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Assessing the benefits of reducing the risk of flooding from sewers

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Executive Summary

OFWAT has published a series of consultation documents and reports on different aspects of flooding from sewers and the issues that arise. Previous reports have explored the costs per property of reducing the risk of flooding from sewers. This report provides simple look-up tables by which to estimate the economic value of reducing the risk of flooding to different types of property. These tables are based upon the accepted methodology for assessing the benefits of reducing the risk of flooding and damage data used for that purpose.

1 Introduction

1.1 In 2002, OFWAT published a consultation paper "Flooding from Sewers – A Way Forward" and later in the year, the responses to the consultation. The companies must also report the number of properties flooding on average twice or more in every ten years, and also those at risk of internal flooding once in every ten years. In the consultation paper, it was estimated that there are some 4,500 properties at risk of flooding once in every ten years and around a further 11,500 properties at risk of flooding once in every ten years (OFWAT 2002). The June return figures for 2002-03 show 3228 properties flooded as a result of hydraulic problems and 3875 properties flooded as a result of other causes. The total figure is equal to the lower estimate of the total number of properties affected in the major river floods of autumn 2001.

1.2 Some climate change predictions include increased rainfall intensities and such increases would acerbate the risk of flooding from sewers.

1.3 Also in 2002, OFWAT published a study by WRc (2002) into the costs of alleviating sewer flooding. This found that the costs of alleviating from sewers varied up to £485,000 per property although the average cost per property was considerably less. A further and just completed study by Babtie's for OFWAT shows that the average cost of alleviating flooding from sewers is £42,000 per property, with an upper limit of £530,000.

1.4 Flooding from sewers therefore is a potentially expensive problem to resolve and OFWAT will look to the companies' sewer flooding programmes to decide whether they are giving value for money, whether the average costs of resolving flooding are acceptable in comparison to the benefits achieved.

1.5 This report (Appendix 4) provides a simple set of look up tables to estimate the present values of the amounts it is worth spending to alleviate flooding. The tables give the equivalent capital sum it is worth spending to reduce the risk of flooding; for example, from a 1 in 2 chance each year of experiencing a flood (a return period of 2 years) to a 1 in 30 chance each year of experiencing a flood (a return period of 30 years). The equivalent capital sums vary between different property types and are very sensitive to the present risk of flooding. For example, to improve the design standard of protection from a 1 in 5 chance of flooding to a 1 in 50 chance each year, the equivalent capital sum for the average house is some £22,000; this falls to around £13,000 the present risk of flooding is 1 in 10 per year.

1.6 The values given in the tables are economic losses and not financial losses, and cover only 'tangible' losses: those that can be measured in economic terms. Floods also can cause significant health damage, stress and result in the loss of irreplaceable items such as wedding photographs. It continues to be difficult to provide reliable estimates of the economic losses associated with those non-tangible losses. The figures for the tangible losses are taken from the most recent data published earlier in the year by the Flood Hazard Research Centre for Defra (Penning-Rowsell et al 2003).

2 The rationale for reducing the risk of flooding

2.1 Although the tables give the economic benefits of reducing damages to buildings and their contents, the primary purpose of all flood alleviation works is to reduce the risk to life. The primary locations where there is such a risk to life are:

- Underground occupied spaces e.g. car parks, shopping areas, underground stations.
- Walking along streets and falling down manholes from which the covers have been blown off by the force of water.
- High velocity flows.

2.2 It is not possible to predict reliably the probability of death in each such circumstances and in any case it is not recommended that a 'value of life' is used in a formal cost-benefit analysis. Rather at the Inquest or Public Inquiry it will be necessary to demonstrate that reasonable consideration was given to the risks and an appropriate response made.

3 Losses

3.1 The benefits of alleviating flooding are the losses avoided. In turn, these losses depend upon the number and type of properties that are flooded, and the loss that a particular type of property experiences in a flood. The loss experienced is primarily a function of the depth of flooding in that property. Over the years, ‘depth-damage curves’ have been built up which express the loss to a particular property as a function of the depth of flooding where this loss is expressed either as a loss per property or as loss per unit area (Penning-Rowsell et al 2003). There are a number of ways of developing such curves, and the curves used here are those generally adopted in England and Wales (Defra 1999). In the case of non-domestic properties, they were derived from interviews with the owners of different types of property. For dwellings, the damages to the fabric of the building were derived by specialist surveyors whilst losses for household contents were derived from market research data as to the ownership of items and loss adjusters’ assessments of the damage to each such item as a function of depth.

3.2 These losses then need to be weighted by the change in the probability that they will occur. The risk of flooding is conventionally expressed as the ‘return period’ of the flood so that for a flood with a return period of five years, there is a 1 in 5 chance of experiencing a flood of at least that magnitude during the year, a probability of 0.2. The formal definition of this probability is that it is the probability in any year of experiencing at least one flood of at least the specified magnitude so it is known as the ‘exceedance probability’.

3.3 This convention has been established when considering rainfall events but sewers can fail through a number of other mechanisms in addition to rainfall events (Appendix 3). It is convention to describe the return period of the most extreme flood, which will not result in any significant losses as the ‘standard of protection’.

3.4 In assessing the benefits of large scale flood alleviation schemes, it is usual to undertake detailed hydraulic modelling in order to calculate the depth of flooding in each property. This will rarely be feasible when considering flooding from sewers. Therefore, based upon experience, it has been assumed that the depth of flooding in a property will vary with the return period of flooding. If the current standard of protection is a return period of one year, then the depths assumed vary as shown in the following table:

Table 1 Assumed depths of flooding in floods of different return periods

Return period (years)	1	2	5	10	20	30	40	50
Depth of flooding (metres)	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9

3.5 For other higher current standards of protection, the depth of flooding is always assumed to –0.3 metres at the current standard of protection, with the other depths shifting one column to the right in the above table. Thus, if the current standard of protection is a 5 year return period, the assumed depth of flooding in the 50 year return period flood is 0.3 metres. The depth of –0.3 metres is adopted for the current standard of protection because this is the lowest depth considered to just cause damage in some dwellings (i.e. damage can be caused to under-floor structures).

