Risk-based management of flooding in the Haute Gironde

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ABSTRACT: The Gironde is an estuary in the southwest part of France on the Atlantic coast. It is about 80 km long and in average 10 km wide. Two rivers flow into the Gironde, the Dordogne and the Garonne. Fairly low dikes protect low-laying areas, mainly swampy areas (Les Marais), but also parts of villages and vineyards. A devastating storm in December 1999 caused large flooded areas all along the Gironde up to Bordeaux. A risk-based study on management of flooding in the Haute Gironde was performed by a combination of French and Dutch experience. In fact experience in the Netherlands on flood and damage calculation was used and transformed to the local situation in the Haute Gironde.

The main aspects of the study were:

- To understand the complete hydraulic system in the Gironde, including climate change (sea level rise).
- To understand the role of dikes, including height and strength, waves and breaching for the Haute Gironde area.
- To calculate and compare flood damages for different events.
- To give different scenarios for dike management (improvement of the dikes, or not), based on a risk scenario.

The main conclusions of the study were:

- High water and possible flooding is completely governed by storm surge on the Atlantic Ocean.
- Sea level rise in future will have a tremendous effect on return periods of flooding.
- Dike improvement is most economical for large areas at risk. Increase of the dike height by 1.5 m is enough.
- For small areas at risk it is more economical to leave the present situation.

1 INTRODUCTION

The Gironde is an estuary in the southwest part of France on the Atlantic coast. It is about 80 km long and in average 10 km wide. Two rivers flow into the Gironde, the Dordogne and the Garonne, see Figures 1 and 2. A devastating storm in December 1999 caused large flooded areas all along the Gironde up to Bordeaux. Although a storm was the cause of flooding, the two rivers might well have effect on the probability of flooding in the future. For this reason the hydraulic system of the two rivers, the estuary and the Atlantic Ocean was investigated. And based on the hydraulic regime a risk-based analysis was performed to investigate the best options for the future to improve the situation of possible flooding.

2 HYDRAULIC SYSTEM

Although two rivers flow into the Gironde, the main water level movement in the Gironde itself is governed by the tide from the Atlantic Ocean, going up the estuary in about two hours up to Bordeaux and also increasing in water level as the estuary becomes narrower. Figure 3 gives the daily high tide levels (lower line in the figure) and clearly shows this increase in tide from the entrance (at Le Verdon) up to Bordeaux.

Extreme water levels in the rivers Dordogne and Garonne can be caused by heavy rainfall and large run-off. And these water levels can be so high that they cause flooding along the rivers. But does high discharge from these rivers have an effect on high water levels in the Gironde?

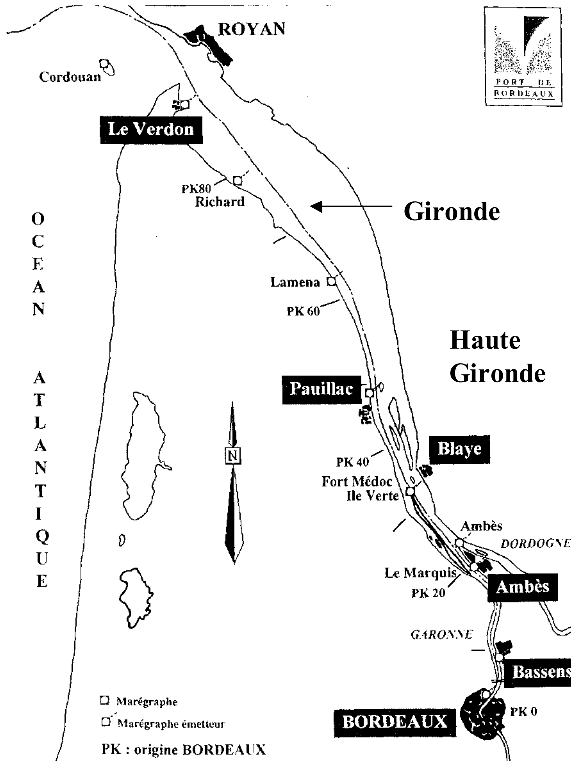

Figure 1. Plan view of the Gironde and the two rivers Dordogne and Garonne between Le Verdon and Bordeaux. The figure also gives the location of tide measurement stations.

Figure 2. The area of Haute Gironde on the east side of the Gironde with flood areas (Les Marais, Blaye, Le Moron and St André-de-Cubzac.

