GEOLOGIC INTERPRETATION OF ANNA CITY WELL POLLUTION*.

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Introduction. At the request of the Central Illinois Public Service Company the State Geological Survey and the State Department of Public Health undertook an investigation of the pollution of the Anna City Well. The writer visited Anna on December 2d and went over the data with Mr. D. W. Johnson, engineer of the Central Illinois Public Service Company and Mr. J. Lyell Clarke, engineer of the Department of Public Health stationed at Carbondale. This paper deals with the geologic aspect of the problem and gives suggestions toward preventing the contamination.

Collected Data, City Well. The city well belongs to the Central Illinois Public Service Company and is situated on their property in the eastern part of the city, about 100 feet northeast of the electric plant between Vienna Street and the Illinois Central Railroad. The well was drilled in 1904 and is reported to be 550 to 650 feet deep. It has 100 to 135 feet of 12-inch casing at the top and the lower part is an uncased 8- or 10-inch hole. It was drilled all the way in limestone. Considerable difficulty was experienced in getting through the upper part because the casing had a tendency to hang on the rock. On December 1st the water stood at 92 feet when not being pumped, and on December 2d at 94 feet. Mr. Johnson says that it pumps down to 113 feet in summer when giving about 500 gallons per minute.

A test was made on December 2d to determine either the length of the casing or the depth at which a leak occurs in the casing. Air was run into the well at 80 pounds per square inch pressure. The pressure gauge, connected to the air pipe on the side of the valve next to the well, immediately registered 10 pounds upon turning on the air. This pressure continued during the first 60 seconds. It then rose slowly until at the end of 3 minutes and 45 seconds it stood at 18.8 pounds where it remained stationary. At the end of 5 minutes the air was turned off and the pressure immediately dropped to 15.8 pounds from which it very gradually fell off, being at 15.0 pounds 5 minutes

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later. 15.8 pounds per square inch is therefore taken to be the weight of a column of water depressed to permit the escape of air at the bottom. The computed length of this column is 36.4 feet. The outlet of the air is therefore at 94 plus 36.4 equals 130.4 feet depth. Since the casing was reported to be between 100 and 135 feet in length, this figure probably represents its true length.

It was noted by Mr. Perrine, of the Central Illinois Public Service Company that, while the last well at the State Hospital

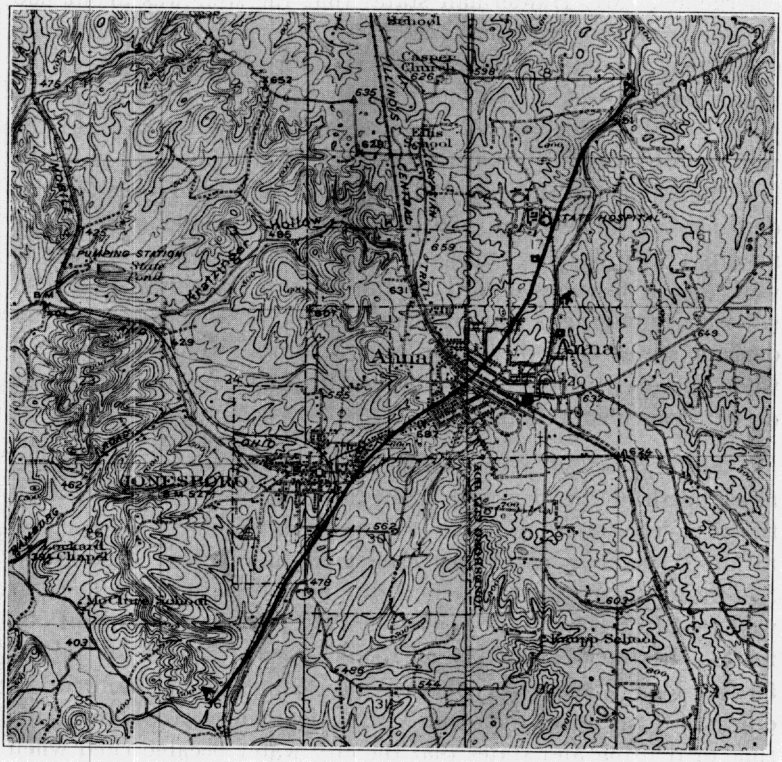


FIG. 1.—Solid circle, city well; open squares, septic tanks; open circle, hospital well; cross, quarry; AA¹, line of cross-section.

was being drilled, the water in the city well contained reddish clay and silt. He also states that when the pump is started after a few days of idleness this same reddish clay and silt shows up.

