Water supply - Waukesha springs. 1935

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REPORT ON VISIT TO WAUKESHA WATER WORKS, JAN. 26, 1935

F. T. Thwaites

Introduction. The writer visited Waukesha on Jan. 26, 1935 at request of Mr. A. P. Kuranz, Superintendent of the Water Department., to check over information needed before asking for bids on a new large-diameter well to replace the three old small wells at the North Street station. Advantage was also taken of information obtained when in Waukesha in connection with the case of Condos vs. City of Waukesha and W. L. Thorne in 1929 and of some of the data collected when making some private studies of the springs in 1923.

Geology. The subsurface geology of Waukesha is known from samples which were kept during the drilling of several deep wells. From this data the drillers logs of the other wells can be interpreted with a fair degree of accuracy. Much confusion has arisen from the fact that the upper part of the Richmond formation which lies immediately below the Niagara dolomite consists largely of dolomite. Even where samples were saved there has evidently been some miscorrelation of these strata. The thickness of true Niagara or "white lime" varies from 395 feet in the Randall well to little more than 0 in the Waukesha Mineral Water well. Part of the variation is due to irregular thickness of the drift and part is due to faulting of the bed rock formations. A fault is exposed in one of the quarries north of the city; it has a displacement of over 40 feet down on the southeast side and trends northeast-southwest. The thickness of true Richmond does not appear to exceed 183 feet although some drillers' logs record up to 251 feet. In every instance this high figure is associated with an abnormally low thickness for the underlying Galena and Platteville (formerly Black River) dolomites. In well authenticated records these formations run very close to 250 feet thick. The sum of the Richmond and Galena-Platteville does not vary greatly running from 435 to 470 feet. Underneath the dolomites there is sandstone with variable layers of shale none of which run more than 20 feet thick. Some logs state that there is "lime" but samples do not support this. Probably the formation was simply hard dolomitic sandstone. Details of the sandstone sequence are shown on the blueprint logs of the Baxter Street and Moorland Ave. wells.

Faulting. The presence of faults is known from the surface exposure mentioned above. Study of the sea level elevations of the top of the sandstones (top of St. Peter) indicates that there must be more faults which are not seen at the surface. The fault in the quarry passes west of the city. The Randall well found the St. Peter 20 feet below sea level. The North Street and White Rock wells find this formation respectively 118 and 170 feet above sea level. The remaining wells range from 244 to 298 feet above sea level. Faulting is important in three ways: (a) it affects the necessary depth to productive formations, (b) adjacent to faults the sandstones are often found to be tight and to produce little water, and (c) if the broken rock along a fault line is encountered in a drill hole much difficulty in drilling results. Unfortunately, the existing data is not enough to locate all the faults with certainty. It is evident that the formations are faulted up between the Randall and all other wells. A fault also raises the formations southeast and east of North Street. All the lower formations lie about 120 feet deeper at North Street than at Baxter Street. Moorland Ave. has the highest formations of any of the wells in or close to the city. In order to reach the same bottom formations at North Street as at Baxter Street it will probably be necessary to drill to about 1900 feet.

Forecast for North Street. The log of the North Street wells as given in Bull 35 of the Wisconsin Geological and Natural History survey was evidently from the memory of the late F. M. Gray, Sr. of Milwaukee who drilled at least one of them. It is not accurate in detail as it gives the thickness of the shale as only 160 feet whereas the thickness of the Galena-Platteville is recorded as 300 feet. However, the sum of these two figures is 460 feet which is not far from the truth. The bottom of the Niagara was placed at 230 feet. The writer expects that the St. Peter will be found at from 640 to 690 feet and the top of the Galena at from 390 to 440 feet from the surface.

Casing. It is recommended that genuine wrought iron pipe either standard or California be landed on a seat in the upper part of the Galena dolomite. There is no point in casing deeper as the Galena-Platteville is tight and carries no water or caving layers. Drilling can be carried to this depth without any more casing than a short string of pipe to rock which cannot be more than 20 feet. Such a liner will exclude water from the Niagara which may be contaminated at times because that formation is exposed in quarries not far away and from the dolomite beds of the Richmond. Water in the Richmond is apt to be very hard and to contain iron.