3.6 The loss from a flood of a given depth depends upon the nature of the property and its use. In addition, for non-residential properties, the standard depth-damage curves give a loss per square metre. Figure 1 summarises the number of properties of the primary different types in the country, and also the total square area of the non-residential properties. For non-residential properties, the average areas given in this table were assumed to be the area of the average property of each of the different classes, so, for example, a shop is assumed to have an area of 134 square metres. Quite clearly some properties of each land use type have a very different ground area with some warehouses, for example, having an area of 50,000 square metres. Where it is known that the actual areas of individual properties at risk of flooding are very different from the assumptions made in the relevant table, then the appropriate adjustments can be made. In practice, since to flood a 50,000 square metre warehouse would require a substantial volume of water, major adjustments should not normally be necessary.

3.7 Tables (Appendix 4) are given for each of the non-residential land use types and the most common residential types although a common table is used for all terraced houses rather than separate tables being given for end of terrace and mid-terrace houses.

3.8 The methodology adopted is discussed in more detail in Appendix 2.

Figure 1 Land use: numbers and types of properties.

	number	1000 m^2 area	average area
retail	492730	66088	134 m^2

housing	pre-1919	1919-194	1945-196	post 1964	1000s
end terrace	576	467	386	703	
mid terrace	1943	618	466	1030	
semi-detached	709	1906	1862	1574	
detached	595	593	717	2287	
temporary	0	0	0	6	
purpose built fla	147	263	815	1788	
converted flat	811	53	9	45	
all	4781	3900	4255	7433	20369

	number	area	average area	
offices	220475	48502	110.0 m^2	assume two stories
factories	167633	149773	893 m^2	
warehouses	122434	67829	554 m^2	

	number	%
retail	492,730	2.3
housing	20,369,000	95.3
offices	220,475	1.0
factories	167,633	0.8
warehous	122,434	0.6
	21,372,272	

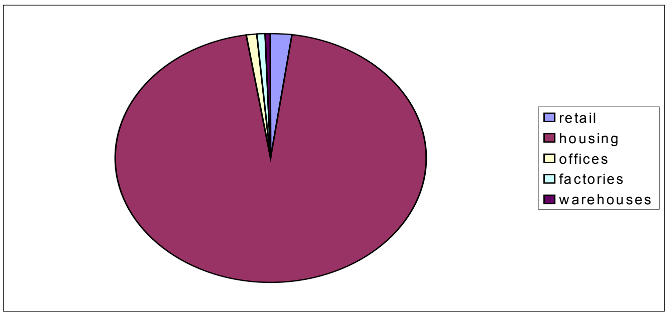

Figure 2 Standard table for pre-1919 terraced house

pre1919 terrace

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		14,085	74,172	79,015	90,796	92,637	94,263	94,850
2			7,043	32,794	35,215	41,761	43,049	44,303
5				2,817	15,693	17,038	21,620	22,614
10					1,409	8,562	9,503	13,038
20						704	5,711	5,893
30							470	4,332
40								352
50								

4 Capitalised values

4.1 The capitalised sum it is worth spending to reduce the risk of flooding depends upon whether the scheme reduces the extent of all floods or just those up to some design standard of protection. For example, if a sewer is enlarged then less water will surcharge from the access points during all floods even in the most extreme floods. Other approaches to reducing the risk of flooding will only have any effect up to the intended design standard of protection. Therefore, the benefits differ according whether or not the scheme reduces the extent and depths of all floods, it provides 'above design standard benefits'. So, two sets of tables are provided.

4.2 The economic value of reducing the risk of flooding to a property cannot exceed the value of the property itself. So, for example, the present value of the benefits of reducing the probability of flooding of a pre-1919 terraced house (Figure 2) from 1 to 0.02 (50 year return period design standard) of approximately £85,000 exceeds the value of terrace houses in the East Midlands, North, North West, Wales and the Yorks/Humber Regions. In those regions it would be more efficient in economic terms to buy the properties, demolish them and convert the land to some other use which would not be so susceptible to damage by flooding. Strictly speaking, the upper bound on the amount that it is worth spending to reduce the risk of flooding to a property is:

(Value of property + removal and demolition costs) – value of land in alternative use

4.3 For dwellings (Table 2), H M Land Registry provides regularly updated data on the market prices of dwellings.

Table 2 House prices

(source: HM Land Registry)

Region	Detached	Semi-detached	Terraced	Flat-maisonette
East Anglia	198,387	126,670	107,118	94,763
East Midlands	184,558	102,012	81,703	89,379
Greater London	515,720	281,597	255,104	207,469
North	173,053	89,547	61,154	72,595
North West	196,606	98,982	59,257	94,065
South East	322,565	185,357	151,254	125,830
South West	246,070	147,863	128,444	120,903
Wales	153,806	86,785	68,722	93,957
West Midlands	214,560	112,928	87,293	96,307
Yorks & Humber	179,687	93,798	64,444	96,432

4.4 In assessing the benefits of the proposed scheme, it is also necessary to consider what effects the proposed scheme will have upstream and downstream on the risk of flooding. Some options may also have other potential benefits (or costs) which also should be taken into account e.g. a reduction in the risk of collapse.

5 Comparison to the methodology used for the cost-benefit analysis of river and sea flood alleviation schemes

5.1 The tables give results that differ from those that are used in schemes to reduce the risk of flooding from rivers or the sea. There are two significant differences:

- The discount rate applied in publicly funded schemes is 3.5% falling to 3.0% in year 30, as opposed to the 5.4% rate used here for the cost of capital.
- The Treasury (2003) applies distributional weights to reflect income effects so that a given monetary loss to someone in the highest quintile of income is given a weight of 0.25 as compared to the same monetary loss to someone in the lowest quintile. Such a loading has not been used in the preparation of these tables.

