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Risk of flooding and insurance in The Netherlands

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Abstract: The loss potential from flooding damage in the Netherlands is enormous. Losses in the order of 100 billion Euro resulting from sea floods and 50 billion Euro for river floods are conceivable. Recently, relative small river flooding events occurred in December 1993 (loss of 100 million Euro) and January 1995 (loss of 80 million Euro). In September 1998, heavy rainfall occured causing losses of some 500 million Euro.

In the Netherlands a combination of damage sharing and construction of flood defences has been applied over many centuries. Recently it has been studied if insurance could be added to this mix. Insurance of whatever form is a tool for spreading negative consequences rather than removing them. It will be concluded that insurance of catastrophical floods seems not to be attractive, but that insurance of damage as a result of local heavy rainfall may be attractive.

Keywords: flood damage, insurance, design of flood defences

1. INTRODUCTION

Insurance of risks of natural hazards has been studied in literature only very recently (OBrien (1997), Nutter (1999), Kunreuther (2001), Kunreuther et al. (2001), Ermoliev et al. (2001), White (2001), and Kunreuther and Linnerooth-Bayer (2002)).

Iwan et al. (1999) reviews the international Decade for Natural Disaster Reduction, a United Nations program for the 1990s, which focused attention on the increasing losses caused by natural hazards and which promoted actions to reduce their impacts. During this period in the United States, disaster managers and other officials increased emphasis on mitigation relative to response and recovery, especially in programs of the Federal Emergency Management Agency. Many other nations and international organisations undertook similar efforts. Iwan et al. (1999) argues that beyond the Decade, efforts should focus on improving risk assessments; implementing mitigation strategies; improving technologies supporting warnings and the dissemination of, and response to, warnings; improving the basis for natural disaster insurance: and assisting developing nations.

Grossi and Kunreuther (2001) focus on the role of homeowners and insurance companies in managing the hazard from earthquake risk. Specifically, they consider alternative earthquake disaster management strategies for a typical homeowner and a small insurance company in the Oakland, California region. These strategies involve the adoption of mitigation measures and the purchase of earthquake insurance by the homeowner and the purchase of an indemnity contract (e.g. excess-of-loss reinsurance) by the insurer. They also focus on how uncertainty impacts these disaster management strategies. Specifically, they illustrate the impact of structural mitigation and risk-transfer mechanisms on the insurer's performance when there is uncertainty in the company's risk profile. This risk profile is captured through a loss exceedance probability (EP) curve, representing the probability that a certain level of monetary loss will be exceeded on an annual basis.

In this paper insurance of risk of flooding will be analysed. First, the principles of insurance will be briefly described, followed by the current practice in the Netherlands as well as solutions in other countries. The flood loss potential in the Netherlands is enormous, as investigated in Sec. 4. The paper furthermore contains a mathematical treatment of an insurance premium calculation in case of an optimal flood defence protection scheme by the government (Sec. 5). The paper ends with a summary of the Dutch insurance policy on floods and with some final remarks.

2. PRINCIPLES OF INSURANCE

Insurance is contractual arrangement that provides for compensation by an insurer to an insured party for loss resulting from a possible event. The insurer conducts its operations by amassing relatively small contributions, premiums, from many persons who are exposed to the risk of occurrence of an unforeseen event in order to create a fund to reimburse those clients who actually suffer from such an occurrence.

A prime requirement is the independence of the events. This requirement is difficult to fulfill in case of flooding where many properties will sustain damage at the same event. The insurance should be spread over many different river basins, coastal areas and polders to guarantee a sufficient degree of independence.

It is important to realise that there is a big difference between insurance of fire events and flood events. Insurance to fire risk is very common. Consider the following illustrative example about an area with 10,000 houses with an average value of 200,000 Euro per house.

Assume that there are two risks in this area:

1. fire: average of 10 fires per year
2. flood: average of 1 flood in 1000 years with all houses destroyed.

The average risk is in both cases 200 Euro per year per house. However, fires are independent events, whereas, on a country scale (or rather river basin scale), a flood is a dependent event which causes destruction at the same time to a large number of objects. A (re)insurance company would be willing to insure flood risk if it can be considered the same as fire risk; i.e. by considering floods or other natural hazards on a world scale as independent events. In this way the (re)insurance company has found compensation outside the country (floods and possibly other natural hazards in other countries).