Shut-off. The "shut-off" at the bottom of the liner may be made either (a) with clay or (b) with cement. This liner will have to hold back a head of over 200 feet of water during pumping and a tight joint is essential. If cement is used the methods usually applied in the oil fields are almost out of the question because the necessary apparatus is not readily available to water-well contractors. The writer suggests that at this relatively shallow depth cement (either straight or mixed with half sand) be placed in the bottom of the hole with a dump bailer. The casing is then plugged at the bottom and run as rapidly as is consistent with good work. To increase speed the pipe should be made ready and all joints cleaned BEFORE any cement is mixed. It will be necessary to fill the pipe with water to make it sink into the cement and force that up around it. To insure that the bottom of the string of pipe is centered guides should be placed on it at intervals throughout the entire string. The writer is convinced that this method of cementing will insure more thorough placing of the cement where it is most needed than will pumping through a string of tubing run in the annular opening outside of the liner although this method might be used to advantage to finish the job near the surface. Under no circumstances should any amount of cement be allowed to set inside the liner as in drilling this out the shut-off is almost certain to be ruined. Particular care should be devoted to proper protection of the top of the well both from subsurface waters and from water on the floor of the pump room.

Straight hole. As it is almost essential that a deep well turbine hang free in the well special attention should be paid to the drilling of a straight hole down to the bottom of the liner. The writer suggests getting in touch with oil well drillers to secure necessary information on the use of hydrofluoric acid in making tests of verticality. The time to redrill to straighten a crooked hole is before it goes too far on the slant. Most trouble with deflection will be found in the Niagara. Guides on the drill stem and long bits are a great help.

Abandoned wells. Every abandoned deep well which allows surface water or shallow ground water to run down into the waters of the deeper sandstones is a potential menace. It is strongly urged that not only the old wells at North Street but all other abandoned wells in the city be plugged with cement either well down in the Richmond or at the top of the liner through that formation. An effort should be made to get the cement grout to flow into the opening behind such liners in so far as it will. The construction of the North Street wells should be explored with a soap block before attempting to plug them. Filling should be placed with a dump bailer and extend to the surface.

Danger of drilling too deep. Deep wells at Milwaukee encounter water which is very high in sulphate (permanent hardness) and iron. North of Milwaukee salt is also found. As it will be necessary to go deeper than any other well in the city at North Street to secure the same penetration into the sandstones, the danger of finding these objectionable waters should be recognized. After 1800 feet it is necessary to take bailer samples of water whenever a shale or other impervious bed is passed through. If there is any suggestion of a marked change in water quality the well should be plugged back through the shale by placing cement with a dump bailer.

Interference during drilling. Trouble may be experienced in operating the old wells or a part of them during the drilling of the new well. This might be due to (a) vibrations set up by the drill loosening cavings or settlings in the old wells, or (b) passage of water contaminated by dirt from the new well through subsurface openings into the old wells. Upon the appearance of excessive sand and/or contamination it would be best to shut down the old wells. When the new well is finished, it should be sterilized with calcium hypochlorite before taking a sample for a bacterial test.

Conclusion. Drilling of a new well with a specific capacity after shooting of at least 10 is a most desirable step in modernizing the water works plant and should result in considerable economies of operation.

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THE WAUKESHA SPRINGS

General. The following report gives the results of field work on October 1 and 31, 1923 and of subsequent studies on the problem of the origin and safety of the Waukesha springs, with special attention to the ROXO spring. Waukesha has long been famous for its springs, often being called "The city of springs," and although it is no longer regarded as a health resort much water is supplied to cities which have contaminated public supplies. At least one producer has a nation-wide business and in addition the making of soft drinks has become very important. The origin of the springs has an important bearing on their use since it is tied up with both the purity and quantity of the water.

