TOLEDO WATER WORKS.

REPORT OF MOSES LANE, C. E.

To the Honorable J. P. FREEMAN, EDWARD MALONE *and* CARL SCHON, *Trustees of Water Works of the City of Toledo, Ohio:*

GENTLEMEN:—In August last, I was requested by you to prepare for your City a plan of Water Works, and the necessary specifications, and make an estimate of the approximate cost, and submit the whole to you at as early a date as possible, the time being limited, and not to extend beyond the 1st of January, 1873, for perfecting the plan; and that the specifications for the work should be prepared as soon as they should be needed. Circumstances which will be explained hereafter, required some of the detailed specifications to be prepared before that time, and the preparation of others, which have not yet been required, has been left to be done after the whole general plan has been perfected.

In the performance of this duty, I have spent such time in learning the topography of your city, as the subject seemed to demand; have carefully examined the proposed location of the pump works, and the River for the whole distance through the city and several miles above it. In examining the streets of the city and the proposed location for the pump works, I have been greatly aided by the City Civil Engineer, H. C. Thacher, Esq., who has on several occasions accompanied me, and who has kindly furnished from his office all needed information of levels and established grades of the city, and also the levels and distances to the pump works, and such other information as would be of service to me.

The topography of the city can be briefly described as follows: The city is located on the Maumee River, about twelve miles from Lake Erie, the most part of it being on the west side of the River, only one ward being situate on the east side. The main portion of the city on the west side of the River is still further divided by Swan Creek, which runs in an irregular course, generally easterly, and discharges into the Maumee at or near the foot of Monroe Street; the main business portion of the city, and in fact much the larger area, being situate to the north of Swan Creek, while most of the structures belonging to the numerous railways which centre here, are situate south of Swan Creek. The extreme length of the shore line in the city along the River front is about nine miles. The area of the present corporate limits of the city is twenty-one and one-half square miles, six and one-fifth square miles of which are situate on the east side of the River. The population in 1870 was 31,584; the estimated population now is 38,000.

The elevation of the grade of the street in front of the Post-office is sixteen feet above city datum, or extreme high water mark. The highest established grade of any portion of the city lying north of Swan Creek is less than thirty feet above city datum. The highest established grade on the south side of Swan Creek is less than thirty-six feet above city datum. The general height of the ground which has been purchased for the site of the pump works is forty feet above city datum, at a distance of about one hundred and fifty feet from the River. This, I am told, is the highest ground within the city limits.

The whole difference between the extreme highest point in the city and the lowest, being less than forty feet, it is apparent that only one system of distribution pipes is necessary: and that, if these be properly designed, both in regard to size and location, a very nearly uniform pressure, as much or as little as may be found expedient or desirable, can be had over the whole, available alike for fire purposes and for the ordinary daily supply.

The surface of the country southerly beyond the city limits, rises very gently, so that it requires no surveys to determine that an elevated reservoir in connection with the works is entirely impracticable; in fact, that question had already been decided by city ordinance before I came here,—it having been determined to adopt the system of direct supply.

I make the above explanation of the general topography of the city, to show that this question of reservoir was correctly decided, and also to enable us to have a full statement and clear understanding of the whole question.

As we have got to raise the water by steam power, and as the construction of a reservoir is entirely out of the question, on account of its great expense; and further, as there are only two possible or practicable sources of supply, viz: The one from Lake Erie and the other from the Maumee River. The consideration of the whole subject is narrowed down to the discussion of a very few questions, all of which may be stated and taken up in the following order:

1. Source of supply.
2. Quantity of daily supply to be provided.
3. The particular system of supply to be recommended.
4. The distributing mains.

The question of what style of fire hydrants to adopt, as well as the kind of valves to be used, when there are so many styles already in use, the most of which give equal satisfaction, need not be considered in this report. Such minor questions can be canvassed and decided hereafter, when you have more time for their investigation.

1. *Source of Supply*.—The water of Lake Erie is admitted to be preferable to that of the Maumee, on account of its greater freedom from organic impurities. It is not so "soft" as the river water, and there is no doubt but what the latter, after proper filtration, would be as good for all purposes as the lake water. The distance which it would be necessary to bring the Lake water to the city is fourteen miles. The cost of a pipe conduit for that distance, of 30-inch diameter, would be $924,000; of 24-inch diameter, it would be $720,720; while the extra head from the friction of so long a line of pipe to be overcome, would be for a delivery of 6,000,000 gallons per day, 46 feet in the 30-inch pipe. The distance from the proposed pumping works on the Maumee is not over three miles from the centre of the city. It is apparent, at once, that for the present the project of going to the Lake as a source of supply, is entirely impracticable on the score of cost.

