LETTERS ON HYDRAULICS

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Letters on Hydraulics by E. S. Chesbrough & C. F. Durant

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E. S. CHESBROUGH & C. F. DURANT

LETTERS ON HYDRAULICS

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Henry Harding

LETTERS

ON

HYDRAULICS:

A CORRESPONDENCE BETWEEN

E. S. CHESBROUGH, of Mass., AND C. F. DURANT, of N. Jersey,

On the Physical Laws that Govern Running Water,

APPLIED TO A DAM AND MILL PRIVILEGE ON THE HOUSATONIC RIVER,
AT GREAT BARRINGTON, MASS.

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1849.

LETTERS ON HYDRAULICS.

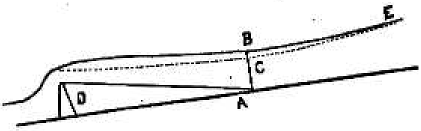
WEST NEWTON, May 8th, 1849.

DEAR SIR:

Understanding, yesterday, both by letter from, and personal conversation with, Mr. Day, that you were confident I had made some mistake in the calculations which led me to state, that more back-water would be caused by a dam, on the first wheel above it, during high water, than in low stages of the stream; and that you would point out the cause of error, if I would send you a statement of the manner in which the calculations were made,—I shall now give you a brief account of my *modus operandi*.

In order to test the principle in question by calculation, in as simple a manner as occurred to me, I supposed a stream 10 feet wide, with perpendicular sides, and having a perfectly uniform declivity on its bottom. I further supposed this stream to have such a declivity, that when filled to a uniform depth of 2 feet, it would have a mean velocity of 4 feet per second; hence the quantity passing any given point per second, would be 80 cubic feet. From these data, and by using a very simple formula, derived from Eytelwein, $\left(I=\frac{V^2}{8744\,R}\right)$ I make the inclination .00128, or 1.28 feet per 1000 feet.

I next supposed a dam 5 feet high, to be built across this stream, and the pond above it filled; but the quantity of water coming down the stream at the same time, infinitely small, (or, if you please, a state of *extreme low water*.) It is very evident that in this case, the surface of the pond would be level, and the highest point on the stream affected by the dam, would be where its bottom is on a level with the top of the dam—as at A in the figure.



I next supposed a freshet in the stream, raising it to a uniform depth of 2 feet, where unaffected by the dam. Now it is very evident, that if the dam has no more effect in high than in low water, above and at the point A, the depth of the water here will be just 2 feet, and the curved surface of the pond will terminate at C; but my calculations, which have been repeated several times, make the depth A B 2.435 feet, and the termination of the curved surface of the pond, at E, a point I did not reach in my investigation, although the calculations were made to a point about 1100 feet beyond B, where I made the depth of water 2.090 feet.

I calculated the depths of water for every 100 feet, for a distance of 5000 feet, and started with a depth at D of 6.40 feet, making the height of over-fall 1.40 feet—in determining which, I took into account the velocity with which the water approaches the over-fall.

Thinking the rule you gave me, might vary the result, so as to show the principle supposed to exist by the method I adopted, to be incorrect, I applied the rule you gave me at Great Barrington, starting with the same depth at D.—(This, by the way, is a very important matter, and I am satisfied that the depth at the point D, is fixed a little too low; but it favors your view of the question, so far as it varies at all from the precise truth.) From the rule you gave me, I derived the formula, $I=\frac{V^2}{12,000\ R}$ according to which the inclination of the supposed stream, when unaffected by the dam, ought to be .000933, or 0.933 feet per 1000 feet, instead of 1.28 feet per 1000 feet. This would make the point A, 5357 feet distant from D, instead of 3906 feet. To my surprise, on calculating the depth of water at the end of the 5357 feet, by your rule, for the bottom inclination of 0.933 feet per 1000 feet, I found it to be 2.424 feet—almost the precise depth obtained at the end of 3906 feet, with a bottom inclination of 1.28 feet per 1000 feet—by the formula derived from Eytelwein.

I have a strong desire that you should go over these calculations yourself, and should like very much to know the result. Please let me hear from you.

Yours, truly and respectfully,

E. S. CHESBROUGH.

C. F. Durant, Esq.

P. S. In looking over your report to Mr. Day, I find you make the declivity of the surface of the stream, in the first 325 feet above the dam 0.19 inch. By my levels, it is just twelve times as great, or 0.19 feet. E. S. C.

New York, 11th May, 1849.

