Cost of Preventing Thames Tidal Flood

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Professor Schofield's appraisal of a recent Greater London Council report on ways of preventing the impending disaster in the flood plain of the River Thames includes the cost of risk of future loss. At present values, it appears economic to use sandbags immediately to raise the embankments.

In January 1968 the Greater London Council (GLC) was asked by the Ministry of Housing and Local Government to undertake "an urgent investigation" into the degree and form of protection of London from tidal flooding. As a result of this, the GLC, in October 1969, published its first report of studies on Thames flood prevention[1].

Although this report has been available to the public for some time, for example, in the library of the Institution of Civil Engineers, I only studied it recently when the GLC sent me a copy. My data are taken from the report, but in calculations I have followed the methods set out in the handbook *An Introduction to Engineering Economics* published by the Institution of Civil Engineers (ICE) in 1969. I am concerned with the urgency and the economics of protection needed for London; there is also academic interest in the manner in which time dominates the calculations for these projects.

If there were catastrophic flooding in Central London, the flood waters could wash from Acton Vale and Shepherds Bush across to Barnes Common; from Earl's Court and Buckingham Palace across to Clapham Junction, South Lambeth, Camberwell and New Cross Hospital; from Stratford, West Ham, Wallend and Dagenham across to the Plumstead Marshes. Levels in the flood plain through which the Thames meanders are well known and, if a tide overtopped the statutory defence level of the river walls, a two mile wide strip of low level ground could have water 10 feet deep in the streets in some areas. The GLC studies state that in the sixty-five square miles of the London Flood Plain 1·5 million people are at risk by day and 1·2 million people by night. The cost of direct damage is estimated at £1,000 million. Indirect costs are not estimated but are called "very great".

On pages 45–50 of the ICE handbook benefits and costs of works to prevent a flood are calculated as follows. The present value A of future losses due to floods which return after a period of m years and each time cause a loss L is approximately $A = L/m\ r$ where r is the annual rate of interest on capital. The handbook goes on to calculate the rising cost and diminishing risk associated with increasing the embankment height and thereby increasing the return period m. This note will attempt by similar calculations to appraise the various projects for prevention of flooding in London, assuming a rate of interest $r = 0{\cdot}08$.

The GLC report is very interesting in its discussion of the return period m. An appendix 7 by J. R. Rossiter dated April 17, 1969, explains that in Central London the river's mean high water height is rising relative to the defences at a rate of 2·5 feet per century. C. T. Suthons in 1963[2] considered the frequency of occurrence of abnormally high tides. River levels observed in a surge tide on December 10, 1965, established the variation of high water height at various points along the river. These various studies are crystallized in Fig. 14 of the report which shows that in 1970 the flood to overtop present defences returns every ten years on average; if the defences are raised 2 feet the flood return period increases to 100 years. The rise of high water heights will continually reduce return periods unless defences are also continually raised 2 or 3 feet a century.

Cost of Risk

The report's estimate of loss in the impending London Flood Plain disaster is based only on a comparison with damage to Hamburg in 1962, and the estimated £1,000 million is the least certain figure in these calculations. If we knew that this loss would occur in ten years and then recur regularly, we might allow for payments of £(1,000 × 0·06903) m = £69 million every year into what Table 4 of the ICE handbook calls a sinking fund. If the loss occurs this year and we know it will recur regularly every ten years we might borrow money to pay for damage and service the debt by annual payments of £(1,000/6·7101) m = £149 million. To assess the annual value of the present risk without unwarranted sophistication of the calculations it seems reasonable to take a convenient figure somewhere between £69 million and £149 million, say, of the order of £100 million per annum. That annual cost will be included in appraisal of projects with various times to completion.

The original project that the report considers is a permanent increase of river wall levels by 6 feet, which would increase the flood return period a thousand times and reduce the risk to a small value. This may cost £65 million (Table 5, ref. 1) but is estimated to need thirteen years for completion (page 34). If every year for thirteen years there is £5 million of engineering cost and £100 million risk, then at present values such a project has the same present value as a 13 year annuity which, from the annuity Table 3 of the ICE handbook, costs £(105 × 7·9038) = £829·9 million. The present value of subsequent risk is then small.

The "least time to provide flood protection including bank reconstruction of any scheme considered" is six years for a tide control structure at Woolwich which may cost £45 million. To calculate the present value of that project we could first calculate the present value of risk for the six unprotected years. The present value of some future cost or benefit is discounted by a factor $(1+r)^{-n}$ if the cost or benefit does not arise for n years, for in those n years the present money value could be earning interest at a rate r. Assuming a rate $r = 0{\cdot}08$ and looking at the ICE handbook's Table 3 the present value of an annuity of £100 per annum for six years of risk is £462·3: the risk thus adds a cost of £462·3 million to the present value of this project. Assuming the tide control structure must be paid for as a single sum paid in 5 years time, from the handbook's Table 2, at present values its cost is £45 million × 0·68058 = £30·6 million. So at present value the cost of risk of loss and of engineering works is the sum of £(462·3 + 30·6) = £492·9 million. Alternatively for the same project we can calculate that every year for six years there is £7·5 million of engineering cost and £100 million risk so at present values such a project costs $£(107{\cdot}5 \times 4{\cdot}6229) = £497$ million. The discrepancies between these two estimates for the same project indicate a measure of uncertainty within the calculations, but clearly the cost of the Woolwich project at present values is about half the cost of the original project at present values, and the Woolwich project seems more profitable to pursue.