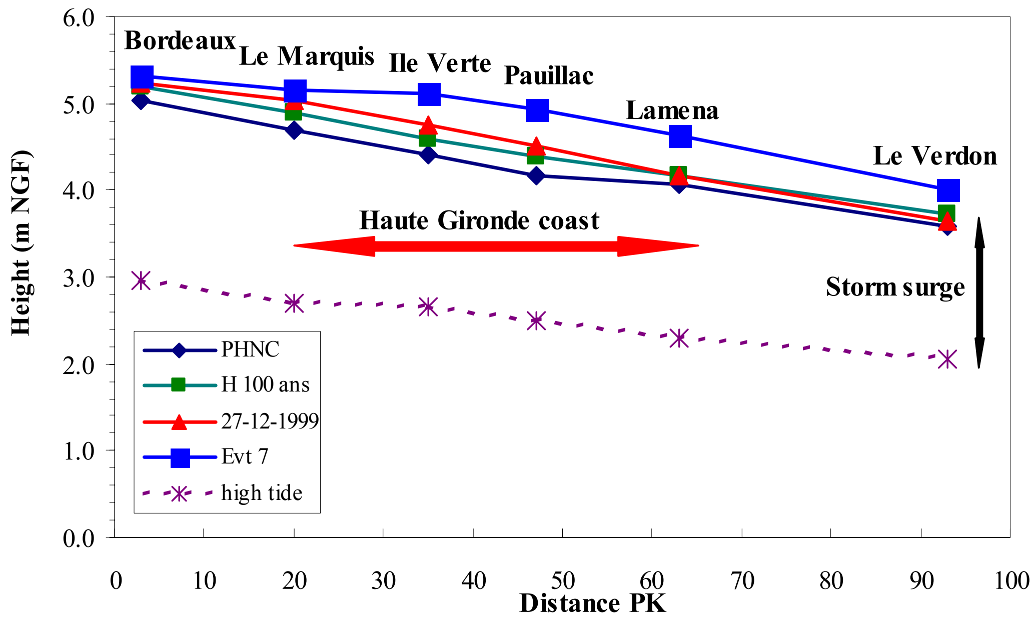

Figure 3. Tide and extreme water levels along the Gironde, up to Bordeaux. Le Verdon is the entrance from the Atlantic Ocean

Seamer, 2002, gives a good description of a storm surge going up the Gironde. From this report it is clear that extreme water levels in the estuary are not caused by high river discharges, but by storm surges at the entrance of the estuary. Also this storm surge, in the order of 1–1.5 m, travels up the estuary in about 1.5 hours and increases stream upwards. The storm surge and tide are independent. The time of extreme high water is, due to the tidal behaviour, less than two hours. In conclusion extreme water levels are caused by storm and sea and not by high river discharges. It means also that they come fast and unexpected and it is very difficult to predict the extreme water level before hand.

In Sogelerg Ingénierie, 1999, various computations were made with different discharges of both rivers, different storm surges and wind directions in order to establish return periods for high water levels in the Gironde. Some results of these calculations are given in Figure 3 with PHNC, H100ans and Evt 7. Evt 7 can be regarded as a very extreme condition, much more extreme than the event with a 100 years return period (H100 ans). Nevertheless the large return periods, the extreme water levels in

Figure 3 do not deviate much (generally less than half a meter).

In December 1999 a devastating storm occurred on the Atlantic Ocean and the Gironde area. Large areas along the Gironde were flooded. But not only had the flooding given damage, also the very severe wind caused damage to forests, marinas and houses. The effect of this storm is well described in Port Autonome de Bordeaux, 2000. The extreme water levels along the Gironde are also given in Figure 3 (27-12-1999) and show that the return period was longer than 100 years and probably close to 200 years.

The hydraulic system includes the Atlantic Ocean, the Gironde and the two rivers Dordogne and Garonne. The present paper on flood risk assessment, however, deals only with the Haute Gironde area, see Figure 2. In Figure 3 the stretch of the Haute Gironde coast along the Gironde has been indicated as from Laména to Le Marquis.

In Port Autonome de Bordeaux, 1998, 85 years of tide measurements along the Gironde (see Figure 1 for the stations) have been analysed and return periods have been established. Table 1 gives these water levels with corresponding return periods. In graphical form they are shown in Figure 4. Lines are almost parallel and it is clear that highest water levels are expected stream upwards (Bordeaux).

Table 1. Return periods of extreme water levels for various stations along the Gironde

NGF	Le Verdon	Richard	Lamena	Pauillac	Ile Verte	Marquis	Bordeaux
H_{1000}	3.93	4.13	4.17	4.78	5.02	5.24	5.34
H_{500}	3.84	4.03	4.25	4.67	4.9	5.12	5.26
H_{200}	3.72	3.9	4.22	4.52	4.75	4.98	5.15
H_{150}	3.68	3.86	4.16	4.47	4.7	4.93	5.11
H_{100}	3.63	3.81	4.1	4.41	4.63	4.86	5.07
H_{50}	3.53	3.71	3.99	4.3	4.52	4.75	4.98
H_{25}	3.44	3.61	3.88	4.18	4.4	4.64	4.9
H_{10}	3.32	3.49	3.73	4.04	4.25	4.49	4.78
H_{5}	3.23	3.39	3.62	3.92	4.13	4.38	4.7
H_{4}	3.2	3.36	3.58	3.89	4.09	4.34	4.67
H_{3}	3.16	3.32	3.54	3.84	4.05	4.29	4.64
H_{2}	3.1	3.26	3.47	3.78	3.98	4.23	4.59
H_{1}	3.01	3.17	3.36	3.66	3.86		