5.2 It might also be noted that the Treasury requires that capital costs be increased by a factor that reflects the tendency to underestimate costs and overestimate benefits when preparing cost-benefit analyses. For flood and coastal defence schemes, the adjustment factor is currently taken to be 30%. No such adjustment is included in these tables.

6 Comparison to the 1989 tables

6.1 There are a number of differences in the tables as compared to those prepared previously.

- The format has been changed with the intention of making their use easier.

- The earlier tables included an estimate of the economic losses from so-called household ‘intangibles’ (health damage, loss of memorabilia, stress, disruption and so on). In crude terms, the estimate of the economic losses from household ‘intangibles’ amounted to roughly twice the damages to the dwelling and its replaceable contents (Green and Penning-Rowsell 1989). These values will be superseded by on-going research and the tables given here do not include these ‘intangible’ losses.

- The direct losses have been increased to take account of the most recent data on these losses (Penning-Rowsell et al 2003). They also include the costs of dehumidifiers to reduce the time necessary for a dwelling to dry out.

- The cost of capital used in preparing those tables was the then prevailing Treasury discount rate which is different from the value used in this analysis (5.4%).

7 Worked example of the use of the tables

7.1 The simplest example is a single property. For example, suppose a pre-1919 terraced house currently is flooded twice in ten years, and assume that this implies to a current design standard of protection of 5 years. It is then worth spending a capitalised amount of £2,817 to improve the standard of protection to a return period of 10 years, £15,693 to a return period of 20 years, £17,038 to a return period of 30 years and so on (Figure 2). In each case, in use the monetary amounts should be rounded since it is optimistic to believe that it is possible to predict the next fifty years to the nearest pound.

7.2 Suppose that two pre-1919 terraced houses are known to flood with a return period of 2 years; that five more and a shop flood with a return period of 5 years (Figure 3). The capitalised amount it is then worth spending to increase the design standard of protection to 10 years is then:

2 * 32,794
5 * 2,817
1 * 27,599

This gives a total capitalised amount of approximately £108,000.

7.3 To increase the standard of protection instead to 20 years, it would be worth spending a capitalised amount of:

2 * 35,211
5 * 15,693
1 * 36,226

This gives a total capitalised amount of some £185,000.

Figure 3 Standard table for shops

retail

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		137,994	178,256	195,512	212,767	221,427	236,342	243,882
2			68,054	85,310	93,937	103,524	109,586	121,091
5				27,599	36,226	41,020	47,730	52,406
10					13,799	18,593	21,948	27,124
20						7,057	10,412	12,057
30							4,757	7,345
40								3,591
50								

7.4 A sensitivity analysis should normally be carried at the beginning of the cost-benefit analysis to identify which are the critical parameters (Green 2003); those to which the results of the analysis are very sensitive. In the case of flooding, the critical parameters are already known:

the estimate of the present value of the benefits is highly sensitive to the estimate of the current standard of protection. In the table for pre-1919 terrace houses, if the current standard of protection is one year and the scheme will increase the design standard to a 10 year return period, then the present value of the benefits is some £79,000. If however the current standard of protection is actually a two year return period event then the present value of the benefits is only a bit more than £33,000. The more frequent flooding is at present, then the more important it is to accurately estimate this probability.

8 Conclusions

8.1 This project provides some simple look up tables by which to assess the benefits of reducing the risk of flooding from sewers. The aim of the tables is ease of use. It is also recognised that data is generally sparse and expensive to obtain so that the much more detailed methods used in assessing the benefits of a flood alleviation scheme for river or sea flooding will rarely be appropriate when assessing a scheme to reduce the risk of sewer flooding. Hence, simplifying assumptions have been used where better data will not generally be available. If better data is available, then the tables can be adjusted accordingly.

8.2 The purpose of economics is to aid thought and not to replace it. That the tables are intended to be easy to use does not mean that they can or should be used mechanically. The different parameters in the tables can be easily adjusted so that the often dramatic effects that changes in those parameters can have on the capitalised amount it is worth spending to reduce the risk of flooding can be observed. In particular, the amounts that it is worth spending are very sensitive to the estimates of the return period of current design standard of protection and, to a lesser extent, to the design standard of protection that will be provided by the proposed scheme.

9 Glossary

Above design standard benefits	Where the scheme reduces the extent and depth of flooding from floods more extreme than the notional design standard of protection offered by the scheme.
Annual average benefits	The expected value of the reduction in flood losses. These are approximated as the difference in the areas under the loss-probability curve for the situation now and that with the proposed scheme.
Depth-damage curve	The extent of the losses to a property as a function of the depth of flooding.
Design standard of protection	The probability of the most extreme flood with which it is intended that the proposed scheme should be able to cope without any significant losses occurring.
Direct losses	The physical damages caused by a flood.
Discount rate	The cost of capital for a commercial organisation and something more complex for a government.
Exceedance probability	The probability of an event of a given magnitude or greater.
Indirect losses	The losses that occur as a result of the physical damages or conditions caused by the flood.
Intangible benefits or costs	Those that it is not presently possible to evaluate in economic terms. The health effects of flooding, the stress caused by flooding are examples of what has come to be called the ‘intangible’ impacts of flooding.
Loss-probability curve	A plot of the losses from flood events on the ordinate axis against the exceedance probability of those flood events on the x axis.
Perfect competitive market	Akin to the perfect gas of the gas laws; a theoretical ideal which can only be approximated in reality.
Present value	Capitalised value of a stream of payments, income, benefits or costs.
PMF (Probable Maximum Flood)	Theoretically, the most extreme flood possible; that with a probability of occurrence vanishingly close to zero.
Return period	Conventionally used instead of the exceedance probability: the reciprocal of the exceedance probability.
Transfer payment	A payment that is not associated with a shift of resources or consumption in the opposite direction.

