National Energy Authority
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THE REDEVELOPMENT OF THE REYKIR HYDROTHERMAL SYSTEM IN S.W. ICELAND.

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ABSTRACT

The Reykir hydrothermal system has been exploited since 1944 for space heating of Reykjavík, 15-20 km distant. Prior to 1970 production amounted to 300 l/s, 86°C, by free flow from 69 narrow gage wells with a maximum depth of 628 m. In early 1970 a redevelopment of the hydrothermal system was begun by the rotary drilling of deep large gage wells intended for production by submergeable turbine pumps. By March, 1975, 29 rotary drilled wells, 800-2043 m deep and 22-31 cm in diameter, had been completed. Production from these wells is expected to exceed 1200 l/s while production from the 20 wells, already equipped with turbine pumps in January 1975, amounted to 851 l/s with an aggregate temperature of 83.5°C. Future production potential of the system is estimated in excess of 1500 l/s with a water level decline of 60-70 m from the 1970 steady state water level.

The essentially horizontal thermal aquifers at Reykir are irregularily distributed, both laterally and vertically, through volcanics of Quaternary age. Values of transmissivity and coefficient of storage, as determined from pumping tests range as high as 2.6×10^{-2} m^2/s and 2×10^{-4}, respectively. Artesian nature of the

aquifers is suggested by the value of the storage coefficient and by the response of the aquifers´ pressure heads to atmospheric pressure changes, earth tides and distant earthquakes.

INTRODUCTION

The Reykir hydrothermal system was the principal source of thermal water distributed by the Reykjavík District Heating Service from the beginning of the Service in 1944 until 1959. By 1969, after the development of the Laugarnes and the Ellidaár hydrothermal systems inside Reykjavík, Reykir´s share in the thermal production had diminished to 38%. At the end of January 1975 new production wells, completed at Reykir 1970-1975, had boasted production from the area to 156 thermal MW or 51% of the thermal energy distributed by the Reykjavík Heating Service.

The Reykir area is located 15-20 km Northeast of Reykjavík. It is divided into two subareas, Reykir to the South and Reykjahlíd to the North, each at an elevation of 40-80 meters above mean sea level. The subareas are 2-3 km apart and are separated by the mountain chain of Helgafell, Aesustadafell and Reykjafell, which rises to an elevation of 200-250 meters above mean sea level. Geologically the area is located on the western flank of the neovolcanic zone in Southwest Iceland and is occupied by volcanics of quaternary age down to a depth of at least 2000 meters.

Prior to 1933, when exploration drilling was begun at Reykir, natural hot springs in the area discharged an estimated amount of 120 l/s (Barth, 1950) of thermal water. By the end of the initial development program, in 1955, free flow from the area had increased to a reported 360 l/s, 86°C, from 43 shallow wells at Reykir and 26 wells at Reykjahlíd. By 1970 the flow had diminished to an estimated 300 l/s , 220 l/s from the wells at Reykjahlíd and 80 l/s from the Reykir wells.

In 1970 a redevelopment program of the hydrothermal area was begun by the rotary drilling of deep large gage wells intended for production by submergable turbine pumps, and by March 1975, 29 wells, 800-2043 m deep and 22 and 31 cm in diameter had been completed. Production of thermal water at the end of January, 1975, amounted to 851 l/s with an average temperature of 83.5°C from 20 pumped wells. This increased production from the new wells had by then caused a decline of 20-35 meters of the relatively steady state 1970 piezometric surface of the area, thereby eliminating free flow from the older wells.

WELLS

The wells completed between 1970 and 1975 are drilled by a rotary rig which has a depth capacity of 2050 meters with 22 cm hole diameter. The wells range in depth from 800 to 2043 m and have diameters of 22 and 31 cm. Completions are of the open hole type, casing ranging in depth from 116 m to 390 m, 24.5 and 34.0 cm O.D. Table 1 gives the construction dimensions and yield of the 29 wells. Yield of the 9 wells, not yet equipped with turbine pumps in January 1975, is computed from reversed step drawdown tests made at the end of drilling.

The drilling program for the diam. 31 cm wells is as follows: the topmost 23 meters are drilled by a percussion rig, which sets a 47 cm I.D. pipe through overburden to a depth of 5-10 m and drills a diam. 46 cm hole to a depth of 23 m in order to accommodate the rotary rig's first two drill collars. The rotary rig then moves in and drills a diam. 44 cm hole to the predetermined casing depth, either by a diam. 44 cm rock bit run with a reamer above it, or with a diam. 31 cm rock bit run with a diam. 44 cm hole opener and a reamer above. A diam. 34 cm O.D. pipe is set and cemented in place to the surface. After hardening of the cement, a diam. 31 cm hole is cut to a depth of

1200-1500 m and from there on a diam. 22 cm hole is cut to total depth, which depends on the number and size of productive horizons encountered while drilling and on the drilling rig's depth limit of 2050 m.

Lost circulation zones to be bypassed, while drilling deeper, are plugged by lost circulation materials, usually sawdust, which is added to the circulating water. At the end of drilling the well is first pumped with compressed air, in order to clean out the sawdust and drill cuttings from the productive zones, and then developed with the packer injection method (see Tomasson and Thorsteinsson, 1975).

Location of the 29 wells and some earlier wells used as observation wells is given on fig. 1. Sites for production wells have been chosen below an elevation of 75-80 m above mean sea level in order to avoid excessive pumping lifts. Spacing of the wells is preferably in excess of 70-80 m on account of hole deviation and interference with other wells. (Fig. 2)

Table 2 lists the construction dimensions of some earlier wells used as observation wells.

Table 2.

Well No.	Depth,m	Diam.cm.	Casing m	Year completed
MG 1	1380	31.0	99	1959
MG 2	1192	22.0	78	1963
SR18	282	15.2		1938
SR34	458	9.2	8.3	1945
SR35	491	15.2	8.2	1945
SR38	415	9.2	32.0	1945
SR40	494	15.2	30.9	1946
SR43	294	16.4	53.8	1947
NR15	353	15.2	19.5	1951

Wells MG1 and MG2 are rotary drilled exploration wells, completed in 1959 and 1963, while the other wells are of still earlier date drilled by Calyx type rigs.

The rotary drilled wells in the Reykir area are designated with the prefix MG while the earlier Calyx drilled wells have the prefix NR at Reykjahlíd and SR at Reykir.

MULTIPLE STEP DRAWDOWN TESTS

The coefficients of turbulent well losses, C, for the wells listed in table 1 were computed from multiple step discharge or recharge tests. The discharge test is performed by the stepwise withdrawal of water by the submergable turbine pumps while the recharge test is made by the stepwise recharge of water by the drilling rig's reeiprocating pumps at the end of drilling and development of the wells. Results from the two methods usually agree fairly well.

The multiple step drawdown test was described by C.E. Jacob in 1947 and modified by M.I. Rorabaugh in 1953. Essentially the test is a determination of the specific drawdown (drawdown at unit discharge) at 3-4 pumping rates, each for a short time interval,(1-2 hours). The increase in specific drawdown for increased pumping rates is attributed to turbulent flow conditions in the well and in its immediate vicinity while flow in the aquifer is assumed to be laminar causing drawdown directly proportional to pumping rates. Jacob assigned a value of 2 to the n in his empirical formula for drawdown in a pumped well. $h = BQ + CQ^n$ in which Q is the rate of pumping, B is the linear aquifer constant and C is the well loss constant due to turbulence in the well bore and in its immediate vicinity.

Roratbaugh found that the value of n in the well loss formula often seemed to exceed 2, especially at high discharge rates, 120-150 l/s. This he attributed to the lengthening of the paths of turbulent flow in the immediate vicinity of the well at higher discharge rates. Rorabaugh proposed a solution for an average value of n by a log-log plot of discharge, Q, vs. (h/Q - B), the value of B being found by trial as shown by the straight line in figure 3. The coefficient C is read off from the intercept of the straight line at Q = 1 , and n is computed from the slope of the line = n-1.