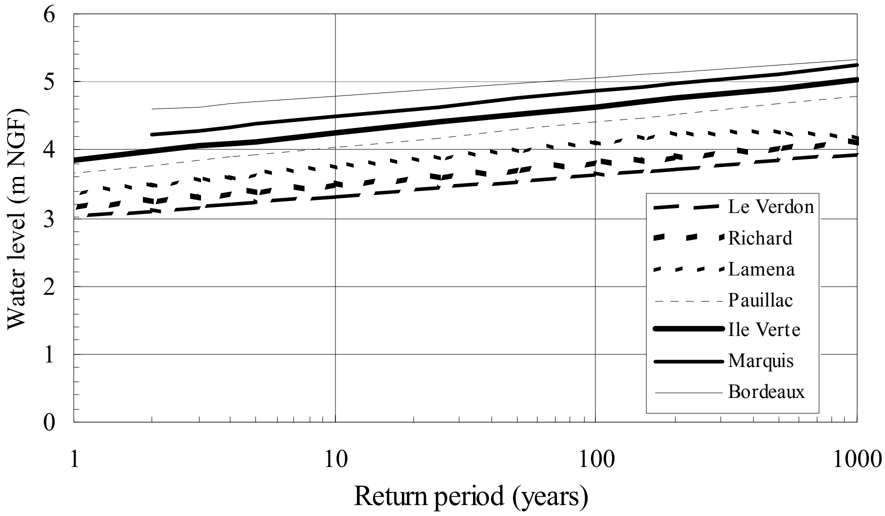

Figure 4. Return periods of extreme water levels for various stations along the Gironde

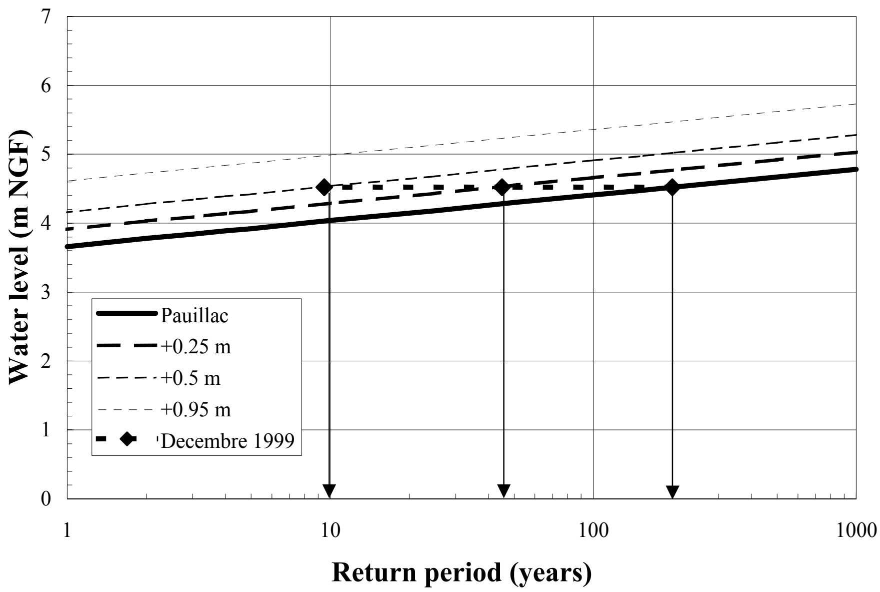

Figure 5. Extreme water levels near Paulliac and the effect of sea level rise on return periods.

Sea level rise will lead to increased extreme water levels in the Gironde with at least the magnitude of the sea level rise itself. And as small variations in extreme water level have large effects on return periods, it is very logical that sea level rise in future might have a large effect on flooding probabilities.

In Figure 5 three possible scenarios of sea level rise are given of 25, 50 and 95 cm (official forecasts per century in France). If only 25 cm of sea level rise will occur, the return period of the 1999 event reduces to only 45 years. For a sea level rise of 50 cm the same event will happen every 10 years instead of every 200 years. It can be concluded that sea level rise will have a tremendous impact on the safety against flooding along the Gironde. Therefore, this possible sea level rise should be taken into account during a flood risk assessment study.

3 FLOODS IN THE PAST

Dikes are not much higher than water levels that occur every 10-50 years and are not designed for wave or flow overtopping. Extreme water levels very often cause dike breaches with consequent flooding of the area behind. The main question on dikes to answer in the study was: for what event does flooding really occur? A historic review gave this answer.

