SUPPLYING WASHINGTON CITY WITH WATER.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING

A report on the subject of supplying pure water to the city of Washington.

March 3, 1851.

Laid upon the table, and ordered to be printed.

War Department,
Washington, January 25, 1851.

Sir: I have the honor to submit herewith a letter of the Colonel of the corps of topographical engineers, communicating a report of the examinations and surveys undertaken, pursuant to an appropriation made at the last session of Congress, "to determine upon the best and most available mode of supplying the city of Washington with pure water," together with "a plan and estimate of the probable cost of the same," as required by said act.

Very respectfully, your obedient servant,

C. M. CONRAD,
Secretary of War.

Hon. Howell Cobb,
Speaker of the House of Representatives.

Bureau of Topographical Engineers,
Washington, January 25, 1851.

Sir: In the act of 30th September, 1850, there is the following provision:

"To enable the War Department to make such examinations and surveys as may be necessary to determine upon the best and most available mode of supplying the city of Washington with pure water, and to prepare a plan and estimate of the probable cost of the same, to be reported to Congress at its next session, five hundred dollars."

In obedience thereto, I have the honor to submit a copy of the report of the investigation which has been made.

The map and profiles are not completed, but will be ready in time, if it should be thought proper to print the report.

Respectfully, sir, your obedient servant,

J. J. ABERT,
Colonel Corps Topographical Engineers.

Hon. C. M. CONRAD,
Secretary of War.

WASHINGTON, D. C., *January* 15, 1851.

SIR: An act of Congress, entitled "An act making appropriations for the civil and diplomatic expenses of government for the year ending the 30th June, 1851, and for other purposes," approved September 30, 1850, appropriated the sum of *five hundred dollars* "to enable the War Department to make such examinations and surveys as may be necessary to determine the best and most available mode of supplying the city of Washington with pure water, and to prepare a plan and estimate of the probable cost of the same, to be reported to Congress at its next session."

By your order of the 2d of October last, I was assigned to the above duty; and I have now the honor to submit the following report on the result of our investigations:

The amount appropriated by Congress was obviously inadequate to effect any useful purpose—the more especially as, from the exigency of the service, it became necessary to employ a civil assistant, whose salary alone would probably more than absorb the sum appropriated.

In this view of the case, the corporation of Washington placed the additional sum of one thousand dollars in my hands for the survey. This, however, was not sufficient to employ a second party in the field; and this fact, in connexion with the short working season that remained, has rendered our examinations less extensive and satisfactory than could have been desired. Enough has nevertheless been accomplished, I think, to enable Congress to act intelligently on the subject; but, at the same time, it must be understood that our plans and estimates can be regarded only as approximations. To carefully revise them; to correct and retrace the line; to modify the projét according to circumstances since ascertained, and to elaborate the details, before a rigid and exact calculation of quantities can be made, and the construction of the works commenced; and, above all, to survey the line from the Great Falls of the Potomac, if it should be deemed essential, will still require much time and labor.

As it was not possible, for reasons already given, to survey all the projected lines, it was considered expedient to confine our labors to the one of which we possessed the least accurate information; but which, after a personal examination, promised to answer the purpose at the least expense. Accordingly, the instrumental surveys were directed mainly to a single source of supply—that of *Rock Creek*—to the selection of sites for receiving and distributing reservoirs (common to any and to all the plans) and the determination of the highest and most important positions within the city; while extensive and careful reconnaissances were made of all other sources from which favorable results might be reasonably expected.

As it regards the elevation of the Great Falls of the Potomac—of its abundant supply of water, and of the general character of the intervening country—we have availed ourselves of the surveys of the Chesapeake and Ohio canal; but to enable us to submit a specific plan, with detailed estimates of cost, on this line, would require a very minute survey executed expressly for the purpose; and it is much to be regretted that such a survey is wanting.

The idea of supplying Washington with pure water was contemporary with the first plans of the city; and all recent suggestions for that purpose may be regarded as mere repetitions or modifications of the original designs. At that early period, the Potomac above the Great Falls, Rock creek, (which washes the conterminous boundaries of Washington and Georgetown,) the northeastern branch of the Potomac, and the numerous springs within the limits of the city, and the smaller streams in its vicinity, were contemplated as the sources of supply of that essential element. The founders of the city were not so wanting in sagacity as to lose sight of this important consideration.

Numerous surveys were made by Major L'Enfant, the engineer and architect of the government, under the direction of General Washington, to ascertain these facts; and it is quite certain that if, in the progress of time, their glorious anticipations of the future greatness of the federal capital should be fully realized, without incurring any very extraordinary expense, all its wants may be supplied with an abundance of pure and wholesome water.

The immense volume of fresh water discharged by the Potomac over the Great Falls, the elevation of its surface at that place above tide, and its comparatively short distance from the city, have naturally attracted public attention to it as the most certain and abundant source of supply. The only objection that can be urged against it is the very great expense it involves on any plan that may be adopted.

To any one acquainted with the nature of the country between the Great Falls and Washington city, it must be apparent that to convey the water from that locality in a *canal conduit* would be attended with an enormous expense, more than proportional to that of the Croton aqueduct, although of less than half its length.