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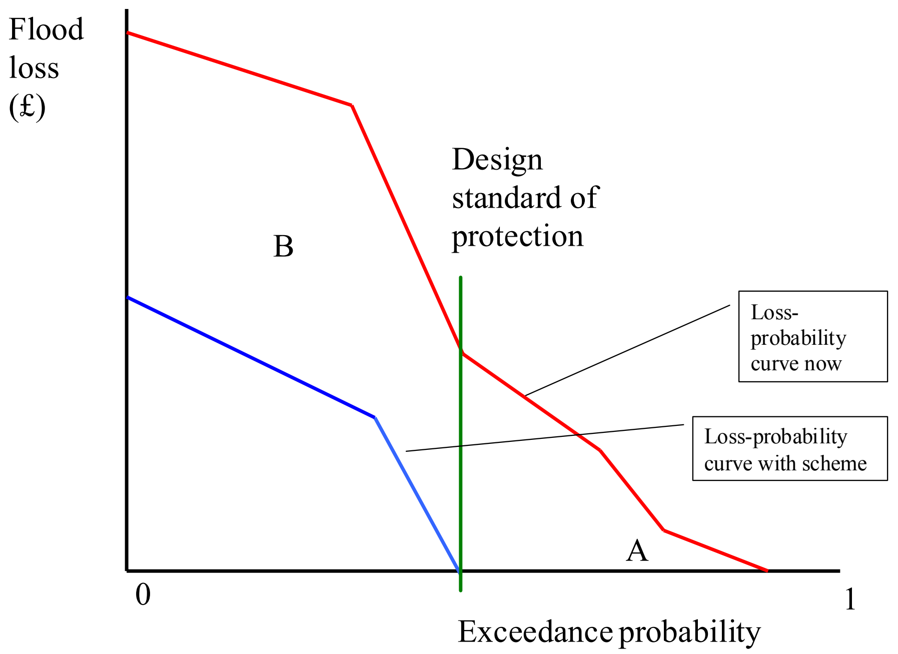
Appendices

Appendix 1 The differences between economic and financial losses

Figure 4 Loss probability curve



1. The benefit of upgrading sewers so as to reduce the risk of flooding is the reduction in the expected value of the losses that would otherwise occur during the lifetime of the proposed scheme. This is usually calculated by plotting the loss-probability curves for the existing situation and that if the scheme is constructed (Figure 4). For each of a number of floods of different probabilities (the inverse of the return period of that event), the loss without the scheme is calculated. The same procedure is followed assuming that the scheme is constructed; the difference in the areas under the two curves is the reduction in the annual expected value of the losses avoided, the annual benefit of the scheme.

2. Once the annual benefit is calculated, the present value of the benefits, the capital sum it is worth spending to avoid those floods, is simply the annual benefits times a factor whose size depends only upon the cost of capital and the expected life of the proposed scheme. Defra (1999) sets out the standard methodology for assessing the economic benefits of flood alleviation.

3. The loss in a flood depends upon the number, type and size of the properties flooded, and the characteristics of the flood which occurs. The difference between the flooding from sewers and river or sea flooding is that data is considerably sparser in the case of flooding from sewers; the depth of flooding in individual properties in floods of differing return periods is not usually known. Hence, whilst the look up tables follow the standard methodology for assessing the benefits of flood alleviation, a number of simplifications have been adopted.

4. The main characteristics of a flood that affect the extent of the losses are:
    - Depth of flooding
    - Velocity of flood
    - Duration of the flood

- Sediment and polluting load carried by the flood

5. Of these, the main causal mechanism from flooding combined or separate sewers is the depth of flooding. In practice, all floods must be considered to be contaminated by sewage, petrol, oil, pesticides and other materials so it is generally the quantity of sediment deposited by a flood, rather than the pollutants, that makes a difference to the priced losses. However, a reasonable counter-argument is that it is the degree of dilution of pollutants that is important and hence flooding from sewers is more disturbing that flooding from larger events, particularly when that flooding involves recognisable materials. In one case, a woman said that she had stopped growing roses because she was fed up removing toilet paper from the thorns. Similarly, some of the reported health affects of flooding may be the result of exposure to water borne disease vectors. However, it has not been possible so far to derive a specific weighting for flooding from sewers as opposed to flooding from other sources.

6. Sediment loads are too small in the UK to be significant. Velocities of flow greater than 2 metres/sec can threaten the structural integrity of a building but the real importance of high velocity flows lies in the risk to life: there is a significant risk that pedestrians and cars will be swept away if flow velocities exceed 2 metres/second. It is assumed flow velocities will be considerably lower than this threshold value. For flooding from sewers, the differences in the duration of a flood are unlikely to be sufficient to make a difference to the losses. Hence, the primary determinant of flood losses is the depth of flooding.

7. Flood losses are conventionally characterised into direct and indirect where direct losses cover the physical damage caused by flooding and indirect losses refer to the losses consequent upon that damage (Table 3). Obviously, the easiest losses to evaluate are those losses that are priced.

Table 3 Categories of flood loss

	Priced	**Unpriced**
Direct	Damage to the building and damage to the replaceable contents	Loss of memorabilia
Indirect	Cost of alternative accommodation, cost of dehumidifiers	Stress induced by the flood, health damage, traffic disruption

8. The losses given in the tables are for economic losses and not for either financial losses or insured losses. Financial losses differ significantly from economic losses in a number of ways (Table 4). Whereas a financial analysis is restricted to changes in flows of money, an economic analysis includes all desirable and undesirable changes whether or not they are priced. Secondly, whereas a financial analysis is concerned with the changes that affect a single individual, household or firm, an economic analysis is concerned with the changes to the country as a whole. From such a wider perspective, some changes result in counter-balancing changes so that the net effect is zero. The test to determine whether there is a real economic effect is: is there a real change to the country as a whole in either the total availability of resources or the total value of all consumption? In neither case does it matter whether those resources or consumption are priced or unpriced.

