REPORTS, &c.

LONDON BRIDGE.

The REPORT of JOHN SMEATON, upon the QUESTIONS proposed to him by the Committee for improving, widening, and enlarging London Bridge.

Queſtion 1ſt. IN what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminiſhed, by removal of the pier, and opening of the great arch?

Anſwer.—By calculation it appears, that the natural power of the water, as the circumſtances of the great arch were in the beginning of February, 1763, was diminiſhed at the monthly average as 2000 to 1277; and that the effect thereof upon the wheels, as appears by the company's regiſter, for above ſix years paſt, was diminiſhed in proportion of 2000 to 1300. The proceſs of which inveſtigation is hereto annexed.

Queſtion 2d.—What are the methods, whereby the effect of theſe works may be reſtored to the ſame quantity, with reſpect to raiſing water, as ſubſiſted before the opening of the great arch?

Anſwer.—The methods that can be put in practice, for reſtoring the effect of the works, are reducible to two, viz: by improving and enlarging the preſent works, or

by penning up the ſame head of water as before the alteration. With reſpect to the preſent wheels, though they are all capable of improvement, yet they cannot all be improved in the ſame degree in which they are now deficient, nor can they be ſo much improved taken collectively; it will, therefore, be neceſſary, not only to improve ſome of the preſent wheels, but to add a new one; but as the old wheels cannot be much improved without rebuilding, and *one* new one cannot be depended upon to make good the deficiency, without rebuilding ſome of the old ones; as the power, while acting, muſt be increaſed, in order to do the ſame buſineſs in a leſs time, and as the preſent mains are but barely adequate to the preſent wheels, (which appears from their refuſing a part of the water thrown up by the engines during the action of the ſtrong ſpring tide, as has happened during my examination of the works), it follows, that the addition of wheels will require an addition of mains, which, upon the whole, will create a great expenſe, and of a very complex nature. On the other hand, the very ſame expedient that will be neceſſary for ſecuring the great arch, will alſo contribute conſiderably towards the relief of the water-works; I, therefore, think it more eligible for the committee not to engage in building or improving the water-works, but to proceed to ſuch method as will reſtore the head of water; which may be done, as I conceive, at a leſs expenſe, and not only without prejudice to the navigation, but in ſome reſpects be an aid thereto, and that is by raiſing the bed of the great lock, and ſome others, that are unneceſſarily deep, and by ſtopping the water-way below the ſtarling of two others, which appear to be of little or no uſe or conſequence to navigation.

Queſtion 3d.—If by ſtopping up arches, or raiſing the bed of the river under the arches, which arches will be beſt to be ſtopped up, or the beds under them raiſed; and what will be the expenſe thereof?

Anſwer.—The addition of water-way is altogether made under the great arch; and if the reduction were to take place there alone, it would totally defeat the purpoſes of the committee in doing ſervice to the navigation, by the opening thereof; it is therefore I propoſe to do only a part here, ſuch as is conſiſtent with thoſe views, and the reſt under ſuch other arches as will admit thereof without prejudice.

For the particular manner of executing this ſcheme, I muſt refer to a drawing (ſee plate I.), containing two ſections of the water-way under London Bridge, the firſt figure ſhewing the water-way as it was before the alteration; and afterwards, as it was at the beginning of February, 1763: figure 2d ſhews the water-way as it is intended to be after the alteration now propoſed.

The

The abſtract of the firſt ſection, figure 1. is as follows:

	Feet, superficial.	
The area of the water-way below the ſtarlings, before the alteration, was - - -		2073
The increase of water-way by removing the ſolid under the great arch, and by the ſubſequent increase of depth, - - - - - - -	861	
The diminution of water-way by ſtopping up the two locks next the ſouth ſhore, -	154	
The difference is the increaſe of water-way, - - - - - -		707
The ſum is the water-way after the alteration, the beginning of February, 1763, - -		2780

It therefore appears, that in order to reſtore the water-way, and of conſequence the water-works, to what they were before the alteration of the great arch, the area of the water-way below the ſtarlings, ſuch as it was the beginning of February, 1763, muſt be reduced by 707 ſuperficial feet; and in order to do this without prejudice to the navigation, I would propoſe 1ſt, to raiſe the bed of the river under the great arch, ſo as to be eleven feet at its higheſt part under the top of the ſtarlings, in which caſe it will have the ſame depth of water as the draw lock, which was accounted the moſt uſeful for large craft before the alteration; and which, as well as the great lock when the water-way is reſtored, will never have a leſs depth of water than five feet at low water.

2dly. By advancing the ſtarlings into the great lock, ſo as to double the fence, as propoſed to the committee by Mr. PHILLIPS, a further reduction will be effected, and this being done three feet on each ſide, will ſtill leave a water-way under the great arch in breadth fifty-two feet, which will be very ſufficient for the craft.