A country worse adapted to such a purpose can scarcely be found. The physical difficulties are also much increased by the construction of the Chesapeake and Ohio canal, which, conforming to the natural formation, and having no other object than a navigable connexion with the level of tide-water, has pre-occupied much of the most favorable ground, especially in the vicinity of the falls; and yet there is probably no similar work of its dimensions in the world more costly, while few have been conducted with more skill, science, and ability.

General Bernard, in his report on the original projét of the Chesapeake and Ohio canal, says: "The breaking of the Potomac through the granite ridge at the Great Falls presents, at first sight, difficulties of the greatest magnitude. The river gradually narrows its channel as it approaches its perpendicular pitch; at this point, and a little below, the width does not exceed one hundred yards at a moderate stage of the stream. Here, the perpendicular rocks, sixty or seventy feet high, forming the banks, the deep water at their foot, the violence and great rise of the freshets, render truly appalling the idea of supporting a canal along this pass by means of walls.

"Below the Great Falls, the ground, with the exception of some portions of easy execution, is generally difficult, requiring a large extent of walling and of steep side-cutting for about seven miles—it is to say, as far down as the head of the actual canal round the Little Falls."

Bearing in mind what has been already said—the pre-occupation of the ground, the difference in the character of the two works, and the absolute necessity that the water conduit should occupy a line of gradual descent of not more than one foot to the mile (while the canal is relieved from that disadvantage by 20 locks,) which would throw it high up on the banks of the river for long distances on nearly vertical rock escarpments, crossing wide and deep ravines, either by high aqueducts or by inverted syphons—it will be readily understood that I do not exaggerate the difficulties and cost when I venture to suggest that it could not be accomplished without an enormous expenditure of time and money.

The only feasible plan, unless all considerations of cost be disregarded, by which water can be derived from the Great Falls, would be through iron pipes, laid nearly coincident with the descent of the canal, tapping that work above left lock number 20, at an elevation of 161 feet above ordinary low tide, and 14¼ miles from the basin in Georgetown. To reach the projected reservoir in Washington, diverging from the canal at some suitable point above Georgetown, would increase the distance to not less than 16 miles, and would involve the expense of crossing Rock creek by a high aqueduct, or by a combination of an arched bridge and an inverted syphon.

That water may be brought from the Great Falls in abundance and at a sufficient elevation to supply every portion of Washington there can be no question; but, unfortunately, we have not the elements (nor can they be obtained except by a special survey) by which to estimate with confidence the cost of such a work, or to determine the precise height in the city to which the water may be brought, or even of the dimensions of the pipes necessary to discharge daily a given quantity of water. It is a popular notion that "water seeks its own level." In experiments, and on a small practical scale, this may be said to be true, but is by no means strictly so on a work of the magnitude and length now under consideration. It is far from my intention (and indeed it would be out of place) to discuss in this report the theory of, and elementary principles which govern, running waters either in open canals or through iron pipes. The curious in these matters are referred to the interesting and able reports of Douglass, Baldwin, Jervis, and McAlpine, on the water-works of this country, and to the writings of Storrow, Robison, and especially of M. d'Aubuisson* de voisins (recently translated by Mr. T. Howard, an English engineer,) on hydraulics generally. It may, however, for the better understanding of our subject, be proper to notice some of the leading principles which regulate the flow of water, more especially of those which exercise a retarding influence. The following remarks on this branch of the question are mainly condensed from the researches of d'Aubuisson.

In long inclined pipes or canals, water moves in consequence of its

* See April and May numbers (1850) of Civil Engineers' and Architects' Journal.

gravity or weight, or rather of that portion of its weight called into action by the inclination, and its accelerating force is in both cases compounded of the velocity acquired by gravity in one second of time, = 32.19 feet + the length of the canal or pipe.

There is generally this difference between canals and pipes. At the commencement of the former there is no accelerated motion from pressure, while there usually is at the head of the latter, due to the slope and to the height of the fluid above the pipe. Where, however, there is no such pressure on the head of the pipe, the accelerating force and its effects are the same as they would be in a canal. For a short distance, under the influence of such a force, the motion in pipes would be continually accelerated, and yet it soon becomes nearly uniform, (on the same inclination) owing to the friction on the sides. The same laws of acceleration and retardation are observed in canals, the only difference being in the form of the conduits.

This difference in form gives rise to peculiar circumstances of movement not now necessary to consider.

In speaking of the resistance arising from the sides of the pipes, M. d'A. says it will be proportional to their superficies; that is to say, to the length of the conduit, and to the circumference of its section, which is here the wet perimeter, for we are supposing that the flow is made in full pipes, otherwise we should have the case of a simple canal. In other words, the more the section is enlarged, the more also will the resistance of the sides be distributed among a greater number of molecules; consequently, it will less affect each of them, and the total mass: it will be in inverse ratio to their number, and consequently to the magnitude of the section. In short, here, as in canals, it will be proportional to the square of the velocity, plus a fraction of the simple velocity. I omit the formulæ, as we have not the data for their application.

