Delft Cluster

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Abstract

In this study the enivronmental impact of flood as desrcibed in various research articles, scientific papers and field is summarized. In this literature study the emphasis is given in collecting the case studies and scientific researches related to environmental impacts caused by a flooding event such as human and animal health, impacts on aquatic live, chemical hazards caused by flooding events, surface and groundwater pollution, soil degradation, impacts on agriculture and farming etc. The results show that very limited research has been done investigating the flood impacts on flora and fauna. Furthermore, there appears to be a lack of research on short-term and long-term environmental impacts of flooding. There has been very limited studies on chemical hazards due to flooding and inundation.

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Executive summary

Systematic, scientific approaches to identifying and mitigating environmental impacts of flood hazard is a recent phenomenon. The subjects discussed in this report are derived from various research articles, scientific papers and field investigations carried out by many environmentalists, engineers, scientists and researchers in developed countries. Emphasis is given in collecting the case studies and scientific researches related to environmental impacts caused by a flooding event such as human and animal health, impacts on aquatic live, chemical hazards caused by flooding events, surface and groundwater pollution, soil degradation, impacts on agriculture and farming etc. This report is not a complete document, which covers all aspects of environmental impacts of the flood. It is rather a starting document, which highlights the importance of environmental impact assessment and its scientific researches for better understanding and cooping with the floods in the future. This report may be helpful for researchers in this area. Having done a short literature research, some case studies and examples of scientific studies are presented in the report. Although, attempts were made to discover some aspects of modelling of flood environment and strategic environmental management of flood, these two sections are relatively weak in this report. A list of commonly available literature references is given at the end of this report.
The results show that :

a) Very limited research has been done investigating the flood impacts on flora and fauna. Furthermore, there appears to be a lack of research on short-term and long-term environmental impacts of flooding. There has been very limited studies on chemical hazards due to flooding and inundation.
b) Sediment transport is a well-studied engineering science. However, contamination of sediment due to the flooding and spreading of any such contamination and its consequences is still an ongoing research subject.
c) Traditionally, assessment of environmental loss is not considered important. Therefore, systematic and scientific environmental impact assessment of a flood is a very rarely investigated, recorded and published.
d) Normally, intangible losses are not taken into account while calculating the flood losses. On the other hand most of the environmental consequences can not be evaluated in the monetary term.
e) There are several models, which can simulate the flooding event. Similarly, there appears to have several environmental modelling programmes, which can simulate the environmental problems. However, this research indicated that there is a need for developing an integrated model, which can simulate environmental problems along with the hydraulic modelling of a flood event.
f) There appears to be flood management plans of each flood prone countries. Some countries appear to have protocols of safety and evacuation of chemical plants in case of flooding. However, official protocols do not appear to in the public domain, that can be easily accessed for example by searching in the internet or in the database.

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1 Introduction

1.1 General

Systematic, scientific approaches to identifying and mitigating environmental impacts of flood hazard is a recent phenomenon. The subjects discussed in this report are derived from various research articles, scientific papers and field investigations carried out by many environmentalists, engineers, scientists and researchers in developed countries. Emphasis is given in collecting the case studies and scientific researches related to environmental impacts caused by a flooding event such as human and animal health, impacts on aquatic live, chemical hazards caused by flooding events, surface and groundwater pollution, soil degradation, impacts on agriculture and farming etc. This report is not a complete document, which covers all aspects of environmental impacts of the flood. It is rather a starting document, which highlights the importance of environmental impact assessment and its scientific researches for better understanding and cooping with the floods in the future. This report may be helpful for researchers in this area. Having done a short literature research, some case studies and examples of scientific studies are presented in the report. Although, attempts were made to discover some aspects of modelling of flood environment and strategic environmental management of flood, these two sections are relatively weak in this report. Few points are presented as conclusion and recommendations at the end of this write up. A list of commonly available literature references is given at the end of this report.

1.2 Historical background

Floods in more than 80 countries have killed almost 3000 people and caused hardships for more than 17 million worldwide since the beginning of 2002 according to the reports published by the World Meteorological Organisation (WMO) a specialised organisation of United nations based based in Switzerland (www.reliefweb.int). WMO estimated the total property damage is more than 30 billion US dollars with over 8 million square kilometres of the total area affected by floods during the first eight months in 2002. The area affected by flood is almost the size of the United States of America. During the August 2002, worst ever recorded floods disasters occurred in Central Europe affecting mainly Germany, Czech Republic and Austria. Similarly, the flood events in China, India, Nepal, Bangladesh have effected the region severely.

Flood is a widespread natural risk. During the period of 1973 and 1997 an average of 66 million people a year suffered flood damages (Douben, 2002). In 1998 the death toll from floods hit almost 30,000 (Douben, 2002). Following are some of the major flood events of the recent past:

Some examples of Flooding:

2002: Germany, Czech Republic, Austria

Heavy rains in Central and Eastern Europe August 2002 was the worst flooding in the region in more than a century. The floods have killed more than 100 people in Germany, Russia, Austria, Hungary, and the Czech Republic and have led to as much as $20 billion in damage. Only in Czech republic 220,000 people were evacuated. A chemical factory was flooded and more than 100 tones of chemicals were spilled (Associate France Press (AFP), www.reliefweb.int). The flood also effected beauty and aesthetics of the historic Prague City. Similarly, Los Angeles Times (17 Aug 2002) under the title of Flood Threaten German chemical plant reported that swelling flood water in two rivers threaten to overwhelm a massive chemical industrial park in Mulde, Bitterfeld, where 350 factories are housed.

2002: China, India, Bangladesh

Extensive floods occurred across many Asian countries during the summer of 2002, mainly in China, India, Bangladesh, Nepal, Thailand, Vietnam, Lao etc (www.reliefweb.int)

In China, the flooding has claimed 793 lives and caused direct economic losses of more than 30 billion Yuan (3.61 billion U.S. dollars). The floods affected 24 province-level administrative zones and a population of more than 100 million by July 8. It was the worst flooding in China since the early 1990s in both area and population affected. More than 80,000 people were evacuated. More than 20,000 houses were destroyed and more than 175,000 ha of crops were inundated.

In Bangladesh, the flood has killed more than 90 people, damaged thousands of homes and 500,000 ha of rice paddies. More than 30,000 people in flooded areas are affected by water-borne diseases (12 Aug 2002, (www.reliefweb.int).

More than 440 people lost their lives and 55,337 families were affected along with a huge amount of property destroyed or damaged by the rains and floods in Nepal this year (www.nepalnews.com) . Death toll of Thailand Flash Floods was recorded 78. The floods and landslides triggered by monsoon rains in Nepal have claimed at least 257 lives. Similarly, in Vietnam, Mekong flood death toll is more than 27.

1991, 1994, 1995 and 1996: China

As far as major flood disasters are concerned, China holds a sad record, with the number of people killed in such catastrophes this century running into the millions. In the summer of 1991, an area in the east of China measuring 130,000 km2 was inundated. Three millions houses were swept away or completely destroyed. Six million dwellings were severely damaged. Ten million people had to be resettled. Three years later, six provinces were hit in south and south east of the country, above all the picturesque region of Guangxi along the Li River. Almost 1500 people lost their lives, with billion dollar losses. More than 100 million people were threatened the next year, when flood caused by melting snow and record levels of rainfall. Ten provinces in central, eastern and southern China were affected. The peak was reached in the flood of 1996. Extremely large amount of rain fell through out central and southern China and triggered many landslides. Again over 100 million people were affected, 2700 were killed, and more than a million had to be evacuated. Way over a million houses were destroyed and almost 10 million damaged. 8000 factories had to close down, 100,000 km2 of farmland were swamped. The estimated loss in 1996 alone exceeded USD 20 billion.

1987: South Africa

In September 1987, the East Coast of South Africa was hit by its worst natural catastrophe in living memory. Day after day the rain fell, some areas recording amounts of 700 l/m2 in just a short time. Rivers and streams were turned into raging torrents, and in Natal, the most heavily drowned, one million were made homeless. Most severely affected were Pietermaritzburg and the port Durban. The overall loss topped USD 500 million.

1982 and 1983: Peru

At the turn of the year 1982/1983, Peru suffered its most severe flood catastrophe since 1925. El Nino, the ‘boy child’ caused weeks of rainfall. On account of the high ocean temperatures, fish supplies were drastically reduced, which had a major effect on the fishing industries. On the main land, one of the most arid regions on earth, enormous flooding occurred. An area measuring 1200 km2 was swamped. In the north of the country, where there were numerous landslides, water and electricity supplies in many areas broke down completely. More than 300 people were drowned. The overall loss came to about US$ 400 million.

1974: Australia

In January 1974, two tropical discharged their loads onto the Australian continent and caused chaos and damage caused costing millions of dollars. In West Australia, the amount of rain registered in just one week was equal to the region' s average precipitation per annum. Peak recordings were taken in the east, too. A lake the size of Western Europe was formed in the 'dead heart' of Australia, where an area measuring almost 2,000, 000 km2 was under water for weeks. Property damage and bodily injury were at their worst in the Greater Brisbane area. Fifteen people were drowned, 14,000 houses were damaged. Industry and commerce were hit particularly hard, especially the firms located on the floodplain, where land for development was relatively inexpensive. The overall loss amounted to some US$230 million.

1970 and 1991: Bangladesh

Large parts of Bangladesh are situated just above sea level. Three huge rivers (Ganges, Brahmaputra and Meghna) and is threatened not only by cyclones and storm surges but also by river flooding as a result of extreme monsoon rainfall. Dramatic flood catastrophes are a regular occurrence. In November 1970,300,000 people died in a violent storm surge. On 29th and 30th April 1991, a cyclone that had built up in the Bay of Bengal devastated a 500 –km stretch of coast and inundated 16 administrative districts, where nearly all the houses were destroyed. 2,000 villages around Chittagong and Cox` s Bazar in the south east of the country were hit, 140,000 were killed, ten million made homeless. The tidal wave, which reached a height of 7 m in some areas, annihilated 75% of the rice crop and laid waste to salt production plants and shrimp farms.

1966: Florence (Italy)

When the inhabitants of Florence were woken by a muffled roaring sound on the morning of 4thNovember1966 some parts of the city were already five meters under water. A third of the average annual precipitation had fallen in just 24 hours, making the Arno river rise at a rate of one meter per hour and causing the worst flood catastrophe in Italy since 1061.In Florence itself, more then 6,000shops and businesses were damaged and many thousands of vehicles were stuck in meter-thick messes of mud. The economic loss was US$1.3 billion. Countless art treasures were irretrievably ruined.

1962: Hamburg, Germany

During the night of 16th February 1962, Germany experienced its worst flooding since the World War II. A heavy northwesterly storm with wind speed of up to 150 km/h drove masses of water from the North Sea into the German Bight. The storm surge reached its climax, when the elevated water level caused by the wind concurred with high tide. In more then 60 places, the sea defenses, with a total length of more then 100 km, were unable to withstand the enormous pressure exerted or were overtopped.125 km^2 (45%of the city area) was submerged.350people were drowned, most of them on the island of Wilhelmsburg, which was completely submerged by the flood waters (backwater) of the Elbe river. The overall loss came to US$600 million, which is roughly equivalent to US$3 billion in today's terms. Immediately after this catastrophe flood and sea defenses were improved, but these were apparently not effective enough because 14 years later, when the gale Capella stormed over western and Central Europe early in 1976,Hamburg again was partially submerged. This time numerous warehouses in the port area were affected, involving huge losses due to goods being soaked.

1953: The Netherlands, Belgium and England

The 1953 storm was the worst natural catastrophe to hit the North Sea region this century. Within three days, a strong northwesterly wind drove almost 500,000,000 m^3 of water into the southern part of North Sea. Fifty sea-dikes in the Netherlands breached. Thousands of square kilometres of land were inundated, in some placed several meters deep. More than 1,800 people were drowned, 3,000 were destroyed and 40,000 badly damaged. Millions of hectares of valuable farmland were washed away. The intrusion of salt water into the agricultural land caused the agricultural problesm for many years. The overall losses exceed half a billion dollars. Belgium and England were also severely affected. In England flooding on the Thames and the Wash claimed more than 300 lives and destroyed 24,000 houses.

2 Objective of the study

The main objective of this research was to get an overview of the environmental consequences that a flood event might bring into the society and the nature. The primary focus is to highlight the major consequences either short term or long term that may be encountered during and after a flood event.

The present scenario on the research related to flood and flood management is more focused on the structural measure as part of flood defence strategies, studying non-structural measures to coop with the flood events, immediate mitigation, restoration and compensation of the flood disasters. Very limited research has been accomplished in the part of environmental impacts of flood itself. One of the largest and very recent international gatherings on flood issues “Flood Defence 2002– Second International Symposium” held in Beijing, China during 10-13 September included the topics on environmental impacts of flood.