3dly. I find there are four locks, whoſe depths exceed that of the draw lock, all of which are, on account of their widths, unfit for the paſſage of the larger craft. I therefore propoſe to raiſe the beds of thoſe locks one foot higher than the level of the draw lock and the great lock. *St. Mary*'s lock was juſtly accounted the beſt for large craft before the alteration, being the wideſt (viz. nineteen feet in the clear) and one of the deepeſt, viz. fifteen feet below the ſtarling, that is four feet deeper than the draw lock; this depth of fifteen feet I apprehend to be totally unneceſſary, and rather tending towards the inſecurity of the bridge; but as the preſerving one lock deeper than the reſt, may poſſibly on ſome occaſion be uſeful, I propoſe raiſing the bed of *St. Mary*'s only two feet, in which caſe it will be thirteen feet below the ſtarlings, that is two feet deeper than what is propoſed for the great lock.

4th.

4th. As Long Entry and Chappel locks, which lie between *St. Mary*'s and the great arch, appear to be of leſs uſe than any of the reſt, being both narrow and ſhallow, and by their indraft tend to bring the craft foul upon the intermediate ſtarlings, without a poſſibility of their paſſage, I would therefore propoſe thoſe to be ſtopped up to ſtarlings' height, the ſame as the firſt and ſecond locks on the ſouth ſide now are; and that the craft may not be entangled with thoſe locks or their ſtarlings, but always find a paſſage either through the great lock or *St. Mary*'s, I would propoſe fender piles to be drove at about three feet diſtance in a circular manner, from the upſtream point of the ſtarling of the great arch, to the upſtream point of the ſtarling of *St. Mary*'s, as repreſented in the draft fig. 3, at R.; thoſe piles to be well braced, and their heads capped over about two feet above high-water mark.

Theſe things thus done, the account will ſtand as follows:

PROPOSED REDUCTIONS of the area of the water-way below the ſtarlings.

	Feet, superficial.
By raiſing the bed of the great arch,	314
By extending the ſtarlings three feet on each ſide,	66
By raiſing the bed of little lock,	52½
By ditto of *St. Mary*'s,	38
By ſhutting up Chappel lock,	50
By ditto Long Entry,	66½
By raiſing the bed of Non-ſuch lock,	60
By ditto of Roger lock,	27
By ditto of the fifth lock,	37½
Water-way to be reduced,	711½
Increaſe of water-way as before ſtated,	707
Overplus,	4½

Now there will ſtill remain an increaſe of water-way above the ſtarlings by the removal of the ſhaft of the middle pier; but as the effect of this can only take place while the water is above the ſtarlings, when the water-way is at the greateſt: the effect upon the water wheels thence ariſing does not appear by computation to be above $\frac{1}{300}$ part of the whole, which will be much more than compenſated by the above overplus of 4½ feet below the ſtarlings.

It is poſſible, notwithſtanding the attention I have paid to this matter, that ſome circumſtances may intervene, which have not occurred to my conſideration; but I apprehend that none can, which may not be compenſated by raiſing the bed of *St. Mary*'s lock to the ſame height as the great lock: to which I can ſee no objection, if experience ſhould ſhew the ſame to be neceſſary.

The eaſieſt, cheapeſt, and moſt effectual method of raiſing the beds, not only of the great lock, but of the others, is, by throwing in rough ſtones, ſo as to form a ſlope both ways, the interſtices of which in time will fill up with gravel and the ſullage of the river, and become as compact and durable as a rock. The heavieſt, rougheſt, and largeſt ſtuff, is beſt adapted for this purpoſe, and none better than large *Kentiſh* rubble; but for want of a ſufficient quantity thereof, *Portland* or *Purbeck* rubble may be uſed, provided it is more large in proportion, as it is leſs ſharp and heavy. For the particular application thereof to the great arch, I refer to the drafts, figs. 4, and 5.

N. B. If the following method ſhould be thought more eligible; inſtead of raiſing the bed of *St. Mary*'s lock, the firſt open lock next the water-works may be ſtopped up, by two pair of gates pointed weſtward; forming a navigable pen lock between them; which would enable ſuch craft as can row or ſail againſt tide to paſs the bridge upward on tide of ebb, without waiting for tide of flood. And in this caſe the ſtopping up of Chappel and Long Entry locks may be diſpenſed with. In what extent this ſcheme may be of advantage to the navigation, I am not enabled to judge, but am of opinion, that if not of material uſe, what was firſt laid down is the moſt eligible, as the gates would need frequent repairs.

Queſtion 4th.—If by improving the old wheels, or adding new ones, which will it be beſt to improve, or where add the new ones; and at what expenſe will this be done?