It is however also possible to follow another approach. In this approach based on social cohesion the population of an entire country agrees to cover the possible loss due to flooding of a sub-group living in a flood prone area. In order to keep the possible payments affordable the sub-group should be relatively small.

If the sub-group is relatively large the damage sharing is not feasible and investing in flood protection (e.g. dikes) becomes a better alternative. Insurance reduces the loss for the individual in case of a flood, but flood protection reduces only the frequency of occurrence of the loss. The sub-group still faces the, although smaller, possibility of ruin.

3. FLOOD HAZARDS AND INSURANCE: CURRENT PRACTICE

Of all the natural hazards encountered in the world, floods are the most frequent, they cause the largest number of deaths, and they generate the largest economic losses. Therefore, the insurance industry has shown great reserve and caution when granting protection for flood damage or has refrained from offering this type of cover altogether

(MRC, 1997). However, people living in regions affected by floods may acquire financial security against flood risks, and ask for compensation if a flood has become reality. This poses a problem for both the state and the insurance industry. It is a problem for the state because the demand for compensation in case of a disaster is always high, and cost sharing by the total society seems to be the solution. However, the loss potential can be very high, and the state does not wish to provide full coverage for all potential losses. In the Netherlands, there is a law for compensation of the natural catastrophes, but floods from the sea are explicitly excluded (because of high potential losses). The insurance industry is also not in a position to provide any coverage. In the Netherlands insurers normally exclude flood risk. The insurance industry, particularly brokers, therefore uses alternative measures, such as the help of the international insurers and the reinsurance industry. In several countries new financial instruments are used to redistribute risk, such as pooling systems. Instruments such as catastrophe bonds pay an attractive return if a specified catastrophe does not occur, and return nothing if the catastrophe does occur. It should be noted that insurance of whatever form always remains a tool for spreading negative consequences rather than removing them.

In Barnhoorn (1995) an overview is given of possible insurance solutions for earthquake and flood risks. An analysis of 19 different countries has shown that the following categories can be made:

1. Compensation rules by the government
    a. ad hoc
    b. by law
2. Insurance systems with governmental support
    a. compulsary insurance of natural risk
    b. voluntary insurance with financial support of the government
3. Insurance solutions without governmental support
    a. insurance possibilities with pool organization of insurers
    b. insurance possibilities with competing insurers

The enormous range of solutions shows that it is not easy to find the optimal mix of compensating the damage. This is mainly due to the fact that the classical insurance solution does not work properly, because of the spatial dependencies, the governmental involvement with the water management system, and the perceptions of risks. The Dutch government has chosen compensation rules by law. In januari 1998, ‘The Calamities Compensation Act’ (WTS) came into existence. In this Act it is stipulated that, under certain circumstances, the State pays compensation for loss or damage which is not (to be) insured.

4. THE FLOOD LOSS POTENTIAL IN THE NETHERLANDS

Floods in the Netherlands can have many causes, such as local heavy rainfall, embankment failure of a small storage reservoir, river floods and sea floods. The different events all have a different probability and a consequence. The highest losses will occur if there is an breach in the flood defences along the river Rhine or along the coast.

The highest impacts of floods are caused by floods from the sea or the largest rivers. In the Netherlands about 70% of the properties is at flood risk because either they lie below sea-level or below the river water-level. Flood protection along the Dutch coast has always received much attention. Flood defences are designed to withstand floods with an exceedance probability of 1/4,000 up to 1/10,000 per year. The target probability of failure for river dikes is between 1/1,250 and 1/2,000 per year and measures are being implemented to reach this goal for inadequate dike sections. Fig 1 provides a map of the Netherlands with its dike ring areas and target probabilities (TAW, 2001).

Fig.. 1 Safety per dike ring area in the Netherlands (TAW, 2001).