WITHDRAWAL OF WATER

Except for short periods of pumping by airline of a few wells at Reykir during times of high demand, production between 1944 and 1970 was exclusively by free flow from earlier production wells. In 1955, at the completion of the first development program, flow from the wells was reported at 360 l/s, 86°C, but at the end of 1970 the flow had diminished to an estimated 300 l/s on account of the gradual decline of the piezometric surface of the area. About 70% of the flow, 220 l/s, came from wells at Reykjahlíd.

The first turbine pumps were installed in wells MG3 and MG4 in January 1971 but by the end of 1973 the discharge from 14 turbine pumps, amounting to 605 l/s, had eliminated free flow from the earlier wells at Reykir and Reykjahlíd. By January 31, 1975, 20 wells had been equipped with turbine pumps having a total discharge of 851 l/s at an aggregate temperature of 83.5°C. Figure 4 shows the metered monthly discharge and operating periods of the turbine pumps between 1971 and 1975, and free flow by years from 1970-1973, estimated from periodic measurements. Table 3 gives the total yearly production from pumps and by free flow.

Table 3.

Yearly discharge in gigaliters by pumping and by free flow.

Year	Pumps	Free Flow	Total
1970	0	9.30	9.30
1971	3.24	6.90	10.14
1972	6.98	4.40	11.38
1973	12.34	2.50	14.84
1974	18.19	0	18.19

Turbine pumps used in wells at Reykir are of three diameters 12.6 , 19.4 and 30.5 cm with approximate capacities, at normal operating conditions of 20 , 45 and 80 l/s respectively. The pumps have enclosed line shafts and bearings of teflon. Lubrication of bearings is by thermal water. Number of stages in the diam. 12.6 and 30.5 cm pumps is 10-12 but 5-6 in the diam. 19.4 cm pumps. Motors are polyphase induction motors 75 , 100 and 150 hp with constant speeds of 1450 and 2950 RPM. Pump yields are given in table 1.

AQUIFERS

The geologic section at Reykir, down to a depth of 1000-1100 m, is almost evenly divided into hyaloclastites and basalt flows in various stages of hydrothermal alteration. Some of the individual hyaloclastic members are hundreds of meters thick while the basalt flows are up to a few tens of meters in thickness. Below the depth of 1100 m hydrothermally altered tholeiite basalts predominate with thin intercalations of hyaloclastites and some dolerite intrusions of varying thicknesses.

Aquifers are irregularily distributed through the geologic section but are commonly at contacts between individual lava flows and dolerite intrusions and hyaloclastites. Packer injection tests suggest an essentially horizontal attitude of the aquifers and impermeable vertical boundaries created by N.E. striking step faults. Figures 5 and 6 illustrate an injection test made at various depth intervals of well MG10. Figure 5 gives the location of MG10 relative to 6 observation wells, which were equipped with automatic water stage recorders during the test. Figure 6 shows the response of the water levels of the observation well to the injection of the various depth intervals. No response is recorded for any injection interval in the three wells, MG9, SR34 and SR40, located Northwest of the impermeable boundary shown on figure 5. Southeast of the boundary the water level in MG2, 1198 m in depth, responds to all three injection intervals, 158-441 m, 441-1045 m and 635-1045 m. The water level of SR38, 414 m in depth, responds to the two uppermost intervals, while the water level of SR18, depth 282 m, responds only to the uppermost one, 156-441 m.

A second major vertical impermeable boundary between wells MG21 and MG29 at Reykjahlíd, figure 1, is suggested by the much smaller response of the water level of MG29 than that of MG21 and MG5 to changes of pumping rates in wells at Reykir. For similar reasons a third vertical impermeable boundary, not shown on figure 1, is suspected, striking NE between wells MG16 and MG25 and MG14 and MG1, respectively.

The temperature gradient at Reykir is reversed, the highest temperatures, 90-102°C being found at a depth of 300-800 meters, while the deepest aquifers at 1900 m have temperatures of 72-82°C. Temperatures are about 10° higher in aquifers Northwest of the impermeable boundary, shown on figure 5, than they are at the same depths Southeast of the boundary.

FLUCTUATIONS OF WATER LEVEL

Water levels in wells at Reykir have been recorded by automatic water level recorders since 1969. The first recorder was installed in well MG2, partly for the purpose of monitoring possible effects on the Reykir water level from seasonal pumping in the two hydrothermal systems inside Reykjavík, Laugarnes and Ellidaár. During the redevelopment period, 1970-1975, a total of 45-50 wells have been equipped with automatic recorders for various lengths of time but a fairly continuous record of water levels for the period is available from the 5 wells, SR34, SR38, NR15, MG2 and MG5, shown on fig. 4, or from their complimentary offset wells which exhibit fluctuations comparable to those of the original wells.

Fluctuations of water levels in the Reykir hydrothermal system are primarily attributable to pumping from production wells, but minor fluctuations occur from the effects of tides, atmospheric pressure changes and distant earthquakes.

TIDAL EFFECTS

Hydrographs of almost all wells in the Reykir area, exceeding 250-300 m in depth, which have been equipped with automatic water level recorders, exhibit fluctuations which are attributable to tidal effects. The fluctuations, illustrated in the hydrograph of well SR34, in figure 8, for the days of June 22-26, 1971, consist of two highs, with amplitudes of about 10 cm, occurring 24 hours apart with a smaller high of an amplitude of 2-3 cm, disrupting the low about midway between them.

The diurnal, or 24 hour, period of the larger highs suggest the earth tides as the cause of the fluctuations while the smaller highs, having a semidiurnal (12 hour) period, suggest effects from the tide in the North Atlantic Ocean, 3-4 km away to the West. This is because the North Atlantic, due to its shape of great depth and relatively short length, is practically inert to the diurnal (24 hour) constituents of the equilibrium tide which dominate in the period 22-26 of June because of the high angle of declination of both the moon and the sun.

The larger magnitudes of the diurnal fluctuations compared to those of the semidiurnal ones suggest that a greater part of the fluctuations is attributable to earth tides than to oceanic tides. Fluctuations comparable to those of the hydrograph of SR34 are obtained in graph III on figure 8 by superposing 1.5% of the amplitude of the ocean tide, with a time lag of 6 hours, as recorded in Reykjavík´s harbor, on to 10% of the fluctuations computed from equilibrium theory, shown inverted in graph I on figure 8. In the formula for the equilibrium tide given in figure 8,

L = Latitude of a place on the earth, (considered positive when North)
d and d, = declination of the Moon and the Sun (considered positive with north declination)
z and z, = angular distance between meridian of the place and the meridian at which lower transit of the Moon and the Sun is taking place.

ATMOSPHERIC PRESSURE AND EARTHQUAKES

The effects of earth tides on the water levels in observation wells at Reykir, described above, suggest artesian nature of the aquifers below a depth of 200-300 m. This is further emphasized by the response of the water levels to atmospheric pressure changes and to waves from the two distant earthquakes shown in hydrographs on figure 9.

The first quake occurred near the coast of Michoacan, Mexico, Lat. 18.5 N, Long. 103.0 W at a depth of 43 km , at 21 hr 01 min G.M.T. on January 30, 1973. Surface wave magnitude was 7,5. The second earthquake took place on February 6, 1973, at 10 hr 37 min G.M.T. at Lat. 31.4 N, Long 100,6 E, in Szechnan Province (Tibet), China. Its epicenter was at a depth of less than 33 km and its surface wave magnitude 7.4. The compressed time scales of the water level recorders used at Reykir preclude identification of individual earthquake waves other than the maximum Rayleigh surface waves.

EFFECTS OF PUMPING

The decline of the piezometric surface at Reykir and Reykjahlíd from 1970 to 1975 is illustrated in figure 4 along with the increased withdrawal of water by turbine pumps. The decline shown amounts to 35-38 m in wells SR38 and MG2 at Reykir and 19-20 m in wells NR15 and MG5 at Reykjahlíd while the rate of withdrawal of water increased from about 300 l/s in January 1971 to 851 l/s in January 1975.