3 Research Methodology

Initially, basic information was searched through the Internet. For this purpose some of the search engines such as www.google.com, www.altavista.com, were used with the input of key words like flood, flood hazards, environmental effects of flood etc. having done some search in this way, a general overview and fundamental area of environmental effects were established. Some of the major sector under consideration for further research was identified as following:

- General environmental consequences
- Surface and ground water pollution
- Soil and sediment contamination
- Chemical pollution and oil spillage
- Human and animal health
- Aquatic life and plant species
- Agricultural and animal farming
- Environmental modelling of flood events
- Management plan and Emergency strategies

Database search was undertaken in order to discover the research papers and scientific articles already published in the above sectors. For this purpose, various databases were accessed through the Technical University Delft Library. Attention was given to the research mainly carried out during the last decade and based on the experience of developed and industrialised countries. Mainly, the following database were used for this purpose:

- Cambridge Scientific Abstracts (CSA)
- ANTE
- Compendex
- Chemical abstracts
- Environment Abstract
- Environmental Science and Pollution
- Fluidex
- Pascal
- Toxnet
- Water resources Abstract
- NTIS reports

It has to be noted that search of the research papers and articles was based on the limited use of key words. The relevant scientific articles, research papers, proceedings of the conference were collected. Emphasis was given to compile the research publications based on the case studies as well as general situation.

Besides the above mentioned literature review, some textbooks on floods were also consulted.

4 Ongoing Research Activities:

Studying environmental consequences of the flood is a relatively recent concept. Limited research and case studies have been recorded on the environmental impacts of flood. Other aspects of flood have attracted more research. Some examples of international forum for the flood research and discussions are:

- EUROflood: Sponsored by European Commission, first phase was carried out during March 1992-February 1994. Second phase another 2 years. Hopefully this is ongoing ??

- In November 2000, European conference on advances in flood research was held in Potsdam Institute for Climate Impact research (PIK), Germany.

- In September 10-13, 2002, in Beijing China, Second International Symposium was held on Flood Defence where a total of 222 research papers were presented out of which 6 papers were under the theme of environmental impacts of flood. One paper out of these 6 papers was from the experience of Germany and all the rest were from Asia.

- Plans are underway for holding the third International Symposium on Flood Defence in 2005 in the Netherlands.

So far the research is more concentred on the hydraulic engineering part of the flood management. The environmental impact assessment of the flood is a rarely discussed subject, although significant work is done in environment and pollution in general. There is a need for integration of the research activities.

5 General consequences of a flood

Floods can be classified in four types (Peterson, 2001) based on their characteristics of the flood event:

a) flash floods of a few hours duration;
b) single event flood of long duration;
c) multiple-event floods; and seasonal floods.

Similarly, based on the source type, floods my be classified mainly as:
a) Rainfall flood,
b) Snowmelt flood,
c) Sea surge or tidal flooding,
d) Dam brake flood.

Broadly floods can be classified as River floods and Coastal & Estuarine floods:
a) River floods: caused by rainfall, snow and ice-melt, ice jams, landslides
b) Coastal and Estuarine floods: caused by coastal storm surges, tides, earthquakes.

The common to all of these floods is the economic, social and environmental effect.

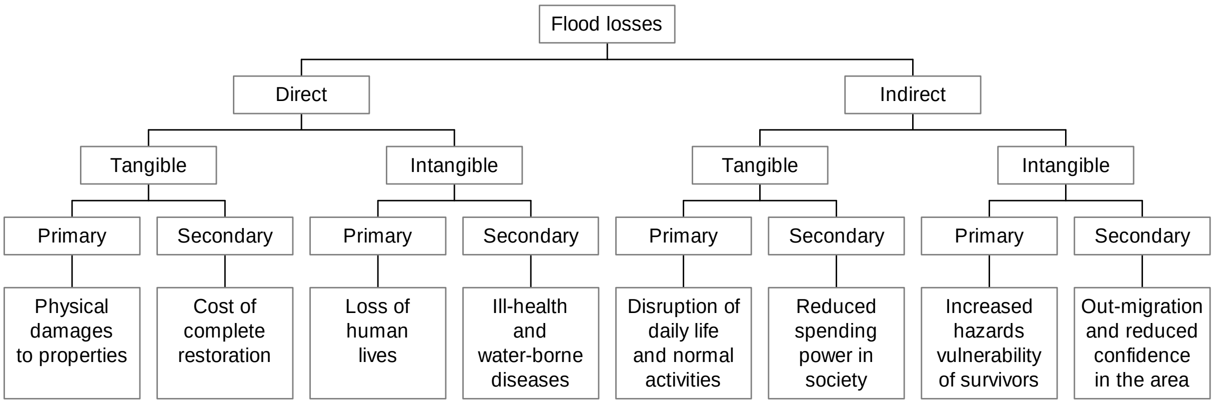
The phenomenon of flooding is a natural occurrence, which may bring both adverse and beneficial environmental changes. Flood is an event that generates loss of lives and properties. If such an event is not so much of life threatening one, it will still generate collective stress and serious disruption of community live even after a long time later. Flash floods generate sudden and massive impacts, whereas the gradually occurring floods may allow longer period of time for evacuation and protection of properties.

Flood impacts are evaluated on the extent of inundation in the floodplains (maximum depth and duration of flooding); velocity of flow, and rate of rise of flood levels.

Basic environmental impacts of flood are on morphological changes along the river course. The shape of the river valley is often determined more by the catastrophic event than by the gradual but insidious process of erosion and deposition that takes place at flows which are confined within banks. Morphological process is a primary factor in forming the natural habitat for flora and fauna (Gardiner,1992). Consideration of environmental impacts of the flood regime should also include the direct as well as indirect impacts including those associated with human activities.

Most flood studies emphasise the negative impacts of flooding. The flood losses can be categorised as direct and indirect (Smith K et al 1998). In particular, attention is given to direct losses, which occur immediately after the event as a result of the physical contact of the floodwaters with human and the damageable property. However, indirect losses, which are less obvious but often operate on long time-scale, may be equally or even more important. Depending upon whether or not these losses are capable of assessment in monetary values, they are termed as tangible or intangible (Smith et al, 1998). Tangible and intangible losses can also be divided into primary and secondary categories. Primary loss result from the event itself while secondary losses are at least one casual step removed from the flood.

Some of the most important direct consequences of flooding, such as the ill health due to water-borne disease or contamination of fertile land are intangible.



Some basic classification of the flood loses are presented in figure 1 below:

Figure1: Flood loss classification (source: Smith K et al, 1998)

Intangible damages of flood are those; such as the stress caused by an event itself and worry of future flooding; subsequent damage to health; loss of memorabilia or other irreplaceable and non-marketed goods; disruption to the normal way of life and possible evacuation and migration. It has been demonstrated that to the households effected, these non-monetary aspects are much more important than tangible effects.

The above definition does not fully account the environmental losses. In many cases the environmental losses either they are short-term or long-term or they are intangible and less obvious. The environmental impacts of flood can be quite wide ranging, from the dispersion of low level house hold wastes into the fluvial system to contamination of community water supplies and wild life habitats with extremely toxic substances. During a flood event, variables such as depth of water, velocity of flows and duration of inundation, in combination with land use attributes, all contribute to the relative severity of flood impacts. Floods of greater depth are likely to result in greater environmental damage than floods of lesser magnitude, in part because more area being flooded. Long duration floods will exacerbate environmental problems because clean up will be delayed and contaminants may remain in the environment for much longer time.

During the post-flood phase, that is the clean up stage, many other environmental impacts can become apparent. Personnel involved in clean up hazard workers may be exposed to infectious agents and chemical hazards, fungal disease, asbestos hazards, hazards of lead poisoning.

Seasonal flooding of the natural environment can be regarded as a natural feedback mechanism whereby the fertility of floodplains can be replenished and natural lifecycles continued; many fish species, for example, rely on seasonal flooding to spawn on the flood plain (Gardiner, 1992). Changes on the flood magnitude , frequency or duration will clearly have an impact on the floodplain as a habitat, hence on wildlife and other natural resources on which humans may rely.

Consideration of the environmental impacts of flood regime should then include not only the direct but also the indirect impacts, including those associated with human activities.

6 Environmental Impact Assessment of Flood Hazards

The occurrence of a flood event usually elicits a response to alleviate losses and return society as quickly as possible to pre-disaster conditions. It is rare to find long-term strategic planning designed to mitigate the many facets of the flood hazard. Particularly, it appears that very few systematic environmental impact assessment have been carried out covering all environmental aspects of a single flood events. Nevertheless, with the exception of water and sewage systems, environmental impacts of development are generally ignored. In part, of course, this is because floods are often low-probability events that do not rank highly amongst the many issues that people face on a day-to-day basis. In addition, many societies have implemented emergency action plans to facilitate the immediate relief of flood victims, which tends to work against the development of comprehensive disaster planning (White, 1975; Williams, 1986). Also, it should be noted that some events are relatively unpredictable, at least in time if not in space, thus compromising effective planning while promoting a simple response mode. However, despite these characteristics, the opportunities for evaluating probable impacts of a given event and for planning accordingly are considerable.

Reasons for this lack of consideration of environmental impacts emanating from flooding are relatively straightforward. Most basically, flood concerns have historically been regarded as economic issues associated primarily with direct damages. In essence, the underlying philosophy has been one of costs versus benefits, while focusing attention on short-term economic variables, rather than consideration of the total range of impacts, including indirect and intangible losses. Secondly, there has been overwhelming interest in relief and rehabilitation efforts and a prevailing desire to get things "back to normal" as soon as possible. Thus, the first step is usually to facilitate economic recovery from the flood and to meet the immediate demands of flood victims. The second step, it seems, is to plan for the next event, thereby initiating a continuing cycle of disaster-relief- repair-disaster. Ultimately, the flood risk and vulnerability do not change. Of course, society can and does learn from some events, to the extent that some communities have even moved off the floodplain, but these tend to be the exceptions rather than the rule (Montz and Tobin, 1997).

The environmental impacts of flooding can be quite wide-ranging, from the dispersion of low-level household wastes into the fluvial system to contamination of community water supplies and wildlife habitats with extremely toxic substances. On the other hand, flood preparedness activities, such as forecasting and warning systems, can help to avoid some of these impacts. Indeed, actions undertaken prior to the event will have repercussions on the level of damages accruing from the flood. Effective remedial actions, such as sandbagging, can significantly reduce losses, and with planning, prevent some of these secondary environmental impacts. Specifically, the removal of fuel tanks and attention to hazardous wastes would eliminate some of the potential problems. In contrast, inadequate attention to these components of the flood hazard will invariably lead to additional problems and intensify adverse environmental impacts. Similarly, during a flood, variables such as depth of water, velocity of flows, and duration of inundation, in combination with land-use attributes, all contribute to the relative severity of flood impact (Montz and Tobin, 1997). Floods of greater depth are likely to result in greater environmental damage than floods of lesser magnitude, in part because more area has been flooded. Long duration floods will exacerbate environmental problems because clean-up will be delayed and contaminants may remain in the environment for much longer time. The argument is the same for other flood traits; extreme conditions are likely to precipitate additional environmental problems.

After the flood event, many other environmental impacts can become apparent. The volume of the debris to be collected, the extent to which public utilities such as water supply systems and sewage operations have been damaged, and the quantity of agricultural and industrial pollutants entering fluvial systems might present pressing problems. These findings, then, should be incorporated into long-term restoration and reconstruction programs to eliminate unacceptable environmental impacts from subsequent flooding. Environmental evaluation of the flood hazard, therefore, sets the stage for the strategic assessment of redeveloping flood prone areas. Specifically, recurring losses and negative intrusions into environmental systems could be avoided, or at least minimised, by identifying, measuring, and interpreting the magnitude and significance of environmental impacts associated with flooding. Currently, there is a tendency to re-analyse the economics of redevelopment in the aftermath of an event, and rebuild with future losses in mind. It follows that a similar approach regarding environmental impacts would provide a comparable basis for decision-making. The guiding principle in this instance would be reducing costs related to environmental clean-up and providing additional protection (Montz and Tobin, 1997).

Strategic environmental assessment (SEA) has been defined as "the formalised, systematic and comprehensive process of evaluating the environmental impacts of a policy, plan, or program, and its alternatives . . . and using the findings in publicly accountable decision-making" (Therivel et al., 1992). The application of this definition to flooding is apparent. Reconstruction of floodplains is a policy that is enabled through federal and state disaster relief funding and private money. Traditionally, this has followed the simple economic model discussed above. However, strategic assessment of floodplain reconstruction permits a comprehensive analysis of policy decisions, prior to the emergency phase immediately following a flood event. Since this is usually a period of chaos and confusion, such planning is essential if meaningful policies are to be implemented.