In Table 1 an overview is given of the losses in the Netherlands in the last 50 years. There has been one disaster: the flooding in 1953. The other events produced a lot of publicity, but the damages were relatively low. The government (tax payer) compensated the damages which happened in the nineties. There is no flood insurance since the flood event in 1953, because after the event it was realised that insurance companies can become bankrupt if they continue to cover the flood damage. At this moment, no insurance company offers standard compensation of flood damage.

All losses caused by the river floods were uninsured. Especially the high water situations in the Meuse valley in 1993 and 1995 inflicted considerable damage on the

Table 1 Overview of flood damages in the Netherlands
(in prices of the year where the disaster occurred, so the flood damage of 1953 in price of this year will be -- with an average inflation rate of 4% -- a factor 7 higher). Source: Jak en Kok, 1999.

Event	Damage (billion euro)	Victims
Disaster South West Netherlands 1953	0.7	1835
Meuse 1993	0.1	-
Evacuations of 200.000 people Rhine 1995	0.2	-
Meuse 1995	0.08	
Extreme Rainfall 1998	0.5	-

properties in the lower parts of the valley. These properties were not insured against floods, because the Dutch insurance industry excludes flooding from rivers or the sea. The reason is that the exposure would be too large, because the potential losses are dependent. Although the likelihood is very small, an extreme discharge of the Rhine could flood a quarter of the Netherlands. The loss would exceed the carrying capacity of the Dutch insurance companies (even the capacity of reinsurers cannot make flood risks insurable). The losses that were inflicted on the owners of the properties in the lower part of the Meuse valley came in the end under consideration of the government that decided to cover them fully. So the owners were in fact compensated by the Dutch taxpayers. It should be noted that insurance does not lower the cost for the owner, it only distributes it over time.

The potential loss is much higher than the losses which have occurred. In Table 2 an overview is given of four selected areas. Note that the gross national product of the Netherlands is 400 million euro per year, and in order to compensate the flood damage of 300 billion euro, each inhabitant has to pay some 20.000 euro per year, which is the average salary of an employee.

Table 2 Overview of four selected events with flooding of part of the Netherlands. The probability of flooding depends on the location, and is between (order of magnitude) 0.001 and 0.0001 per year. Source: DWW, 2000.

Dikering area	Damage (billion euro)
6 Groningen en Friesland	70
14 Centraal-Holland	300
43 Betuwe, Tieler- en Culemborgerwaarden	10
21 Hoeksche waard	7

Given the loss potential of a certain area, as well as the probability of flooding of the area, the optimal level of flood protection can be derived from a mathematical point of view. The model leads to an estimation of the annual insurance premium, which the population has to pay to the insurance company or as tax money to the state. The description of the model is subject of the next section.

5. INSURANCE PREMIUM UNDER OPTIMAL FLOOD DEFENCE DESIGN

The principle of a reliability-based economic optimal structural design for flood defence can be explained with the following illustrative example (Van Dantzig, 1956). Assume that an existing structure has a height of h_0. The structure will be heightened to an optimal height h (Fig. 2). There are costs involved with this heightening, which are a function of X where $X = h - h_0$. The total cost of heightening the structure with length X may be assumed to be linear by:

$$I=c_f+c_vX \tag{1}$$

where c_f is the initial fixed cost and c_v the subsequent variable cost of heigtening the structure per meter.

Assume F is the maximum load distribution function per year with known parameters. If the load is higher than the resistance, we assume that there will be a loss c (independent of the value of the load; i.e. a step loss function (extension for making this loss function more general exist)). The expected loss over the unbounded design time of the structure is given by:

$$D=(1-F(h_0+X))\forall(1-\forall)^{-1}c \tag{2}$$

where $\forall$ is the discount factor with $\forall=[1+(r/100)]^{-1}$ and r is the discount rate. Discounting costs is based on the fact that the utility of a certain amount of money decreases in time from the standpoint of the present. The present discounted value of an amount c in year n is equal to $\alpha^n c$. Note that $\sum_{i=1}^{\infty} \alpha^i = \frac{\alpha}{1-\alpha}$, if we start counting from year *1 (for 0< α<1).*

Summation of both types of costs gives the objective function which has to be minimized over the design variable X in order to find the optimal design:

$$dI/dX+dD/dX=0 \tag{3}$$

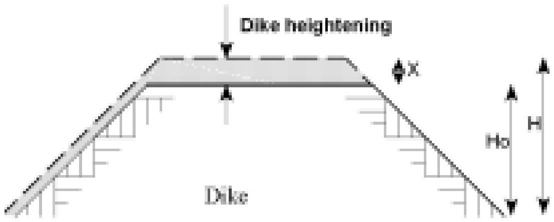

Fig. 2 Simplied model for dike heightening.

