OPEN FILE

(260)

U. S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

EFFECT OF GROUND-WATER DEVELOPMENT ON THE POOL LEVEL IN DEVILS HOLE, DEATH VALLEY NATIONAL MONUMENT NYE COUNTY, NEVADA

By

G. F. Worts, Jr.

Prepared at the request of
the National Park Service

Carson City, Nevada

August 1963

CONTENTS

ILLUSTRATIONS[1]

Page

1. Plates 1 through 3 from report by Walker and Eakin (1963).

EFFECT OF GROUND-WATER DEVELOPMENT ON THE POOL LEVEL IN DEVILS HOLE, DEATH VALLEY NATIONAL MONUMENT, NYE COUNTY, NEVADA

By G. F. Worts, Jr.

CONCLUSIONS

The National Park Service is concerned whether the increasing ground-water development in the Amargosa Desert will cause the natural pool level in Devils Hole to decline. The Geological Survey was requested by the Park Service to make a brief reconnaissance of the area and to report on the pertinent aspects of the geology and hydrology; the principal conclusions of this study are presented below.

1. The ground-water system.--Ground water in the Amargosa Desert occurs in the alluvium and in a regional system in the carbonate rocks. Devils Hole is a natural sink in the carbonate-rock system. Beneath the valley floor, where the carbonate rocks are at considerable depth, the hydraulic continuity between the two systems is poor. Along the west side of Ash Meadows a north-northwest-trending hydrologic barrier is postulated, and its affect on impeding the southwestward flow in the carbonate-rock system is believed to be the principal control on the occurrence of the large springs in Ash Meadows, which discharge about 25 cubic feet per second, and on the pool level in Devils Hole, about 2 miles east of the line of springs.

2. Effect of pumping the alluvial system.--The upper few hundred feet of the alluvial system has been developed for irrigation in an area centering about 12 miles northwest of Devils Hole. Although pumpage has increased steadily to about 3,000 acre-feet in 1962, and is expected to increase in the future, as of April 1963 it had had no affect on the pool level in Devils Hole. Pumping from the alluvium in this part of the area and in the areas to the south and east is not expected to affect the level in Devils Hole for at least the next several decades.

On the other hand, if substantial ground-water development should occur in the alluvium in Ash Meadows within a mile of Devils Hole, the pool level might be affected after a period of several years. However, the depth of wells, the magnitude of pumpage, and the proximity of the pumping to spring systems and other conduits connecting the two systems would control the time response and magnitude of decline in pool level.

3. Effect of pumping the carbonate-rock system.--A few wells reportedly have bottomed in the carbonate-rock system, but pumping has caused no affect on the level in Devils Hole. The permeability of the flow system, largely in solution channels and fractures, is moderately large; the coefficient of storage throughout most of the system probably is in the artesian range, or less than 0.001. Accordingly, if deep wells were drilled in the carbonate-rock system, pumpage a mile from Devils Hole probably would affect the pool level within a year. Again, the magnitude of decline would depend on the magnitude of the pumpage and upon the degree of hydraulic connection. For wells drilled 4 to 8 miles away, pumping probably would not affect the pool level for several years. If any of the nearby springs are heavily pumped or their outlets lowered, the pool level probably would be affected within a year.

If wells were drilled into the carbonate-rock system west of the postulated barrier, pumping probably would not affect the pool level for several tens of years.

INTRODUCTION

Nature of the Problem and Scope of this Report

Devils Hole is a natural pool of water about 10 feet in width and 40 feet in length, contained in carbonate rocks; the water surface is about 50 feet below the general land surface. The water extends downward through fractures and caverns and is part of a regional ground-water system contained in the carbonate rocks. The pool contains a species of fish, Cyprinodon Diabolis, not known in other parts of the world; the fish are about 1 inch in length. The protection of these rare fish was one of the principal reasons why the National Park Service incorporated Devils Hole in Death Valley National Monument.

The National Park Service now is concerned whether the increasing development of ground water in Ash Meadows and Amargosa Desert will cause the level in the pool to decline, which in turn might adversely affect the environment in which the small fish live. Moreover, a substantial decline would cause the pool level to retreat deeper into the fracture system, thereby destroying its scenic attraction.

Because of this immediate problem, the National Park Service requested the U.S. Geological Survey to investigate and report on the pertinent aspects of the geology and hydrology of Devils Hole and vicinity. Accordingly, on April 16 and 17, 1963, G. T. Malmberg and the author conferred with W. W. Danielson, Chief Ranger, at the headquarters of Death Valley National Monument, and made the field study.