Geology. Waukesha is underlain from the surface down by (a) glacial drift, mainly sand and gravel, maximum known thickness about 70 feet, (b) Niagara limestone, hard, white, magnesian or dolomitic, thickness from 200 to 300 feet, (c) Richmond or Cincinnati shale, soft, blue, about 200 feet thick, (d) Galena-Black River or Galena-Trenton limestone, hard, gray, magnesian, about 250 feet thick, and (e) St. Peter and older sandstones and shales, with some limestones.

penetrated by wells to a maximum of about 850 feet. The drift can be studied in a number of gravel pits around the city, and the Niagara limestone, which forms the bed rock, is well exposed in quarries; the other formations at Waukesha are known only from study of well records.

Underground water conditions. Water is abundant in the drift since it is quite porous; it is found at depths of less than 20 feet in most parts of the city. The Niagara limestone carries much water in fissures which are in many places separated by considerable thicknesses of nearly dry rock. Wherever such fissures reach the bottom of the drift there is connection between the drift and bed rock waters. The thick shale beneath the Niagara limestone cuts off its waters from the porous sandstones at greater depth. That this barrier is effective is indicated by the fact that the water level in wells which have the Niagara waters cut off is much lower than that of the shallow waters. For instance water stands 58 feet below the surface in the Resthaven well and, according to Mr. Thorne, at 111 feet in the White Rock well. Even in wells which are not cased off in this manner the level is lower than in shallow wells. Water is reported to stand at 60 feet in the city wells on North Street, at 32 feet on Tenny Avenue, and at about the same on Genesee Street. Furthermore, the water in the sandstones is, according to Mr. Barney, engineer at Resthaven Hospital, only about half as hard as is the water from the Niagara limestone. The deep waters have absolutely no connection with the springs and are not further considered. The springs have rise from the waters of either the drift or the Niagara limestone and the study was directed to see from how deep beneath the surface the waters have come.

Description of springs. The Waukesha springs can be divided into (a) those that issue from the Niagara limestone and (b) those that come from the drift. The first class is represented by the springs on the White Rock property and possibly by the Almanaris spring on the opposite side of the river. Men who have worked in the White Rock plant claim that even the exhibition spring is really a drilled well; a false bottom prevents examination. The writer visited the following drift springs: Supreme, Fountain, ROXO, Silurian, Glen Rock, Arcadian, Lythia, Horeb, Hygia, and Henk; of these the last four are now dry. All these springs are pits from 10 to 25 feet deep which are walled with masonry. Water flows at a level several feet below the surface of the ground and false bottoms, some of which are covered with gravel to resemble the real bottom, are present a few inches from the water surface. Water bubbles up through various styles of orifices in these bottoms, the idea evidently having been both to conceal the real depth of the hole and to make the flow more conspicuous to the eye than would otherwise have been the case. As the springs were all improved in this manner many years ago it is not possible to get any definite idea of the material penetrated in digging them. Mr. Lemingn stated that he once dug a spring on the west side of Hartwell Avenue which showed from surface down, peat, 14 inches of clay, gravel, quicksand, and gravel at the bottom. Mr. M. T. Peterson, a well driller of Madison, informed the writer that he once saw a spring being dug in the same locality which showed a thin layer of clay at a depth of over 15 feet. However, inasmuch as the sands and gravels were deposited by shifting glacial streams it could not be expected that any layers of particular kinds of material would extend over any considerable area; this is especially the case with clay or silt beds which were formed only in slack water spots. It is, therefore, probable that there are no extensive impervious layers in the drift; the spring waters are not separated from the surface by any continuous impervious layer.