Numerous pumping tests (see Thorsteinsson and Elíasson, 1970) have been made in the wells at Reykir for determination of the coefficients of Transmissivity and Storage of the aquifers. Figure 7 illustrates a pumping test made in well MG11 while well MG4 was being pumped. Values of the coefficients computed from the test along with those from 5 other tests are given below.

Pumped well	Observation well	T m^2/sek	S
MG4	MG11	2.65×10^{-2}	2.10×10^{-4}
MG7	MG10	2.76×10^{-2}	3.90×10^{-4}
MG22	MG2	2.20×10^{-2}	2.80×10^{-4}
MG6	MG8	1.20×10^{-2}	1.5×10^{-4}
MG6	MG18	8.6×10^{-3}	1.7×10^{-4}
MG14	MG15	4.8×10^{-3}	1.2×10^{-4}

The results from the pumping test may be used for predicting in a general way the future response of the aquifers at Reykir to increased pumping rates. However further tests are needed in order to reveal the hydraulic properties of aquifers SE and NW of the two impermeable boundaries suspected striking NE near wells MG25 and MG29 respectively.

The value of T , the coefficient of transmissivity, computed from the pumping tests is an average value for the total thickness of the aquifers: $(m^3/5)/m$. The hydraulic conductivity of the aquifers, K , is T divided by aquifer thickness and is the rate of flow per unit area and is measure of the properties of both the fluid and the aquifer medium. In order to obtain a measure of the hydraulic properties of the aquifer medium by itself, for comparison with those of other hydrothermal systems, K is multiplied by the ratio of the Kinematic viscosity of the fluid to the acceleration of gravity: intrinsic permeability $= k = K\frac{Y}{g}$

In the table below, aquifer thicknesses are estimated from values of the coefficient of storage from pumping tests and from temperature logs for the three hydrothermal systems at Laugarnes, Ellidaár and Reykir, shown on figure 10.

Hydrothermal system.	Temp. C°	Thickness m	T cm^2/sek	K cm/sek	k cm^2
Laugarnes	135	33	60	1.8×10^{-2}	4.1×10^{-8}
Ellidaár	100	17	35	2.1×10^{-2}	6.2×10^{-8}
Reykir Eastern part	85	60	250	3.8×10^{-2}	13.7×10^{-8}

Table I

Construction Dimensions of Production Wells at Reykir and Reykjahlíd

Well No.	Depth	Casing		Yield				Year of Completion
				Q	Temp.	Drawdown	C	
	m	m	cm	l/s	C°	m	m/(l/s)^2	
MG 3	1414	116	24.5	42	84	34	0.019	1970
MG 4	1334	129	"	35	83	43	0.035	1970
1) MG 5	1592	136	"	40	85	62	0.039	1970
MG 6	1416	136	"	43	83	30	0.016	1970
MG 7	1484	135	"	47	68	8	0.0035	1971
MG 8	1562	136	"	38	80	38	0.026	1971
MG 9	1803	158	"	32	86	53	0.052	1971
MG10	1044	159	"	45	76	10	0.005	1971
MG11	1235	170	"	35	86	31	0.025	1971
MG12	800	195	"	39	88	17	0.018	1972
MG13	1905	185	"	45	90	18	0.009	1972
MG14	2035	214	"	20	84	48	0.10	1972
MG15	1988	214	"	20	85	48	0.10	1973
MG16	2033	215	"	40	100	35	0.022	1973
MG17	1766	390	"	45	75	8	0.004	1973
MG18	2043	187	"	43	82	33	0.018	1973
MG19	1513	183	"	50	90	27	0.011	1973
1) MG20	2036	202	"	32	85	36	0.035	1973
1) MG21	1768	146	"	48	88	18	0.008	1973
MG22	1582	200	33.8	75	85	13	0.002	1973
MG23	1203	207	"	75	81	22	0.004	1974
MG24	1950	203	"	70	80	32	0.005	1974
MG25	2025	203	"	40	92	40	0.025	1974
MG26	867	202	"	70	80	49	0.008	1974
1) MG27	2004	196	"	43	80	50	0.025	1974
1) MG28	2040	194	"	20	88	40	0.10	1974
1) MG29	1353	274	"	75	90	6	0.001	1974
1) MG30	1605	200	"	70	85	17	0.0035	1975
1) MG31	1478	201	"	70	81	28	0.005	1975

1) Yield is computed from reversed step drawdown tests.

FIGURE CAPTIONS

Fig. 1. Map of the Reykir - Reykjahlíd hydrothermal area showing location of rotary drilled wells (solid circles) and some earlier wells (open circles) and aquicludes.

Fig. 2. Magnetic single shot survey of well MG27.

Fig. 3. Results of step drawdown test in well MG8 solved by the methods of Jacob and Rorabaugh.

Fig. 4. Hydrographs of observation wells 1970-1975 along with monthly discharge and operation periods of turbine pumps at Reykir and yearly discharge by free flow from earlier wells.

Fig. 5. Map of Reykir showing location of injection well MG10 and several observation wells.

Fig. 6. Response of water levels in observation wells to injection of various depth intervals in well MG10.

Fig. 7. Logarithmic plot of drawdown in well MG11 during pumping of well MG4.

Fig. 8. Hydrograph of well SR34 illustrating response of the water level to tides. Resultant of 1.5% of the ocean tide, with a 6 hour time lag, and 10% of the inverted equilibrium tide is shown for comparison.

Fig. 9. Hydrograph of observation wells illustrating response of water levels to atmospheric pressure changes, pumping rates and to earthquake waves from distant earthquakes in Tibet and Mexico.

Fig. 10. Values of intrinsic permeability computed for the hydrothermal systems of Reykir, Ellidaár and Laugarnes.

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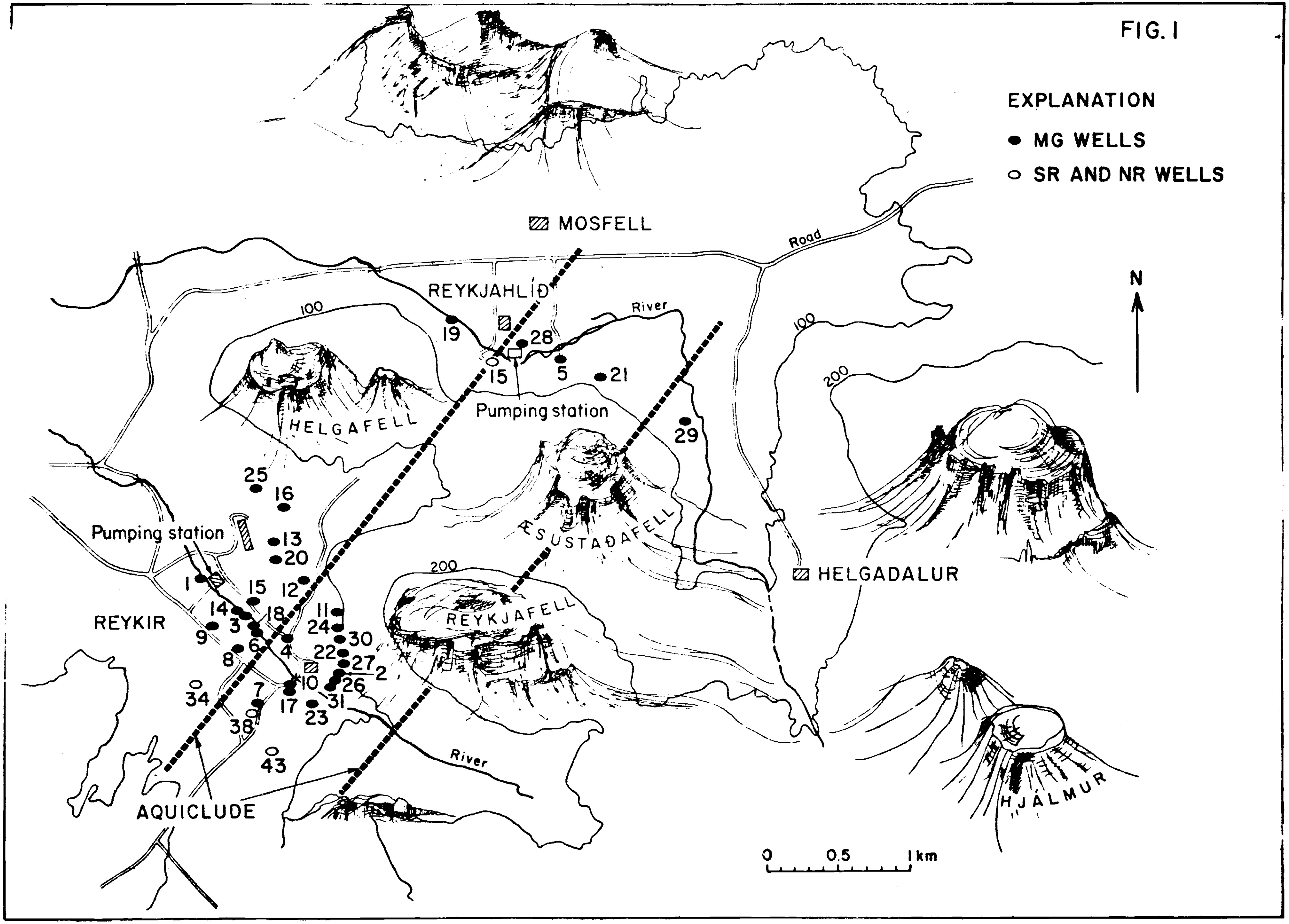
FIG. I