Information on floods was found from 1770 – 1999. Almost all information was focused on flooding in or near Bordeaux and only a little information was available for the Haute Gironde. Limited data was available on the swampy areas (Les Marais). Floods in or near Bordeaux very often do not coincide with extreme water levels more down stream of Bordeaux. Of the 7 highest water levels at Bordeaux, including December 1999, only two are found for Pauillac. For this study the Haut Gironde is the topic and not Bordeaux.

Les Marais were completely flooded during 20 December 1952. The water level for this storm does not belong to the 7 highest reported. Probably this means that dikes have been improved (increased in height) after this event. Therefore, the study should only concentrate on the period where the dikes had the same level as present, probably the period after 1970.

Four tidal measurement stations are important for Les Marais and the other locations along the Gironde: Laména (near Vitrezay), Pauillac, Ile Verte (near Blaye and Bourg) and Le Marquis (near le Moron). Table 2 gives the extreme water levels in m NGF for six high water levels.

The storm of 27-12-1999 gave flooding of all areas and many dikes were breached.

The storm of 7-2-1996 gave flooding at Blaye and at Ambès, where a dike was also breached near Ambès. About Blaye it was reported that the lowest part of the city centre and the commercial areas along the river were flooded. At Ambès waves of 2-3 m were reported and damage was less at the other side of the Dordogne, which indicates that indeed waves play a role.

Table 2. Measured extreme water levels for severe storms

Event	Laména	Pauillac	Ile Verte	Le Marquis
27-12-1999	4.16	4.52	4.76	5.04
7-2-1996	<3.88	4.09	4.40	4.66
23-12-1995	3.97	4.15	4.41	<4.58
28-2-1994	<3.88	<4.02	4.29	<4.58
13-12-1981	<3.88	<4.02	4.29	4.69
28-3-1979	3.94	4.15	4.30	<4.58

The event of 23-12-1995 gave high water levels in the north of the Gironde and specially the area of the Medoc. There were no floods in the Haute Gironde.

The event of 28-2-1994 was no storm, but severe rainfall and high run-off in the Dordogne. This caused floods upstream of St André de Cubzac, but not downstream.

The 1981 storm gave serious floods near Bordeaux, but water levels were not extremely high near Les Marais. Due to the wind a dike was breached along Les Marais and these were flooded. Also floods are reported in Plagne, Ambès, Blaye, Plassac, Villeneuve and Saint Vincent. Actually the whole area in the Haute Gironde.

The event of 28-3-1979 gave flooding at Blaye, Port Neuf, Plagne and around Pauillac. No floods were reported for Les Marais.

All of above events give more or less the same water levels for each tidal station, except for the 1999 storm which was much higher. For Laména this is between 3.8 and 4.0 m NGF, for Pauillac between 4.0 and 4.15 m NGF, for Ile Verte between 4.3 and 4.4 m NGF and for le Marquis 4.5 and 4.7 m NGF. But not all water levels gave flooding. The main reason for this is probably the effect of wind and waves. If strong winds occur with the high water levels, high waves will attack the dikes. In such a case flooding might occur. If there is no wind, or from the wrong direction, waves do not attack the dikes and if they are high enough they will withstand the high water level.

4 DIKES ALONG THE HAUTE GIRONDE

Simple earthen dikes do exist along the borders of the Gironde. The average height increases stream upwards in order to cope with the increasing tide levels in this direction. Figure 6 gives the dike heights along Les Marais, from Vitrezay to Blaye. Also the water levels of the severe storm in 1999 are given in this figure.