These remarks are applicable only to sectilinear pipes, which are seldom used to any great continuous extent. The nature of the ground compels many deviations from a straight line, in vertical or horizontal directions, and when the water arrives at the bends it is also forced to change its direction, losing thereby a portion of its velocity. The resistance encountered at the flexures is opposed to the motive power, a part of which it counteracts. Another cause of retardation is to be found in the want of uniformity in the bore of the pipes, which may be an original defect in the castings, or may arise from want of care in adjusting the joints, from deposites of concretions of mud or sand, and sometimes from the vegetation of seeds lodged in the joints. "Thus water, in its motion in pipes, meets or may meet with three kinds of resistance: that due to the effect of the sides, and which is by far the most considerable; that which arises from bends, and that from contractions. The forces or portions of the head employed to overcome these lessen the total head; and it is only by reason of the remaining part that the efflux takes place; this portion is the height due to the velocity of discharge."

By a series of careful experiments *Du Buat* deduced the laws regulating the resistance of bends. He first used rectilinear pipes, and noted the head or pressure by which they discharged certain quantities of water in certain times. He then bent them in different directions, so that the central currents had a tendency to be reflected at angles of determined number and value. The difference in head between the straight and bent pipes (discharging the same quantities in equal times) was obviously due to the bends, and was the measure of their resistance. From these experiments he infers that the resistance from bends is proportional to the square of the velocity of the fluid, to the number of angles of reflection and to the square of their sines.

All diversions from a straight line should be in curves of large radii, in which case the resistance will be scarcely appreciable; but elbows or abrupt turns should be carefully avoided, as they may generally be in practice.

The retardation from the accidental difference in the diameter of pipes is usually small. M. D'A. says that in some experiments, conducted by himself, it was ascertained that even a diminution by a sliding valve of $\frac{24}{100}$ of a pipe, caused a reduction of discharge of only $\frac{1}{100}$. The introduction of a short pipe larger than those of the main conduit, is also prejudicial.

M. D'Aubuisson makes the following sound but cautious observation on the practical application of his formulæ: "The coefficients of the formulæ which we have given, especially those concerning the principal resistance—that due to the friction against the interior of the pipe—have been determined by experiments made chiefly on pipes of small diameter and of no great length. They have been generally well-bored pipes, well joined, and free from incrustations. But can such formulæ be safely applied without modification to conduits of a different description—namely, to those used in large distributions of water? This is a question which we must now examine.

"The pipes of which conduits are formed are almost always, more or less, imperfect, from the effect of the mould, or in casting: their section is no longer exactly circular; and consequently, *cæteris paribus*, it is smaller than it ought to be. The interior surface presents inequalities which retard the motion. When joined, the axis of the whole is not always a line without rebatement; the interior is not a perfectly cylindrical surface: the edges of some of the pipes project, and the currents reaching these points are arrested, divided, and sometimes reflected back again.

"Thus arise eddies in the movement, loss of motive force, and consequently a diminution of the discharge. Even when the pipes are well cast, so that the channel is very regular, there will be nevertheless, at each joint, a little annular hollow, or a break of continuity, which will produce, to a certain extent, the effect of projections, and which, repeated at every joint in a long conduit, cannot but give rise to a perceptible reduction in the discharge.

"M. Gueymard, *ingenieur des mines*, has rightly insisted on this cause of reduction, and has endeavored successfully to obviate its effects in the establishment of the fountains at Grenoble.

"Moreover, when the conduits are sinuous in their vertical planes, as is generally the case if there are no vents at the summits of the highest parts, the air which the water carries with it, and which is disengaged in a greater or less quantity, rises into these elevated parts, and, being there collected, produces the effect of contractions, the bad effects of which we have already seen. The cleanest waters in appearance always carry with them foreign bodies, and especially extremely fine earthy particles, which are deposited in parts of the pipe, and, in time contracting the section, again diminish the discharge. I do not here speak of calcareous and silicious matters, which, although held in solution in the water, become precipitated on the interior of the pipes, lining them with a stony crust, and, gradually increasing in thickness, would end by stopping them altogether if not removed in time: this evil is peculiar only to certain localities. It is the same with regard to ferruginous deposites, which are made in a tubercular form in the conduits of Grenoble, and which, continually increasing in number and size, diminish the discharge to such a degree, that in eight years it has been reduced more than one-half.

"The aërated water, running in pipes, likewise attacks the material, and forms a hydrate of iron, which is deposited in long nipples parallel to the direction of the current, and in greatest quantity on the lower part. Underneath these the iron is, as it were, corroded, nearly to one-tenth of an inch."—(*Annales des Mines*, 1834, *p.* 203 *et seq*)

"Setting aside these local circumstances, it often happens that in experiments made on conduits apparently in a sound state, the discharge has been found to be less by a quarter or a third than that indicated by the formulæ: it is scarcely ever equal to it. I have quoted many of these experiments in my history of the formation of the fountains at Toulouse. In consequence of these ascertained facts, the hydraulic engineers of Paris, when making use of the formulæ of discharge, diminish by one-third the value of the numeric coefficients. I have adopted an analogous method by augmenting by one-half the quantity of water which should determine the size of the conduit. It is, in my opinion, with such latitude that an engineer charged with the establishment of a plan for a large distribution of water ought to employ the formulæ which we have set forth. He will then avoid the disappointments which would often occur if he uniformly adhered to results given by conduits made with a precision which can seldom belong to his own."