The question of the source of supply had also been virtually settled before I came here, by the purchase of the site for the pump works on the Maumee. The Lake project is alluded to only because it has been mentioned as the source to which the city would in the future probably have to go for their water supply, and it has been suggested to me that the locations and sizes of the pipes in the present scheme of Works should be arranged as far as practicable, with that ultimate end in view. It was not that question that determined the location and size of mains recommended; still it is worthy of remark that the plan of distribution recommended is hardly perceptibly different from what it would have been, if that ultimate aim had been kept in view.

2. *Quantity of daily supply to be provided.*—The supply per inhabitant in different cities is so variable, depending upon the kind of manufacturing industries carried on in the several cities; the habits of the population with regard to the free and abundant use of water, and other circumstances, almost always different in different cities, that no certain quantity can with absolute safety be assumed. So, it is always well to decide upon a quantity large enough. It is assumed here that for the first two years after the completion of the Water Works, the consumption of water should not go above three million gallons per diem, or at the rate of 50 gallons per capita for a population of 60,000. Accordingly the pumping power recommended to be provided at the outset, is 3,000,000 gals. per diem, and as these are to be Works where the supply is direct, it has been recommended to do as in all similar cases where the supply is direct, *i. e.*—directly and wholly dependent upon the pumping power,—to duplicate this power, viz: To erect at the start two pumping engines, which shall be duplicates of each other, and each of which shall be of sufficient power and capacity to pump 3,000,000 gals. in 24 hours to the height determined upon, as the head under which the water in the distribution pipes should always be maintained.

The diameter of the distributing main has been fixed at thirty inches, a size that will deliver six million gallons without a greater loss of head from friction per mile than 3.28 feet. It is designed to erect the pump-house large enough to admit of the introduction of a third engine with a capacity of 5,000,000 gallons per day. Such an engine will be required when the population of the city gets as high as 65,000 or 70,000.

3. *The particular System of Works to be recommended.*—The consideration of this question involves almost all the points about

which there appears to be any difference of opinion in the community here; so far as I have learned or heard any expression of opinion, all seem to be desirous of having the best, and only the best. The aim that has been kept in view in discussing this question and recommending to you a plan for adoption, has been to state the facts clearly, and recommend that form of engine which should be the most economical in duty and the most liable to run without breakage or accident, keeping out of view, until after this question was decided, the first cost of the particular style of engine you might adopt; for you all know that a poor engine—one that is expensive in the use of fuel, and liable to get out of order frequently from breakage or otherwise—is an expensive machine to have, even if it could be had for nothing. Fortunately, in the consideration of this question, the style of engine recommended is not only the most economical, as far as duty is concerned, but it will be found on investigation to be cheaper than other forms which have been urged.

I find a difference of opinion expressed by gentlemen whom I have conversed with here on the subject of Water Works, as to the meaning of the term "direct supply," and as you have asked me for an explanation of the term, as used by Engineers in referring to the supply of water to towns and cities, I will here state what is understood by it. A "direct supply" is a supply wholly and entirely dependent upon the pumping power, and such that when the pumping ceases, the supply ceases. There are three ways of providing a direct supply: 1st, By the use of a stand-pipe; 2d, By the use of an air-chamber; 3d, Without the use of either stand-pipe or air-chamber.

1st. With the use of the stand-pipe, the water passes through the bottom of the stand-pipe, which could be defined as a section of pipe introduced into the main pipe, where, to prevent a too great strain upon the main, the pipe is left open upon the upper side, and this open space, generally three or four feet diameter, is carried up vertically to any required height to which it may be thought advisable to maintain the head of water; and at the top it is left open, so that by no possibility can there be a greater head on the pipes in the city, than that due to the height of the stand-pipe.

