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Risk assessment and management of potential flooding in the Netherlands

J.G de Ronde
National Institute for Coastal and Marine Management/RIKZ
Rijkswaterstaat
P O Box 20907, 2500 EX The Hague, The Netherlands

Introduction

The Netherlands are situated on the delta of three of Europe's biggest rivers the Rhine, the Meuse and the Scheldt, at the border of a shallow regional sea : the North Sea (see fig.2) Without dikes more than half of the country would be flooded (see fig.1) The area is threatened from one side by storms which can generate huge surges, due to the shallow sea and the funnel shaped geometry of the southern North Sea, and from the other side by river floods. Without flood defences much of the Netherlands would be regularly flooded as large parts lie below mean sea level In 1953 a big storm caused a flooding disaster with enormous damage and nearly 2000 deaths in the Netherlands In 1995 a river flood caused a situation so serious that the security against flooding of various polders could no longer be guaranteed and 200,000 people together with many millions of animals were evacuated. Fortunately the polders were not inundated and no disaster occurred Still, the mass evacuation gave rise to considerable social unrest and the government decided to rapidly accelerate the existing programme of river dike reinforcement

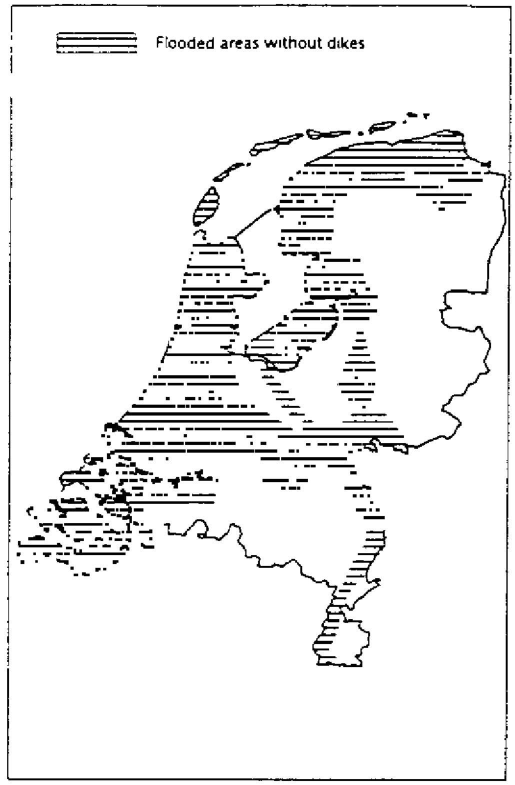

Fig.1. Without dikes these areas in the Netherlands would be flooded.

History

Approximately 10,000 years ago the last Ice Age ended and the warmer Holocene period started. As a result of the rising sea level an increasingly large part of the west and north of the country came under the influence of the sea From approximately 5,000 years ago the coastline of the Netherlands looked broadly as it does now. In the Roman era (circa 2,000 years ago) local people started to drain the low lying peat and clay areas to give access to more agricultural land The dewatering of the marshes also

Fig 2: Situation of the Netherlands.

resulted in a lowering of the ground level by which again damage from flooding rose From the twelfth century farmers also started building dikes to protect their land Drainage of the low lying land could then no longer take place in a natural manner Drainage ditches and sluice systems were built. Later windmills were used to raise the water into the drain system from low lying "polders" This again resulted in further lowering of the ground level Since the early Middle Ages ground levels dropped several metres as a consequence of drainage, oxidation and settlement. In the following centuries the building of dikes was continued in response to the needs of an increasing population and to make greater use of the low lying polder areas

Management and organisation

The history of the Netherlands is closely interwoven with the country's fight against the water. This is also to be seen in the structuring of the national water management organisation For more than a thousand years sayings such as "To live by water, manage that water", "Pump or drown", and "Dike or depart" have been the main guidelines in protection against flooding Concern for the dikes and control of water levels are firstly handled at the local level, later at a regional level From the 13th century the water boards received the responsibility for the maintenance of the dike system and the water levels These water boards are in fact the oldest democratic institutions in the Netherlands The contribution that each citizen has to pay to a water board was, and is today a function of the value of their property. The water boards also regulate the water levels in the polders. The number of polders in the Netherlands increased drastically over time and in parallel with this the number of water boards. In the first half of the 20th century there was a total of more than 2,500. Over the last decades the number of water boards has been strongly reduced. There are currently some 85 water boards left. A further reduction is likely in the context of efforts to create strong "all-in" local authorities