9. One particular instance where a financial loss does not necessarily result in an economic loss is if a shop or factory is closed by a flood. In this case, the owner will experience a financial loss of the profits that they would otherwise have earned during the period it was closed. But in general

this loss is not countable as an economic loss. In the perfect competitive market that forms the starting point of economic analysis, the result of the temporary or permanent closing of one firm is the instantaneous and costless transfer of demand or supply to other firms. So one firm's loss is another firm's gain. A real economic loss occurs to the extent that this does not happen. The more imperfect the market, the more likely and the greater these losses are likely to be. As concentration and specialisation increases, so the market moves further and further away from the hypothetical perfect competitive market. Conversely, since small retail and leisure outlets are generally a reasonable approximation to a perfect competitive market, indirect economic losses are conventionally assumed to be zero in these cases.

10. Where the market is imperfect, in principle, economic losses can result both on the production side and to the consumer. The consumer may incur costs as a result of having to buy the good or service from another supplier, what they can buy may be less desirable to them than what they would normally have bought from the flooded supplier, and they may have to wait for the supply of the desired good. These costs are very difficult to evaluate and are not included in the attached tables. The producer may also incur costs either to avoid a loss of business abroad (costs to avoid a loss of business at home are only financial costs and not counted) or otherwise to minimise the loss of profits. These costs, notably clean up costs, are real economic costs and can be counted. The difficulty is that they can vary markedly between different types of producer.

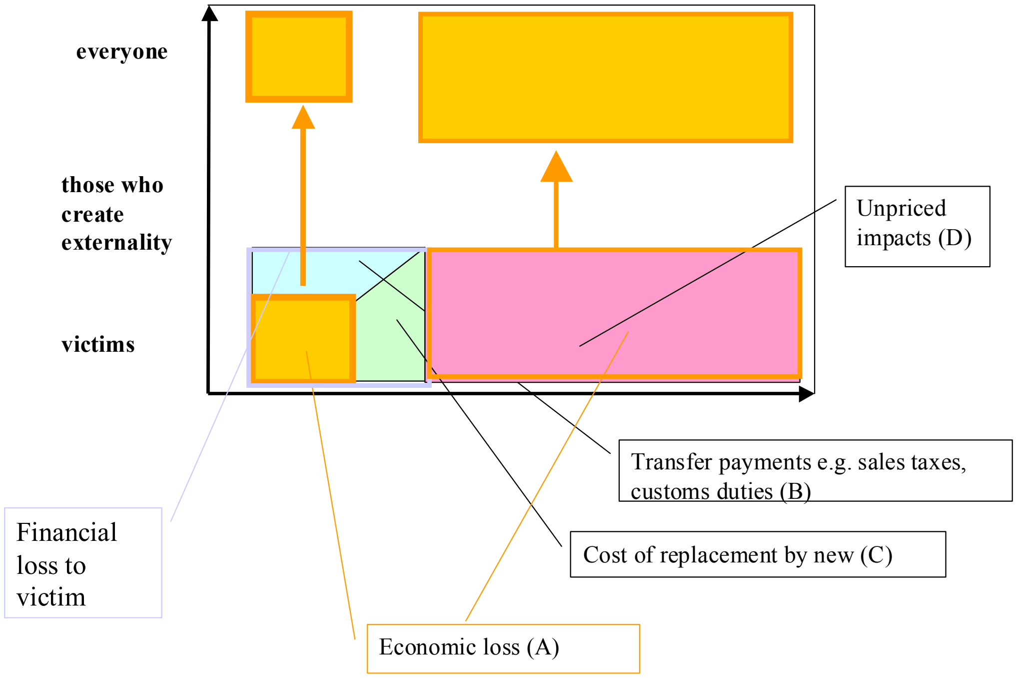
Table 4 Comparison of financial and economic analysis

Financial	**Economic**
Cost of repairing or replacing building including insurance company markup	Damage to building
Replacement of building contents	Replacement of building contents by equivalents (e.g. the loss is equal to the depreciated value of the item of contents)
Indirect taxes e.g. VAT, exercise duties	Not counted as these are transfer payments
Loss of profits	Additional costs incurred to the country of providing those goods or services including imports from overseas plus loss of exports
Costs of drying and cleaning property in so far as others are paid to undertake these works	Costs of drying and cleaning property; in principle includes the value of time to those who undertake these works whether or not they are paid to undertake that work
Disruption to household life, health – not counted because does not involve a significant monetary cost	Counted in principle, the difficulty is to actually measure such losses
Rental of alternative accommodation whilst home is uninhabitable	Counted but ignores contractual requirements as to minimum rental periods

11. If economic and financial costs differ, insured losses differ again. In particular, even though a household may have a 'new for old' insurance policy, the real economic loss is the value of what was lost. If a household loses a 5 year old television, that they receive a new television through insurance means that both the household and the country now has one new television and one less 5 year old television. The household gained by the replacement of an old television by a new one; the country loses a 5 year old television.

12.Flooding from sewers is generally a fairly clear cut example of an externality; one person's wastewater and runoff floods another person's property. That flood is often a result of the way which the first person decided to use their land; the sewerage company simply provides the sewer which enables the first land user to discharge their waste water onto someone else's land. In that this is the case, the economic question is how much should those who cause the flooding pay to reduce the risk of flooding of others. Strictly speaking this is given by the amount those who are flooded would require in compensation and this can differ from the amount that those who are flooded would be prepared to pay to avoid being flooded (Coursey et al 1987), not least because willingness to pay is constrained by income whereas willingness to accept compensation is not so constrained. In addition, those who are flooded would generally regard being asked to say how much they would be prepared to pay to avoid being flooded as adding insult to injury, and of implying a violation of basic social norms.

Figure 5 Difference between what a rational individual should be prepared to pay to reduce the risk of flooding to someone versus what the rational individual will be prepared to pay to reduce risk of flooding to self



12. The method that has been described is then a compromise; if the individual who was flooded had to pay to reduce the risk of flooding then that individual would take into account some costs that have been excluded as transfer payments (Figure 5), notably VAT. Conversely, the person causing the flooding would not be prepared to pay for a new television to replace the old television destroyed in the flood. Nor should the person causing the flood include VAT because that tax income would otherwise be raised from them in other ways.