6.1 Types of Flood impacts

Representative sepecific effects, classified as economic, social and environmental impacts are listed below :

Table 1: Economic, social and environmental impacts (source: Petersen 2001)

Economic Impacts	Social Impacts	Environmental impacts
Infrstructure losses such as transportation, communication network, water supply and sewer system	Human endangerment., loss of life	Destruction of flora
Government facility losses (including military)	Human injury (physical, emotional, psychological)	Destruction of fauna
Residential losses such as property, furniture	Displacement of people	Damage to habitats, food chains, species diversity and stability
Public facility losses such as schools, hospitals	Health hazards: polluted water, communicable diseases, shortage of food supply, exposure to cold, rain etc due to lack of shelter	Damage to rare to endangered species
Employing business losses, Sales losses	Emitional and psychological trauma associated with loss of relatives and loved ones, loss of personal property and memorbilia, homes,	Damage to natural recreational resources

	communities	
Displacement of business and farm	Loss of social (community) cohesion	Damage to scenic resources
Job losses, Income losses	Disruption of educational programmes	Damage to archaeological and historical resources.
Agricultural losses: amage of agricultural land and facilities, loss of crops, animal losses	Loss of security related to job and income interruptions	
Loss of recreational facilities and resources	Loss of recreation opportunity	
Increase in operational costs such as fuel and lost time due to traffic delays and use of alternative routes and resources	Disruption of cultural programmes (sports events, church programmes etc)	
Cost of emergency measures	Disruption of law enforcement programmes.	
Increased taxes due to cover costs of replacement, repair and rehabilitation of infrastructure and public facilities		

Evaluation of flood impacts is an objective analysis to identify and measure economic, social and environmental effects. The extent and severity of each loss most be identified as preciously as possible. Some impacts are primarily local, while others may be of regional or national significance.

6.2 Environmental Impacts of River Floods in The Netherlands

The environmental impacts of 1993 and 1995 floods in the Netherlands were studied by Zwolsman et al (2000). The environmental impacts of these floods were assessed in terms of the suspended matter composition in the rivers and its ecotoxicological effects. River floods are generally accompanied by a decreasing contamination of the suspended matter, especially in the Meuse river. This is a short-term phenomenon, which is related to increased erosion of unpolluted soils in the catchment basin of the rivers. On the longer term, however, river floods may lead to a deterioration of the suspended matter quality, due to erosion of recently deposited sediments, exposing ancient sediment layers (which are far more polluted) at the surface. A variety of organic contaminants has been measured in the suspended matter e.g. polynuclear aromatic (PHA), polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB). This hypothesis is supported by the HCB content of the suspended matter in the Rhine river (station Lobith), which increases slowly but continuously since 1994.

According to the studies carried out by Zwolsman et al (2000), a major fraction of the suspended matter transported during river floods is deposited in the floodplains of the Rhine and Meuse rivers. The floodplains are moderately to strongly polluted due to previous deposition of suspended matter, especially during the sixties and seventies. Compared to the average sediment composition of the floodplains, the quality of the suspended matter deposited during river flood is similar or better, at least in the river Rhine. In this way they concluded that sedimentation is unlikely to increase the direct ecotoxicologycal effects risks to biota in the floodplain. However, they noted that indirect ecotoxicological effects of river floods may occur, e.g. related to a change in feeding behaviour of predators. For instance, little owls are forced to change their diet from mice to earthworm after inundation of the floodplains, which leads to increased uptake of contaminants (especially cadmium) and increased potential for ecotoxicological impacts.

6.3 Socio-economic impacts of 1995 flood on the Han river in Korea

Woo et al (1997) carried out studies of the above flood and found out that a total of about 50 fatalities occurred and properties damage of about US$ 600 million. Cultivated area of about 57,000 ha and 9,000 houses were inundated by the flood. There are other flood, which had higher fatalities and greater property losses in Korea. The notable impact of the 1995 flood was a one-time nation-wide traffic stoppage due to the flood. On August 25, most national rail traffic, which transports 23% of passenger traffic and 22%of cargo traffic, was halted due to flooding of railway systems and bridge collapses. This was the worst recorded damage to the rail transportation system in Korea.

The large cities also suffered from urban traffic jams during this flood (Woo et al,1997). For example, on August 25th when the river stage on Inkokyo station rose to 10 m, most of the freeways constructed along both sides of the Han River and its tributaries were inundated and traffic on these roads was halted for several days, causing terrible traffic jams in the capital city of Seol. These riverside freeways favourably constructed in the past due to zero purchase cost of the land for freeways (riverside lands are mostly public properties in Korea), compose a vital part of the main road traffic arteries in metropolitan Seoul, including suburban areas where more than 20 million people live.

Besides these impacts on traffic, numerous flood impacts, including temporary stoppages of water supply, electricity supply, telecommunication, and temporary shutdown of schools and markets prevailed during the flood event in 1995 (Woo et al,1997). Prices for vegetables in urban areas doubled during and after the flood because of a complete stoppage in transportation of vegetables from rural areas. Most water purifying plants withdrawing water from rivers were on emergency status because of exceptionally high concentrations of suspended solids, which increased from about 20-30 ppm in normal time to more than 1000 ppm during the flood.

Besides that, a large amount of sediment deposition took place along the floodplain. The damage incurred by sedimentation were mainly associated with cleaning sediments from recreational areas, parking lots, roads and highways, piers and grasslands on the floodplain. The total cost of cleaning the sediment deposits was estimated to be about US$ 4 million.

7 Chemical hazards during the flood events

Generally, there are two phases of 'flood chemistry'. Initially, the floodwater reaches places where the chemical substances are stored. They are slowly dissolved, but this process results in formation of a diluted solution of certain chemicals. This mixture is a subject of many secondary chemical processes, such as: reactions between dissolved chemicals, hydrolysis, oxidation of certain compounds etc. Afterwards, when part of floodwater evaporates, concentration of the solution increases – and this can result in sever contamination of the polluted place. Many compounds can be easily absorbed by soil and thus included in the flood- chain. Some chemicals (especially heavy metals like lead, cadmium etc.) tend to accumulate in certain plants that are then eaten by animals. Meat of these animals is then used to prepare meals for humans – the last link of the food chain.

There are many possible sources of chemical contamination during and after the flood. Some of them are: dumping ground, graveyards, chemical works (such as car batteries containing acid), pesticide and fertilisers in warehouses, oil spillage from petrol stations. Household and chemical hazardous waste from municipal and private lagoons, septic tank, septic fields and domestic fuel-oil heating tanks are some of the potential source. Chemical factories may induce more dangerous and severe consequence if they are damaged during the course of flooding and chemicals are spilled into the floodwater. Chemicals released into the environment may have a variety of adverse ecological effects. These effects may bring substantial economic, health and social losses. The adverse effects can be grouped as:

1. Short term effects (acute effects) and
2. Long term effects (chronic effects).

Some case studies of chemical hazards caused by flooding events are presented below, to demonstrate the diverse chemical hazards associated with floods:

7.1 Case study: Chemical hazards, Oder River, Poland, 1997

The effects of 1997 flood in Poland on ecosystem can not yet be fully estimated. Although there were no major chemical pollution revealed, some graveyards, dumping ground, chemical works, warehouses containing pesticides and fertilisers and other chemicals were flooded. The reports indicated that no evidence of release of radioactive materials was found (www.kpk.org/FC-KPK/powodz2.htm). There appears to have done some research covering the environmental impacts of 1997 flood, but publications were not found in English.

7.2 Case study: Spolana Chemical plant, Czech republic, 2002

Officials at a chemical plant 'Spolana de Neratovice' near Prague have admitted that carcinogenic substances leaked out into the River Elbe during August 2002 flooding (AFP: www.reliefweb.int, 5 Sept 2002). The plant leaked some 80 tonnes of liquid chlorine and several dozen tonnes of other chemical substances in mid-August during the worst flooding in living memory in Czech Republic. The head of the commission investigating the flood damages at the plant said that chlorine seepage from the factory could cause a disaster comparable to the 1986 Chernobyl accident at a nuclear power plant in Ukraine (www.reliefweb.int).

Spolana chemical plant spokesman Jan Martinek said on 9 September that nearly 81 tonnes of chlorine gas and liquid leaked into the Labe (Elbe) River and the air last month, when the Neratovice-based plant, some 20 kilometres north of Prague, was seriously affected by flooding (www.reliefweb.int). A laboratory analysis commissioned by Czech Radio and Czech Television concluded that dangerous quantities of dioxins that leaked from the plant settled in sediments on the shores of the Labe. The analysis concluded that dioxin levels in the village of Libis, half a Kilometre downstream from Spolana, were three times higher than safety norms. However, the reasonable evaluation of the impacts caused by this chemical pollution would not be available until several years. Such impacts can obviously pose threat to aquatic lives and would easily be transferred to terrestrial and human body on long term.

On 4th September 2002, it was reported (www.reliefweb.int) that about 600 litres of sulphuric acid leaked on Sazecska ulice in Prague. Since the sewer system of Prague was severely damaged by the flood and the water treatment plants are out of operation, thus the acid would go directly into the Vltava River. Although such an accident was independent of a flooding event, but the acid is finally discharged as a consequence of flood damaged treatment plants.

An official investigation of Spolana case was underway during the preparartion of this report.

7.3 Case study: Chemical hazards in Red River (USA) flood, 1997

In the case of 1997 Red River Flooding following chemical contamination was experienced according to the investigation report published by Canadian authorities (www.gov.mb.ca):

Concentration of many water quality variables including dissolved solids, some nutrients and metals were correlated with river flow. Concentration of most physico-chemical variables (e.g., dissolved oxygen, dissolved solids, and trace elements) was found to be within levels normally observed over the period of record. However, maxima, or near minima were reached for sediment load, total nitrogen and phosphorus load, fecal coliform, fecal streptococci, nickel and zinc. Arsenic, lead, and manganese were generally higher than observed over the previous 3-5 years. Minima were reached for dissolved solids and conductivity; near maxima, were reached for sediment load, total nitrogen and phosphorus load, fecal coliform, fecal streptococci, nickel, and zinc. Arsenic, lead and manganese were generally higher than observed over the previous 3-5 years. Minima were reached for dissolved solids and conductivity, near minima were reached for sodium and magnesium.

Dieldrin, total DDT, and total chlordane were also correlated with river flow in 1997. As expected, the pesticides 2,4-D, trifluralin, triallate, dicamba, metolachlor, EPTC, pendimethalin, acetochlor, alachlor, metribuzin, malathion, and atrazin were detected at various sites. Dieldrin, gamma-chlordane, endrin, o, p'-DDT, p,p'-DDT and total PCB were detected in the Red River in 1997 but were not detected in previous years by Environment Canada at Emerson. As well pentachlorophenol, a wood preservative was detected at several sites during the flood. It is thought that this product likely originated from flooded railway ties, fence posts, bridge works, or other flooded wood structures that may have been treated with this preservatives.

As a common situation during a flood event, oil spillage from oil storage and gas stations may occur. Two accident associated with the spillage of hazardous materials into the flood water were reported during Lower Mississippi river flood in Louisiana in 1997 (www.lmrcc.org/library/1297flood.html).

Within Manitoba, more than 550 containers that held or may have held hazardous materials before being swept into the floodwaters were retrieved from the Red River during 1997 flood (Interim Report, 1997). These included propane cylinders and home heating fuel tanks. A total of 40 containers with some contents were also collected between Wahpeton, North Dakota, and the international border. The contents of these containers were wide-ranging: petroleum products, fire-fighting foam, tar, alcohol, solvents, corrosive liquids, polyester resin, flammable liquid, paint, pesticides, compressed gases such as propane, and home heating fuel.

Home heating fuel tanks were a source of hazardous materials in Grand Forks, where approximately 1,000 of the flooded homes used heating oil. During the flood, many of these tanks broke free from their connections and spilled fuel oil. After the flood, heating-oil-contaminated water was removed by vacuum trucks from 726 flooded homes and businesses in Grand Forks and separated. The water was discharged into the Grand Forks sanitary sewer system while the oil was recycled.

Estimates of the number of residential fuel oil tanks that spilled in Manitoba are not available. However, 56 home heating tanks were retrieved from the Red River within Manitoba. Other petroleum products were also lost. For example, approximately 15,000 gallons (68,100 liters) of gasoline spilled from service stations in Breckenridge, Minnesota. Several petroleum components were detected in water samples collected in the U.S. portions of the basin.