The water boards are now the foundation for the national management organisation for flood defence and water management. Every Dutch resident pays taxes to his or her water board and can participate in the elections for the management of the organisation. The chairperson of the water board is appointed by the crown.

Some 200 years ago, in 1798, the institution "Rijkswaterstaat" was founded to give a national guidance to the water management as some aspects could be better addressed at a national level. Rijkswaterstaat (currently employing some 9,500 staff) is the executive organ of the national Ministry of Transport, Public Works and Water Management

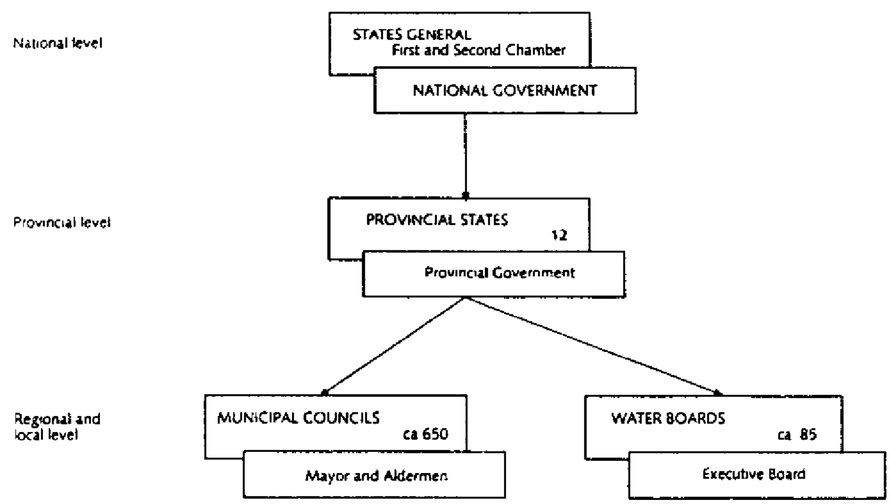

Fig. 3: Constitutional structure of the Netherlands

In spite of the considerable power of Rijkswaterstaat, the water boards have always retained a significant role in the management organisation (see fig.3). The management of water and the flood defences in the Netherlands are strongly decentralised. Water boards are responsible for the management and maintenance of defences and the quality and quantity of the local and regional water supplies. The Provinces are supervisors and the national authorities (through Rijkswaterstaat) have final control The Minister of Transport, Public Works and Water Management is responsible to Parliament (States General) for all aspects of flood defence and water management.

The twelve provinces form the national middle management structure They represent the link between the national government and the local authorities (water boards and municipalities) with important tasks in the domain of spatial planning and regional adaptation of national plans in the area of the environment, traffic and transport, and integrated water management.

The different roles and responsibilities of central government, provinces and water boards are clearly visible in the challenge of maintaining and reinforcing dikes. The standards which the flood defences

must satisfy are laid down by Parliament. The plans for reinforcement programmes are set up by the water boards. The provinces must approve these while taking into careful consideration other factors such as spatial planning, nature, landscape and historical culture. The water boards then provide supervision for the actual defence strengthening work. The role of national government is restricted to supervision and specialist support if this is required The national government does, in fact, still directly manage some flood defences, such as the enclosure dams of the IJssellake and the enclosure dams of the former tidal inlets in Zeeland.
Management relationships are also clearly visible in the event of high water conditions; wherever possible the responsibilities are laid at the feet of local authorities. Water boards judge the strength of the defences, municipalities carry responsibilities for the safety of citizens and provide information. If necessary the regional coordination is handled by the Province Only in very special situations coordination is transferred to a national level.