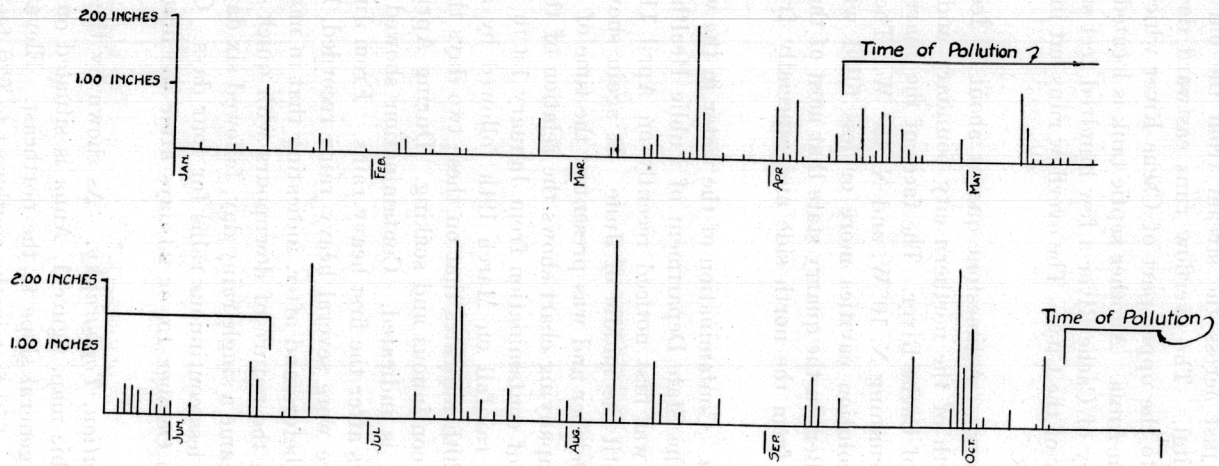
In an attempt to locate the source of contamination, and suspecting a certain sink hole at the Hospital into which the sewage from a dwelling was emptied, a small amount of fluorocene was poured into the suspected sink hole. None of it how-

ever was ever detected in the city water. To test whether or not there is a downward movement of water from the creek, 25 feet east of the well, a hole was bored a foot deep in the bottom of the creek and a small amount of fluorocene was poured into it. None of this showed up in the well water.

Old Ice Plant Well. A well was drilled in 1897 at the ice plant about 330 feet southwest of the city well by Mr. Halderman, a driller of Anna. The well is not used now except in an emergency. Mr. Halderman states that the well was about 300 feet deep entirely in limestone. The limestone contained much chert, making drilling difficult. There were some crevices in the upper part and at the bottom a crevice 4 or 5 feet deep was entered. The driller poured two wagon loads of gravel into the well in order to fill up the crevice and continue on down with the hole, but, since all the gravel disappeared with no effect, further drilling had to be stopped. The well yielded 60 gallons per minute. Approaching storms raise the height of the water in the well, and it becomes muddy. The water also contains reddish silt when pumping is started after a period of idleness. Mr. Halderman states that the water in a Hospital well became riled when this well was being drilled. Hospital employees however do not remember this incident

State Hospital Wells. The State Hospital is located 1¼ miles north of the city well. Several wells have been drilled on the property, none of which was very satisfactory. According to Mr. Alexander, of the machine shop, a well over a thousand feet deep was of small bore and produced little water. The last well was drilled by Buck Wilson in 1910 to a depth of about 500 feet. The top casing is 14 or 16 inches in diameter and about 50 feet long. Below this there is no casing and the well tapers down to 8 inches in diameter. Mr. Alexander was there at the time of drilling and states that the city water became riled when the lower part was being drilled. The well was finally abandoned because it did not supply sufficient water.