This report briefly describes the general geologic features as they pertain to the occurrence of ground water at Devils Hole, the physical environment that controls the hydrostatic head of water in the pool, and the possible future effects of pumping on the pool level. Because the hydraulic properties of the carbonate-rock and alluvial ground-water systems are not known, this report of necessity presents highly generalized quantitative conclusions with respect to the effects of pumping either system on the pool level in Devils Hole.

Not evaluated in this report is the possible effect that climate might have on the pool level. This is brought to the attention of the National Park Service, because, for example, a prolonged drought conceivably could result in a decline in pool level, which in turn could be misconstrued as the effects of pumping. For the period of observation, 1956-63, no trend or net change in water level has occurred.

Location of Devils Hole

Devils Hole portion of Death Valley National Monument is a 40-acre tract, about 65 miles west of Las Vegas, Nevada, 12 miles northeast of Death Valley Junction, California, and 30 miles east of the Park Headquarters, Death Valley National Monument (pl. 1). It is in the SW¼SE¼ sec. 36, T. 17 S., R. 50 E., in the Amargosa Desert along the east side of the area known as Ash Meadows. It is reached from Death Valley Junction by taking a paved road, which trends northeastward, to the California-Nevada boundary, then northward along a dirt road past Ash Meadows Rancho. Devils Hole is at the south end of an unnamed ridge.

The area studied is on the Ash Meadows quadrangle, Nevada-California (scale 1:62,500), of the U.S. Geological Survey (1952). The quadrangle shows the principal highways, the secondary and dirt roads in the vicinity of Devils Hole, the principal springs in Ash Meadows, and the topography (contour interval 40 feet).

Plate 4 is a view of the pool in Devils Hole, showing the water-level recorder operated by the U.S. Geological Survey and the general configuration of the opening. The water deepens in the background where the roof of the hole intersects the water surface.

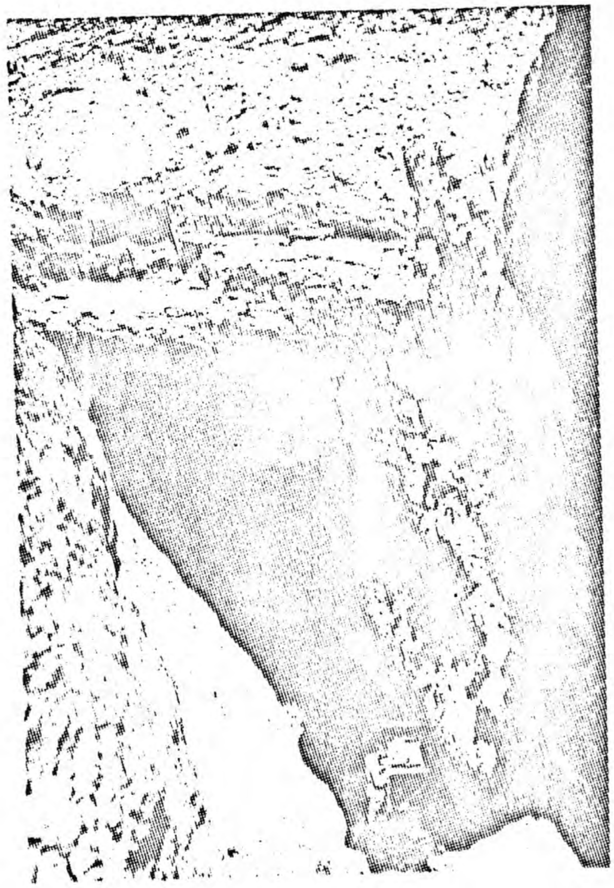


Plate 4.--View of Devils Hole showing pool and water-level recorder. (view is toward the northeast)

Photo by author

Previous Investigations

The detailed geology of the Ash Meadows quadrangle has been mapped by Denny and Drewes (written communication, March 1963), Regional Geology Branch, U.S. Geological Survey. The basic geologic mapping of Denny and Drewes and additional work done by Walker and Eakin (1963) are generalized on plate 2. The plate shows that Devils Hole is contained in carbonate rock (limestone and dolomite), which presumably underlies the younger alluvial deposits to the west from which the springs in Ash Meadows discharge.

