FILE M-1-D

OTH KEN

2 COPY

GROUND-WATER CONDITIONS IN THE VICINITY OF THE DEEP RUTH MINE AT RUTH, NEVADA

Prepared for

Kennecott Copper Corporation

Nov. 1959

Leggette, Brashears & Graham
Consulting Ground-Water Geologists
551 Fifth Avenue
New York

GROUND-WATER CONDITIONS IN THE VICINITY OF THE DEEP RUTH MINE AT RUTH, NEVADA

A study of ground-water conditions in the vicinity of the Deep Ruth Mine at Ruth, Nevada has been made at the request of S. D. Michaelson, Chief Engineer of the Nevada Mines Division of the Kennecott Copper Corporation. During the construction of the Deep Ruth vertical shaft, a heavy inflow of ground water was encountered in a fractured zone in the limestone at a depth of about 520 feet (about 6,385 feet above sea level). Mining officials estimate that ground water entered the shaft at the rate of about 10,000 gpm (gallons per minute) immediately after the fractured zone was intersected. After this fractured zone had been grouted off, the shaft was sunk to a depth of about 1,360 feet where another heavy inflow of water was encountered.

The Deep Ruth Mine will be developed by caving methods to depths nearly 1,000 feet greater than the fractured zone encountered at 520 feet. Because of this, officials of the Nevada Mines Division are concerned over the possibilities that as the ground is broken during the caving operations, ground water may be released from the limestone in sufficient quantities to cause serious flooding problems in the mines. Accordingly, the study was made for the purpose of evaluating the probable extent and potential ability of the fractured zones to transmit ground water into the Deep Ruth Mine. An evaluation was also desired of the feasibility of lowering ground-water levels in the limestones around the mine down to the bottom of the pro-

posed mine workings.

A field inspection was made during January 1959 to investigate surface conditions and to observe ground-water conditions in the Deep Ruth Mine. An inspection was made of the various open pits in the area and the underground workings of the Deep Ruth Mine. In addition to the field inspection, a study was also made of the ground-water information in the files of the Nevada Mines Division at Ruth and in U. S. Geological Survey Professional Paper 96 (The Geology and Ore Deposits of the Ely, Nevada, by Arthur C. Spencer). The ground-water problem was discussed with J. C. Kinnear, Jr., R. C. Nispel, L. A. Green, H. L. Bauer, Jr., and other mining officials. Following the field inspection, the problem was discussed with S. D. Michaelson and C. B. Michaelson at the Kennecott Copper Corporation offices in Salt Lake City.

The ore body at the Deep Ruth Mine consists of weathered monzonite poryphry. It is surrounded by beds of shale and limestone. The monzonite and the beds of shale are relatively impermeable and yield very little ground water. The limestones, however, contain many fractures, faults and solution openings that contain large quantities of ground water in storage. Some of the fracture systems include openings that are closely interconnected and can readily transmit large quantities of ground water.

The limestones that produce water in the Deep Ruth Mine crop out extensively at the land surface, where they are readily recharged whenever moderately heavy precipitation occurs. Ruth, Nevada is located in a semi-arid region where the yearly

precipitation is often less than 10 inches. However, the surface runoff and the use of water by the sparse vegetation is small. Although evaporation losses are high, a considerable part of the precipitation sinks into the ground and ultimately infiltrates down to the water table in the limestone, after periods of heavier precipitation. The rainfall records at Ruth show that the monthly rainfall often exceeds 1.5 inches several times each year and in some months, it may be considerably greater than 1.5 inches. For example, the precipitation in March 1958 was 3.1 inches and in May 1957, it was 4.9 inches.

The ore body at the Deep Ruth Mine is a downward extension of an ore body that was mined through the Star Pointer Shaft of the Ruth Mine. Ground water was pumped continuously from the Ruth Mine from about 1915 to 1948, when mining operations were discontinued. From 1915 to 1941, the bottom of the Star Pointer Shaft was at an elevation of about 6,200 feet above sea level. The shaft was then sunk to an elevation of about 5,680 feet above sea level.

