Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments:/ Commentaires supplémentaires:

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Includes supplementary material/ Comprend du matériel supplémentaire
- [ ] Only edition available/ Seule édition disponible
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/ Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X 14X 18X [x] 22X 26X 30X

12X 16X 20X 24X 28X 32X

The copy filmed here has been reproduced thanks to the generosity of:

McLennan Library
McGill University
Montreal

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol —► (meaning "CONTINUED"), or the symbol ▼ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:

L'exemplaire filmé fut reproduit grâce à la générosité de:

McLennan Library
McGill University
Montreal

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole —► signifie "A SUIVRE", le symbole ▼ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

1	2	3

1
2
3

1	2	3
4	5	6

Not in C.A. G.h
Not in T.P.L.

A PAPER

ON THE

LATERAL PRESSURE OF RUNNING WATER,

READ BEFORE

The American Association

FOR THE ADVANCEMENT OF SCIENCE,

At the Meeting of that body in Montreal in the year 1857,

BY

THOS. GUERIN,

Civil Engineer.

Montreal:

PRINTED BY J. STARKE & CO.

1858.

LATERAL PRESSURE OF RUNNING WATER.

This subject I have selected in order to call to it the attention of Scientific Men, for, as a general principle, it has not as yet been thoroughly developed. A full investigation of it would be a great acquisition to the Science of Hydraulics; several cities would reap the advantages of it, and among others, Montreal at the present time.

In all cities which are built on a low flat surface, there exists some difficulty in ascertaining the best mode of their effectual drainage. The outlet for the drainage of a city must be some adjacent stream or River, and if the surface of the town be not sufficiently elevated above the bed of such stream or River, so as to afford the necessary fall to the main sewers, the consequence will be inadequate sewage with all its concomitant evils.

It is generally thought that to ensure the discharge from the main sewers of a town, it is necessary to construct them so that their bottom levels may not be below the low water surface of the River into which they are discharged. There is no doubt, such an idea must have arisen from the Hydrostatic principle, that the pressure of water against any point in the side of a Reservoir, is proportional to the depth of that point below the surface of the fluid, and hence, that a stream discharging into such reservoir must have its bottom level above the surface of the fluid in order that it may meet with no resistance.

But to the Hydraulician it is evident, that in the case of a River or water running in a bed, that principle no longer holds, but that there is a portion of the depth in which the lateral pressure is nothing, and where if a stream were made to enter, there would occur no resistance to its faithful discharge into the River intended to receive it. At the end of such portion of the depth the lateral pressure commences, and below this and counting from this point, the pressure must increase as the depth increases, so that the determination of this point will be nothing more nor less than solving the question of lateral pressure of running water, as well also as ascertaining the point at which to discharge the sewage of a town or city into a stream or River with the most advantage.

I have the honor now to submit the reasoning which induced the conclusions I have arrived at, and I flatter myself that, as a general subject, I have somewhat advanced its investigation, and especially so far as the River St. Lawrence is concerned at Montreal. I believe I have given a solution to this intricate question in the present paper.

As the lateral pressure of water running in pipes, is included in the heading of this paper, I will, therefore, first devote some attention to this part of the subject, and for the purpose thereof, I will mention the following experiment which I have witnessed.

At the end of 6000 feet of a conduit which had been 10 inches in diameter and which communicated with a reservoir, there was attached a branch pipe of .0625 feet diameter, the last portion of which for a distance of 20 feet was laid horizontally, and to its end was attached a cock, a hole of one eighth inch diameter was made in the horizontal part, and it was found that while the cock was opened no water had issued from the hole.

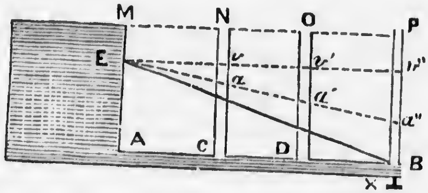
The height of the Reservoir above the horizontal part was 42 feet, and at first sight, therefore, it did appear a little surprising, that under so great a head no water had issued from the hole referred to, and consequently no lateral pressure existed, while the cock remained opened. What, therefore, is the real state of things ?