2d. An air-chamber takes the place of the stand-pipe, and it is placed over the main usually very near the engine, and this air-cham ber is supplied by a separate pump with air to a given pressure per square inch; that is, whatever pressure it is desirable to maintain in the mains, and the vibrations or shocks of the water flowing into the mains, due to the changes of velocity in the engines, are received by the column of air in the air-chamber, allowing the water to rise or fall as the case may be, and thus relieve the mains from the blows or shocks, which otherwise would have a tendency to rupture them and start the joints.

3d. In the third case the water is pumped into the mains without having either air-chamber or a stand-pipe attached to them; but the purpose of these is sought to be obtained by "relief valves," so-called, placed at different points on the mains, arranged somewhat after the manner of safety-valves on boilers. These relief-valves are designed to open when the pressure of water in the mains gets above a fixed number of pounds per square inch, and allow the water to escape out into the air. There are certain other attachments to the service pipes, leading into the houses of water-takers, and designed to close under an excessive pressure, or what is called a "fire-pressure," and shut off temporarily the increased head from the service pipes within the buildings. This last arrangement it is not necessary very particularly to understand, as it is not considered indispensable, and is not always, as I am informed, put on, being one of those minor matters of detail, with which I will not encumber this report. There are other peculiarities about the engines and boilers which will be described farther on, when we come to speak of engines.

The name by which this system is generally known is the "Holly System," so-called from Mr. Holly, the designer of it. This system is at present in usein Peoria, Ills., Dayton and Columbus, Ohio, and many other places that might be mentioned. The pressure upon the mains under this system can, of course, be placed at whatever point is considered desirable, the same as with either of the other described systems. In the city of Peoria, in 1869, it was stated as follows: For the ordinary city consumption, a pressure of 40 to 45 lbs. per square inch,—equal to a head of 92 to 104 feet. The pressure to which they advanced it in case of fire, was 90 lbs. per square inch,—equal to a head at the pump house of 207 feet.

In the city of Burlington, Vermont, the water is pumped from the lake directly into the city distributing pipes, an air-chamber being used at the pump-house. The length of the pumping main, which is also the supply main, is a little over one mile, and it passes directly across the whole town into a reservoir. Between the pump-house and the reservoir it sends off branches at all the streets it crosses, to supply the whole city. Here, you will see, they have a direct supply when the engine is working, and an indirect supply when the engine stops,—that is, a supply from the reservoir. The elevation of the reservoir is 300 feet above the lake.

On the Brooklyn Water Works, built by J. P. Kirkwood, Chief Engineer, the idea has been suggested of having a direct supply, in addition to the supply asa t present, through the reservoir. Their pumping works are located about five miles from the City Hall, which may be called the centre of the city, while the reservoir is also about the same distance, being about three-fourths of a mile, almost at right angles from the engine house, when looking toward the city. The method suggested was to erect a stand-pipe at the engine house, and lay a main directly into the city without going to the reservoir,—so that in case it might ever be necessary for any purpose to clean both divisions of the reservoir at the same time, which would hardly be possible; or in case of accident to the mains near the reservoir, the supply of water would be kept up from the works by pumping directly into the city. Of course, in that case the supply would be wholly dependent upon the running of the engine. Numerous other instances of the similar use of this term might be mentioned.

I have recommended the use of the stand-pipe for this city. The proposed height for the stand-pipe is to be high enough to allow the surface of water in it to be 175 feet above city datum. The pumping power heretofore stated to be necessary, was a daily capacity of six million gallons, or 4,167 gallons per minute. The size recommended for the principal main is thirty inches diameter. The loss of head in a 30-inch main, deliverimg six million gallons per diem, would be 3.28 feet per mile; 3.28x4 would give 13.12 feet as loss of head in the principal main; add to this 10 feet to allow for loss of head in lateral mains, which is more than it would be, and we have 23.12 feet; call this 25 feet for loss of head in the mains; 175—25=150; now from 150 take 30, which is higher than any established grade on the north side of Swan Creek; and we have left an available head, or fire pressure, due to a delivery of 4,167 gallons per minute, of 120 feet. Let us see how many fire streams this would throw through nozzles of one inch diameter. A jet from a nozzle one inch diameter, under a head of 120 feet, will rise to the height of 97 feet in a solid stream; [see Box's Hydraulics, page 14;] and it will discharge under that head 168 gallons per minute. [See page 16 of same work.] Now, as we have available under the same head 4,167 gallons per minute, we have 4,167 divided by 168=24.8. Call it twenty-four streams of solid water that can be thrown ninety-seven feet high, from any twenty-four hydrants that can be selected on the north side of Swan Creek. Of course, along the lower levels the water could be thrown from the mains to a greater height. This is high enough for all practical purposes as a fire protection on the north side; let us see what can be done on the south side of Swan Creek. The highest established grade on the south side of Swan Creek does not exceed thirty-six feet above datum; but as this side is so much nearer the proposed pump works than the extreme points on the north side, the loss of head from friction would more than counterbalance the higher grades, so that I can positively assure you that with the works as at present designed, you can from any twenty-four several hydrants you may select, throw twenty-four solid streams of water ninety-seven feet high, and all at the same moment; and they can be continued all day, if you so desire it. In this calculation no allowance has been made for the water the city would be using at the same time for other and domestic purposes. Suppose this amounts to 2,000,000 per diem, we still have sixteen streams of solid water playing ninety-seven feet high, which is as many fire streams as the advocates of other plans, proposed for these works, have offered to furnish.

