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A PROBLEM IN MUNICIPAL WATERWORKS FOR A SMALL CITY.

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The problems of a municipal water supply, not only for fire protection but also for domestic use, are important ones confronting numerous towns in Iowa. The attempt to solve those problems at Indianola presents features of general as well as local value.

After the drought of 1894–5, when not only the cisterns and shallow wells but even the rivers went dry, the city voted to put in a system of waterworks. Since bonds to the full amount allowed by law had already been issued on an electric light plant, the city was unable to become the sole owners of the proposed plant; but arrangements were made with a waterworks company in Chicago, whereby that company undertook the work with the city nominally the owner. The method of procedure in the early part of the work was a good illustration of how *not* to proceed. It was assumed that the nearest supply that was sufficient in quantity was also satisfactory in quality, and the work begun was continued regardless of the fact that it was soon found that the water was a mineral water. I am not aware of any attempt to learn what the minerals in solution were and what effect their presence would have on the acceptance of the water by the public. The committee and the parties from Chicago went ahead as if a plan which worked all right in some other places would prove satisfactory at Indianola whatever the conditions. After the work was completed opponents of the measure tested the contract at law and proved the arrangements relating to ownership illegal. Because of this decision the Chicago parties became the sole owners of the plant. Later the firm failed and the city operated the plant for several months until, this last spring, a private company studied the difficulties involved and bought the depreciated stock.

The interesting geological problems associated with this subject I wish to reserve for a future paper and consider here only problems related to municipal waterworks apart from those strictly geological.

It is desirable to have the waterworks plant as near the city as possible and near a railroad by which coal may be obtained. First, then, let us consider the facts on which the possibility of locating the plant near the city depend. This involves the general relation of run-off to precipitation, which is applicable both at Indianola and in a general way at all other places, and conditions which are peculiar to the location.

The ultimate source of supply is rainfall, either sufficiently local to affect our rivers and shallow wells, or in some region more remote where it may ultimately get into a porous stratum and find its way beneath a city where it can be obtained in deep wells.

Evidently the cheapest supply and that first to be sought is the one at the surface. The presence of running water in a draw or ravine in dry weather seems to suggest that all one need do is to sink a few wells and the supply is obtained, regardless of the area drained or the character of the deposits from which the trickling water may have come. This water, like the water in the streams, came from ground water, the original source being, near Indianola at least, a quite local rainfall. The consideration of precipitation, run-off and evaporation is rendered especially important because in at least the street corner discussions, some have advocated the sinking of a battery of shallow wells in the uplands west of the city, or locating a reservoir a mile east of the city, expecting to obtain a full supply at either place, those favoring the latter location basing their opinions on the reported approval of a Chicago engineer who visited the city, gave a casual glance at the surface and listened to various statements.

A recent government report states that in studying the rainfall with reference to reservoirs it has been found advisable to divide the year into three periods: for storage, growing and replenishing. From our own data on rainfall we find the following result for one square mile:

CATCHMENT AREA, ONE SQUARE MILE.

	Minimum Rainfall.	Average Rainfall.
Storage Period, Dec.—May, 182 days..........	6.36 inches.	12.48 inches.
Growing Period, June—Aug., 92 days.........	2.64 inches.	11.88 inches.
Replenishing Period, Sept.—Nov., 91 days....	2.95 inches.	6.41 inches.

One inch of rainfall over a square mile of surface gives 17,378,743 gallons. The local precipitation in gallons for the storage, growing and replenishing periods is as follows:

	Minimum Rainfall.	Average Rainfall.
Storage Period....	88,457,802 gallons.	216,886,713 gallons.
Growing Period...	4,518,473 gallons.	20,680,704 gallons.
Replenishing Period..............	12,165,120 gallons.	26,415,689 gallons.

Our city even now with a water supply not generally acceptable is said to use about 75,000 gallons per day in addition to the large amounts from cisterns and wells, while the supply that is looked for is 3,500,000 gallons. In Boston the water used was 119 gallons per inhabitant per day in 1903.