Cleanup after the flood revealed a plethora of household hazardous wastes, such as paint, pesticides, oil, solvents, aerosols, water putty, detergents, tar and batteries, in flooded basements. In the United States alone, excluding Grand Forks, 86 barrels of household waste were removed from flooded areas.

7.4 Case study: A tailings dam failure in Romania, 2000

On January 30, 2000, a tailings dam failure at the Aurul S.A. plant in Baia Mare, Romania, resulted in the release of 100,000 m^3 of cyanide-contaminated liquid into the Lapus stream, tributary of the Somes/Szamos, Tisza/Theiss, and Danube Rivers, killing hundreds of tonnes of fish (www.panda.org). Practically all aquatic life has been killed in the Szamos and upper Tisza River. This accident affected the drinking water of more than 2 million people in Hungary (www.antenna.nl). The long-term effects on the ecological system can not be estimated so far, but experts fear that it will take years until the rivers will be back to pre-disaster stage, and some of the effects may be non-reversible. The concentration of cyanide at the Hungarian boarder was recorded to be 32 mg/l and decreased very slowly while moving down the river.

The failed Aurul tailings dam is part of an operation of retreatment of gold tailings from the old unlined Meda tailings pond, originally containing 4.43 million tonnes of solids, with a recoverable gold grade of 0.60 grams per tonne. Starting in May 1999, the tailings were pumped from the Meda pond to the Aurul S.A. processing plant, where sodium cyanide was added for recovery of residual gold. After gold and silver extraction, the remaining tailings contained total cyanide concentrations of 400 mg/Litre, with free cyanide concentrations of 120 mg/Litre. These tailings were pumped over a distance of 6.5 km to the new Aurul tailings pond, which is lined with a plastic membrane and covers some 93 hectares (www.antenna.nl).

Cyanide is killing the Hungarian otters that were to be used as a seed group to restore vanishing otter populations elsewhere in Europe (www.mpi.org.au).

7.5 Case study: A coal tailings dam failure in USA, 2000

On Oct 11, 2000, a coal tailings dam of Martin County Coal Corporation's preparation plant near Inez, Kentucky, USA, failed, releasing a slurry consisting of an estimated 250 million gallons (950,000 m3) of water and 155,000 cubic yards (118,500 m3) of coal waste into local streams (www.antenna.nl). About 75 miles (120 km) of rivers and streams turned an iridescent black, causing a fish kill along the Tug Fork of the Big Sandy River and some of its tributaries. Towns along the Tug were forced to turn off their drinking water intakes.
The spill contained measurable amounts of metals, including arsenic, mercury, lead, copper and

chromium, but not enough to pose health problems in treated water, according to a federal official. The full extent of the environmental damage isn't yet known, and estimates of the cleanup costs go as high as $60 million.

At Martin County Coal's Inez operations, three mines feed coal into a preparation plant on conveyor belts through underground mine workings. Plant waste is poured into the 72-acre (29 ha) Big Branch impoundment that holds 2.3 billion gallons (8.7 million m3) of slurry.
Martin County Coal Corporation is a subsidiary of A.T. Massey Coal Company, Inc., Richmond, VA, which, in turn, is a subsidiary of Fluor Corp., Aliso Viejo, California.

7.6 Case study: A tailings dam failure in Philippines, 2002

Mine wastes from two damaged tailings dams and spillways of the Dizon Copper Silver Mines Inc. (DCSMI) in San Marcelino, Zambales, have spilled into the Mapanuepe Lake and eventually into the Tomas River, the Department of Environment and Natural Resources confirmed on Friday Aug. 30, 2002. (www.antenna.nl). An Aug. 27, 2002, inspection revealed that heavy rains impounded water on the Bayarong and Camalca dams and spillways, eroding these and eventually causing the mine wastes to leak to the lake below. Each dam's catchment area spans 50 hectares. About 2,000 families live near the mine site, located in an upland area some 30 kilometres east of the San Marcelino town proper, according to the Zambales Disaster Response Network. The lake and the river, although silted with lahar (volcanic mudflow), remained as fishing grounds and irrigation sources for five Zambales towns. The 122-hectare Bayarong tailings dam is holding some 47 million cubic meters of tailings and the Camalca waste dam is holding silt and debris.The spillway of an abandoned mine here collapsed Sep. 11, 2002, flooding low-lying villages with other chemicals and mine wastes. At least 250 families in Barangays Buhawen, Sta. Fe and Poblacion were evacuated to safer grounds shortly after the spillway burst at 1 p.m. at the height of a strong downpour. No one was reported hurt but town and provincial officials, led by Gov. Vicente Magsaysay, feared that mine wastes that leaked from the spillway might endanger lives of villagers On Sep. 12, 2002, environment officials ordered the evacuation of some 1,000 families in three villages here following the collapse of a spillway of a mine tailings dam and continuous heavy rains in the province. Leonardo Sibbaluca, Department of Environment and Natural Resources executive director in Central Luzon, said the villages of Buhawen, Aglao and Makarang were in danger of being swamped with mine wastes and water from the damaged Bayarong spillway of the DCSMI.

7.7 Case study: Ohio River Oil Spill, 1998

The spill of diesel oil fuel in January 1998 (Clark et al, 1990) raised a number of technical, legislative, administrative as well as environmental issues. A storage tank containing more than 3.8 mil gal (~14,385 m^3) of diesel collapsed near Pitsburgh and entered the Monongahela River. Many water utilities were forced to alter their treatment and to close intakes as the spill passed. Many communities used bottled water as an emergency measures. Some obvious damage such as the staining of concrete walls occurred when the diesel oil passed through the locks and dams on the upper Ohio. Long term and short-term environmental damages were not fully assessed until 1990. Ohio and Pennsylvania officials (Clark et al, 1990) estimated that 10,000 fish and 2,000 ducks were killed Dead fish were found floating in upper Ohio after the spill passed.

In the 26 may issue Williams reported (Chemical Engineer, 1994) various cases of river pollution due to fire events. They mentioned that the most notorious example of fire water pollution is the 1986 Sandoz fire at Schweizerhalle, Switzerland which seriously polluted 250 km of the river Rhine. Similarly another accident took place in August 1993 after an explosion at the Rhone-Poulenc plant near Charlestone which polluted a river in West Virginia, USA. In 1991, contaminated water used to put out the fire at Coode Island, near Melbourne; Australia reached a nearby river.

7.8 Case study: Agricultural Chemicals- Mississippi river, 1993

During the great Midwestern flood of 1993, along the lower Illinois river, the middle Mississippi river and their tributaries, flood water damaged properties and farmlands and transported huge amount of sediment-sorbed and dissolved pollutants contributed by agricultural watersheds. It was estimated (Ray et al, 1998) that 175 metric tons of atrazine were transported through the Mississippi river at Baton Rough, LA, between July 7 and August 12 in 1993, although the average annual load was 160 metric tons.

Ray et al (1998) studied the 282 km stretch of the Illinois river to assess the potential effect of flooding on the quality of pumped ground water. They analysed the water pumped from four municipal water supplies wells. Three of these wells were vertical wells located about 60 m from the river's edge at normal pool stages. The fourth well was a radial-arm collector well with laterals extending beneath the riverbed. Although concentrations of atrazine in the Illinois river during peak flow of 1995 and 1996 were as high as 6 and 12µg/L, respectively, the concentration of atrazine in groundwater pumped at the three vertical well sites remained below the 0.1µg/L detection limit. In 1996 a small breakthrough of atrazine was observed in the collector well water. The high concentration of nitrate in river water appeared to have slightly increased the nitrate in pumped groundwater at two locations. Dilution and other factors may have affected the transport of river water contaminants in the alluvial aquifer between the river and the pumping wells.

A two-year reconnaissance study carried out by Ray et al (1998) showed that floods on the Illinois river had minimal effect on these constituents in the pumped ground water of three riparian municipalities with vertical wells. No atrazine was found above the detection limit at any of the vertical well sites. Low concentrations of atrazine were found at the fourth radial arm collector well site during flood period in 1996. However, the measured concentrations were all below the maximum level allowed in drinking water. The nitrate content of groundwater at one vertical well site was apparently increased slightly by that in surface water. At the radial arm collector well site, despite a clear breaking through in nitrate concentration during the summer of 1996, nitrate concentrations remained below the drinking water standard. The Total Dissolved Solids (TDS) concentrations in river water during low-flow conditions reflected those in groundwater. However, during flood periods, the concentrations in river water fell below those in groundwater, implying a lesser influence of high TDS groundwater on river water quality during peak flows.

The research carried out by Ray et al (1998) indicated that nitrate and atrazine in floodwater did not affect most of the vertical-well sites but that the radial-arm collector well has the potential to be contaminated by river water. It is not clear of what concentration of atrazine in river water, persistent for what length of time, will cause a breakthrough that will exceed the Maximum Contaminants Level (MCL) for atrazine. The pumping rates of the wells at the three vertical well sites were small, 140-500 gpm. As a result, the amount of induced infiltration is thought to be minimal. Furthermore, the presence of anaerobic (reduced) zones around the perimeter of the river, as well as the sorption of contaminants to river sediments and aquifer solids, may have further reduced contaminant concentrations.

7.9 Case study: Post-flood assessment of St Maries, Idaho 1996.

The Environmental Protection Agency collected approximately 260 containers that had been inundated and were either floating around in floodwaters or were under water. Of these, 241 had been recovered from the Meadowhurst district, 17 from Riverdale, 59 from north of the town, and 5 were brought in by residents. Many of these had been used for home fuel, such as kerosene; for the storage of lubricants, hydraulic oils, grease, petroleum products, and other waste oils; and for heavy duty cleaners and household chemicals. Some of the barrels were punctured and their contents had leaked out, while others were open. It was thought that most of these had come from residences and businesses located in the Meadowhurst and Riverdale areas. In fact, there are numerous small businesses that would use such materials, including automobile repair operations and activities associated with wood products. In addition, Potlatch had a 1,000 gallon fuel tank in the flood waters and several other fuel tanks were floating around the airport according to the reports of Rodin (Montz and Tobin, 1997).

It appeared that no serious contamination had resulted from the flood, although some materials were tested to see if they were hazardous. Of the 238 samples tested, 107 proved positive. Chemical testing revealed primarily oils, grease, and some household chemicals, along with some agricultural pesticides, acids, and paints. Quantities were variable, with containers ranging from 1 to 55 gallon drums. Not all of these were full; many had clearly leaked into the surrounding environment. Barrels were stored temporarily at a landfill during the flood, eventually to be sent to a RCRA facility if hazardous. Visible evidence of contamination was not high. In places there was a thin film on the top of the floodwater from petroleum and hydrocarbons, most of which was expected to dissipate or mix into soils. There was a possibility that such products could get into groundwater depending on the depth and condition of wells. Some of the contaminated areas had been boomed and absorbent materials used to soak up the wastes according to the reports of Rodin (Montz and Tobin, 1997).

8 Human and animal health

The human and animal health consequences of any one flood event will vary depending upon the nature and severity of the flood as well as the effects upon a given human or animal population. So far the researches have tried to establish the key aspects of flood characteristics, which suggests anticipated fundamental effects. Although the potential for disease outbreaks is always anticipated after a disaster, there are certain conditions that must be present for this potential to manifest in the form of epidemics. Human and animal health can be effected by flood directly or indirectly. Some of these effects can be summarised as presented in the table below:

Table2: Impacts of floods on human health (UN: www.unisdr.org/unisdr/guidewater.htm)

The impact of floods on human health – Direct effects	
Causes	Health Implications
Stream flow velocity, topographic land features, absence of warning, rapid flood onset, deep floodwaters, landslides, risky behaviour, fast-flowing waters carrying boulders and fallen trees	Drowning, injuries
Contact with water	Respiratory diseases, shock, hypothermia, cardiac arrest
Contact with polluted waters	Wound infections, dermatitis, conjunctivitis, gastrointestinal illnesses; ear nose and throat infections; possible serious water borne diseases
Increase of physical and emotional stress	Increase of susceptibility to psychosocial disturbances and cardiovascular disease.
Disruption of transport	Food shortage, disruption of emergency response

The impact of floods on human health – Indirect effects	
Causes	
Damage to water supply systems, sewers and sewage disposal systems, insufficient supply water for drinking, cleaning and washing	Possible serious water-borne infections (enterogenic E-coli, shigella, hepatitis A, leptospirosis, giardiasis, campylobacteriosis) dermatitis and conjunctivitis
Underground pipe disruption, dislodgement of storage tanks, overflow of toxic-waste sites, release of chemicals, destruction of petrol storage tanks (may lead to fires)	Potential acute of chronic effects of chemical pollution
Standing waters, heavy rainfalls, expanded range of vector habitats	Vector-borne diseases
Clean up activities following the flood	Electrocutions, injuries, laceration, skin punctures
Destruction of primary food production	Food shortage
Damage to health services, disruption of “normal” health services	Decrease of “normal” health care services, insufficient access to medical care.