Water levels. The next question to be considered is whether the springs are fed by water which has traveled only through the drift above the rock surface or whether they are supplied by waters which have passed a longer distance through the rock before emerging into the drift. An attempt was made to determine approximately the comparative height to which water rises in the springs and in adjacent rock wells. No levels were run but elevations were obtained from the city engineer and from the topographic map published by the United States Geological Survey. It was found that the level of the spring waters declines toward the river as shown in the diagram. The Supreme spring has a water level about 40 feet above the river at Wisconsin Street bridge; the Fountain spring must be nearly as high; the Hartwell Avenue springs are from 20 to 23 feet above the same point; the old Hygia spring never rose more than a few feet above the river. On the other hand, the water in the Niagara limestone rises above the surface along the river as shown by flowing wells at Baxter Street and at the White Rock plant, the latter reported by Mr. Barney. Weidman and Schultz in Bulletin 35, Wisconsin Geological and Natural History Survey, report a well 114 feet deep which had a head of 11 feet above the surface but do not locate it. The well at the Arcadian bottling works formerly flowed into the basement at a level about that of the water in the Arcadian spring; at present the water level could not be measured. The old shallow well on Genesee Street is reported by Mr. Hayford to have shown water at 17 feet which is apparently not much if any higher than the level of the ROXO spring. Mr. Peterson informed the writer that he drilled a well 100 feet deep at the brewery which served as a drainage outlet for their spring. The evidence cited seems to show that the head of water in the rock is higher than the surface ground water along the river but is somewhat lower on higher ground. This leads to the conclusion that water is leaving the drift to enter the rock beneath the high ground whereas on low ground there is a tendency for water to escape to the surface from the limestone. Some of the water in the limestone has doubtless come a long distance from the higher land west of the river. Natural channels of escape to surface are not common enough but that some wells at low elevations offer freer passage and therefore flow. It, therefore, seems doubtful if any water is leaving the limestone except just along the river and that the springs, with the exception of the White Rock and probably the old Hygia and Henk, are fed wholly by waters which have passed only through the drift.

The rate of flow of water in the sand and gravel of the drift is probably considerably less than it is in the crevices of the limestone but no data are available. The direction of flow of water in the drift is toward the river from the higher lands on both banks. The lower level of the land, combined with the fact that the bed rock, which in many places has but few water passages, is near to the surface causes the ground water to come to the surface along the sides of the valley. The natural seepages have been developed into the present springs which offer better points of escape that were formerly present.

Interference between wells and springs. The interference between wells and springs was investigated very carefully. Much more water is now being pumped from the rock in Waukesha than was the case in former times. The present superintendent of waterworks, Mr. Hayford, believes in scattered wells and in taking as much water as possible from the Niagara limestone since the water level in it is so much higher than that in the deeper formations. There are five groups of wells, as well as an isolated well on Tenny Avenue, now being pumped from the Niagara. A new well is being drilled on Genesee Street, about a half mile east of the ROXO spring. Four of the groups of wells draw only from the limestone;

each produces from 250 to 400 gallons per minute. The deep wells on North Street give 1000 gallons per minute but an unknown proportion of this is from the deeper formations, a remark which also applies to the Tenny Avenue well which is pumping 250 gallons per minute. The only other known deep wells at Resthaven and the White Rock plant are reported to be cased from the top through the shale. The nearest wells now being pumped are about a half mile northwest of the ROXO spring. These wells, therefore, do not intercept the flow. A shallow well on Genesee Street, which gave 200 gallons per minute, was pumped in 1922 but is now idle pending the completion of a deep well. Mr. Barney reported a now abandoned shallow drift well at the corner of Barney and Broadway which when pumped caused the complete drying up of all the Hartwell Avenue springs. The same informant also stated that when the Resthaven well was being drilled it "bled off" the water from the Ardadian spring. Apparently the installation of the casing through the limestone put a stop to this drainage of the upper waters down the well. Such a process is going on around all uncased deep wells. The clearest case of interference is that of the Wisconsin Street wells and the Hygia and Henk springs as reported by Mr. Hayford. These springs were connected to a sanitary sewer which had backed up and caused bad contamination. Pumping not only dried up the springs but resulted in bad contamination of the wells. These springs were the lowest in the city and had water of different composition from that of other springs. They must have been fed in large measure by water which rose from crevices in the limestone. Pumping of these and the State Street wells is also reported to have destroyed the flow of the Bethesda spring. A definite case of interference between the Newhall Street group of wells and the shallow drift well of the gravel company, west of West Avenue, shows that interference is possible between rock wells and drift wells or springs. The wells in this case intercept the flow of water and have lowered the water level in the well over 9 feet while not much affecting the Fountain spring to the east. The writer concludes that the pumping of rock wells constitutes a menace to the springs wherever such wells are located so as to intercept the flow of water. They draw water down into the rock and the zone over which they lower the water level is bound to increase in time especially in dry years. The greatest danger to the ROXO spring, therefore, lies in the Genesee Street well. The testimony of wells, therefore, indicates interconnection of drift and Niagara limestone waters but confirms the previous conclusion that the Hartwell Avenue springs are fed by drift waters.