13. The person flooded would be prepared to pay to avoid the stress and health damage, along with the other 'intangible' losses caused by the flood. Since this is a real loss to the person affected, the person causing the flood should be prepared to pay to reduce that risk. The real problem in both cases is to able to predict the extent of these effects which should be expected to vary according to the nature of the flood, the characteristics of the victims and other factors; this is not yet possible (Green et al 1994).

14. In summary, the following elements are included in the analyses:

Cost of damage to the building
Cost of replacing carpets, furniture
Cost hiring and running dehumidifiers, heaters
Cost of cleaning

The following factors are not included as the cost is not readily predictable:

Cost of alternative accommodation (varies between areas and regions)
Intangible effects e.g. stress, ill-health
Administrative costs incurred by a sewerage company relating to sewer flooding

The following are not included because to do so would be to double count the losses as these are incorporated into the value of the loss included the tables already:

Social Fund payouts
Increases in insurance premiums
Insurance payouts
Compensation by sewerage companies
GSS payments by sewerage companies

Finally, one element is not included because in national terms the effect is simply to move money from one pocket to another:

VAT on replacing household items

Appendix 2 The basis upon which the tables were calculated

1. The basis upon which these tables were calculated is as follows. The present value of the benefits of improving the design standard of protection from flooding is conventionally calculated by plotting the loss-probability curve for the current situation where the loss-probability curve is defined by the event loss on the y axis and the exceedance probability of the flood (the reciprocal of its return period) as the x axis. The annual average benefits of the proposed improvement is then given by the area under the curve (Figure 4). Multiplying this value by a scalar, whose value depends only upon the discount rate and the engineering life of the proposed strategy for reducing the risk of flooding, gives the present value of the benefits of reducing the risk of flooding.

2. The two problems in estimating the present value of the benefits are therefore to assess the probabilities of events and, secondly, the losses that will result in those events so as to obtain an estimate of annual average benefits. A general problem is that it is necessary to use a sample of combinations of events and the associated exceedance probability to obtain an approximation of the loss-probability curve; this is a sampling problem, the question is how to select how many events and which events to select in order to give an adequate approximation to the unknown true curve. A second problem specific to the question of assessing the benefits of reducing flooding from sewers is that there will generally be only very limited information as to the nature and extent of flooding during each event, and as to the return period of that event. Hence, a number of simplifications have had to be adopted in order to prepare the attached tables.

3. In Figure 4, the area between the loss-probability curve for the present situation and the curve with the proposed scheme is separated into two zones; one up to the proposed design standard of protection (zone A) and a zone above the design standard of protection (zone B). In principle, the benefits of the proposed scheme are given by the sum of A plus B. Unfortunately, the benefits given in zone B depend upon the nature of the proposed scheme and it is not possible to estimate them precisely without very detailed hydraulic modelling. Some types of scheme should be expected to reduce the losses from all floods, even the PMF flood, below those expected now. So, for example, in theory the addition of controlled storage (where inflows and outflows can be controlled) should be able to store the peak flow from any event so that there is always less flooding and fewer losses however severe is the flood. Other types of scheme should be expected to have no significant effect upon extreme floods.

Appendix 3 Probabilities

1. The probability of a flood depends upon the mechanism that gives rise to flooding, principally:

    - under capacity of the sewer so that surface storage or flow occurs
    - under capacity so that water surcharges from manholes
    - blockage of sewer
    - collapse of the sewer or a burst of a pressurised sewer
    - failure of pumps
    - damage to a sewer

2. In principle, the tables can be used to assess the benefits of reducing the probabilities or outcomes from each type of problem.

3. In the first two cases, the relevant probabilities are those of a given rainfall intensity over a given area. But in the other cases, the probabilities are system dependent rather than load dependent i.e. the probability of a sewer collapsing is likely to be primarily dependent upon the condition of the sewer and the load upon it rather than the flow it is carrying at a particular point in time. The failure of a pump to operate on demand will depend upon the age and standard of maintenance, the probability of an electricity outage, local flooding and other factors. These probabilities are not necessarily independent of each other and estimating the joint probability of failure on demand can be complex and require the use of the techniques of quantitative risk analysis. Defra (1999) illustrates the use of such a procedure for assessing the benefits of improvements to a pumping system.

4. These probabilities may be changing over time; for example, as pumps age, so the likelihood of failure on demand tends to increase. Increases in development, changes in impermeable area and climate change are other reasons why the probability of failure may increase over time. Where probabilities are increasing over time, a question is when, if at all, it will be most efficient to take action.

Appendix 4 Tables

factory

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from \ to	**1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
1		**0**	**78,312**	**156,624**	**234,936**	**281,558**	**328,825**	**368,013**
2			**0**	**26,104**	**65,260**	**91,364**	**114,675**	**143,035**
5				**0**	**13,052**	**26,104**	**39,156**	**53,142**
10					**0**	**4,350**	**10,876**	**18,707**
20						**0**	**2,175**	**3,480**
30							**0**	**1,305**
40								**0**
50								

factory

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		**0**	**182,728**	**261,040**	**339,352**	**398,436**	**524,766**	**562,666**
2			**0**	**78,312**	**117,468**	**160,975**	**202,333**	**299,788**
5				**0**	**39,156**	**60,909**	**91,364**	**123,269**
10					**0**	**21,753**	**36,980**	**60,474**
20						**0**	**15,227**	**24,363**
30							**0**	**11,746**
40								**0**
50								

warehouse

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		12,489	213,019	407,555	600,591	706,302	790,464	853,720
2			7,493	74,337	171,604	235,950	288,805	339,302
5				2,497	35,919	68,342	100,514	132,228
10					1,248	12,389	28,600	47,904
20						416	5,986	9,253
30							208	3,550
40								124
50								

warehouse

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		27,476	474,398	665,936	857,474	957,889	1,106,746	1,137,081
2			13,488	205,026	300,795	407,205	477,495	592,328
5				5,495	101,264	154,469	228,956	283,180
10					2,747	55,952	93,196	150,657
20						1,415	38,658	60,930
30							957	29,688
40								724
50								