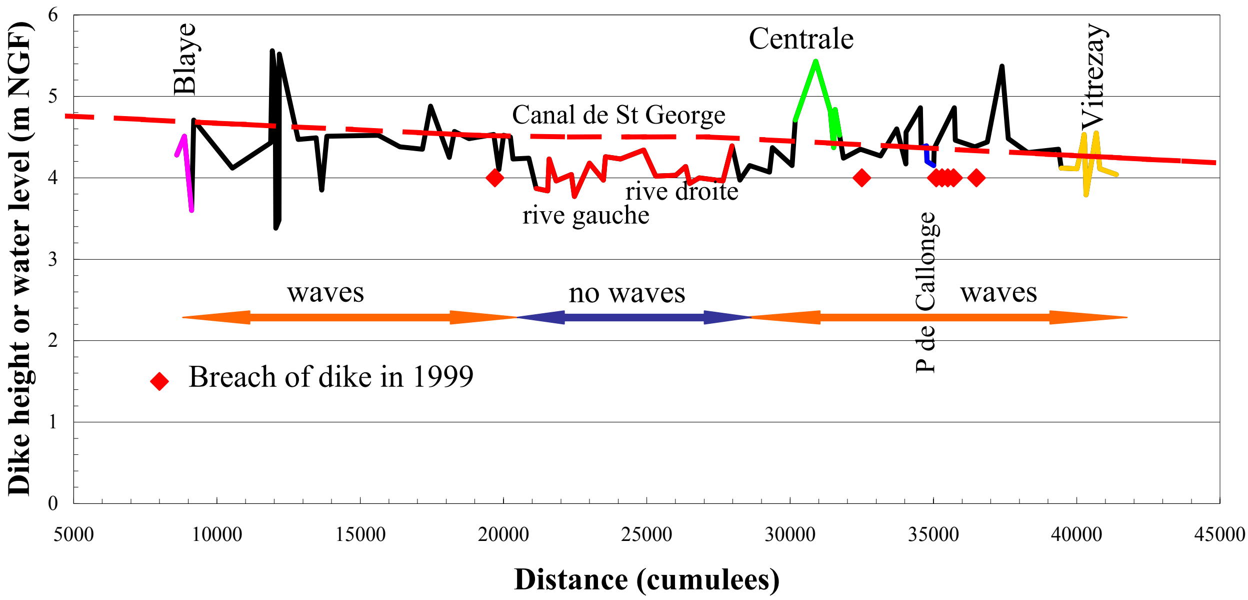

Figure 6. Dike heights along the Haute Gironde from Vitrezay to Blaye (Les Marais) with the water levels of the storm of 1999.

It is clear that the dikes could never resist the 1999 storm as the water levels at many places are higher than the crest of the dike. Figure 6 shows too that at least at six locations dikes were breached. In the middle of the graph the dikes are lower along Canal de St George than along the Gironde. In the very narrow Canal de St George wind and waves will have no effects, where this is important in the Gironde. For the 1999 storm these canal dikes were clearly too low, but they did not breach.

The water levels in Table 2 are in general 0.3 to 05 m lower than in 1999. In such a situation the wind determines whether there will be flooding or not. Based on the water levels given for the events and the historical floods of areas as described above, a water level has been determined for each area which will give flooding of the area considered. Table 3 gives an overall view.

Table 3. Extreme water levels giving (partly) flooding along the coast of the Haute Gironde

	Reference station	Flooding above
Les Marais	Pauillac	+4.15 m NGF
City of Blaye	Ile Verte	+4.3 m NGF
Between Blaye and Bourg	Ile Verte	+4.3 m NGF
City of Bourg	Le Marquis	+4.5 m NGF
Le Moron	Le Marquis	+4.5 m NGF
St André Cubzac and Cubzac les Ponts	Le Marquis/ Bordeaux	+4.6 m NGF

If there is no wind, or wind from the wrong direction, it is possible that the dikes may withstand given water levels. If there is a strong wind it is also possible that flooding occur for little lower water levels. The given water levels should only be considered as an average.

Based on the return periods and water levels given in Figures 4 and 5 it is possible to estimate return periods for flooding using the values in Table 3.

It is also possible to calculate the change in return period if a sea level rise of 0.25 m is taken into account. Table 4 gives the results.

Table 4. Estimations of return period for flooding for different areas including effect of sea level rise.

	Present return period	Return period in 2055
Les Marais	20 year	4 year
City of Blaye and Blaye à Bourg	13 year	2-3 year
Bourg et Le Moron	10 year	2 year
St André de Cubzac and Cubzac les Ponts	8 year	2 year

The results show that the area of Bourg to St André is flooded more often than Les Marais. This is also the outcome of the historical review. An other conclusion is that sea level rise in future will have a tremendous effect on the return periods for flooding. For all areas it will reduce to 2-4 years in 2050!

5 SCENARIOS FOR DIKE IMPROVEMENTS

The safety against flooding can be based on two pillars: the *damage* which happens if flooding occurs and possible *investments* to raise the dike height. Raising the dike height means that flooding occurs less frequently and, therefore, damage decreases.

In order to make good decisions on measures to be taken a good economic evaluation, including a full life cycle cost analysis, should be made, see TAW, 2000 and Jorissen et al., 2001. This was not possible under the present contract and here, a simple calculation has been done, more with the objective of giving insight in the problem than giving exact values for decision.

It is proposed to consider 3 scenarios. The first is the present situation where dikes are not improved and where only flood damage occurs. The damages will increase with time as the sea level rise will give floods more frequently. For the purpose of comparison an economical lifetime of 25 years is taken. In order to be able to estimate the flood damage in 25 years for each area considered, estimation has to be made how many floods will probably occur in this period. Based on a sea level rise of 0.25 m in 50 years and the return periods given in Table 4, estimation has been made of 2-6 times in 25 years.

The second scenario proposed is a raising of the dikes to a level that floods will hardly occur. This means that a high safety level is reached. In the Netherlands river dikes should withstand a river discharge or storm event with a probability of occurrence per year of 1/1250. The effects in the low-lying Netherlands (large flood depths, large areas and a large number of people at risk) are probably bigger than in the Haute Gironde. Therefore, a return period of 500 years has been chosen.