Composition of waters. The available chemical analyses of Waukesha spring waters were studied, classified, and compared with analyses of waters from drift and shallow rock wells in the same region. The results of this study are presented in the accompanying table. The waters of the White Rock and Hygia springs were found to differ from the remainder; this difference appears to be related to a difference in geological conditions. The White Rock water is known to come from the Niagara limestone and, as noted above, the Hygia is suspected of being of the same origin. The spring waters contain mainly carbonates of calcium and magnesium, the quantity of sulphates of calcium, magnesium, and the alkalies is much less, the amount of alkalie chlorides is small. The analysis of the ROXO water was recomputed into the modern form and is given herewith

Analysis of ROXO spring water by W.S.Haines

Recomputed by F. T. Thwaites

Ca	68.7 parts per million
Mg	34.0
CO_3	213.4
Na	14.8
K	1.7
SO_4	4.4
Cl	5.8
Fe	Trace
Al_2O_3	3.0
SiO_2	10.0
Total	355.8

Averages were made of total solids, chlorides (Cl), and sulphates (SO_4) in the three classes of waters. The two last show an increasing percentage with depth. This is apparently due to decreasing amount of washing of these soluble substances from the drift and rocks with depth. The rock waters offer some exceptions since some of them are probably supplied by crevices which lead directly from the surface to the well. Another difficulty is that the many analyses made for boiler purposes doubtless include some contaminated waters which have an abnormal amount of chlorides derived from organic matter. The testimony of chemical composition supports that of geology in a very striking manner; there can be no doubt that the drift spring waters have never penetrated far from the surface of the ground.

Temperatures. The temperature of waters offers another means of checking the above conclusion since it depends upon the depth from which the water comes. The influence of the season extends with diminishing strength to a depth of about 60 feet; at that level the temperature is constant throughout the year. The mean annual temperature of the air at Waukesha is given by the United States Weather Bureau as 45.9°F.; the temperature at 60 feet is not accurately known but is probably higher as the snow in winter prevents the effect of the cold from being as great as that of the heat in summer. Below 60 feet the temperature increases with depth. The rate of increase is less than the average at Waukesha on account of the vigorous circulation of waters at great depth; Mr. Hayford states that the water from the deep wells has a temperature of only 45°. The low conductivity of earth and rock causes the effect of change in seasons to lag much behind the surface changes. At 20 feet depth the maximum is not reached for several months after midsummer; the temperatures taken on October 31, therefore, represent a hangover from the summer but may not be the maximum for the year. In making comparisons with well water temperatures it was found to be impossible to get readings except after the well water had passed through pumps which warm it. Observations were taken with a small but accurate thermometer and are correct to the nearest half degree.