This calculation emphasizes the insensitivity of present values of projects to the detailed engineering cost. The significant data are the estimated total loss, the return period of floods, the interest rate and the time for completion of works. To test the sensitivity of the calculation suppose that the loss is very much less, with an annual value of only £10 million. At present values the costs of the Woolwich project fall to $£(46{\cdot}7 + 30{\cdot}6) = £76{\cdot}8$ million. To demonstrate the insensitivity of even this calculation to engineering cost, suppose that it increases by £10 million in five years, the present value of the variation is £6·5 million which is less than 10 per cent of the total present value even at that greatly reduced level of loss.

Alternative Proposals

It seems to be worth getting a detailed survey and estimate of probable flood plain losses: this action seems more likely to produce benefits by identifying reducible risks than an engineering design study is likely to produce benefits by reducing costs. If borough engineers were simply to have marks painted on the street lamps at the level of the statutory defences of the adjacent river, occupants of the flood plain could themselves attend to easily reducible risks and could advise their engineers of the value of less easily reducible risks.

If the engineering design study reduced construction time, that would be valuable. But six years is more or less what was quoted in the report from the Ministry of Housing and Local Government[3], so no technical advance since then is evident. Suppose a proposal were made that could reduce construction time to three years. The present value of an annuity of £100 million/year for three years is £257·7 million: for six years it is £462·3 million. Such a proposal could therefore be worth $£(462{\cdot}3 - 257{\cdot}7) = £204{\cdot}6$ million at present values.

An interesting comment occurs on page 38 of the GLC report. The disruption of shipping by intermittent action of a barrier was estimated to be equivalent to a present value of £10 million, and the sentence continues: "the river walls could be raised by about 2 feet for that sum". No time is assigned for that task but a similar task described in appendix 11 is raising banks below Woolwich in a period of three years. The cost is about the same, so I shall assume that the raising of river walls in central London by 2 feet will take three years. The risk costs £257·2 million as before. The construction cost in two years may be $£10 \times 0{\cdot}857 = £8{\cdot}6$ million in present value. In addition, in three years' time we must make allowance for the risk of loss with a flood that rises 2 feet above the statutory defences. Fig. 14 of the report shows that flood returns in 100 years. Our allowance against that risk of loss might then be a single sum such as the ICE handbook calculates of $A = L/m\ r = 1{,}000/100 \times 0{\cdot}08 = £125$ million. Discounting that to a present value of $£125 \times 0{\cdot}79383 = £99{\cdot}2$ million we see that we might allow for three years of high risk, raise the banks only 2 feet, and allow for a future risk for a sum of present value $£(257{\cdot}7 + 8{\cdot}6 + 99{\cdot}2) = £365{\cdot}5$ million. There is a direct advantage over the Woolwich project of $£(492{\cdot}9 - 365{\cdot}5) = £127{\cdot}4$ million and direct benefit in not interfering with any shipping.

Advantage of Sandbags

The great advantage of an early completion is clear. Wherever discounting methods are introduced it follows that project teams will introduce "critical path" methods and other planning and programme evaluation techniques that are directed towards early completion of design and construction. It seems on the face of the matter quite likely that the defences could be raised 2 feet by use of sandbags in a few months of emergency action. The cost of sandbag defences may be large, but perhaps it will be less than the £150 per foot quoted for embankment works in appendix 11 of the report; let us assume the cost is £50 million. Subsequently there could be alternative developments, but suppose we return to the original project and every year for thirteen years allow £10 million for risk and £5 million for engineering work, redeveloping the river frontages to new statutory defence levels above the present levels. At present values the preliminary sandbag defences and the embankment raising work only costs $£(50 + 15 \times 7{\cdot}9038) = £168{\cdot}6$ million, and one might well consider what costs of development of frontage could be met by the various categories of frontages.

The GLC report explains on page 34 that "at present the London Floods Acts are administered by the GLC and the frontager is responsible for the provision and maintenance of flood defences to a line and level to be determined by the statutory authority" who can "determine a new line and level and enforce the provision of flood defences by the frontager". But while the GLC has power to enforce a solution of this problem on the banks, it requires new powers and finance to solve the problem by works in the river.

At this point this appraisal of the GLC report may have been taken far enough. The data on which my economic evaluations are made are probably out of date, for they were all available in April 1969. Since then much scholarly work and wide consultation in many committees has clearly continued with urgency and dedication on the part of all involved. The report has proved to be full of interest and clearly merits academic attention: it is to be hoped that other publications will include full economic evaluation of alternative projects. The lesson of my economic evaluation is that this is an urgent problem that needs a crude solution. I am only too well aware of a tendency for engineers and scientists to want to "solve" problems like floods with solutions more elegant than sandbags. I am also aware, as the GLC report points out on page 45, that in development of amenities "the greatest restriction at present lies in the physical barrier between land and water created by the flood defences". But there is real risk to life, and when I adopt the economic criteria advocated in the ICE handbook my calculations emphasize the economic value of a timely physical barrier. At present, as we approach yet another winter when a gale in the North Sea may raise another high tide like that of 1953, the occupants of the flood plain have again to face an impending London flood plain disaster inadequately protected and unprepared.

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[1] *Thames Flood Prevention Barrier/Barrage Project, First Report of Studies* (Greater London Council, 1969).

[2] Suthons, C. T., *Proc. ICE*, **25**, 433 (August 1963).

[3] *Technical Possibilities of a Thames Flood Barrier*, Cmnd 956 (HMSO, London, March 1960).