The regional hydrology of the area has been described by the U.S. Geological Survey; briefly by Loeltz (1960) and in more detail by Walker and Eakin (1963). Both reports postulate that the water in Devils Hole and in the springs in Ash Meadows originates largely in the Spring Mountains, 15 to 20 miles to the east (pl. 3). (Plates 1 to 3 of this report are from the report by Walker and Eakin.)

A field-trip letter report, dated January 9, 1955, from P. M. Neely, National Speleological Society, to the Superintendent, Death Valley National Monument, describes the exploration of the underwater parts of Devils Hole. Exploration was made to a depth of about 120 feet and for a lateral distance (northeastward ?) of about 300 feet. Several caverns, both above and below water level, were found. In addition, numerous cavern openings were observed but were not entered or investigated.

Similar underwater surveys were made by the Southwestern Speleological Society in February and April 1961. The letter reports that exploration was made to a depth of 200 feet, and that at that depth the cavern follows a fault having a 70° dip; the width of the opening is about 20 feet. Dives made to the west indicated that several "rooms" were encountered and that the "main fault" continues unobstructed to the farthest point of observation.

PHYSICAL FEATURES OF DEVILS HOLE

Geologic Setting

This brief reconnaissance indicates that Devils Hole in large part is structurally controlled. The northeastward alinement of the pool and opening is controlled by a nearby vertical fault, which strikes about N. 40° E. (pl. 4, right wall). The strike of the carbonate-rock strata, which are intensely fractured, is nearly at right angles to the fault and is about N. 45° W.; the strata dip about 40° W. Two faults having minor displacement are exposed in the walls of Devils Hole: One exposed on the northeast end of the opening has a strike and dip of about N. 40° W., 70° E. (pl. 4); the other exposed along the northwest side has a strike and dip of about N. 20° E., 75° S. (pl. 4 left wall)

In the geologic past, movement along the faults resulted in a zone of weakness and openings in which ground-water could flow. Solution action by the water has enlarged, and still is enlarging, these openings. Fragments of carbonate rocks are sloughing into Devils Hole and range in size from boulders 8 to 10 feet in diameter (pl. 4, background) to small pebbles and sand (pl. 4, floor of pool).

Continued structural movement or solution action could cause extensive modification in the configuration of Devils Hole at any time. The instability of the walls, roof (pl. 4, background), and floor on which the water-level recorder rests presents a hazard to those who service the recorder or explore the underwater parts of the pool system.

Quality of Water

The water from Devils Hole was sampled January 22, 1953, and the analysis is shown below.

Constituent	ppm[1/]	Constituent	ppm[1/]
Silica (SiO_2)	23	Bicarbonate (HCO_3)	311
Iron (Fe)	.04	Carbonate (CO_3)	0
Calcium (Ca)	51	Sulfate (SO_4)	79
Magnesium (Mg)	21	Chloride (Cl)	22
Sodium (Na)	66	Fluoride (F)	1.6
Potassium (K)	7.2	Nitrate (NO_3)	.5
		Boron (B)	.38

Dissolved solids (residue at 180°C)	425 ppm
Hardness as $CaCO_3$: calcium and magnesium.	214 ppm
noncarbonate	0
Percent sodium	39
pH	7.4
Specific conductance (micromohs at 25°C)	686
Temperature.	92°F

1. Parts per million.

The analysis shows that the water is a sodium-calcium bicarbonate type. Water found in carbonate rocks is usually a calcium-magnesium bicarbonate type. The uncommonly large concentration of sodium in the water of Devils Hole and also in the springs in Ash Meadows suggests that the water in part may have been in contact with another rock environment, such as alluvium, between the recharge area and Devils Hole.

The fluoride concentration also is unusually large. In other desert areas a large fluoride concentration is commonly associated with faulting. The concentration of 1.6 ppm (parts per million) is somewhat more than that recommended by the U.S. Public Health Service, (1962, p. 8) for drinking water on interstate carriers.

The water temperature in the 1953 chemical analysis was 92°F; it was the same in April 1963. The relatively high temperature suggests deep circulation of the ground water in the carbonate rocks.