With the data already given, and supposing that there had been no other discharge nor leakage through the conduit, we shall find that the discharge through the branch will be .024 cubic feet per second; if now we compute the friction on the 90 feet of branch we will find it to be equivalent to a head of 38.6 feet, thus leaving only 3.4 feet of effective head to force out the water, that is to say, of the entire 42 feet of head of the reservoir, above the orifice of efflux, there had been only 3.4 feet efficient, and even this quantity is obtained on a supposition of there having been no leakage or that there had been no water drawn off elsewhere from the conduit while the flow was passing through the branch.

This head of 3.4 feet must cause a pressure on the water in the branch of 1.5 lbs. per square inch, and whereas no water issues through the hole alluded to, it would appear that in the instance just cited there was no lateral pressure, but that the whole force or pressure of 1.5 lbs. per square inch, must have been exerted in the direction of the pipe.

Will the water which is running through pipes exert a lateral pressure in any instance, and if it does, what is the amount of such pressure?

Before answering these questions I beg to remark that although the measurements and calculations in the above instance have been made with the greatest care, yet it is not my intention to draw any general conclusions therefrom, being well aware of the danger that exists in drawing conclusions from experiments which are roughly made. The reader will permit me, however, to submit the following explanation to which I have been led by a few experiments and which is almost entirely original as far as I am aware of :—



Let a horizontal pipe A B be fitted to a reservoir which is kept full of water, let X be a cock whose orifice equals the section of the pipe, let C N, D O, B P, be tubes inserted in the pipe, and let us supose for a moment that there is no contraction at A, by the water running through the pipe.

When the cock is closed, the whole of the inside surface of the pipe will experience a pressure and the water must rise in the tubes to the same level as the reservoir, but when X is opened, the water rushing out at A with a velocity due to the head A M will immediately acquire the direction A B, and by its impulse will rush along the pipe without being turned into any other direction, the water in the tubes coming in contact every moment with that in the pipe will be borne along, the level in the tubes must soon fall and be reduced to nothing, hence while the section at A and B are the same, the horizontal pipe can experience no lateral pressure.

If the cock be only partially opened, the phenomena must change; the water will pass through the orifice with a velocity due to the head A M, but the head due to the velocity at C or D must be less, for the reason that the sections there are greater; let V be the velocity at C or D, and $\frac{V^2}{2g}$ will be the head employed to produce it, (g denoting the force of gravity or 32.18 ft.) and whereas it still acts in the direction A B, it can produce no lateral pressure.

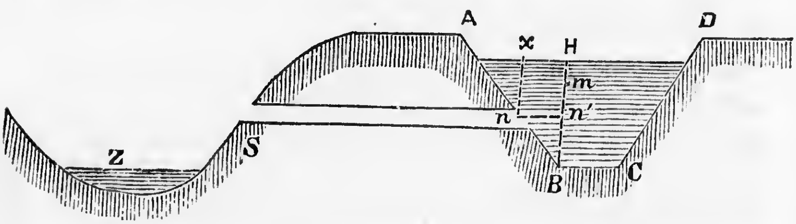
The quantity $\frac{V^2}{2g}$ is less than A M, it is that portion of A M which produces the velocity V along the pipe A B, but as the water in the pipe experiences the force of the whole head A M the remaining portion A $M-\frac{V^2}{2g}$ would appear to be the head indicating the pressure on the pipe, and under these circumstances, if there had been no friction, the water rise in the tubes to that height, or if we take M E equal to $\frac{V^2}{2g}$, A E will represent the height to which the fluid will rise in the tubes. Now it is well known that friction in pipes destroys a great portion of the head, and it is also well known, that this friction is directly proportional to the length, that is, it increases from nothing at A to its greatest limit at B; let us call F the friction at B and make v'' a'' equal to F and join E a'', the friction at C & D will then be represented by v a & v' a', hence we conclude that the column C N which measures the pressure when in a state of rest, will, when motion begins, first fall the quantity N v

$(=\frac{V}{2g})$ and secondly $v\,a$; this last part of the head being destroyed by the friction of the pipe from A to C. The pressure at C will therefore be represented by a C and will be equal to A M—$\frac{V^2}{2g}$—friction at C. This last term or *friction at C,* will be equal to .00071 $\frac{L\,Q^2}{D^5}$ where L is the length, Q the discharge, and D the diameter of the pipe, but in the present instance, these quantities are to be estimated at C.