Rock Creek.—The experimental survey was commenced near St. John's church, on the north side of La Fayette square, opposite to the President's House, at a few feet elevation of it. Lines of level were run from this place to tide-water, near the Georgetown basin, to the Observatory, the Capitol, and to all the highest points within the city limits, and to tide-water in the Washington canal. A line was also run from the same point up Rock creek, to ascertain its fall, and the distance from which water might be brought to the city. The creek was repeatedly gauged at different places and on different days, to determine the daily discharge of water during the driest portion of the season. These observations resulted in the conviction that from this source a sufficient supply of water could be obtained, and at such an elevation as to furnish every portion of the city, on a short line, and at a reasonable cost. It was also found that excellent natural sites might be selected for receiving and distributing reservoirs, and in fact it offered many striking advantages for the object in view, and would probably fulfil all the conditions of the problem—the supplying the city with pure water at a moderate expense. The following are the levels of some of the more prominent points within the city above ordinary low tide:

The foundation of St. John's church - - -	65.50	feet.
Corner of I and 19th streets (west) - - -	82.10	"
Base of Observatory - - - - - -	96.20	"
Eastern base of Capitol - - - - -	89.50	"

Corner of N and 11th streets west, (immediately in the rear of the buildings called Franklin Row, the highest point in the city) - - - - - - - 103.70 feet.

Rock creek, for nearly its whole course, may be described as a very rapid stream, falling in one section sixty feet in less than a mile. In this section it is one continuous cataract—its boiling waters rushing and foaming over and between the huge granite boulders which occupy its bed, and stem its torrents. The highest point which we reached on Rock creek was 193.70 feet above tide, at a distance of about ten miles from St. John's church, or from our proposed receiving reservoir of, say eight miles and a half. As this elevation was considerably greater than was necessary for our object, and as the upper portion of that part of the stream was comparatively sluggish, it was thought most expedient to select the initial point of location for the conduit. Some four miles lower down, by which, while we had the command of more water than above, at a sufficient height for all practical purposes, that length of aqueduct would be saved, even if, in both cases, we assumed the same height of dam for retentive reservoirs. Besides this, an excellent position for a dam was offered, with a natural rock foundation and abutments. At this point, near the southern boundary of Mr. Darius Clagett's farm, the valley is very narrow, being contracted by high, rocky promontories on either side, while the valley, opening widely immediately above, may be converted into a capacious retentive reservoir.

In regard to our measurement of the flow of water in Rock creek, it is proper to remark that the last year was, until late in August, usually wet; and although there had been a considerable drought at the time our observations were made, which was just before the first autumnal rains, the ground had been so saturated with the previous summer rains as to render the results much above the average of several preceding years, and greatly exceeding those of extraordinary drought. What deduction should be made on this account, it is, of course, difficult to determine, as we have no gaugings except of the last autumn. While it is the *driest season* that must control the maximum amount of water that we may command at certain times, at least so far as it regards the natural flow of the stream, I should suppose, however, that it would be perfectly safe to make an abatement of one-third of the daily flow, according to our measurements, on this account, which would still leave a most profuse supply of water to meet the present and any probable future wants of the city.

The mode adopted in gauging the creek was to select a portion of the stream of nearly uniform width, depth, and apparent velocity; then to measure a cross-section, on which soundings were taken at short intervals and the velocity carefully observed on different lines of flow, but at equal distance from each other, usually corresponding very nearly with the soundings on the cross section.

From these several velocities a mean surface velocity was derived; and as the creek was shallow, this was assumed as the mean velocity of the water flowing through the section, which may be slightly in excess, but not sufficient to have produced any serious exaggeration of results. It may be well to state in this connexion that almost any quantity of water, to supply the deficiency of the dry season and to meet any future wants, may be secured by constructing reservoirs above our projected lake, or by damming the lateral valleys; but it is by no means likely that it will ever be necessary to resort to these expedients. Piney branch, a tributary to Rock creek, yielding a flow of nearly 800,000 gallons per diem, might also be introduced into the conduit, while the navy yard and its dependencies might be advantageously supplied from "Isherwood's spring," to the east of the Capitol. This spring, 41 feet above tide, one of the most noble I have ever seen, and whose waters for coolness and purity are unsurpassed, discharges into the Eastern branch of the Potomac, and might be conducted to the navy-yard at little expense, furnishing water not only for domestic purposes, but also for navy machinery. Its source is so high that it might drive an over shot wheel of very large diameter. I am so fully impressed with the value of this spring, that I consider it my duty to call the attention of the government to it. I had no opportunity of measuring its flow, but I should think it might yield nearly or quite 200,000 gallons daily.

The water* of Rock creek is pure, cool, and pleasant to the taste. In all of these particulars it is unexceptionable. For analysis of this and the water of the Potomac above the Little Falls, see the annexed paper by Dr. Forman, of the Smithsonian Institution.