Temperatures of waters at Waukesha, October 31, 1923

Locality	Temperature Fahrenheit	Depth	Remarks
Roxo plant	52.7	25	Discharge from pump
Coal yard	55.4	6	Comes through long pipe
Arcadian spring	53.6	?	
Glen Rock spring	51.8	?	
ROXO spring	51.8	25	
Supreme spring	50.9	?	Possibly some melted snow
Arcadian well	50.0	about 70	Pump discharge. Well about 80 feet
Fountain spring	48.2	?	Contaminated by melting snow
Baxter Street wells	50.0	300	Discharge from centrifugal pump
Wisconsin Street wells	53.0	250	Same, possibly warmed by pump. Wells connect with surface through fissure?
	Other Observations		
White Rock spring	50.0	?	Measured by chemist, may be high, but suggests deeper source than drift springs
White Rock deep well	56.0	1525	Measured by chemist
City deep wells	45.0	1500	Measured by Mr. Hayford, probably affected by air lift and is mixture of waters
Roxo spring	46.5	25	On card giving analysis of water
Roxo spring	52.5	25	October 1, 1923
Roxo spring	50.0	25	Reported winter temperature

The above data are sufficient to prove that the waters from the drift springs along Hartwell Avenue are affected by seasonal changes and hence come from less than 60 feet from the surface.

Source of water. The water of the drift springs at Waukesha is derived ultimately from snow and rain. This moisture or precipitation, which falls on the ground is divided between that which soaks in, that which runs off, and that which is evaporated. In the vicinity of Waukesha the gravelly drift and the marshy pockets between the hills tend to promote the first disposition. Other factors are kind and abundance of vegetation, degree of slope, and rapidity of rainfall; much of the winter precipitation never enters the frozen ground. The water which enters the earth creeps slowly toward the low places. The rater of flow is not known; judging from the results obtained when the writer was working for Prof. Slichter it can hardly be as much as five feet a day or a third of a mile a year. Effect of drought on the watershed east of Waukesha could probably not be felt at the springs for several years. The amount of soak-in is also being diminished by drainage of marshes, cultivation of fields, and tramping of the ground by cattle, all of which are steadily increasing in amount. All over the region springs are diminishing in volume; this is partly due to the several dry seasons in the nineties but the other causes are by far more important since they are permanent. The accompanying tables give the rainfall at Waukesha as reported by the United States Weather Bureau; missing figures were supplied from the Milwaukee station. The table indicates that the great drought of the nineties was not as marked at Waukesha as it was at Madison. The years during which much of the water now flowing from the springs fell were above the average which is about 31 inches, although the amount of precipitation has been on the whole decreasing since 1916. It hardly seems possible to ascribe the loss of volume of the springs in 1923 to variation in rainfall alone. It is more likely the cumulative result of changes on the supply area, especially marsh drainage, pumping of the city wells, and of the relatively dry seasons of 1920 and 1922.

Sanitary conditions around springs. Inasmuch as the waters of the springs flow close to the surface they are exposed to contamination from sewers. The water which supplies the ROXO spring comes from the east and passes beneath several lines of tile sewers, some of which are less than 30 feet from the spring itself and none of which can be more than 10 feet above the water level. Engineers agree that such sewers can never be tight no matter how much cement was placed around the joints. The springs are also exposed to contamination from surface wash and from material dropped or blown into them. For instance it was noted on October 31 that the ROXO spring had in it an angleworm and a cricket as well as a considerable amount of dirt all of which had fallen from the board roof. In view of these conditions it is remarkable that the sanitary analyses show up as well as they do. Bacteria which entered from the surface may account for the occasional high counts of harmless forms although the lack of cleanliness of the bottles is also a plausible explanation; this point cannot be decided now. It is said that no trouble has ever been experienced with bacterial growth in soft drinks made with this water. Whatever sewage leaks into the ground is evidently purified by passage through the finer beds of sand where the rate of flow is probably only two or three feet a day. That there is some such purified leakage is evinced by the fact that all analyses show some trace of free ammonia and albuminoid of ammonia and that some tests also show traces of nitrites. Nitrates, formed by oxidation of organic matter, have run from a trace to 4 parts per million and chlorine has been as high as 17 parts which is high for these waters. The fact that a little oxygen is consumed by the water also indicates a small amount of contamination, though not enough to be dangerous. The safety of the springs therefore depends mainly upon the tightness of the curbing; if leaks occur in this near the water surface, dangerous comtamination might occur at any time.