At the end of December 1993 and also at the end of January 1995, the river Meuse one of the major river in Europe, flooded and riverbanks were inundated. Albering et al (1999) studied the possible human health risk of exposure to heavy metal concentrations in riverbank soils resulting from the flooding of the river Meuse at the end of 1993. They evaluated the heavy metal contents (e.g. As, Cd, Cu, Pb, and Zn) of the topsoil and flood deposits and the corresponding food and feed crops. They used two different methods to estimate human exposure in relation to the soil pollution in the floodplain. First the general multiple pathway exposure model (HESP) was used to estimate potential human exposure in relation to soil contamination. This model relates the soil concentration of a pollutant to various environmental media and predicts the concentration of a pollutant in vegetation, beef, and dairy products.

Further more, Albering et al (1999) carried out research on human exposure by taking into account the location specific data of heavy metals in vegetables grown in the established experimental gardens. They concluded that although the soils of the floodplain of the river Meuse appeared to be enriched with heavy metals, the heavy metal contents in crops grown on these soils were within normal background values. They further made a note that incidentally the high Cd values were observed in wheat, lettuce and potatoes. The human health risk associated with the heavy metal contamination of soil, and indirectly the food chain, seemed very low. The most important exposure risks were associated with Cd and Pb levels in soils that have a flooding frequency of once every two years. In the case of Pb, the most important pathway was ingestion of soil, whereas for Cd, ingestion of locally grown vegetables was the predominant exposure pathway.

8.1 Case study: Norway, 1995.

During the 1995 river floods in eastern Norway, 7,000 people were forced to abandon their houses and the public water supplies of some 150,000 people were threatened. The national Institute of Public Health feared outbreak of waterborne diseases. They provided additional preventative measures with expert advice and public information. According to the research carried out by Iversen et al (1996) the emphasis was given to maintain safe water supply, and to provide information on flood water management during evacuation and clean-up. This resulted in no increase of acute gastro-enteritis or other possible flood related communicable diseases among the 329,000 people living in the municipalities effected by the flood. Iversen et al (1996) concluded that the flood did not cause a measurable increase in the incidence of communicable diseases. This was probably due to some extent to the measures taken to protect the water supplies.

On April 18, 1997, a flood struck the cities of Grand Forks, North Dakota and east grand Forks, Minnesota as spring snowmelt and runoff caused the water level of the red river to rise above its banks. More than 47,000 people were evacuated. After flood it was assessed that 80% of the 19,500 homes were suffered damages (Collins, 1997). The potential for environmental health problems in the aftermath of a flood is tremendous. Flood related health risks included direct exposure to toxic chemicals dispersed by flood waters, inhalation of mold spores and mold toxins that proliferate on saturated indoor sheetrock, consumption of contaminated drinking water, consumption of spoiled food due to lack of electricity for properly cooking and cooling it, spread of infectious diseases as sewage lift stations become disabled, and increased incidence of respiratory illnesses as a result of mass sharing of evacuation shelters. The municipal water treatment plants were lost and 20 out of 36 sewage lift stations were inundated (Collins, 1997) with flood water. The water treatment plants were out of operation for four to six weeks following the flooding event. Around 17,000 houses were out of electricity, potable water and sewage facilities. The main reason for having no electricity for so many households was that their basements got flooded and that is where everyone had their electrical panels (Collins, 1997). Due to the failure of municipal water supply system, the municipality had to evacuate their local hospital and the entire medical centre too, because they could not function in the absence of such a service. They were shuffled all over the places and were scattered up to 300 miles away. This made difficult for their relatives to visit them for instance, which was quite traumatic from a mental health point of view. The cases related to respiratory and/or diarrheal illness in the evacuation centre was reported to be relatively low. During the flood event some oil spill also occurred which caused minor health effects such as getting nauseated and having headache during clean up operations. Meantime a fire occurred in the city although can not be established the reason of fire whether it is associated with oil spill. Since the hydrants were under water, fire fighters had difficulties and about six fire-fighters got the hypothermia trying to fight the fire. The airforce brought in a crane helicopter with a 2,000 gallon bucket underneath it, dipped it in the river and dumped it on the fire, The also sprayed fire retardant, which created problems once it got in the water that was settling all over people's home.

8.2 Case study: Finland in 1998-1999:

Fourteen waterborne epidemics occurred in Finland during 1998-1999 (Miettinen et al, 2001). About 7,300 illness cases were registered in these outbreaks. All except one of the waterborne epidemics were associated with undisinfected groundwater. An equal number of waterborne epidemics occurred in public and private water systems, but most cases of illness occurred in public water systems. The three largest epidemics comprised 6,700 illness cases. Insufficient purification treatment unable to remove Norwalk-like viruses caused the only waterborne epidemics in a surface water plant. The main reasons for ground water outbreaks were floods and surface runoffs that contaminated water. Norwalk-like viruses caused eight and Campylobacter three of the outbreaks. In two cases the epidemic ceased by the exhaustion of susceptible persons in the exposed community but in most cases it was terminated by changing the water sources, boiling and drinking water and starting chlorination.

8.3 Case study: Human health risk assessment in The Netherlands

Albering et al (1999) carried out a study to investigate the human health assessment in relation to recreational activities on two artificial freshwater lakes along the river Muese in The Netherlands. According to their studies, although the discharges of contaminants into the river Meuse have been reduced in the last decades, which is reflected in decreasing concentrations of pollutants in surface water and suspended matter, the levels in sediments are more persistent. Sediments of the two freshwater lakes appear highly polluted and may pose a health risk in relation to recreational activities. To quantify health risk for carcionogenic (e.g. polycyclic aromatic hydrocarbons) as well as noncarciogenic compounds (e.g. heavy metals), an exposure assessment model was used. First, they used a standard model that solely uses data on sediment pollution as the input parameter, which is the standard procedure in sediment quality assessment in The Netherlands. The highest intake appeared to be associated with the consumption of contaminated fish and resulted in a health risk for Pb and Zn (hazard index exceeded 1). For other heavy metals and for benzo (a) pyrene, the total averaged exposure levels were below levels of concern. Secondly, input data for a more location-specific calculation procedure were provided via analysis of samples from sediment, surface water, and suspended matter. When these data (concentrations in surface water) were taken into account, the risk due to consumption of contaminated fish decreased by more than two orders of magnitude and appeared to be negligible. In both exposure assessments, many assumptions were made that contribute to a major degree to the uncertainty of this risk assessment. However, this health risk evaluation is useful as a screening methodology for assessing the urgency of sediment remediation actions.

8.4 Case study: Red River Flooding 1997

Water treatment facilities in the valley continued to provide good quality drinking water throughout the flood. The drinking water treatment facility at Grand Forks was disabled for about three weeks because of flooding. Drinking water treatment facilities within the Manitoba portion of the basin were able to operate throughout the flood with the exception of the system at Ste. Agathe. This system was shut down for about one month when floodwaters entered part of the storage reservoir through an overflow drain.

Many flooded homes experienced mold problems, especially when basements were not completely dried prior to re-entry. Molds create health problems for some people. In a number of cases, even partially damaged and rebuilt homes had to be declared unsafe for occupation.

8.5 Effects of flood on food safety

During the flood, electricity supply may be cut off. Without electricity cold stores and refrigerators will stop functioning. Normally, the food stored in these facilities will start decaying after 4 hours. On the other hand, the food stores may come into contact with floodwater and thus food being contaminated.

Rats may be problem, during and after flood. The displaced rats, snakes and other animals may contaminate food storage as they may be a source of rabies and poisonous.

8.6 Effects of flood on sanitation and hygiene

Floodwater may contain fecal materials from overflowing sewage system, and agricultural and industrial by-products. Although skin contact with floodwater does not, by itself, pose a serious health risk, there is some risk of disease from eating or drinking anything contaminated with floodwater. Despite of other hazards, children playing in the floodwater may be threatened hygienically. The toys contaminated with floodwater should not be allowed for playing without disinfection.

Large amount of stagnant water remaining during and after flood will lead to an increase in mosquito populations. Mosquitoes are most active at sunrise and sunset. These mosquitoes may spread mosquito-borne communicable diseases.

8.7 Miscellaneous health and hygiene issues

Drainage and sewer system may overflow. Thus causing to malfuntioning of the services and creating a health and hygiene concern.

Hazardous household materials mainly include the items such as:
drain cleaner, furniture stripper, motor vehicle oil, toilet bowl cleaner, antifreeze, pesticides, and fertilisers. Asbestos containing materials are found in many households and public buildings. Asbestos is a material considered to be hazardous for human health. Flood may damage the asbestos containing houses or construction.

Post-disaster carbon monoxide (CO) poisoning is a growing problem in the United States (Daley et al, 2001). They have carried out a study in Grand Forks, North Dakota following the severe flooding of 1997. To help address the public health impacts of this disaster, the department of health initiated an active surveillance system for flood-related illness and injury. Thirty three laboratory–confirmed cases were identified, involving 18 separate incidents. Patients ranged in age from 7 to 67 years, and most of them were men. Exposure was uncommon in sensitive subpopulations, such as the elderly or pregnant woman.

The need for gasoline-powered equipment to provide a temporary supply of electricity or rehabilitate water-damaged homes increases after flooding (Daley et al, 2001). This equipment includes generators, pumps and pressure washers. Pressure washers have caused CO poisoning previously when used in an enclosed space such as a barn or parking garage. Environmental models and field simulations have demonstrated (Daley et al, 2001) that CO will reach dangerous levels within minutes when small gasoline-powered engines run inside buildings.

Flooding of the wild life habitat will force the wild life to move towards higher and drier places and they encroach the human habitat. Such a situation may pose human threat by wildlife, creatures and poisonous insects.

On the other hand, deceased bodies of the animals, wild life will obviously pollute the watercourse and posing a threat of epidemic breakout.

9 Plant, biology, aquatic lives

9.1 Destruction of forest

Nejad (2002) has presented a case study regarding the environmental impacts of heavy flash floods (10,11 Aug 2001) of Golestan province, Iran. He described the situation with an emphasis on the impacts of watershed and forest. More than 1,500 ha forest were destroyed and more than 250 people dead during this event.

A study was carried out by Chapin et al (2002) to investigate the relationships between flood frequencies and riparian plant communities in the upper Klamath basin, Oregon. Plant communities were sampled with 1m2 quadrants along established cross sections. Data collected for purposes of hydraulic modelling included channel and floodplain elevations (i.e. cross-sectional profiles) and water surface elevations associated with specific discharges. The elevational distributions of hydrophytic plant communities relative to modelled return periods provided the basis for establishing relationships between these variables for nine sites. Results indicated that, on average, a peak flow frequency of 4.6 years (range of 3.1 to 7.6 years) was needed to sustain riparian plant communities at seven of nine sites. At two sites, results indicated return period of more than 25 years were needed; these results possibly were influenced by local geomorphic conditions (a narrow steep channel in one case and an incised channel in the other). Overall, these results tend to confirm a strong dependency of riparian plant communities on overbank flows.

9.2 Toxicity of Cyanide and Cyanide –Breakdown Compounds to Fresh water Fish

Fish are the most sensitive species and impacted by relatively low cyanide concentrations (Moran, 1998). For example fish are killed by cyanide concentrations in the microgram per litre range, whereas bird and mammals deaths generally result from cyanide concentrations in milligram per litre range. Acute toxicity is described as those concentrations of cyanide that lead to the death of more than 50 % of the test population within 96 hours (Moran, 1998). Chronic toxicity may be described as exposure too less than lethal concentrations of cyanide. Some chronic effect reproduction, physiology, and levels of activity of many fish species, and may render the fishery resource non-viable. Whether the toxic effects of HCN are cumulative is apparently not known.

Santon and others states (Moran, 1998) that HNC ingested orally is fatal to humans in doses ranging from 50 to 200 milligrams, about the size of a grain of rice. Similarly, HNC concentrations above 40 to 200 milligrams per litre are likely to be toxic to mammals including humans.

Free cyanides (the cyanide ion and hydrogen cyanide) are well known to be the forms of cyanide derivatives most toxic to mammals and aquatic life. Acute toxicity to various fish species ranges from about 20-640 µg/l (Moran, 1998). The more sensitive rainbow trout generally exhibit acute toxicity in the range of 20-80 µg/l of free cyanide. Chronic toxic effects are reported in fish in the range of 5-20 µg/l. Metal-cyanide complexes are generally though (Moran, 1998) to be less toxic than free cyanide. Ammonia is a routinely encountered breakdown product wherever cyanide processing occurs. US Environmental Protection Agency reports (Moran 1998) ammonia to be toxic to fish at concentrations between 0.083 and 4.6 µg/l.