E. S. Chesbrough—

Dear Sir:

Your letter of 8th inst. is just received. "More back-water would be caused by *a* dam, on the first wheel above it, during high water, than in low stages of the stream." And it is a mistake to suppose that I had disputed that point. And, it is equally certain, that *a* dam can be made (and Day's dam at Great Barrington is of this class,) which, not affecting the first wheel above it in a low stage of water, *it cannot* affect it in any freshet, however high the water may rise.

In the case that you send me, the estimates are based on *a* dam of the precise width of stream. Without examining the calculations, I have no doubt your estimates are there correct, because—

If $R = \frac{a}{p}$

And declivity in 6000 feet $= \frac{V^2}{2R}$

Then a depth of 1 foot in a river 100 feet wide, of even sides and bottom, would require for velocity 3.35, - - - 5.72

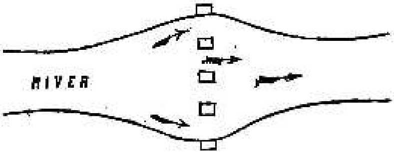
And a depth of 6 feet, with velocity 8.20, would require 6.28

Making a difference in declivity required of - - 0.56

for which there would be no relief.

But if you extend the length of dam, with sluice or gateway, beyond the width of stream at that point, or, make the length of dam greater than width of stream, at *any* point between it and the first wheel above, then the increased declivity is instantly relieved, so far as the dam has any agency in the matter, in lowering the column by increased length. And, if the length of discharge exceeds the width of river by ⅛, then in the foregoing case, the excess of length will lower the column on dam 0.91, which exceeds by 0.35 the increased declivity caused by the additional five feet of water.

The raising of water by piers of bridges, in a river of equal depth and width, is a good illustration of this principle. When the piers fill up 0.5 of the channel or waterway, it is very evident, from Du Buat, in the foregoing formula, that the piers are *a dam*,—and the greater the flood, the greater will be the amount of rise due to the piers. But, if the river at the bridge, is increased in width, the sum of piers, 0.5, added to the amount required to balance the angle of the new water-way, then the stream must flow on precisely as if no piers had ever obstructed its passage; thus—



In a P. S. you mention a difference from 0.19 by my report, to 2.28 by your survey, in level, near the dam. I have no doubt that both are correct. At the time of your survey, there was an increased flood; a portion of the 2.28, say 0.28, was due to the increased velocity, while the balance, say 2., was entirely due to *a natural dam of rocks and narrowed channel*, of the precise character of a dam of piers; and, if instead of 2.28 inches, you had found 2.28 feet, then clearly *it—the natural dam*, and *not* Day's dam—was the cause of the excess of rise. Suppose the river at that point, to be contracted by natural sides or rocky piers, to 0.5 its present width, then, computation will show us very plainly, that the great difference in level, is *caused by the natural dam;* also, that the lower dam (Day's) may in all cases of greater flood, be raised so much as *to flow that great difference*, without in the least degree affecting the first wheel above.

The subject is replete with interest, and if I have omitted to make myself clearly understood, you must attribute the cause to a desire to be prompt in acknowledging your letter. I shall at all times be most happy to hear from you on this matter.

Yours, &c.

C. F. DURANT.

West Newton, May 18th, 1849.

Dear Sir:

Yours of the 11th inst., was received two or three days ago; and I have delayed answering it, in order to give you the result of some investigations I have been making.

We certainly came much nearer agreeing with regard to the effect of a dam, *square* across a stream of regular width and bottom declivity. In such a case, I now understand you to say, that you never disputed the conclusion I have arrived at. You say, however, that if the length of dam be increased ½, (in the case proposed,) the effect to cause back-water on the wheel above, will be entirely done away, *in any stage of the river*.

I have looked into this subject carefully, and made calculations for three new cases. 1st. Where the dam is 50 per cent. longer than the stream is wide. 2d. Where it is 100 per cent. longer; and, 3d. Where it is 1000 per cent. (or 10 times as long.) The result is, they all show an increase of effect, for an increased quantity of water; but the amount of effect diminishes, as the dam is lengthened: very slowly however, after you get beyond double the width of the stream. My calculations, as well as reflections on the nature of the case, irresistibly lead me to the conclusion, that it is impossible to build a dam across a stream, uniform in width as the Housatonic is, without producing this effect in some degree—no matter how curved or oblique the dam may be in its form: provided, of course, there are no perpendicular (or nearly so) falls in the stream. I, of course, mean to include the Housatonic among the cases, where the effect referred to, would be caused by a dam.

You mention the case of a stream being obstructed, and consequently dammed up, by piers, and then widened out so as to prevent