THE GROUND-WATER SYSTEM

A Dual System

Ground water in Amargosa Desert occurs principally in two environments -- the carbonate-rock system, of which Devils Hole is a part, and the system in the alluvium, or the alluvial system. As mentioned previously, the bulk of the supply in the carbonate-rock system probably originates in the Spring Mountains, east of Ash Meadows, and moves generally westward to Ash Meadows where most of it is discharged through about 12 springs (pl. 3). Loeltz (1960) and Walker and Eakin (1963) state that the total spring discharge is about 17,000 to 18,000 acre-feet per year. Unpublished work by the Geological Survey (Winograd, oral communication, 1963) and Walker and Eakin (1963), indicate that part of the supply, probably a relatively small proportion of the total, is contributed through that part of the carbonate-rock system underlying and adjacent to the Nevada Test Site, which is northeast of Amargosa Desert.

Water in the alluvium is supplied from two sources: infiltration of precipitation within the surficial drainage area, which probably supplies most of the recharge, and by upward and lateral leakage from the carbonate-rock system, which has a higher head. Walker and Eakin (1963) estimate that the total recharge to the alluvium is roughly 7,000 acre-feet per year.

The contours on plate 3 show the general direction of ground-water movement in the dual system. In general, those east of Nevada Highway 29 (California Highway 127) reflect water levels in the carbonate-rock system, and those to west, water levels in the alluvial system. South of Death Valley Junction the southward movement of ground water down the Amargosa River valley is largely in the alluvium. The isolated set of contours west of Nevada Highway 16 also represent ground-water levels in the alluvium.

The extent to which the two flow systems are interconnected has not been determined, except in general terms. Several deep wells in the alluvium in the southeastern part of T. 16 S., R. 49 E., have heads higher than nearby shallower wells, which suggests upward flow from the underlying carbonate-rock system. However, I. J. Winograd (oral communication, 1963) believes that volcanic rocks of low permeability may occur between the carbonate rocks and the alluvium beneath much of Amargosa Desert, principally north and west of Ash Meadows. If so, in these areas the hydraulic interconnection between the two flow systems would be poor.

Plate 3 shows that most of the springs in Ash Meadows have a north-northwest-trending alinement, extending from Last Chance Spring on the south to Fairbanks Spring on the north--a distance of about 10 miles. The water-level contours in this reach are closely spaced, because they are drawn on the altitudes of the discharging pools. They of course do not represent the "static" head at depth in the carbonate-rock system.

The reason for the alinement of the springs was not determined during previous investigations nor during this study. It is likely that the springs are structurally controlled--their alinement appears to be parallel to the major north-northwestward-trending faults (not shown on pl. 2) in the unnamed hills along the east side of Ash Meadows. Furthermore, the spring flow issues from lake beds and older alluvial deposits, which may be several hundred feet thick in the vicinity of the springs and which may thicken substantially and may become finer grained to the west. If these deposits of generally low permeability are underlain by poorly permeable ~~soils~~ rocks of Percambrian age, which may occur there as a result of structural deformation, the west-southwestward flow of ground water in the carbonate-rock system would be greatly impeded. However, this hypothesis does not explain the seemingly anomalous position of Ash Tree Spring, about 5 miles west of the general line of springs in Ash Meadows.

Whatever the exact cause may be, the barrier effect has caused the bulk of the flow in the carbonate-rock system to discharge, as it does, through the springs in Ash Meadows. Accordingly, it is concluded that the hydrologic barrier provides poor hydraulic continuity between the carbonate-rock system in the vicinity of Devils Hole and the alluvial system west of the barrier in the principal area of ground-water development southwest of Lathrop Wells.

Ground-Water Development in 1963

The principal area of ground-water development for irrigation in 1963 is in Tps. 16 and 17 S., and Rs. 48 and 49 E. (pl. 3). The supply is derived almost wholly from the alluvium; a minor amount may be supplied by upward flow from the underlying carbonate rocks. Although irrigation from wells has been carried on for many years, the amount pumped prior to 1955 was small. Since that time the pumpage has increased progressively until by 1962 about 18 wells pumped an estimated 3,000 acre-feet; pumpage for domestic use probably did not exceed 100 acre-feet (Walker and Eakin, 1963).

Although only 18 irrigation wells were pumped in 1962, nearly 90 reportedly had been drilled, principally west of Nevada Highway 29. Many of these are new wells, and in 1962 they were awaiting pumps and the installation of power lines. Thus, pumpage from the alluvium probably will be larger in 1963 than in 1962 and can be expected to increase in the future.

Most of the spring discharge of 17,000 to 18,000 acre-feet per year from the carbonate-rock system in Ash Meadows runs to waste; a minor amount is used to irrigate pasture.