In Van Dantzig's (1956) model, the only failure mechanism of dikes that is considered is overtopping. If the applied water level h is higher than the dike height H, then inundation takes place with a total damage of c. The probability of inundation can be modeled in many different ways (Van Gelder, 1999).

Simple closed-form expressions for the optimum design can be obtained for several PDF's, as will be shown next. The closed-form expressions can be used to understand the significance of certain parameters in the design load determination.

If the total costs formula is given by the expression:

$$c(h) = c_f + c_v[h - h_0] + \frac{\alpha}{1-\alpha} c(1 - F(h)) \tag{4}$$

Then the optimal height follows from the equation:

$$\frac{c_v}{c} \frac{1-\alpha}{\alpha} = f(h) \tag{5}$$

If *F ~ Exp,* $F(h) = 1 - \exp\{-(h - x_0)/\lambda\}$ it can be derived that:

$$h^* = x_0 - \lambda \ln\left(\lambda \cdot \frac{c_v}{c} \cdot \frac{1-\alpha}{\alpha} \right) \tag{6}$$

This corresponds to a failure probability of:

$$p_{opt} = \lambda \frac{c_v}{c} \frac{1-\alpha}{\alpha} \tag{7}$$

Notice that the optimal failure probability is independent of the location parameter x_0.

Therefore, using "exponential uncertainty modelling", the behaviour of the optimal design and probabilities of failure can be described as follows:

A larger location parameter leads to higher optimal design according to Eq. (6), but has no influence on the optimal probability of failure according to Eq. (7). A larger scale parameter leads to smaller optimal design (Eq. (6)) and a higher probability of failure (Eq. (7)).

If F ~ Gumbel, the approximation $e^{-x}.1\text{-}x+O(x^2)$ *for* $|x|<<1$ can be used, leading to exactly the same solution as in the Exponential case.

If F ~ Normal, $$h=\mu+\sigma\sqrt{-2\log\left(\frac{c_v}{c}\frac{1-\alpha}{\alpha}\sigma\sqrt{2\pi}\right)} \tag{8}$$

If F ~ LogNormal, $$h=\exp\left(\mu-\sigma^2+\sqrt{\sigma^4-2\sigma^2(\mu+\log[\sigma\sqrt{2\pi}\,\frac{c_v}{c}\frac{1-\alpha}{\alpha}])}\right) \tag{9}$$

If F ~ Weibull, $$h=\zeta+\beta\left(\frac{1-\delta}{\delta}\right)^{1/\delta} lambertW^{1/\delta}\left(\frac{\delta}{1-\delta}\left(\frac{\beta}{\delta}\frac{c_v}{c}\frac{1-\alpha}{\alpha}\right)^{\frac{\delta}{\delta-1}}\right) \tag{10}$$

The LambertW function satisfies:

$$\text{Lambert}W(x) * \exp(\text{Lambert}W(x)) = x\,. \tag{11}$$

The probabilities of failure are given by substituting the expressions (8) to (11) in the corresponding CCDFs.

Given the optimal probabilities of failure p_{opt}, the insurance premium follows from the multiplication of three factors A p_{opt} c, in which A contains the costs and profit of the insurance company (A=2). If the state acts as an insurance company, then $A=1$ (the state is a 'non-profit organisation').

In case of an exponential load distribution, the insurance premium IP becomes independent of the loss c (according to Eq. (7)):

$$IP=\lambda c_v A\frac{1-\alpha}{\alpha} \tag{12}$$

This is a remarkable result, but is caused by the fact that the flood defence has been designed in an optimal sense. In case of other load distributions, other IP's can be determined by Eqs. (8) to (11).