Anſwer.—I apprehend, as was mentioned before, that all the wheels may be improved, but the wheels in the firſt and fourth arches from the north ſhore are the moſt ſuſceptible thereof, and the moſt want it; if any wheel were to be added, it ſhould undoubtedly be in the fifth arch, which, though a capaciouslock, is not much uſed by craft going down on tide of ebb, on account of the ſhipping commonly lying before it; but as I look upon it to be more eligible to reſtore the effect of the water-works by the more certain, and perhaps leſs controvertible method above deſcribed; I have not made eſtimates for theſe erections and improvements, to do which, with any tolerable degree of exactneſs, (being very compounded) would take up ſome time.

Queſtion

Queſtion 5th.—If arches are ſtopped up, or beds raiſed, what effect will this have upon the channel of the river?

Anſwer.—If done in the manner before propoſed, no ſenſible effect of any kind whatever.

Queſtion 6th.—What effect upon the channel of the river has been produced by opening of the great arch, and by what means are the inconveniencies, if any, to be removed, and particularly with reſpect to what is alledged in the memorial of the Waterman's Company?

Anſwer.—Upon opening the great arch, the water finding a more free and open paſſage there than in any other part of the bridge, the main current would, of courſe, be drawn thither, and in conſequence, acting more ſtrongly upon the bed of the river than before, ſome thouſand tons of matter appear to have been moved by the action of the tides ſetting in each way, above, between, and below the ſtarlings; the moſt groſs and heavy parts ſubſiding as ſoon as the ſtrength of the ſtream is ſpent, form ſhoals or banks of matter both above and below bridge; yet ſuch banks, though encreaſed by the freſh action of the great arch, appear, in a great meaſure, to have been formed before, by the rapidity of the current ſetting through the arches; and I remember to have ſeen the ſhoal above bridge many times dry before the alteration took place, and if I am not miſtaken that below likewiſe. The preſent channel below bridge, ſtands quite fair to the great arch, and has about $4\frac{1}{2}$ feet navigable water over it at low ſtill water; but above bridge the caſe has been more untoward, for the body of the former ſhoal happening to lie ſomewhat to the ſouth of the direction of the great lock, the new-formed matter has, in a great meaſure, lodged itſelf in addition to the north ſide thereof, which has of conſequence thrown the main channel of the river conſiderably more to the north ſide, ſo that the current, on tide of ebb, making a ſudden turn near the bridge, has rendered it difficult for the craft to make the great arch, notwithſtanding the great enlargement of its width. The effect of this grievance will, in ſome meaſure, be remedied by the alterations propoſed in the bridge itſelf, becauſe the ſet of the tide being leſs ſtrong to the great arch, as well as more equally all over the bridge, the direction of the current will be leſs diverted towards any particular place: towards this end the ſtoppage of Long Entry, and Chappel locks will alſo contribute; for being ſituated between two of the principal arches, the balance will be preſerved, and the current leſs diverted in its paſſage through either of them. This, together with the fender piles before theſe two locks, will direct the craft, ſo that they cannot fail of hitting one

one or the other, when there is water enough over the ſhoal above; but at or near low water, I don't apprehend that any thing leſs than taking the whole ſhoal away, down to the depth of the main channel, can procure a true ſet of the tide; however, it may in a great meaſure be remedied, by making a paſſage or channel through the ſhoal, which channel, to prevent as much as poſſible the effect of the ſuperior indraught of the main channel from acting upon it, ſhould be exactly in the direction of the great arch, but its weſt end declining a little to the ſouthward; this new channel ſhould be at leaſt four feet deep at low water, and as wide as the great arch, and I know no better method of performing it, than by the ballaſt lighters; it will alſo be adviſable to widen and deepen the preſent channel through the ſhoal below bridge, ſo as to make two and a half feet more water over the ſame but this will be a much leſs work than the former.

I come now to conſider the matter of the memorial of the Watermen's Company.

I apprehend, when all is finiſhed, the great lock will be found moſt uſeful to ſmall as well as large craft, as no boat can catch upon the ſtarlings there, being wide enough for moſt veſſels to go through ſideways.

I apprehend, the ſmall locks moſt uſed by ſmall boats ſhould be planked or lined, which will be of ſervice to the ſtarlings, and at the ſame time prevent boats from catching upon the irregularities of the piling, in which, I apprehend, conſiſts the greateſt danger in paſſing London Bridge on tide of ebb, with the water below the ſtarlings.

I am informed there are ſeveral ſtumps of piles in ſeveral of the locks; but while I was making my obſervation, there was always too much water to ſee them; it would be right to ſaw or cut them off with a large chiſel made for the purpoſe, but not to draw them or drive them down.

Reſpecting the bank oppoſite Fiſhmonger's-Hall; the methods foregoing tend to procure a true ſet of the tide through the great arch; but I know of no bank, either about or below bridge, that is of material conſequence to the water-works; the current ſets over from the water-works towards the great arch, not becauſe it is impeded by a ſhoal but becauſe it finds a readier paſſage that way.

