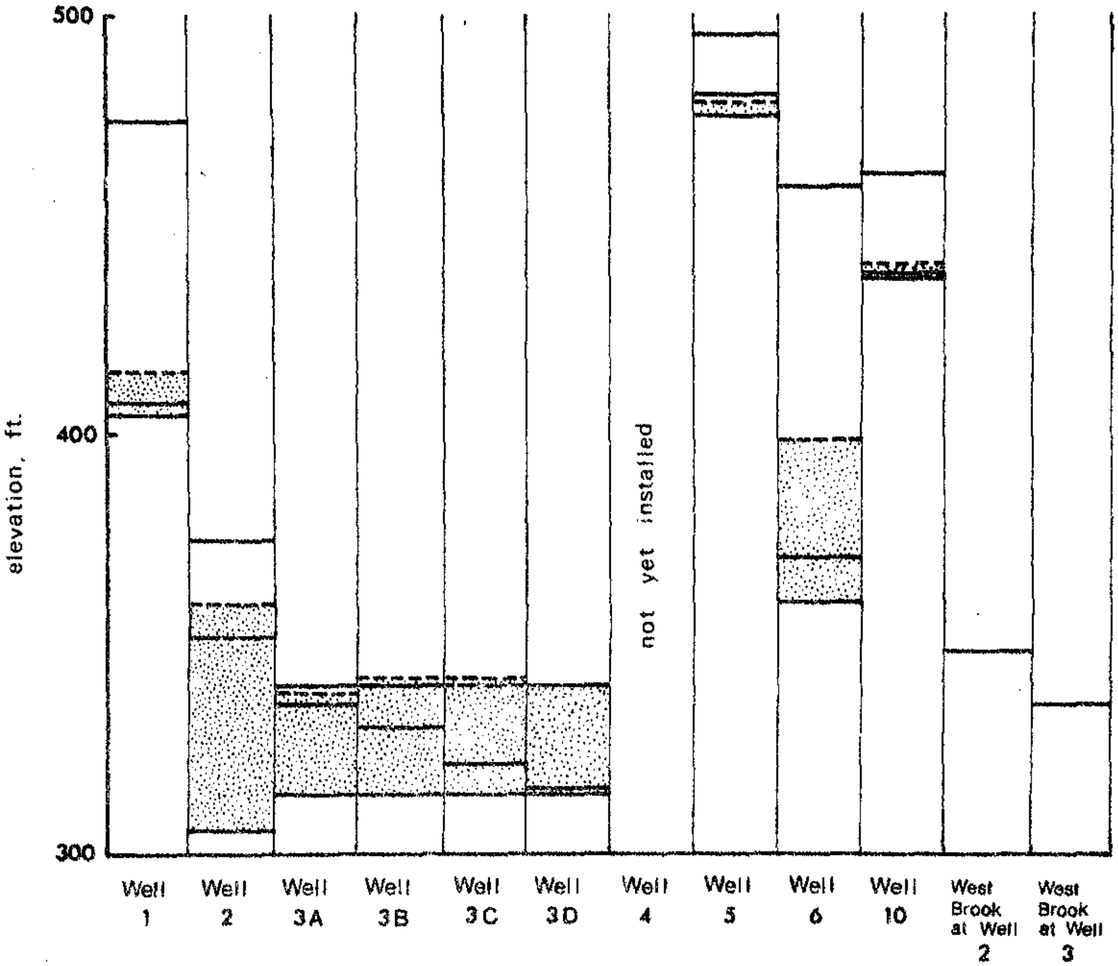
Figure 13

TABLE 1 WELL DATA

	Surface Elevation	Ground Water Elevation	Bottom of Point	Bedrock Elevation
Well 1	475.0	415.66	407.80	405.0
Well 2	375.40	359.22	352.13	306
Well 3A	339.90	339.74	336.44	314
Well 3B	339.90	340.01	329.06	314
Well 3C	339.90	340.08	321.23	314
Well 3D	339.90	340	314	314
Well 4	-	-	-	-
Well 5	495.37	480.98	379.40	477.40
Well 6	458.7	397.6	370.68	360.0
Well 10	462.73	441.7	438.91	438.91
West Brook at Well 2	348.0	-	-	-
West Brook at Well 2	334.9	-	-	-

Figure 14

WELL DATA



Upper solid line is ground surface level

Upper broken line is ground water level

Next solid line is bottom of well point

Bottom solid line is bedrock level

Shaded area represents ground water saturation sections (see Figure 13) are shown in the Appendix (Figures A1 - A4).

RESULTS

Samples were secured from the various locations in the area during the spring and summer of 1973. These results are summarized in Table 2. In addition to the data shown in Table 2, measurements were made of the depth to water table in each one of the wells. Also, studies of the virus content were made in one set of samples, as will be discussed later. The results of Table 2 may be separated into three categories: (a) the temperature and DO indicate the condition of the water in the ground, (b) the dissolved solids, pH, alkalinity, and chloride may be used to indicate the relationship to the sewage effluent discharged to the ground, and (c) the phosphorus and nitrogen indicate the nutrient transport to that point and/or dilution by the available groundwater.

(a) Groundwater condition.

In general, the temperature of the groundwater decreased with depth and distance from the sand beds. Well 1 had a lower temperature when the bed was dry. This indicates the direct effect of the sewage effluent on the bed. Well 3 decreased in temperature with depth. This indicates the effect of close contact of the water nearer the surface with the warm air during the time of sampling and/or the possibility that the warmer sewage effluent remained nearer the surface of the groundwater. The one anomaly is the high temperature in well 10 on

TABLE 2 SUMMARY OF RESULTS OF WATER TESTING

Date	Location	Time	Temp. °C	D.O. mg/l	Diss. Solids mg/l	pH	Alk. mg/l	Cl mg/l	Tot. Sol. P µg/l	Tot. P µg/l	NO_3-N mg/l	NH_3-N mg/l	Total Kjeldahl N mg/l
4/17/73	West Br.Upstr.				49				11	18.5	0.132	0.0325	0.063
	West Br.Dnstr.				70				7.2	11.4	0.525	0.0652	0.191
	Seepage Ab. Gage Rd.				250				92	110	6.250	0.0299	Interfer.
	Seepage Below Gage Rd.				320				16.6	142	8.210	0.0376	1.030
4/25/73	West Br.Upstr.				60	7.7		8					
	W.B. Bel.Culvert				-	7.8		10					
	West Br.Downstr.				-	7.7		13					
	Seep.Ab.Gage Rd.				195	7.9		26					
	Pond Ab.Gage Rd.				160	7.3		25					
	Seep.St. @ W.B.				125	7.2		22					
	Pool Bel.Gage Rd.				300	7.2		-					
	Seep.Bel.Hol.Inn				550	7.3		153					