office

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		162,347	353,838	461,291	547,734	590,034	620,600	642,724
2			97,408	161,238	214,965	243,779	264,929	283,269
5				32,469	64,384	82,293	96,700	109,390
10					16,234	26,873	35,827	44,471
20						5,411	10,730	12,871
30							2,705	5,897
40								1,623
50								

office

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		372,443	525,121	590,555	655,988	687,066	731,222	745,359
2			181,446	246,880	279,597	315,949	337,703	371,766
5				74,488	107,205	125,381	150,827	167,609
10					37,244	55,420	68,143	87,773
20						19,417	32,141	38,724
30							13,210	23,025
40								10,027
50								

retail

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		64,284	125,765	157,762	182,388	194,246	203,172	209,806
2			38,570	59,064	75,062	83,271	89,200	94,556
5				12,856	23,103	28,436	32,540	36,098
10					6,428	9,844	12,510	14,973
20						2,142	3,850	4,506
30							1,071	2,096
40								642
50								

retail

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		137,993	178,256	195,511	212,766	221,426	236,341	243,881
2			68,054	85,309	93,937	103,523	109,585	12,1091
5				27,598	36,226	41,019	47,729	52,406
10					13,799	18,592	21,947	27,124
20						7,056	10,411	12,056
30							4,756	7,345
40								3,591
50								

average dwelling
does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		5,229	33,776	53,762	68,820	75,573	79,368	81,782
2			3,137	12,653	22,646	27,665	31,042	33,319
5				1,045	5,803	9,134	11,644	13,670
10					522	2,108	3,774	5,280
20						174	967	1,416
30							87	562
40								52
50								

average dwelling

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		10,458	69,746	75,750	87,941	89,837	91,440	92,110
2			5,229	30,638	33,640	40,413	41,740	42,977
5				2,091	14,796	16,464	21,204	22,229
10					1,045	8,103	9,271	12,928
20						522	5,463	5,814
30							348	4,160
40								261
50								

Pre-1919 flat

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		6,430	33,409	51,453	64,515	70,294	73,508	75,541
2			3,858	12,851	21,873	26,227	29.116	31,045
5				1,286	5,783	8,790	10,967	12,700
10					643	2,142	3,645	4,952
20						214	964	1,381
30							107	557
40								64
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		12,859	66,810	70,841	80,945	82,456	83,671	84,244
2			6,430	29,551	31,567	37,180	38,238	39,175
5				2,572	14,133	15,252	19,182	19,997
10					1,286	7,709	8,492	11,524
20						643	5,139	5,259
30							429	3,897
40								321
50								

1919-1944 flat

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		3,832	36,931	61,017	79,187	87,282	91,849	94,764
2			2,299	13,332	25,375	31,432	35,479	38,220
5				766	6,282	10,297	13,325	15,754
10					383	2,222	4,229	6,046
20						127	1,047	1,579
30							63	615
40								38
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,664	79,530	87,889	102,092	104,391	106,422	107,331
2			3,832	34,631	38,811	46,701	48,311	49,877
5				1,532	16,932	19,254	24,778	26,019
10					766	9,321	10,947	15,208
20						383	6,372	6,954
30							255	4,875
40								191
50								

1945-1964 flat

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		3,832	29,898	47,969	61,531	67,623	71,018	73,173
2			2,299	10,988	20,023	24,544	27,590	29,627
5				766	5,111	8,123	10,383	12,210
10					383	1,831	3,337	4,693
20						128	852	1,267
30							64	498
40								38
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,665	63,118	67,501	78,890	80,416	81,794	82,299
2			3,832	27,598	29,790	36,117	37,185	38,248
5				1,533	13,416	14,633	19,062	19,886
10					766	7,368	8,220	11,637
20						383	5,004	5,173
30							255	3,820
40								192
50								

1965-1974 flat

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	1	2	5	10	20	30	40	50
1		2,687	32,953	55,055	71,792	79,284	83,519	86,225
2			1,612	11,701	22,752	28,331	32,077	34,618
5				537	5,581	9,265	12,054	14,302
10					268	1,950	3,792	5,465
20						89	930	1,421
30							44	549
40								26
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		5,374	72,234	79,619	92,983	95,125	97,050	97,901
2			2,687	31,341	35,034	42,458	43,957	45,442
5				1,074	15,402	17,453	22,650	23,807
10					537	8,496	9,932	13,942
20						268	5,840	6,334
30							179	4,477
40								134
50								

pre1919 terrace

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	**1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
1		7,042	37,019	57,210	72,039	78,659	82,386	84,761
2			4,225	14,217	24,313	29,256	32,566	34,802
5				1,408	6,404	9,769	12,241	14,227
10					704	2,369	4,052	5535
20						234	1,067	1,531
30							117	616
40								70
50								

including above design standard benefits

from	**1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
1		14,085	74,172	79,014	90,796	92,637	94,262	94,850
2			7,042	32,794	35,215	41,760	43,049	44,303
5				2,817	15,692	17,037	21,619	22,613
10					1,408	8,561	9,503	13,037
20						704	5,711	5,892
30							469	4,332
40								352
50								

1919-1944 terrace

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,286	37,985	59,212	75,417	82,673	86,706	89,261
2			4,371	14,604	25,218	30,620	34,248	36,667
5				1,457	6,573	10,111	12,812	14,989
10					728	2,434	4,203	5,823
20						242	1,095	1,570
30							121	633
40								72
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		14,572	76,003	82,658	96,103	97,907	99,480	100,075
2			7,286	33,613	36,941	44,410	45,673	46,886
5				2,914	16,078	17,926	23,155	24,129
10					1,457	8,770	10,064	14,098
20						728	5,847	6,259
30							485	4,434
40								364
50								

1945-1964 terrace

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		4,337	27,984	43,927	55,352	60,268	62,907	64,560
2			2,602	10,484	18,456	22,264	24,722	26,306
5				867	4,808	7,465	9,369	10,844
10					433	1,747	3,076	4,218
20						144	801	1,173
30							72	466
40								43
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		8,674	57,778	60,916	69,708	70,362	71,172	71,522
2			4,337	25,381	26,950	31,835	32,292	32,917
5				1,734	12,257	13,128	16,547	16,901
10					867	6,713	7,323	9,960
20						433	4,525	4,571
30							289	3,445
40								216
50								