If dikes are improved, also sea level rise should be taken into account. For dikes, which are relatively easy to improve, a period of 50 years is taken in the Netherlands. For city areas, where it is much more difficult to improve water defences, a period of 100 years is taken. In the present calculation a sea level rise of 0.25 m has been taken into account as being the average estimation in 50 years.

In the present situation floods occur if the water level becomes within 0.4-0.5 m of the crest of the dike. In that case often a dike breaches by severe wave attack. In order to be sure that a dike does not breach by waves, an extra crest height is required. In the Netherlands the minimum difference, if no waves are present, between water level and crest height should be 0.5 m. If waves are present, a limitation is given to the wave overtopping allowed, see TAW, 2002. Very often this is only 1 l/s per m length. Applying this to the Gironde would mean in many cases that the dikes should be raised to 2-3 m above the maximum water level. Only if wind velocities and waves are known for very extreme events in the Gironde, a right estimation can be made for each dike location. For the time being *an extra safety of 1 m is proposed*. In such a case there will be wave overtopping if high waves are present, but the probability of a breach is limited.

In summary, for scenario 2 the dikes should be raised to a:

- water level for 500 years return period +
- 0.25 m sea level rise in 50 years +
- 1 m extra safety for wave attack

If the dikes were raised to the 1/500 years level only (+1 m for waves) the probability of flooding would be 1/500 per year. But also 0.25 m sea level rise has been added, which only partly is present during the considered period of the first 25 years. In this first 25 years the average probability of flooding will be about 1/1000 per year, giving a total probability for 25 years of 0.025.

Scenario 3 is proposed as an intermediate solution. The safety will be increased by raising the dikes, but not so high that the area will "never" be flooded again. For this scenario the dikes should be raised to water levels with a return period of 50 years, and including similar sea level rise and dike safety.

Scenario 3 can be summarized as:

- water level for 50 years return period +
- 0.25 m sea level rise in 50 years +
- 1 m extra safety for wave attack

The probability of flooding in 25 years for scenario 3 can be calculated according to the method for scenario 2. The probability of 25 years will be around 0.25, ten times larger than for scenario 2, but still many times smaller than for the present situation. Table 5 gives the dike heights which are present or required for the various scenarios.

Table 5. Present or required dike heights, depending on scenario.

	present m NGF	scenario 2 m NGF	scenario 3 m NGF
Les Marais	± 4.5	5.92	5.55
City of Blaye and Blaye à Bourg	± 4.7	6.15	5.77
Bourg et Le Moron	± 4.9	6.37	6.00
St André de Cubzac and Cubzac les Ponts	± 5.0	6.54	6.12

Comparison of the required dike heights shows that in average the dikes have to be raised by 1.5 m for scenario 2 and 1 m for scenario 3.

6 COSTS FOR DIKE IMPROVEMENTS

Only little information has been found about the cross-sections and soil material of the dikes. Also hardly any information is available on costs of dike improvements along the Gironde. Therefore, quite some estimates had to be made to come to total costs of dike improvements. Figures from the Netherlands for simple dike improvements by adding soil or clay to an existing dike, are 15-25 €/m^3 for soil and 25-35 €/m^3 for clay.

These figures are total costs, including design, engineering, supervision and VAT. For making a cost estimate of dike improvement a typical cross-section of a dike has been chosen. If the actual cross-sections are different, the cost estimates can be modified. The typical cross-section has slopes of 1:2 (which in fact is quite steep), a height of 2 m above the hinterland and a crest width of 3 m, see Figure 7.

Increasing the dike height is possible by adding soil on top and the rear side. Figure 7 gives examples of 1 m and 1.5 m raising of the dike.

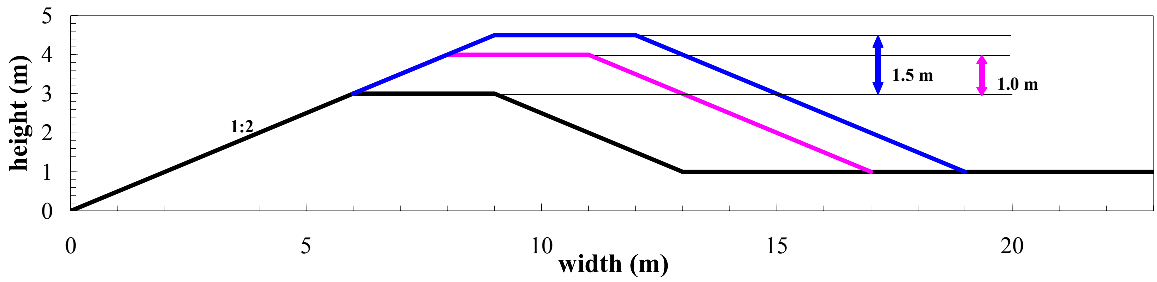

Figure 7. Average cross-section of dike with improvements of 1 m or 1.5 m in height.