REFERENCE

REFERENCE to the plans annexed.

Plate I.

Fig. 1.—A, The ſhaded ſpace ſhews the pier, ſtarling, and bed of the river, which, before the alteration, were ſolid, but which, at the beginning of February, 1763, were converted into water-way.

N. B. The light ſhaded ſpaces ſhew the dimenſions of the water-way in each lock, taken at ſuch part where the bed of the lock is higheſt. The figures above the ſpaces are the widths of the reſpective locks, (the piers and ſtarlings between them being omitted), the figures beneath are the depths taken from the ſurfaces of the ſtarlings at the place where the depths are leaſt.

E E are two locks—the firſt and ſecond from the *Surry* ſhore, which, before the alteration, were open, but which were cloſed up by dams of piles, in the beginning of February, 1763.

Fig. 2.—The light ſhaded ſpaces ſhew the intended dimenſions of the water-ways of the reſpective locks, as they will be after the propoſed alteration, the widths, except the great lock, are the ſame as fig. 1. and the depths are ſpecified beneath.

C C C C C C—Solids, added in order to raiſe the depths of the reſpective locks.

D D—Two locks to be cloſed up with dams of piles to the height of the ſtarlings.

E E—Two locks already cloſed, which are to remain ſo.

f f—Solids, to be added to ſtrengthen the ſtarlings within the great arch, three feet thick on each ſide.

N. B. Both theſe ſections ſuppoſe the water-ways laid together, both above and below the ſtarlings, and all the ſolids removed, except ſuch as are the ſubject of the alterations.

The meaſures differ ſomething from thoſe before taken, by reaſon of their being taken at different places.

Fig. 3.

Fig. 3.—R ſhews the diſpoſition of the fender piles, extending from the great lock to *St. Mary*'s, to prevent the craft getting foul of the two intermediate locks.

D D—Locks which are to be cloſed up as before ſtated in fig. 2.

E E—The ſame as fig. 2, and C, the ſix locks, to be raiſed as in fig. 2.

The names of the different locks in this figure, and the numbers, which are the ſame in fig. 1 and 2, will point out the names in the latter figures.

Fig. 4.—Plan, and fig. 5. ſection of the propoſed alterations under the great arch.

H—A body of *Kentiſh* rubble for lining the bottom of the river under the great arch, to reſiſt the action of the water, and for raiſing the bed of the lock for the ſervice of the water-works, leaving five feet depth of water over the crown of the dam at low water, for the ſervice of the craft.

I—Blocks of *Portland* ſtone, eight feet long up and down ſtream, and two feet ſix inches thick for capping the top of the rubble.

K K K—Ground pier of larger rubble ſtones than the reſt, for ſupporting the ſmaller until a compleat bed is formed.

L L—Fig. 5. dotted lines, ſhewing in what manner the ſtarling of the great arch may be enlarged three feet on each ſide.

APPENDIX.

INVESTIGATION of the anſwer to queſtion 1ſt, viz.

1ſt. IN what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminiſhed, by the removal of the pier, and opening of the great arch?

An exact ſolution of this queſtion is, perhaps, impoſſible, on account of the very great variety of circumſtances that affect it; yet from the great number of obſervations that I have made upon the bridge and water-works, relative thereto, by attending to the moſt material and leading circumſtances, and by repeating ſuch as are of ſmall account, or whoſe effects are likely to balance each other; I flatter myſelf that what is here offered, will be found ſufficiently near the truth to fulfil the purpoſes for which the queſtion was propoſed. And here I muſt premiſe this principle, that where water moves through confined paſſages, which occaſion a ſenſible pen or difference of elevation of their ſurfaces, above and below the paſſage, the water moves through the ſame as one column, that is, nearly the ſame at bottom as at top, abſtracted from friction; and therefore, that an increaſe of depth is of equal conſequence with an increaſe of width. This appears from reaſon to be the caſe, ſince every part of the effluent column is put in motion by a column of the ſame height, viz. one whoſe height is equal to the difference of the two ſurfaces; this is alſo confirmed by experience, and in the preſent caſe is remarkable, ſince it was the action of the effluent column upon the bottom of the river, that has removed ſuch a large quantity of matter from under the great arch.

On this account I have taken the ſection of all the water-ways below the ſtarlings afreſh, and as I did not confine myſelf to any particular part of the locks, but where I found the ſhalloweſt part, there I took the width between the ſtarlings, this occaſions ſome difference between theſe and former meaſures.

Plate 1. Fig. 1.—Is a ſection of the water-way at London Bridge, in which the dark ſhaded place A. repreſents the ſolid of the pier, ſtarling, and ground upon which they