Instances of contamination. It is definitely known that the Wisconsin Street city wells were contaminated when first drilled and even after prolonged pumping and the cleaning up of the old Hygia spring, it was thought necessary to chlorinate the water. Apparatus for this purpose was still in place when the writer visited the wells and the water was still running 45 parts chlorine and 4 parts nitrates per million although it is true that the Hygia spring always showed a high chlorine content. Mr. Hayford reported that the old Lithia spring, opposite the Arcadian plant, was abandoned on account of dangerous contamination, possibly from the Resthaven Hotel on the hill above. Mr. Peterson informed the writer that when he lived in Waukesha there were many rumors about contamination of springs and that some springs had probably been abandoned on that account. Bacterial contamination was suspected in the well at the Arcadian plant; it was shown by precipitates in soft drinks and by a bad odor. It is reported that the odor no longer is present but that the water is now used only for washing. The cause might well have been a rusted-out casing. Mr. Baker, of the State Board of Health, informed the writer that he looked with suspicion on the water of all springs and shallow wells in a city such as Waukesha. He mentioned the case of the Wisconsin Street wells and gave confidentially the names of some springs which had displayed contamination in sufficient degree to prevent the use of the water for soft drinks without sterilization. In view of these facts it is easy to understand the reluctance of some spring owners to permit visitors!

Suggestions for safeguarding the ROXO spring. The writer suggests the following safeguards against contamination of the ROXO spring.

(1) A tight cover should be installed at once to prevent any thing falling from the roof from getting into the water.

(2) Provision should be made against surface wash getting into the pit by either (a) a higher wall above

the surface of the ground or (b) rearrangement of the drainage outlet so that no water getting into the pit could back up into the spring.

(3) The old masonry curb should be reenfored with a tube of riveted genuine wrought iron inside it with watertight connection to the false bottom.

(4) The outlet pipe should be guarded with a screen to prevent entrance of rats or mice since it does not carry water all the time.

(5) The old well at the bottling works should be overhauled and put in shape so that it could be used at once if contamination should be found in the spring, or provision should be made so that city water could be used in case of emergency.

Future water supply. With the above improvements the ROXO spring can probably be used for a number of years. There can be little question that pumping of city wells and changes on the supply area are steadily reducing its volume and that following another period of dry years it might prove insufficient. Dangerous contamination may appear in the spring even in spite of the above safeguards. The pending completion of the Genesee Street well which is so placed as to intercept much of the supply of the spring is a great menace. The writer suggests:

(1) That pressure be brought to bear to have the Genesee Street well cased from surface to bottom of the shale. To do this the reported sulphur water in the Niagara and the softer character of the deep waters might well be urged.

(2) That preparation be made to drill a deep well at the bottling works; this well to be 15 inch to 450 feet and 8 inch from 450 to 1200 feet with 8 inch liner from surface to 450; space between liner and wall of well to be filled with concrete inserted through a small pipe pulled back as hole is filled. This well would give perfectly safe water for all reasonable time. It would cost, with deep well pump, about $10,000. According to Mr. Hayford at least one other water company has come to the use of such a well. A shallower well in the Niagara limestone would not be as safe from contamination.

Conclusions. (1) The water of the ROXO spring is surface underflow in sand and gravel above the bed rock which comes from the east.

(2) The spring is now safe but should have the improvements listed above carried out at the earliest possible opportunity; it is nevertheless liable to dangerous contamination at any time.

(3) The future water supply is menaced by marsh drainage and by the Genesee Street well; it may become inadequate, especially following some dry years.

(4) A deep well with cement grouting offers the only absolutely dependable, safe, permanent supply.

Respectfully submitted,

Consulting geologist

Madison, Wisconsin, November 14, 1923.