The available drillers' logs show that about six wells penetrate "limestone" in the lowermost 10 to 100 feet of the wells. Of these, well 8c1 in T. 17 S., R. 52 E., is the closest to Devils Hole; the remainder are 12 to 15 miles to the northwest. All are near outcrops of the carbonate rocks. Only three of these wells, including well 8c1, are known to have been pumped in 1962, and the pumping had not affected the level at Devils Hole in April 1963.

With regard to the suitability of water in the alluvial system for irrigation use, Walker and Eakin (1963) state that although the chemical quality is generally suitable, water of median salinity is common and water of high salinity occurs locally. Boron commonly is found in relatively small concentration, but the wide range suggests that concentrations harmful to plants may occur locally. Despite these problems, large-scale irrigation development of water from the alluvium will not be limited by the chemical quality of water in selected areas. The moderate sodium content of water in the carbonate-rock system might present a problem if applied to sodium-rich soils.

Water-Level Fluctuations in the Alluvium

Water-level measurements in the alluvium in Amargosa Desert have been made by the U.S. Geological Survey since 1952, principally in the area of ground-water development in Tps. 16 and 17 S., Rs. 48 and 49 E. Except for seasonal fluctuations caused by pumping, only small net declines have occurred in these observations wells.

Walker and Eakin (1963, fig. 2) show that virtually no decline occurred from 1952 to 1958, but that from 1958 through 1962, water levels have declined 3 to 6 feet in most wells and as much as 12 feet in one well. Water levels in the alluvium in this area, which is about 12 miles from Devils Hole, will continue to decline as pumping continues. Moreover, levels can be expected to decline at an increasing rate and over a larger area as annual withdrawals become progressively larger in the future.

Water-Level Fluctuations in Devils Hole

The U.S. Geological Survey has maintained a continuous water-level recorder at the pool in Devils Hole since November 1956. The record shows two pertinent features: No net change in pool level has occurred since the record was started, and the pool level responds to several natural phenomena.

The natural phenomenon affecting the pool level are of interest but do not bear directly on the problem at hand. Briefly, the level responds to what appears to be diurnal earth tides on a regular 28-day pattern similar to ocean tides. The amplitude of the fluctuations ranges from less than 0.1 foot to about 0.3 foot. Changes in barometric pressure also cause the pool level to rise and fall, the magnitude depending on the rapidity and amount of barometric change. In general the amplitude ranges from less than 0.1 to as much as 0.4 foot, and may occur over a period of a day to as much as a week.

Finally, instantaneous fluctuations caused by earthquakes may produce an oscillation of pool level of a few hundredths of a foot to more than a foot, depending in general on the magnitude of the earthquake and its distance from Devils Hole. For example, the disasterous earthquake in Mexico City in July 1957 caused the pool to fluctuate more than a foot.

EFFECT OF PUMPING ON POOL LEVEL IN DEVILS HOLE

Pumping from the Alluvium

Pumping southwest of Lathrop Wells.--The extent of ground-water development in the alluvial system southwest of Lathrop Wells has been described. It is the only substantial development within a radius of about 25 miles of Devils Hole, the next nearest being at Pahrump Valley to the southeast.

The pumpage in the area southwest of Lathrop Wells was about 3,000 acre-feet in 1962 and is expected to increase in the future. Most of the pumped wells tap only the uppermost few hundred feet of saturated alluvium. Because the vertical permeability across the fine-grained lenses in the alluvium is small and because fine-grained volcanic rocks may occur between the alluvium and the carbonate rocks beneath much of the area, pumping the alluvial system, even at increased rates in the future, probably will have a relatively small effect on the flow in the underlying carbonate rocks.

The center of the pumped area is about 12 miles northwest of Devils Hole. Between the two there is the postulated north-northwestward-trending hydrologic barrier, which would impede or even terminate any effects of pumping that might extend that far southwest. Thus, even with increased pumping in the area southwest of Lathrop Wells, the distance, poor hydraulic continuity between the alluvial and carbonate-rock systems, and the probable existence of a barrier lead to the considered opinion that pumping from the alluvium west of Nevada Highway 29 will have no effect on the pool level at Devils Hole for at least the next several decades.