TABLE 2 (CONT'D) SUMMARY OF RESULTS OF WATER TESTING

Date	Location	Time	Temp. °C	D.O. mg/l	Diss. Solids mg/l	pH	Alk. mg/l	Cl mg/l	Tot. Sol. P µg/l	NO_3-N mg/l	Total Kjeldahl N mg/l
6/19/73	Well 1 (D)	1100	11.8	3.4	160	6.6	87.3	40	237	8.600	0.0207
	Well 2	1215	10.1	12.7	190	7.8	147.4	28	25.2		0.133
	Well 3A	1230	16.4	5.0	350	7.5	330.8	43	42.1	0.065	0.033
	Well 3B	1230	15.1	4.6	360	7.3	223	66	32.1		Tr.
	Well 3C	1230	14.3	3.6	330	7.0	173	53	29.9		Tr.
6/26/73	STP Inf.	1150			250	7.6		46	4,540		
Well 1 (F)	STP Eff.	1155			190	6.7		31	2,680		
Well 5 (D)	Well 2	1215			190	7.6		26	24.1	2.717	0.0245
	Well 3A	1230			390	7.1		–	39.9		0.0384
	Well 3B	1235			320	7.1		69	30.8	10.319	0.0474
	Well 3C	1240			290	6.9		59	27.4	11.960	0.0371
7/6/73	STP Inf.	1045	20	–	240	7.02	161	35	4,010		
Well 1 (F)	STP Eff.	1215	20	2.6	200	6.54	106.5	33	3,070		
Well 5 (D)	Well 2	1115	11.0	10.8	165	7.62	139	28	27.9	2.786	
	Well 3A	1135	19.5	4.5	350	7.26	352	41	42.0	0.194	
	Well 3B	1140	15.2	2.6	320	7.00	192	53	19.5	9.555	0.106
	Well 3C	1150	14.5	3.0	285	7.00	173	53	20.3	11.194	
	West Br. Upstr.	1205	13.5	11.0	52	7.46	33.3	9	117.6	0.207	0.0641
	West Br. Dnstr.	1155	13.5	10.6	86	7.45	56.7	15	70.4	1.846	0.103

TABLE 2 (CONT'D) SUMMARY OF RESULTS OF WATER TESTING

Date	Location	Time	Temp. °C	D.O. mg/l	Diss. Solids mg/l	pH	Alk. mg/l	Cl mg/l	Tot. Sol. P µg/l	NO_3- N mg/l	Total Kjeldahl N mg/l
7/25/73	STP Inf.	1050	22.5	-	250	7.30	186	35	5,240		8.200
	STP Eff.	1120	22.9	2.4	212	6.63	150	32	3,275		1.580
	Well 1 (F)	1145	17.0	5.6	210	6.66	88	39	377	1.196	1.713
	Well 2	1435	14.4	9.4	180	7.80	128	30	28.2	2.340	0.1438
	Well 3A	1525	20.4	3.2	310	7.22	276	-	37.2	0.133	0.9755
	Well 3B	1525	19.2	4.9	330	7.43	175	71	26.8	9.139	0.393
	Well 3C	1530	15.0	2.3	300	7.05	161	57	25.4	10.829	0.0869
	Well 5Cu(D)	1055	20.0	5.8	82	6.63	31	8	686	21.320	0.712
	Well 6	1310	13.6	2.8	210	8.88	178	35	16.1	4.592	3.948
	Well 10	1235	23.4	3.4	43	6.42	42	~10	41.4	0.358	1.150
	West Br. Upstr.	1555	14.5	9.6	75	7.63	42.7	14	18.3	0.153	
	West Br. Downstr.	1535	14.1	9.6	115	7.71	69.1	21	19.7	3.218	
8/16/73	STP Inf.	1410	24.9	2.3	232	6.88	142	38	4,093		17.819
	STP Eff.	1415	24.5	1.3	240	6.53	150	35	4,310		12.722
	Well 1 (D)	1200	15.4	6.3	230	6.61	96	42	597	14.378	0.102
	Well 2	1035	12.0	9.8	185	7.65	122	33	17.9	2.795	0.0245
	Well 3A	1125	19.3	4.3	309	7.19	290	41	29.9	0.478	0.478
	Well 3B	1130	18.0	5.4	360	6.99	162	112	16.3	9.730	Tr.
	Well 3C	1135	14.3	2.7	300	6.90	159	67	18.0	10.404	Tr.
	Well 5Cu(F)	1345	23.6	1.7	138	6.08	75.7	36		2.516	0.533

TABLE 2 (CONT'D) SUMMARY OF RESULTS OF WATER TESTING

Date	Location	Time	Temp. °C	D.O. mg/l	Diss. Solids mg/l	pH	Alk. mg/l	Cl mg/l	Tot. Sol. P µg/l	NO_3- N mg/l	Total Kjeldahl N mg/l
8/16/73 (Cont'd)	Well 6	1110	12.1	6.6	162	8.73	106	35	13.0	3.627	3.646
	Well 10	1225	14.0	6.0	99	6.50	44.8	21	8.4	3.084	0.0379
	West Br. Upstr.	1050	11.0	10.9	70	7.71	44.8	17	12.5	0.439	0.0695
	West Br. Dnstr.	1125	12.7	10.2	120	7.54	83.5	29	14.7	1.976	0.0283
	Across Sewell Rd.	1325	12.0	8.9	90	7.29	61.7	23	15.2	0.237	0.0535

NOTE: For Wells 1 & 5 (in sand beds): F = sand bed flooded

D = sand bed dry (not flooded)

July 25 which may be an error in recording the data. It may be noted that West Brook is a cold water stream, never exceeding 15°C during the period of this study.