1965-1974 terrace

does not include above design standard benefits

Present value of benefits to improve from one design standard to another

from	**1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
1		3,579	31,841	51,878	66,843	73,525	77,276	79,663
2			2,147	11,568	21,587	26,575	29,916	32,166
5				715	5,426	8,765	11,259	13,264
10					357	1,928	3,597	5,094
20						119	904	1,357
30							59	530
40								35
50								

including above design standard benefits

from	**1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
1		7,160	68,093	73,828	85,798	87,617	89,211	89,864
2			3,580	29,694	32,562	39,212	40,485	41,714
5				1,432	14,489	16,082	20,737	21,719
10					716	7,970	9,085	12,676
20						358	5,436	5,747
30							239	4,156
40								179
50								

pre 1919 detached

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,980	49,574	81,406	107,291	119,266	126,186	130,606
2			4,788	18,652	34,568	43,197	49,184	53,336
5				1,596	8,528	13,833	18,147	21,740
10					798	3,108	5,761	8,349
20						266	1,421	2,074
30							133	826
40								79
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		15,961	101,840	118,937	140,295	145,165	148,284	149,969
2			7,980	44,785	53,334	65,200	68,608	71,015
5				3,192	21,594	26,344	34,650	37,279
10					1,596	11,819	15,144	21,551
20						798	7,954	9,580
30							532	6,052
40								399
50								

1919-1944 detached

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		4,319	34,399	56,014	72,629	80,163	84,420	87,129
2			2,591	12,618	23,425	28,964	32,731	35,285
5				863	5,877	9,479	12,248	14,509
10					431	2,103	3,904	5,565
20						143	979	1,459
30							71	573
40								43
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		8,638	72,778	80,055	93,838	96,160	97,964	98,736
2			4,319	31,807	35,446	43,103	44,729	46,120
5				1,727	15,471	17,493	22,853	24,107
10					863	8,499	9,914	14,049
20						431	5,776	6,267
30							287	4,411
40								215
50								

1945-1964 detached

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		4,418	37,314	61,229	79,548	87,808	92,478	95,451
2			2,651	13,616	25,573	31,680	35,810	38,612
5				883	6,366	10,352	13,405	15,883
10					441	2,269	4,262	6,094
20						147	1,061	1,587
30							73	621
40								44
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		8,837	79,409	88,011	102,796	105,351	107,344	108,268
2			4,419	34,664	38,965	47,178	48,967	50,505
5				1,767	16,890	19,280	25,029	26,409
10					884	9,285	10,958	15,393
20						442	6,323	6,944
30							295	4,831
40								221
50								

1965-1974 detached

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		3,733	33,583	55,063	71,565	79,062	83,307	86,013
2			2,240	12,190	22,930	28,431	32,179	34,726
5				747	5,722	9,302	12,052	14,301
10					373	2,032	3,822	5,472
20						124	954	1,432
30							62	560
40								37
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,467	71,890	78,869	92,666	94,981	96,838	97,711
2			3,733	31,343	34,833	42,498	44,118	45,551
5				1,493	15,298	17,237	22,603	23,852
10					747	8,416	9,773	13,912
20						373	5,742	6,194
30							249	4,390
40								187
50								

pre1919 semi

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,358	36,266	55,753	70,303	76,838	80,509	82,846
2			4,414	14,051	23,794	28,644	31,911	34,114
5				1,471	6,289	9,537	11,962	13,922
10					735	2,341	3,965	5,420
20						245	1,048	1,493
30							122	604
40								73
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		14,716	71,868	76,927	88,816	90,635	92,192	92,801
2			7,358	31,851	34,381	40,986	42,259	43,460
5				2,943	15,190	16,595	21,219	22,201
10					1,471	8,275	9,259	12,825
20						735	5,498	5,727
30							490	4,164
40								367
50								

1919-1944 semi

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		7475	36689	56618	71569	78253	81996	84375
2			4485	14223	24187	29171	32513	34759
5				1495	6364	9685	12177	14182
10					747	2370	4031	5526
20						249	1060	1510
30							124	611
40								74
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		14,951	72,651	78,495	90,533	92,344	93,891	94,500
2			7,475	32,204	35,126	41,814	43,081	44,274
5				2,990	15,354	16,977	21,659	22,637
10					1,495	8,364	9,500	13,111
20						747	5,555	5,885
30							498	4,207
40								373
50								

1945-1964 semi

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		7,475	36,689	56,618	71,569	78,251	81,994	84,373
2			4,485	14,223	24,187	29,171	32,512	34,758
5				1,495	6,364	9,685	12,177	14,182
10					747	2,370	4,031	5,526
20						249	1,060	1,510
30							124	611
40								74
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		14,951	72,652	78,495	90,534	92,337	93,889	94,498
2			7,476	32,204	35,126	41,814	43,077	44,274
5				2,990	15,355	16,978	21,659	22,633
10					1,495	8,364	9,500	13,112
20						748	5,556	5,886
30							498	4,208
40								374
50								

1965-1974 semi

Present value of benefits to improve from one design standard to another

does not include above design standard benefits

from	1	2	5	10	20	30	40	50
1		3,273	29,711	48,423	62,567	68,936	72,513	74,790
2			1,964	10,776	20,132	24,847	28,031	30,178
5				654	5,061	8,179	10,537	12,447
10					327	1,796	3,355	4,769
20						109	843	1,267
30							54	495
40								325
50								

including above design standard benefits

from	1	2	5	10	20	30	40	50
1		6,546	63,654	68,875	80,629	82,373	83,898	84,479
2			3,273	27,747	30,358	36,888	38,109	39,285
5				1,309	13,546	14,996	19,568	20,509
10					654	7,453	8,468	11,994
20						327	5,086	5,358
30							218	3,889
40								163
50								