Safety standards

The implementation of safety standards started after the big flooding in 1953 During the night of 31 January to 1 February 1953, a severe north-westerly storm drove the sea-water up against the Dutch coast. At Hook of Holland the water reached a level of 3 85 m above mean sea level: 57 cm higher than the previous record. This is a level expected to occur approximately once in every 250 years. The storm surge led to severe flooding. A total of 136,000 ha of land was inundated and 1835 people were drowned. The economic damage was approximately 14 % of the gross national product. Almost immediately the Minister of Transport, Public Works and Water Management appointed a special Delta committee to consider urgently what action should be taken to prevent any future recurrence of such a major disaster. This resulted in the Delta-Plan (Deltacommissie, 1960) and the closure of many of the tidal inlets in the southern part of the Netherlands. In 1986 the last tidal inlet, the eastern Scheldt, was closed with a storm surge barrier with 62 openings and a total width of 2800 metres. At the same time this committee studied the required safety standards for the coastal areas of the Netherlands The outcome of an economic study (Deltacommissie, 1960) was that a safety standard of 10^{-5} to 10^{-6} against flooding should be applied to the central part of the Netherlands Currently the total invested capital behind the dutch flood defences is estimated at 4,000 billion guilders or 2,400 billion US Dollars (Resource Analysis et.al. 1992).

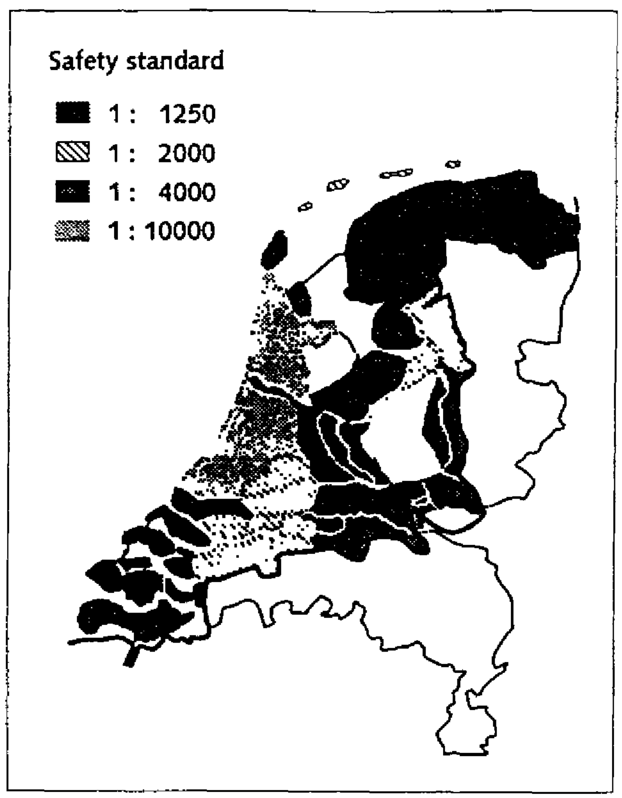

Fig 4 Safety standards in the Netherlands

Finally these results were implemented in the following safety standards against flooding. For the central part of the Netherlands (see fig. 4) the safety standard and the design criteria were set to 10^{-4} (so a chance of 1/10,000 per year), whereby the construction should be designed so that under these conditions the construction will not fail with a high degree of security (Ronde et.al, 1995a). In practice this would lead to a safety against flooding as mentioned in the economical study. For other parts of the coast different safety standards were applied due to what was called an economic reduction. In areas with an economically lower value, the safety standard should be lower resulting in values of 1/2000 per year for the small Wadden Islands and 1/4000 per year for the other coastal areas (see fig. 4).

River Areas

In 1956 the safety standard for areas in danger of flooding by rivers were established. The safety standard was set at 1/3000 per year, following the idea of economical reduction and the idea that:

- any flooding would be with fresh water
- advance flood warnings could be given
- there would be no tidal action to impede closure of gaps

During the sixties the reinforcement plans of the river dikes, needed to establish this safety, came under fire. Social attitudes towards the river landscape did not always parallel the need for significant strengthening of the river dikes (Hillen et.al.,1995a). After a study by the Committee "Becht" it was decided that this safety standard was too high and could be lowered. In 1977 the safety norm for the river dikes was established in Parliament as a probability of 1/1250 per year.