The presence of dissolved oxygen (DO) is considered desirable for the efficient treatment of sewage effluent discharged into the ground. In general, the DO increased with distance from the sand beds. Well 2 always had a high DO. Well 3C always had a lower DO than 3A. West Brook was nearly always saturated with DO at the upstream location, but on several days a measurable decrease in DO was noted at the downstream location. This is attributed to the mixture of the emergent lower DO groundwater with the water of West Brook.

(b) Similarities to treated sewage effluent.

The dissolved solids are high in the water seeping out of the ground at the base of the sand hill. This seepage enters West Brook at two major locations, one immediately upstream from the culvert under Gage Road, and the other just slightly downstream from the location of Wells 3. The tributary above Gage Road is estimated to be in the general order of 0.5 million gallons per day. The lower stream, which is higher in dissolved solids, has a flow in the order of 100,000 gallons per day. West Brook, at this time of year as measured at the gaging station downstream from all of the locations indicated in the map in Figure 13, was in the order of 5 mgd. Thus, it may be seen that in the order of 10 - 15% of the flow of West Brook is added from the two seepage streams in the area of Gage Road. This inflow is reflected in the dissolved solids content of West

Brook. The dissolved solids varied between 49 and 75 mg/l at the upstream location, and from 70 to 120 mg/l at the downstream location. In all cases there was an increase which varied between 20 and 50 mg/l. Timewise, the dissolved solids in West Brook increased from April through August. The increase from upstream to downstream was greater during August. This is due somewhat to the fact that the stream flow in West Brook was less in August than in April but the amount of seepage seemed to be somewhat greater beginning with the July 25 sampling. Very definitely, the area around Wells 3 was more moist during the July and August sampling than it was during the June and early July sampling. It appears that the seepage flow increases during the time when the population and thus the flow at the sewage treatment plant also increases. In general, the wells in the sand beds (Wells 1 and 5) exhibited noticeable fluctuation in dissolved solids with time and in particular with whether or not the bed was flooded. On the other hand, the wells not located in sand beds had a relatively constant dissolved solids content throughout the period of the sampling.

The high alkalinity found in the wells is reflected in the increase in the alkalinity from the upstream to the downstream sampling locations within West Brook. The lowest alkalinities were found in Well 10 consistently and in Well 5 when it was dry. This latter would indicate that the alkalinity is being flushed away by fresh groundwater after the treated sewage has percolated through upper bed 3. In each case, higher alkalinities were found in Well 3A with noticeably lower values in Well 3B and slightly lower values in Well 3C. This obviously represents the depth profile and indicates that the high alkalinity liquid is coming in near the surface and with a deeper location, there is probably more dilution due to lower alkalinity groundwater.

The chloride concentration of the sewage treatment plant effluent varied between 30 and 35 mg/l during this sampling period. Generally, the chloride concentration may be used as a tracer of groundwater due to the fact that there is little adsorption of chloride by the soil. In general, Wells 6 and 2 had chloride concentrations similar to that of the sewage effluent. Well 5 had a concentration similar to the sewage effluent during the period that the bed was flooded but when the bed was dry, the concentration was only 8 mg/l, probably representing the chloride content of the natural groundwater in the area. Wells 3, however, were consistently higher in chloride content than the sewage effluent discharged onto the sand beds, and the chloride content of Well 3B was consistently higher than that of Wells 3A and 3C. In one instance, the chloride content of the seepage in the small drainage ditch behind the highway department garage reached a maximum of 153 mg/l. Since this is much greater than the sewage effluent, this raises some doubt as to the validity of using chloride as a tracer in this particular case. It must be restated that the town garage is located atop the hill very close to this location. It is also known that the highway department stores salt on their property for use on the roads during the winter. It is probable that this salt has leached into the ground and is thereby invalidating the use of chloride as a tracer for the treated sewage effluent.

(c) Nutrients

Having reasonably well established that the water recovered from Wells 2, 3, and 6 and the seepage as it emanates from the ground near West Brook is the same water which was applied to the sand beds at the sewage treatment plant, the transport of the nutrients nitrogen and phosphorus through the soil may be observed. At Well 6, approximately 500 ft. downstream from the percolation beds, the phosphorus content was less than 1% of that found in the sewage effluent applied to the beds. Similar low results were found in Wells 2 and 3 with generally higher phosphorus content being found nearer the surface at Well 3A than at the deeper Wells 3B and 3C. With the exception of the one high value of 92 μg/l of soluble phosphorus on April 17 at the seepage area above Gage Road, all of the results showed that the soluble phosphorus content in the area of West Brook was less than 50 μg/l. In two instances, the soluble phosphorus content appeared to decrease from the upstream to the downstream location in West Brook whereas on three occasions there was a slight increase. The results from the July 6 sampling in West Brook are questioned. It is possible that a decimal point was misplaced and the results should be 12 μg/l upstream and 7 downstream.

The nitrogen results are not quite so conclusive due to the lack of some data, particularly the nitrate content in the sewage effluent. It must be pointed out that the total Kjeldahl nitrogen includes both the ammonia nitrogen and the organic nitrogen. In general, where the total Kjeldahl nitrogen was high, the nitrate was low and when the nitrate was high, the total Kjeldahl nitrogen was low. At Well 6, the nitrate content was about the same as the total Kjeldahl nitrogen content. However, by the time the water reached Wells 2 and 3, nearly all of the nitrogen was recovered as nitrate. No exact balance of the nitrogen content was made due to the fact that there was a large fluctuation in the nitrogen content of the sewage influent and the effluent discharged onto the sand beds. Obviously, daily fluctuations in the nitrogen content would not be reflected in the content in the wells on the same day. In all instances, there was a significant increase in the nitrogen content of West Brook between the samples secured above and below the entrance of the groundwater seepage.

One set of samples (July 25, 1973) from the influent, effluent, brook (upstream and downstream) and several wells was examined for the occurrence of coliphage as a preliminary indication of the possible presence of other such infectious agents. As seen in Table 3, infectious coliphage were present in all samples examined.

Of the well samples analyzed, only that sample from well 6 possessed an average titer below 30 phage ml^{-1}. The average titer for this well sample was 5 phage ml^{-1}. The greatest number of viral particles (73 phage ml^{-1}) was found in well 1 during the time when this sand bed was flooded.

DISCUSSION

There has been considerable concern over the best means

Table 3 : Coliphage (ml^{-1}) from Lake George Sewage Treatment Plant Well Samples (7/25/73).