The added material for 1.0 m rising is 12 m^2 per m length and for 1.5 m raising 20 m^2 per m. With an estimated minimum cost of 15 €/m^3 and maximum cost of 35 €/m^3 the following figures for dike improvement are reached in €/m length:

Dike improvement 1.0 m	180	420
Dike improvement 1.5 m	300	700

Dike improvements can quite easily be proposed for areas with no infrastructure, but it is a much more difficult situation for cities like Blaye and Bourg. Therefore, only the larger areas which can be flooded are considered here. The total lengths of dikes to be improved (rough estimates only) for the different areas are:

	Km dike
Les Marais	30
Entre Blaye et Bourg	12
Le Moron	11, excluding dikes along le Moron
Cubzac les Ponts	2, till border

The total costs for possible dike improvements for scenarios 2 and 3 can now be composed, see Table 6.

Table 6. Estimated costs for dike improvement

	Scenario 2 1.5 m improvement million €	Scenario 3 1.0 m improvement million €
Les Marais	9.0 – 21.0	5.4 – 12.6
Entre Blaye et Bourg	3.6 – 8.4	2.2 – 5.0
Le Moron	3.3 – 7.7	2.0 – 4.6
Cubzac les Ponts	0.6 – 1.4	0.4 – 0.8

7 DAMAGE BY FLOODING

Based on available topographic information a GIS was built of the area of the Haute Gironde, including a digital elevation system and land use such as agriculture land, vineyards, roads, railways, buildings, etc. Flood depths were calculated for cells of 50 x 50 m and damage was calculated according to modified damage functions as in use in the Netherlands, see Vrisou van Eck and Kok, 2001. These damage functions had to be modified as in the Netherlands the method is based on infrequent flooding (less than once in 1000 years), where the Gironde gives flooding every 20 years.

In this way total damage and damage for each category could be calculated for various events with different return periods. Figure 8 shows a flow diagram of the information and Figure 9 gives, as an example, the roads and railways used in the system.

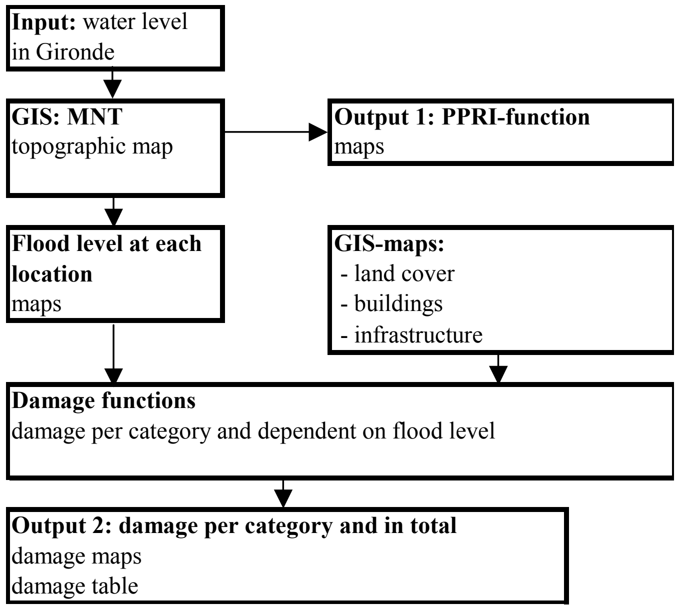

Figure 8. Flow diagram of calculation of flood damage

Figure 9. Roads and railways used in calculation of flood damage in the Haute Gironde

The “standard method” in Vrisou van Eck and Kok, 2001, consists of a damage function for each category. This damage function gives the relation between the flood depth and the damage factor, see Figure 10. The full method includes also the effect of flow velocities, but in this first risk assessment study this was not included, only the flood depth plaid a role in estimating damage. The damage factor in Figure 10 has a maximum of 1 and it is assumed that if this flood depth has been reached, a larger flood depth will not increase the damage. For example, in Figure 10 a damage factor of 0.75 is reached for a flood depth of 1.5 m.

The actual maximum damage depends on the category concerned. Table 7 gives the main categories for the Haute Gironde and the maximum damage assumed for frequently flooded areas, which was adapted from the Dutch values for infrequently flooded areas. The main problem was the estimation of damage to agricultural land. At this stage it was estimated as half of the damage for infrequent flooded areas, but this might be too high.