I have stated the above calculation at length, so that any one at all familiar with the principles of hydraulics, can verify it if they so desire. The calculation is from a well-established formula. To prove to you that it is correct, and not mere theory, I refer you to the following brief resume of a public trial of the hydrants of the Water Works at Providence, R. I. These are new works, not yet entirely completed. They were designed and constructed under the direction of J. Herbert Shedd, Esq., Chief Engineer. These works are built on the reservoir plan. The pressure due to the whole head was, during the experiment, about 75 lbs. The pressure due to a head of 175 feet would be $75\frac{3}{4}$ lbs. The whole number of streams they played at one time was twenty-six, one inch diameter at the nozzle, and the height to which the water run varied from seventy to about ninety feet. The description occupies a column in the Providence Daily *Journal* of Nov. 25th, 1872. The exhibition took place Nov. 23d. The reason given why they threw only twenty-six streams, was because that was all the attachments that could be obtained for use from the Fire Department. The population of Providence was in 1870, 68,900.

One other illustration about fire pressure from Water Works, without the intervention of fire engines. The head at Salem, Massachusetts, is 115 feet. I was told last Spring in New York by Capt. Silver, one of the Commissioners, who had the charge of their construction, that on the test of their fire-plugs and hydrants, they threw forty-two streams, higher than any building in the city, and all at the same time. The supply there is from a reservoir.

It is unnecessary for me to explain to you that the same display could have been made with works on the Stand-pipe system, except that during the experiment the pumping engines would have to be kept running the same as they have to be in any system of direct supply.

The reason for recommending a horizontal, double-cylinder engine, is, because such engines are regarded with great favor from their performance of a high duty, when compared with any other engines in use in this country where the quantity to be pumped, ranges from five to seven or eight million gallons per day. Such engines are at present in use in Salem, Charlestown and Cambridge, Mass.; Providence, R. I.; Jersey City and Newark, N. J.; Burlington, Vt.; Harrisburg and Philadelphia, and other cities, and are regarded with favor in all. An engine of this type is now under construction for the city of Buffalo, N. Y., to have a capacity to lift ten million gallons per day one hundred feet high. The duty to be guaranteed for such engines in Toledo, with a lift of 175 feet, is fifty-five millions. This style of engine is called the "Worthington Duplex Pumping Engine."

While I here recomend a particular style of engine, it is proper to say, that there can be no objection to the use of any other style guaranteed to do the same duty and capacity. Still, you should always keep in mind, that in acting as Trustees for a city, it is not safe or advisable to recomend any experimental style of engine that has not before done the duty and the capacity required, and has not made a public record at least equal to the requirements of your specifications

The term "duty" has been used several times in this report, when speaking of engines; it cannot, therefore, be out of place to explain its technical meaning which is familiar to all who have to do with engines. By the term "duty," is meant the amount of work done from the consumption of a given amount of fuel. For instance, we require here a duty of 55 millions to be guaranteed for the engines. This means that the engines must lift 55,000,000 pounds of water one foot high for every one hundred pounds of coal consumed in the boiler furnaces. The *capacity* required is for each engine to raise three million gallons, 175 feet high, every 24 hours. Now, combining both these terms—duty and capacity—as applied to the Works here, each engine must lift three million gallons of water 175 feet high, in twenty-four hours, by consuming in its boiler furnaces during that time, only 7,960 pounds of coal. This is more than three times the duty ever claimed for any of the engines which are used with the rotary or gang pumps. In fact their builders make, so far as I am able to ascertain, no pretension to duty for these engines.