Description	pH	Assay* No. 1	Assay* No. 2	Average Titer
Well #1	6.66	75	70	73
Well #2	7.80	38	57	48
Well #3B	7.43	30	36	33
Well #3C	7.05	42	40	41
Well #5	6.63	35	30	33
Well #6	8.88	6	4	5
West Brook (upstream)	7.63	10	2	6
West Brook (downstream)	7.71	6	2	4
LGSTP Influent	7.30	10	8	9
LGSTP Effluent	6.63	1	3	2
Control		—	—	—

* According to Hershey et al.

of disposal of domestic wastes from rural areas and small towns. This is of particular concern in areas where the discharge of wastes may affect a local recreational lake. Whereas information is fairly readily available as to the effects of wastewaters which are collected and treated and discharged into a stream which enters a lake or discharges directly into a lake, there is insufficient information available as to the effectiveness of discharging wastewaters, either treated or untreated, directly into the soil to make use of the characteristics of the soil which enable it to purify wastes. It has been fairly well established that under properly operating aerobic conditions, soils are quite capable of removing pathogenic bacteria and organic matter in the wastewater applied to the soil. However, much less information is available relating to the removal of nutrients, primarily nitrogen and phosphorus, by the soil. Studies indicate that different soils have different capabilities for removing these nutrients. In general, sand has been considered to be less capable of removing phosphorus than finer clay-like soil. In addition, the total capacity of any soil to remove nutrients over a long period of time has not been sufficiently evaluated.

The treatment system at Lake George Village offers an opportunity to study both the treatment efficiency of sandy soils and the effect of relatively long years of use. For approximately 35 years, the Village treatment plant has discharged biologically treated effluent onto natural delta sands. Studies have confirmed the ability of the sand to remove coliforms, BOD, and organic and ammonia nitrogen, with some apparent oxidation of the reduced nitrogen compounds to nitrate. There was very little effect upon the chloride concentration in passing through the sand. There was a variable removal of phosphate which was attributed to the ion exchange capacity at least within the first 10 ft. of depth within the sand percolation beds.

By studying the water seeping out of the base of the sand hill, approximately 2000 ft. (600 m) from the treatment plant, and wells at various locations in the area, the characteristics of the purified wastewaters discharged into the ground have been studied. The presence of dissolved oxygen, although low at some locations, in all of the well samples, confirmed that the soil has an oxidizing capability. This is considered desirable as it aids in oxidizing any organic matter remaining in the wastewaters as well as removing pathogenic bacteria and oxidizing reduced nitrogen compounds to nitrates. The lowest dissolved oxygen recorded was in Well 5 during the period of time when this bed was flooded. The relatively high values of DO in the sewage influent may be attributed to the splashing of the water as it comes out of the pipe and into the treatment plant influent distribution box. At all times, a small residual DO was found in the treatment plant effluent as discharged onto the sand percolation beds. Thus in this case, the soil system receiving the effluent from the Lake George Village sewage treatment plant may be considered adequate to provide what is normally considered desirable treatment or polishing of the treated wastes discharged into the sand.

During the entire period of this study, the sewage effluent was warmer than the air and the groundwater as represented by the wells. The temperature in West Brook was also in the same range as the cold temperature in the deep wells. The only place where depth profiles could be made was at Wells 3. Here, consistently, Well 3A, closest to the surface, had the highest temperature and Well 3C, the deepest at the time of the study, had the coldest temperature. This may be attributed to the contact of the water with the surface of the ground which was warm during the time of the study. On the other hand, it may indicate that the warmer sewage floats on the surface of the colder groundwater in this area. The chloride content of the wastewater discharged into the ground is somewhat higher than that of the natural water which would give the sewage effluent a greater density than the natural water. However, it is possible that the temperature density difference is greater than the dissolved solids density difference and the sewage discharge tends to remain near the surface of the groundwater. If this is true, it indicates that the samples secured from Well 6 may not truly represent the sewage effluent discharged into the soil due to the fact that this well point is located approximately 27 ft. (8 m) below the surface of the groundwater at this location. It is difficult to make any positive conclusion as to the location of the sewage effluent with respect to the natural groundwater without performing tracer studies and utilizing wells at various depths. The fact that the temperature in Well 1 was higher when the bed was flooded again indicates the effect of the higher temperature sewage.

The dissolved solids, alkalinity, and chloride may normally be used to identify the location of the sewage effluent in the ground with reasonable accuracy. Well 10, the control, had consistently low dissolved solids, alkalinity, and chloride as compared to the other wells. Also, Well 5, when the bed was dry, exhibited low values in these categories indicating that the high solids content which occurred during the time that the sewage was being applied to the bed was flushed away after the sewage was no longer being applied. Based upon these criteria, it appears that the wastewater applied to the percolation beds does reach Wells 6 and 2. This does not completely confirm the speculation that the deep sampling location of Well 6 may not represent the wastewater, as indicated by the temperature measurements.

Wells 3 present some problem as to interpretation. Fairly consistently, Well 3B, the medium depth sample, indicated higher dissolved solids and chloride than the other two depths; whereas Well 3A, the shallow location, had consistently higher alkalinity than the deeper samples. Moreover, all three parameters were higher in Wells 3 than the equivalent parameters in the effluent discharged to the sand beds. This indicates that there is some other source of dissolved solids being added to the groundwater somewhere between the treatment plant and the locations of Wells 3. The higher dissolved solids and chloride could be attributed to the leaching of road salt stored at the highway department garage located on the hill above the location of Wells 3. However, this would not explain the increased alkalinity in this area. Normally, chloride would be a good tracer; however, due to the extreme chloride found in the area of Wells 3, it is impossible to conclude positively that the water recovered in this area is the same as that discharged onto the sand beds at the sewage treatment plant. Thus again, additional tracer studies are necessary in order to confirm positively the flow of the treatment plant effluent to the area of Wells 3.