The Hospital then pumped water from a spring in a draw one quarter of a mile south. To insure a continuous supply a reservoir was constructed in a sink hole west of the Hospital. In dry weather the water was allowed to run into an open sink hole coming out lower down in the spring. It took half a day for the water from the reservoir to affect the water in the spring.



RELATION OF RAINFALL TO POLLUTION

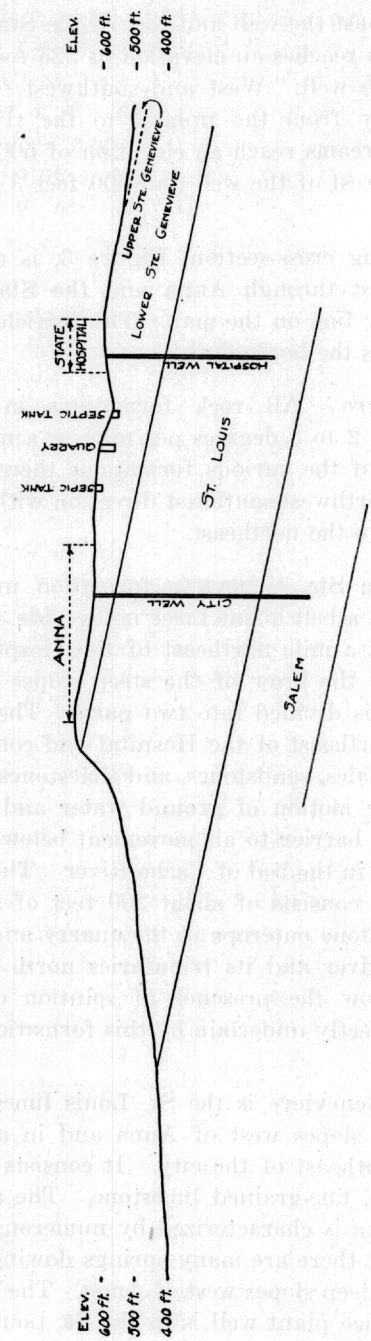
FIG. 2.

City Sewage. At present a septic tank of the city sewage system is located just across the stream from the old spring south of the Hospital. The overflow runs eastward down the draw on bed rock to the upper part of Cache River which flows northeastward from Anna. Another septic tank is located in the bottom of the valley of Cache River a few hundred feet south of the north boundary of the City. The overflow runs out in Cache River over bed rock.

Limestone Quarry. A limestone quarry about 50 feet deep is located just north of the northern city boundary and a few hundred feet east of Cache River. The faces of the quarry show joints in the rock running N. 10°W. and N. 45° W. The upper beds have many solution cavities more or less filled with red clay and silt. Drillers in the quarry state that most of the water enters the quarry from the north side and especially from the northwest corner.

Contamination. Contamination of the water in the well has been reported by the State Department of Public Health as far back as 1921, but was first noticed recently on April 11, 1927. This continued until the middle of June. It again showed up in the middle of October and was present at the time of investigation. The accompanying chart shows the relation of the rainfall to the periods of contamination from January 1st to November 1st. A heavy rainfall on March 19th followed by another good rain on the 20th indicates that on these two days the rainfall was probably continuous and soaking. During April 2d to 10th a wet season is indicated. Contamination showed up on April 11 or 22 days after the first heavy rains. From June 4 to September 28 there were several heavy rains recorded, but the weather was clear before and after, indicating that in most cases they were more in the nature of downpours with quick run-off. On September 22 came a single rainy day, followed six days later by heavy, more or less continuous rains for four days. Contamination showed up October 15, or 23 days after the first of the series.