The Deep Ruth Mine is served by two shafts located about 5,200 feet apart, as shown by figure 1. The northerly shaft, the Deep Ruth vertical shaft, and the southerly shaft, the Kellinske Inclined Shaft, are connected by a haulage drift (the "D" level) driven at an elevation of about 6,105 feet at the Deep Ruth Shaft to an elevation of about 6,125 at the Kellinske Shaft. The Star Pointer Shaft has also been connected to the "D" level haulage drift. At present, this shaft yields about 300 gpm by gravity flow. In January 1959, the pumpage at

the Deep Ruth Shaft amounted to about 1,600 gpm and the pumpage at the Kellinske Shaft, including the drainage from the Star Pointer Shaft, amounted to about 1,200 gpm.

When water is withdrawn from a rock well, the water level in the ground-water reservoir is drawn down in the vicinity of the well, forming an inverted cone of depression in the water level or the artesian pressure surface. The drawdown is greatest in the well and diminishes as the distance from the well increases. Removal of water from a mine shaft which intersects water-bearing openings will produce approximately the same results. The amount of drawdown at a given distance from the shaft is dependent not only on distance, but also on the rate and duration of pumping and the hydraulic properties of the rock formation.

The hydraulic properties of water-bearing rocks, such as the limestones at Ruth, Nevada, may be determined by analyzing the decline of artesian pressure produced by an increase in the rate of withdrawal of water or by analyzing the recovery of water levels produced by a decrease in the rate of withdrawal from a mine shaft. Moreover, an analysis of the rise or decline of water level in observation wells resulting from a change in rate of withdrawal from a mine shaft will also provide the basis for determining the rate of decline of water level that will be produced by increasing the pumping rate. Such information would provide a basis for determining the rate of withdrawal required to lower the artesian pressure in the limestone around the Deep Ruth Mine to safe operating levels.

Available data indicate that the rise and fall of water

level in the limestones at Ruth, Nevada has been more or less proportional to the rate of pumping from the Ruth Mine and the Deep Ruth Mine. This indicates that the openings in the limestones are freely interconnected and that drainage of ground water has occurred over an extensive area.

Many exploratory shafts were sunk in the Ruth area from 1900 to 1910, during the early period of the development of the ore bodies. Water-level measurements were made in some of these shafts by Spencer in 1910 before heavy pumping had started. These measurements indicate that the elevation of water levels in the limestones near the Ruth Mine was approximately 6,700 feet above sea level. Measurements of water level in several of the shafts penetrating the limestone in the vicinity of the Deep Ruth Mine are given in the following table.

The Ruth Mine was operated from 1915 until it was shut down in 1948. Discussions with mining men who had worked in the Ruth Mine, and an inspection of mine records indicates that the average pumpage from this mine from 1915 to 1948 was probably about 500 gpm. Thus, during the life of the mine, a total of nearly 10 billion gallons of ground water were withdrawn from the limestone. In April 1951, just before pumping was again resumed at the Star Pointer Shaft as part of the dewatering operations connected with the deepening of the Kellinske Shaft, the water level in the Star Pointer Shaft was 6,617 feet above sea level, as shown by the following table. It is also reported that the water level in the Star Pointer Shaft rose to an elevation of about 6,700 feet above sea level earlier in 1951. Thus, complete or nearly complete recovery of water levels

ELEVATION OF WATER LEVEL IN LIMESTONES
IN THE VICINITY OF DEEP RUTH MINE
(Feet above mean sea level)

Shaft	Collar elevation	Bottom elevation	Water level elevation	Date water level measured a/	Distance from Deep Ruth Shaft (feet)	Distance from Kellinske Shaft (feet)
Ruth Incline	7050	6630	6700	Aug 1910	4700	1300
Zack	7100	6465	6700	1910	4300	2400
American	7140	6620	6720	1910	5400	200
Brilliant	7030	6405	6595	1910	5700	2000
Star Pointer	7130	5680	6617	Apr 1951	3600	1300
Kellinske	7141	6096	6613	June 1952	5200	--
Deep Ruth	6905	5545	6613 b/	Apr 1952	--	5200

a/ 1910 water-level measurement taken from U. S. Geological Survey Professional Paper 96. Other measurements taken from records of Nevada Mines Division.