Pumping in other areas.--Only minor amounts of water are pumped from the alluvial system in areas other than southwest of Lathrop Wells. The principal areas of potential development are Ash Meadows, between Ash Tree Spring and Death Valley Junction, and northeast of Devils Hole (pls. 2 and 3). Except for the Ash Meadows area, the distance, existence of barriers, and poor hydraulic continuity between the alluvial and carbonate-rock systems would virtually preclude any effect of pumping on the pool level at Devils Hole for at least several decades.

The effect of development in Ash Meadows, however, is more difficult to evaluate. In this area the alluvial deposits comprise lake beds, spring deposits, and some gravel and sand. Whether large-capacity wells can be developed in these deposits is not known. Moreover, the thickness and character of the alluvium and the hydraulic continuity between the alluvial and carbonate-rock systems has not been defined.

The subsurface channels of the large springs in Ash Meadows lead upward from the carbonate rocks through the alluvial deposits to the spring orifices. Substantial development of the alluvial deposits conceivably could divert a large part of the spring discharge and thereby reduce the head in the spring system and underlying carbonate rocks. This in turn would cause a decline in pool level at Devils Hole--the closer the development the sooner the time response would occur, and the larger the pumpage the larger the decline in pool level.

In the absence of any data on the coefficients of transmissibility and storage of either the alluvial or carbonate-rock systems, the hydraulic characteristics can not be determined, and hence the pumpage-time-distance-drawdown relationships can not be evaluated. Based on the experience gained in other desert basins and considering the complex hydraulic character of the two flow systems, substantial development a mile from Devils Hole probably would not affect the pool level for several years, possibly longer.

Pumping from the Carbonate Rocks

Wells 24a1 and 36d1, T. 16 S., R. 48 E., and 8c1, T. 17 S., R. 52 E., which the drillers' logs show as penetrating the carbonate rocks in their lowermost part, are the only known wells pumped in 1962 that might derive a part of their supply directly from the carbonate-rock system. Other wells, near outcrops of carbonate rocks or where the irregular surface of these rocks is close to land surface, may derive part of their supply from this source, but the bulk of the supply probably is obtained from the overlying alluvial system.

Beneath most of the valley floor of the Amargosa Desert the carbonate rocks probably are considerably more than 1,000 feet below the land surface. Moreover, if deep wells were drilled, the difficulty of tapping the solution channels and fractures, which convey the ground water, would be great. Nevertheless, a large organization might undertake an exploratory drilling program to develop water from this source.

The following brief analysis of pumping effects is based on the knowledge that the permeability of the solution system in the carbonate rocks must be moderately large to convey the total spring discharge in the Ash Meadows area of 17,000 to 18,000 acre-feet per year (about 25 cubic feet per second); it also is based on the reasonable premise that the coefficient of storage is in the artesian range, about 0.001 or less. Hence, transmission of pumping effects through the carbonate system would be rapid, except across or through any barriers.

The pumping of any wells that might be drilled into the carbonate rocks west of the postulated hydrologic barrier along the west side of Ash Meadows probably would not affect the pool level in Devils Hole for several tens of years. However, any pumping east of the barrier would affect the pool level - -the distance and amount of pumping would control the time and magnitude of the response. Wells pumping in Ash Meadows a mile from Devils Hole in all probability would affect the pool level within a year

Pumping directly from the orifices of nearby springs in Ash Meadows or lowering the outlet levels of these springs also would affect the pool level, probably within a year. Again the distance and amount of pumping would control the time and magnitude of the response.

On the other hand, substantial pumping in the valley west of Nevada Highway 16, some 4 to 8 miles north and northeast of Devils Hole, probably would not affect the pool level for several years or possibly longer, especially if the structure in the unnamed mountains immediately northeast of Devils Hole impeded the transmission of pumping effects through the carbonate-rock system.