Geologic Situation, Topography. As shown by the accompanying topographic map, figure 1, Anna is situated on an upland which has a general slope to the northeast. Elevations in the city range from 670 feet in the southwest to 620 feet in the northeast. The top of the well stands at about 600 feet. Cache River has its source about a mile south of the well and flows



CROSS SECTION ALONG 'A-A' THROUGH ANNA, ILLINOIS

FIG. 3.

north and northeast past the well and east of the State Hospital. The bed of the stream reaches an elevation of 525 feet about 1½ miles northeast of the well. West and southwest of Anna the surface slopes steeply from the upland to the tributaries of Dutch Creek. The streams reach an elevation of 500 feet in less than 1½ miles southwest of the well and 400 feet 3 miles southwest.

The accompanying cross-section, Figure 3, is drawn from southwest to northeast through Anna and the State Hospital as shown by the reavy line on the map. The verticle scale is exaggerated to 7½ times the horizontal.

Geologic Structure. All rock formations in the region have a general dip of 2 to 5 degrees per mile in a northeasterly direction. Outcrops of the various formations therefore extend across the area in a northwest-southeast direction with the youngest beds outcropping to the northeast.

Formations. The Ste. Genevieve formation underlies the whole city of Anna in a belt about three miles wide. The northeastern limit is about a mile northeast of the Hospital and the southwestern is along the brow of the steep slopes west of the city. The formation is divided into two parts. The upper Ste. Genevieve lies just northeast of the Hospital and consists of 100 feet of interbedded shales, sandstones, and limestones. The shales are impervious to the motion of ground water and, since they dip northeast, form a barrier to all movement below the highest shale bed outcropping in the bed of Cache River. The lower part of the Ste. Genevieve consists of about 200 feet of nearly pure limestone. This limestone outcrops in the quarry and at various places along Cache River and its tributaries north of the city. The quarry faces show the presence of solution cavities and joints, and regions directly underlain by this formation have sink holes.

Below the Ste. Genevieve is the St. Louis limestone which outcrops in the steep slopes west of Anna and in a large area two to eight miles southeast of the city. It consists of 400 feet of very cherty, bluish, fine-grained limestone. The area of outcrop southeast of Anna is characterized by numerous sink holes, and it is reported that there are many springs flowing out of the formations along the steep slopes west of Anna. The large cavity found in drilling the ice plant well is in the St. Louis.

The Salem limestone lies under the St. Louis. It is gray, crystalline and oolitic, and fairly pure, and has a thickness of 200 or more feet. Outcrops are found in the Jonesboro region west of the St. Louis limestone outcrops. Solution cavities and sink holes indicate that the formation permits the movement of underground water. The city well, if it is 650 feet deep. extends 100 to 150 feet into the Salem.

Interpretation of Pollution, Ground Water Movement in the Limestone. All the formations described are characterized by sink holes and cavities. These were first produced by the solution of the limestone during slow percolation of water along joint planes and relatively porous parts of the rock. It is a common observation that joint planes are very important in determining the direction of movement of the water, and it might therefore be expected that the ground water in the Anna region flows along lines N. 10° W. and N. 45° W. Drainage factors however are very important in producing a change in direction of flow in this region.

The ground water table conforms in a general way to the variations in the topography of a region. Being the upper surface of a liquid, however, it has the tendency to flatten out, sinking lower under the hills and flowing out on the surface in springs and as seep water along streams. There are two major drainage systems into which the ground water may flow. These lie on either side of the northwest-southeast divide through the western part of Anna. The surface drops off with much steeper slopes to the southwest than to the northeast, so that three miles southwest of the divide the outlets may be at an elevation of 400 feet above sea-level whereas the closest lowland to the northeast is the Cache River valley at an elevation of 500 feet in the same distance. The elevation of the northeastern outlet may even be up to 525 feet due to the impervious beds of shale which prevent lower movement to the northeast. To the southeast the elevation reaches 400 feet about six miles away. Thus it seems very probable that because of the nearness of the outlets in that direction and in spite of the joint system which often governs the direction of ground water movement, the general movement under the city is to the southwest.