The leakage in the rotary pump, as every one knows who is at all familiar with the subject, is very great. Besides this, it wears out very quickly, and both the rotary and gang-pumps, are a frequent source of expense for repairs.

4. *The Distribution Mains.*—A schedule of the streets in which it is proposed to lay the distribution pipes, showing their sizes, &c., accompanies this report; the locations of the fire-plugs or hydrants and stop valves, is also given in the same schedule.

The estimated expense of this plan of distribution has been criticised as being very high, and this renders a lengthy explanation of the whole subject of Distribution Mains necessary. The following table is given, which will be explained further on:

Diam.	Capacity.	Weight. per ft.	Cost per ft. laid.
4 in.	32	22 lbs.	$1 00
6 in.	88	35 "	1 50
8 in.	181	50 "	2 10
12 in.	499	87 "	3 40
16 in.	1,024	137 "	5 15
20 in.	1,789	194 "	7 33
24 in.	2,822	267 "	9 75
30 in.	4,929	350 "	12 50

The first column gives the diameter, the second gives the value or capacity, and the third gives the weight in pounds per foot, and the fourth the cost per foot. The velocity of water flowing in pipes under pressure varies in pipes of different diameters. For example, in a pipe of 4-inch diameter and one of 16-inch diameter, both being under the same pressure and of the same length from the source of supply, the velocity of water in the 4-inch pipe would be to that in the 16-inch pipe as 2 to 4—that is, the velocity in the 16-inch pipe would be double that in the 4-inch pipe. The *quantity* of water that each of these pipes would deliver under the same conditions would be found by multiplying the area of each pipe by the velocity due to this pipe. The areas of the pipes vary as the squares of the diameters,—that is, the area of a 4-inch pipe is to the area of a 16-inch pipe as the square of 4 to the square of 16, or as 16 to 256; and multiplying these numbers representing the areas by the numbers representing the velocities, we have 16x2=32, for the 4-inch, and 256x24=1,024 for the 16-inch. Hence, the quantity of water a pipe 4-inch diameter will deliver, is to the quantity of water a pipe 16-inch diameter will deliver as 32 is to 1,024=1 to 32; that is, a 16-inch pipe will deliver 32 times the quantity of water a 4-inch pipe will deliver under the same conditions. The worth or value of pipes for Water Works must be directly proportioned to the quantity of water they will deliver; hence the value of a 16-inch pipe is 32 times the value of a 4-inch pipe. The cost of a 4-inch pipe laid, is $1.00 per foot; the cost of a 16-inch pipe laid, is $5.15 per foot. You will notice that by increasing the cost 5 times, you get 32 times increase in value for the purposes you want, because the 16-inch pipe will deliver 32 times the quantity of water a 4-inch pipe will deliver. It is in the way explained above that all the numbers in the second column of the table are obtained.

Again, let us take one or two more comparisons from the table. The cost of 4-inch pipe is $1.00 per foot; the cost of 6-inch pipe is $1.50 per foot. The value of a 4-inch is to the value of a 6-inch as 32 to 88, or as one to 2¾. By adopting a 6-inch pipe as the minimum size of pipe, you will increase the cost over a 4-inch 50 per cent., while you get an article that is worth for the very purpose you want it, 2¾ or 175 per cent. more than the other. The cost of a 20-inch pipe is $7.33 per foot, while the cost of a 30-inch pipe is $12.50 per foot, or as 1 to 1.7; the value of the 20-inch as compared with the

30-inch, is as 1,789 to 4,929, or as 1 to 2¾. Here again, by increasing the cost 70 per cent, you increase the value 175 per cent.

One other, and only one more illustration of these pipes: A 24-inch pipe is worth, as compared with a 30-inch pipe, as 2,822 to 4,929; or as 1 to 1¾; while the cost of a 24-inch pipe is to the cost of a 30-inch, as $9.75 to $12.50, or as 1 to 1.28, that is, by increasing the cost of a 24-inch pipe 28 per cent., you can buy a 30-inch pipe, which, for the purpose of conveying water, is worth 75 per cent. more than the 24-inch pipe.