Within West Brook, the dissolved solids, alkalinity, and chloride were consistently increased between the upstream and downstream sampling locations. Although no stream flow measurements were made of the small tributary streams entering West Brook in the area, a rough estimate was that the flow in West Brook is approximately ten times that of the flows in the small tributaries. A rough calculation was made based upon only the dissolved solids content, and a dilution factor of 1:9 agreed fairly well with the increase in the dissolved solids in this general area. It must be pointed out that during the period of sampling, the flow in West Brook decreased according to the normal summer pattern of a stream. However, the ground around Wells 3 became more moist and saturated with water beginning approximately the middle of July as compared to the earlier Spring sampling when the ground is normally more saturated with water. Toward the end of June, and particularly the Fourth of July weekend, the flow at the sewage treatment plant increases appreciably due to the influx of the tourists in the area. If this is truly the cause of the increased wetness of the ground around Wells 3, this would indicate a flow time of in the order of 2 weeks from the treatment plant to this location. Again, this can be confirmed only by means of the addition of a tracer which is not naturally present in the area.

It is difficult to evaluate completely the nitrogen balance within the system. Even with sufficient data, a nitrogen balance is always difficult to establish due to the possible reduction of nitrates to nitrogen gas with its subsequent escape to the atmosphere and the possibility of fixation of nitrogen either by plants or algae at the surface of the ground which could be carried into the groundwater by percolation of rainfall. Furthermore, during the time of these studies, the total Kjeldahl nitrogen in the sewage treatment plant influent and effluent varied over a large range. Also, the nitrate was determined in the sewage on only one occasion during which time it was in the order of 0.5 mg/l. Since the earlier studies[2] indicated nearly complete oxidation of the reduced nitrogen within the first 10 ft. of the sand bed, it is difficult to evaluate the high concentration of total Kjeldahl nitrogen in Well 6. This indicates either incomplete oxidation or later reduction of the nitrogenous material at this point. There are also some inconsistencies in the nitrate values for Well 5 during a wet and dry period and for Well 10 which is intended to be a control. It is possible, particularly with Well 10, that a decimal point may have been misplaced in one of the analyses. Thus, additional studies will have to be made in order to make a more realistic nitrogen balance in this system. In any event, it may be concluded that significant amounts of nitrogen, particularly nitrate, do reach West Brook and there is a significant increase in the nitrate concentration in West Brook as it passes through this area.

Probably the nutrient of most concern is the phosphorus. The effluent from the sewage treatment plant has in the order of 4 mg/1 (4000 μg/1) of total soluble phosphorus. The phosphorus content of Wells 1 and 5, located in sand beds, indicated a reduction of in the order of 90% of the phosphorus at the point of securing of the samples. In Well 1, this represents a vertical passage through approximately 67 ft. of sand and in Well 5, through approximately 16 ft. of sand. However, caution must be used in interpreting these results. It must be remembered that in both instances the well point was placed within the groundwater. Thus it is possible that this low phosphorus content represents some dilution by the groundwater. However, the solids and alkalinity results indicate that there is relatively little dilution by the groundwater, assuming that the solids in Well 10 represent fairly the quality of the groundwater in the area. Furthermore, at Well 6, approximately 500 ft. (150 m) from the lower sand beds, less than 1% of the original phosphorus applied to the sandbeds was recovered. Again, it must be pointed out that this well point is approximately 27 ft. (8 m) into the groundwater and may not necessarily be representative of the effluent from the treatment plant at this point. It becomes obvious that an additional well point at the location of Well 6 should be installed at a depth very close to the surface of the groundwater. In addition, tracer studies must be made to confirm the direct passage of water from the percolation beds to the point of sampling. Whereas the phosphate concentration in Wells 2 and 3, close to West Brook, was low on all occasions, the one occasion in which the phosphate was measured in the seepage in the areas of Gage Road indicated considerably higher results. This indicates that further measurements should be made of the phosphorus content of this seepage. The effect of the phosphate in West Brook appears to be negligible. In some instances, there was a slight increase in the phosphate content of the stream as it passed through this area and in other instances, there was actually a slight measured decrease. This is probably within analytical error.

One other consideration is whether or not the majority of the sewage discharge reaches West Brook or whether some passes under West Brook to the other side. Only one sample was secured on the northern side of West Brook and this was from a small stream which reputedly appears as springs on the property of a homeowner across Sewell Road. This stream indicated low concentrations of dissolved solids, alkalinity, chloride, phosphorus and nitrogen. This lends some credence to the possibility that the sewage effluent floats on the top of the groundwater and therefore emerges from the ground prior to the groundwater in the area of West Brook. The main implication here is whether this sewage effluent reaches Lake George via West Brook or via groundwater. In any event, it is considered that ultimately the effluent does reach Lake George and the prime concern is the quality of the water when it does so. These results indicate that more information is needed as to the quality of water on the north side of West

Brook and an additional well should be placed in this general area.

The lowest phage titer was found in Well 6. This could be attributed to two factors. The pH of the sample from Well 6 was 8.88 which is high enough to cause a more rapid loss in viral infectivity than in the other well samples (pH range 6.63 - 7.43). The other factor is that the sample was obtained from approximately 27 ft. below the surface of the groundwater. Thus, the water sample obtained from Well 6 may be more representative of natural groundwater than of the effluent from the treatment plant if the effluent travels along the surface of the groundwater. Either or both of these phenomena would explain the low level of phage in Well 6 comparable to the other well sample data.

Although the sample from Well 1 contained the greatest number of viral particles (73 phage ml^{-1}), flooding of that well at the time of sampling prevents complete consideration of these data in this preliminary assessment. It is expected that the number of phage associated with Well 1 would be similar to those found in Well 5 under similar conditions of bed flooding. The numbers of infectious particles in Wells 2, 3B, 3C and 5, in comparison to those average phage values found in the sewage influent (9 phage ml^{-1}) and treated effluent (2 phage ml^{-1}), suggest that adsorption or retention of the phage particles after effluent discharge to the sand beds is likely, followed by a release or desorption into the surrounding aqueous medium. It is also possible that little or no adsorption occurs but that a buildup in the number of phage occurs in the soils from continuously discharged effluents, resulting in slow but uniform passage of these particles through the surrounding terrestrial system.

The low level of viral particles in the upstream and downstream samples from West Brook can be misleading. The presence of phage in the upstream samples is attributed to natural runoff, whereas the average titer of two particles ml^{-1} in the downstream sample has as its possible sources both natural runoff and wastewater effluent. Both dilution and distance play significant roles in lowering the phage titer in West Brook from those values observed in Wells 2 and 3, if, in fact, the source of these particles is wastewater effluent.