On this basis the present amount required for Indianola would be 416,500 gallons per day, but plans for the future should allow for possible growth. We know that prior to the installation of water works the people of our city did get along with the rainfall, though it was frequently embarassing as wells and cisterns frequently give out. In the drought of 1895 there were fears of a serious conflagration. When the supply is not carefully treasured in cisterns and doled out by the dipperfull, a much larger supply is necessary. Then, the greater the drought the larger the amount of water used for streets, lawns and gardens, and

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the more imperative is the demand for fire protection; all this at the very time when the supply is near its minimum. It is evident that the minimum precipitation is the precipitation that must be considered. The government report* already mentioned gives us the relation of run-off and evaporation to precipitation in the storage and growing periods but not in the replenishing period; for this the average of thirty-seven records given in the tables in the same pamphlet is assumed to be correct. For the rainfall at Indianola the figures are as follows:

RUN-OFF AND EVAPORATION.

	Run-Off.	Run-Off.		Evaporation.	
		Minimum.	Average.	Minimum.	Average.
During Storage Period......	80 %	5.09 in.	9.98 in.	1.27 in.	2.50 in.
During Growing Period ...	10 %	.26 in.	1.19 in.	2.38 in.	10.69 in.
During Replenishing Period.	23.7%	.70 in.	1.52 in.	2.25 in.	4.89 in.

The loss by evaporation of water stored in a reservoir is at a different rate than the loss by evaporation from the surface of the ground. The record for Lake Cochituate† for thirty-eight years gives the following averages:

	Mean Precipitation.	Mean Evaporation.	Evaporated.
Storage	23.15 inches.	8.23 inches.	35.5 per cent.
Growing	11.59 inches.	9.51 inches.	82 per cent.
Replenishing...........	12.38 inches.	9.06 inches.	73 per cent.

Indianola is situated on a divide which is thoroughly drained. The nearest places toward which the drainage is sufficient to supply even the demand for half a million gallons daily are the river bottoms, one, a mile south of the city, the other, six miles north. The location already spoken of as a mile east of the city is at a point where the rock formation is unusually good for a dam; but the area drained past that place is only one square mile. As this location is close to a railroad by which a supply of coal

*Water Supply and Irrigation Paper No. 80.

†Water Supply and Irrigation Paper No. 80, page 89.

may be easily obtained, the possibility of obtaining water from deep wells must not be overlooked. The following table gives data concerning the quality of water found in deep wells penetrating the same strata from which a supply at Indianola would be obtained:

Place.	Test.	Acceptability.	Level of surface of water.	Authority.
Greenwood Park.	576,000 gals. per day	?	872 A. T......	Iowa Geol. Surv., Vol. VI, p. 294.
Pella	360,000 gals. per day	Not acceptable	768 A. T......	Iowa Geol. Surv., Vol. VI, p. 310.
Grinnell	151,200 gals. per day	Acceptable	798 A. T......	Iowa Geol. Surv., Vol. VI, p. 287.
Sigourney	?	Not acceptable	726 A. T......	Iowa Geol. Surv., Vol. VI, p. 305.
Centerville	50,400 gals. per day	Acceptable.....	737 A. T......	Iowa Geol. Surv., Vol. VI, p. 327.
Boone	100,800 gals. per day	Not fully acceptable . . .	940 A. T.. ..	Iowa Geol. Surv., Vol. VI, p. 252.

From this table it is far from certain that an acceptable quality of water would be secured from a deep well. To reach the deepest strata from which water is obtained in the above mentioned wells (the Saint Peter and Saint Croix sandstones) the well at Indianola would have to reach a depth of 1800-2200 feet. The receipts, which are at present only about $2,500 per year, will not warrant expenditure on such an uncertainty.