Evidence of the relatively large amount of drainage to the southwest is given on the topographic map, where numerous permanent streams are shown to flow out from the steep slopes in

that direction, whereas Cache River is the only permanent stream on the map northeast of the surface divide. Other evidences of such a direction of drainage are the movement of ground water into the quarry from the north side and the fact that while the last hospital well was being drilled the city water became muddy.

Source of pollution. Pollution of water in the city well may come from the vicinity of Anna in close proximity to the well or from the region to the north and northeast.

If from the city close to the well, pollution comes from that portion north and east of the well or within a block around the well. Movement of the underground water below the level of the stream, which is about 600 feet at the well is probably in a general southwesterly direction although the water may follow the joints in a S. 10° E. direction for a short distance before finding a channel to the west. It cannot be definitely stated that local currents would not bring water from any direction within a limited distance of perhaps a block from the well. It is possible however that such water cannot get to a depth of 130.4 feet to enter the well below the casing, for the general movement westward would tend to carry it away before it could get that deep.

It is more probable that pollution comes from the region to the north and northeast. Here also the exact source of the pollution has not yet been determined, but it seems altogether likely that it is the water from the septic tanks which overflows and runs downstream on bed rock. The more southerly of the two tanks is between the well and the quarry and seepage from the overflow may be expected to follow the movement of the water as seen in the quarry.

Relation of Rainfall to Pollution. Pollution seems to show up only after heavy and continuous rains. This may be explained in two ways.

First, it is possible that ground water flowing from the region of the septic tanks to the well follows a different course in wet seasons from the one taken in dry seasons. As in the case of surface drainage in times of flood, the main channels cannot carry all the flow and the water must seek other lines. Thus the polluted water may be in the nature of flood water from the main streams.

Second, the underground seepage from the septic tanks may in dry seasons have outlets to the northeast, east, or southeast

but in wet seasons flow to the southwest. Naturally the outlets to the southwest do not drain the entire region and a ground water divide exists somewhere northeast of the surface water divide, conceivably in the general region of the septic tanks. In wet seasons the ground water may be so backed up by the small size of solution channels, by a limited number of openings, or by the greater friction encountered in traveling underground for a long distance to the outlets, that easier exit is found to the southwest. Blocking of the water in this way may serve to shift the location of the underground water divide to the northeast during the period of saturation changing the direction of flow from the septic tank. Comparison of the time of appearance with the times of heavy and continuous rainfall (Figure 2) suggests that the length of time necessary to bring about such a change in conditions and the movement of the polluted water to the well is about 22 or 23 days. This interval may also explain the fact that only while the last of the 500-foot well was being drilled at the Hospital did muddy water appear in the city well.

Recommendations. It is recommended that the casing in the present well be continued on down as far as possible without shutting off the water supply. If contamination comes from the near vicinity it cannot go deeply into the ground water before it flows off to the west or southwest. If from the septic tanks it may enter at any depth in the well because of the varying elevations of the solution channels. But since the outlet is not below 400 feet elevation and the bottom of the well is about 50 feet below sea-level, the contamination is most likely to come in in the upper part. There is doubtless some vertical diffusion, and mixing because of the action of the pump, but the danger decreases rapidly with depths below 250 feet.

Any well drilled in the future should also be cased as far down as possible. To make it very safe the location of a new well should be over half a mile east of the present location. This will place the well away from a southwesterly flow from the septic tanks.

To test whether contamination comes from the neighborhood of the well a dye should be introduced around the casing to see if the upper ground water enters the well. If pumping draws the dye into the well, it may reasonably be assumed that some private cesspool in the vicinity is giving the trouble. If

the dye does not appear, the possibility is not eliminated, but the chances are small that pollution from this area is able to reach 130.4 feet depth.

In case contamination shows up continuously in the future or is likely to prove dangerous in any way the septic tanks should be moved to a new location. The best location is in the bed of the stream flowing southward through the eastern half of sec. 30, T. 32 N., R. 2 W., half a mile south of the city. A second but not so desirable location would be in Cache River at least a mile northeast of the State Hospital.