CONCLUSIONS

It appears that the sewage effluent applied to the sand beds at the Lake George Village sewage treatment plant enters the groundwater and flows in a generally northerly direction and emerges in some form or another from the ground near West Brook, following which it flows into West Brook and ultimately into Lake George. The sandy soil involved in this area appears to be adequate for the conventional treatment of the applied effluent. The dissolved solids, alkalinity, and chloride of the water which emerges from the ground in the area of West Brook is considerably higher than the natural groundwater in the area, reflecting the quality of the sewage effluent applied to the sand beds. These parameters are increased in West Brook as the stream flows past this area. Although insufficient data are available to make a positive statement concerning the nitrogen contributions from the sewage effluent, it does appear that the reduced nitrogen is completely oxidized to nitrate prior to its emergence from the ground where the nitrate content is quite high. This does have a significant effect of increasing the nitrate content of the water of West Brook.

It appears that the total phosphorus content of the applied sewage effluent has been reduced by greater than 99% in its passage through approximately 2000 ft. (600 m) of sand from the treatment plant to West Brook. There is no significant increase in the phosphate content of West Brook in passing through this area. The analyses in one sample of spring water secured across West Brook indicate that the quality of this water is quite high and not representative of the sewage effluent applied to the sand beds.

Although the presence of phage particles in the samples necessitates further and more extensive investigations, the discharge of infectious coliphage into West Brook does seem to occur, with wastewater effluent from the sewage treatment plant as one likely source. It is not possible at this time to state conclusively whether or not infectious enteroviruses also are present in these wastewater effluents and eventually reach West Brook. Nevertheless, sufficient coliphage is present in those wells examined to warrant the introduction of labeled attentuated viruses into the influent and subsequently assay for these tagged particles in the effluent and well samples to obtain more conclusive data regarding the source of these particles and their adsorption and/or desorption kinetics within the surrounding soils.

There is some question whether all of the samples secured were truly representative of the effluent discharged onto the sand beds. The sample at Well 6 was secured 27 ft. below the surface of the groundwater. Also due to some interferences, the total solids, alkalinity, and chlorides at Well 3 were considerably higher than those in the sewage effluent. This negates the possibility of using these parameters as tracers of the sewage effluent. Tracer studies using some tracer foreign to the area and the addition of several wells at new locations and at several different depths in the present locations will be needed in order to make a positive confirmation of the flow of the effluent from the treatment plant to the various wells and ultimately to West Brook.

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APPENDIX

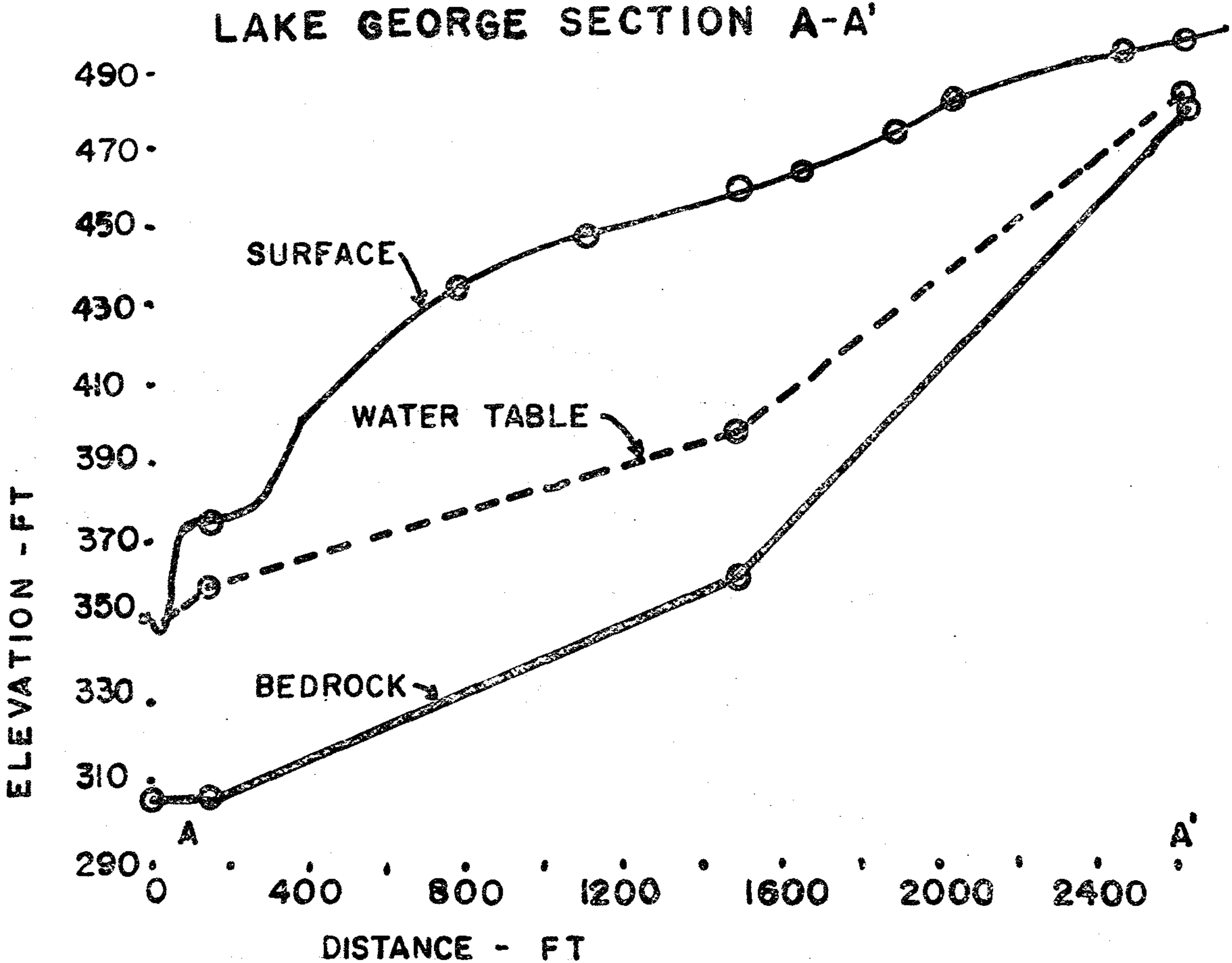
LAKE GEORGE SECTION A-A'
490
470
450
430
410
390
370
350
330
310
290
ELEVATION - FT
SURFACE
WATER TABLE
BEDROCK
A
A'
0
400
800
1200
1600
2000
2400
DISTANCE - FT