b/ Pumpage from shaft was 660 gpm.

occurred in the limestones in the three-year period, 1948-51. This indicates that much of the water pumped during the period 1915-48 was derived from rainfall infiltration. Moreover, this also indicates that the limestones are capable of transmitting water toward the Star Pointer Shaft from considerable distances.

It is reported that similar recoveries of ground-water level have occurred at the Alpha Shaft, an old mine shaft located about three miles west of the Star Pointer Shaft. The Alpha Shaft penetrates beds of limestone similar to those encountered by the shafts at the Deep Ruth Mine. In Professional Paper 96, Spencer reports that in 1910, the elevation of the water level in the Alpha Shaft was about 6,160 feet above sea level. Mining records indicate that the Alpha Shaft was operated from 1917 to 1923, from 1928 to 1931, and from 1938 to 1940.

Miners who worked in the Alpha Shaft report that it was necessary to pump water from this shaft at rates of from 2,000 to 2,500 gpm to hold the water level in the shaft below the principal mine workings. According to these miners, the pumping water level in the shaft was held at an elevation of 5,350 feet above sea level (the 1800 level). Moreover, these miners indicate that during the periods when the mine was shut down, the water level in the Alpha Shaft recovered to about 6,100 feet above sea level (the 1,000 level) after each shut down, or about to the 1910 level measured by Spencer. It is also reported that recovery of water level immediately after cessation of pumping was very rapid, as it would rise from the 1,800 level to the 1,400 level, a vertical distance of about 400 feet, in about 45 minutes. This indicates that the limestone can freely

transmit water over large distances.

The sinking of the Deep Ruth Shaft and the deepening of the Kellinske Shaft was begun in 1951. This work and the construction of the "D" level haulage drift which connects the two shafts, was completed in March 1955. The total amount of ground water pumped from these shafts from about April 1951 to January 1959 was about 12 billion gallons. Most of the ground water was pumped during the period from January 1953 to January 1959. The highest monthly withdrawal occurred during November 1953, when the average rate of pumping was about 5,300 gpm.

The rate of pumping at the Deep Ruth Mine from January 1952 to January 1959 is shown on figure 2. This graph shows several significant features. First, the data show that the monthly pumping gradually increased during 1953 as both shafts were being deepened simultaneously. Following this, a gradual decrease in the rate of pumping occurred in 1954, even though the sinking of the Deep Ruth Shaft was continued throughout the year.

As the Deep Ruth Shaft was being completed at a depth of 1,360 feet in January 1955, it intersected an open fractured zone which produced considerable amounts of water, and caused a sudden increase in the rate of pumping. Following this incident, the rate of pumping gradually decreased until February 1957, when the bottom of the Deep Ruth Shaft was plugged with cement grout. The grouting caused a sudden drop in the rate of pumping as shown by figure 2. Since then, pumpage has been gradually decreasing.

The pumpage data for the Deep Ruth Mine have also been plotted on figure 3, which is a plot of the average monthly pumping rate against the logarithm of time. As shown, the rate of decline of pumpage after the shaft bottom had been plugged was about 5 mgd (million gallons per day) per log cycle, or about the same as that which occurred prior to the grouting. In view of this, it is believed that if no new workings are opened in the Deep Ruth Mine, the decrease in the rate of pumping will follow the trend shown on figure 3. This would indicate that the rate of pumping will gradually decline to about 3 mgd by the end of 1962.

The behavior of the water level in the limestones around the Deep Ruth Mine in response to changes in the rate of pumping, and the slow decrease in rate of pumping at the Deep Ruth Mine, indicate that the mine workings have intersected an extensive ground-water reservoir. Furthermore, the water-level behavior indicates that the two shafts at the Deep Ruth Mine are acting as two large-diameter wells, one located north of the ore body and the other south of the ore body. However, there is insufficient data available to accurately determine the hydraulic characteristics of the limestones except in a very general way.