Summary Statement

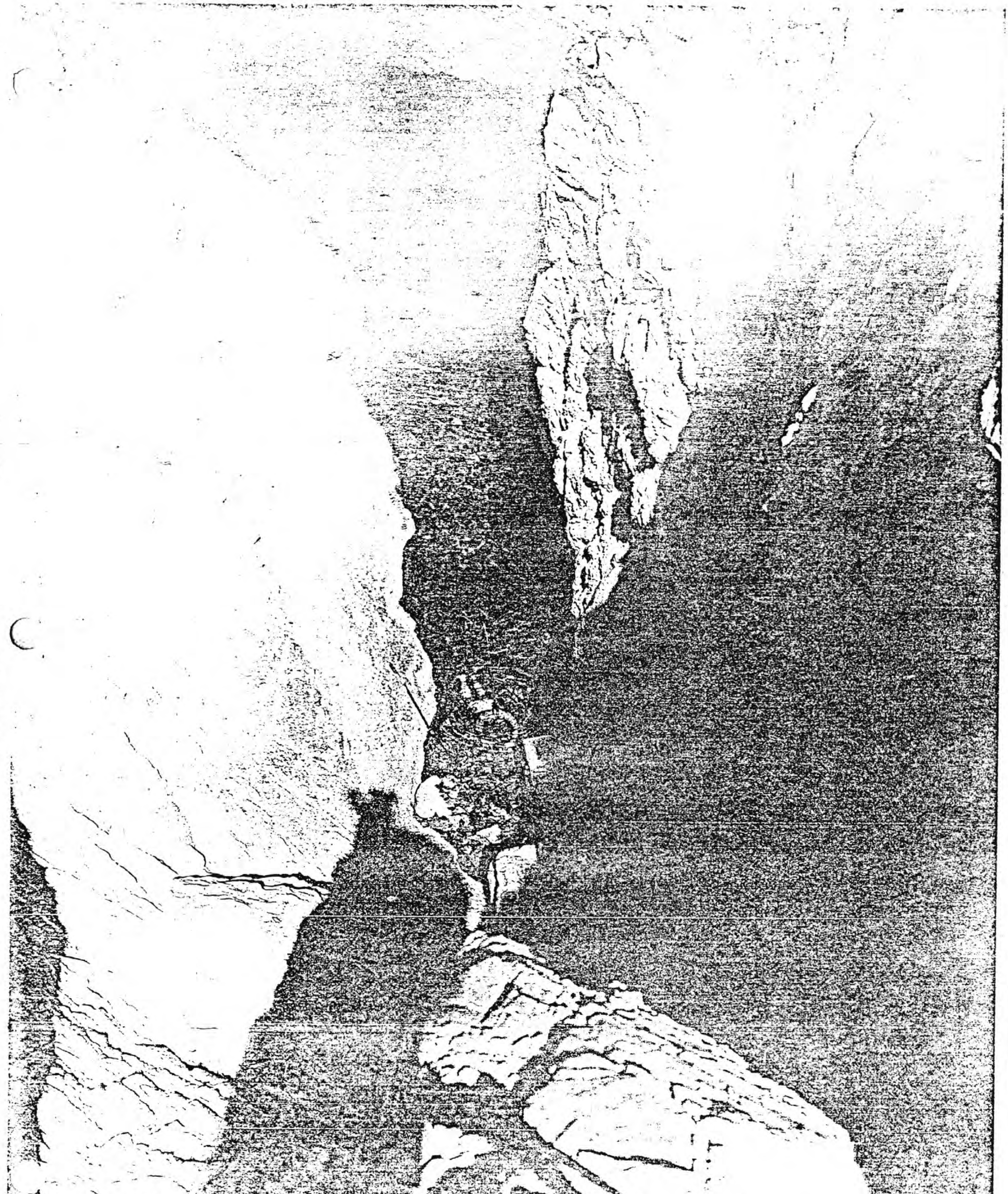
The foregoing highly generalized quantitative appraisal of the effects of pumping on the pool level in Devils Hole can be restated briefly by indicating the descending order of time response: pumping directly from or lowering the outlet levels of nearby springs in Ash Meadows and withdrawals from wells that might be drilled in the carbonate rocks (a) near Devils Hole and (b) some distance away that have good hydraulic connection; and pumping from the alluvial system (a) near Devils Hole and (b) far from Devils Hole. The range in time response would be from less than a year to more than several decades.

REFERENCES

Loeltz, O. J., 1960, Source of water issuing from springs in Ash Meadows valley, Nye County, Nevada: Geol. Soc. America Bull., v. 71, p. 1917 (abstract).

U.S. Public Health Service, 1962, Drinking Water Standards: U.S. Dept. Health, Education, and Welfare, Public Health Service pub. 956, 61 p.

Walker, G. E., and Eakin, T. E., 1963, Geology and ground water of Amargosa Desert, Nevada-California: Nevada Department of Conservation and Natural Resources, Reconnaissance series report 14, 45 p.



Devils' Hole nr. Lathrop Wells, Nev.
Stage Recorder and Shelter inst. this date.
Sept. 30, 1964 D. Clendenon