Another example of severe impact on aquatic lives is the January 2000, a tailings dam failure at in Romania, resulted in the release of 100,000 m^3 of cyanide-contaminated liquid into the Lapus stream, tributary of the Somes/Szamos, Tisza/Theiss, and Danube Rivers, killing hundreds of tonnes of fish (www.panda.org). Practically all aquatic life has been killed in the Szamos and upper Tisza River. The long-term effects on the ecological system can not be estimated so far, but experts fear that it will take years until the rivers will be back to pre-disaster stage, and some of the effects may be non-reversible.

10 Agriculture and animal farming

River floods are a serious threat to farmlands in many parts of the worlds, because restoration of a flooded area takes along time and much effort, particularly when the flooding has formed a thick sediment cover, usually consisting of mud and debris. However, these conditions vary for each case. Field observations from the floodplain of river Filyos indicate that horizontal shallow burrows of anelid Lumbricus terrestris are an important factor of mud desiccation and the development of large open cracks (Kazanci, 2001)

Wing et al (2002) have studies the potential impact of flooding on confined animal feeding operations in Eastern North Carolina. Thousands of confined animal feeding operations (CAFOs) has been constructed in this area. The fecal waste pit and spray field waste management systems used by these operations are susceptible to flooding in this low laying area. To investigate the potential that flood events can lead to environmental dispersion of animal waste containing numerous biologic and chemical hazards Wing et al carried research on three cattle, one poultry, and 237 swine operations which was flooded in 1999. During this flooding period, 22 fecal waste pits were reported to have been ruptured. Their studies indicated that flood events have a significant potential to degrade environmental health because of dispersion of wastes from industrial animal operations. These analysis are relevant to conditions in other areas, regions or even states or nations, where flood event occur and where CAFOs are located under consideration for future development.

The agricultural statistics Service of the North Carolina department (Schmidt, 2000) reported that up to 28,000 hogs, 2 million chickens, 750,000turkeys and 700 cattle were killed in the Hurricane Floyd flooding of September 1999. In addition to the economic damage, the damage of livestock operations this has also contributed to the environmental effect in the area of North Carolina. Water-borne animal and human wastes produced nutrient pollution and raised the potential for both exposure to pathogens and the risk of disease. Most of the flood related environmental damage caused by livestock industry in North Carolina came from Swine wastes (Schmidt, 2000). Similarly the poultry farms also brought some consequences, The fecal wastes containing nutrients such as nitrogen and phosphorus as well as by-products such as ammonia contributes to excessive algal growth in aquatic system, which depletes dissolved oxygen in the water.

The great flood of 1993 inundated more than 355,000 ha of Illinois cropland along the Mississippi River in USA, creating great concern for the possible contamination of farmland by herbicides. Chong et al (1998) carried out investigation studying the herbicide contamination of floodwaters and farmland due to the flood. Their studies indicated that concentrations of alachlor, atrazine and cyanazine were no greater than 1.1µg/L in the flood water samples. No detectable herbicides (>=0.01µg/L) were found in the solids suspended in the floodwater. The only herbicide detected in both flooded and nonflooded soils was atrazine, where significantly higher concentrations were found in the flooded soils. However, concentrations were less than the 3.5 µg/kg application rate of atrazine to soil. The concentration of herbicides detected in both water and soils were much lower than the regulatory level set by the USEPA indicating no contamination of flood water or farmland. Due to the volume and rapid movement of the floodwater, the potential for herbicide contamination of flooded soils was never realised. The lack of herbicide detection in the suspended solids of flood water samples, and the lack of any correlation between the atrazine content of flooded soils with the percent sand or clay content indicated that flooding did not result in the herbicide contamination of soil (>1 mg/kg).

11 Soil and sediment pollution

Soil and sediment pollution is a common problem due to a flood. Normally flood water carries a heavy load of silts, sediment, debris, gravel etc and will deposit in the flat areas where flood water velocity is relatively slow. In case of flooding in the agricultural area, deposition of silt, sediment and debris will deteriorate the fertility of the agricultural land. Similarly, tsunami and storm surges may cause salt water intrusion into the agricultural land causing a long term adverse effect in the agriculture.

Helios-Rybicka et al (1998) carried out studies of crucial loads in river Odra in Poland studying the impacts of 1997 flood on the situation of hazardous substances. They have found out that the metal concentrations in the Odra River, its tributaries and in the Szczecin Lagoon water samples are lower than the limited contents for drinking water in Poland and Germany. Results of the study indicated that both, the suspended matter and the <20µm size fraction of sediment samples from the Odra river catchment area have been strongly contaminated with heavy metals, mainly with Cadmium, zinc, lead and copper. The detected levels of metal concentrations were found to exceed the geotechnical background values of the fine grained sedimentary rocks.

Their studies indicated that from the metals that were studies, cadmium seems to be of particular concern because of high level over the whole Odra river system, and its high mobility exhibited even in neutral and slightly alkaline systems. For all metals studies in the Odra river sediments the substantial reduction with cadmium contamination, neither at the period after flood nor if compared with the earlier results obtained for 1991 (Helios-Rybicka et al, 1998) has been observed. Mullereta al (Helios-Rybicka et al, 1998) found that a comparison of sediment contamination expressed in l_{geo} classes has showed an improvement for Zn, Cu and Pb, but not for Cd situation for the Odra river sediment between 1991 and 1997.

Ecotoxicological effect of 97 flood in Odra river should be cause due to release of the heavy metals from the flood sediments, since they were exposed to the oxidation processes, and in some regions to the acidic leaching. Most of the Odra river bottom sediments are in the anoxic conditions (average Eh-330 mV) according to the report of the studies published by Helios-Rybicka et al (1998). Their earlier studies have shown that if the anoxic sediments are exposed to the atmosphere the metal speciations will move to the more mobile forms.

The link between sediment contamination and flooding is not well established (Tobin et al, 2000), since flooding may exacerbate problems by spreading pollutants throughout the floodplain, or alternatively may dilute contaminants in sources areas. To determine the substance of such relationships, the pattern of sediment contamination was examined in a small town of Idaho following the flooding in 1996. Four heavy metals were tested, nickel, chromium, zinc and copper in 97 soil samples obtained from sites across the floodplain of St Joe River. Flooding history and land uses at each sample site were noted. Results showed that contamination levels generally were not high, with flood areas having lower concentrations than non-flood areas. A stronger relationship could be argued for land use, with higher concentrations of contamination associated with some industrial sites. High levels of contamination were also found in several samples taken from recreational sites. The study identified timber-processing plant as one of the major sources of hazards including many others such as metal works, engine repair, welding, plating shops in the community.

12 Flood Hazards for Nuclear Power Plants

Flood hazards for nuclear power plants can be divided in to two groups (Yen, 1988): internal and external flooding. Internal flooding are those caused by malfunction of the power plant internal facilities. External floods are those produced by heavy rain, river floods, failure of dams or levees, high wind induced waves, tsunamis and other external hydrologic events. Internal flood may also occur due to external flooding. It appears that in current practices in reactor safety considerations, flood risks attracts far less attention than the risks of earthquake and fire. Flooding hazards for nuclear plants should not be ignored at either the design and construction stage or the operation stage. There are various external geophysical causes that could induce reactor incidents. Among rain related floods, hazards due to heavy rain at the plant site and due to flash floods should also be considered in additions to river floods.

There are two types of hydrologic flood hazards prediction (Yen 1988): a) the probability of flooding for an expected service period and b) a real time forecasting of the probability of flooding for an incoming event. In both case randomness and uncertainties of all the factors such as spatial and temporal variabilities of rainfall and watershed, measurement errors and model accuracy should be accounted for inclusively, not merely the frequency of occurrence of the flood events.

In case of an accident in the nuclear station, the consequence would be very extensive, although no cases have been revealed of any such accident associated with any flood.

Nuclear power plans cannot be “switched off” like the engines of a motor car. The shut down of a stream turbine, whether in a conventional or nuclear power plant, requires power for turning the shaft as it is cooling down; the nuclear section must similarly undergo a lengthy shutdown for which power and other services are required.

13 Surface and ground water pollution

Floodwater can be heavily contaminated with varieties of pollution starting from mud, sewage, decay of animal bodies, and pesticides to highly hazardous chemicals. Water treatment plant may go out of order or malfunction due to flood impacts and sewer discharge may directly enter the watercourse without purification.

13.1 Water quality during flood in 1997 in Czech republic

Matejicek and Hladny (www.env.cebin.cz) have published a summary of 1997 flood in Czech Republic. They have reported that heavy metals concentration in suspended sediments that their proportion during the flood situation was significantly lower than corresponding averages in the reference period of 1986 –1995, only for nickel, iron and, although in a relatively small rate also for mercury, an increase was observed. The total loads of metals in suspended sediments were, however, relatively very high. In inundated areas an increase was identified in a number of cases of alkalinity, calcium and total phosphorus. Concentration of a range of heavy metals increased significantly, it was not necessary, however, to consider it essential in view of the limiting values of water quality. Water retained in inundation belonged to flood peaks of the first flood episode. At a number of inundated places high concentration of polychlorinated biphenyl (PCB), absorbable organic halogens (AOX) and polycyclic aromatic hydrocarbons (PAU) were found, the source of which were the flooded industrial plants in majority of cases.

To evaluate groundwater quality, they selected infiltration areas abstracting water from quaternary alluvia in the Morava and Opava basins. In a major of cases increase was identified of microbial pollution (psychrophilic, mesophilic and coliform bacteria) and in a number of places also of sulphates. Decrease was identified for chlorides and in smaller extent for nitrates. In the infiltration area of the Moravská Nová Ves increase of oil contamination was identified. As a result of inundation and contamination of groundwater infiltration areas, drinking water supply was disrupted in a number of cases. It was concluded that it would be necessary to identify hydrogeologically compensating sources for similar future situations, which would be protected against the harmful flood effects. The longest disruption of operation of the wastewater treatment plants took place at the upper Morava River and its tributaries. The disruption of waste water treatment resulted in changes of water quality substantially by the end of July 1997 when the relevant parameters showed increase (chemical oxygen demand - COD, ammonium nitrogen, total phosphorus and bacteriological pollution) not only in watercourses, but in a number of cases also in inundated areas and in some of the groundwater infiltration areas.

In the affected region more than sixty cases of spill of harmful substances of various importance were observed in July. In majority of cases it concerned spill of hydrocarbons or mineral oils. Release of nitrogen during flood in 1997 in Moravia from the soil layer was not of a dangerous character and it behaved according to the known natural principles. The flood events in Moravia represent however the upper limit of the nitrogen release for agricultural land that can appear in conditions of this region. Amount of groundwater being accumulated during the flood situation in riverside zones proved high capability of the hydrogeological environment to rapidly absorb a relatively large amount of water. The model estimates of water infiltrated from precipitation, watercourses and areas of inundation ranged between 60 and 150 mm during the flood period in the selected pilot areas. In the major part of the region affected by floods the regime of groundwater returned to the long term average values by January and February 1998.

13.2 Impacts on Water Quality during Red River Flooding 1997.

Major environmental impacts caused by the 1997 flood have not yet been identified for the Red River itself or in Lake Winnipeg or its recreational beaches. The flood's effect on the environment may have been minimal for two reasons (Interim Report, 1997). Many sources of pollution were safeguarded before the flood arrived, and the tremendous volume of relatively clean snowmelt water diluted contaminants.

Several agencies assessed water quality during the flood at a number of sites throughout the basin. One of the most important sites was near Selkirk, Manitoba. Since this location is only a few miles upstream from Lake Winnipeg, water quality there reflects an integration of basin-wide effects.

Sediment loads in the Red River at Selkirk during the flood rose quickly as river flow increased, reaching a near-record maximum of 138,516 tons (125,634 metric tons) a day. During the flood, sediment loads remained above 55,115 tons (49,989 metric tons) a day from April 22 to approximately May 20, then gradually decreased.

Upstream from Winnipeg, fecal coliform densities exceeded only briefly the water quality objective adopted by the IJC for the protection of recreation, and then declined to normal levels.

Densities downstream from Winnipeg, although substantially higher than those observed at the international boundary, did not differ markedly from normal for this reach of the river. Densities of the fecal streptococci group appeared higher than normal at Emerson near the international boundary in samples collected by Environment Canada. This is common during floods, since some bacteria measured in this test are native to soils and plants. These findings were similar to those reported by the United States Geological Survey. Fecal streptococci levels were higher in 1997 at Fargo and Pembina than in recent years. The elevated levels of fecal coliform and fecal streptococci may have been from agricultural sources.