Some information as to the decline of the water level in the limestones in the vicinity of the Deep Ruth Shaft is available but none is available for the Kellinske Shaft. It is known, however, that the water level in the limestones around both shafts was at an elevation of about 6,600 feet above sea level, or somewhat greater, before dewatering was started in 1951.

Diamond drill holes at the 605 level pumping station at the Deep Ruth Shaft were flowing during the early stages of shaft sinking. Since then, these drill holes have ceased flowing. This shows that the water level in the limestones near the shaft has been drawn down below an elevation of 6,300 feet above sea level. At present, ground water is issuing from the shaft walls about 100 feet above the "D" level drift. Apparently therefore, the water level in the limestone around the shaft lies somewhere between an elevation of 6,200 and 6,300. This indicates that continuous pumping during the last seven years has caused a water-level decline of approximately 300 to 400 feet.

The average rate of pumping from the Deep Ruth Shaft during the five-year period from 1954 to 1958 is estimated to have been about 2,000 gpm. Apparently, the rate of drawdown in the limestone is proportional to the rate of pumping. Accordingly, it may be assumed that if the Deep Ruth Shaft could have been pumped at an average rate of 4,000 gpm (double the actual average pumping rate), the water level in the rocks surrounding the shaft would have been lowered approximately 1,200 to 1,400 feet (double the actual decline). However, because the pumping water level in the Deep Ruth Shaft is only about 155 feet above the bottom of the shaft, it would not be possible to double the rate of pumping. In order to pump greater quantities of water from the shaft, it will be necessary to penetrate additional water-bearing zones in the limestone. This may be accomplished by deepening the shaft, by extending the mine workings or by intersecting water-bearing zones with holes drilled from the mine workings. The yield of the Kellinske

Shaft could be increased by similar measures.

A reliable estimate of the rate of pumping required to dewater the limestone around the Deep Ruth Mine to levels that would prevent serious flooding problems, if caving operations intersect highly productive water-bearing zones, cannot be made until hydraulic characteristics of the limestone have been determined. Carefully controlled drawdown tests involving a pumping well and a number of observation wells are needed to provide this information. Such tests can be run by pumping water from a large-diameter well or a mine shaft. Diamond drill holes in the mine or churn drill holes from the surface could be used as observation wells. It would be preferable to use a mine shaft as the pumping well because more water usually can be pumped from a mine shaft than from a well and because pumping from a shaft will usually more adequately sample the actual conditions involved in the dewatering problem.

Before drawdown tests are made, observation wells should be drilled from the mine workings and from the land surface to determine the elevation and extent of the cones of depression that have been developed around the Deep Ruth Shaft and the Kellinske Shaft. After the general extent and shape of the cones of depression have been determined, pumping tests should be made to determine the ability of the limestone to transmit water into the mine.

The pumping water level in the Deep Ruth Shaft is maintained at an elevation of approximately 5,700 feet, or about 400 feet below the floor of the "D" level. The rate of pumping from that part of the Deep Ruth Shaft below the "D" level is about

1,000 gpm. If the rate of pumping in the Deep Ruth Shaft is reduced to about 400 to 500 gpm, the water level in the shaft would probably recover to an elevation of about 6,100 feet, an elevation just below the floor of the "D" level. Although such a decrease in rate of pumping is relatively small, it is possible that this reduction might cause sufficient recovery of water level in the vicinity of the shaft to provide the data needed for determining the hydraulic properties of the limestone. Observation wells drilled from the "D" level would be needed to detect changes in artesian pressure.

If a reduction in pumping rate in the Deep Ruth Shaft of 500 to 600 gpm is not sufficient to cause measureable recoveries of artesian pressure, some other method would have to be employed, such as the drilling of one or more high-capacity artesian wells. It might be possible to drill such wells from underground stations rather than start at the land surface.