EXPLANATION
● MG WELLS
○ SR AND NR WELLS
N
MOSFELL
Road
REYKJAHLÍÐ
River
100
200
HELGAFELL
Pumping station
ÆSUSTAÐAFELL
REYKJAFELL
HELGADALUR
HJALMUR
REYKIR
AQUICLUDE
0
0.5
1 km
1
3
2
4
5
6
7
8
9
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11
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14
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16
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21
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30
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34
38
43

MAGNETIC SINGLE SHOT SURVEY OF

MG - 27

FIG 2

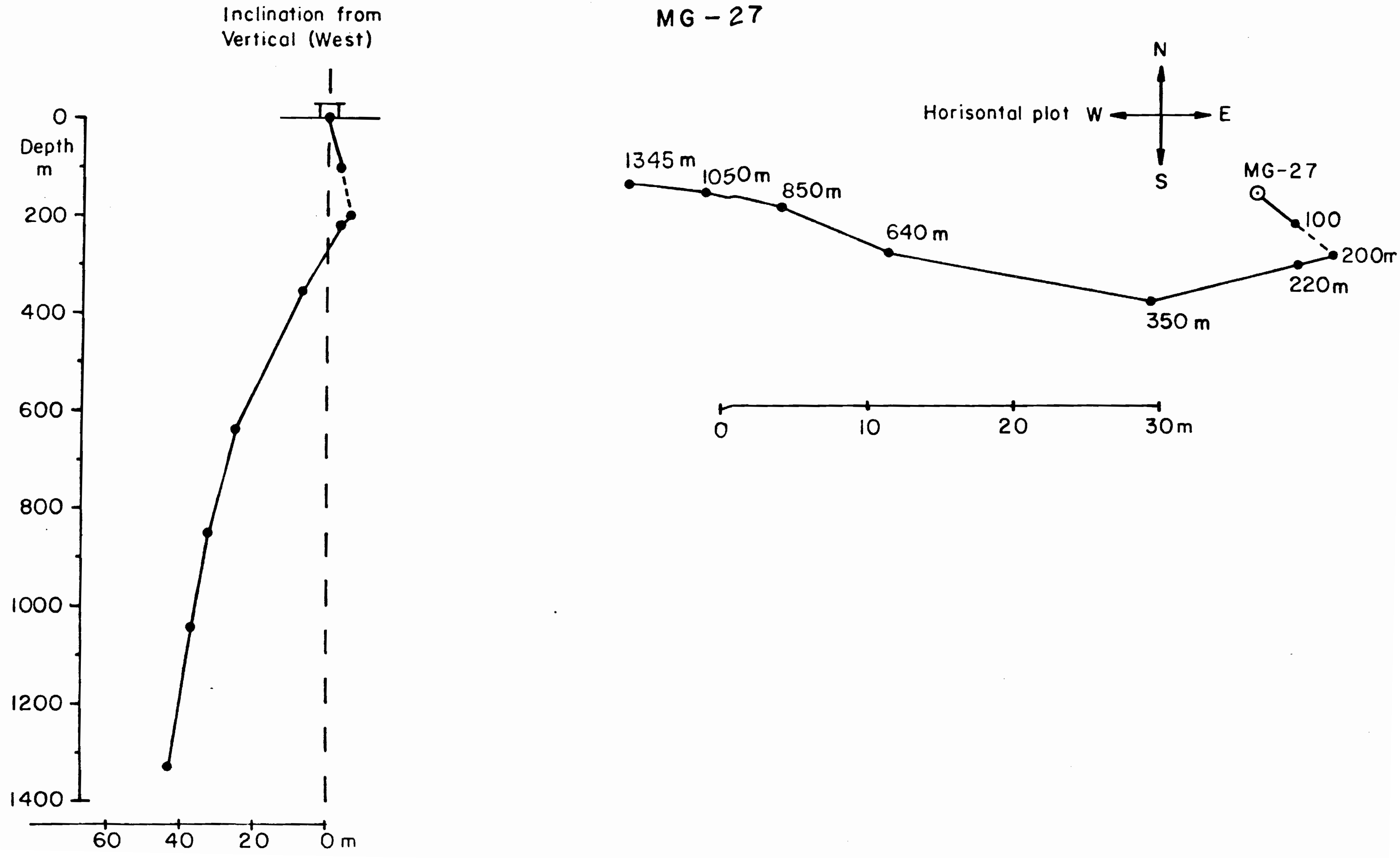


FIG 3

STEP DRAWDOWN TEST IN WELL MG-8

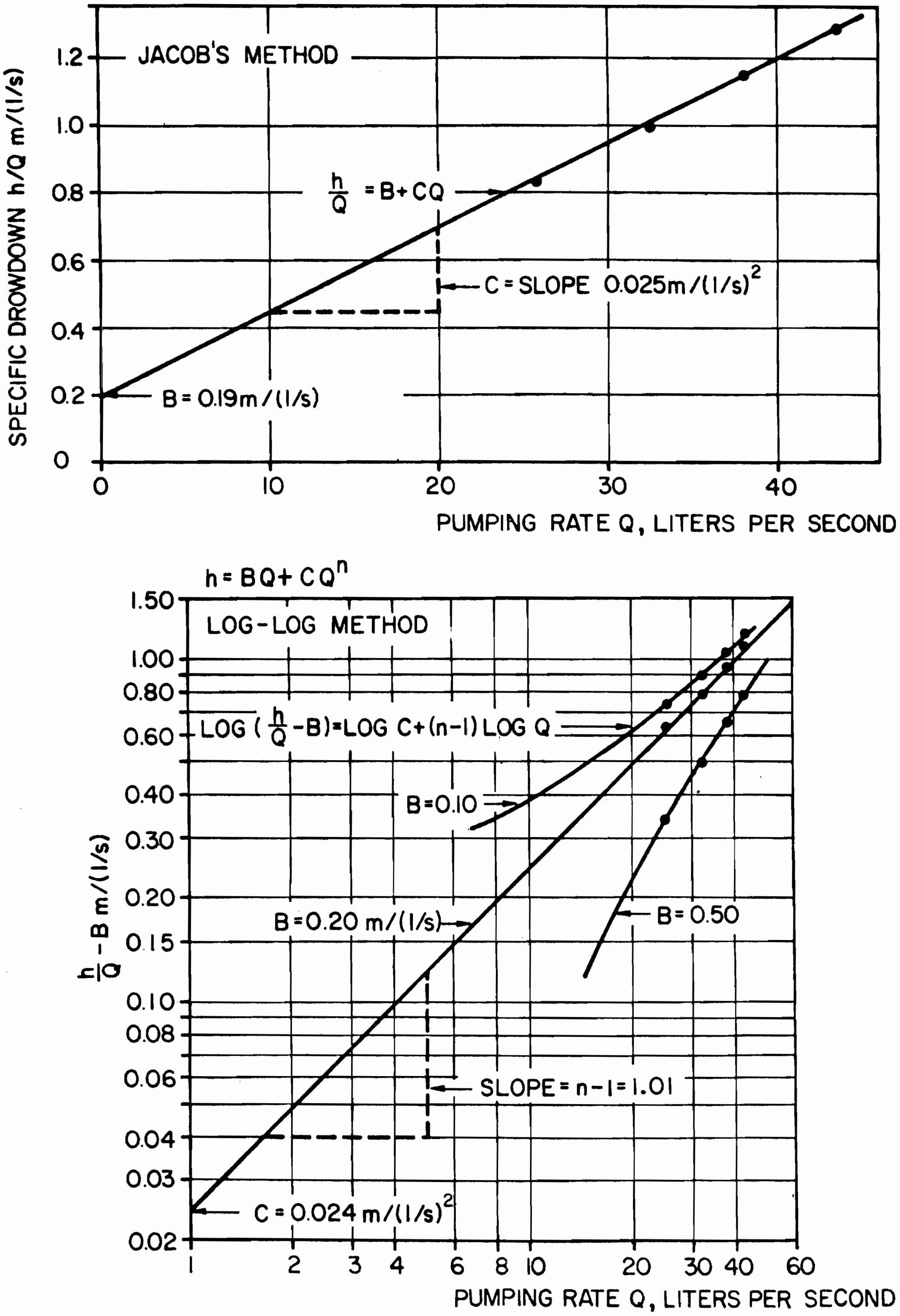


FIG 4

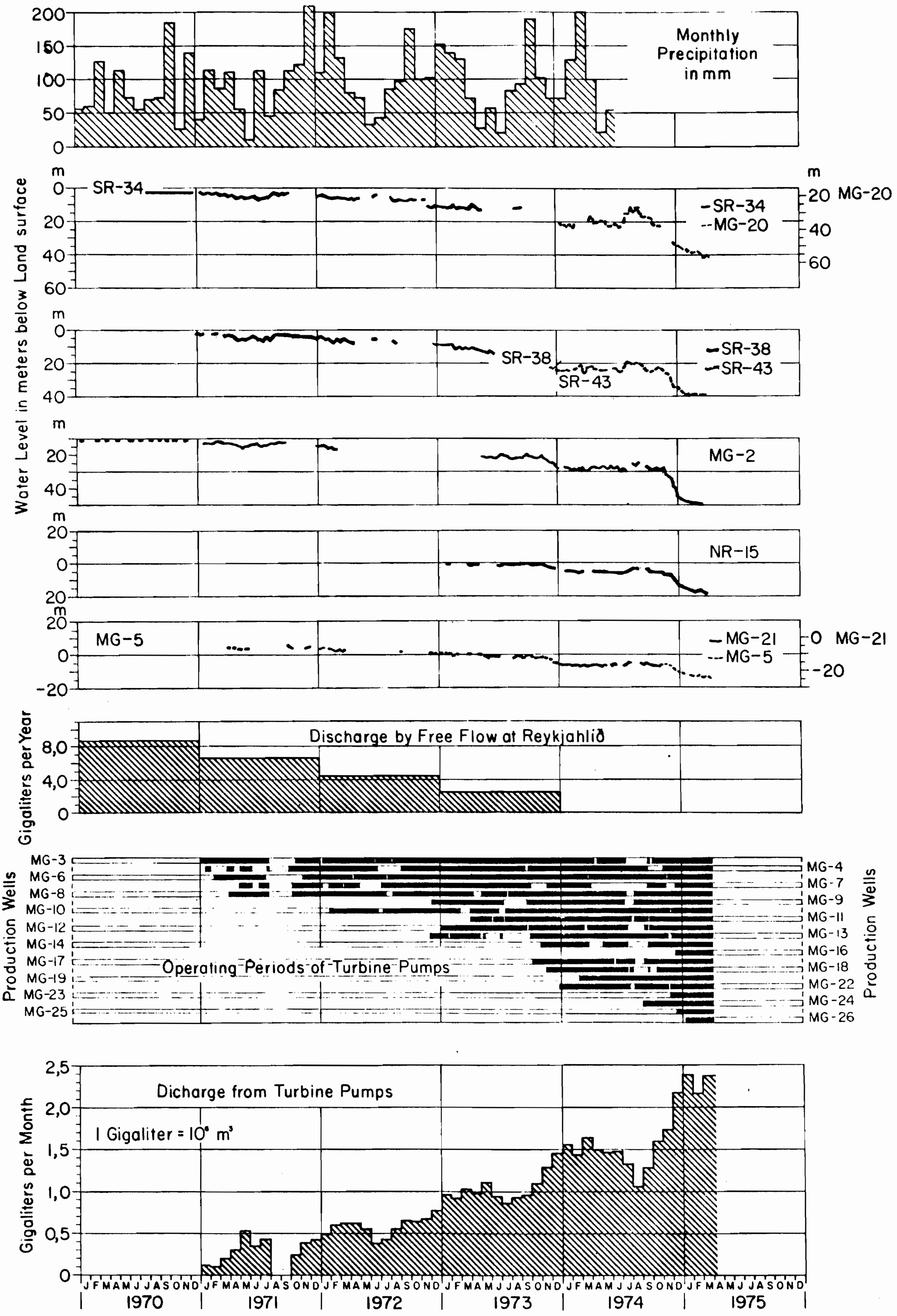
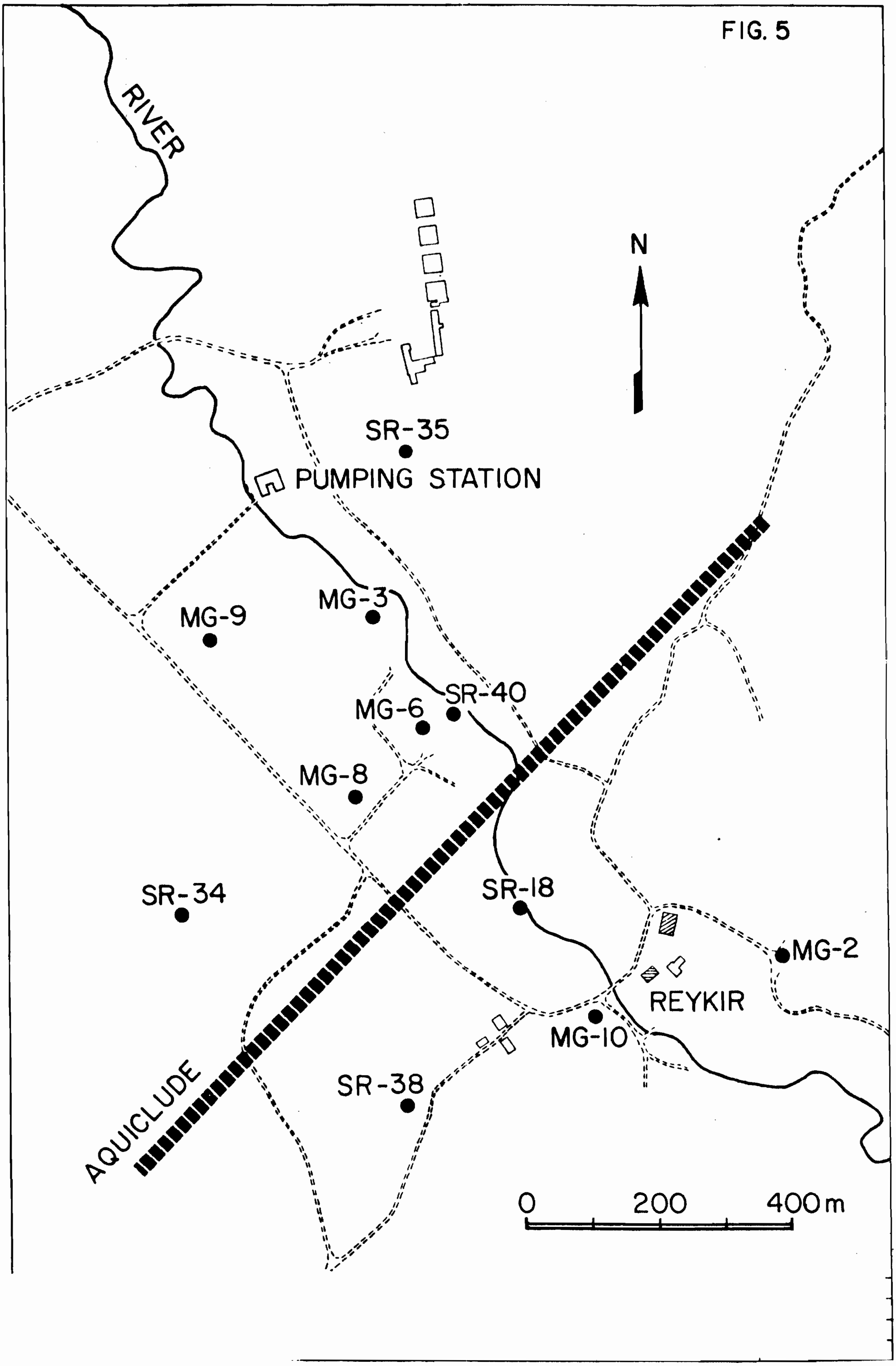