During the seventies and eighties the reinforcement plans came again under fire for the same reason and a new committee (WL/RAND, 1993) was installed to study the safety standard and reinforcement plans The conclusion of this committee, after a study of the economical and the environmental values, was that the safety standard could not be lowered further. Their conclusion was that the statistics of the river discharges used until then were not correct and that it was allowed to lower the design discharge, keeping the safety standard at 1/1250 per year This resulted in a lowering of the design levels of the river dikes by 20 to 50 cm and a lowering of the number of reinforcements necessary. Parliament agreed with the conclusions of this study and that strengthening of the river dikes along the river Rhine and Meuse should be undertaken. Completion of the programme by the year 2008 was deemed acceptable In the following years it became clear that nature had its own schedule.

In 1993 severe flooding occurred in the undiked areas of the river Meuse. A discharge peak was measured of 3120 cubic metres per second with a flood return period of about 150 years. Total damage was of the order of 150 million US Dollars. The discharge in the river Rhine of 11,100 cubic metres per second had a return period of only 30 years and did not cause any major problems.

Again in 1995 very high river discharges occurred. The peak discharge of the river Meuse was lower than the one in 1993 (2,860 cubic metres per second) and the resulting damage was significantly less. The reason for the much lower damage lay especially in the better state of preparedness of citizens and authorities

The maximum discharge in the river Rhine reached about 12,000 cubic metres per second. This was significantly higher than in 1993 and only 600 cubic metres per second lower than the highest recorded discharge in 1926 The return period of the 1995 discharge of the river Rhine is estimated at 100 years The big difference is that the river Meuse floods undiked areas in a river valley, where water levels rise relatively slowly and no lives are at stake (see fig. 5) In contrast the river Rhine has diked areas where water levels will rise extremely quickly if dikes collapse and many lives will be at risk

Although the difference in maximum water levels between 1993 and 1995 was only some decimeters, the water boards along the river Rhine considered the 1995 situation so serious that the security against flooding of various polders could no longer be guaranteed This was primarily due to the uncertainty of the soil-mechanical stability of the dikes. On the basis of this and an evaluation of the risks and

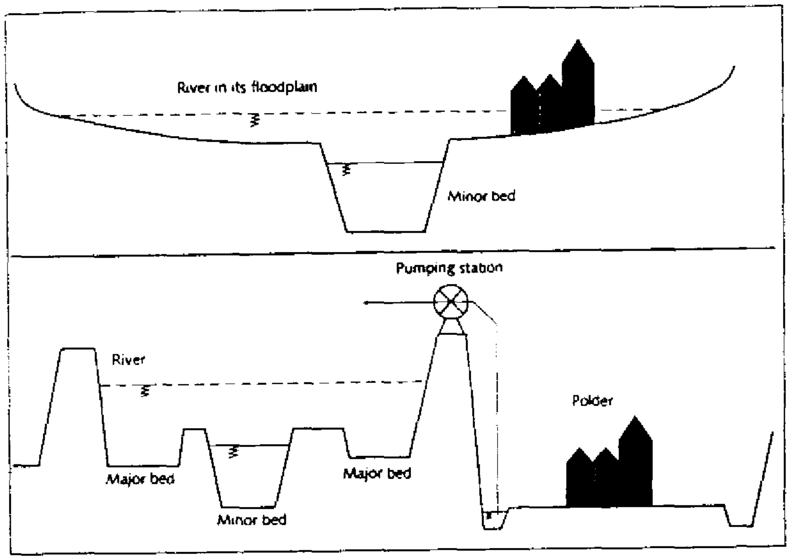

Fig. 5: Different situations for the rivers Rhine and Meuse. The upper panel shows the situation for the Meuse and the lower one for the Rhine.

consequences of a possible dike collapse, it was decided to evacuate more than 200,000 people and many millions of animals.