Diamond drill holes that are installed on the "D" level should be of Ex size and several hundred feet long, to make sure that sufficient water-bearing openings are intersected to provide representative data on artesian pressure. The upper part of the wells should be cased with a 20-foot length of pipe grouted into the limestone. The wells should be provided with valves and fittings for installing pressure gages to read the artesian pressures. Churn drill holes put down from the land surface should be not less than 6 inches in diameter and should be carried to depths about that of the "D" level. The churn drill holes should be cased through the overburden and grouted tightly into the underlying bedrock.

In view of the fact that the present low pumping water level in the Deep Ruth Shaft provides an opportunity for testing the limestone by reducing the rate of pumping, it is recommended that observation wells be drilled in this area first, and that observation well drilling in the Kellinske Shaft area be held in abeyance until testing has been completed at the Deep Ruth Shaft. It is, therefore, recommended that observation wells be drilled at the following sites:

1. A 90 degree down hole, north of the Deep Ruth Shaft, starting at the north end of the "D" level.

2. A 90 degree down hole starting at the "D" level about 200 feet south of Deep Ruth Shaft.

3. A 90 degree down hole starting at the "D" level about 400 feet south of Deep Ruth Shaft.

4. A 90 degree down hole starting at the "D" level about 600 feet south of Deep Ruth Shaft.

5. Completion of the surface holes located 1,000 feet and 2,000 feet north of the Deep Ruth Shaft, as described in M. L. Brashears' letter dated May 25, 1959 to L. A. Green. The drilling of these holes is being carried on with yearly assessment funds.

After the holes called for in items 1 and 2 above have been drilled, it would be desirable to make a preliminary recovery test at the Deep Ruth Shaft to determine the rise of artesian pressure caused by a reduction in pumping rate. Such preliminary data might provide a basis for changing the suggested spacing of observation wells on the "D" level.

SUMMARY

1. The limestones surrounding the Deep Ruth ore body contain extensive water-bearing zones that freely transmit large quantities of ground water over considerable distances.

2. Infiltration of precipitation is continuously recharging the limestones.

3. The pumpage at the Deep Ruth Shaft is gradually dewatering the limestone in the vicinity of the shaft. The water level around the shaft has declined from 500 to 400 feet since 1951. The pumping at the Kellinske Shaft is probably causing similar dewatering of the limestones in that area.

4. The pumping rate at the Deep Ruth Mine has been gradually declining since 1955. If no new mine workings are opened, it is estimated that the pumpage will decline to about 3 mgd (2,100 gpm) by about 1965. Under these conditions, the water level in the limestones around the shaft may decline to about "D" level by that time.

5. If new mine workings intersect additional water-bearing zones, the rate of pumping may have to be greatly increased. This would, however, cause an acceleration in the rate of dewatering.