By measurements of the stream made in the manner before described, we obtained the following results of its daily discharge, viz:

On Hoyle's farm - - - - -	22,021,080 gallons.
At proposed dam - - - - -	22,000,000 "
At Clagett's ford - - - - -	17,067,616 "
Above Jones's dam - - - -	13,693,312 "

As the gauging at Clagett's ford was made with great care and particularity, and as the section of the creek at that place was favorable for accurate results, I have taken it in preference to the gauging at the proposed dam, as the amount of daily flow. The measurement is given in United States standard gallons of 231 cubic inches each, weighing 8,355 lbs. The cubic foot is equal to a fraction more than 7½ gallons.

By making, for reasons already given, the liberal deduction of one third from the gauging at Clagett's ford, for the assumed excess of the last season over those of extreme drought, it will still leave at our command 11,375,408 gallons for the daily flow of the stream.

It is usual in estimating for the supplying of a town with water, to allow to each soul 30 gallons daily. This is the highest calculation I have seen, and is, no doubt, ample for all the uses of a city, except for manufacturing purposes.

According to the recent census, Washington city contains 40,027 inhabitants. This would require for present wants 1,200,810 gallons of water daily. It is therefore perfectly apparent that a most abundant supply of water can be procured from Rock creek, on the plan I have proposed. An allowance of 1,500,000 gallons daily may be regarded as a very liberal supply for the present, and to meet this the capacity of the distributing reservoir might be reduced to 5,000,000 gallons, which would greatly diminish its cost. I have, however, estimated for one of larger dimensions.

The plan which I propose, as at present advised, for supplying the city of Washington with water, is to erect a dam across Rock creek at a point near the southern boundary of Mr. Clagett's farm, as already suggested, 20 feet high, so arranged as to draw off the water five feet below the crest

*This water has been kept bottled for more than two months, and has made no deposits.

of the dam, and to conduct it through an arched oval culvert of *three* by *four* feet diameter, on a slope of one foot to the mile, on which principle our line has been located, to a receiving reservoir on Meridian Hill ridge. This ridge, or rather high plateau, skirts the northern boundary of the city; and its numerous ravines declining towards the city, there are many eligible sites for a reservoir. There are two especially which may be reached, without any serious difficulty, from the valley of Rock creek, with earth-cuttings of 25 to 26 feet. These positions will be more particularly mentioned in a subsequent part of this report.

The estimates contemplate that the culvert will be constructed of two courses of brick-masonry (eight inches thick) laid in hydraulic mortar of the best quality, and reposing on a foundation of concrete and of rubble masonry, when the embankment exeeeds seven feet in depth. It would be well, also, that it should be plastered on top and in the interior with hydraulic cement, although this is not absolutely requisite. It is proposed to cover it with dirt seven feet above grade line, whether in excavation or embankment, to prevent the water from freezing and the works being injured.

Waste-wiers are provided for at suitable localities, and ventilators or "man-holes" at short distances, except where the waste-wiers render them unnecessary. The ventilators may be made to answer a double purpose—that of letting off the air, and of affording easy access to examine and to repair the conduit.

It is calculated that the culvert of the above dimensions will discharge, when full, about eight millions of gallons daily; and when the water is three and a half feet deep, something like seven millions; but the actual discharge may be regulated according to the wants of the city, by the head at the dam.

I will take this opportunity of saying that for many of the practical details of this report I have availed myself freely of the admirable report of Messrs. Jervis & McAlpine,* both gentlemen of enlarged experience in hydraulics, to whom my acknowledgments are due.

The excavations to receive the culvert will be cut in slopes of forty-five degrees, (except through rock, when they will be nearly vertical,) and to a width of four feet and three inches, at a level one foot and three inches above the upper surface of the lower arch, and below that level will conform to the exterior surface of that portion of the culvert.

The earth embankment will be thirty-three feet wide at the level of grade, (and the slopes two horizontal to one vertical, when the embankment exceeds seven feet in depth.) The conduit will rest on rubble masonry carefully laid, and the interstices filled with broken stone, six feet wide at top, covered with a course of concrete, with a batter of one inch to the foot. The base of the wall should rest on firm earth or rock: when less than seven feet deep, the foundation wall will be dispensed with, but the embankment of fine dirt will be carried up in layers six inches thick, and will be wetted and rammed when required.

The whole conduit will be covered with a back filling of dirt seven feet above grade line, five feet wide at top, with slopes of two horizontal to one vertical.

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* The dimension of the conduit and many of its details are nearly identical with those recommended by Mr. McA. for the Albany water-works.