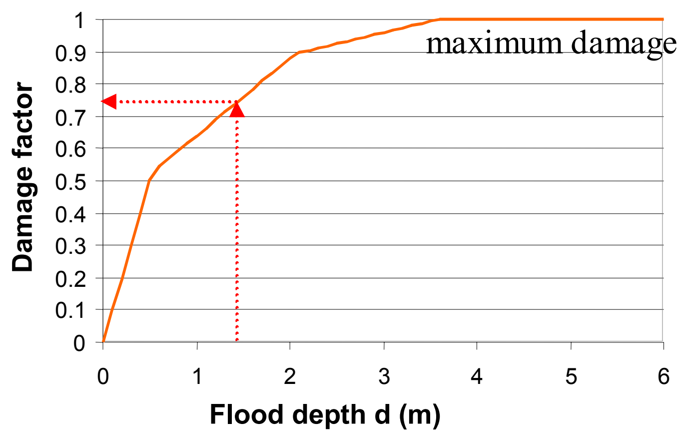

Figure 10. Damage factor for Land use.

Table 7. Maximum damage per category, adapted for frequently flooded areas.

	Damage category	***Unit***	***Maximum Damage amount (€)***
Land use	Agriculture direct	m²	**0.5**
	Agriculture indirect	m²	**0.2**
	Vineyards	m²	**1.0**
	City area	m²	**1.2**
Infrastructure	Roads	m	**10**
	Railways	m	**170**
Households	Single-family houses & farms	item	**50.000**

The maximum damage was calculated for each scenario described in chapter 5. In this case the design water level for each scenario (Table 5) was used to calculate the damage. Partly flooding, or flooding with higher water levels was not considered and was not required, as the uncertainty in damage modelling was too large to be fine tuned by differentiation in flood levels.

The maximum flood damage for each scenario and for three areas is given in Table 8. Of course, scenario 2 with the highest design and flood level, gives also the largest damage. But flood damages for the different scenarios do not differ so much for each area. It means that if flooding occurs, it will give certain damage, which is not too much depending on the actual flood level. But all calculations are made under the constraint that indeed flooding occurs, it is not yet a risk analysis.

Table 8. Maximum flood damage for each scenario under the constraint that flooding occurs.

	present 1000 €	scenario 2 500 years 1000 €	scenario 3 50 years 1000 €
Les Marais	49,500	60,500	54,500
Entre Blaye et Bourg	990	1.835	1.390
Cubzac les Ponts	870	1.410	1.210

8 RISK ASSESSMENT AND MANAGEMENT

Damage costs in time and investments have to be compared in order to make conclusions on suitable management options in future. The basic material has been described in the previous chapters.

Scenario 1 is the present situation. Here there are no investments for dike improvements, but quite some flood damages to be expected in the next 25 years. For scenario 2, a safety level of 500 years, the investment is largest, but the probability of flooding with consequent damage is the smallest. Scenario 3 with a safety level of 50 years is in between the two other scenarios. The investment in dike improvement is smaller, but the probability of flooding with consequent damage is larger.

The risk assessment for the low-lying swampy areas, Les Marais, has been given in Table 9.

Table 9. Comparison of damage and possible investments for different scenarios, for the area of Les Marais.

Scénario	Probability of flooding in 25 years	Damage/ flooding M €	Damage in 25 years M €	Investments M €	**Total costs in 25 years M €**
1 : présent	2-3	49.5	99 – 149 (9.9 – 14.9)*	0	**99 – 149** (10 – 15)*
2 : 500 yrs +1.5 m	0.025	60.5	1.5 (0.2)*	9.0-21.0	**11– 23** (9 – 21)*
3 : 50 yrs +1.0 m	0.25	54.5	13.6 (1.4)*	5.4-12.6	**19 – 26** (7 – 14)*

Total costs are lowest for scenario 2, the option with the largest safety. The main reason is that a large area becomes flooded in this case with corresponding damages.

In Table 9 the figures in brackets give the damages and total costs if the damage to land use (see Table 7) is reduced by a factor 10, due to the fact that the land is frequently flooded area. Now scenario 3 gives lowest total costs, but actually in this case the figures for all 3 scenarios are comparable.

Similar risk assessment comparisons were made for the other areas. The main conclusion is that dike improvements for large areas at risk is the best economical solution. For long stretches of dikes protecting small areas at risk, for example between Blaye and Bourg, it is more economical to accept the present situation. Of course, all these calculations were based on a simplified method compared to Dutch practise, where flooding will give tremendous damages. But nevertheless this simplified method gave a good insight in the flood problems along the Gironde and in the Haute Gironde in particular.

9 CONCLUSIONS

High water and possible flooding is completely governed by storm surge on the Atlantic Ocean and is hardly influenced by river discharges.

Sea level rise in future will have a tremendous effect on return periods of flooding. Return periods of 200 years may reduce to less than 10 years.

Dike improvement is most economical for large areas at risk. Increase of the dike height by 1.5 m is enough.

For small areas at risk it is more economical to leave the present situation.

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