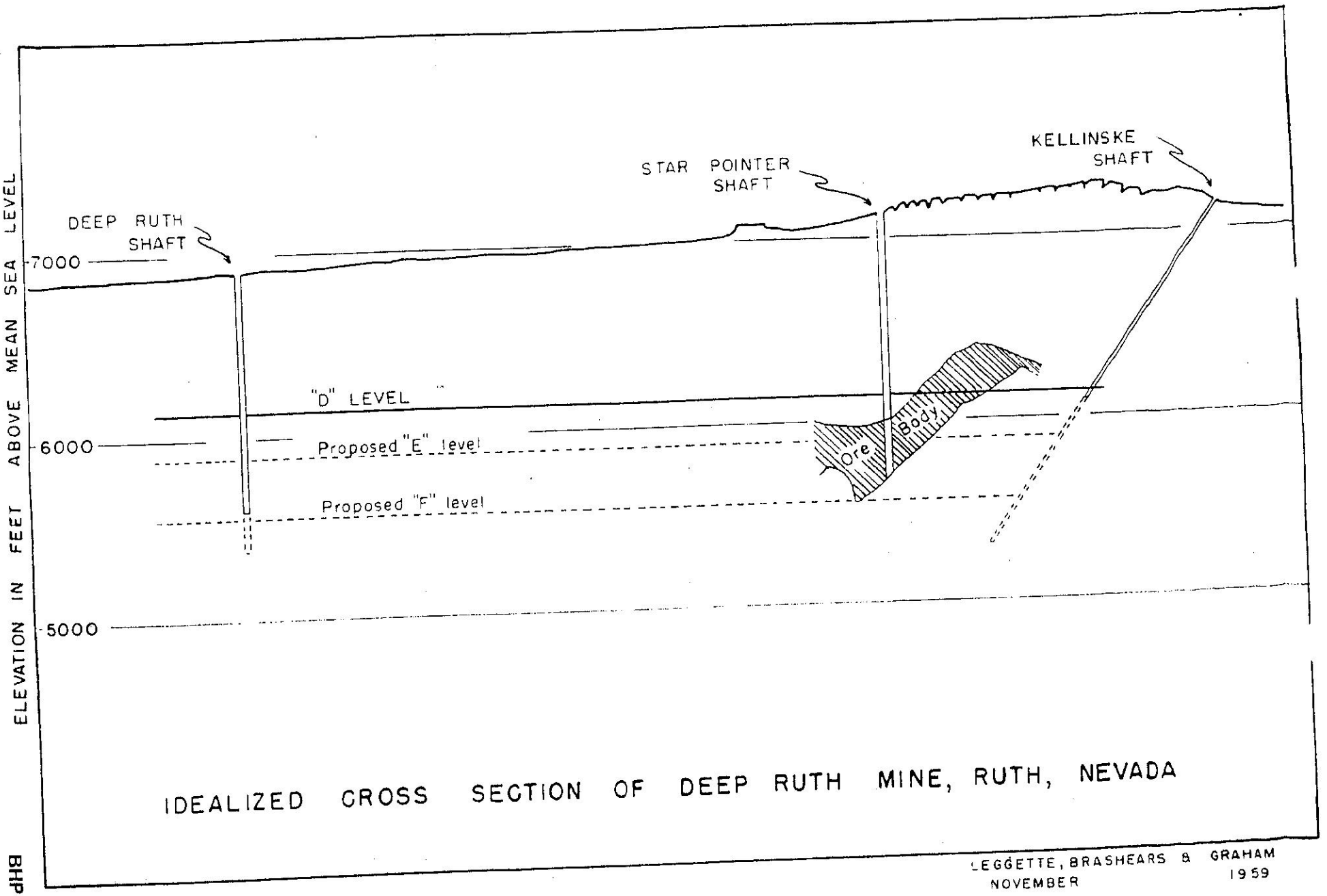
6. Reliable estimates of the rate of pumping and length of time required to dewater the limestones around the Deep Ruth Mine to different levels cannot be made until the hydraulic properties of the limestones have been determined. Observation wells in the mine and from the surface to the north of the Deep Ruth Shaft are needed to determine the shape and extent of the cone of depression and for measuring changes of

artesian pressure caused by varying the rate of pumping at the Deep Ruth Shaft. Such data will provide means for determining the hydraulic properties of the limestones and furnish a basis for meeting future water problems.