It is proposed to construct two reservoirs—the one for receiving and filtering the water, the other for its distribution throughout the city. The former to be located in a ravine on Mr. Little's farm, adjoining Meridian Hill; or in a ravine near the country residence of the late Mr. Jesse Brown, near the Seventh street road, on the northern verge of the city. The distributing reservoir to be established just back of Franklin Row, the highest ground within the city. The first may also be used for the distribution of water if it should be found necessary. It is proposed to make it of the capacity of 25,000,000 of gallons, and the distributing of 10,000,000 of available water, or a total of 35,000,000. As the wants of the city increase, other reservoirs may be built. The surface of the water in the receiving reservoir, when full, will be 160 feet above ordinary low tide, or fifty-seven feet above the highest point in the city, and seventy-three above the eastern base of the Capitol. The surface of the water in the distributing reservoir, when full, will be 147 feet above ordinary low tide; but, for all ornamental purposes, such as great *jet d'eaux*, if they should be desired, the water can be drawn from the high reservoir at but little extra expense; and its height may be increased by raising the dam across Rock creek five feet, which would considerably add to the cost, or by giving less declivity to the conduit, neither of which, I think, would be advisable. If it should be considered desirable to obtain a higher head for the distributing reservoir, that may be accomplished by giving to the receiving reservoir less depth of water than has been assigned to it, and extending its surface so as not to decrease its capacity.* These are, however, matters for future consideration, when the project may be more nearly perfected, and my object now is to lay down general principles merely, which may hereafter admit of important modification in details. It will be seen that I have confined myself literally to the intentions of Congress—to the introduction of water into the city, and the storing of it in reservoirs, and have said nothing about the subsequent distribution of it: that, I conceived, was no part of my duty, and would properly belong to the city, or to an incorporated company. This, however, would be but a simple and by no means an expensive operation, which low water-rates would amply justify. Ordinarily the great expense is in the introduction, not the distribution of water in a city.

The dam across Rock creek will be 20 feet high (above the water in the creek) and 220 feet long, measured on the crest, provided with a waste-wier, excavated principally through rock, on the right bank of the creek; that is, on the side opposite to the conduit.

For the foundation of the bottom of the dam, the rock will be cut down to a level plane of such depth as to be below all that which is not perfectly solid; that is to say, 2½ feet below the present bottom. In like manner, the escarpment of the bed of the stream on both sides, against which the extremity of the dam is to be built, will be excavated until perfectly sound rock is found; the form being that of steps of which the height is the thickness of the courses, the length that of the thickness of the dam at that particular height, and the width that which would result from the present inclination of the rock, viz: from two to six feet. By this means the rock and the masonry will be united by a perfect bond, and be parts of the same system of construction.

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* Or the two reservoirs may be built adjacent to each other on Meridian Hill ridge, separated by a single wall, which would diminish the cost and preserve a higher head. It would not, however, be as convenient an arrangement.

It is intended that the dam shall be 5 feet thick at the overfall, which will extend all the way across and increase in thickness until at the bottom, 22 feet below the overfall, it will be 34 feet thick, besides a curved toe to deflect the falling water. The top courses, three feet in thickness, and the whole interior face to the depth of 3 feet, will be closely cut stone; the remainder of the dam of hammer dressed stone, of large size, and good beds. The whole dam to be laid in hydraulic cement. Two wings or buttresses will face the rock, below the dam, to prevent the destruction of the rock by frost and attrition, and to lend it additional strength. On the inside, or upper face, an earthen bank will rest against the dam, its height being equal to that of the dam, and its slope such as to strike the bed of the stream about 80 feet up. That part of this bank which lies against the dam, 3 feet in thickness, will be well puddled; the remainder, which will be of good gravel, will be deposited in strata of a foot thick, and well packed. On the surface of this embankment will be strewn broken stone, or it may be paved in the way of a street pavement.

This dam will cause an overflow of 69.85 acres of land. It is proposed, for the purpose of increasing the capacity of the retentive reservoir, and to prevent the growth of aquatic plants, to excavate it to a depth of not less than five feet, except where rock may be encountered. This will give, above the level of the conduit, 113,797,400 gallons of water, and the entire capacity of the reservoirs will be 145,483,600 gallons; but we cannot avail ourselves of the lower portion of it without sinking the initial point of the conduit. The supply-water for the use of the mills on the stream will be discharged through the waste-wiers, and an iron pipe of thirty inches diameter will be inserted through the bottom of the dam, and provided with a gate to be opened in time of flood for the purpose of removing earthy deposite. The retentive reservoir, for a century to come, will hold water sufficient to supply the city for about forty days of drought, independently of the daily flow thorugh the stream, and without depriving the mills of a gallon of water; and for fifty years, will certainly be sufficient to supply the deficiency of any probable drought.

The receiving reservoir will be formed by damming the ravine in which our conduit may terminate with an earth embankment, and excavating the area to such depth or width as will secure the required capacity. The top of the dam will be six feet above the surface of the water, ten feet wide, and enclosed with a fence. The exterior slope will be two to one, and the interior one and a half to one. The foot of the exterior will be secured by a stone wall six feet high, laid in mortar, and the remainder of it sodded; the top gravelled, and the interior and bottom protected by a brick pavement laid in cement and resting on a course of puddling. Large waste-pipes, inserted in brick arched chambers, will be placed in the wall for the purpose of drawing off the water for cleaning and for repairs. A waste-wier will also be requisite.

The distributing reservoir will be constructed of hydraulic stone masonry, the walls of which, in order to maintain the proposed elevation of the water, will be, on an average, forty-four feet above the surface of the ground, and rising four feet above the surface of the water. To diminish the quantity of masonry, they may be built with openings which admit of a wide base. This plan contemplates an outer and inner wall, connected at every ten feet by cross-walls, to within seventeen feet of the top, where the two walls will be connected with a brick vault, and from thence carried up, solid, to within ten feet of the top, from which level the interior wall will be dispensed with. The bottom of the reservoir to be puddled, and covered with a layer of concrete. The interior will be protected with a puddled embankment, faced with hydraulic masonry, carried to the full height of the wall, and making, with it, a top width of seventeen feet, coped with flag-stones, and surrounded with an iron railing. It will also be fitted with discharge cocks, near the bottom. The distributing mains will be inserted through brick arched chambers, and provided with valves.