mm
200
150
100
50
0
Monthly Precipitation in mm
Water Level in meters below Land surface
m
0
20
40
60
SR-34
-SR-34
--MG-20
m
20 MG-20
40
60
m
0
20
40
SR-38
SR-43
-SR-38
--SR-43
m
20
40
MG-2
m
20
0
20
NR-15
m
20
0
-20
MG-5
-MG-21
--MG-5
0 MG-21
-20
Gigaliters per Year
8,0
4,0
0
Discharge by Free Flow at Reykjahlið
Production Wells
MG-3
MG-6
MG-8
MG-10
MG-12
MG-14
MG-17
MG-19
MG-23
MG-25
MG-4
MG-7
MG-9
MG-11
MG-13
MG-16
MG-18
MG-22
MG-24
MG-26
Operating Periods of Turbine Pumps
Gigaliters per Month
2,5
2,0
1,5
1,0
0,5
0
Dicharge from Turbine Pumps
1 Gigaliter = 10⁶ m³
J F M A M J J A S O N D
1970
1971
1972
1973
1974
1975

FIG. 5


RIVER
N
SR-35
PUMPING STATION
MG-3
MG-9
SR-40
MG-6
MG-8
SR-34
SR-18
MG-2
REYKIR
MG-10
SR-38
AQUICLUDE
0
200
400 m

ORKUSTOFNUN

FIG. 6

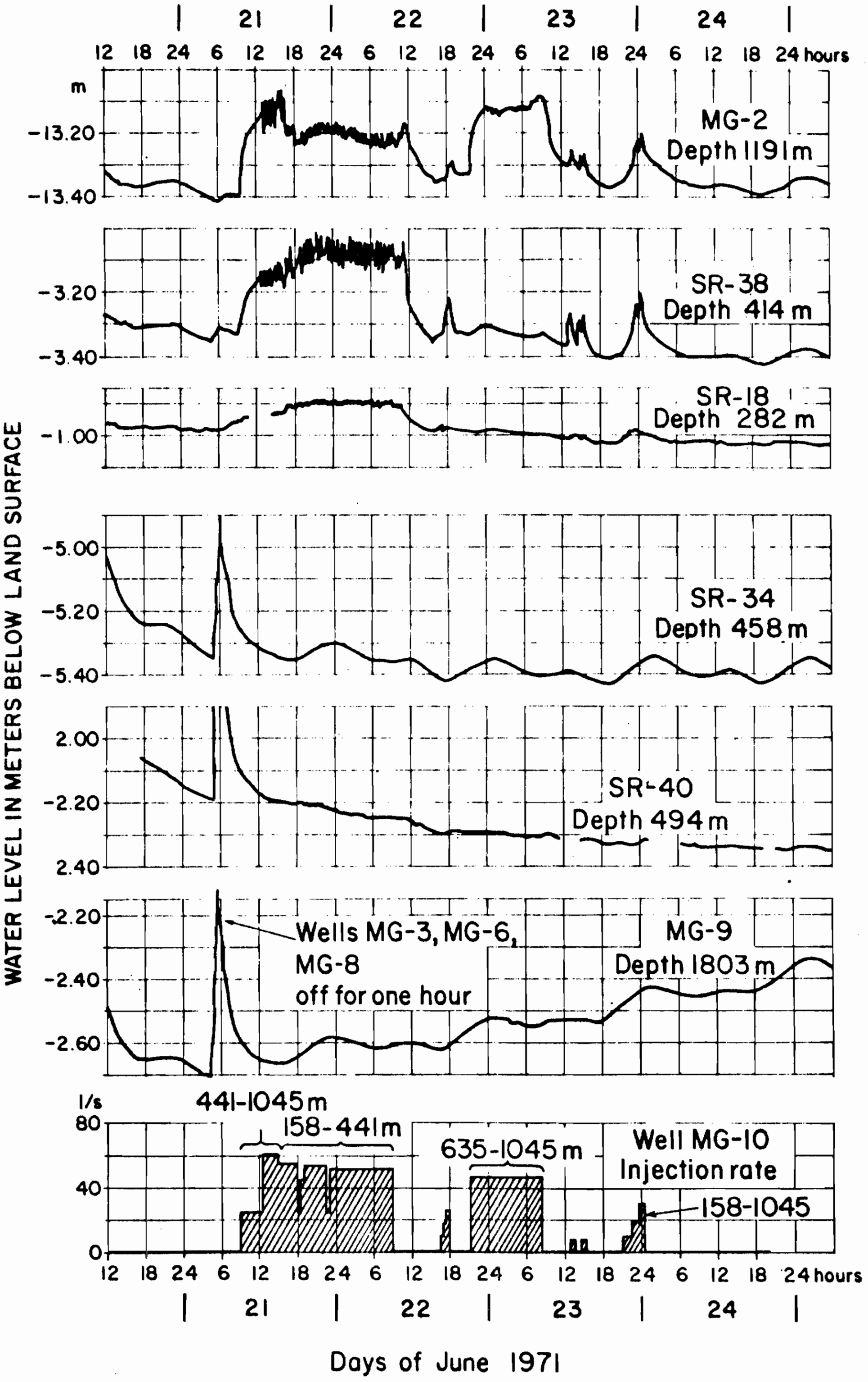
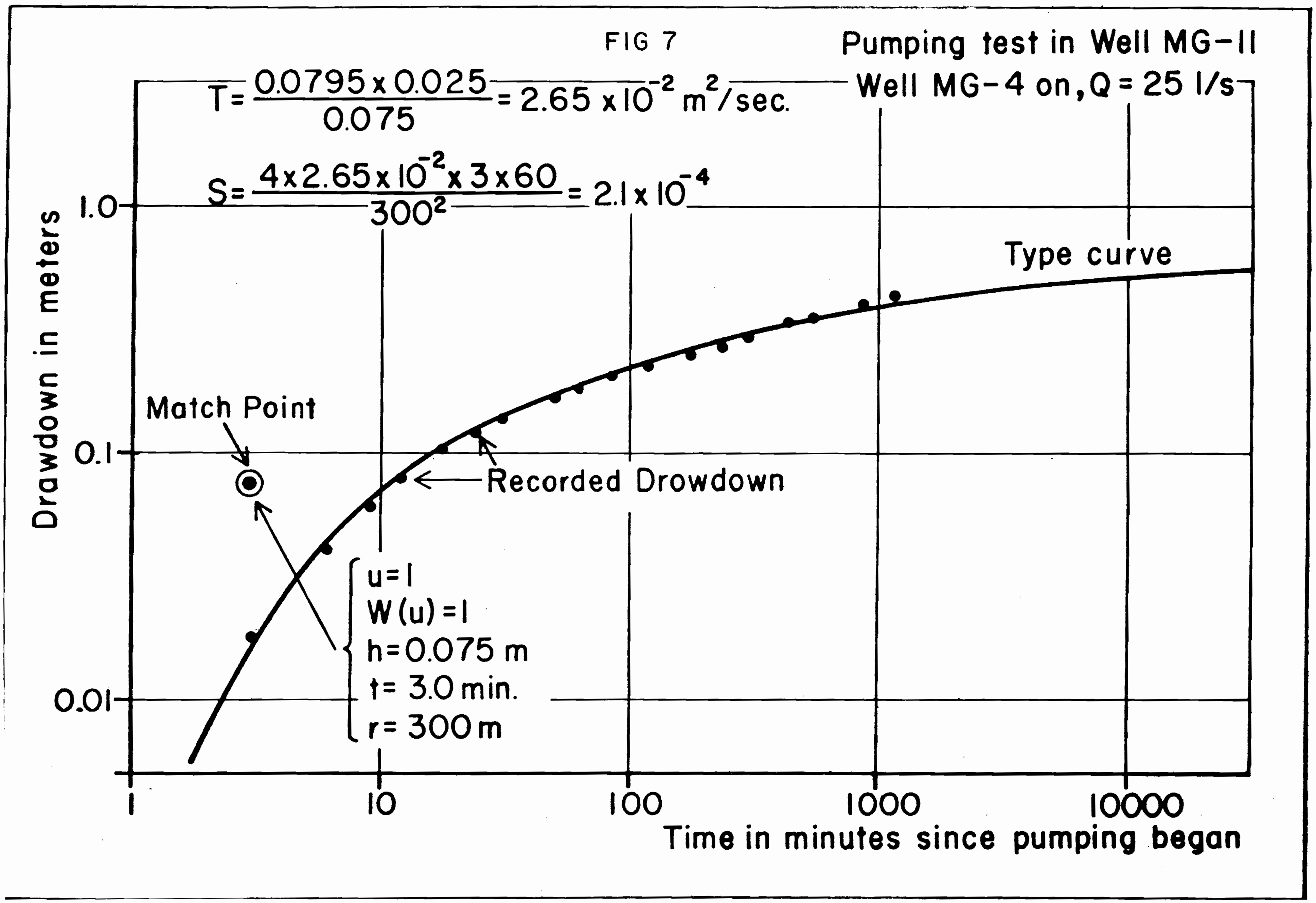