Tests were also conducted for a variety of materials such as dissolved salts, nitrogen, phosphorus, metals and other trace elements, and pesticides. Concentrations of these compounds generally did not exceed normal levels or levels that presented an unacceptable risk to human or aquatic ecosystem health. Several compounds were detected during the flood that had not previously been recorded. Pentachlorophenol, a wood preservative, was likely leached from inundated railway ties or bridge structures, while several persistent organochlorines such as the pesticides dieldrin, g-chlordane, and endrin were likely mobilized from previously undisturbed soils. A number of pesticides currently in use were detected, including 2,4-D, trifluralin, triallate, dicamba and atrazine. Concentrations of atrazine in the U.S. portion of the Red River were higher than previously observed in spring runoff. The IJC alert levels established at the international boundary are exceeded if any pesticide is detected; they are therefore commonly exceeded.

The 1997 flood contaminated many dugouts used by farmers for agricultural production (in particular, hog and poultry water supplies) and others used for general purposes, such as mixing water for farm chemicals and household needs. According to producers, such poor water quality had never been experienced before.

Although bacteria densities during the flood were not unusually high for the Red River, levels were sufficient to contaminate groundwater in areas south of the City of Winnipeg. Floodwater entered the aquifer through both active and improperly sealed abandoned wells. Some wells were covered with up to 8 feet (2.4 meters) of standing water for extended periods, while in one case, an abandoned well allowed floodwater to flow into the aquifer for about four days at such a rate that a vortex formed over the well. Subsequent to the flood, 250 wells in the Grande Pointe, St. Adolphe and St. German areas south of Winnipeg were rehabilitated by pumping followed by chlorination. Thirty-six abandoned wells in the region were permanently sealed, and a further 17 wells were equipped with proper sanitary seals.

14 Miscellaneous River pollution

14.1 A 70 year records of contamination along the Garone River in SW France.

Grousset et al (1998) studied and documented the historical records of 70 years of contamination from industrial activities along the Garonne river and its tributaries in SW France, through the geotechnical study of a sediment core recovered from the inner section of a flood-tidal dock, located in the city of Bordeaux, along the Garonne River. The chronology of the core was estimated by extrapolation from and interpolation between a few geochemical datum provided by a high resolution Cs record, the atmospheric initiation of radioactive fallout (~1952); the maximum of atmospheric radioactive fall out (~1953) and the Chernobyl accident (1986). Concentrations of Sc, V, Cr, Co, Ni, Cu, Zn, Cd, Sn, U, Pb and the Pb isotope composition were analysed by ICP-MS, in the 'exchangeable' fraction.

The pollution impact of a few heavy metals mostly Pb, Cb, Zn, Sn) was particularly enhanced from 1950 to about 1980, due to the activity of a mining and foundry company located on the lot, a tributary of the Garonne river. A five-step historical evolution of the foundry's activity is faithfully recorded in the sedimentary record. Despite the fact that the mining activity stopped 20 years ago and that the contamination seems to be very limited at present, enrichments are still observed in the estuary waters and sediments. These may be due to the release of both particulate and dissolved metals from previously released tailings in the downstream from Decazeville mining/foundry site. Over the last 20 years, another kind of pollution by Cr and V is identified, and is related to a different industrial origin, tanneries and electrolysis factories, located along other tributaries of the Garonne river (Dordogne and Tarn). Contamination from local sources (Bourdeaux) is negligible compared to the dominant influence of the remote pollution sources.

14.2 Case study: Cyanide Spill in Kyrgyzstan, 1998

On May 20, 1998, a truck transporting cyanide to the Kumtor gold mine in Kyrgyzstan plunged off a bridge, spilling about 1763 kg of sodium cyanide into a river upstream of several villages. After few days of the incident hundreds and possibly thousands of local residents sought treatment at local medical clinics. According to a report by the Russian Federal Ministry of defence, at least one death was related to the cyanide spill (Moran). According to the research studies sponsored by CANMET (Moran, 1999) concluded the following:

Some river fishes were killed by the spill. The cyanide concentration in Barskum river water was potentially high enough to cause serious health effects at least several hours after the spill to anyone who drank a sufficient quantity of the water. River modelling indicated that the total time required for the cyanide to clear from the Barskaum river would have taken approximately 10 hours.

15 Modelling of flood related environment

The purpose of researching the flood modelling papers was to investigate whether there are systems/models developed which can simulate the environmental issues directly related with flood and inundation. Several modelling packages have been in use for simulation of the flood hazards assessment and management. History of the development of these models varied, and reflects the nature of the institutions from which they have been developed, the data used in the process of hazard assessment, and the different decision-making contexts. Most of the models do not consider the impact categories for ecology, industry and infra-structures. Most of them take national average value for properties loss evaluation. Similarly, there appears to be several models used separately for isolated or independent environmental issues.

Following are some examples of the combination of both i.e. environmental issues related to river flow, flood water or inundation:

15.1 BOD Pollution in River

Yeh and Chu (2002) presented a paper in Flood Defence 2002 -Symposium in China, regarding “An economic-environmental scenario simulation model of biological oxygen demand (BOD) pollution in Taiwan”. In this paper, the authors have presented an aggregated model of a large-scale region of the Taiwan Island that was developed for exploring the surface water pollution in Taiwan. The trend for river pollution were simulated associated with various scenarios using a system dynamic software tool ***Vensium***, where the BOD is the index pollutant of concern. The interrelationships between economic and environmental aspects were emphasised. According to the assumptions with respect to some policy variables in each of the scenarios, the generation, treatment, and emission of BOD for each county and each main river basin were simulated. The length ratios of not or slightly and severely polluted river segments were also predicted. Moreover, the treatment costs and the SEEA maintenance costs can be calculated and accordingly the Green GDP’s taking into account the BOD pollution in rivers can then be derived. They concluded their papers stating that simulation model can demonstrate the variation of economic-environmental variables of major concern and also identify possible means to accomplish specified goals. This can help the government or policy managers to understand the potential development trends of a nation or and area in various aspects.

15.2 Modelling the loss of live

Jonkman et al (2002) summarised the overview of methods available in literature to estimate the loss of life caused by floods. These methods are:
As suggested by Waarts- relations of mortality and depth of water derived from data of 1953 flood in the Netherlands.
“Standard method for predicting damage and casualties as a result of Floods described by HKV – relations of mortality (probability of drowning) and rate of rising the water (meter/hour)
TNO has also developed a model based on the 1953 flood, which takes into account of three causes of drowning i.e. collapsing of building, due to dike breach, collapsing of houses due to flood wave attacks and others causes of drowning.
Jonkman himself proposed another model with improvement in Waarts methods where he considered the probability of drowning as a function of stream velocity. Also simplified model for evacuation is introduced. The probability of a successful evacuation of flight is assumed to be a function of the time available for evacuation.

Graham provided a framework for estimation of loss of life due to dam failure where fatality rates are the function of flood severity, the amount of warning and understanding of the population of the flood severity.
Further explanation of the above techniques can be found in Jonkman et al (2002)

15.3 Accidental pollution Simulation System

A widely used modelling method for pollution transportation is a numerical solution of advection-dispersion equation.

Shagalova (1996) simulated the system of accidental pollution and pollutant transboundary transport problem for the River Tura in Russia. The quality of the river Tura in the state of Tumen (middle Urals and west Siberian region) is often affected by industrial discharges from the neighbouring state of Sverdlovsk, which is located upstream and has a concentration of large-scale metallurgical and machine-building industries. Modelling the transport of pollutants from accidental spills is extremely important for the protection of the environment and drinking water resources downstream. A good model allows one to forecast water quality and to give a warning even before the spill crosses the boundary between the states of Sverdlovsk and Tumen. The algorithms for accidental spill transport cover the period from the onset of a spill to the moment it reaches the boarder of the state of Tumen. The forecast is based on preliminary information on the spill and on a database for potential spill sources. Transfer functions are used for calculating when the spill will arrive at the boundary and to provide a first estimate of maximum concentration of the spill there.

Shagalova (1996) estimated the fate of accidental spill when there are incomplete initial data and transport information – a situation typical of transboundary problems. The method suggested by her is based on the transfer function technique.

15.4 Computer modelling of fecal coliform contamination of an urban estuarine system:

Scarlatos (2001) studies the sources, distribution and fate of fecal coliform population in the North Fork of the New river that flows through the city of Fort Lauderdale, Florida inn USA. The dynamics of this brackish river are driven by weak tides, regulated freshwater discharges, overland runoff, storm water drainage from sewers and groundwater exchange. Extensive field studies failed to document any alleged sources of contamination, including birds, domesticated and undomesticated mammals, humans, septic tank leakage, urban runoff, non-point discharges from agricultural lands, waste disposal from live-abroad vessels and/or in-situ re-growth of fecal coliform. In order to facilitate field sampling , and support the data analysis efforts, computer simulations were applied to assess the likelihood of the various possible pollution scenarios. The physically based computer model used in the WASP (water Quality Analysis Simulation Programme Modelling System) of the US Environmental Protection Agency. In addition, the neutral Network MATLAB Toolbox was utilised for data analysis. WASP was bale to accurately simulate the water hydrodynamics and coliform concentrations within the North Fork, while the neutral network assisted in identifying correlation that fecal coliform and the various parameters involved. The numerical results supported the conclusion that fecal coliform were introduced by the animal populations along the riverbanks and by storm water washout of the adjacent drainage basins and the banks. The problem is exaggerated due to the low flashing capacity of river according to the Scarlatos (2001).

15.5 Modelling pesticide losses from diffuse sources in Germany.

Pesticide pollution of surface waters represents a considerable hazard for the aquatic environment. Bach el al (2001) presented a GIS based model estimation of the losses from diffuse sources in surface waters in Germany, for 42 active ingredients applied to 11 field crops, vineyards and orchards. For the following pathways of entry: tile drainage, run of and spray drift, the calculated mean pesticide input amounts to 1490 kg/year., 9060 kg/year and 3350 kg/year, respectively, in 1994. The model results are highly sensitive to the model parameters, primarily the chemical properties of the active ingredients. The modelled water inputs were compared with measured pesticide loads in smaller catchment and larger river basins to validate model results. Both database agree as to the order of magnitude, nevertheless due to the scale of the study the results should be addressed mainly to comparative interpretations with the focus on the proportions between different active ingredients, soil regions, climates and application periods.

15.6 Non-point pollution of Ishikari River, Hokkaido, Japan

A research was carried out by Tachibana et al (2001)for Ishikari river in Japan, the Japan's second longest river, to clarify the characteristics of non-point pollution by comparing flux characteristics of chemical components in three periods of one year: the snow melting period, the typhoon flooding period and the stable period. They found non-point pollutants present in great amounts because a large amount of suspended matter, which is contained in soil, flows into the river and concentrations of nutrients and organic matters do not decrease in a short time in the flooding period by rain and the snow melting period.

They have taken measurements during the flooding period. The concentration of the chemical compositions during the flooding period and snow melting period was changing. The surface run off components, which have accumulated at the soil surface, are suspended solids (SS), chemical oxygen demand (COD (Cr)) , biochemical oxygen demand (BOD), and some nutrients. These components reached high concentration when the river flow increased, and flows out in large quantities as non-point pollutants. In contrast, concentration of inorganic components became low by dilution.

Their studies (Tachibana et al ,2001) concluded that non-point pollution does not greatly influence the water quality of forest rivers, whereas it does greatly influence the water quality of the Ishikari river. The chemical components are present in great quantities as non-point pollutants at the ground surface and in the soil. As the area used by people expands, these pollutant loads which are washed out when the river rises also increase.

15.7 Study on real time control of non-point pollutants discharged from urban areas during a storm event

Pollutant run off to receiving waters from sewer systems during storm events is a serious problem for sewered urban areas. The unsteadiness and unpredictability of storm events makes it very important to control the effluent and hence the pollutants by using real time control (RTC) method. Yamada et al (2001)installed the storm water storage tank and studied the system, which has three functions: pollutant control, flood control and water use, to the end of a separate system. They examined the effect of real time control (RTC) introduction with the scenario selection in the study area in the catchment basin, which has measured data. As a result, a latter period centering-type case is satisfied with the pollutant reduction by the RTC and also at the water use tank, the best control settles COD concentrations at about 0.45mg/l. It was clarified how to use a RTC method as a measure of the discharge problem from an urban area during a storm event.