LEGGETTE, BRASHEARS & GRAHAM

M. L. Brashears

November 27, 1959 M. L. Brashears



IDEALIZED CROSS SECTION OF DEEP RUTH MINE, RUTH, NEVADA

LEGGETTE, BRASHEARS & GRAHAM
NOVEMBER 1959

BHP 1048

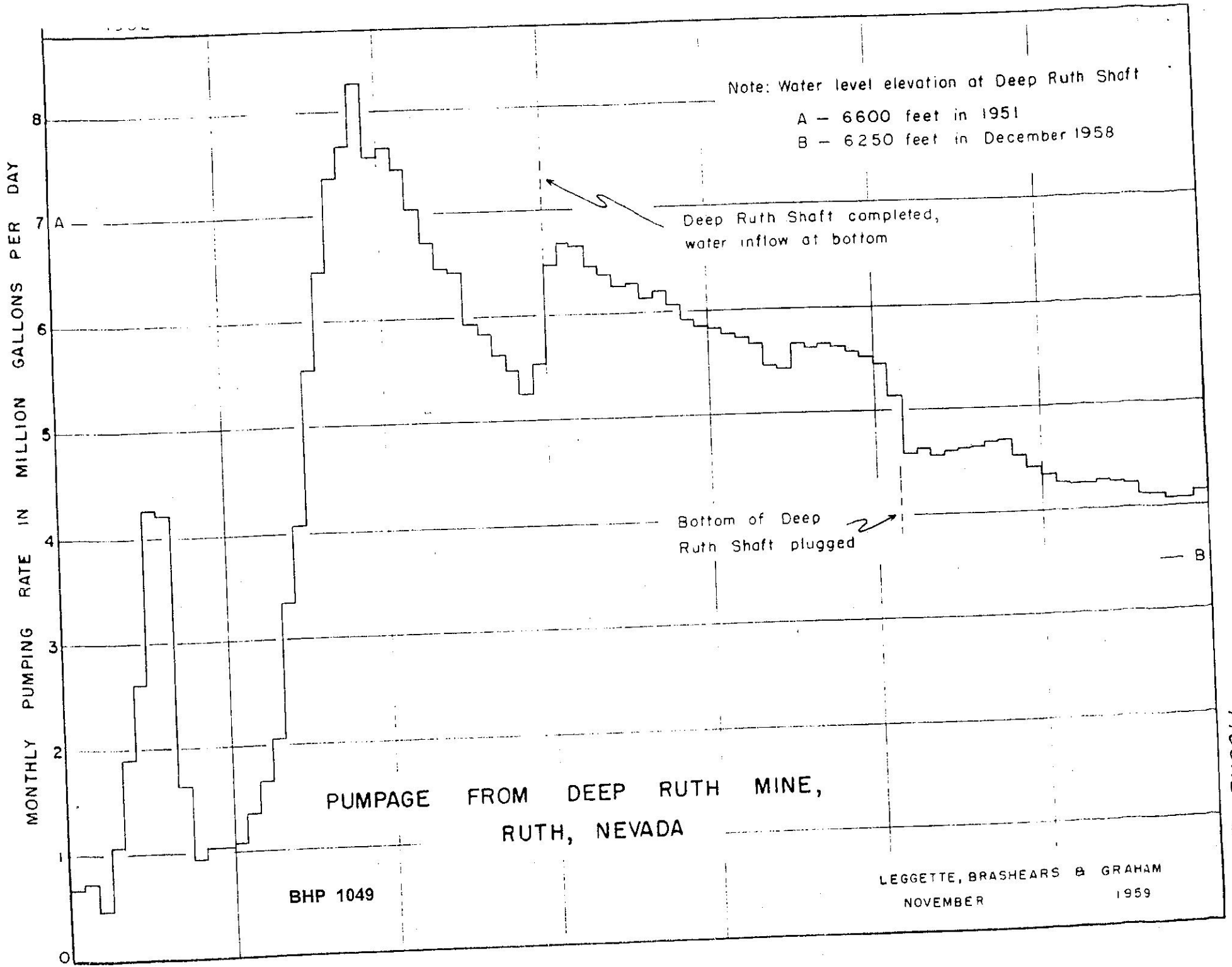

Note: Water level elevation at Deep Ruth Shaft
A – 6600 feet in 1951
B – 6250 feet in December 1958
Deep Ruth Shaft completed, water inflow at bottom
Bottom of Deep Ruth Shaft plugged
A
B
MONTHLY PUMPING RATE IN MILLION GALLONS PER DAY
0
1
2
3
4
5
6
7
8
PUMPAGE FROM DEEP RUTH MINE, RUTH, NEVADA
BHP 1049
LEGGETTE, BRASHEARS & GRAHAM
NOVEMBER 1959