There is one other point in connection with the subject that furnishes a strong argument for favoring the use of large pipes, on economical grounds. I can only allude to it here. I have not time to make the calculations, and the tediousness of listening to their detail would only weary you. They are so simple, that it hardly requires an engineer to make them. You have seen that one of the great points to be attained in building Water Works for towns and cities, is to furnish water for the purpose of extinguishing fires. This object was kept steadily in view here. For this purpose we want, in any system of direct supply, reliable engines and pumps that will throw a large quantity with certainty, and we want this delivered under a head. Now, the loss of head from friction in small pipes, is very great; hence, the smaller the pipes, the greater the head or pressure you must have at your pump station, to procure the head you want where you are delivering the water at the fire. You save a trifle in the first cost of your pipes by using small pipes, but you lose very much more than the interest on it by the extra amount of coal you have to burn, to pump or force the water through the small pipes. The calculation is a very interesting one, and I would like to make it, but would in doing so, make this report quite too lengthy.

ESTIMATED COST OF THE WATER WORKS.

The approximate estimate of the cost of the Water Works is as follows, to-wit:

20,375 feet of 30-inch mains at $12.50,.........	$254,687 50
Add for extra expense at crossing of Swan Creek	
175 feet at 17.50,........................	3,062 50
375 feet of 20-inch pipe at $7.33,............	2,748 75
1,000 " 16-inch " " 5.15,............	5,150 00
7,600 " 12-inch " " 3.40,............	25,840 00
17,070 " 8-inch " " 2.10,............	35,847 00
46,380 " 6-inch " " 1.50,............	69,570 00
142 hydrants at $60,........................	8,520 00
81 stop-cocks,............................	8,800 00
1 check-valve,............................	1,000 00
	$415,225 75
Add for superintendence, etc., 5 per cent.,......	20,761 25
	$435,987 00
Two pumping engines, including foundations, &c.	65,000 00
Engine House,............................	20,000 00
Stand-pipes,............................	15,000 00
Filtering Beds,............................	60,000 00
Total,............................	$595,987 00

This is the estimated cost, with pumping works on the House of Refuge grounds. This sum could be diminished about $60,000, if you could get permission to move the works about three-fourths of a mile down the river, to the property just south of the intersection of the Wabash Railroad and Broadway. It might be temporarily further reduced $60,000 by omitting to build the filters until one or two years after building the other portions of the Works. There would not be a very large domestic consumption of water the first year after the Works were built; the principal use of it would be for fire purposes and manufactories, and for the railways.

After a careful review of the whole subject since the recommendation made to you in November last, , the only point in which I would desire to change the present proposed plan, would be to substitute, in accordance with our first design, two engines, each to have a capacity to deliver five million gallons per day, in place of the two now proposed, which are to deliver three million each per day. In making the recommendation to you of the smaller engines, I was governed by your very earnest desire, frequently expressed to me, to keep, if possible, the whole cost of the works below the original appropriation of $500,000. While speaking on this subject, it is pertinent here to say that the city of Salem, Mass., has one engine of five million gallons capacity, of the same style as those here proposed, which was erected in 1867. They also have a reservoir which holds 20,000,000 gallons; and they have within the past few weeks contracted for a second engine of the same capacity, to be delivered the present year. Their population in 1870 was 24,000. The consumption of water there is much greater now than it will be here for the first few years. It requires a year or two before the people generally appreciate fully the advantages and direct saving in money to them in using the water in their houses, and when they do fully realize it, and acquire the confidence that the works are going to furnish them a sure and certain supply, not liable to frequent interruptions from breaks, etc., the consumption of water increases very rapidly, and is generally taken by every one within the districts where the pipes are laid.

I was informed by you in September last that you wished to lay the pipes in one block on Madison Street last fall, and also in Summit Street, between Perry Street and Cherry Street, and that you would require the forms of proposals and specifications for this work. These forms were prepared and presented to you for approval. The form of proposals for the engines, together with the general specifications for the same, was prepared in December, and presented to you.

In the hope that this report may aid, to some extent, in arriving at an intelligent understanding of the whole question of Water Supply for your city,

I am, very respectfully,

Your servant,

MOSES LANE, Civil Engineer.

MILWAUKEE, WIS.,
January 13, 1873.