Figure A-1

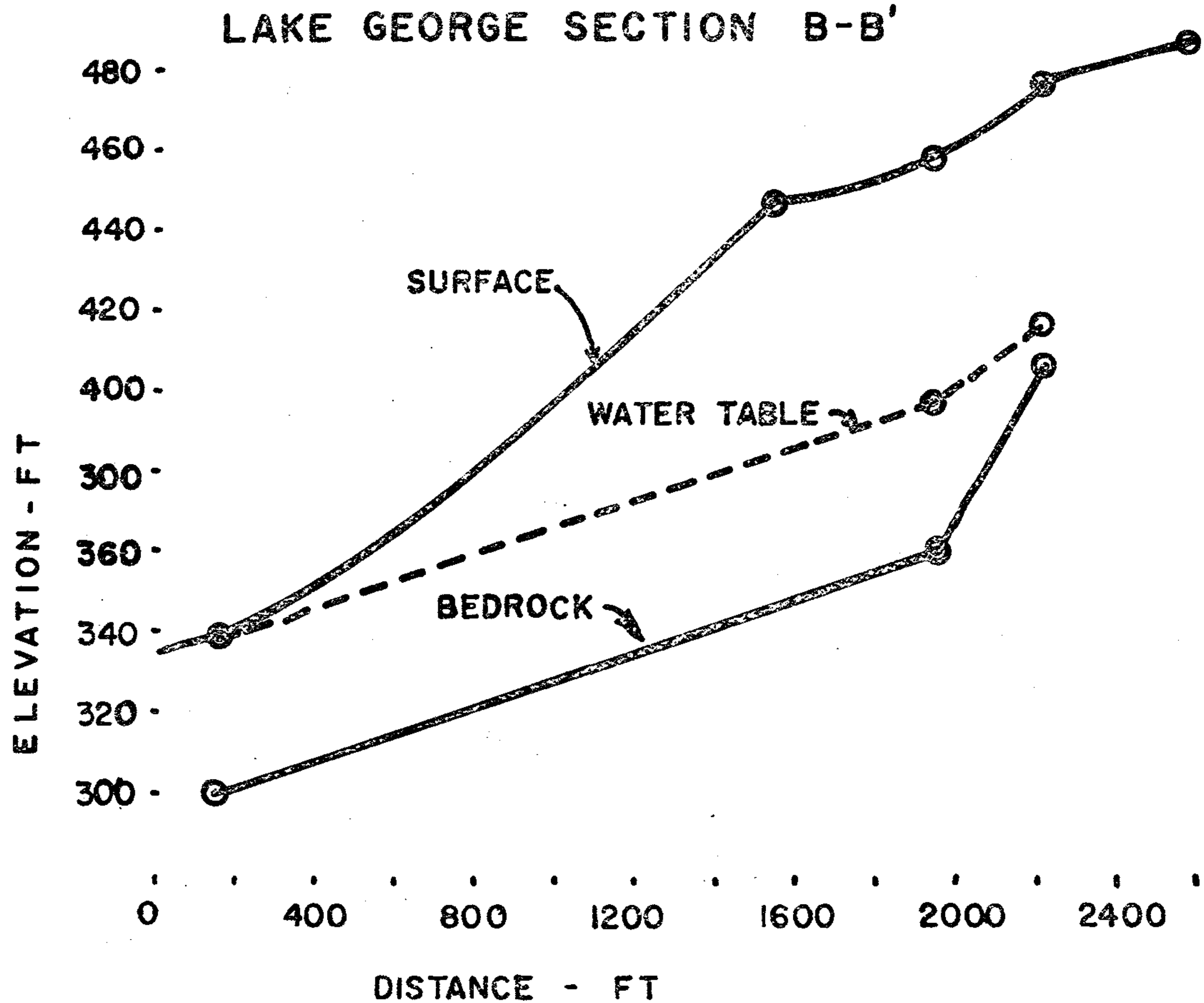
LAKE GEORGE SECTION B-B'
480
460
440
420
400
300
360
340
320
300
ELEVATION - FT
SURFACE
WATER TABLE
BEDROCK
0
400
800
1200
1600
2000
2400
DISTANCE - FT