Eq. (12) represents an annual premium to be paid by the population of the flood-prone area to the insurance company (or to the state as tax money; A=1). The costs of possible flood damage will be paid by the insurance company (or the state in case they act as insurer). The availability of an accurate flooding probability model and the existence of an optimal flood defence line are important assumptions in the model derivation.

6. FLOOD INSURANCE POLICY IN THE NETHERLANDS

After each extreme event with damage the demand for compensation of the damage is high. This results in high pressure on the government. One of the issues is solidarity with the victims of the flood or more economical reasons: without compensation a lot of companies would have become bankrupt (especially agricultural companies in the extreme rainfall events in 1998). The government in the Netherlands decided in 1998 that a special committee has to investigate the question whether the water management system was up to adequate standards or that measures have to be taken to increase the performance of the system. One of the issues of the committee was the flood insurance policy: members of the government had the idea that flood insurance can limit the pressure on the government to compensate the damages.

In august 2000 the committee advised the government to distinguish between three different types of events (Committee water management 21st century, 2000):

- Failure of the primary flood defences (along the sea and the big rivers and lakes):

not attractive to have insurance for these risks

- Failure of the regional flood defences (along the small rivers and canals): to be investigated
- Damage as a consequence of local heavy rainfall: there should be the possibility to have insurance for this type of damage.

Note that the committee did not advise about the damage that can occur in the floodplains, or in the not protected areas in the coastal zone.

The government decided to accept the recommendations of the committee. There is no policy to have flood insurance for failure of flood defences. The association of the insurance companies supported the flood damage of content and dwellings can be part of the property insurance, but only if this damage is a consequence of local heavy rainfall and not of failure of flood defences. As a result new (rainfall) cover was introduced to the property market in January 2000. The events covered are precipitations defined as 'direct precipitation: damage as a result of heavy rain, snowfall, hail or melt water that entered the building unforeseen' and 'indirect precipitation: damage as a result of water that entered the building unforeseen, if this water is a result of flooding due exclusively to heavy local rainfall'. Heavy local rainfall is defined as being at least 40 mm precipitation in 24 hours, 53 mm in 48 hours or 67 mm in 72 hours, on or near the location where the damage occurred.

At this moment the agricultural damage can not yet be covered by insurance. The government appointed a special group to set up an agreement between the agricultural sector, the reinsurance companies and the government. There are common interests: the agricultural sector wants to have compensation of all damages in case of extreme events, and the government wants to have insurance possibilities for these risks. But the agricultural sector also wants to have acceptable premiums. This makes involvement of the government necessary. The government however only wants to have involvement if the damage exceeds a very high threshold of the total damage per year. Until now there is no agreement between the different parties.

7. FINAL REMARKS

The highest impact of floods in the Netherlands are floods from the sea and the large rivers. There is a strong tradition of mitigating the impacts of floods by building flood defences. As a consequence, the impacts of floods are very high so that insurance of these impacts can not realized without support of the government. However, for the government there seems to be no reason to contribute to premiums in order to compensate the flood damages, because flood damage mitigation might be more attractive. If there is a flood, there is no formal agreement that the losses will be compensated by all Dutch tax payers. It is a question of solidarity (between the victims and the other members of the society) that the damages are compensated.

Damages as a result of local extreme rainfall events are less severe than the losses of floods from sea or river. Therefore it is attractive for the government to have insurance options for these risks, because it reduces the pressure on the government to compensate these damages. Nevertheless, these risks and also the larger flood damage risks need establishment in risk partnership of the state, the insurers and the reinsurers. Risks of natural disasters and failing flood defences are interesting to compare with impacts of man-made accidents such as large scale nuclear power plant accidents: the nuclear power industry has never been required to have full commercial insurance for its activities.

Currently, in the Netherlands, the Calamities Compensation Act' (WTS) compensates most of the flood damage which is not (to be) insured.

REFERENCES

Barnhoorn. Overstroming en aardbeving, deel I en II. De Beursbengel, 1995.

DWW. Schade na overstroming; een eerste verkenning (Damage after flooding; a first investigation; in Dutch), Report 16 October 2000.