This is the general arrangement, without going into details, of the Croton reservoir, on Murray's Hill, in the vicinity of New York city.

Looking to the great expense of this structure, it may be deemed advisable, after a full consideration of the subject, to diminish its height or capacity, or perhaps both, while the capacity of the receiving reservoir might be increased without very greatly augmenting the expense.

For the first two miles of our line a good deal of rock will be encountered; for the remainder of the distance the cutting will be principally in dirt, except a portion of the deep excavations. The rock is a hard gneiss, or blue granite, as it is termed, and will answer a good purpose for ordinary masonry; and I think that stone of a fair quality for the dam may be found in the vicinity of that work. An inspection of the profile will show that no very formidable difficulties (with a single exception) are presented—the cutting and filling being generally moderate, and not many streams to be crossed requiring anything more than common box culverts. Nearly two-thirds of the line is in woods, the country being well timbered with oak, chestnut, pine, and a few hickory. Our survey followed the bank of the creek for about two miles and a half, when, crossing a narrow ridge, it entered Bodisco's branch, a tributary to Rock creek. From this point there are two widely diverging routes—the one leaving the valley of Rock creek, crossing high ground in front of the Russian minister's country seat, and then, crossing Piney branch considerably above the Montgomery road, on Mr. Holmead's farm, strikes for a ravine near the residence of the late Jesse Brown, a little to the west of the termination of 7th street, where a receiving reservoir may be built. The water in Piney branch is, where we cross it, 62 feet below grade, and the valley 710 feet wide on the grade line. This is a truly formidable obstacle, but may be surmounted by an inverted syphon without seriously diminishing the head. It is supposed that one foot's difference of level would be sufficient. The whole length of this line, from the dam to the receiving reservoir, is 22,124 feet, or four miles and 1,004 feet. It is proposed to tunnel through Bodisco's ridge, which is 50 feet above grade, and 1,550 feet wide. The tunnel need not exceed 1,000 feet in length, but must be driven through hard rock.

The other line follows Bodisco's branch nearly to its junction with the valley of Rock creek, and thus turns the flank of the intervening ridge on which was built Mr. Bodisco's house. It then winds in a crooked course from the creek, crosses Piney branch near its mouth, then two other wide and deep ravines, and by a cut of 26 feet reaches Little's valley, where it is proposed to construct a receiving reservoir, if this portion of the route should be adopted. The whole length of this route is 24,230 feet, or 4 miles and 3,110 feet.

This line admits of two important modifications which will save distance and expense. It is upon these changes that the estimates are based.

They are—1st. Instead of following the sinuous trace from Bodisco's branch towards Rock creek, to tunnel the dividing ridge, and unite with the crooked line near Piney branch. The ridge is 50 feet high and 1,010 feet wide, but the tunnel through solid rock will not exceed 800 feet in length. 2d. After crossing Piney branch to keep more towards the sources of the two ravines already spoken of, and thus diminishing the embankment. This will increase, at that point, the amount of excavation, but it will be wanted for the filling; and it is always better, in a work of this nature, to throw it, when practicable, into cutting rather than into embankments. By these changes, the line to Little's ravine will not exceed four miles in length.

The most formidable difficulty (and really the only one) is the crossing of Piney branch, which is here 1,200 feet wide on the grade line and 100 feet below it. To span it with a high bridge would be enormously expensive, in consequence of which it is proposed to resort to iron pipes laid over an arched stone culvert of ten feet opening, which is necessary to pass the water of the stream. It may be found advisable to increase the size of this culvert. It is contemplated to lay down two separate lines of pipes, to guard against accidents, of sixteen inches diameter.

I have been ably assisted in this survey by Lieutenant William F. Raynolds, of the corps of topographical engineers, and S. Thayer Abert, esq., civil engineer. The former ran the level, and the latter the transit lines; and it affords me great pleasure to bear testimony to the zeal, industry, and intelligence which each of those gentlemen evinced in the discharge of his appropriate duties.

Very respectfully, colonel, your obedient servant,

GEO. W. HUGHES,

Brevet Lieut. Col. corps of Topographical Engineers.

Colonel J. J. Abert,

Chief Topographical Engineers.

Estimates for retentive reservoir in Rock creek.

For clearing and grubbing - - - - - -	$150 00
10,560 cubic yards of earth excavation, at 15 cents -	1,584 00
Excavating rock for foundation of dam and wings, say -	700 00
Dam, 1,568; wings, 93 = 1,661 cubic yards of hammer-dressed stone masonry, laid in cement, at $5 - -	8,305 00
631 cubic yards face stone masonry, at $10 - - -	6,310 00
4,561 cubic yards of common earth, at 15 cents - -	684 15
533 cubic yards of puddling, at 50 cents - - -	266 50
Turning water, pumping, and clearing and excavating earth, say - - - - - - -	1,000 00
Iron drain pipe - - - - - - -	150 00
Gate chamber-pipes, &c. - - - - - -	1,450 00
Waste wier - - - - - - - -	800 00
House for gate keeper - - - - - -	650 00
	22,049 65

For crossing Piney branch.