Figure A-2

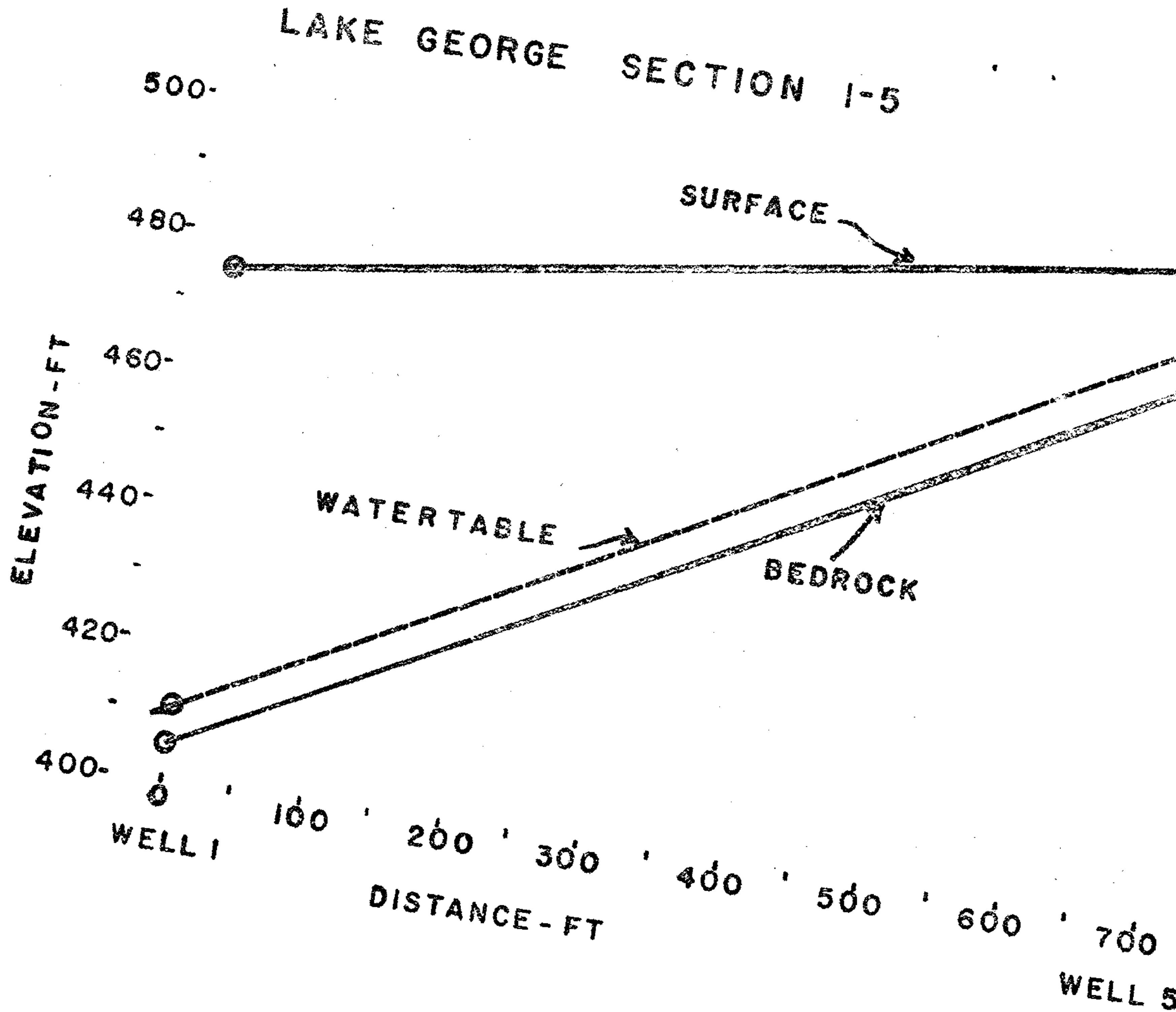
LAKE GEORGE SECTION 1-5
500-
480-
460-
440-
420-
400-
ELEVATION - FT
SURFACE
WATERTABLE
BEDROCK
0
100
200
300
400
500
600
700
WELL 1
WELL 5
DISTANCE - FT

Figure A-3

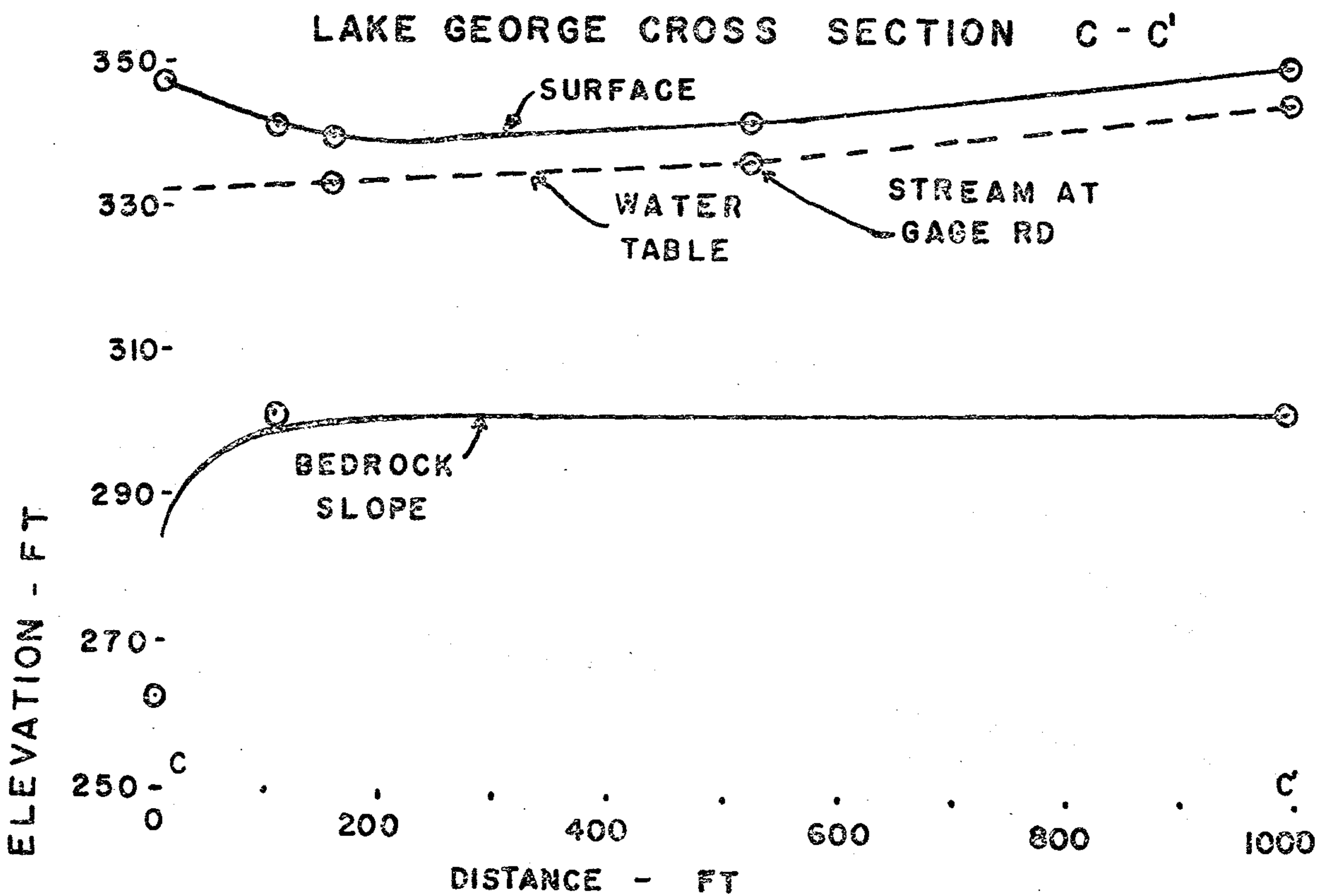
LAKE GEORGE CROSS SECTION C - C'
350-
330-
310-
290-
270-
250-
SURFACE
WATER TABLE
STREAM AT GAGE RD
BEDROCK SLOPE
C
C'
0
200
400
600
800
1000
DISTANCE - FT
ELEVATION - FT

Figure A-4