If the necessary quantity and quality of water alone were to be considered the place where the pumping station ought to have been located is just north of Middle river, six miles north of Indianola, on a strip of "second bottom" land which extends southward to near the river. Here, at a depth of only twenty-five feet below the second bottom, the sands contain an inexhaustible supply free from iron. The drainage area up the river from this place is about four hundred and eighty square miles. Should the river itself go dry, as it did in 1895, the sand below the bed of the river could be relied upon to furnish a supply during the drought. At this point the pumping station would be within half a mile of a railroad on a level bottom land over which a branch road could be easily laid, and near coal mines from which coal could also be hauled in wagons. But a change in the location of the pumping station from about two miles southwest of the city to six miles north is for the present out of the question. Even using as much as possible of the material now owned the cost of the change would be about thirty thousand dollars.

At the present location of the pumping station, southwest of the city, there is an abundance of water from a drainage area of 281 square miles. The entire flat near and above the plant is underlain by sand containing water charged with an abundance of iron bicarbonate, but it is not yet known whether this condition of the water actually persists in the bottom land down the river. It has already been found that the water, though wholesome and perhaps endurable so far as taste is concerned, is wholly unacceptable for cooking and for bathing. The iron can be precipitated by lye or by ammonia and the water strained, or it can be quite fully removed by allowing it to stand exposed to the air and then filtering it; but such processes are too troublesome to be acceptable. I have not been able to ascertain, either from published data or from experiment, whether iron bicarbonate in solution under pressure can be precipitated either by alum or ammonia and can be immediately filtered out under pressure as a fine sediment can be treated. This may be possible, for iron bicarbonate is very unstable, but as pressure is so effective in maintaining the bicarbonate of iron it must be proven that the bicarbonate can be so removed before it would be advisable to install a pressure filter. Without this evidence water that is free from iron must be obtained from some other local source.

There is on the opposite side of the river from the pumping station a point of land in a large bend of the stream. The sand in the distant part of this bend and nearest the upland is charged with iron, but it is not known whether the sand which lies where the circulation of the ground water from the upper limb of the bend to the lower limb may not be washed free from iron, for the stream itself, of course, has no iron in solution. While it is possible that wells located on the inside of this bend near the river may be sufficiently free from iron, it is probable that water from beneath and from the upland side may carry iron in solution into such wells. This can only be determined by driving a few wells and analyzing the water; but, as even a small quantity of iron in solution is so very undesirable, the chances of securing a satisfactory supply are not very attractive.

The last possibility is to filter the water from the river itself. Here the difficulty is to filter out the bacteria and the very fine clay which is so slow in settling, and after a rain, to dispose of the mud which the river carries in abundance. If the "English method" of filtration were used, 17,424 square feet of filtration surface would be needed per million gallons. This would require a trench twenty feet wide and 871 feet long, or two trenches each at least half as long, that the surface of one filter may be cleaned while the surface of the other is flooded. A filter placed in the bed of the river would answer for a while, but it would not be conveniently placed for care. If 500 feet were placed in the river bed and 500 feet in a new trench, a total excavation of at least 46,611 cubic yards would be required, 12,666 cubic yards of sand and gravel for the filter, and 16,000 feet of tile for the bottom of the filter, besides controlling gates and a receiving well.

If the "American method" of quick filtration is employed a centrifugal pump is needed, settling basins, and tanks for sand filters. At one grain of alum per gallon of water it would require 143 pounds of alum per million gallons as a coagulant of the fine clay. The bacteria will be caught in the coagulated clay and filtered out at the same time. This method can with reasonable care give the city the water supply which it needs. It seems the only method that is feasible.

The company which has recently bought the plant is now installing two settling tanks each with a capacity of 43,000 gallons and two filtering tanks each ten feet in diameter in which the sand forming the filter is to be three and one-half feet deep. It is also proposed to put in a battery of wells in gravel west of the city where there is good water and pump whatever can be obtained there directly into the main, using a gasoline engine and an automatic pump.