Ermoliev, Y.M., Ermolieva, T.Y., and MacDonald, G.J., et al. A system approach to management of catastrophic risks, EUR J OPER RES 122 (2): 452-460 APR 16 2000

Grossi, P., and Kunreuther, H. The role of uncertainty on alternative disaster management strategies, INTERNATIONAL GEOLOGY REVIEW, 43 (5): 391-400 MAY 2001

HKV Consultants. Mogelijkheden voor het verzekeren van waterrisico's (In Dutch: Possibilities for insuring water risks). Rapport PR351 voor de Commissie Waterbeheer 21e eeuw (Report to the Committee Water Management 21st century), April 2000.

Iwan, W.D., Cluff, L.S., Kimpel, J.F., Kunreuther, H., Masaki-Schatz, S.H., Nigg, J.M., Roth, R.S., Ryland, H., Stanley, E., and Thomas, F.H. Natural hazards and policy - Mitigation emerges as major strategy for reducing losses caused by natural disasters, SCIENCE, 284 (5422): 1943-1947 JUN 18 1999

Jak, M., and Kok, M. A database of historical flood events in the Netherlands. In: J. Marsalek, W.E. Watt, E. Zeman and F. Sieker (eds), Flood issues in Contemporary Water Management. Proceedings NATO Advanced Research Workshop, Kluwer Academic Publishers, Dordrecht, 2000, 139-146.

Kok, M. and I. Lammers. Onderzoek waterschade ten gevolge van neerslag (In opdracht van het Verbond van Verzekeraars). HKV Consultants, October 1999.

Kunreuther, H., "Risk Management in an Era Of Global Environmental Change" Encyclopedia for Earth and Environmental Science, New York: Wiley, 2001.

Kunreuther, H., and Joanne Linnerooth-Bayer. The Financial Management of Catastrophic Flood Risks in Emerging Economy Countries. (submitted to Risk Analysis).

Kunreuther, H. Nathan Novemsky and Daniel Kahneman, "Making Low Probabilities Useful", Journal of Risk and Uncertainty, 2001.

Kunreuther, H. Mitigation and Financial Risk Management for Natural Hazards.The Geneva Papers on Risk and Insurance, Vol.26 No. 2 (April 2001), 276-295.

Kunreuther, H. Incentives for mitigation investment and more effective risk management: the need for public-private partnerships, J HAZARD MATER 86 (1-3): 171-185 Sp. Iss. SI SEP 14 2001

LTO-Nederland. Weer zelfverzekerd? Verkennende studie naar de mogelijkheden voor risico-afdekking tegen schade door extreme weersomstandigheden. (In Dutch: Again self-assured? Investigation to the possibilities of risk coverage against extreme weather conditions), June 1999.

Ministerie van Justitie. WTS (wet tegemoetkoming schade) bij rampen en zware ongevallen, (In Dutch: Law on compensation of damage in disasters and large accidents), Staatsblad 1998.

MRC. Flooding and insurance. Munich Reinsurance Company, Munich, Germany.

Nutter, Franklin W. Global Climate Change: Why U.S. Insurers Care, Climatic Change, ISSN 0165-0009, Publisher Kluwer Academic Publishers Group, Issue 1999 - volume 42 - issue 1

Obrien, T. Hedging strategies using catastrophe insurance options, INSUR MATH ECON 21 (2): 153-162 NOV 15 1997.

Raad van State. Notitie betreffende de wet aanspraak op vergoeding zoetwateroverstromings- en aarbevingsschade (In Dutch: Law on claiming compensation for fresh water flooding damage and earthquake damage), 1995.

Swiss Re. Floods - an insurable risk? 2000.

TAW, 2001. Technical Advisory Committee of the Water Defences, Report 'From exceedance probability to inundation probability' (in Dutch).

Van Dantzig, D. Economic decision problems for flood prevention. Econometrica 24, 276-287,1956.

Van Gelder, P.H.A.J.M.. Statistical Methods for the Risk-Based Design of Civil Structures, Delft University of Technology, ISBN 90-9013452-3, 1999.

White, R.R. Catastrophe options: An experiment in the management of catastrophic risk in the United States, J ENVIRON MANAGE 62 (3): 323-326 JUL 2001