FIGURE 2

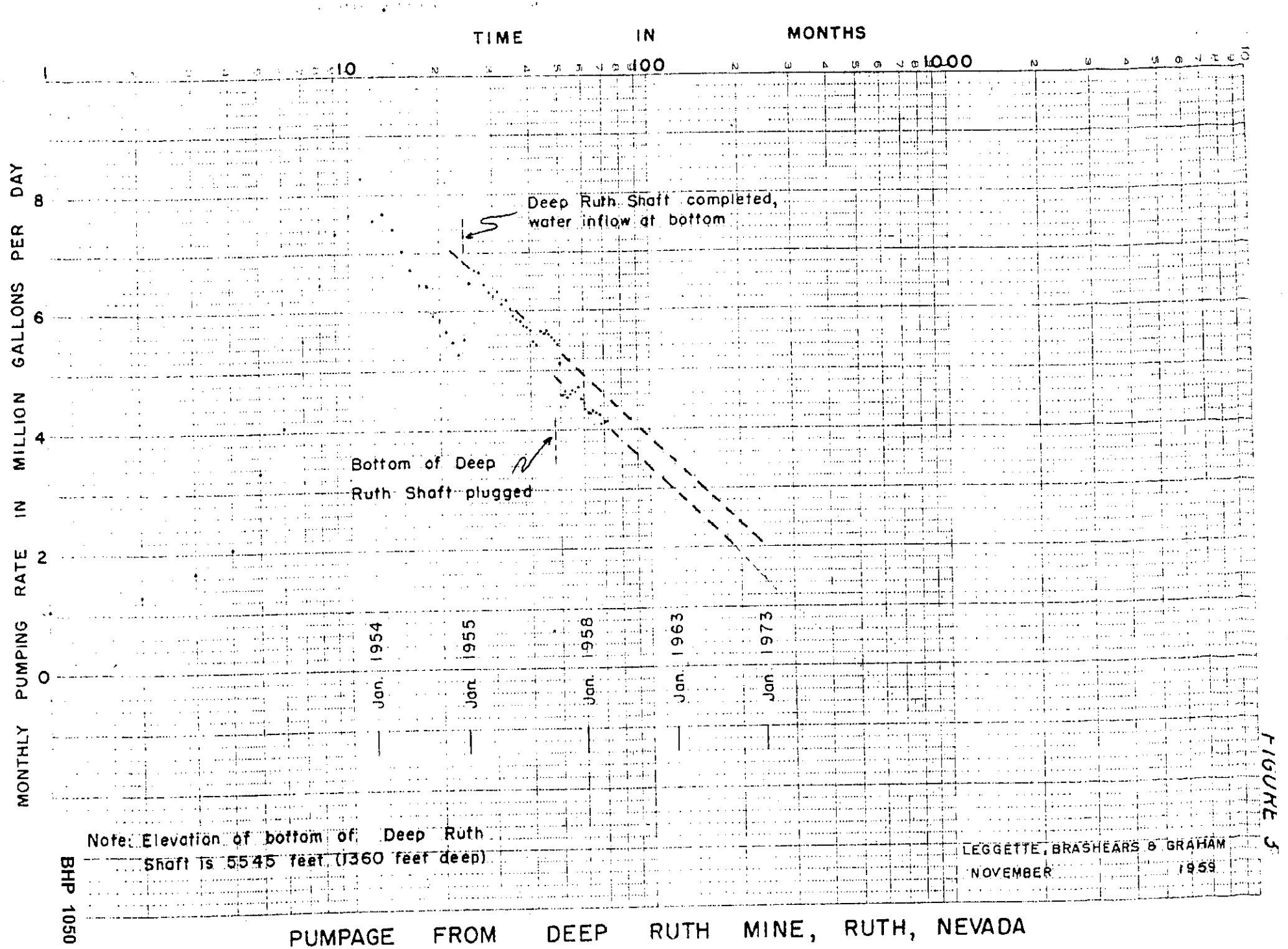


FIGURE 5

PUMPAGE FROM DEEP RUTH MINE, RUTH, NEVADA