2,600 linear feet of pipe, at $4 50 - - - -	$11,700 00
Influent and effluent pipe chambers - - - -	1,400 00
Stops and water-cocks, waste-pipes and vent-valves -	650 00
Clearing, grubbing, and preparing foundation for culvert and support-wall for the pipes - - - -	525 00
600 yards of rubble masonry, at $2 - - - -	1,200 00
1,000 cubic yards of masonry, laid in cement, for culvert and sustaining walls for pipes, at $4 50 - - -	4,500 00
	19,975 00

For clearing and grubbing the line - - - -	$500 00

For the conduit terminating at Little's.

70.916 cubic yards of excavation of earth, at 16 cts. per yard	$11,346 56
52,000 cubic yards of excavation of rock, at 87½ cents -	45,500 00
181,053 cubic yards embankment, at 18 cents per yard -	32,589 54
15,552 cubic yards dry masonry, at $2 per yard - -	31,104 00
450 cubic yards concrete, at $5 per yard - -	2,250 00
21,120 linear feet of brick arch culvert, at $3 50 per foot -	73,920 00
Culverts and drains other than Piney branch - -	10,000 00
	206,710 10

Reservoirs.

For receiving reservoir and appurtenances - - -	$35,500 00
For distributing reservoir and appurtenances - -	76,800 00
For, say, 12,000 linear feet of double mains connecting the two reservoirs, at $6 per foot - - - - -	72,000 00
	184,300 00

If one line of main should be considered sufficient, this estimate will be reduced $36,000.

For the conduit terminating at Brown's.

76,482 cubic yards of excavation of earth, at 16 cents per yard - - - - - - -	$12,237 12
63,000 cubic yards of excavation of rock, at 87½ cents per yard - - - - - - -	55,125 00
132,448 cubic yards of embankment, at 18 cents per yard -	23,840 64
9,588 cubic yards of dry masonry, at $2 per yard -	19,176 00
248 cubic yards of concrete, at $5 per yard - -	1,240 00
22,124 linear feet of brick arched culvert, at $3 50 per foot	77,434 00
Culverts and drains other than Piney branch - -	10,000 00
Bridge over Montgomery road - - - -	15,000 00
	214,052 76

Add for crossing Piney branch by embankment—	
95,187 cubic yards of embankment, at 18 cents	$17,133 66
7,618 cubic yards dry masonry, at $2	15,236 00
75 cubic yards concrete, at $5	375 00
Culvert for Piney branch	10,000 00
	256,797 42

For crossing Piney branch with iron pipes.

1,600 feet linear of pipes, at $4 50	$7,200 00
Influent and effluent pipe chambers	1,400 00
Stops and water-cocks, &c., &c.	650 00
Clearing and preparing foundation	450 00
400 cubic yards dry masonry, at $2	800 00
850 cubic yards masonry, laid in cement, at $4 50	3,825 00
	14,325 00

RECAPITULATION *(Little's line.)*

Dam	$22,049 65
Crossing Piney branch	19,975 00
Conduit	206,710 00
Clearing and grubbing	500 00
Reservoirs and connecting mains	184,300 00
Waste-wiers	4,500 00
Ventilators	1,500 00
	439,534 75
Or, including contingencies, engineering, superintendence, and land damages, say	$500,000 00

RECAPITULATION *(Brown's line.)*

Dam	$22,049 65
Conduit	256,797 00
Clearing and grubbing	500 00
Reservoirs and connecting mains	184,300 00
Waste-wiers	5,000 00
Ventilators	1,500 00
	470,146 65
Crossing Piney branch by syphons, instead of enbankments, will reduce this	28,419 00
	441,727 65

Or, it may be said, in round terms, that the work on either line may be completed for $500,000. I regard these estimates as to quantities and prices very liberal.

If the money should be supplied when wanted, the work may be finished in two years from the commencement of the construction.

GEO. W. HUGHES, *Bvt. Lt. Col.*,
Corps of Topographical Engineers.

Col. J. J. Abert,
Chief Topographical Engineers.

Smithsonian Institution, *January* 17, 1851.

Dear Sir: I have the honor to communicate to you the following results obtained from an examination of the specimens of water collected by Colonel Hughes, as mentioned below. The time and appliances at my command did not permit me to make a more extended investigation of their chemical constitution.

Water from Rock creek—Dr. Clagett's farm.—Eight fluid ounces were evaporated, and yielded 0.197 grain solid matter.

Water from Potomac river, above Little Falls.—Eight fluid ounces were evaporated, and yielded 0.514 grain solid matter.

From the effervescence which was exhibited on cleaning the platina capsule with a little acid, after each evaporation, I should infer that the above solid matter consists for the most part of carbonate of lime.

Respectfully, your obedient servant,

E. FOREMAN, *Assistant S. I.*

Hon. Walter Lenox.