If the pipe instead of being horizontal is inclined, our course of reasoning will be similar to the foregoing—when the orifice is closed, the water will rise in the tubes to the same level as in the reservoir, but when motion begins the level in the tubes will undergo the same diminutions as in the case of horizontal pipes, and their summit will only attain the line E *a.*"

If the pipe is bent and not a straight line, the expression for pressure must be the same, recollecting that L is the real length along the sinuosities of the pipe. Hence we conclude in general terms, that if H, represent the height of the reservoir above any point of a pipe whether curved or straight, that the pressure on this point will be H—$\frac{V^2}{2g}$—.00071 $\frac{L\,Q^2}{D^5}$ where V denotes the velocity at that point, and .00071 $\frac{L\,Q^2}{D^5}$ is the height representing the loss from friction at the same point, then as H—.00071 $\frac{L\,Q^2}{D^5}$ is the efficient head, we have the pressure always equal to the efficient head (not the ordinary head) minus the height due to the velocity.

Having treated of the lateral pressure of water in pipes, I come now to the pressure of water running in a bed, the subject which this paper principally aims at. I will suppose A B C D to be a section of the bed of a River, the depth of water there being H B, and I will suppose that at the depth x n, (=H n') an opening is made; it is required from thence to deter-



mine the quantity of water that will flow out at n, through the small canal n S into the basin Z. The velocity of the River being given.

Suppose that the motion of the water in the bed of the stream is arrested for a moment, then it is evident that the flow through n would be that due to the head x n, but as soon as motion commences this phenomena no longer holds, a portion of the head on n, will be destroyed by so much as causes the velocity in the bed; let us denote this by H m, that is, let the head H m be that which is due to the velocity in the bed or $\frac{V^2}{2g}$ where V denotes the velocity, and g the force of gravity (32.18 ft.), then it is evident that x n will be diminished by H m. Now besides the force which H m exerts, there is another force acting in the direction of the current which is resisted and destroyed by the friction of the water against the wetted perimeter, and which, were it not for this resistance, would continually accelerate the motion of the current. If we assume g equal to the force of gravity (32.18 ft.) and g the inclination of the surface of the stream, then we get $g\,S$ equal to the force which is continually impelling the stream, it is the accelerating force referred to, and it tends to increase the velocity of the water at every moment. In all streams, however, there appears to be a uniformity of motion, there seems to be no acceleration, even in canals of the smoothest and most uniform bottoms, where one would suppose the friction would be exceedingly small, hence it follows, that the force $g\,S$ is invariably destroyed in all streams by some latent resistance, such as friction, &c.

Now if V denote the velocity in the bed of the stream, $\frac{V^2}{2g}$ would be the head, which would be sufficient to generate this velocity if there had been no such thing as friction, but as $g\,S$ also assists in its generation, although being destroyed by friction, we have therefore $\frac{V^2}{2g} + g\,S$ equal to the head employed to generate the velocity V. This force is employed in the direction of the current, it cannot exercise any lateral pressure, consequently the head on the opening n must be diminished by this quantity, in order to determine the head which forces the water through this opening The head on the opening will therefore be $H\,n - \frac{V^2}{2g} - g\,S$.

From this it follows, that at least the portion of H n which is equal to $\frac{v^2}{2g} + g$S will be employed in the direction of the current, it will cause no pressure on the banks, and it will therefore denote the point below the surface of a stream at which the lateral pressure commences.

To apply this theorem to the St. Lawrence at Montreal, the reader will perceive that owing to St. Helen's Island and Isle Ronde, which are opposite to this city, the bed of the River is divided into two parts, by far the greater portion flows between the Islands referred to and the city, and is called the current St. Mary, a name which I will adopt in this paper.