In retrospect, it can be said that the occurrence of very high water levels in 1993 was of great influence to the decisions taken in 1995. After the flood in 1993 it was decided, for the river areas, to start preparing disaster plans and evacuation schemes. A pilot study was started for the Nijmegen-area, which was finished before the 1995 event. Due to the preparation of the disaster plan there was a high degree of awareness of what could happen in the case of inundation of a river polder. This and the plan itself meant the Nijmegen local authorities were able and prepared to call for an evacuation. After discussions and preparations on the 29th and 30th January 1995 the decision was taken at 11.00 hours on the 30th January that an evacuation of the first polder was necessary. Up to 8.00 hours on the 31th the evacuation was voluntary and after this time obligatory. Peak discharge occurred at the first of February and on the 4th of February the people of this polder could go home. In the days after the 30th January more polders were evacuated and the last people were allowed to return on the 6th of February. In total 200,000 people together with many millions of animals were evacuated. Without the occurrence of the 1993 flood the evacuation of 1995 would probably not have taken place (as was said by the Mayor of Nijmegen (COT, 1995)).

It must be clearly stated that such an evacuation of an area in danger of flooding by a river is possible, because there is time of at least one day to get everybody out. In case of an area in danger of flooding by a storm surge an evacuation is much more difficult due to the short prior notice of a warning. A reliable warning is only possible 6 to 12 hours ahead. The chance that at the moment of an eventual collapsing of a dike there are still people moving around (or are standing still in a traffic jam) is too high. So, especially in the densely populated polders along the coast, an evacuation is completely unfeasible.

Immediately after the high waters of 1995 the government decided to accelerate the existing programme of dike reinforcement and implemented an emergency bill to make this_acceleration possible. For the river Rhine and the diked sections of the river Meuse all dike reinforcements must be completed in the year 2000. The most urgent dike sections (with a theoretical chance of failure larger than 1/100 per year) must be reinforced by the end of 1996. The dike sections requiring urgent stengthening fall under the regime of the emergency bill. This means that less extensive procedures can be followed at accelerated pace. The other dike sections fall under standard law, which demands an environmental impact report. A total of 800 km of dike will have to be reinforced, of which 150 km have to be reinforced urgently. This will amount to a total cost of approximately 1.8 billion US Dollars.

Precautionary measures

Because there will always be periods of high water levels, and because man has considerably reduced the river flood plain, there will always be a need for precautionary measures against flooding. These will mainly have to be aimed at limiting the (probability of) damage as a result of high water levels. Examples of such measures are: effective prediction and warning systems, building regulations and services, and an insurance scheme for high water damage In addition, much attention will have to be paid to information and making the people in the area aware of the consequences of living in flood-prone areas. There is no such thing as complete protection. Also, during times in which high water levels do not occur, undesirable developments (that could damage the river and/or increase the risk of damage) must not be allowed. Especially over the short term, precautionary measures can be very effective when it comes to damage control. In the Meuse area as well as in Cologne in Germany, the total damage during the high water levels of 1995 was about half of the damage in 1993!

Maintaining the safety

the Flood Protection Bill

To have a safe and strengthened flood protection is not enough. This safety must also be ensured for the future Water defences must be maintained and regularly checked, the relative height can diminish by subsidence of the subsoil or by shrinkage of the body of the dike itself Also sea level rise or changing hydraulic design conditions may impact safety of a construction.

To maintain safety against flooding at the required level the flood protection bill of 1996 demands a 5-yearly check of all water defences in the Netherlands, not only along the coast, but also along the rivers and main lakes.