FIG 7



Pumping test in Well MG-II

Well MG-4 on, Q = 25 l/s

$$T = \frac{0.0795 \times 0.025}{0.075} = 2.65 \times 10^{-2}\ m^2/sec.$$

$$S = \frac{4 \times 2.65 \times 10^{-2} \times 3 \times 60}{300^2} = 2.1 \times 10^{-4}$$

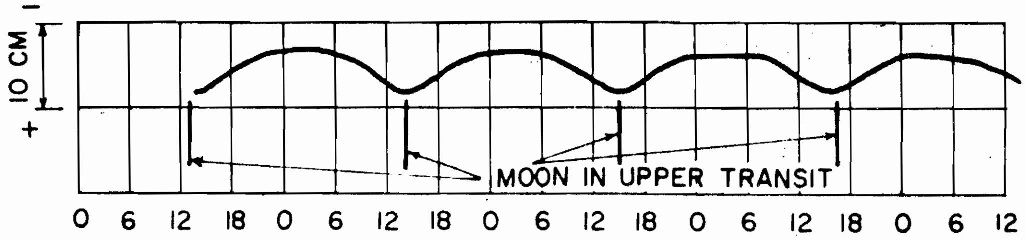
$u = 1$
$W(u) = 1$
$h = 0.075\ m$
$t = 3.0\ min.$
$r = 300\ m$

FIG 8

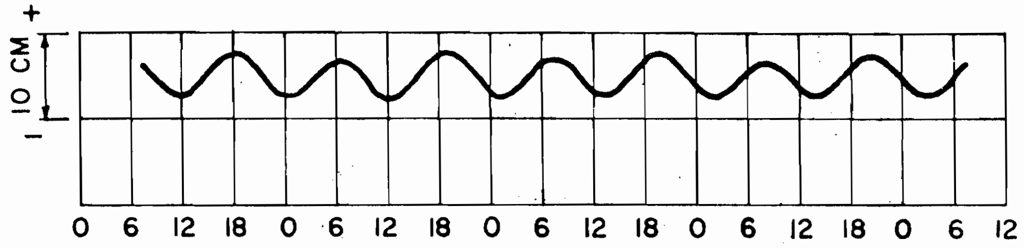
I. THE EQUILIBRIUM TIDE X 10^{-1}

MOON: $0.26\left[\cos^2 L \cos^2 d \cos 2Z - \sin 2L \sin 2d \cos Z\right]$

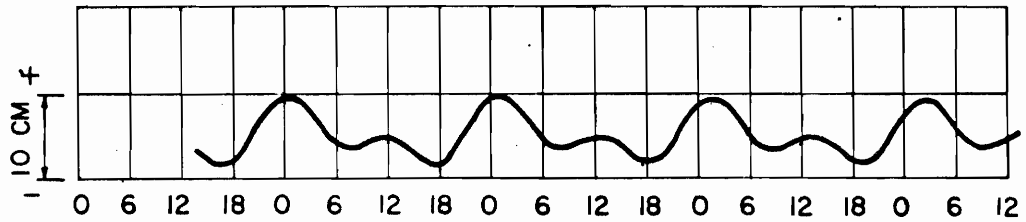
SUN: $0.12\left[\cos^2 L \cos^2 d_1 \cos 2Z_1 - \sin 2L \sin 2d_1 \cos Z_1\right]$



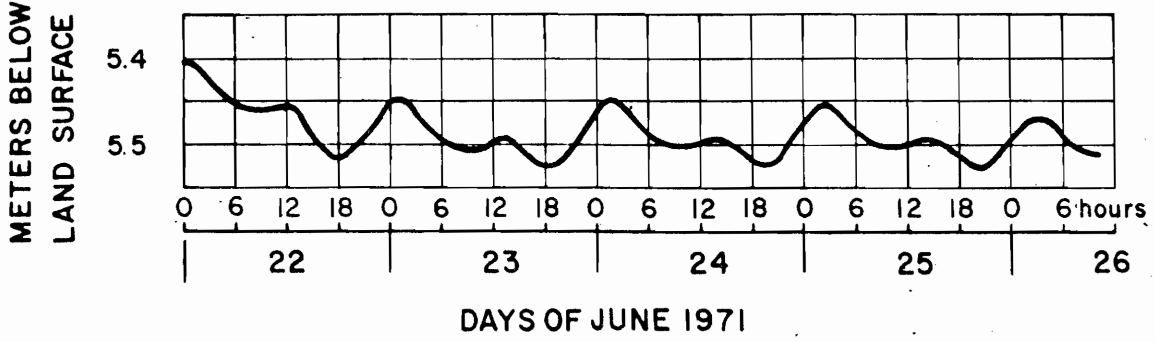
II. THE OCEAN TIDE X 1.5 X 10^{-2}



RESULTANT OF I AND II
(TIME LAG OF II = 6 HOURS)