The length of the current St. Mary is about 5,000 feet, its width is about 3000 feet, its Hydraulic depth in Summer is 35 feet *(estimated)*, and the difference of level in Summer between the head and foot of the current St. Mary or rather between those portions of the River St. Lawrence, above and below those Islands referred to, is $2\frac{1}{2}$ feet. From these data we can easily ascertain the value of the expression $\frac{v^2}{2g} + g$ S, it will be 2.36 feet. Hence we conclude, that a stream or sewer can be discharged in Summer into the current St. Mary, at a depth of 2 feet 4 inches, below the surface of the River without meeting any impediment.

In Winter the St. Lawrence rises so high as to cause a hydraulic mean depth in the current St Mary of about 52 feet; there will be a difference of level between the head and foot of the current in Winter generally of 8 feet.

From these data, combined with those already given, we obtain the value of the expression $\frac{v^2}{2g} + g\ S, = 11.10$ feet. This is the depth during which in Winter there is no lateral pressure, and it is at the termination of this depth that the lateral pressure commences. If an opening were made in the bank of a River at any portion of this depth no water could flow through it, and if a stream or sewer discharged into the current St. Mary at any portion of this depth it would meet with no impediment from the water of the River.

Having thus far developed the problem of lateral pressure of running water, I would suggest, before concluding this paper, that it is possible that a greater head than g S is destroyed by friction; all that can be said by theory at present is that at least g S is destroyed for the reason that there is no acceleration in the velocity of the stream. If friction destroys a greater portion than g S we must conclude that H n must be diminished by a greater quantity than $\frac{v^2}{2g} + g\ S$ and consequently the point at which the lateral pressure commences must be still farther below the surface of the stream than $\frac{v^2}{2g} + g\ S$.

To develope fully this suggestion it would be necessary to make experiments which the writer of this paper has not at present the means of accomplishing, but it is to be hoped that some of this body will also give the subject a thought.

THOMAS GUERIN.

of
di
in

bo
8
th
no
sta

its
bac
hav
the
ale
rive
sew
the
abo
Mar
Th
wate
appe
at th
in th

COROLLARY.

From the foregoing paper it follows that the sewerage of the City of Montreal would be more advantageously discharged into the current St. Mary, *near its foot*, than into any other part of the river.

The advantages that this locality has over the harbour are manifest; the water in the harbour is about 8 feet higher in the winter and its velocity adjacent to the shore being retarded by the wharves is almost nothing; hence the water in the main sewer would stand at or near the level of the water in the river.

A sewer discharging into the current St. Mary, near its foot, will have the advantages of being relieved of a back pressure of about eleven feet at high water, as I have already shewn, and as compared with a sewer at the harbour it will be relieved of a back pressure equivalent to the difference of level between the water of the river in the harbour and that at the locality of the sewer, which difference, as the sewer is near the foot of the current, will be, say six feet, hence there will be about 17 feet of advantage in favor of the current St. Mary in this case.

The advantages that the current St. Mary at high water has over the vicinity of Hochelaga Bay, &c., will appear from the fact that at the latter places the velocity at the shore is very small, and hence the level of water in the sewer will be about as high as that in the river.

Now if we suppose that the water of the river at the locality of the proposed sewer at the current St. Mary is two feet higher than at Hochelaga Bay, &c., it would appear from what I have already shewn that the level of the water in a sewer at the current St. Mary will stand almost nine feet lower than in a sewer at Hochelaga Bay, &c. Hence there will be about nine feet in favor of the current St. Mary, when it is high water in the St. Lawrence, this being the stage of the river for which these calculations have been made, because at any other stage there can be no difficulty or impediment to the discharge of a sewer in any locality.

Other important advantages which can be urged in favor of the current St. Mary when compared to Hochelaga Bay, are the increased length and increased depth of excavation which the latter locality requires.

From levels which I had occasion to take in that vicinity some time ago, it appears that there is a regular ascending grade from the Victoria Road onwards to Hochelaga. This will appear evident, even to a casual observer, from the fact that the stream which crosses the Victoria Road near the Queen's Square comes from the direction of Hochelaga, so that there can be no doubt of the increased depth of excavation in that direction. Hence, I conclude that a main sewer from the City, entering the river near the foot of the current, will be much more efficient and much less expensive than one entering Hochelaga Bay, or any point below it.