To make this 5-yearly check possible, the government (Rijkswaterstaat) has to provide updated hydraulic design conditions every 5-years taking into account sea level rise, soil subsidence, changes of storminess, changes in geometry etc, etc. After that the local authorities responsible for the water defences (in most cases the water boards) have a time period of 5 years to test their defences. The rules, how to perform these tests are provided by the government (Rijkswaterstaat). At the end of the period the local authorities have to report the conditions of the water defences to the provinces together with any necessary plans for strengthening defences. The provinces in their turn have to inform the Minister of Transport, Public Works and Water Management.

preservation of the dune coast

Discussion on a new policy for coastal defence of dune coasts started in the 1980's (Hillen et. al., 1995b). Until 1990, large sections of the Dutch coast were eroding, at some locations resulting in a retreat of 5 km in four centuries. Only an ad-hoc policy against coastal erosion was followed: measures were only taken when the safety of polder land was at stake or when special values in the dune area - e.g drinking water areas, nature reserves, camping places - were threatened. If no measures were taken against ongoing coastal erosion tens of kilometres of coast would become unsafe and hundreds of hectares of valuable dune area would be lost every decade. An accelerated rise in sea level will enhance this problem even further.

In 1990 Parliament (Kustnota, 1990) decided to stop further retreat of the coast and to follow a policy of preservation, meaning that the entire coastline will be maintained at its 1990 position. Further erosion will be counteracted by sand nourishment. Sand nourishment has been a common measure to combat coastal erosion in the Netherlands since the end of the 1970's. When a nourishment project is carried out, sand excavated from the bottom of the North Sea (outside the -20 m depth contour), is added to the near shore zone (see fig. 6). Since 1990 about 7 million cubic metres of sand has been added to the Dutch beaches annually. For this purpose a yearly budget of about 35 million US Dollars is available. In fact these costs can be considered the maintenance costs for the coastline. For comparison: the average costs for the maintenance of one km of sandy coastline is less than the average maintenance costs of one km of motorway. After the first 5 years of 'preservation' an evaluation study in 1995 concluded sand nourishment to be an efficient method to combat erosion on the sandy coast of the Netherlands (Kustbalans, 1995).

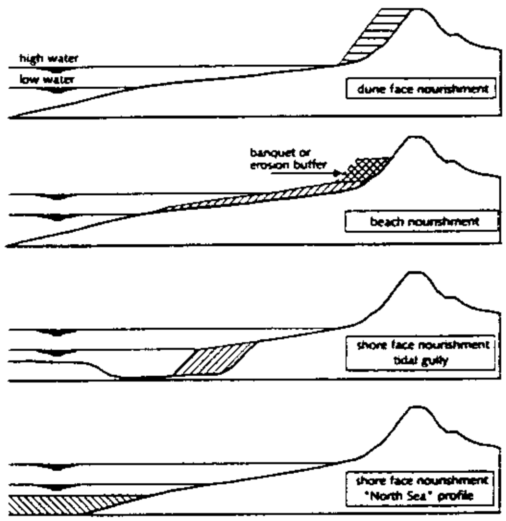

Fig. 6 Methods of nourishment along the coast

Flood warning systems

the Storm Surge Warning Service

There always will be circumstances which pose a threat to public safety. Accurate advance warning of storm surges and high river discharges are vital and should help to ensure that dike watches can be instituted to prevent dike failure. Forecasts of expected high water levels are also necessary to enable those responsible to decide whether to close the storm surge barrier in the Eastern Scheldt and the one soon to be completed in the New Waterway near Rotterdam. Where closure appears to be necessary, this will be performed at the appropriate moment, usually fairly shortly after low-water. Rijkswaterstaat produces these forecasts and provides advance warning for the dike authorities. This duty is laid down in the Flood Protection Bill.

Errors in forecasting can have major consequences. If dike surveillance teams are absent or late getting into position during extremely high storm surges or river discharges, there may be extensive damage to the dikes resulting in dike failure, with all the consequences of such an event. Alternatively, due to cost implications, it is important that surveillance teams are not called out too frequently for no good reason. Likewise, storm surge barriers must not be closed unnecessarily, but must certainly not be left open when very high water-levels are due to occur, which could mean vast economic damage. But, each and every closure of the storm surge barrier in the Rotterdam New Waterway will automatically mean the loss of millions of US Dollars, since the port of Rotterdam - the economic lifeline of the Netherlands - will be sealed off and the discharge of the rivers Rhine and Meuse interrupted. Unnessary closure of the Eastern Scheldt barrier must also be avoided because of the possibility of damage to the fragile environment of the Eastern Scheldt basin.