HYDROGRAPH OF WELL SR-34



J-Mosfhr.Tnr.451 Fnr.12797

FIG 9

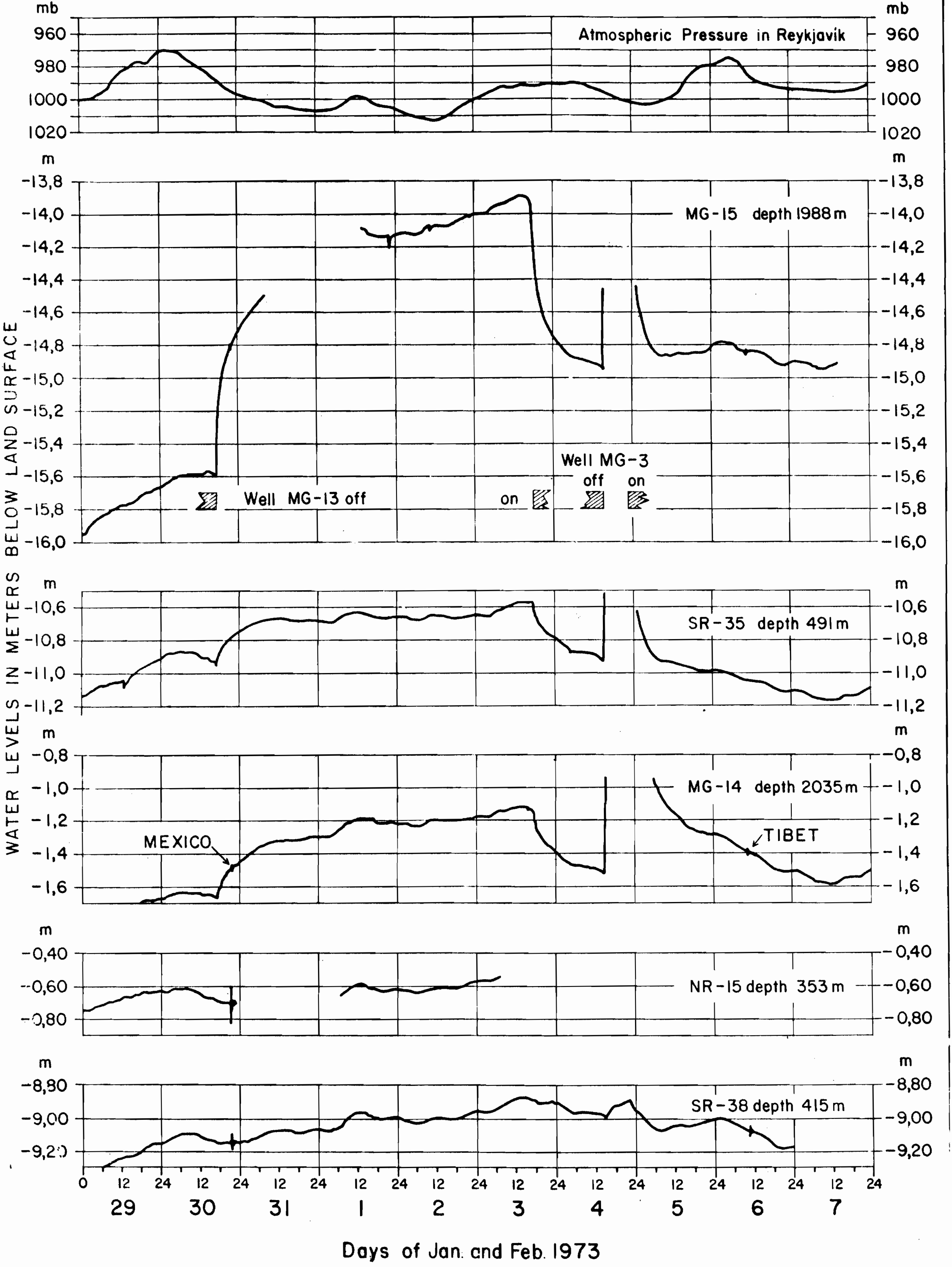
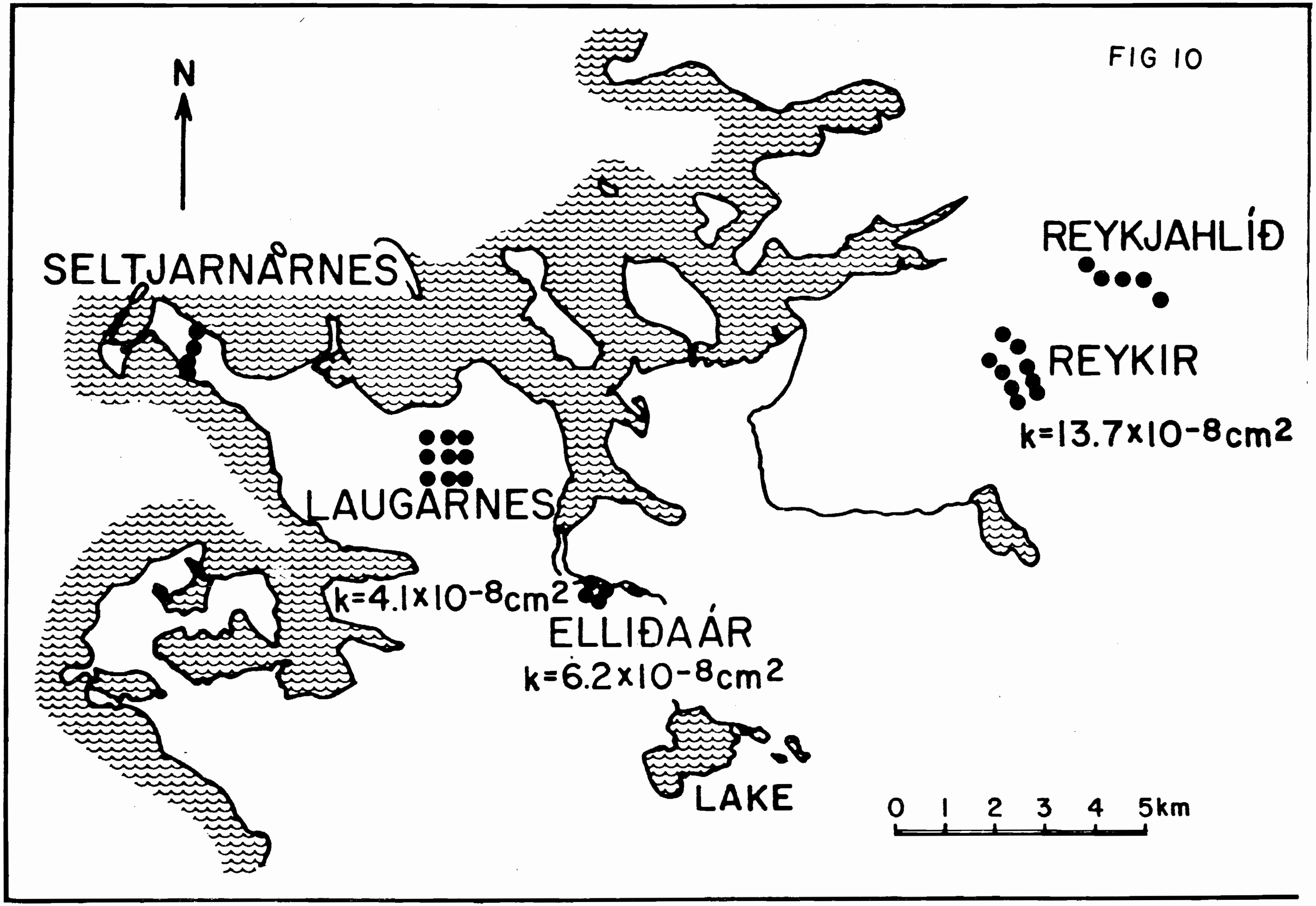

mb
960
980
1000
1020
Atmospheric Pressure in Reykjavík
m
-13,8
-14,0
-14,2
-14,4
-14,6
-14,8
-15,0
-15,2
-15,4
-15,6
-15,8
-16,0
MG-15 depth 1988 m
Well MG-13 off
on
Well MG-3
off
on
WATER LEVELS IN METERS BELOW LAND SURFACE
-10,6
-10,8
-11,0
-11,2
SR-35 depth 491 m
-0,8
-1,0
-1,2
-1,4
-1,6
MG-14 depth 2035 m
MEXICO
TIBET
-0,40
-0,60
-0,80
NR-15 depth 353 m
-8,80
-9,00
-9,20
SR-38 depth 415 m
0
12
24
29
30
31
1
2
3
4
5
6
7
Days of Jan. and Feb. 1973

FIG 10


N
SELTJARNARNES
LAUGARNES
k=4.1x10-8cm2
ELLIÐAÁR
k=6.2x10-8cm2
LAKE
REYKJAHLÍÐ
REYKIR
k=13.7x10-8cm2
0 1 2 3 4 5km