15.8 A model of liquid release from a submerged vessel

An accident, which involves hazardous fluid leaking from an oil-tanker or a barge-tank, can have disastrous consequences. Although there have been several accidents involving submerged leaking vessels, no complete model has been published that can be used to determine fluid leakage due to hydrostatic pressure and movements of vessels (Fthenakis and Rohatgi (1999). To analyse the consequences of such accidents, one must first estimate the source-term (e.g., the composition and flow rate of the leaking fluid). Earlier studies were limited to releases caused by the initial differences in hydrostatic pressure, they do not describe leakage caused by movement of vessel induced by recovery activities, ocean waves or river currents or even flood waves.

Fthenakis and Rohatgi (1999) presented an application of fluid mechanics in calculating the leakage of a fluid from a vessel submerged in a river, lake or ocean. They developed a model to determine leakage due to changes of gravity and pressure forces caused by movements of the vessel or waves at the surface. The equations in the model are solved analytically, and the solution is tested for the sensitivity of its predictions to the variation of input data. The model was developed for calculating underwater discharges of a volatile liquid from a vessel inside a large body of water which is either stagnant or in a periodic motion. The model is based on fundamental equations of fluid mechanics. The model’s predictions of discharges due to differences in hydrostatic pressure are verified with experimental data of incident of the release of APG in the Mississippi River. Finally the model is applied to a known case of gasoline leakage from an overturned barge in a river. In the model, sensitivity analysis was carried out for the following conditions:
a) effect of gas-phase pressure,
b) effect of the fluid saturation pressure,
c) effect of the depth of break,
d) effect of the area of the break,
e) effect of the discharge coefficient,
f) effect of the fluid density,
g) effect of the amplitude of the barge’s movements and
h) effect of the period of the barge’s movements.

The predictions obtained in this model were in agreement with the observations of personnel responding to the accident.

16 Management, plan and strategy

The objective of researching the literature on flood management, plans and strategy was to investigate whether there are sufficient management plans emergency protocols and strategic plans in case of environmental disasters caused by flood or flooding events. Generally, there appears to be quite a large number of public information in the internet as well as publication in the forma of brochures etc for general knowledge of common public vulnerable to flood disasters. For example, there are good information posted in the internet regarding what to do in case of flooding, where to go, how to arrange safe drinking water etc. However, in the internet and database, within limited time of search, it was rather difficult to discover a single and complete emergency protocol posted by any authorised bodies. Most likely, these types of documents are not available in public domain, including the research data base.

Occurrence of frequent floods is a common problem throughout the world. Floods accounts about one third of all natural catastrophes, they cause more than half of fatalities, they are responsible for third of the overall economic losses etc. Therefore it is obvious as to how vulnerable is the society against the flood. It has become increasingly clear that the search for sustainable and optimised ways to cope with floods needs a more comprehensive and broadly based response from society in general or in other words flood management is a concern of the society under flooding risk. As part of the contemporary flood management concept, environmental impact assessment is an integral part of the flood management strategy. Such plans should incorporate the sustainable environmental management including the precious studies on socio-economic, ecological, chemical and physical impacts of flood hazards.

While considering the Environmental Impacts Assessment of Flood hazards as part of the Flood management strategies, following checklist may be useful to consider:

Table 3: Check lists of some key environmental issues:

Type of Impacts	Impacts
Hydrology	Low flow regimes, Flood regime, Flow compensation, Water table variation
Pollution	Solute dispersion Toxic substances Organic pollution Anaerobic effects Gas emission
Soils	Soil salinisation Soil properties

Type of Impact	Impacts
Ecology	Project lands Water bodies Surrounding area Valley and shores Wetlands and plains Rare species Animal migration Natural industry
Socio-economic	Population change Income and amenity Human migration Resettlement Women’s role Minority groups Heritage sites Regional effects User involvement
Health	Water and sanitation Habitation

	Saline groundwater Saline groundwater Saline drainage Saline intrusion		Health services Nutrition Relocation effect Disease ecology Disease hosts Disease control Cultivation risks
Sediments	Local erosion Sediment yield Channel regime Local siltation Hinterland effect River morphology Estuary erosion	Others	Chemical plans and industries located in the flood prone area, Agricultural and animal farming practices, Mining activities.
Imbalances	Pets and weeds Animal diseases Aquatic weeds Structural damages Animal imbalances		

Following are some of the relevant information regarding the management, plans and strategies:

In March 2001, a report on Flood hazard Management in Britain and the Netherlands (Handmer, 2001) was published as part of the European Commission studies. In the report flooding problems of both UK and The Netherlands are highlighted. The Netherlands and UK have very different flood histories, although both suffered serious flooding in the post war period including the 1990s. About half the Netherlands is protected from flooding by dikes and over half of the Dutch population is at risk and it is no surprise that structural flood protection is a mater of national survival. The major threat is flooding by sea, but as the country is located on the Rhine delta, reverie flooding is also very significant. The situation in the UK is very much contrast. Approximately five percentage of the population are subject to flooding with about another five percent protected to varying levels by river and sea dikes. The major threat to life comes from sea flooding and considerable resources have been spent providing protection at the coast (Handmer et al, 2001)

16.1 Comparison of Dutch and English management concepts

The report submitted by Handmer et al (2001) also compared the flood management strategies adopted by The Netherlands and England & Wales in a tabular form, which is presented in Table 2:

Table 4: Flood Management in The Netherlands and England and Wales (source: Handmer et al, 2001)

The Netherlands	England and Wales
Integration – within Flood Hazard Management	
Emphasis lies on protection. Residual risk management relies on generic policies	Engineering and planning have pursued different priorities, and there has been minimal co-ordination. There are now attempts to improve this, but still in a voluntary way. Residual risk management is kept separate.
With Water Management	
Flood risk management has been a part of water management for centuries. Integration	Since 1996 the Environmental Agency has had responsibility for flood protection and other

takes shape in the establishment of the national water management plan (five year cycle)	aspects of water management. These tasks are carried out by different departments and there is still little integration
With other policy Fields	
Increasing Integration with the policy fields of environment, spatial planning and nature protection	Increasing integration with environmental policy. Little integration with planning or land use policy.
Internationalisation	
Increasing direct influence of international river basin authorities. The German and Belgian federal system complicate matters considerably.	There is some international influence, this is primarily through the adoption of ideas and approaches.
Improvement of early warning systems, including the prolonging of the forecasting period, by strengthening the co-operation between national and international stakeholders.	Arrangements with relevant Scottish authorities for flood warnings are informal. The different institutional arrangements on either side of the boarder create problems for formalising arrangements.
Democratisation	
Increasingly open planning processes and consensus-oriented decision-making, involving an increasing number of stakeholders, recently, project legislation was introduced, reducing the number of permits required and containing NIMBY	Primarily a command and control approach, although implementation bodies have a large degree of discretion. The new national Flood Warning Centre may strengthen the command and control approach.
Stakeholder Access to Decision-Making	
Most interests represented in advisory committees; all major infrastructure works go through a process of public consultation	Primarily a command and control approach, although implementation bodies have a large degree of discretion. The new National Flood warning Centre may strengthen the command and control approach. Traditionally the scene has been dominated by experts and the publics at risk have been largely excluded from decision making.
Key Informal Stakeholders	
Residents and other local stakeholders are increasingly consulted in an early stage of planning and decision-making processes, so-called informal participation.	The public at risk (limited involvement in formal decision-making, influence effectiveness of formal procedures, may have their own informal arrangements for flood protection) , academics and consultants (policy advice), the media (warning dissemination), insurance companies (compensation), local charities, public utilities and business involved in repairs (emergency response).
Commercialisation/Marketisation	
Flood management remains a government matter. Attempts to introduce flood insurance for households in the early 1990s failed.	????

Rise of Ecology	
Fully penetrated, but it is unclear whether it is a token or a significant contribution to flood management; appeal to nature is a key element in the public acceptance of new interventions.	Major issue as far as rivers are concerned, but have yet to fully penetrate the mindsets of flood managers. (Does seem to be addressed by flood managers in UK – but at a token gesture rather than commitment level.)
Funding	
Funding is provided by EU, nationals, provincial and regional/local governments, depending on the interests to be served.	Funding is provided for at the national level (through taxes), and distributed according to cost-benefit analysis.

16.2 Risk of flooding and Insurance in The Netherlands

The loss potential from flooding damages in the Netherlands is enormous. Losses in the order of 100 billion Euro resulting from sea and 50 billion Euro from river are conceivable (Kok et al 2002). Recently, relative small river flooding events occurred in December 1993 (loss of 100 billion Euro) and January 1995 (loss of 80 million Euro). In September 1998, heavy rainfall occurred causing losses worth of 500 million Euro (Kok et al, 2002). 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 be realised 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 damages mitigation might be more attractive. If there is a flood, there is no formal agreement that the losses will be compensated by all Dutch taxpayers. It is a question of solidarity (between the victims and other members of the society) that the damages are compensated.

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 tool for spreading negative consequences rather than removing them. Kok et all (2002) concluded that insurance of catastrophically floods does not seem to be attractive, but that insurance of damages as a result of local heavy rainfall may be attractive. However the question of insurance that covers all the environmental consequence is still an open question.

16.3 Risk of Flooding and Contingency Plans

If a facility such as chemical plant or a nuclear plant or even a petrol station is located in an area that is prone to flooding or is protected by a levee or located downstream of an artificially created reservoir, must have a written flood contingency plan (Hathaway, 2001). Such a plan has to be developed bearing in mind all the consequences that a flood may generate with respect to the facility under question.

17 Conclusions

Within the limited period of time, it was not possible to accumulated all the research references which may be available around the world. So this work is based on the limited literature review which was accessible through GeoDelft and the library of TUDelft.

a) Very limited research has been done investigating the flood impacts on flora and fauna. Furthermore, there appears to be a lack of research on short-term and long-term environmental impacts of flooding. There has been very limited studies on chemical hazards due to flooding and inundation.

b) Sediment transport is a well-studied engineering science. However, contamination of sediment due to the flooding and spreading of any such contamination and its consequences is still an ongoing research subject.

c) Traditionally, assessment of environmental loss is not considered important. Therefore, systematic and scientific environmental impact assessment of a flood is a very rarely investigated, recorded and published.

d) Normally, intangible losses are not taken into account while calculating the flood losses. On the other hand most of the environmental consequences can not be evaluated in the monetary term.

e) There are several models, which can simulate the flooding event. Similarly, there appears to have several environmental modelling programmes, which can simulate the environmental problems. However, this research indicated that there is a need for developing an integrated model, which can simulate environmental problems along with the hydraulic modelling of a flood event.

f) There appears to be flood management plans of each flood prone countries. Some countries appear to have protocols of safety and evacuation of chemical plants in case of flooding. However, official protocols do not appear to in the public domain, that can be easily accessed for example by searching in the internet or in the database.

18 Recommendations

a) There is a need for establishing a precious environmental impact assessment methodology for any flood events. Investigating post flood environmental assessment should be regulated by national environmental policies.

b) There is a need of a systematic publication on flood environment, so that researchers, scientists and policy makers are encouraged for publication of their works on a regular and systematic manner. For example starting a publication of a journal on “Flood and Environment” would be an ideal.

c) In order to promote and encourage scientific research as well as to assist decision making process, a workshop/ seminar/ symposium/ conference with special topics of “Environmental Impact Assessment of Flood” is recommended. Such a gathering may help to streamline and generate future strategies. Such a forum should invite the multidisciplinary research contributors such as Chemical engineers. Environmental engineer, agricultural scientists, economists along with the civil/hydraulic engineers.

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General Appendix: Delft Cluster Research Programme Information

This publication is a result of the Delft Cluster research-program 1999-2002 (ICES-KIS-II), that consists of 7 research themes:
►Soil and structures, ►Risks due to flooding, ►Coast and river , ►Urban infrastructure, ►Subsurface management, ►Integrated water resources management, ►Knowledge management.

This publication is part of:

Research Theme	:	Risk of Flooding		
Baseproject name	:	Consequences of floods		
Project name	:	Consequences of floods		
Projectleader/Institute		Prof. A.C.W.M. Vrouwenvelder		TNO
Project number	:	02.03.03		
Projectduration	:	01-02-2002	-	1-07-2003
Financial sponsor(s)	:	Delft Cluster		
		Ministry of Public Works, Road and Water Management		
Projectparticipants	:	GeoDelft		
		WL|Delft Hydraulics		
		TNO		
		Delft University of Techonology		
		Twente University		
		Alterra		
		CSO		
		Delphiro		
Total Project-budget	:	€ 450.000		
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Number of involved PostDocs	:	0		

Delft Cluster is an open knowledge network of five Delft-based institutes for long-term fundamental strategic research focussed on the sustainable development of densely populated delta areas.

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