Water-level forecasting for locations in the tidal area demands not only tidal forecasts but also weather predictions To provide these, and more particularly wind forecasts, the Royal Dutch Meteorological Institute (KNMI) uses a model of the earth's atmosphere which produces a thirty-hour forecast four times a day. Based on the predicted wind and pressure areas, it is then possible to forecast the movement of water in the North Sea for the next thirty hours. This is done by inputting the KNMI weather forecast into Rijkswaterstaat's Continental Shelf Model (Gerritsen et.al.,1994) of water motion. The KNMI and Rijkswaterstaat have set up two Hydro Meteo Centres. Whenever there is any possibility of a storm surge occurring, the Hydro Meteo Centre alerts the Storm Surge Warning Service: the SVSD from Rijkswaterstaat. This is normally done at least ten hours before the dangerous high tide is actually due to occur The SVSD then takes over final responsibility from the Hydro Meteo Centres.

The SVSD keeps the situation along the Dutch coast under close observation and produces new predictions of the expected high water-levels at least once every three hours, in consultation with the Hydro Meteo Centres Where necessary, those responsible for the dikes and storm surge barriers are alerted, as well as other interested parties, at least six hours before the actual time of high-water so that they have time to take action

It is extremely difficult to produce accurate forecasts for the changeable North Sea area The improvement of numerical weather and water motion models, recent access to techniques, and on-line access to water-level data have opened the way to the use of data assimilation (Ronde et. al., 1995b). In the context of water-level forecasting, data assimilation means that water-level predictions are modified on the basis of statistical techniques (see fig.7). The result is a considerable improvement in water-level prediction, particularly for the short term (up to around 6 hours in advance). For data assimilation on the forecasting of storm surge levels along the Dutch coast, water-level measurements from the east coast of England and along the Dutch coast are used.

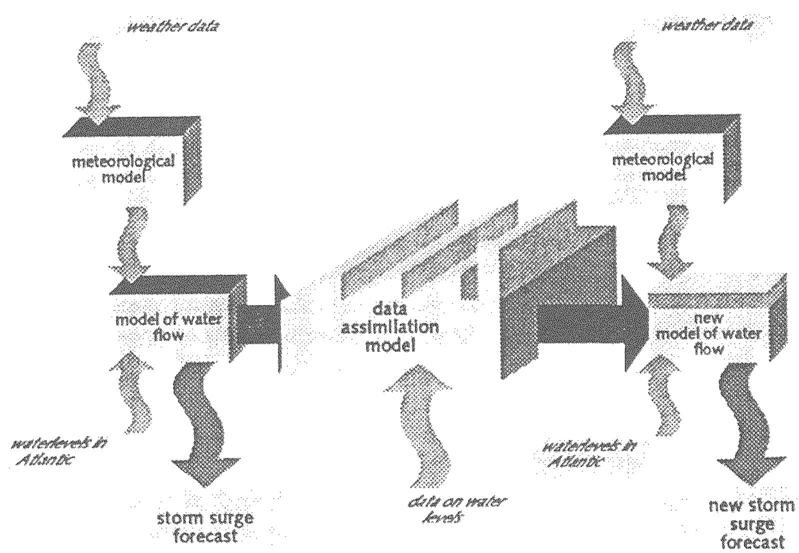

Fig 7 Storm surge prediction system for the North Sea

The Inland Water Information and Warning Centre

Forecasts for the river Rhine and Meuse are produced by the IWIWC (The Inland Water Information and Warning Centre). These are of great importance when high river discharges are expected and enable the industry during normal discharges to deduce the water-level, minimum navigable depth and headroom under bridges, and to take account of these factors when arranging cargoes.

For the river Rhine a multi-day forecast is produced daily and broadcast on radio, teletext, etc. Where there is any danger of extremely high water-levels occurring in the rivers, the Inland Water Information and Warning Centre issues a daily alert to the dike authorities and other interested parties.

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